BRIEFING - May 2024

Coastal fug: the UK's most polluted ports, ranked in order

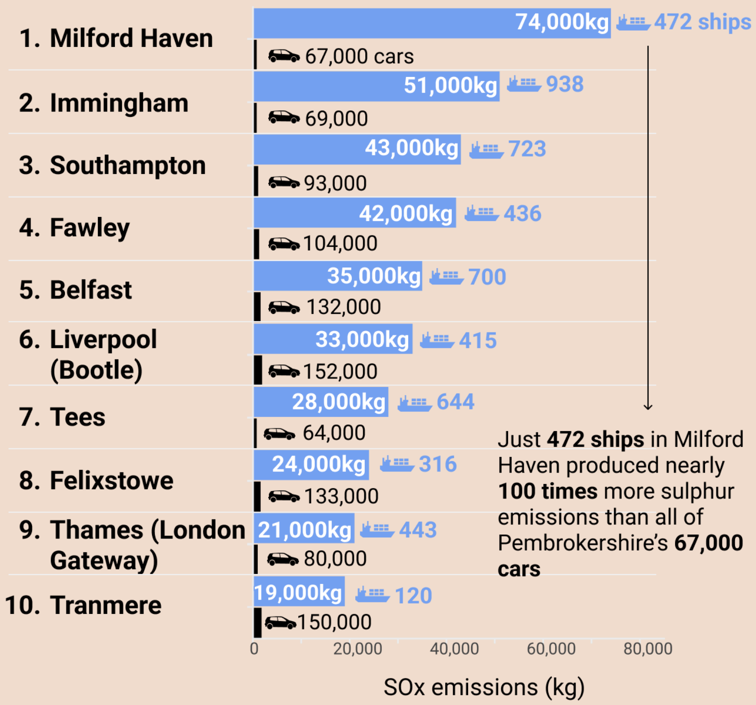
How the UK's ports are choking on ship fumes

Summary

T&E has ranked the UK's top 10 dirtiest ports, in order of air pollution from shipping activities within ports

Milford Haven, Southampton and Immingham top the list for emissions of harmful sulphur oxides (SO_x), nitrogen oxides (NO_x) and fine particulate matter ($PM_{2.5}$). In 2022, in Milford Haven alone, just 472 ships produced almost 100 times more poisonous SO_x emissions than all of Pembrokeshire's 67,000 cars. In the top 10 SO_x polluted ports, 3,700 ships produced 30 times more SO_x emissions than all ~1 million cars in the same areas.

Top 10 SOx polluted UK ports



Source: Transport & Environment (2024)

More vessels in ports do not necessarily mean more pollution. Vessel type and size play a big part in how polluted ports are. For example, Milford Haven - a deep water port able to accommodate the largest vessels - saw half the vessel numbers and vessel time in port of Immingham, but 50% higher SO_x emissions. In Southampton, 46 cruise ships - just 6% of vessels calling there - produced more SO_x than 200 containerships, and over 50% of NO_x and $PM_{2.5}$ emissions.

Shipping pollution is not just an issue for the UK's top 10 dirtiest ports. All residents of port towns are forced to breathe poisoned air because vessels burn fossil fuel whilst at berth - around half a million tonnes in 2022 - to meet on-board heat and electricity requirements.

As well as producing significant greenhouse gas (GHG) emissions, this practice also discharges very large amounts of harmful air pollutant emissions directly into the UK's port towns, in many cases 24 hours a day. Ships also routinely discharge pollutant-laden wash water from exhaust gas cleaning systems ("scrubbers") straight into the sea and only a small number of UK ports prohibit this.

The health impacts for dock workers, port town populations and people living further afield of breathing shipping fumes include respiratory and cardiovascular disease. The health costs of shipping's contribution to $PM_{2.5}$ exposure alone in the UK are estimated at £1.5bn/year.

Avoidable

Solutions exist, and with the right policies from the Government they could be developed rapidly. Shore side electricity (SSE) allows vessels to plug in at berth rather than running engines for energy requirements. Alternative fuels like hydrogen from renewable electricity can also greatly reduce air pollutant emissions. And designating all UK waters and ports as an emission control area (ECA), where limits and even charges are placed on ship pollution, would lower emissions and could help fund cleaner forms of energy.

But at present, in the continued absence of an updated Clean Maritime Plan, the UK government has no credible policies or regulations for zero-emission shipping - either for GHG emissions which must be eliminated for Net Zero, or air pollutant emissions. Existing regulations to prevent air pollution from ships go no further than weak international standards, whilst UK limits for SO_x, NO_x and $PM_{2.5}$ concentrations are up to 4 times higher than World Health Organization (WHO) guidelines. Port Air Quality Strategies (PAQS) are voluntary and powerless to address emissions from visiting ships.

T&E therefore recommends that the Government:

- **Require all berths in UK ports to be zero-emission** (for both air pollutants and GHGs)
- **Publish a plan for SSE in UK ports** (recommended by the Climate Change Committee)
- **Implement a UK variation on the Norwegian NO_x fund** and charge all ships making UK port calls for their emissions, effectively making all UK ports maritime clean air zones
- **Designate all UK territorial waters as an Emission Control Area (ECA)**
- **Prohibit the discharge of scrubber wash water** in UK territorial waters
- Signal its intention to pursue these options (alongside T&E's broader zero-emission shipping energy policy recommendations) in the forthcoming updated Clean Maritime Plan

1. The ports of Milford Haven, Immingham and Southampton suffer the worst shipping pollution in the UK. Solutions exist and will bring significant environmental and health benefits - but strong action from the Government is essential

Emissions from ships burning fossil fuels in the UK's ports for manoeuvring and to meet on-board heat and electricity requirements are a major contributor to the country's air pollution, with serious impacts for human health. However, the UK has no strategy or effective regulations in place or even proposed to eliminate these emissions. Meanwhile, UK air quality regulations permit levels of pollutants well in excess of World Health Organisation (WHO) guidelines (see Section 1.1).

A major overhaul of regulations is needed to address emissions from ships in ports, and the UK's forthcoming updated Clean Maritime Plan must set out how. The Government should require all berths to be zero emission, and publish a plan for shore side electricity (SSE) so vessels can plug in at berth instead of burning fuel for electricity. As first steps, all UK waters should be designated as an Emission Control Area (ECA) and ships charged for their port pollution. Revenues could be used to help fund the transition to zero-emission technologies.

1.1 Context

Most goods used by households and industry around the world, as well as large numbers of passengers, are transported by ship. But with shipping still relying almost entirely on fossil fuels of the dirtiest kind, the sector is also a major source of pollution. As well as greenhouse gas (GHG) emissions, marine fuel exhaust also contains high levels of air pollutants such as oxides of nitrogen (NO_x), sulphur oxides (SO_x) and particulate matter 2.5 ($PM_{2.5}$). All are damaging to human health (see Info Box).

Regulatory standards for marine fuels lag far behind those applicable to other modes of transport. The best marine fuel sulphur standard (0.1% sulphur) is 100 times worse than the sulphur standard for road diesel (EN 590) sold in the UK and EU (0.001%). In Europe, including the UK, the 0.1% marine fuel sulphur standard is only implemented in ports and in two designated emission control areas (ECAs). Outside these restrictions, sulphur limits are five times higher.

Higher sulphur fuels are still permitted as long as they are used in combination with sulphur reduction technologies such as exhaust gas cleaning systems ("scrubbers") to comply with the standard. Scrubbers spray water into ship exhaust to remove sulphur oxides. The resulting "wash water" contains mercury and polycyclic aromatic hydrocarbons (PAHs) as well as sulphur, and is highly toxic to marine life. "Open loop" scrubbers - the majority - discharge their wash water directly into the sea.[1] Only a small number of UK ports prohibit scrubber wash water discharge (see Annex B).

Ship NO_x emissions are limited by regulations set by the International Maritime Organization (IMO) but only target new ships coming into service. NO_x Tier III controls (the strictest limit) only apply in NO_x ECAs, and were only introduced in 2021 so have had limited effect to date. Concerns have been raised about observed NO_x levels significantly higher than expected levels under these controls.[2]

Info Box: the health impacts of air pollution

SO_x are chemical compounds that result when fuels containing sulphur are burned in air, and include sulphur dioxide (SO_2) and sulphur trioxide (SO_3). SO_x can provoke cardiovascular and respiratory diseases and lead to premature death.[3]

[1] International Council on Clean Transportation (2021). Global Scrubber Washwater Discharges under the IMO's 2020 Fuel Sulfur Limit. Retrieved from https://theicct.org/publication/global-scrubber-washwater-discharges-under-imos-2020-fuel-sulfur-limit/
[2] https://www.scipper-project.eu/wp-content/uploads/2023/03/press-release_march-2023_f.pdf
[3] Sofiev, M., Winebrake, J. J., Johansson, L., Carr, E. W., Prank, M., Soares, J., … Corbett, J. J. (2018). Cleaner fuels for ships provide public health benefits with climate tradeoffs. Nature communications, 9(1), 406. Retrieved from https://doi.org/10.1038/s41467-017-02774-9

NO_x emissions result from the combustion of fossil fuels and include nitric oxide (NO) and nitrogen dioxide (NO_2). They can lead to respiratory diseases and are a precursor of ground-level ozone, another health-impacting pollutant.

Together, SO_x and NO_x emissions contribute to the acidification of rain, which affects the balance of ecological systems, especially plants and animals that are sensitive to acidic waters.

$PM_{2.5}$ emissions are particles made up of fine dust, soot and smoke, and are inhaled through human lungs.[4] The contribution that shipping makes to exposure to $PM_{2.5}$ is estimated to bring health costs of ~£1.5bn / year in the UK (2017 prices).[5] Worldwide, shipping emissions are estimated to cause more than 250,000 premature deaths per year from cancer and cardiovascular diseases.[6]

In 2021, UK domestic shipping (vessels which both begin and end their voyages in UK-only ports) alone accounted for 13% of the UK's domestic NO_x emissions in the same year, 2.2% of total domestic primary $PM_{2.5}$, and almost 5% of UK total domestic SO_2 emissions. NO_x emissions from UK international shipping (voyages either beginning or ending in UK ports) in the seas surrounding the UK and vessels transiting UK waters were estimated to be up to 6 times higher than from UK domestic shipping in 2016.[7]

The vessels included in this study burned almost half a million tonnes of fossil marine fuel in the UK's ports in 2022.[8] This is a significant proportion of UK shipping's total fuel use and associated emissions. This means that moored vessels are discharging very large amounts of air pollutants directly into the UK's port towns and cities, in many cases 24 hours a day.

At first glance, this appears at odds with political ambition on shipping pollution and also UK regulatory requirements on pollutant emissions more broadly. For example, in both the 2019 Clean Maritime Plan and Clean Air Strategy, the Government acknowledged the issues posed by shipping pollution. And UK

[4] PM emissions fall into two size categories: the one with a diameter of 2.5 micrometres or lower ($PM_{2.5}$) which were looked at in this study, and the one with a diameter of 10 micrometres (PM10) which are not part of this study. Ships also emit ultra-fine particles (UFPs) which are not yet regulated and are roughly the size of a virus

[5] HM Government (2024). Extending the emission control area to all UK waters. Retrieved from https://www.gov.uk/government/calls-for-evidence/extending-the-emission-control-area-to-all-uk-waters/extending-the-emission-control-area-to-all-uk-waters#fn:9

[6] Sofiev, M., Winebrake, J. J., Johansson, L., Carr, E. W., Prank, M., Soares, J., … Corbett, J. J. (2018). Cleaner fuels for ships provide public health benefits with climate tradeoffs. Nature communications, 9(1), 406. https://doi.org/10.1038/s41467-017-02774-9

[7] UMAS / Frontier Economics (2023). Options for Extending the North Sea Emissions Control Area. Retrieved from https://assets.publishing.service.gov.uk/media/64dce58860d123001332c657/options-for-extending-the-north-sea-shipping-emissions-control-area.pdf

[8] We define in-port emissions as those occurring from cargo and passenger vessels <1.5 nautical miles from the port centre and at a speed-over-ground (SOG) of <3 knots, and excluding emissions from stops longer than 5 days. Total CO_2 emissions in 2022 from vessels meeting these criteria were 1.46 megatonnes (Mt), corresponding to ~0.5 Mt fossil marine fuel.

regulations on emissions[9] and the 2023 Environmental Improvement Plan[10] require SO_x and NO_x reductions of nearly ¾ of their 2005 levels by 2030, and $PM_{2.5}$ reductions of 35% in 2040.

However, the UK actually permits[11] levels of sulphur dioxide (SO_2), nitrogen dioxide (NO_2) and $PM_{2.5}$ to be around four times greater than World Health Organization (WHO) guidelines.[12] Broad targets on reducing air pollutants on historical levels may be binding, but very little is actually required of the shipping sector, which is bound only by regulations reflecting weak international standards on emissions of SO_x and NO_x.[13] Port Air Quality Strategies (PAQS)[14] are voluntary and powerless to address shipping emissions.

2. Scope and methodology

This analysis covers SO_x, NO_x and $PM_{2.5}$ emissions from commercial passenger and cargo ships of more than 400 gross tonnage (GT) making UK port stops in 2022. T&E analysis shows that in 2021, around two-thirds of UK port emissions were produced by the vessel types included in this analysis. Emissions totals are therefore conservative.

GHG emissions are calculated using automatic identification system (AIS) data purchased from Spire, and ship technical specifications from IHS Markit and Clarksons' World Fleet Register (WFR). AIS messages are sent by ships at regular intervals during their operation and contain information such as timestamp, position, speed and draught of the vessel.

We aggregated emissions results from vessels within a 1.5 nautical mile (nm) radius of a port's main coordinates[15] and at a speed-over-ground (SOG) of less than 3 knots (this being the speed below which a vessel is considered moored by the International Maritime Organization 4th greenhouse gas study[16]). We calculated energy consumption and emissions for vessels meeting these criteria.

[9] HM Government (2018). The National Emission Ceilings Regulations 2018. Retrieved from https://www.legislation.gov.uk/uksi/2018/129/schedule/3
[10] HM Government (2023). Environmental Improvement Plan. Retreived from https://assets.publishing.service.gov.uk/media/64a6d9c1c531eb000c64fffa/environmental-improvement-plan-2023.pdf
[11] HM Government (2010). The Air Quality Standards Regulations 2010. Retrieved from https://www.legislation.gov.uk/uksi/2010/1001/schedule/2/2020-12-10
[12] World Health Organisation (2021). WHO global air quality guidelines. Retrieved from https://iris.who.int/bitstream/handle/10665/345334/9789240034433-eng.pdf
[13] HM Government (2021). The Merchant Shipping (Prevention of Pollution from Ships) (Amendment) Regulations 2021. Retrieved from https://www.legislation.gov.uk/uksi/2021/1108/contents/made
[14] Department for Transport (2019). Port Air Quality Strategies. Retrieved from https://assets.publishing.service.gov.uk/media/5d24a9aa40f0b660ad3b68b3/port-air-quality-strategies.pdf
[15] We used port locations from available public sources (e.g. World Port Index and Eurostat) and completed these with the locations with a high frequency of stops in our AIS data.
[16] See Annex B

We then compared pollution from ships to pollution from cars registered to the lowest tier Local Authority (LA) where ports are located, according to UK government Vehicle Licensing Statistics Data[17] for 2022.

The full methodology is provided at Annex B.

3. Findings

We present the top 10 most polluted UK ports for SO_x, NO_x and $PM_{2.5}$ from port shipping activities in the year 2022 and attribute emissions to vessel type for the top 3 polluted ports in each pollutant category. Detailed examination of emissions according to vessel characteristics (eg size, engines) is beyond the scope of this analysis.

However, it should be noted that these variable characteristics, combined with other factors including time spent in port and the UK ECA excluding western ports, mean that emissions totals for each port do not correlate directly with total vessel hours in port. For example, Milford Haven saw half the number of vessels and half the total vessel time in port as Immingham, but Milford Haven's SO_x emissions were 50% higher. Generally, the greater a vessel's capacity the greater its emissions, whilst average fuel sulphur content increases by around one third in non-ECA ports.

A full breakdown of all emissions for the top 20 most polluted ports is included at Annex A.

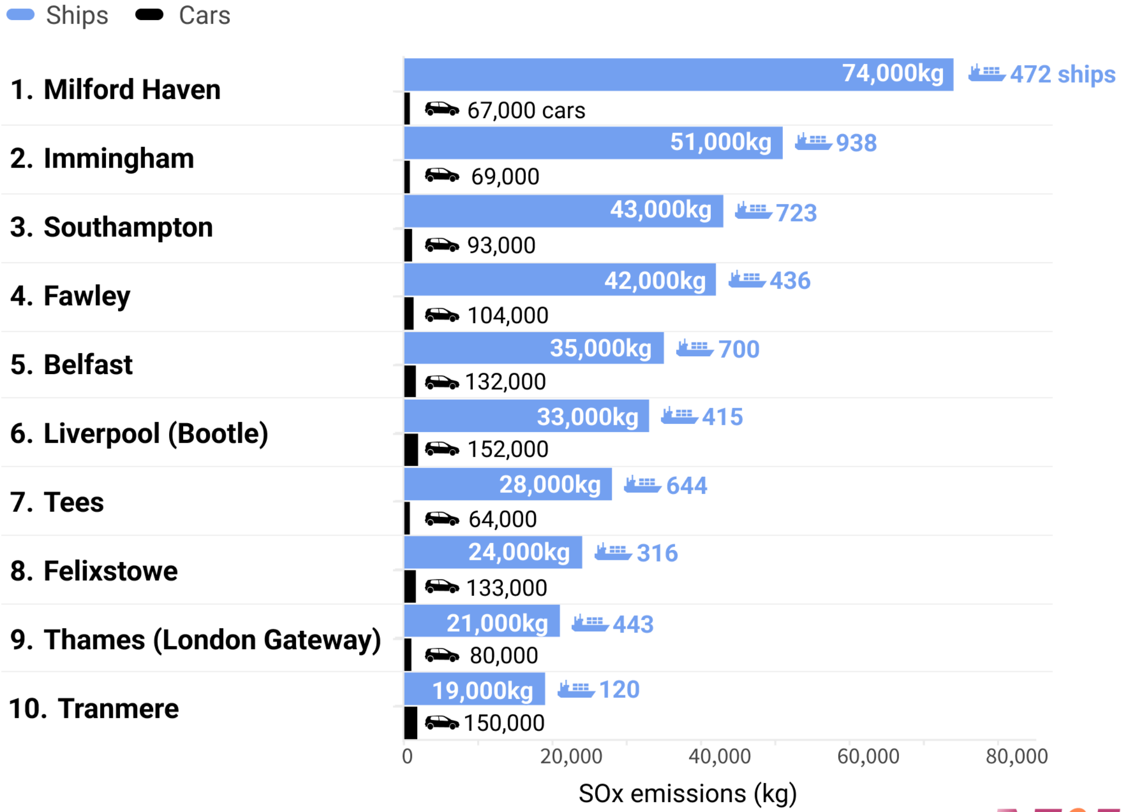
3.1 Sulphur oxides (SO_x)

In the top 10 SO_x polluted ports, ~3,700 unique ships[18] produced ~370,000 kg SO_x, 30 times as much as the ~1 million cars registered to the same LA areas as the ports. SO_x emissions according to vessel type for the top three SO_x polluted ports are shown at Figure 2.

Milford Haven has by far the highest SO_x emissions even though it ranks only 8th for total vessel hours in port. 472 vessels produced nearly 100 times more SO_x than all of Pembrokeshire's 67,000 cars. 70% of vessels calling at Milford Haven were oil and chemical tankers (332/472 vessels) producing 84% of the port's total SO_x emissions. Milford Haven is outside the UK ECA, meaning the 0.1% sulphur fuel standard only comes into force once a vessel has been at berth for two hours.[19] Milford Haven is a deep water port and can accommodate the largest vessels.

[17] Department for Transport and Driver and Vehicle Licensing Agency (2023). VEH0105: Licensed vehicles at the end of the quarter by body type, fuel type, keepership (private and company) and upper and lower tier local authority: Great Britain and United Kingdom. Retrieved from https://www.gov.uk/government/statistical-data-sets/vehicle-licensing-statistics-data-tables#all-vehicles
[18] Our data shows the number of unique ships making port calls, and also total hours spent in port. However, we do not present how many times each unique vessel called at each port in 2022. "Number of unique vessels" does therefore not indicate total vessel traffic. Total time all vessels spent in port is presented at Table 1.
[19] HM Government (2010). The Merchant Shipping (Prevention of Air Pollution from Ships) (Amendment) Regulations 2010 (Schedule 2A, paragraph 4). Retrieved from https://www.legislation.gov.uk/uksi/2010/895/schedule/1/made

Top 10 SOx polluted UK ports

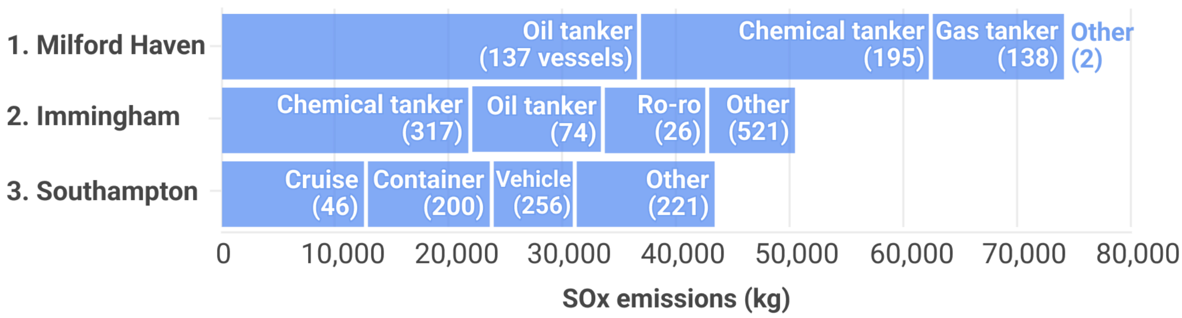


Source: Transport & Environment (2024)

Figure 1

In Immingham, chemical and oil tankers produced the majority of SO_x emissions (66%), followed by roll-on roll-off (ro-ro) cargo vessels (18%). In Southampton, cruise ships were the most polluting vessel type, where just 46 cruise ships contributed almost 30% of Southampton's SO_x emissions (and more than the 200 containerships also calling there).

SOx emissions according to vessel type, top three SOx polluted ports



Source: Transport & Environment (2024)

Figure 2

	Port	Number of unique vessels	Hours in port	SO_x from ships (kg)	Number of cars	Local Authority where cars are registered	SO_x from cars (kg)	Ratio of ship SO_x to car SO_x
1	MILFORD HAVEN	472	47429	74382	66618	Pembrokeshire	812	91.6
2	IMMINGHAM	938	108562	50516	69339	North-East Lincolnshire	845	59.8
3	SOUTHAMPTON	723	78849	43427	93067	Southampton	1134	38.0
4	FAWLEY	436	42037	42396	103623	New Forest	1263	33.6
5	BELFAST	700	63223	35345	132235	Belfast	1612	21.9
6	LIVERPOOL (Bootle)	415	60377	32899	152341	Liverpool	1857	17.7
7	TEES	644	54139	27719	63578	Redcar and Cleveland	775	35.8
8	FELIXSTOWE	316	36971	24235	133105	East Suffolk	1622	14.9
9	THAMES (London Gateway)	443	28115	20806	79570	Thurrock	970	21.5
10	TRANMERE	120	6943	19288	146120	Wirral	1781	10.8

Table 1: comparison of SO_x emissions from vessels and cars registered to LAs, top 10 SO_x polluted ports

3.2 Nitrogen oxides (NO_x)

In the top 10 NO_x polluted ports, ~3,700 ships produced ~5.5 million kg NO_x, around 1.75 times as much as all ~970,000 cars registered to the same LA areas as the ports[20]. There were significant variations however: the greatest difference was in Southampton, where ships produced four times more NO_x than cars. In Liverpool (Bootle), cars produced 20% more NO_x than ships. This is due to differences in vessel numbers and types, and the number of cars registered to each LA area.

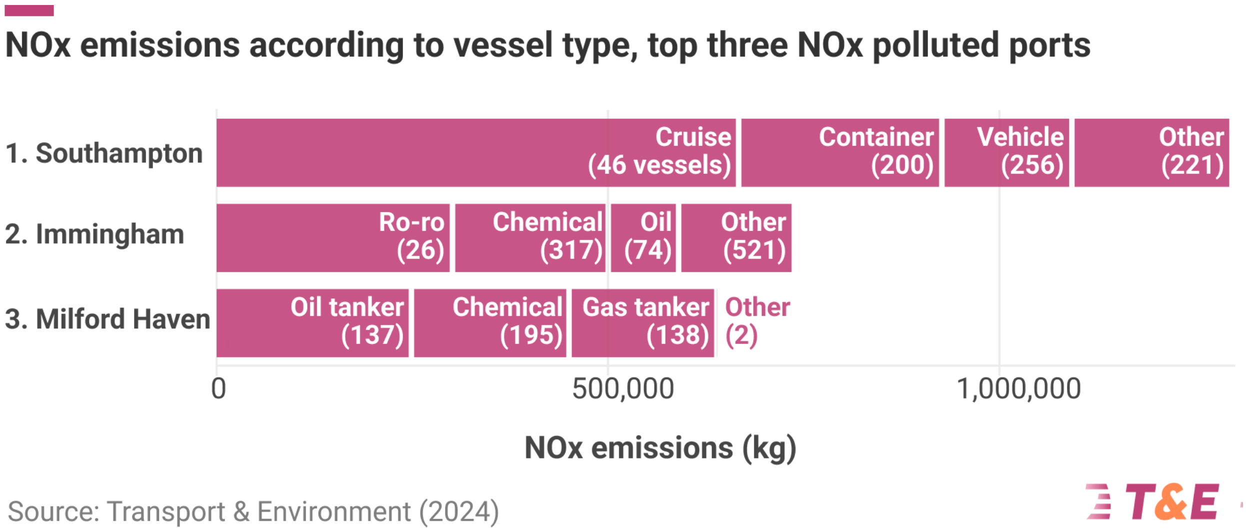


Figure 3

[20] For consistency with the other pollutant rankings we count cars and their emissions in Thurrock twice, on the basis that both Tilbury and Thames (London Gateway) are located in the same LA area.

NO_x emissions according to vessel type for the top three NO_x polluted ports are shown at Figure 3. First was Southampton (1.3 million kg NO_x from 723 vessels). Just 46 cruise ships, or 6% of Southampton's total vessels, produced over 50% of Southampton's NO_x emissions. Second was Immingham, where ~40% of NO_x emissions were produced by 26 ro-ro vessels (just 3% of vessels calling there, but making up 20% of total vessel hours in port). Third was Milford Haven, where almost 40% of NO_x emissions came from 137 oil tankers (30% of vessels calling there).

	Port	Number of unique vessels	Hours in port	NO_x from ships (kg)	Number of cars	Local Authority where cars are registered	NO_x from cars (kg)	Ratio of ship NO_x to car NO_x
1	SOUTHAMPTON	723	78849	1293497	93067	Southampton	322574	4.0
2	IMMINGHAM	938	108562	734482	69339	North-East Lincolnshire	240331	3.1
3	MILFORD HAVEN	472	47429	639542	66618	Pembrokeshire	230900	2.8
4	FELIXSTOWE	316	36971	508479	133105	East Suffolk	461347	1.1
5	BELFAST	700	63223	448393	132235	Belfast	458331	0.9
6	LIVERPOOL (Bootle)	415	60377	425340	152341	Liverpool	528019	0.8
7	FAWLEY	436	42037	398314	103623	New Forest	359161	1.1
8	TILBURY	496	51340	372239	79570	Thurrock	275792	1.3
9	THAMES (London Gateway)	443	28115	359268	79570	Thurrock	275792	1.3
10	DOVER	125	13472	344361	57222	Dover	198333	1.7

Table 2: comparison of NO_x emissions from port vessel traffic and cars registered to LAs, top 10 NO_x polluted ports

3.3 Fine particulate matter ($PM_{2.5}$)

In the top 10 $PM_{2.5}$ polluted ports, ~3,700 ships produced ~155,000kg $PM_{2.5}$, 40% of the $PM_{2.5}$ emissions from the ~980,000 cars registered to the same LA areas as the ports. $PM_{2.5}$ emissions according to vessel type for the top three $PM_{2.5}$ polluted ports are shown at Figure 4.

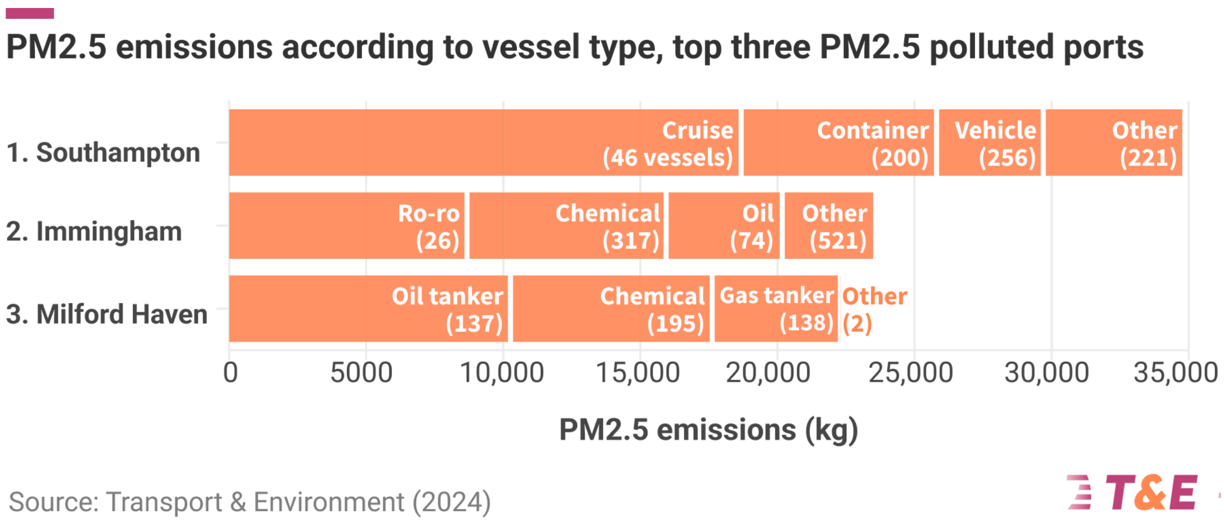


Figure 4

The order is the same as for NO_x: Southampton (32,000kg $PM_{2.5}$); Immingham (22,000kg $PM_{2.5}$); and Milford Haven (21,000kg $PM_{2.5}$). The proportions of $PM_{2.5}$ emissions from different vessel types are similar to NO_x: cruise ships produced over 50% of emissions in Southampton, ro-ro vessels nearly 40% in Immingham and oil tankers nearly 50% in Milford Haven.

	Port	Number of unique vessels	Hours in port	$PM_{2.5}$ from ships (kg)	Number of cars	Local Authority where cars are registered	$PM_{2.5}$ from cars (kg)	Ratio of ship $PM_{2.5}$ to car $PM_{2.5}$
1	SOUTHAMPTON	723	78849	31986	93067	Southampton	36323	0.9
2	IMMINGHAM	938	108562	21613	69339	North-East Lincolnshire	27063	0.8
3	MILFORD HAVEN	472	47429	20523	66618	Pembrokeshire	26001	0.8
4	FAWLEY	436	42037	15361	103623	New Forest	40443	0.4
5	BELFAST	700	63223	13951	132235	Belfast	51610	0.3
6	LIVERPOOL (Bootle)	415	60377	12172	152341	Liverpool	59458	0.2
7	FELIXSTOWE	316	36971	11602	133105	East Suffolk	51950	0.2
8	THAMES (London Gateway)	443	28115	10031	79570	Thurrock	31056	0.3
9	TEES	644	54139	9267	63578	Redcar and Cleveland	24814	0.4
10	KILLINGHOLME	259	31753	8055	85865	North Lincolnshire	33513	0.2

Table 3: comparison of $PM_{2.5}$ emissions from port vessel traffic and cars registered to LAs, top 10 $PM_{2.5}$ polluted ports

4. Solutions

4.1 Shore Side Electricity (SSE) and Zero Emission Berths (ZEBs)

SSE allows ships to plug in to power at berth instead of running engines. It is a mature technology suitable for many UK ports. However, as described at Annex B, SSE is largely unavailable in the UK. Barriers include port capital expenditure (capex) requirements, inadequate electricity grid strength in some areas and the price differential between industrial electricity and untaxed fossil marine fuels. Furthermore, ships are not required to use it. Without government intervention, SSE will not be provided at commercial scale.

The Government should publish a plan for SSE as recommended by the Climate Change Committee.[21] The plan should include a strategy for electricity grid strengthening[22] and also for shore-based battery energy storage which can provide electricity to ships in ports where grid strength and infrastructure are particular challenges in the short-term. But zero-emission, hydrogen-based fuels may also play a role in eliminating at-berth emissions. A technology-agnostic policy such as a zero-emission berth (ZEB) mandate is warranted, to drive the provision and use of SSE whilst allowing ports and ship operators

[21] Climate Change Committee (2023). Progress Report to Parliament, Section 5. Retrieved from https://www.theccc.org.uk/publication/2023-progress-report-to-parliament/
[22] Particular consideration should be given to ports used by vessel operators intending to fully electrify routes, such as some ferries, where at-berth electricity requirements will include battery-electric vessel charging

flexibility to address emissions according to circumstances. Current EU regulations[23] requiring major ports to provide shore power from 2030 and ships to use it (or alternative equivalent energy sources at berth) are an example of how a mandate could be configured.[24]

4.2 Maritime clean air zones

A charge on ship NO_x emissions is applied in Norway,[25] and Catalonia is considering charging ships for both NO_x and PM.[26] The UK could implement a similar policy on all shipping pollutants produced in UK ports. Current legislation permitting charging for vehicle emissions only applies to road vehicles, but powers in UK primary legislation derived from international law (to prevent pollution of the marine environment under the jurisdiction of Port State Control)[27] could be explored to impose pollution levies on all ships calling at UK ports.

This would discourage ships from using highly-polluting fuels and could provide ports and LAs with a much-needed revenue-stream to invest in zero-emission technologies. For example, a UK NO_x levy at the same level as Norway's on ships in the UK's top 20 most NO_x polluted ports would generate ~£15m/year. Southampton alone would generate ~£2.4m/year.[28]

4.3 Emission Control Areas (ECAs)

T&E supports the designation of all UK waters (instead of just the North Sea and English Channel) as an ECA (recently the subject of a government Call for Evidence).[29] Of the 10 most SO_x and NO_x polluted ports, four and three, respectively, are not currently subject to ECA controls. However, present ECA emission limits are weak (see Section 1) which is why the UK should introduce more stringent, complementary measures such as the ZEB mandate and maritime clean air zones described here.

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[23] The Alternative Fuels and Infrastructure Regulation (AFIR) mandates core and comprehensive EU ports to install enough SSE stations to meet the relevant electricity needs of container and passenger ships calling at those ports. The Fuel EU Maritime regulation requires passenger and containerships to use shore side electricity (SSE) or alternative equivalent zero-emission energy sources at berth from 2030 onwards. Further explanation is provided at our briefing, How Does Fuel EU Maritime Work, https://te-cdn.ams3.digitaloceanspaces.com/files/202307_FUEM_Explainer_Briefing_2023_TE.pdf

[24] Noting that currently, the shore power requirement excludes vessels' heat and steam energy needs, and applies only to vessels at berth and not at anchor

[25] The Norwegian Tax Administration (2024). NOx tax. Retrieved from https://www.skatteetaten.no/en/business-and-organisation/vat-and-duties/excise-duties/about-the-excise-duties/nox/#:~:text=A%20tax%20is%20payable%20on,generation%20from%20certain%20specified%20sources.

[26] https://www.lavozdegalicia.es/noticia/somosmar/2023/09/22/cataluna-espera-recaudar-75-millones-impuesto-contaminacion-grandes-barcos/00031695386552052966545.htm

[27] The jurisdiction of Port State Control is explained in our briefing and legal analysis, The Case for Zero Emission UK Shipping, https://transport-environment.vercel.app/te-united-kingdom/articles/the-case-for-zero-emission-uk-shipping-maritime-energy-policy-recommendations

[28] In Norway, a NO_x tax of NOK 25.59/kg (£1.88/kg) is applied to NO_x emissions arising from propulsion machinery with a total installed capacity of over 750 kW and engines, boilers, and turbines with a total installed capacity of more than 10 MW. Total NO_x emissions from the 20 most NO_x polluted ports in this analysis were 7.83m kg; NO_x emissions from Southampton were 1.3m kg

[29] See footnote 5

4.4 Scrubbers

Prohibiting scrubber wash water discharge in UK waters, including from "closed loop" scrubbers which discharge less than open-loop systems, would drive the use of cleaner fuels and result in lower GHG emissions (intensified scrubber usage with high-sulphur fuels increases GHG emissions).[30] The environment minister of Denmark has recently proposed to ban all scrubber discharging in Danish territorial waters.[31]

5. Conclusions and recommendations

Shipping is a major contributor to air pollution in the UK, which itself has notable impacts on human health. Present UK air quality and shipping pollution policies and regulations fall far short of what is needed to meet WHO guidelines, and are failing to address the problem of port pollution. Without reform, this will not change.

T&E therefore recommends that the Government should:

1. **Consult as soon as possible on mandating ZEBs in UK ports**, which must target GHGs as well as pollutant emissions
2. **Publish a plan for SSE in UK ports** (as recommended by the Climate Change Committee)
3. **Implement a UK variation on the Norwegian NO_x fund,** possibly through Port State Control powers, where all ships calling at UK ports would be charged for their emissions whilst moored, effectively designating UK ports as maritime clean air zones
4. **Designate all UK territorial waters as an Emission Control Area** (ECA)
5. **Prohibit all scrubber wash water discharge in UK territorial waters**, which includes ports
6. Signal its intention to pursue these options (alongside T&E's broader zero-emission shipping energy policy recommendations)[32] in the forthcoming refreshed Clean Maritime Plan

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Further information

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[30] See footnote 7
[31] https://shippingwatch.com/regulation/article16924250.ece
[32] T&E (2024). Long, loud and legal: the case for UK zero-emission shipping. Retrieved from https://transport-environment.vercel.app/te-united-kingdom/articles/the-case-for-zero-emission-uk-shipping-maritime-energy-policy-recommendations

Annex A

Full breakdown of emissions for all pollutants from vessels and cars, top 20 ports for each

Sulphur oxides (SO_x)								
	Port	Number of unique vessels	Hours in port	SO_x from ships (kg)	Number of cars	Local Authority where cars are registered	SO_x from cars (kg)	Ratio of ship SO_x to car SO_x
1	MILFORD HAVEN	472	47429	74382	66618	Pembrokeshire	812	91.6
2	IMMINGHAM	938	108562	50516	69339	North East Lincolnshire	845	59.8
3	SOUTHAMPTON	723	78849	43427	93067	Southampton	1134	38.0
4	FAWLEY	436	42037	42396	103623	New Forest	1263	33.6
5	BELFAST	700	63223	35345	132235	Belfast	1612	21.9
6	LIVERPOOL (Bootle)	415	60377	32899	152341	Liverpool	1857	17.7
7	TEES	644	54139	27719	63578	Redcar and Cleveland	775	35.8
8	FELIXSTOWE	316	36971	24235	133105	East Suffolk	1622	14.9
9	THAMES (London Gateway)	443	28115	20806	79570	Thurrock	970	21.5
10	TRANMERE	120	6943	19288	146120	Wirral	1781	10.8
11	TILBURY	496	51340	19086	79570	Thurrock	970	19.7
12	DARTFORD	225	27274	17738	52016	Dartford	634	28.0
13	PORTBURY (Bristol)	482	37557	16083	117590	North Somerset	1433	11.2
14	KILLINGHOLME	259	31753	16030	85865	North Lincolnshire	1047	15.3
15	STANLOW	248	27666	15372	182798	Cheshire West and Chester	2228	6.9
16	HULL	426	52615	14701	95087	City of Kingston upon Hull	1159	12.7
17	PORTSMOUTH	177	33050	13844	85914	Portsmouth	1047	13.2
18	ABERDEEN	201	22566	13692	89011	Aberdeen	1085	12.6
19	GRANGEMOUTH	256	29214	11948	76474	Falkirk	932	12.8
20	DOVER	125	13472	11333	57222	Dover	697	16.2

Nitrogen oxides (NO_x)								
	Port	Number of unique vessels	Hours in port	NO_x from ships (kg)	Number of cars	Local Authority where cars are registered	NO_x from cars (kg)	Ratio of ship NO_x to car NO_x
1	SOUTHAMPTON	723	78849	1293497	93067	Southampton	322574	4.0
2	IMMINGHAM	938	108562	734482	69339	North East Lincolnshire	240331	3.1
3	MILFORD HAVEN	472	47429	639542	66618	Pembrokeshire	230900	2.8
4	FELIXSTOWE	316	36971	508479	133105	East Suffolk	461347	1.1
5	BELFAST	700	63223	448393	132235	Belfast	458331	1.0
6	LIVERPOOL (Bootle)	415	60377	425340	152341	Liverpool	528019	0.8
7	FAWLEY	436	42037	398314	103623	New Forest	359161	1.1

8	TILBURY	496	51340	372239	79570	Thurrock	275792	1.4
9	THAMES (London Gateway)	443	28115	359268	79570	Thurrock	275792	1.3
10	DOVER	125	13472	344361	57222	Dover	198333	1.7
11	PORTSMOUTH	177	33050	332990	85914	Portsmouth	297781	1.1
12	KILLINGHOLME	259	31753	312231	85865	North Lincolnshire	297611	1.0
13	TEES	644	54139	309606	63578	Redcar and Cleveland	220364	1.4
14	DARTFORD	225	27274	261432	52016	Dartford	180289	1.5
15	HULL	426	52615	256437	95087	City of Kingston upon Hull	329575	0.8
16	PORTBURY (Bristol)	482	37557	222186	117590	North Somerset	407571	0.6
17	ABERDEEN	201	22566	198192	89011	Aberdeen	308515	0.6
18	TRANMERE	120	6943	147595	146120	Wirral	506456	0.3
19	GRANGEMOUTH	256	29214	136257	76474	Falkirk	265062	0.5
20	STANLOW	248	27666	127175	182798	Cheshire West and Chester	633584	0.2

Fine particulate matter ($PM_{2.5}$)

	Port	Number of unique vessels	Hours in port	$PM_{2.5}$ from ships (kg)	Number of cars	Local Authority where cars are registered	$PM_{2.5}$ from cars (kg)	Ratio of ship $PM_{2.5}$ to car $PM_{2.5}$
1	SOUTHAMPTON	723	78849	31986	93067	Southampton	36323	0.9
2	IMMINGHAM	938	108562	21613	69339	North East Lincolnshire	27063	0.8
3	MILFORD HAVEN	472	47429	20523	66618	Pembrokeshire	26001	0.8
4	FAWLEY	436	42037	15361	103623	New Forest	40443	0.4
5	BELFAST	700	63223	13951	132235	Belfast	51610	0.3
6	LIVERPOOL (Bootle)	415	60377	12172	152341	Liverpool	59458	0.2
7	FELIXSTOWE	316	36971	11602	133105	East Suffolk	51950	0.2
8	THAMES (London Gateway)	443	28115	10031	79570	Thurrock	31056	0.3
9	TEES	644	54139	9267	63578	Redcar and Cleveland	24814	0.4
10	KILLINGHOLME	259	31753	8055	85865	North Lincolnshire	33513	0.2
11	PORTSMOUTH	177	33050	7702	85914	Portsmouth	33532	0.2
12	DOVER	125	13472	7543	57222	Dover	22333	0.3
13	TILBURY	496	51340	7435	79570	Thurrock	31056	0.2
14	DARTFORD	225	27274	7120	52016	Dartford	20301	0.4
15	TRANMERE	120	6943	6477	146120	Wirral	57032	0.1
16	PORTBURY (Bristol)	482	37557	6041	117590	North Somerset	45895	0.13
17	HULL	426	52615	5905	95087	City of Kingston upon Hull	37112	0.2
18	ABERDEEN	201	22566	4644	89011	Aberdeen	34740	0.1
19	STANLOW	248	27666	4430	182798	Cheshire West and Chester	71345	0.1
20	GRANGEMOUTH	256	29214	4067	76474	Falkirk	29847	0.1

Annex B

Detailed methodology

This analysis looks at different air pollutants and greenhouse gas emissions as a result of the chemical composition of marine fuel and the combustion process of ships' engines. The specific air pollutants included are SO_x, NO_x and $PM_{2.5}$. We have not assessed the extent of scrubber wash water discharge because no data is available.

We analysed commercial passenger and cargo ships of more than 400 gross tonnage (GT) stopping at UK ports in 2022. We do not have data for other vessel types in 2022 and we estimate that ~63% of UK port emissions in 2021 were produced by the vessel types included in this analysis (so the emissions totals are conservative).

We followed the bottom-up methodology from the Fourth IMO Greenhouse Gas (GHG) study[33] to calculate GHG emissions from ships using automatic identification system (AIS) data and ship technical specifications. We purchased ship technical specifications from IHS Markit and Clarksons' World Fleet Register (WFR)[34] and pre-processed them to fill in the data gaps.

We purchased terrestrial and satellite AIS data from Spire. AIS messages are sent by ships at regular intervals during their operation and contain information such as timestamp, position, speed and draught of the vessel. We removed erroneous entries from the AIS data, resampled it at 1-hour intervals and infilled the gaps in the time series for position, speed and draught.

We then took the following steps:

1. Allocation of hourly samples to UK Exclusive Economic Zone
2. Detection of port stops
3. Assignment of operational phases
4. Allocation of voyages
5. Calculation of vessel energy consumption and emissions at port

In estimating emissions, we have not assumed that any shore-side electricity (SSE) was used. Many UK ports provide low-voltage shore power connections for leisure boats, fishing vessels and port vessels and workboats. But at the time of writing, only three ports (Southampton, Orkney and, most recently, Montrose)[35] offer high-capacity, commercial-scale SSE connections for large vessels or cruise ships. Furthermore, there is no requirement (or even incentive) for ships to use it. Data on SSE usage is

[33] Faber, J., Kleijn, A., Hanayama, S., Zhang, S., Pereda, P., Comer, B., … Xing, H. (2020). Fourth IMO Greenhouse Gas Study. Retrieved from https://docs.imo.org/Shared/Download.aspx?did=125134
[34] World Fleet Register. (n.d.). Retrieved in February 2024 from https://www.clarksons.net/wfr
[35] https://maritime-executive.com/article/montrose-is-scotland-s-first-port-with-shore-power-for-energy-sector-s-osvs

unavailable, and a recent Open Democracy investigation of SSE use by cruise ships in Southampton[36] indicated chronic under-usage.

We have assumed that ships equipped with dual-fuel liquefied natural gas (LNG) engines were running exclusively on LNG since we have no data to determine the precise fuel mix used on board. Other vessels were assumed to run on heavy fuel oil (HFO), very low sulphur fuel oil (VLSFO) or marine gas oil (MGO), complying with the relevant fuel sulphur standards in the North Sea ECA and the UK's non-ECA zone. Specifically:

- Ships sailing, anchoring or mooring in the North Sea ECA are required to use fuel with at most 0.1% sulphur content, or rely on exhaust gas cleaning systems (scrubbers) to respect SO_x standards
- Ships at berth or at anchor within the boundaries of UK ports outside the North Sea ECA must follow the same rule as above once they have been in port for 2 hours
- From 1st January 2020, all ships sailing outside the ECAs are required to use residual fuels complying with a maximum 0.5% sulphur content mandated under the global MARPOL Annex VI (or rely on "approved equivalent methods" such as scrubbers to achieve the same standard)

We used Clarksons' WFR to identify ships equipped with scrubbers and assumed they were using 2.6% sulphur heavy fuel oil (HFO) with scrubber treatment of exhaust gases when they needed to comply with 0.1% sulphur standards. In ports where the discharge of scrubber wash water is forbidden we assumed 0.1% sulphur marine diesel oil (MDO) / marine gas oil (MGO) was used instead. We used International Council on Clean Transportation (ICCT) analysis[37] to estimate the decrease or increase in different emission species due to the use of scrubbers and their most recent list of ports banning or restricting scrubber use.[38]

We then aggregated emissions results from vessels within a 1.5 nautical mile (nm) radius of a port's main coordinates and at a speed-over-ground (SOG) of less than 3 knots. 3 knots is the speed observed in AIS below which a ship is considered at anchor or at-berth as per the Fourth IMO GHG study. 95% of the CO_2 emissions occurring from vessels within a 5nm radius of a port occur within a 1.5nm radius. This shows that the vast majority of vessels moor or anchor within 1.5nm of the main coordinates of ports included in this study, allowing the accurate allocation of ships' emissions to ports. Port stays longer than 120 hours (5 days) were excluded on the assumption that a longer timeframe places a vessel outside normal commercial activities. Stays at dry docks were excluded.

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[36] https://www.google.com/url?q=https://www.opendemocracy.net/en/cruise-ships-greenwashing-energy-shore-power-diesel-uk-ports-mislead-tourists/&sa=D&source=docs&ust=1713182817659788&usg=AOvVaw3Bjd6Icg bKbFS5bHp1Jxkv

[37] International Council on Clean Transportation (2020). Air emissions and water pollution discharges from ships with scrubbers. Retrieved from https://theicct.org/publication/air-emissions-and-water-pollution-discharges-from-ships-with-scrubbers/

[38] International Council on Clean Transportation (2023). Global Update on Scrubber Bans and Restrictions. Retrieved from https://theicct.org/publication/marine-scrubber-bans-and-restrictions-jun23/

We then compared pollution from ships to pollution from cars according to 2022 Vehicle Licensing Statistics Data[39] published by the UK Department for Transport (DfT) and Driver and Vehicle Licensing Agency (DVLA). Vehicle keepership is registered by Local Authority (LA) (upper and lower tier). We therefore compiled car numbers according to the total number of registrations for the lowest tier under the LA where each port is located. In some cases this corresponds to the same city (eg Southampton) whereas in others the lowest tier LA is at county level (eg Pembrokeshire for the port of Milford Haven).

We used European Union Transport Roadmap Model (EUTRM) car emission factors assuming car fleets entirely made of diesel vehicles, which have worse NO_x performance than petrol cars. Because the comparisons between ships and cars rely on ship emissions being divided by those of the passenger cars, the final results are therefore likely to be on the conservative side, i.e. they may well underestimate the comparative extent of air pollution from ships versus cars if we included petrol cars too.

[39] See footnote 17