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Shipping steers a clear course on emissions

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SHIPPING steers a clear course on emissions

Pollutants and greenhouse gas emissions from shipping form a significant part of the overall air quality picture and are now included in national and international reporting obligations. Surrounded by some of the world's busiest shipping lanes the UK is a particular focus, and Ricardo has been commissioned to deliver a comprehensive update of the shipping emissions inventory for the UK National Atmospheric Emissions Inventory.

The 2015 Paris Agreement on Climate Change, reinforced a year later at the climate summit in Marrakech, has been the starting point for significant additional moves to help limit international greenhouse gas (GHG) emissions. At the highest strategic level some 200 nations agreed to measure, report and verify their emissions of GHGs: by cataloguing emissions from activities such as industry, agriculture, power generation and transport, countries establish their individual national GHG inventories, the first step towards applying targeted reductions. Ricardo Energy & Environment has been involved in such strategic initiatives for many countries.

On a more detailed level, Ricardo's work also includes running the UK's National Atmospheric Emissions Inventory (NAEI).

Although the inventories that countries have to report under the Paris agreement do not need to include international shipping, for some nations – especially island states such as the UK that are on busy shipping lanes – the reporting

Pollutants: what they are and what they do

The project at present covers emissions to air, not to water, with the main focus being on greenhouse gases (GHGs):

- **CO_2, CH_4 and N_2O are all powerful greenhouse gases, and CO_2 can increase ocean acidification over time**
- **SO_2 and NOx are pollutants with local and regional rather than global, air quality impacts. At a local level they impact on health, while further afield they can lead to environmental acidification and eutrophication**
- **PM (particulate matter) has local health impacts and some fractions of PM can have global warming impacts as black carbon**
- **VOCs, or volatile organic compounds, have local health impacts and, like NOx, are precursor gases for the formation of ozone. Ozone is a health and environmental issue due to photochemical effects, especially in summer.**

of purely inland sources is insufficient to provide a complete picture of atmospheric pollutants. Such is the intensity of shipping around Britain, through the English Channel and around some UK ports, that emissions that occur at sea are likely to have a significant effect on air quality in coastal communities on land; they can make a sizeable contribution inland too.

Under present agreements the UK has to report domestic shipping emissions in its national inventory, but chooses to report an estimate for international shipping emissions as a 'memo item' which is not subject to policy controls. Related programmes such as CLRTAP (the Convention on Long Range Transboundary Air Pollution), the National Emissions Ceiling Directive and the UK annual carbon budgets have focused attention on the need to encompass all significant emissions sources, including shipping.

However, although existing inventories of shipping emissions are reasonably detailed, they do not cover several important classes of shipping activity. What is more, levels of shipping activity are forecast to rise significantly in the coming years as global trade expands. For these reasons, therefore, Ricardo Energy & Environment was commissioned by the UK government to undertake an update of the shipping emission inventory component of the NAEI.

The NAEI, explains Tim Scarbrough, principal consultant at Ricardo Energy & Environment, is a high-level strategic programme and is required to cover all emissions sources within the UK. "It's used by the government for official reporting, at international level for UNFCCC reporting on greenhouse gases and for CLRTAP reporting on air quality pollutants, and at EU level for the National Ceilings Directive," he explains. "And it's also used for national-level reporting for the carbon budgets we have in the UK."

Capturing marine emissions: the new initiative

Where the NAEI is especially useful, says Scarbrough, is because it is spatially disaggregated, meaning that it shows the distribution of emissions rather than simply an overall total; this makes it a vital tool for local air quality modelling.

Ricardo's analysis, in conjunction with project partner University College London Consultants, has addressed several drawbacks to the existing maritime inventories – principally that they were based on estimated rather than actual routes taken by ships, that they did not take account of variation in vessels' engine loads or speeds, and that they failed to capture certain types of craft, especially fishing vessels, offshore fleet and service vessels.

Reviewing the available options, Ricardo and its partners opted for an entirely new methodology relying on AIS (Automatic Identification System) data from the UK's Maritime and Coastguard Agency. AIS uses VHF radio signals to report vessels' positions and identify them. The AIS messages are sent up to every three seconds, and the messages are received directly by other vessels and by the AIS receivers operated by the UK Coastguard. AIS messages also provide additional information on the speed of the vessel among other parameters. This, says Scarbrough, enables very precise plotting of ships' courses and speeds,

The Automatic Identification System *(below)* **tracks the positions, courses, speeds and draught of vessels. Cross-referencing with technical databases allows accurate prediction of each ship's emissions at three second intervals**

How the scope of the inventory has broadened

Earlier UK inventory studies focused their attention on only eight categories of ships, ranging from bulk carriers and ro-ro cargo ferries to certain types of fishing and cargo vessels. The new inventory system improves emission prediction accuracy by increasing the scope to 20 basic categories, many of them further subdivided by tonnage or cargo capacity.

All Class A passenger ships and cargo vessels over 300 gross tonnes are obliged to carry AIS equipment, meaning that all are tracked for the inventory. Fishing vessels are also obliged to use AIS. AIS is optional for smaller Class B craft: this means that not all are captured by AIS, and so the inventory has to make separate considerations of aggregate emissions to ensure completeness.

The new categories include:

- **Bulk carrier**
- **Chemical tanker**
- **Container**
- **General cargo**
- **Liquefied gas tanker**
- **Oil tanker**
- **Cruise**
- **Refrigerated bulk**
- **Roll-on, roll-off**
- **Yacht**
- **Service tug**
- **Miscellaneous – fishing**
- **Offshore**

with the high degree of granularity that is essential to understanding the effects of maritime emissions on the air quality of coastal cities such as Southampton. One year's worth of stored AIS data was used.

The ships' identities are then cross-referenced to a register of world shipping. The register contains a host of detail for the majority of the world's registered vessels over 100 gross tonnes, giving technical information on each vessel's engines and performance characteristics.

Marrying the two streams of data together, says Tim Scarbrough, enables the model to predict with a high degree of accuracy the emissions of any AIS-tracked vessel at any given speed and load condition; even when in port or at anchor, the emissions of the ship's auxiliary engines and boiler are accounted for.

Adding to the magnitude of the challenge was the inclusion of many more classes of vessels, notably offshore service vessels, passenger ships and fishing boats, many of which were poorly covered in earlier studies.

The only drawback of this approach is the enormous amount of data that it generates. "One year's data for all the vessels around the UK, each reporting up to every three seconds, resulted in more than 2 billion data points," notes Scarbrough. "We had to thin these down to around 100 million, but it was still a considerable data processing task."

Accurate estimation of selected pollutants

The present model confines itself to predicting the emissions to air of greenhouse gases (CO_2, methane and nitrous oxide), sulphur dioxide, NOx, particulate matter, carbon monoxide and volatile organic compounds (VOCs). No attempt is yet made to quantify fugitive emissions of refrigerants – although this is believed to be negligible compared to the greenhouse gases included. Emissions to water – for example as ships flush out their tanks – could later be of interest, though this would demand a very different methodology.

The complex exercise will not need to be repeated: the 2015 snapshot has so much detail and so many layers that it can serve as a starting point to model future forecasts as well as a basis to "back-cast' to earlier years to gain greater understanding of emissions phenomena. As Scarbrough explains, the official national emission inventories also require estimates of historical emissions, domestic shipping included.

"We will be able to estimate previous years – and future years – by comparing it to this base year", he says. "The way that we do this is to look at the three main variables affecting emissions that have changed over time: how many ships are operating, what their fuel type is, and changes in emission factors over time as engines themselves have improved. We make indices for these three things, and this allows us to back-cast. The main thing is the activity driver, and for this we use statistics published by the Department of Transport for each vessel type, for example, or the number of tonnes of cargo from each vessel type landed in the UK for each year."

So while there is no historical time series that can be projected forward into the future, estimates can be made for the average annual growth or contraction for each individual vessel category. These, overlaid with estimates of the improvements in engine efficiency over time and changes in the fuel type driven by legislation, can be used to generate forecasts for future years.

Predicting the emissions

The Clarksons World Fleet Register database employed by the inventory project contained technical detail on tens of thousands of the world's registered vessels operating internationally or domestically.

Position, speed, vessel size and draught information provided by AIS is overlaid on these specifications to give an accurate prediction of the emissions of each of those ships between each AIS message, using the speed and draught data to infer engine load conditions.

The database holds details of vessels' main engines, but additional estimates for the auxiliary engines and boilers have been made so that emissions can be predicted even when the ship is manoeuvring, moored, or at anchor.

A full year's dataset contains details on more than 100 million data points, each matched uniquely to the database of vessels so as to give a complete record of each ship's emissions over the year.

Shipping accounts for between two and three percent of global man-made CO_2, and the International Maritime Organisation has put into place efficiency improvement measures for categories of shipping responsible for 85 percent of maritime CO_2 emissions

The environmental picture

The Ricardo maritime air quality work comes in the context of growing international concern over pollution at sea, be it in the atmosphere or in the water. Ricardo's water practice offers expertise on monitoring port water quality for environmental permit compliance, while on the engineering side of the business Ricardo specialists in large marine engines are working at the forefront of technical developments.

Domestic or international

Strict definitions govern the meaning of these terms when it comes to building maritime emissions inventories for national reporting purposes.

- **Domestic emissions are those from ships starting and finishing in the same country. Fishing trips are counted as domestic, even though they may be longer and reach well outside territorial waters. The 'domestic' label has nothing to do with what flag the ship is flying, which country the owner or operator of the ship is from, or the origin or destination of its cargo. All these emissions count towards the UK's national inventory.**
- **International emissions are those from ships travelling from one country to another, such as vessels passing through the English Channel to dock at, say, a UK port or Rotterdam. The emissions related to international trips which do dock at the UK can be included as 'memo items' in UK inventory reporting, but they are not currently subject to policy controls.**

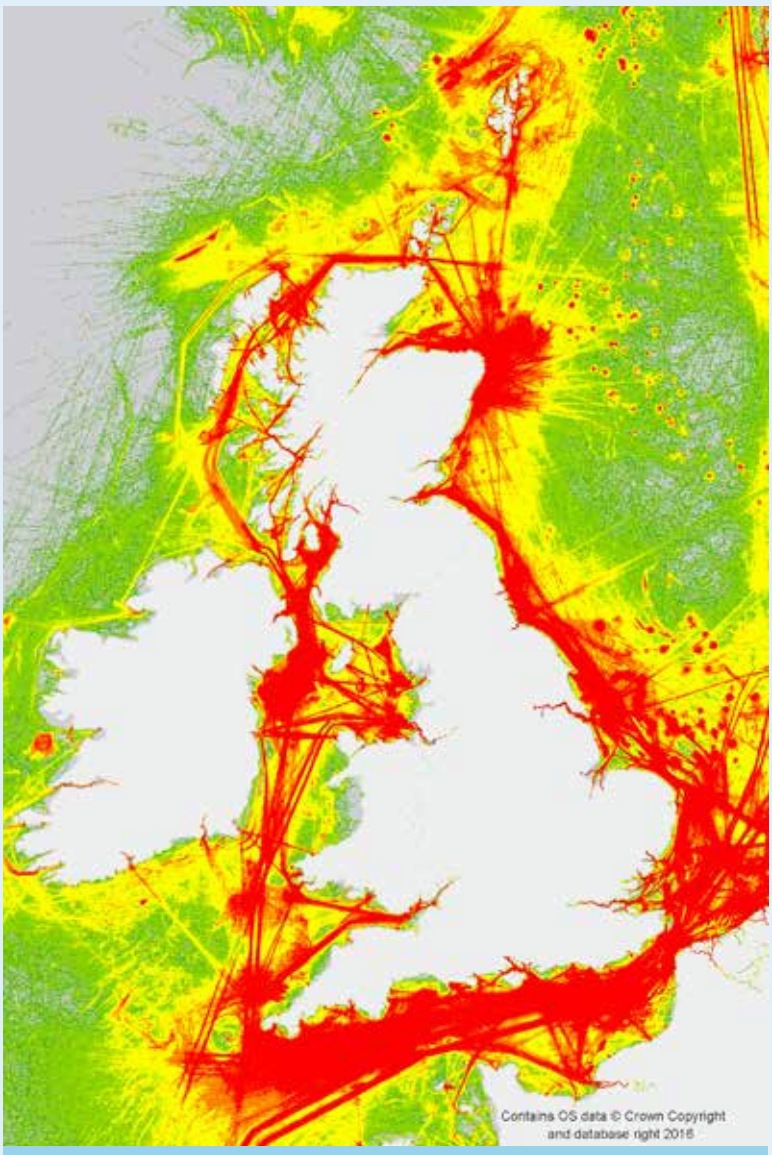
When considering local air pollution impacts, emissions from all shipping movements need to be considered – for example the level of pollution in high-traffic sea routes such as the English Channel must be significantly higher than might be expected from the UK-allocated emissions alone.

Firmly in focus among all concerned are the steadily tightening controls on international shipping and marine fuels. A sulphur emission control area (SECA) is already in force across the North Sea and English Channel, following the lead set by the Baltic in 2005; most of the US east coast, along with parts of the Canadian coast and the Caribbean also control fuel sulphur content. Tighter NOx controls on new engines, depending on the vessel's engine rpm, are in force for large vessels within 200 nautical miles of the US coast and will apply to new ships built from 2021 operating in the North Sea and Baltic. This is expected to lead to increases in the use of exhaust gas recirculation in engines, or the use of selective catalytic reduction as an end-of-pipe measure – or the use of alternative cleaner fuels such as LNG.

Fuel is a particularly contentious issue, with MEPs calling for the International Maritime Organisation (IMO) to implement a ban on traditional heavy fuel oil (HFO) in the Arctic. HFO has already been banned in the Antarctic and there are fears that the accelerated melting of the ice in the northern polar region will allow an opening up of new shipping routes and thus a further twist in the pollution spiral.

Greenhouse gas emissions, largely in the form of CO_2 and methane, are a global rather than regional or local issue. A comprehensive study of maritime GHG emissions published by the IMO in 2014 concluded that shipping contributed around three percent of global CO_2e emissions on average between 2007 and 2012. Fluctuations over this period are related to the effects of the 2007-8 financial crisis, which led to the widespread adoption of slow steaming – down to as low as 60 percent of design speed in some cases. Slow steaming, while reducing real-time CO_2 emissions by as much as 27 percent, means more days at sea and masks an effective fleet over-capacity.

Either way, however, the existence of a comprehensive spatially resolved inventory such as that developed by Ricardo and University College London provides a sound basis from which to model future scenarios and policy options such as speed restrictions, fuel



Position density of shipping around the UK – AIS Class A
Data generated for the shipping emissions inventory shows clearly the concentrations of movements around the UK's major ports and through the English Channel and off the coast of Cornwall in the south west. Also clearly identifiable is the frequent service traffic to and from the offshore installations in the North Sea, with oil and gas fields in the north and offshore wind farms further south.

improvements and mandatory itineraries in sensitive areas.

Expansion and outlook

Given the success of the inventory capture rate around the UK coast and through the English Channel, a natural next step would be to extend the scheme further afield. The reach of the data gathering is effectively only limited by the range of the terrestrial AIS signal, and the use of satellite AIS data could potentially be added to widen the system's operating radius. Already, the system estimates emissions for the UK fishing fleet even after these vessels travel a long way out of terrestrial AIS range before returning to land their catch in the UK; emissions for the whole trip can be calculated and included in the overall inventory.

Nevertheless, counsels Tim Scarbrough, the very high spatial resolution of the data makes it much more relevant to studying air quality effects at a local level.

Whether the discussion is macro or micro, however, the multi-layered emissions inventory will be a very valuable resource on a technical level and also from a planning perspective. Future environmental measures could be modelled and their effects predicted with some degree of confidence; this could be done relatively simply by changing some of the assumptions in the existing forecasting models.

Forecasts have already been completed as far as 2035 to model the effects of projected changes in shipping activity, transport efficiency, fuel types and emission factor improvements. However, it is not possible to anticipate structural or route changes or cater for their effects, and while work is still in progress no quantitative data can yet be released.

Yet one thing is abundantly clear. Despite the greater coverage of smaller craft, such as tugs, service vessels and passenger ships that are now included in the emissions inventory, as far as the UK is concerned it will still be the bigger vessels that are the dominant source of emissions. And in contrast to domestic traffic, which has remained roughly level since 2009, international movements are on an upward trend.

"The big vessels are really the problem," says Scarbrough. "They consume vast amounts of fuel, even though there are fewer of them; but that doesn't mean that the other categories are not important. As an island nation with an active offshore energy market, we have a lot of passenger vessel movements, as well as offshore service and fishing boats that are an important part of the UK inventory."

According to IMO estimates, shipping accounts for between two and three percent of global man-made CO_2 and, even in 2011, when the world economy was still recovering from the financial crisis, international shipping consumed four-fifths of the 254 million tonnes of fuel sold to the industry; domestic shipping was far from negligible at 40 million tonnes. The IMO has put into place efficiency improvement measures for categories of shipping responsible for 85 percent of maritime CO_2 emissions, but even on a business as usual basis the same organisation forecasts that, by 2050, CO_2 from shipping could have grown by between 50 and 250 percent to as much as 2,500 million tonnes a year – which gives a chilling idea of the scale of the problem.

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