The Development of a Global Maritime Emissions Inventory Using Electronic Monitoring and Reporting Techniques

Dale Neef PhD
Managing Director
DNA Maritime LLC

P.O. Box 270
Mystic, Connecticut
dale.neef@dnamaritime.com

Abstract

Emissions from maritime shipping are a significant source of airborne pollution. Recent studies have estimated that ocean-going ships produce at least 15% of the world's NOx, between 3%-6% of greenhouse gasses, and between 3%-7% of global SOx output.

Many partial maritime emissions inventories have been compiled in the last decade using both fuel-based and energy-based survey methods, but without accurate data on load factor, engine speed, and fuel type – data that must be taken directly from the ship's onboard systems – these surveys remain as high-level estimates; not precise enough to use as a basis for assigning emissions credits in an emissions cap-and-trade mechanism.

The Port Emissions Reduction Credit Scheme (PERCS) is the first comprehensive program that can provide the maritime shipping community with a mechanism for creating a global ship emissions inventory by ship type and size.

Based on data captured electronically from a ship's onboard navigation/control, fuel, and emissions monitoring systems, emissions performance information will be sent electronically to the PERCS database. Data will be collected automatically and electronically from ships anywhere, and at any time, and will provide a more complete and accurate snapshot of current emissions output in coastal routes, in ports, or in open seas around the world.

This emissions data will then be used both to "norm" performance expectations at an industry-level, and also to calculate emissions allowances at a company level – both necessary steps before the maritime industry can participate in wider emissions cap-and-trade schemes.

Introduction

Emissions from sea-going vessels are a significant source of air pollution and greenhouse gasses, and although port authorities, state regulatory agencies, the US government, the EU, and the IMO are all supporting various techniques and technologies for reducing

those emissions, efforts to encourage abatement by shipping companies is hampered by a lack of empirical data on the emissions output at the vessel level.

This is in part because the emissions output of a vessel is dependent on wide-ranging variables such as ship and engine type, main vs auxiliary engine use, engine cycle, voyage time in port and in mode, vessel speed, etc. The complexity of those variables combined with the labor intensity and inaccuracy of typical paper-based data collection techniques (from ships' logs and reports prepared by the crew), has meant that although various emissions inventories have been completed by port authorities in the past two decades, these inventories tend to be based on "average" or "typical" vessel criteria, and results vary widely.

It is possible, however, to simply extract most of the information required for accurately gauging a ship's emissions directly and electronically from digital systems aboard the ship. Data concerning vessel location, speed, fuel type and usage, load, wave height and wind resistance, etc., is available from their Nav/Con systems; similarly, data can be captured directly from emissions monitoring equipment on funnels, or from in-line fuel testing equipment or other fuel or emissions-related sensors. And because the data for those systems exists in a standard data format, it is possible to collect and transmit that information directly to an onboard server or, via satellite, to a shore-side database.

Once captured, the emissions monitoring data can be cross-matched against the vessel's registration data using the relational database and report generation features available in standard Environmental, Health and Safety software - producing an accurate, real-time picture of a vessel's emissions performance: by location, in mode and by engine type. The accuracy and integrity of the data and the data collection process can then be certified by a class society.

The Port Emissions Reduction Credit Scheme (PERCS) database system is "virtual" (i.e., available via the Internet), so vessel performance data can not only be be transmitted from ships anywhere in the world, but can also be accessed by multiple parties at anytime, from anywhere: regulatory authorities can monitor company performance by ship, fleet, or company, and shipping companies can monitor their fleet's emissions totals and take advantage of online emissions and commercial planning tools to improve their emissions performance.

And because the data is collected based on pre-set parameters for vessel location, a ship's data can be analyzed for its performance during its entire voyage – i.e., mid-ocean, in transit in coastal waters, or only when it enters a port. In this way multiple ports within a region or ECA, or even globally, can participate with little administrative overhead.

Most importantly, the PERCS program will provide the data necessary for a global maritime emissions inventory that can be calculated at the ship and company level, and will be relevant to state, regional or port authorities wishing to set an emissions performance baseline. As data is collected from many hundreds of ships of different types, and with different voyage parameters, a clear picture of "normal" emissions by

ship category will emerge. A program of incentives and rewards for emissions abatement (lower dockage fees for per annum emissions reduction/below industry average emissions output, “green flag status”, assignment of carbon credits or debits, etc.) can then be developed based on relevant and accurate historical data, collected directly from appropriately categorized ships.

Emissions From Sea-Going Ships

Recent studies have demonstrated that maritime shipping (ocean-going vessels) contribute significantly to coastal air pollution and greenhouse gasses. That air pollution principally takes the form of SOx , NOx , PM, and greenhouse gasses: recent studies have estimated that ocean-going ships produce at least 15% of the world's NOx (more than all of the world's cars, busses and trucks combined), between 2%-3% of greenhouse gasses, and between 3%-7% of global SOx output. Without intervention, these figures will potentially double in the next decade.[1]

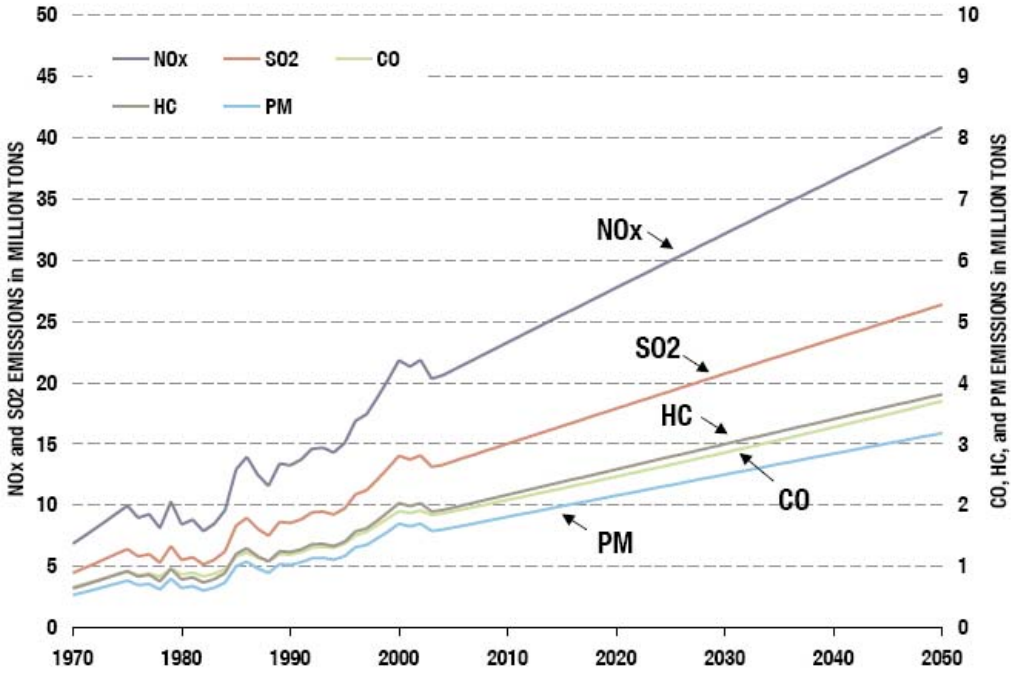
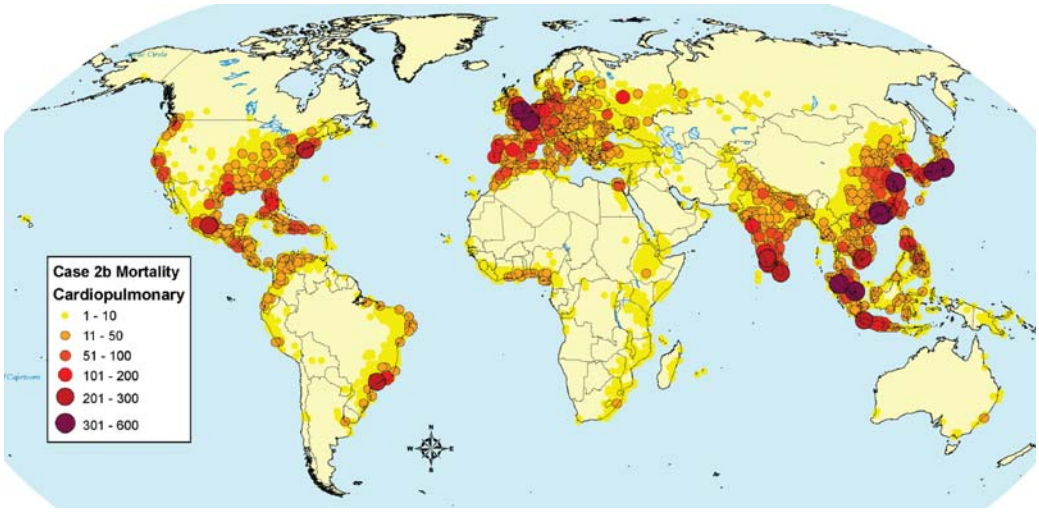


FIGURE 11. NO_x SO_2, CO, HC, and PM Emissions from International Shipping: 1970–2050

And because some 70% of shipping traffic is concentrated along coastal shipping lanes within 250 miles from land, in the US alone, 40 ports and an estimated 87 million people are in areas where emissions from ocean-going ships have significantly contributed to levels of air pollution that violate air quality standards for health and safety.[2]

Unlike most land-based industries, emissions output from the maritime industry for many years remained largely unregulated, in part because of the international and multi-jurisdictional nature of ocean-going vessels, and in part because of a lack of empirical

data on emissions output (a standardized and recognized emissions inventory) at the individual vessel level, that could provide reliable readings of emissions output. Recent studies completed using more sophisticated emissions measurement technologies have suggested that the maritime industry is responsible for far greater levels of air pollution, illness and mortality, than previously thought.[3]



Cardiopulmonary mortality attributable to ship PM emissions worldwide…
- Dr. James J. Corbett and Dr. Paul Fischbeck

In part because of the conclusions reached in these recent studies, and as part of its acceptance of MARPOL's Annex VI, the US has agreed with many other nations represented through the IMO to significantly reduce the sulfur content of bunker fuel, to encourage the use of lower sulfur grades of diesel fuel in coastal areas, and to improve vessel emission output by encouraging the use of new technologies: the installation of pollution control equipment, more efficient engines and propulsion systems, and improved architectural design of future ships.[4] In recent years, progressive shipping companies and port authorities have also collaborated to reduce NOx emissions through speed reduction programs in port control areas.[5]

Climate Change and Greenhouse Gasses

Although the shipping industry's main emissions abatement focus over the past decade has been the reduction of NOx, SOx and PM, there has recently been a greater focus on reduction of greenhouse gasses. This comes both from a heightened appreciation of the effects of global climate change by governments, and also because of the conclusions reached by the UN's Intergovernmental Panel on Climate Change in their 2008 report, which revealed that the true scale of climate change emissions (CO_2) from shipping, at 1.12bn tons of CO_2 each year, was nearly 4.5% of all global emissions of CO_2 – almost three times greater than previously believed. (The aviation industry, by contrast, although heavily criticized, is responsible for 650m tons/year - just over half of the amount of CO_2

emissions a year produced by maritime shipping). Without intervention, maritime CO_2 emissions are expected to grow 30% by 2020.[6]

Authorities have reacted to these emissions figures with a variety of new initiatives. Most analysts believe that the maritime industry will be included in CO_2 emissions reduction requirements with the revision of the Kyoto Protocol in Copenhagen, and importantly, it is expected that maritime emissions will also be included as part of the EU Environmental Trading Scheme carbon dioxide cap-and-trade system by 2010.

In January 2009, the Ministerial Conference on Global Environment and Energy (representing twenty-one countries) called on the IMO to begin new emissions talks by 2010, and in February 2009 IMO Secretary General Mitropoulos stressed the need for the IMO to take action on greenhouse gases – announcing that the theme for this year's World Maritime Day would be, "Climate change: a challenge for IMO too!"[7]

In the US, ratification of MARPOL's Annex VI and its provisions for greatly reducing NOx and SOx emissions marks an important milestone, and the Obama Administration's acceptance of the rights of California and thirteen other states to set their own, more stringent auto emission and fuel efficiency standards, presages similar support for local emissions standards being set for sea-going vessels.

Unreliable Inventories

While a greater political emphasis and these various initiatives and abatement measures have the potential to significantly reduce hazardous vessel emissions, at the same time, they create the need for a much more rigorous and demanding approach to monitoring, reporting, and enforcement. As with land-based industries, these new initiatives and regulatory measures will only be effective if authorities are able to:

- accurately and simply monitor and verify compliance and overall emissions performance from ships – i.e., measure and record vessel speed, fuel content, cargo loads, and the effectiveness of scrubber or filtering technologies;

- encourage shipping companies through additional financial incentives that go beyond mere regulatory compliance (lower dockage fees, emissions credits, etc.), to continuously apply new techniques and emissions abatement technologies over time to reduce the industry's overall emissions output.

Currently, most emissions abatement programs are still voluntary, and verification of compliance is administered by local port or state authorities. These programs usually involve paper-based, good-faith reporting of fuel use while in local waters through bunker delivery receipts. Information on vessel speed, location, load, fuel use, and time in port, when collected, is usually taken from copies of the ship's logs, occasionally cross-referenced with electronic tracking where available. Confirmation of fuel use is verified through random, time-consuming and labor intensive manual samples, taken while the vessel is in port, and analyzed at a land-based laboratory. As a result, administrative costs

are high, and numerous disputes arise around the validity of the data and the distribution of the rewards.

Moreover, information that is collected by local port authorities is often piecemeal and program or port-specific, and there is little sharing of data with other ports or authorities. Although a number of port-specific emissions inventories have been completed, these have used a variety of methodologies and formula. There remains no standardized or accepted method for measuring and reporting a vessel's overall emissions footprint. As a result, these inventories have often been criticized for their lack of rigor and inapplicability for use as calculations for emissions performance at a vessel or company level for broader incentive programs, penalties, or emissions trading markets.[8]

Finally, even if there were a standardized formula for calculating a vessel's emissions performance, there is no single or collaborative database framework that is available to collect, organize and make available emissions data to regulatory authorities, shipping companies, or emissions trading mechanisms.

This inability to calculate emissions at the vessel level, and the rudimentary methods for reporting, data collection, and analysis, mean that:

- There is no standardized or collaborative effort (beyond fuel-usage rules) to put downward pressure on maritime emissions output;

- An additional administrative and enforcement burden is being placed on local authorities;

- Shipping companies are likely to find emissions liabilities assigned to their books (by regulatory authorities) with little ability to respond with alternative statistics;[9]

- Progressive shipping companies will end up subsidizing poor performers and getting no credit for environmental improvements themselves.

Overall, under the present framework, there is little company-level accountability for emissions, and beyond regulatory compliance, the industry has little incentive to reduce its emissions output in the future.

The Port Emissions Reduction Credit Scheme (PERCS)

The key to creating a workable maritime emissions inventory is making emissions data collection easy, accurate and secure. The Port Emissions Reduction Credit Scheme (PERCS) is a maritime emissions inventory collection program that combines electronic monitoring and reporting of ship emissions with an independent, 3rd-party, data warehouse and data management center. From that data, it will be possible to produce an accurate, real-time picture of ocean-going vessel emissions performance by category of ship and by engine type.

The key features of the PERCS approach include:

Electronic monitoring and reporting

Automatically activated by the ship's longitude and latitude as it enters an ECA or coastal zone (information taken directly from the ship's navigation system), the PERCS system collects data on engine performance, fuel type and usage, and vessel speed from the ship's electronic nav/con systems. Because it is activated by location, it can be programmed to collect information for any port or region (including ocean transit).

That voyage performance data, along with any output from sensor or emissions measuring devices that are installed onboard, is collected either from the ship's local area network (LAN), or directly from the electronic systems themselves, via a software interface module that extracts the data from the various systems at desired intervals, tags the data for time and source, and files the information on an onboard database server.

An environmental, health and safety software module residing on the server is used to cross-reference this data against fuel type (either entered and confirmed by bunker receipts, or sampled during the voyage with in-line fuel sampling "lab-on-a-ship" type technologies), and matched with the ship's IMO number and with pre-entered data on ship size, engine type, and cargo weight. This information can be analyzed by the Master or the Chief Engineer in various dashboard or report-generated formats (see Figure 2), and can include voyage and engine-related data (average engine speed in mode, average revolutions, cargo weight, fuel oil consumption, etc.) as well as data taken directly from emissions monitoring devices.

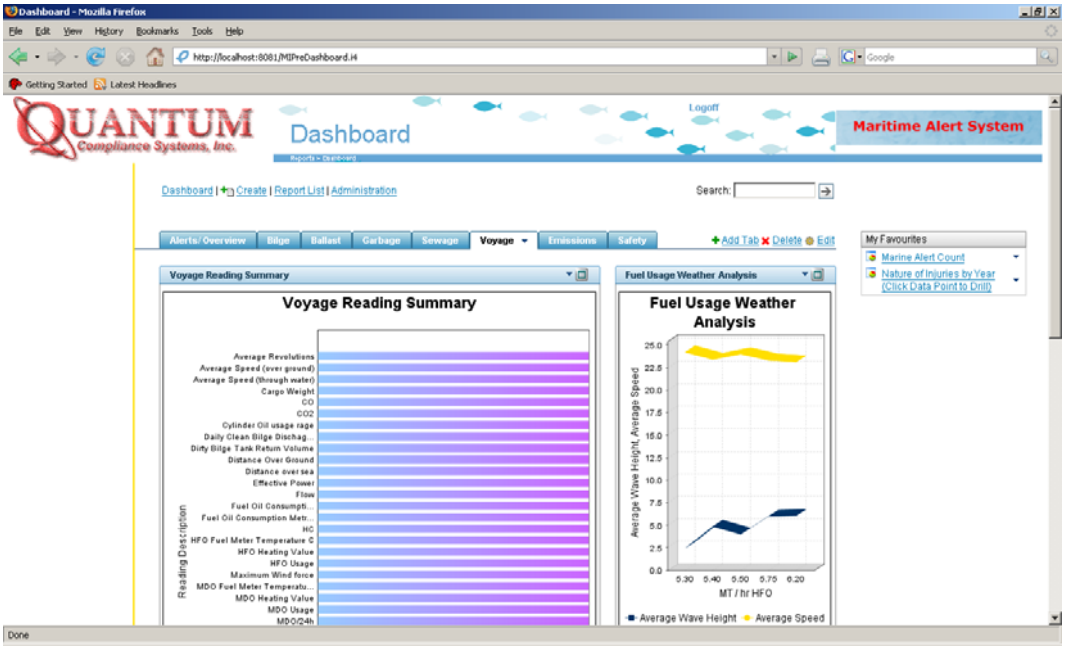


Figure 2. Screen shot from the Maritime Compliance Solution (MCS), Quantum Compliance Systems, Inc., www.qcs-facts.com

The PERCS data warehouse and information portal

At a pre-determined interval (e.g., every 12 hours), that data is sent via a satellite Internet link to the PERCS shore-side server, where it is stored and organized so that it can be accessed by the ship's owner/operator employees and regulators through the PERCS site via an Internet-based portal.

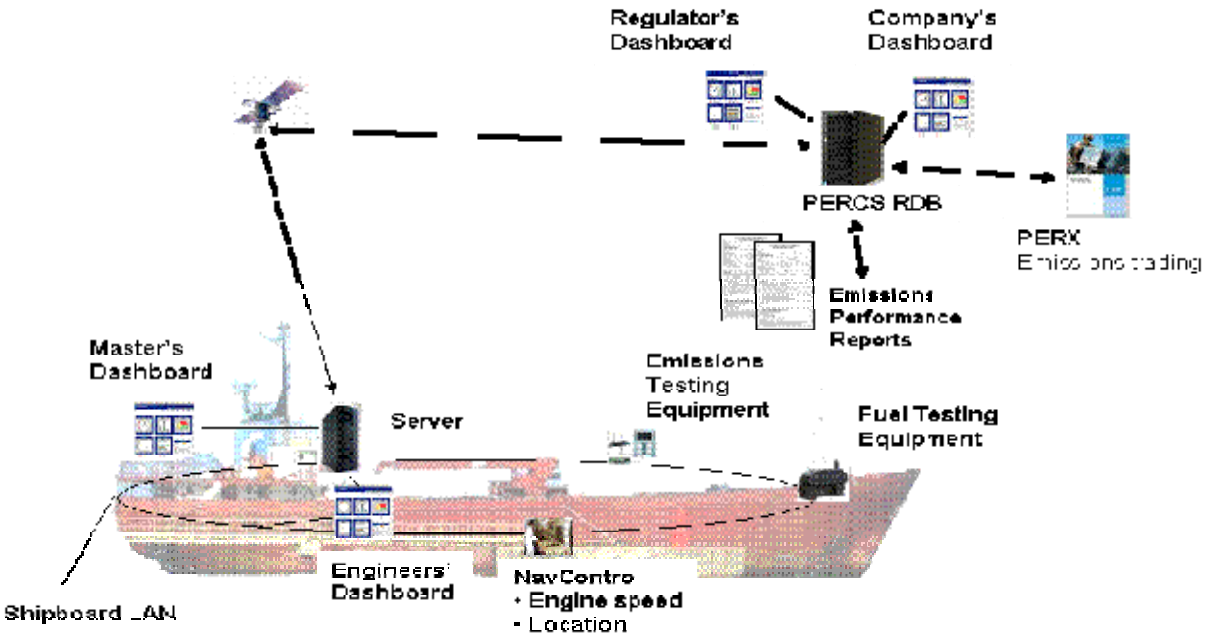


Figure 3. Maritime Electronic Monitoring and Reporting Framework, DNA Maritime LLC at www.dnamaritime.com

Because the PERCS system is an "Application Service Provider", it can be accessed through the Internet (see Figure 3) by any authorized party, and the portal provides not only historical data, but also emissions calculators and report generating tools that will allow both owner/operators and regulators to analyze emissions performance by ship, by voyage, by fleet, and by company - and compare that information with other ships and companies.

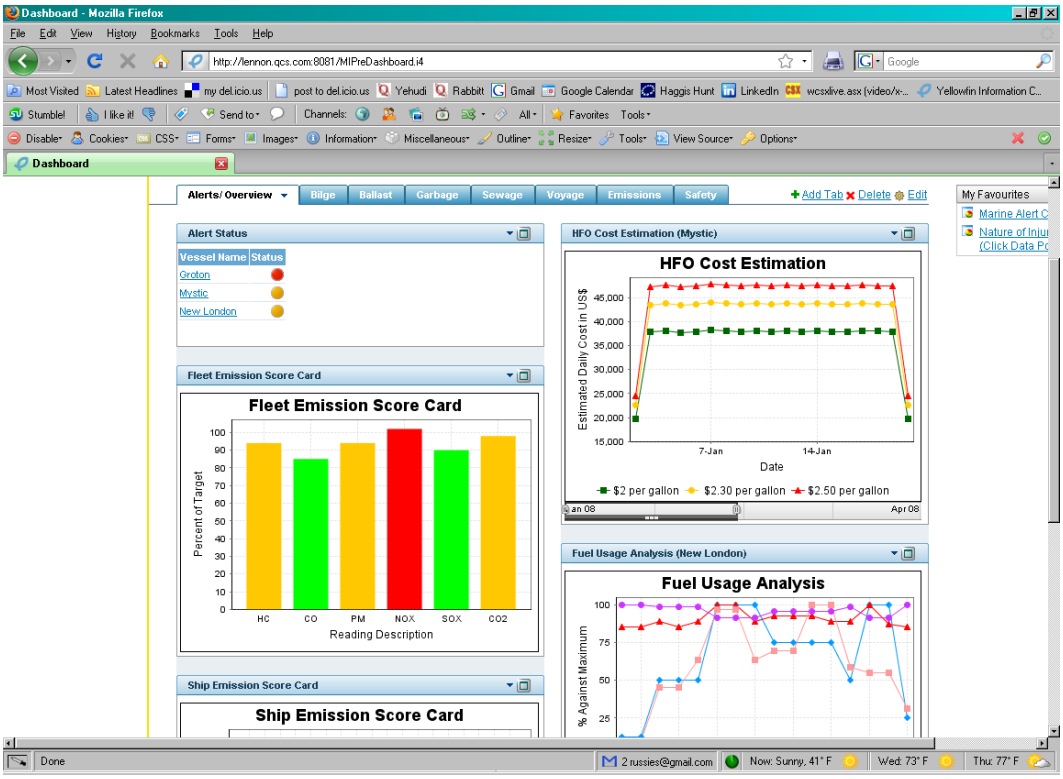


Figure 4. Screen shot from the Maritime Compliance Solution (MCS), Quantum Compliance Systems, Inc., www.qcs-facts.com

Creation of ship emissions inventories and performance baselines

Using the empirical data collected on emissions performance, it will be possible in time to set a performance baseline (see Figure 4) for emissions by type of ship (tanker, RoRo, LNG, container) and by size (GmT or engine type/size). That data can then be used by regulatory authorities, regional energy traders, or the IMO, to set targets and establish incentive programs for emissions reduction.

Conclusion

The maritime industry is a uniquely global in scope, and it needs global standards and uniform, worldwide representation. If responsibility for emissions monitoring remains paper-based and limited to inspections by port authorities or flag states, enforcement will invariably be unevenly applied around the world. A single, reliable emissions reporting database, with data that is collected automatically and electronically from ships anywhere, and at any time, will ensure consistency and accuracy of enforcement. It will also provide a more complete and accurate snapshot of current emissions output in coastal routes, in ports, or in open seas around the world.

Most important, that emissions data collected can be used both to “norm” performance expectations at an industry-level, and also to calculate emissions allowances at a company level. Once an emissions baseline has been set, it will be possible to reward

emissions reductions by shipping companies not only based on slower speeds and low-sulfur fuel content, but also on the introduction of scrubber technologies, hull and propulsion improvements, participation in Cold Ironing schemes, etc. - in short, any method that contributes to a verifiable overall reduction in not only NOx and SOx, but also Greenhouse (GHG) emissions and particulate matter (PM).

The performance baseline could potentially then be used as the basis for a “ring-fenced” maritime emissions trading market, or could be equilibrated and used for trading credits with larger national and international emissions cap-and-trade programs (e.g., the U.S. Acid Rain Program for SOx, the Chicago Carbon Exchange or the EU's Emissions Trading Scheme for GHGs, etc.).

Benefits of this approach include:

- Collecting empirical evidence for setting performance baseline for emissions control and emissions trading schemes.

- Giving regulatory authorities access to accurate company emissions performance and compliance records electronically.

- Absolute accuracy of electronic information gathering means that emissions performance reporting is fair, transparent and consistent: data on emissions per ship and per company is collected automatically and electronically - directly from the ship's systems; the integrity of the process is ensured by independent classification audits, and data is held in a secure, independent repository.

- Relieving crew, company staff and regulatory authorities of paperwork and prevents administrative disputes. Apart from the data interface module and EHS software, the PERCS approach uses technology and systems already in everyday use on the ships to capture emissions data and send it to a central data repository.

- After the initial investment for onboard monitoring technologies, there is little ongoing administrative cost or effort for shipping companies or regulators.

- Providing the company with valuable commercial/operational information for use in emissions output and fuel use planning.

- Because it is virtual system, and monitoring is based on pre-determined location triggered by a ship’s latitude and longitude, a ship's proximity to the coast, and its time within the emissions zone of participating ports, enforcement does not depend on individual port authorities, and therefore the system is potentially international, in scope.

References

[1] Statistics and Figure 11 from Friedrich, Axel; Heinen, Falk; Kamakaté, Fatumata; Kodjak, Drew, "Air Pollution and Greenhouse Gas Emissions from Ocean-Going Ships: Impacts, Mitigation Options and Opportunities for Managing Growth", *The International Council on Clean Transportation*, March 2007, p.p. 4-6 ; Corbett, James J.; Wang, Chengfeng; Winebrake, James; Green, Erin: "Allocation and Forecasting of Global Ship Emissions," *The Clean Air Task Force*, January 11, 2007, p.5; Cannon, James, U.S. Container Ports and Air Pollution: A Perfect Storm, *Energy Futures*, 2008, p. 4; Friends of the Earth International, Review of MARPOL Annex VI and the NOx Technical Code, IMO Subcommittee on Bulk Liquids and Gases,11th Session, Agenda Item 5, p. 3.

[2] International Maritime Organization, "Report on the Outcome of the IMO Study on Greenhouse Gas Emissions From Ships, MEPC 45/8. *International Maritime Organization*, London.

[3] The California Air Resources Board estimates that port pollution alone is responsible for roughly 640 premature deaths every year in the state and $1.0 billion in health costs just in the Los Angeles metropolitan area. See California Business, Transportation and Housing Agency and California Environmental Protection Agency, *Goods Movement Action Plan*, Sacramento, California, January 2007, p. III-4.

[4] MARPOL Annex VI requires ships to switch to marine distillate fuels with a cap of 0.50 percent sulfur content by 2020 in all waters; sulfur content in Environmental Control Areas will be reduced to 1.00% by 2010 and 0.10 % by 2015. In addition, NOx emissions will be reduced through engine tuning and conversion to 85% of present output in all waters by 2011, and 20% of current output in ECAs by 2016. See "Revised MARPOL Annex VI," Resolution MEPS.176(58), adopted on 10 October 2008, on the IMO website at imo.org.

[5] See, for example, the Port of Long Beach's Green Flag voluntary vessel speed reduction program at their website: www.polb.com.

[6] See the UN's Intergovernmental Panel on Climate Change's report at their website: www.ippc.ch.

[7] See the IMO website at www.imo.org

[8] Corbett concludes that "there are, however, significant differences among various global ship emission inventories; inventories estimated by one approach may be 50% higher than inventories estimated by another." See p. 4, Corbett, James J.; Wang, Chengfeng; Winebrake, James; Green, Erin: "Allocation and Forecasting of Global Ship Emissions," *The Clean Air Task Force*, January 11, 2007. A similar criticism was reached by Ang-Olson in a white paper prepared for the EPA, in which he asserts that, "Marine vessel emission inventories in the early 1990s were prepared using emission factors released by EPA in their emission inventory preparation guidance document,

where emission rates were given in terms of kilograms of emission per ton of fuel.. Such emission factors require either a knowledge or estimation of fuel consumption rates. Fuel consumption rates are not usually measured, but are estimated from engine design and loading data, where engine loading itself can only be estimated. The data that underlie these emission factors is limited and is an aggregation of engine tests on a variety of engine types and sizes…It should be noted, however, that the emission factors are still derived from limited data. Emission testing of ocean-going vessels is an expensive and difficult undertaking, and thus emissions data are relatively rare. In most cases, the power generated is only estimated, leading to inaccuracies in the overall emission factors. See Ang-Olson, "Port Emission Inventories and Modeling of Port Emissions for Use in State Implementation Plans (SIPS), White Paper #3, Prepared for the U.S. EPA by ICF Consulting, May 4, 2004, p.5. For a good critique of current maritime inventories, see Corbett, James J.; Wang, Chengfeng; Winebrake, James; Green, Erin: "Allocation and Forecasting of Global Ship Emissions," *The Clean Air Task Force*, January 11, 2007, or Smirti, Megan L; Zou, Bo ; Hansen, Mark; "Greenhouse Gas Emissions Inventories in Maritime Shipping and Aviation Sectors: Comparative Analysis and Evaluation of Best Practices," *Transportation Research Board Annual Meeting*, 2009, Paper #09-3618.

[9] Well established in the electricity generation and manufacturing industries globally, emissions trading is integral to the Kyoto Agreement and a significant force for emissions reduction - trading on the world's carbon markets was estimated to have exceeded $60 billion in 2007 alone. Emissions markets provide companies with financial incentives to improve their emissions output by allowing good performers (measured against a verifiable norm) to be rewarded with emissions "credits" which they can sell at auction to under-performing competitors. National and regional emissions trading markets in the U.S. and Canada include the Chicago Climate Exchange (CCE) and the Regional Greenhouse Gas Initiative (RGGI) for CO_2, the long-running Acid Rain Program for SO2, and the rapidly developing Western Climate Initiative in the Western US and Canada. Possibly most important, the European Union's Emissions Trading Scheme (EU-ETS) is expected to require maritime shipping emissions to be included in its GHG cap-and-trade market from 2012.

If required to join in these cap-and-trade markets without accurate emissions measurements and a defendable emissions "baseline" for various ship sizes and categories, maritime owner-operators risk having significant liabilities assigned to their balance sheets without the means to negotiate against the baseline itself. And without a proper emissions data collection scheme, companies that have already voluntarily taken real steps to reduce their GHG emissions output risk being unable to claim for the emissions credits that they deserve.

Lack of preparation for entry into this type of trading scheme can mean significant additional costs to the maritime industry, and if emissions allowances are significantly misallocated, could undermine the effectiveness of the emissions trading market scheme itself.