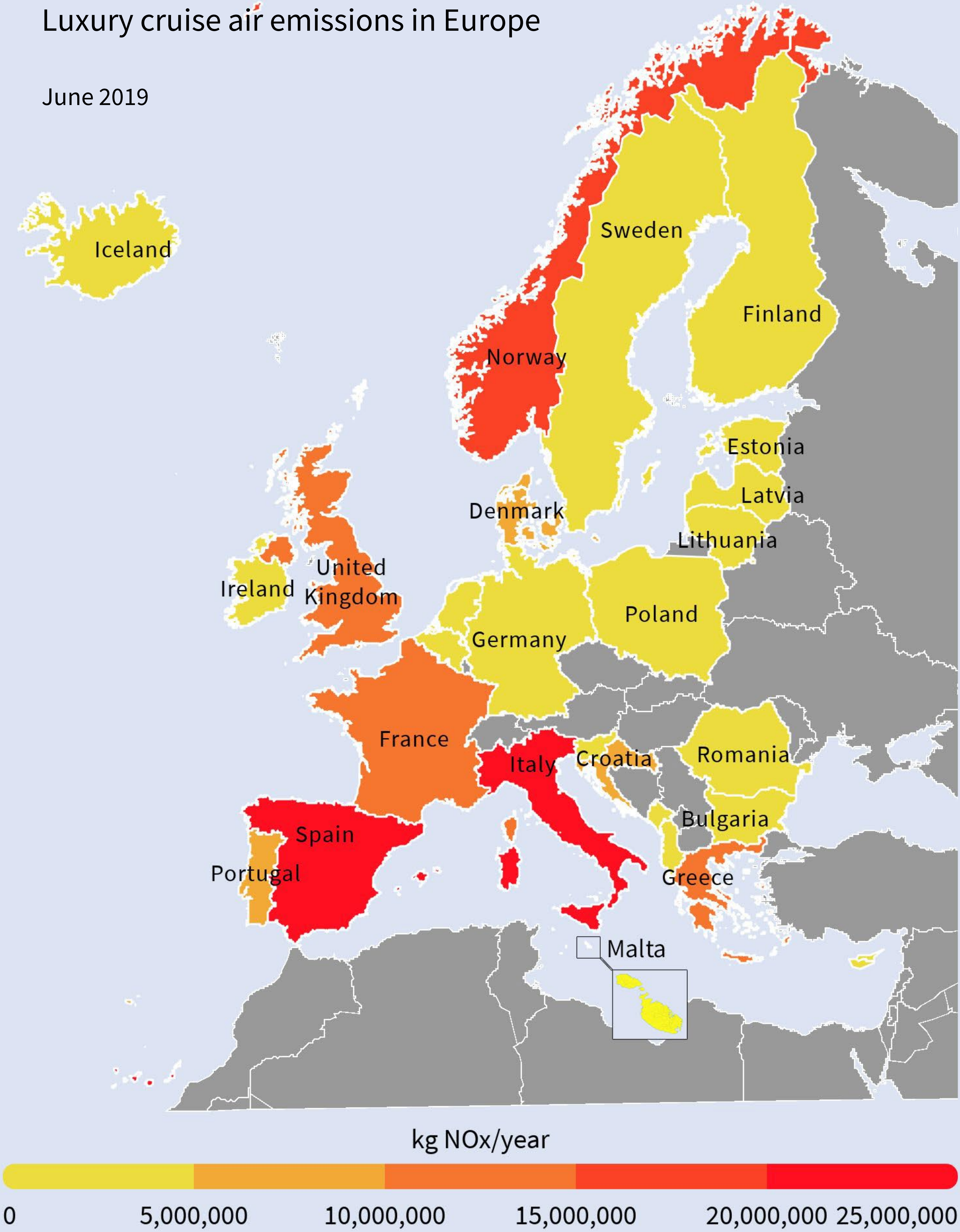
One Corporation to Pollute Them All

Luxury cruise air emissions in Europe

June 2019



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Executive Summary

The main purpose of this study is to analyse air pollution caused by luxury passenger cruise ships in European waters. The results show that the luxury cruise brands owned by Carnival Corporation & PLC emitted in 2017 in European seas alone 10 times more disease-causing sulphur oxide than all of Europe's 260+ million passenger vehicles. Spain, Italy, Greece, France and Norway are the most exposed countries to cruise ship air pollution in Europe. Among the major cruise ports, Barcelona, Palma Mallorca and Venice are the most polluted.

Analysis also reveals that even in sulphur emission control areas (SECAs), where the most stringent marine sulphur fuel standard is mandated, air pollution from cruise ships remains of great concern. In Denmark, for example, whose coasts are entirely within SECAs, cruise ships emitted 18 times more SO_X in 2017 than all the country's 2.5 million passenger vehicles in a year. This is a reflection of both the effectiveness of the fuel quality directive for road transport fuels and the failure to implement equivalent standards for the shipping industry. Ships SO_X will still remain considerably large compared to passenger car fleet even after the introduction of the global 2020 marine sulphur cap.

When it comes to nitrogen oxide (NO_X) emissions, cruise ships are also of great concern despite the air pollution impact of the ongoing land-based "dieselgate" in Europe. In Denmark again, 107 cruise ships analysed emitted as much NO_X in the Danish maritime economic exclusive zone (EEZ) as half the passenger cars operating in the country itself.

This report recommends a **zero-emission berth standard** for all European ports. In addition, extra stringent air pollution standards are recommended to apply to cruise ships. These ships usually operate close to the coast with long port calls at major tourist destinations, hence disproportionately affecting air quality. Initially, it is recommended to extend the emission control areas, currently in place in the North and Baltic Seas, to the rest of the EU seas and to tighten marine **SECA standard in Europe to 10ppm**, equivalent to fuel used in road transport. The report also suggests that cruise ships, the industry's public-facing luxury segment, be looked up and targeted as *first-movers* in regulations to decarbonise the sector. So, in addition to a zero-emission berth standard, cruise ships should also be the first required to switch to **zero emission propulsion in EU territorial waters**.

Figure 1: Heatmap of NOx emissions from cruise ships in European EEZ in 2017 (T&E).

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1. Description of the policy context

Shipping is an important transport sector relying on the use of fossil fuels as a source of energy. Unlike other transport modes, marine fuel is less refined and standards for emission of air pollutants are less strict. As a result, shipping is a source of considerable air pollution despite fewer number of operational vessels in the global fleet. Sulphur oxide (SO_X) emissions form sulphate (SO_4) aerosols that increase human health risks. SO_X, ultrafine particles (PM2.5) and nitrogen oxides (NO_X) cause premature death, including from lung cancer and cardiovascular disease, and morbidity, e.g., childhood asthma. They also contribute to acidification in terrestrial and aquatic environments.[i] NO_X contribute to particle and ozone formation, in addition to causing acidification and eutrophication upon deposition on land, lakes and seas. It is moved long distances in air and is, therefore, often considered a 'regional' pollutant.[ii]

Over the past 10 years, governments acting locally, regionally and globally have commended efforts to reduce ship air pollution by setting SO_X and NO_X standards for marine fuels and engines. In addition, certain geographical areas in Europe and North America, and more recently in China (only local) have been designated emission control areas (ECA) for air pollutants.

Yet, shipping remains the least regulated transport sector as regards air pollution. The best marine sulphur standard (0.1% | 1000 ppm) remains 100 times worse than Europe's sulphur standard for road diesel/petrol (0.001% | 10 ppm) in place for the past 15 years. Recent studies have shown the staggering amount of air pollutants emitted by the global fleet[iii] and that increasingly large proportion of NO_X and SO_X depositions on land in coastal regions and port cities come from ships.[iv] But these studies have had a generic global and/or regional scope. Estimations of ship emissions have not been undertaken for individual countries with a coastline. Analysis of emissions from passenger ships, especially luxury cruise vessels, is also missing yet recent reports suggest they dramatically aggravate local air quality, especially in famous cruise ship ports.[v]

The purpose of this report is to analyse air pollutants, notably, sulphur oxides (SO_X), nitrogen oxides (NO_X) and particulate matter (PM) from cruise ships in the exclusive economic zones (EEZ)[1] of European countries and major cruise port cities.

2. Methodology

The study analysed 203 cruise ships that sailed according to ship automated identification system (AIS) in the EEZ of European countries in 2017. Operational data (incl. ship coordinates and speed) was obtained from *ExactEarth* which tracks ship movements using satellite data from AIS readings. The AIS data for the analysed ships had a nominal 1-hour interval between each data point.

We first allocated each data point to the EEZ and port cities (see Appendix I). We then used the methodology followed by the IMO 3rd GHG Study (2014)[2], previous T&E reports[vi] and the ICCT's GHG inventory[vii] to estimate the fuel consumption of each ship and associated emissions of air pollutants for each data point and summed them for respective country EEZs and ports.

In estimating emissions, we assumed that all the ships analysed complied with the relevant fuel sulphur standards in place in each geographical area. Notably, ships sailing in SECAs are required to use only 0.1% sulphur compatible marine gas oils (MGO)[3], while cruise ships sailing outside SECA are obliged to use

[1] An exclusive economic zone (EEZ) is a sea zone prescribed by the 1982 United Nations Convention on the Law of the Sea over which a state has special rights regarding the exploration and use of marine resources, including energy production from water and wind. It stretches from the baseline out to 200 nautical miles (nm) from its coast.
[2] 3rd IMO GHG study developed a unique scientific methodology to estimate ship energy consumption and emissions and remains the most trusted methodology.
[3] Alternatively, ships are also allowed to use exhaust gas cleaning systems (scrubbers) to achieve similar results.

residual fuels complying to a maximum 1.5% marine sulphur cap mandated under the EU Sulphur Directive (2012/33/EU) (Figure 2). The Sulphur Directive requires ships, including cruise ships to switch to 0.1% sulphur compatible fuels if they spend more than 2 hours at berth. Given that cruise ships normally spend far more 2 hours at berth during cruise port calls, we have assumed that all the cruise ships analysed complied with the 0.1% fuel standard during (the entire duration of) all port calls.

According to both global MARPOL Annex VI and EU Sulphur Directive, cruise ships will be required to switch to fuels with a maximum of 0.5% Sulphur content starting from 1 January 2020 when sailing outside SECAs, when operating outside the berths. This standard will remain less stringent compared to EU berth Sulphur standard (0.1%) in all European ports.[4] To take into account the new standard we also modelled an additional forward-looking scenario, the results of which are presented in Appendix 3.

This report provides conservative estimates for shipping, both for absolute cruise emissions and for the comparisons with passenger cars (light duty vehicles – LDVs[5]). Our analysis assumes that ships fully comply with the existing SO_X and NO_X standards in place in the relevant geographical locations. This has been shown not to be always the case with some ships being found to violate the standards including some cruise ships.[viii] On the other hand, the "dieselgate" scandal has unearthed ample evidence of consistent cheating by car manufacturers of emission standards using defeat devices. This masks the fact that real world passenger vehicle emissions exceed standards by a considerable degree. For this reason, we have based vehicle emission levels, for comparison with cruise ships, on verified real-world emission factors, which have been shown to be several times higher than legal limits. Furthermore, the European passenger car fleet is assumed for this study to be exclusively composed of diesel cars, which have better CO_2 but a worse NO_X performance compared to petrol cars. As the comparisons rely on the ship emissions being divided by those of the passenger cars, the final results are therefore likely to be on the conservative i.e. they may well underestimate the comparative extent of air pollution from cruise ships versus cars.

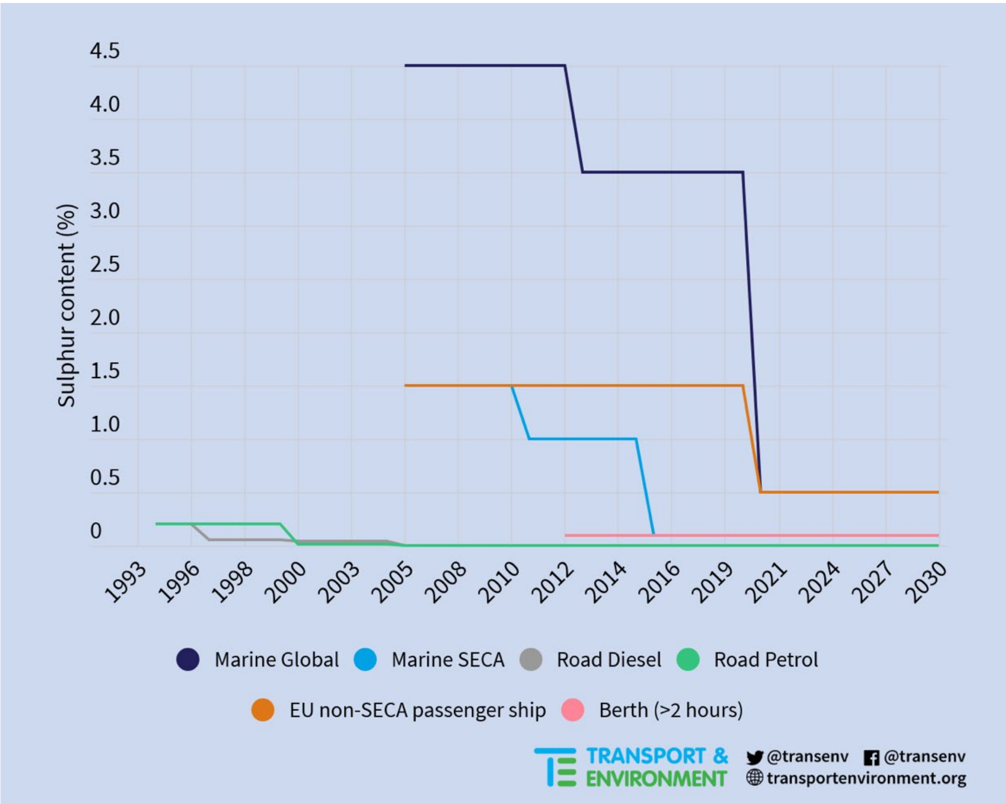

Figure 2: EU Sulphur standards for marine and road fuels

[4] Norway has also mandated 0.1% Sulphur fuels for ships sailing in the Norwegian fjord from March 2019.
[5] In general, LDVs also include vans, too. But in this report, we concentrate only on passenger cars.

3. Findings

3.1. General findings for Europe

The report found that in 2017, 203 cruise ships in Europe emitted about 62 kt of SO_X, 155 kt of NO_X, 10 kt of PM and more than 10 Mt of CO_2 (table 1). Most of these emissions (especially SO_X) took place in the Mediterranean Sea and other major touristic destinations, but also along the coasts of the key member states where cruise ships depart from/terminate at or operate around. (Figures 1 and 3). CO_2 emissions from the 203 analysed ships alone (covering only the sailing time in European EEZs) are on par with total national GHG emissions of Latvia, Luxembourg and Cyprus, but twice as big as the total national GHG[ix] emissions of Malta.

Table 1: Fuel consumption and air emissions from cruise ships in Europe in 2017*.

Number of cruise ships	**Total SO_X** (kt)	**Total NO_X** (kt)	**Total PM** (kt)	**Total CO_2** (kt)	**Total Fuel consumption** (kt)
203	62	155	10	10,286	3,267

** Geographic scope: EU EEZ, Norway (incl. Svalbard), Iceland, Albania, Montenegro and Denmark's Greenland, Bornholm, and Faroe Islands.*

Figure 3: Heatmap of SO_X emissions from cruise ships in 2017, T&E.

3.2. Ranking of cruise ship companies by air pollution

Table 2 ranks, on the basis of SO_X, the top 30 cruise ship companies that emitted the largest amount of air pollution while sailing in European EEZs. In particular, 47 ships of cruise brands owned by the global Carnival Corporation & PLC emitted about 10 times more SO_X in European EEZs than 260+ million passenger vehicles in Europe (figure 4). Global Royal Caribbean Cruises ranks second emitting about 4 times more SO_X

than all of European cars. Among the luxury cruise brands, Costa Cruises, MSC Cruises, P&O Cruises, AIDA Cruises and Royal Caribbean International were the biggest emitters of the luxury brands in 2017.

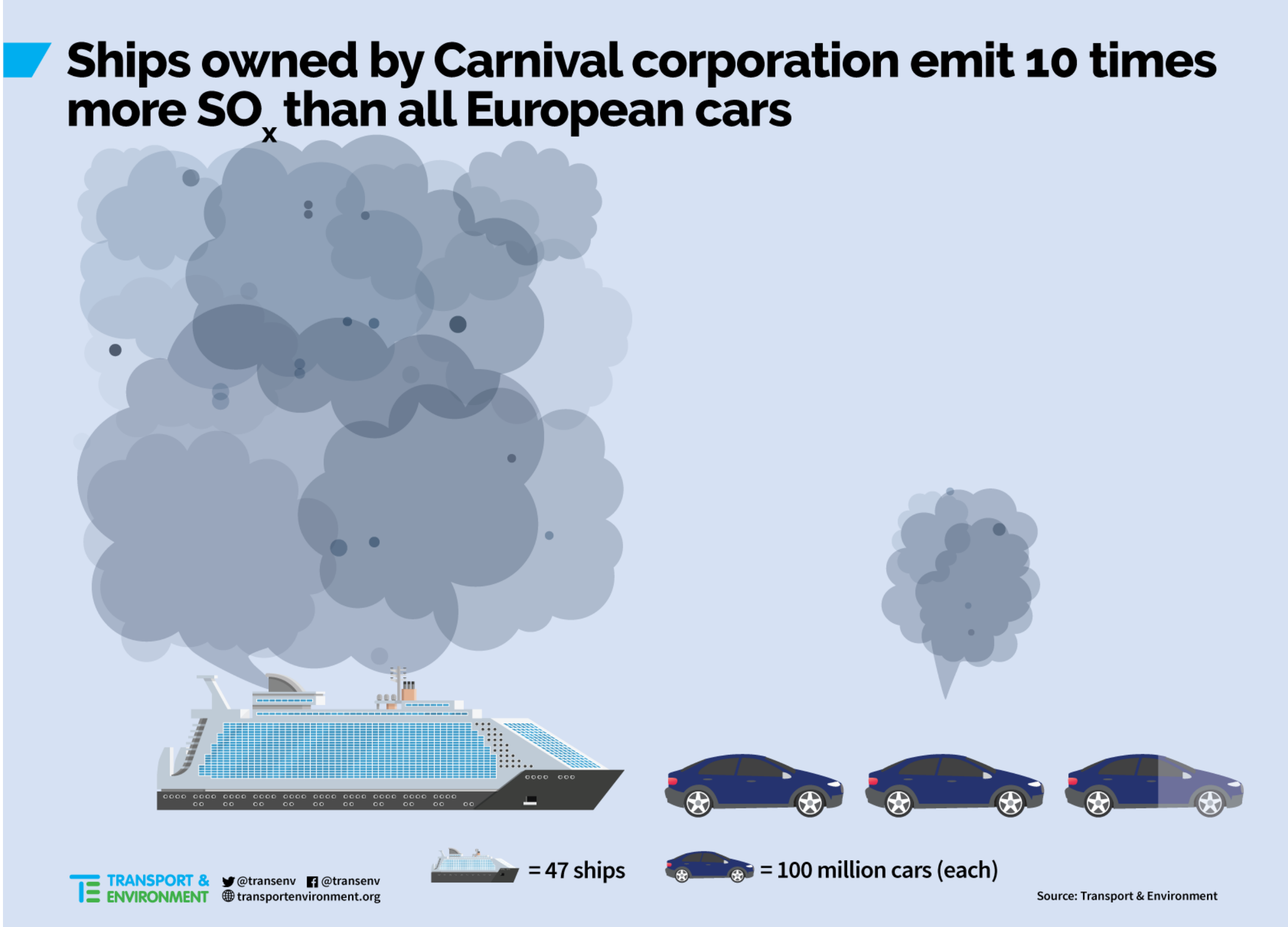

Figure 4: Comparison of SO_x emissions in 2017 by Carnival-owned ships with all European passenger cars, T&E.

Table 2: Ranking of top 30 cruise shipping companies for SO_x emissions in European EEZ in 2017.

Ranking	Cruise companies	Parent company	# ships	Emissions from the cruise ships (kg)			Ratio of emissions from cruise ships to LDVs		
				SO_x	PM	NO_x	SO_x	PM	NO_x
1	Costa Cruises	Carnival	9	10,789,223	1,654,527	19,891,566	337%	1.11%	2%
2	MSC Cruises		11	10,235,089	1,577,045	18,847,762	319%	1.06%	2%
3	P&O Cruises	Carnival	7	7,019,625	1,113,087	15,161,168	219%	0.75%	1%
4	Royal Caribbean International	Royal Caribbean Cruises	8	5,513,187	860,836	11,102,580	172%	0.58%	1%
5	AIDA Cruises	Carnival	12	4,718,663	797,561	14,219,074	147%	0.54%	1%
6	Norwegian Cruise Line		6	3,888,899	606,330	8,981,323	121%	0.41%	1%
7	Princess Cruises	Carnival	8	2,845,009	456,871	6,673,180	89%	0.31%	1%
8	Hurtigruten		10	2,800,801	525,805	7,531,572	87%	0.35%	1%
9	Cunard Line	Carnival	3	2,718,473	440,601	5,399,197	85%	0.30%	1%
10	TUI Cruises	Royal Caribbean Cruises	5	2,446,595	413,577	6,374,538	76%	0.28%	1%
11	Marella Cruises		5	2,261,468	381,540	6,217,960	71%	0.26%	1%

Ranking	Cruise companies	Parent company	# ships	Emissions from the cruise ships (kg)			Ratio of emissions from cruise ships to LDVs		
				SO_X	PM	NO_X	SO_X	PM	NO_X
12	Celebrity Cruise	Royal Caribbean Cruises	4	2,247,077	355,824	4,770,378	70%	0.24%	0%
13	Oceania Cruises		5	1,698,406	263,715	3,589,772	53%	0.18%	0%
14	Seabourn Cruise Line	Carnival	3	1,128,800	170,082	1,907,724	35%	0.11%	0%
15	Cruise & Maritime Voyages		5	1,032,019	193,871	4,599,622	32%	0.13%	0%
16	Pullmantur Cruises	Royal Caribbean Cruises	3	859,719	157,743	2,965,637	27%	0.11%	0%
17	Holland America Line	Carnival	5	856,837	150,514	3,241,168	27%	0.10%	0%
18	Silversea Cruises	Royal Caribbean Cruises	6	751,978	128,240	1,989,050	23%	0.09%	0%
19	Fred. Olsen Cruise Lines		4	677,119	131,211	2,751,768	21%	0.09%	0%
20	Viking Cruises		4	587,021	95,838	1,627,405	18%	0.06%	0%
21	Regent Seven Seas Cruises		3	564,809	89,275	1,231,596	18%	0.06%	0%
22	Phoenix Reisen		4	540,105	103,356	2,078,439	17%	0.07%	0%
23	Disney Cruise Line		1	402,250	64,966	1,388,042	13%	0.04%	0%
24	Saga Cruises		2	380,120	71,238	1,453,249	12%	0.05%	0%
25	Azamara Club Cruises	Royal Caribbean Cruises	2	357,865	55,085	701,833	11%	0.04%	0%
26	Star Cruises		1	311,388	58,325	887,864	10%	0.04%	0%
27	Mano Maritime		1	303,747	48,615	623,154	9%	0.03%	0%
28	Compagnie du Ponant		3	261,582	40,769	445,296	8%	0.03%	0%
29	Celestyal Cruises		1	237,464	43,641	635,022	7%	0.03%	0%
30	Crystal Cruises		2	212,753	34,607	709,833	7%	0.02%	0%

* *Partial ownership*

3.3. Port-level findings of cruise air pollution

The resolution of the modelling permits the calculation of cruise ship emissions at the port and port city levels. These values were then compared to the city or port level fleet of light duty vehicles. Tables 3, A.2.1 and A.2.3 summarise the findings for SO_X, PM and NO_X emissions, respectively.

Tables 3 and A.2.1 shows that the top 10 most exposed cities to SO_X and PM from cruise ships are almost exclusively located in two countries, Spain and Italy. Barcelona, Palma Mallorca and Venice are the most cruise ship polluted cities in Europe (figure 5). This can be explained by these countries being popular cruise destinations with prolonged port calls, but also because they are located outside the SECAs where stringent marine sulphur standards.

In large cities such as Barcelona, Marseille and Hamburg, cruise vessels emitted while docked at port about 2 to 5 times more SO_X throughout 2017 than that emitted by these cities' entire passenger car fleet during the same year (Table 3).

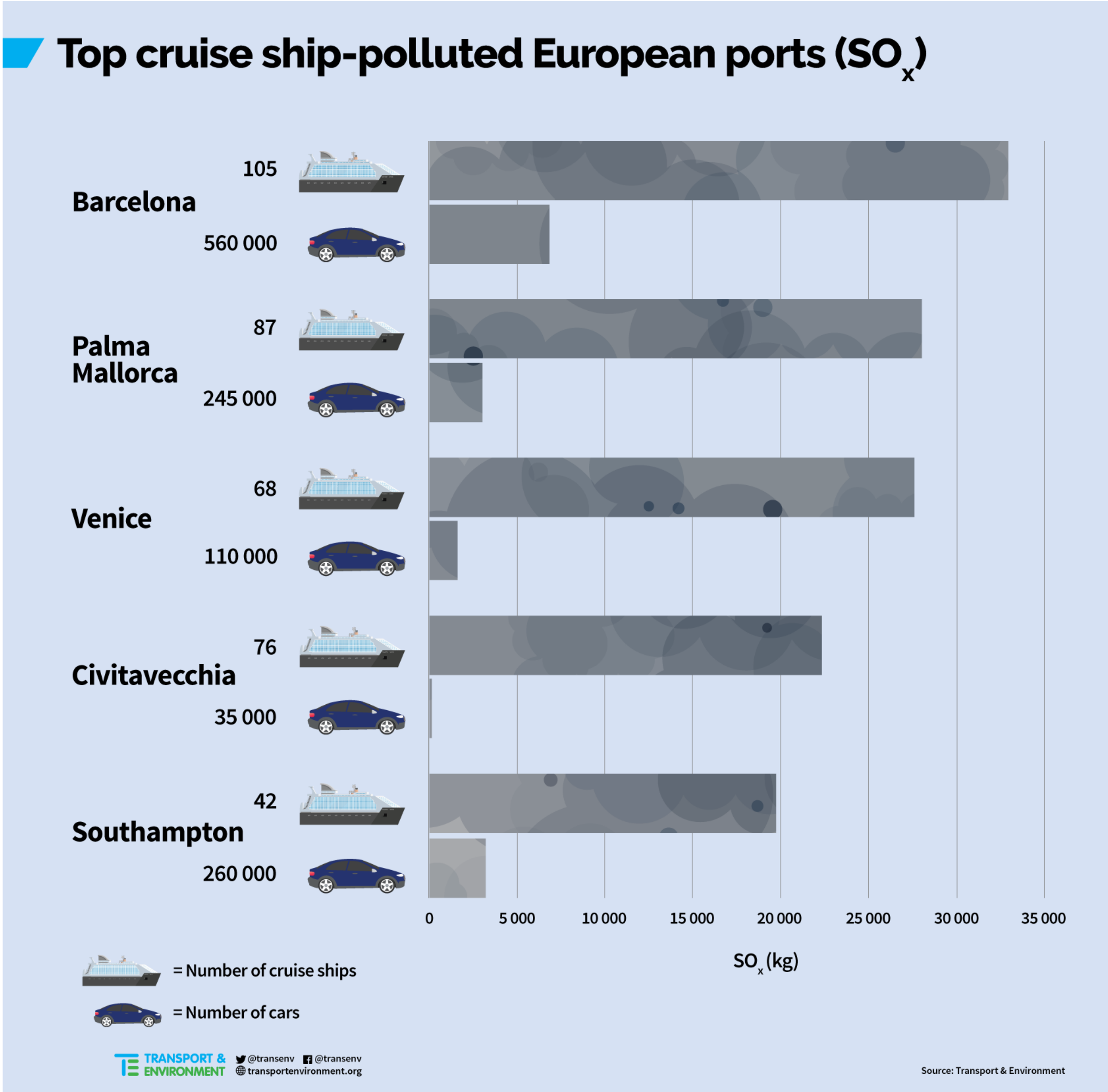

Figure 5: Top European cruise ship ports exposed to highest SO_x emissions in 2017, T&E.

Table 3: Emissions of SO_x from cruise ships and LDVs in top 50 cruise polluted European port cities in 2017*.

Ranking	Country	Port cities	Number of cruise ships	Port call time (hours	SO_x from cruise ships (kg)	Number of registered LDVs	SO_x from registered LDVs (kg)	Ratio of SO_x from cruise ships and LDVs
1	ES	Barcelona	105	8,293	32,838	558,920	6,812	4.8
2	ES	Palma Mallorca	87	6,766	28,011	245,005	2,986	9.4
3	IT	Venezia	68	7,988	27,520	111,712	1,362	20.2
4	IT	Civitavecchia	76	5,466	22,293	33,591	409	54.5
5	UK	Southampton	42	4,510	19,734	261,696	3,189	6.2
6	PT	Lisbon	115	7,953	16,111	374,855	4,569	3.5
7	ES	Santa Cruz de Tenerife	75	4,363	15,605	115,574	1,409	11.1
8	FR	Marseille	57	3,342	15,219	339,987	4,144	3.7

Ranking	Country	Port cities	Number of cruise ships	Port call time (hours	SOx from cruise ships (kg)	Number of registered LDVs	SOx from registered LDVs (kg)	Ratio of SOx from cruise ships and LDVs
9	ES	Las Palmas	63	4,899	14,658	183,913	2,241	6.5
10	DK	Kobenhavns Havn	71	4,069	14,425	206,054	2,511	5.7
11	DE	Hamburg	42	3,539	14,079	767,202	9,351	1.5
12	IT	Napoli	52	2,968	12,834	540,385	6,586	1.9
13	IT	Genova	31	3,376	12,398	271,943	3,314	3.7
14	DE	Warnemunde	35	2,615	11,245	122,514	1,493	7.5
15	ES	Arrecife de Lanzarote	60	2,638	10,912	30,353	370	29.5
16	HR	Rijeka	9	5,908	10,169	67,792	826	12.3
17	EE	Tallinn	71	2,768	9,953	135,733	1,654	6.0
18	IT	La Spezia	43	3,278	9,330	47,563	580	16.1
19	ES	Cadiz	68	3,136	9,034	44,695	545	16.6
20	IT	Savona	10	1,849	9,018	33,813	412	21.9
21	FR	Le Havre	44	1,762	8,441	65,546	799	10.6
22	FI	Helsinki	63	2,199	8,052	243,000	2,962	2.7
23	ES	Ibiza	50	2,376	8,038	89,569	1,092	7.4
24	SE	Stockholm	33	1,775	8,022	356,236	4,342	1.8
25	NL	Rotterdam	18	1,538	7,714	225,210	2,745	2.8
26	UK	Marchwood	18	1,549	7,327	--	--	--
27	BE	Zeebrugge	45	1,577	7,213	57,049	695	10.4
28	NL	Amsterdam	52	1,880	6,955	235,026	2,864	2.4
29	IS	Reykjavik	64	2,598	6,481	79,887	974	6.7
30	IT	Cagliari	45	1,486	6,477	100,600	1,226	5.3
31	NL	Eemshaven	3	1,271	6,393	--	--	--
32	HR	Dubrovnik - Gruz passenger port	40	2,791	6,344	27,173	331	19.2
33	DE	Kiel	24	1,661	6,260	109,052	1,329	4.7
34	GI	Gibraltar	76	1,795	6,231	17,000	207	30.1
35	IT	Palermo	33	1,493	5,981	388,986	4,741	1.3
36	IT	Messina	45	1,610	5,736	144,546	1,762	3.3
37	NO	Alesund	58	2,048	5,651	--	--	--
38	SE	Loudden	38	1,548	5,635	356,236	4,342	1.3
39	FR	Nice	44	2,574	5,563	--	--	--
40	MC	Monte-Carlo	48	2,644	5,516	--	--	--
41	FR	Cannes	33	2,947	5,366	36,556	446	12.0
42	HR	Split	47	3,535	5,266	89,473	1,090	4.8
43	IE	Dublin	55	1,878	5,241	--	--	--
44	NO	Oslo	43	1,393	5,017	--	--	--
45	ES	Puerto del Rosario	17	1,194	4,982	19,856	242	20.6
46	ES	Valencia	56	1,462	4,917	359,938	4,387	1.1

Ranking	Country	Port cities	Number of cruise ships	Port call time (hours	SO_X from cruise ships (kg)	Number of registered LDVs	SO_X from registered LDVs (kg)	Ratio of SO_X from cruise ships and LDVs
47	DE	Bremerhaven	26	2,368	4,799	--	--	--
48	ES	Malaga	62	1,667	4,380	269,170	3,281	1.3
49	FR	La Seyne-sur-Mer	29	1,003	4,369	--	--	--
50	IT	Bari	13	906	4,354	178,521	2,176	2.0

** passenger vehicle numbers in some cities refer to broader regional figures.*

The analysis shows that European major cruise ship destinations are exposed to amounts of cruise NO_X equivalent to sizeable share of their entire car fleets. For example, the 57 cruise ships which called at Marseilles in 2017 emitted about as much NO_X as a quarter of the city's 340,000 passenger cars (Table A.2.2). In smaller port cities, such as Civitavecchia or Venice, cruise ships emit more NO_X than the total local passenger car fleet.

These figures are likely to get worse in the coming years, because unlike SO_X, NO_X emissions remain largely unaffected by local, regional or global standards on the sulphur in marine fuels. The north European NECA only applies to new ships built after 2021 and they are only required to operate their NO_X control devices (e.g. selective catalytic reduction – SCR) when operating in NECAs. Therefore, existing European NECAs will unlikely have any impact on NO_X emissions in the South. Secondly, even in NECAs, it will take more than 30 years for fleet replacement and the consequent impact of a more stringent ship NO_X standard on maritime emissions.[x] This progressive NECA obligation on cruise ships will also likely take place against the backdrop of the accelerated transition of road transport to electric vehicles (EVs), which are emissions free, hence augmenting the share of ship emissions in European port cities compared to vehicle sources.

3.4. **Country-level findings of cruise air pollution**

Comparative analysis of SO_X emissions from cruise ships and registered passenger cars reveals staggering results. In main tourist destination countries and countries with coastlines along the main shipping lines, maritime SO_X emissions exceed many times over the SO_X emissions from all the registered passenger vehicles in each country. In general, 203 cruise ships alone emitted about 20 times more SO_X along European coasts than all of Europe's 260+ million passenger vehicles in 2017 (table 4 and figure 6).

In absolute terms, the Spanish coast is the most exposed to ship air pollution, with about 15 kt of SO_X emitted by 172 cruise ships in the country's EEZ in 2017. This is about 50 times more than the total SO_X emissions by Spain's 23 million passenger vehicles in the same year. In relative terms Croatia has the highest ratio of ship to LDV SO_X emissions among the EU countries, with 78 cruise ships outdoing the national passenger vehicles by a factor of 189. The coastal counties least exposed to air pollution are Bulgaria and Romania with passenger vehicles emitting more SO_X than cruise ships, a result of significantly lower cruise ship movements in their waters.

Four out of the top five European countries exposed to cruise ship SO_x (Spain, Italy, Norway, Greece and France) are major tourist destinations in the South, notably, in the Mediterranean basin. This not only reflects the large amount of time that cruise ships spend in the South but also the less stringent marine sulphur standard (i.e. 1.5%) in force outside the SECAs (i.e. 0.1%).

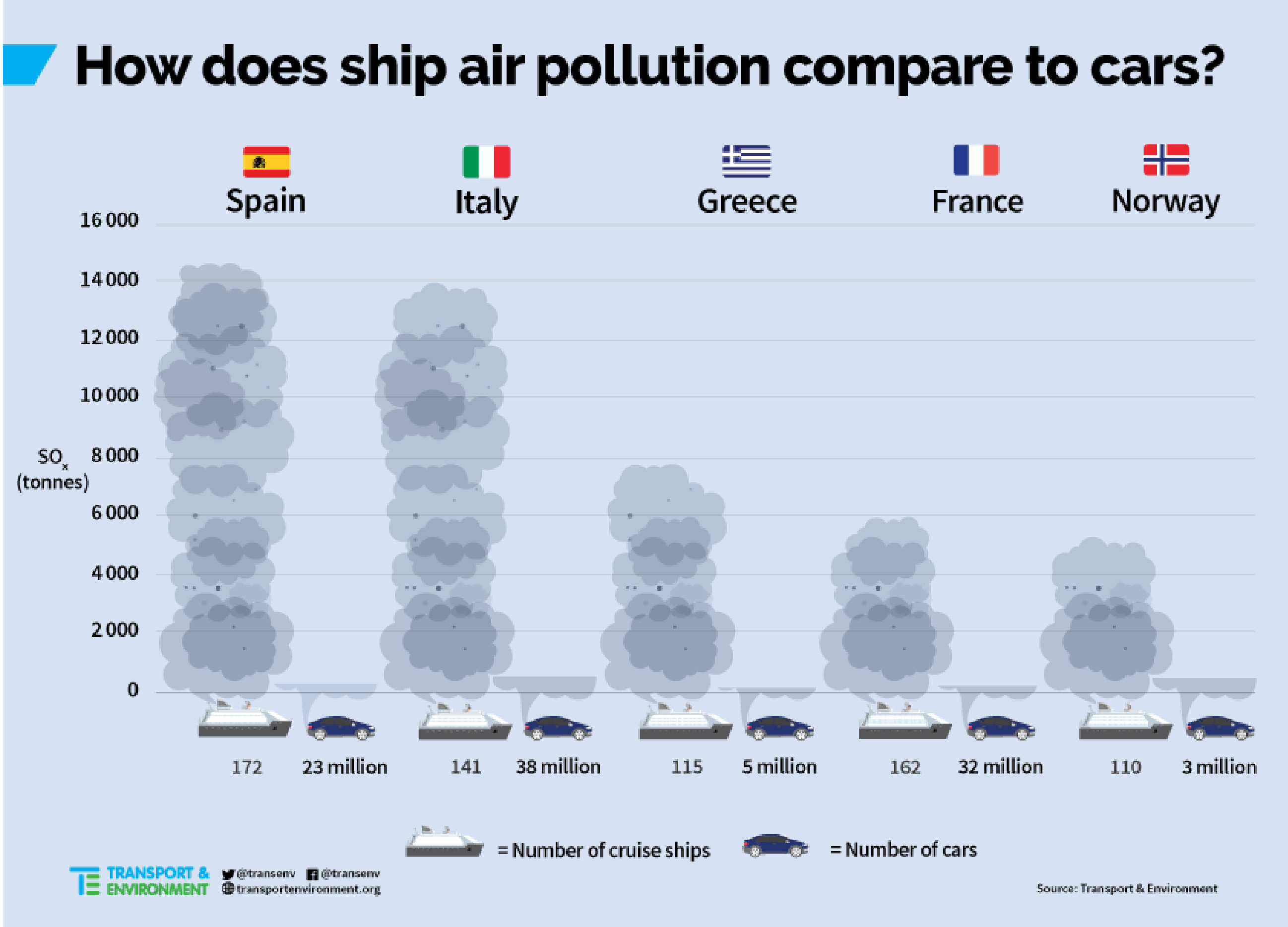

Figure 6: Comparison of SO_x pollution from cruise ships in individual EEZs and domestic car fleet in each corresponding country.

Ships SO_x will still remain considerably large compared to passenger car fleet even after the introduction of the global 2020 marine sulphur cap (table A.3.1).

Table 4: Emissions of SO_x from cruise ships and LDVs in European countries in 2017.

Country	Number of cruise ships**	Sailing time *(hours)*	SO_x from cruise ships *(kg)*	Number of registered LDVs *(thousand)*	SO_x from registered LDVs† *(kg)*	Ratio of SO_x from cruise ships and LDVs
ES	172	129,742	14,496,409	22,877	278,818	51.99
IT	141	128,164	13,895,078	37,876	461,627	30.10
EL	115	97,949	7,674,156	5,236	63,814	120.26
FR	162	63,541	5,949,724	32,074	390,914	15.22
NO	110	160,253	5,260,533	2,663	32,455	162.09
PT	154	46,042	5,107,572	4,850	59,114	86.40
HR	78	42,324	3,589,093	1,553	18,926	189.6
UK	162	75,670	1,714,826	31,834	387,991	4.4
IS	72	19,396	988,982	240	2,931	337.4
AL	67	5,460	784,888	436	5,314	147.7

Country	Number of cruise ships**	Sailing time *(hours)*	SO_x from cruise ships *(kg)*	Number of registered LDVs *(thousand)*	SO_x from registered LDVs† *(kg)*	Ratio of SO_x from cruise ships and LDVs
DK	107	29,547	544,460	2,466	30,049	18.1
MT	83	7,490	502,778	283	3,448	145.8
IE	71	6,687	448,425	2,049	24,969	18.0
ME	62	3,830	319,311	193	2,355	135.6
CY	34	8,192	220,746	508	6,195	35.6
SE	80	34,780	182,034	4,768	58,112	3.1
DE	92	21,692	157,366	45,804	558,245	0.3
NL	97	19,612	146,228	8,223	100,220	1.5
FI	72	11,823	79,355	3,346	40,780	2,0
EE	71	8,509	70,904	703	8,569	8.3
BE	86	2,990	28,461	5,731	69,848	0.4
LV	43	3,288	17,033	664	8,095	2.1
PL	41	3,123	13,513	21,675	264,175	0.1
SI	33	1,228	13,471	1,097	13,364	1.0
LT	36	974	4,183	1,299	15,829	0.3
BG	3	126	3,846	3,144	38,312	0.1
RO	3	62	987	5,472	66,697	0.01
CZ*	0	0	0	5,308	64,691	0.0
LU*	0	0	0	391	4,765	0.0
HU*	0	0	0	3,313	40,381	0.0
AT*	0	0	0	4,822	58,764	0.0
SK*	0	0	0	2,122	25,860	0.0
TOTAL	**203**	**932,491**	**62,222,174**	**263,019**	**3,205,628**	**19.4**

** refers to landlocked countries with no coastline; hence, no maritime emissions.*
*** the sum of cruise ships in each country is larger than the total of the 203 ships in European EEZs, because the same cruise ships travel across multiple EEZs.*
† SO_x emissions from LDVs are estimated by T&E. Number of registered can be found in the EU Statistical pocketbook, 2018.

With regards to NO_x ship emissions, the comparative picture is somewhat different. Even though the relative distribution of NO_x emissions from cruise ships among European countries mirrors that of SO_x, cruise NO_x emissions are generally inferior to those of passenger vehicles. This can be partially explained by the real-world emission factors that we used to estimate car NO_x, which have been shown to be several times higher than legal limits. This creates a distorted comparative picture between cars and cruise ships, as real-world car emissions appear to be much larger than the legal limits of ships, which this analysis is based on. In general, NO_x emissions from the analysed cruise ships are about 15% of total NO_x emitted by Europe's passenger car fleet in a year. But there are significant variations. For example, in Norway and Croatia cruise ships emitted more NO_X than these countries' entire domestic passenger car fleet in a year. In Greece, Denmark, Malta and Estonia these figures a handful of cruise vessels were responsible for more NO_X than the majority of these countries' domestic car fleet (table A.2.3).

In absolute terms, the Spanish and Italian coasts are still the most exposed areas to ship NO_X emissions, with about 27 and 25 kt of NO_X emitted by cruise vessels in these countries' EEZs in 2017, while Bulgaria and Romania remain the least exposed.

Similar to SO_X, 4 out of top 5 NO_X exposed European countries are major tourist destinations in Southern Europe, notably, in the Mediterranean basin. This is most explained by the large amount of time that cruise ships spend along the coasts of the Southern European countries.

PM emissions from shipping are generally linked to the quality of fuel used and are a function of fuel sulphur content. Distribution of PM too follows a similar pattern to SO_X and comparisons to PM2.5 from the European car fleet are similar to that of NO_X (table A.2.4).

4. Conclusions and recommendations

Analysis shows that even a relatively small number of cruise ships emit vast amounts of air pollution. High emissions are due to insufficient stringency of the marine fuel quality and engine emissions standards. These are further compounded by the large size of marine engines and longer operational times of cruise vessels in ports and closer to the coasts. The evidence shows that even SECA ports are still exposed to high amounts of SO_X and PM from ships. Emissions at berth are of a special concern given that main cruise passenger terminals are very close to densely populated cities. This is despite the 0.1% standard in place for all European ports for passenger ships with port calls longer than 2 hours.

In 2020, marine sulphur standard for ships sailing in the EU EEZ outside the SECAs and outside the (berths in) European ports will improve from 1.5% to 0.5%. This will have considerable impact on ship air pollution. However, emissions from cruise ships will still remain considerably large compared to the emissions from the European passenger car fleet. As table A.3.1 demonstrates, even after the 2020 standard, a handful of cruise ships will still emit about 18, 10 and 41 times more SO_X than all of the passenger vehicles respectively in Spain, Italy and Greece – top cruise ship polluted countries in Europe. Also, 2020 standard will have no impact on emissions in ports and in SECAs, because the standard in SECAs and in European ports is more stringent than the upcoming global standard (0.1% vs. 0.5%).

Fortunately, there are technologies available to eliminate all ship emissions at berth and at sea. Notably, shore-side electricity (SSE), the possibility for ships at berth to connect to the local electricity grid and power their on-board equipment, is a proven and mature technology which can greatly reduce the local air pollution generated by docked vessels in ports. The European Alternative Fuels Infrastructure Directive requires SSE in major European ports, but only if it is cost-beneficial; as a result, there is little uptake so far by ships and ports. Two main issues are hindering the widespread adoption of SSE:

1. A "chicken-and-egg" problem, whereby owners of the vessels do not invest in ships to make them SSE-compatible because of limited connections available in ports, while at the same time ports do not invest in SSE connections because few ships can use them.
2. There is also a market distortion because of taxation. Shore-side electricity is taxed under the 2003 EU Energy Tax Directive, while fossil marine fuels are tax exempt. Such an uneven playing field creates a disincentive for ship owners to use SSE in ports wherever these technologies are available. This situation further disincentivises ports interested in SSE capacity.

Recommendation 1: In order to create a level playing field between SSE and fossil fuels used on-board, the EU should exempt by default SSE from electricity taxation for a transitional period of time, and/or tax at an equivalent rate fossil fuels used on board.

Recommendation 2: The EU should mandate zero emission berth standard in European ports, hence requiring ships to use SSE or implement alternative measures to achieve equivalent results. This would help ports that have invested in SSE avoid stranded assets.

Recommendation 3: Extend SECA standards to the rest of the EU seas and further tighten the SECA standard, notably, in favour of 10ppm sulphur standard (0.001%) currently applicable to road transport.

Recommendation 4: Given that NO_X from existing and new ships is of great concern and that upcoming Baltic and North Sea and English Channel nitrogen emissions control areas (NECAs) will only address emissions from new ships built after 2021 alone, there is a need to tackle NO_X from existing ships in all European waters (outside ports). For this reason, we recommend for a stand-alone EU measure, including possibly a financial mechanism similar to the Norwegian NO_X Fund. Ships can use SCR systems and diesel particulate filters (DPF) to reduce their NO_X and PM.

Recommendation 5: Consider zero emission control areas, as an extension of zero emission berth standard, in European territorial waters, especially in the major touristic destinations.

Ship sourced air pollution is a huge problem in many parts of the world. Even though the scope of this analysis was limited to continental Europe and surrounding islands only, one could expect similar levels of ship pollution elsewhere, too. For this reason, the recommendations of this report can be valid for countries as well.

Appendix 1 – Detailed methodology

Transport & Environment acquired automatic identification system (AIS) data for the global cruise ship fleet in 2017. These data contain information such as the IMO number, geographical coordinates, bearing, speed over ground (SOG), and the time of the signal. These data were analysed using a suite of in-house programs for filtering and collating the data for post-processing using our in-house ship energy and emissions model. This appendix outlines the methodology employed in the pre-processing and filtering of the data, along with the merging of other datasets.

The first step was to identify the cruise ships that operated in European waters. This involved a pre-filtering phase whereby ship coordinates were filtered based on a geographical polygon around the European continent and into the Atlantic Ocean (Figure A1.1). Following this, ship coordinates were tagged depending on whether or not they were in the North Sea SECA, and similarly ships were tagged as being in open sea or within a country's EEZ using a ray-casting algorithm. We used a database of port locations to assign port tags to the ship movements. Emissions were assigned to ports under the condition of SOG < 3 knots and the distance was less than 12 nautical miles. Dry docks were also identified, and whenever ships were registered as being within a dry-dock through spatial filtering, those data were deleted from the analysis.

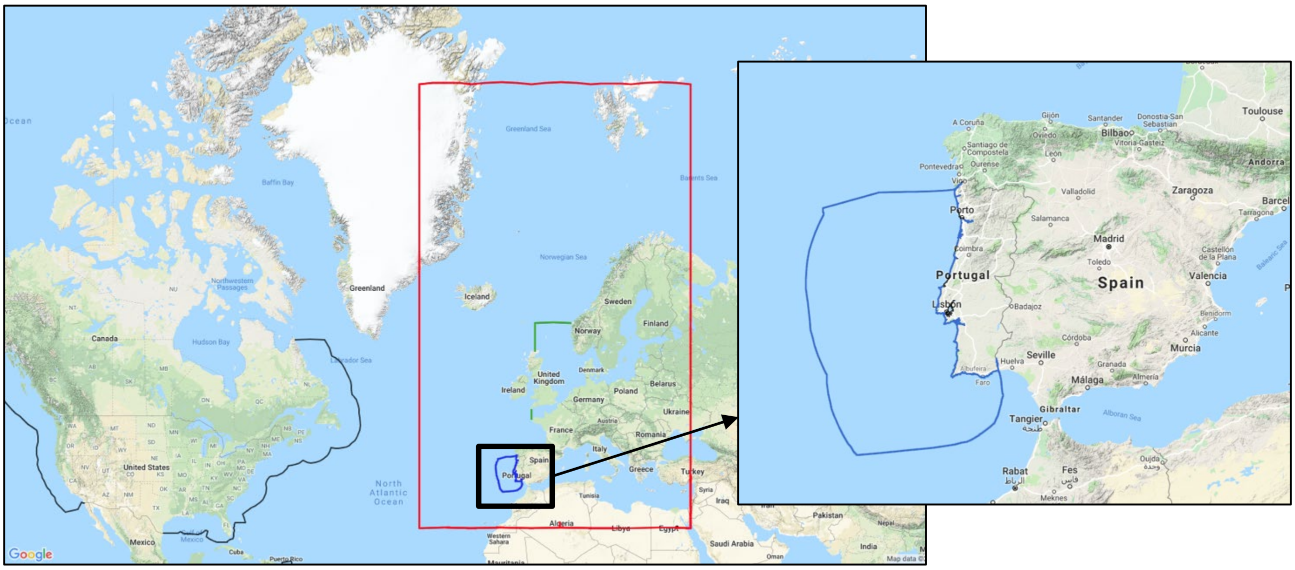

Figure A1.1: Geographical filtering (red), SECA (green), and insert showing the Portuguese EEZ (blue).

Spurious velocities were filtered in two ways. The first compared the calculated velocity (from distance and time) to the recorded SOG; a clustering algorithm was used to automatically identify outliers that were deleted. In a second step, any remaining readings that had a SOG > 35 knots had the velocity corrected to that of the previous time step. The time interval, d*t*, was calculated from the signal times by $dt = t_i - t_{i-1}$, where *i* represents a data row. This metric allows the calculation of fuel consumption and emissions of pollutants across the records. The data had nominal d*t* = 1 h, however some ships or some regions yielded higher frequency readings, d*t* < 1. In this case the data was under-sampled so that d*t* ~ 1, mainly for the performance of the downstream model. On the other hand, if d*t* > 5, the following data row was deleted and d*t* set to 1. This covered to common events: ships that pass through the geographic boundaries (for example travelling to and from Europe to the Americas and back), and more rarely for ships that were inactive in a port.

These filtered and collated results were then fed into our in-house ship energy and emissions model, to compute fuel consumption and emissions. The model allowed us to sum the pollutants for ports and for each EEZ. Results were compared to the ICCT study, and our results correspond well to their results for cruise ships using operational hours as a proxy for emissions.

Appendix 2 – Detailed Results

Tables below provide detailed breakdown of emissions per country and per port city.

Table A.2.1: PM emissions from cruise ships and LDVs in the top 50 cruise polluted European port cities in 2017.

Ranking	**Country**	**Port cities**	**Number of cruise ships**	**Port call time** (hours)	**PM from cruise ships** (kg)	**Number of registered LDVs**	**PM2.5 from registered LDVs** (kg)	**Cruise ship PM2.5 vs. LDVs*** (%)
1	ES	Barcelona	105	8,293	13,101	558,920	345,439	3.5%
2	ES	Palma Mallorca	87	6,766	11,196	245,005	151,425	6.8%
3	IT	Venezia	68	7,988	10,961	111,712	49,729	20.3%
4	IT	Civitavecchia	76	5,466	8,898	33,591	14,953	54.7%
5	UK	Southampton	42	4,510	7,890	261,696	161,347	4.5%
6	PT	Lisbon	115	7,953	6,335	374,855	319,430	1.8%
7	ES	Santa Cruz de Tenerife	75	4,363	6,205	115,574	71,430	8.0%
8	FR	Marseille	57	3,342	6,091	339,987	157,601	3.6%
9	ES	Las Palmas	63	4,899	5,834	183,913	113,667	4.7%
10	DK	Kobenhavns Havn	71	4,069	5,738	206,054	93,640	5.6%
11	DE	Hamburg	42	3,539	5,612	767,202	272,615	1.9%
12	IT	Napoli	52	2,968	5,138	540,385	240,556	2.0%
13	IT	Genova	31	3,376	4,946	271,943	121,057	3.8%
14	DE	Warnemunde	35	2,615	4,492	122,514	43,534	9.5%
15	ES	Arrecife de Lanzarote	60	2,638	4,357	30,353	18,760	21.4%
16	EE	Tallinn	71	2,768	3,960	135,733	63,184	5.8%
17	HR	Rijeka	9	5,908	3,878	67,792	28,842	12.4%
18	IT	La Spezia	43	3,278	3,721	47,563	21,173	16.2%
19	IT	Savona	10	1,849	3,616	33,813	15,052	22.1%
20	ES	Cadiz	68	3,136	3,572	44,695	27,624	11.9%
21	FR	Le Havre	44	1,762	3,383	65,546	30,384	10.2%
22	SE	Stockholm	33	1,775	3,210	356,236	187,115	1.6%
23	FI	Helsinki	63	2,199	3,205	243,000	149,564	2.0%
24	ES	Ibiza	50	2,376	3,198	89,569	55,358	5.3%
25	NL	Rotterdam	18	1,538	3,095	225,210	108,086	2.6%
26	UK	Marchwood	18	1,549	2,935	--	--	--
27	BE	Zeebrugge	45	1,577	2,888	57,049	16,135	16.5%
28	NL	Amsterdam	52	1,880	2,765	235,026	112,797	2.3%
29	IT	Cagliari	45	1,486	2,592	100,600	44,783	5.3%
30	NL	Eemshaven	3	1,271	2,565	--	--	--
31	IS	Reykjavik	64	2,598	2,559	79,887	--	--
32	HR	Dubrovnik - Gruz passenger port	40	2,791	2,523	27,173	11,561	20.1%
33	DE	Kiel	24	1,661	2,491	109,052	38,750	5.9%
34	GI	Gibraltar	76	1,795	2,485	17,000	10,481	21.8%

Ranking	Country	Port cities	Number of cruise ships	Port call time (hours)	PM from cruise ships (kg)	Number of registered LDVs	PM2.5 from registered LDVs (kg)	Cruise ship PM2.5 vs. LDVs* (%)
35	IT	Palermo	33	1,493	2,393	388,986	173,159	1.3%
36	IT	Messina	45	1,610	2,296	144,546	64,346	3.3%
37	SE	Loudden	38	1,548	2,239	356,236	187,115	1.1%
38	NO	Alesund	58	2,048	2,232	--	--	--
39	FR	Nice	44	2,574	2,199	--	--	--
40	MC	Monte-Carlo	48	2,644	2,161	--	--	--
41	FR	Cannes	33	2,947	2,130	36,556	16,946	11.6%
42	HR	Split	47	3,535	2,076	89,473	38,066	5.0%
43	IE	Dublin	55	1,878	2,070	--	--	--
44	NO	Oslo	43	1,393	1,994	--	--	--
45	ES	Puerto del Rosario	17	1,194	1,990	19,856	12,272	14.9%
46	ES	Valencia	56	1,462	1,957	359,938	222,459	0.8%
47	DE	Bremerhaven	26	2,368	1,857	--	--	--
48	FR	La Seyne-sur-Mer	29	1,003	1,750	--	--	--
49	IT	Bari	13	906	1,746	178,521	79,470	2.0%
50	ES	Malaga	62	1,667	1,733	269,170	166,360	1.0%

** The majority (about 92%) of ship PM is PM 2.5. This has been taken into account when comparing to car PM 2.5.*

Table A.2.2: Emissions of NO_X from cruise ships and LDVs in top 50 cruise polluted European port cities in 2017.

Ranking	Country	Port cities	Number of cruise ships	Port call time (hours)	NO_X from cruise ships (kg)	Number of registered LDVs	NO_X from registered LDVs (kg)	Cruise ship NO_X vs. LDVs (%)
1	ES	Barcelona	105	8,293	729,481	558,920	2,562,913	28.5%
2	ES	Palma Mallorca	87	6,766	629,833	245,005	1,123,464	56.1%
3	IT	Venezia	68	7,988	600,337	111,712	436,279	137.6%
4	IT	Civitavecchia	76	5,466	500,326	33,591	131,186	381.4%
5	UK	Southampton	42	4,510	419,435	261,696	1,142,692	36.7%
6	PT	Lisbon	115	7,953	374,811	374,855	1,976,056	19.0%
7	ES	Santa Cruz de Tenerife	75	4,363	366,886	115,574	529,962	69.2%
8	ES	Las Palmas	63	4,899	341,486	183,913	843,328	40.5%
9	FR	Marseille	57	3,342	326,460	339,987	1,285,961	25.4%
10	DE	Hamburg	42	3,539	311,088	767,202	2,526,310	12.3%
11	DK	Kobenhavns Havn	71	4,069	310,488	206,054	806,206	38.5%
12	IT	Napoli	52	2,968	303,708	540,385	2,110,417	14.4%
13	HR	Rijeka	9	5,908	273,622	67,792	249,916	109.5%
14	IT	Genova	31	3,376	261,550	271,943	1,062,045	24.6%
15	ES	Arrecife de Lanzarote	60	2,638	254,580	30,353	139,183	182.9%
16	DE	Warnemunde	35	2,615	245,380	122,514	403,425	60.8%
17	ES	Cadiz	68	3,136	231,880	44,695	204,948	113.1%

Ranking	Country	Port cities	Number of cruise ships	Port call time (hours)	NO_x from cruise ships (kg)	Number of registered LDVs	NO_x from registered LDVs (kg)	Cruise ship NO_x vs. LDVs (%)
18	EE	Tallinn	71	2,768	215,364	135,733	548,181	39.3%
19	IT	La Spezia	43	3,278	194,646	47,563	185,752	104.8%
20	IT	Savona	10	1,849	191,830	33,813	132,053	145.3%
21	FR	Le Havre	44	1,762	181,303	65,546	247,920	73.1%
22	ES	Ibiza	50	2,376	176,276	89,569	410,716	42.9%
23	SE	Stockholm	33	1,775	175,943	356,236	1,443,419	12.2%
24	FI	Helsinki	63	2,199	175,434	243,000	1,134,968	15.5%
25	NL	Rotterdam	18	1,538	167,938	225,210	896,444	18.7%
26	UK	Marchwood	18	1,549	166,317	--	--	--
27	NL	Amsterdam	52	1,880	158,953	235,026	935,517	17.0%
28	BE	Zeebrugge	45	1,577	155,433	57,049	162,113	95.9%
29	IS	Reykjavik	64	2,598	152,799	79,887	--	--
30	GI	Gibraltar	76	1,795	145,418	17,000	74,230	195.9%
31	IT	Cagliari	45	1,486	144,070	100,600	392,883	36.7%
32	HR	Dubrovnik - Gruz passenger port	40	2,791	140,259	27,173	100,174	140.0%
33	NL	Eemshaven	3	1,271	135,395	--	--	--
34	DE	Kiel	24	1,661	135,166	109,052	359,096	37.6%
35	FR	Nice	44	2,574	133,791	--	--	--
36	NO	Alesund	58	2,048	133,193	--	--	--
37	IT	Messina	45	1,610	130,777	144,546	564,509	23.2%
38	IT	Palermo	33	1,493	130,054	388,986	1,519,144	8.6%
39	SE	Loudden	38	1,548	121,330	356,236	1,443,419	8.4%
40	MC	Monte-Carlo	48	2,644	118,897	--	--	--
41	IE	Dublin	55	1,878	117,721	--	--	--
42	ES	Puerto del Rosario	17	1,194	116,939	19,856	91,049	128.4%
43	FR	Cannes	33	2,947	116,119	36,556	138,269	84.0%
44	DE	Bremerhaven	26	2,368	116,024	--	--	--
45	HR	Split	47	3,535	113,167	89,473	329,844	34.3%
46	NO	Oslo	43	1,393	111,166	--	--	--
47	ES	Valencia	56	1,462	108,877	359,938	1,650,486	6.6%
48	FR	La Seyne-sur-Mer	29	1,003	107,225	--	--	--
49	ES	Malaga	62	1,667	106,979	269,170	1,234,272	8.7%
50	ES	Santa Cruz de la Palma	39	1,122	93,058	*7,213*	33,075	281.4%

Table A.2.3: Emissions of NO_X from cruise ships and LDVs in European countries in 2017.

Country	**Number of cruise ships****	**Sailing time** (hours)	**NO_X from cruise ships** (kg)	**Number of registered LDVs** (thousand)	**NO_X from registered LDVs†** (kg)	**Cruise ship NO_X vs. LDVs** (%)
ES	172	129,742	27,423,604	22,877	104,901,104	26%
IT	141	128,164	25,395,875	37,876	147,921,275	17%
NO	110	160,253	18,856,703	2,663	13,122,591	144%
EL	115	97,949	14,899,584	5,236	23,438,486	64%
FR	162	63,541	12,706,186	32,074	121,316,906	10%
UK	162	75,670	11,333,184	31,834	139,004,386	8%
PT	154	46,042	9,595,870	4,850	25,568,081	38%
HR	78	42,324	6,373,174	1,553	5,724,808	111%
DK	107	29,547	5,314,834	2,466	9,646,650	55%
SE	80	34,780	4,170,896	4,768	19,319,524	22%
DE	92	21,692	3,669,861	45,804	150,825,969	2%
NL	97	19,612	3,402,294	8,223	32,731,391	10%
IS	72	19,396	2,155,163	240	--	--
FI	72	11,823	1,793,443	3,346	15,628,013	11%
EE	71	8,509	1,610,180	703	2,839,592	57%
AL	67	5,460	1,302,371	436	--	--
MT	83	7,490	1,127,542	283	1,544,274	73%
IE	71	6,687	982,858	2,049	6,750,547	15%
CY	34	8,192	686,612	508	2,598,464	26%
BE	86	2,990	647,698	5,731	16,285,433	4%
ME	62	3,830	593,984	193	--	--
LV	43	3,288	404,891	664	2,064,949	20%
PL	41	3,123	318,400	21,675	116,825,406	0%
LT	36	974	93,755	1,299	3,432,384	3%
SI	33	1,228	55,800	1,097	4,351,971	1%
BG	3	126	10,923	3,144	9,962,539	0%
RO	3	62	3,296	5,472	21,105,378	0%
CZ*	0	0	0	5,308	21,400,673	0%
LU*	0	0	0	391	822,064	0%

Country	Number of cruise ships**	Sailing time (hours)	NO_x from cruise ships (kg)	Number of registered LDVs (thousand)	NO_x from registered LDVs† (kg)	Cruise ship NO_x vs. LDVs (%)
HU*	0	0	0	3,313	14,307,402	0%
AT*	0	0	0	4,822	21,214,471	0%
SK*	0	0	0	2,122	8,303,397	0%
TOTAL	203	932,491	155,085,540	263,019	1,062,958,126	15%

** refers to landlocked countries with no coastline; hence, no maritime emissions.*
*** the sum of cruise ships in each country is larger than total 69 ships in European EEZ, because the same cruise ships travel across multiple EEZs.*
† NO_X emissions from LDVs are also estimated by T&E. Number of registered can be found in the EU Statistical pocketbook, 2018.

Table A.2.4: Emissions of PM from cruise ships and LDVs in European countries in 2017.

Country	Number of cruise ships**	Sailing time (hours)	PM from cruise ships* (kg)	Number of registered LDVs (thousand)	PM 2.5 from registered LDVs† (kg)	Cruise ship PM2.5 vs. LDVs†† (%)
ES	172	129,742	2,283,225	22,877	14,138,969	15%
IT	141	128,164	2,168,985	37,876	16,860,791	12%
EL	115	97,949	1,227,580	5,236	2,879,151	39%
NO	110	160,253	1,002,787	2,663	1,895,734	49%
FR	162	63,541	955,579	32,074	14,867,999	6%
PT	154	46,042	809,360	4,850	4,133,092	18%
HR	78	42,324	558,084	1,553	660,678	78%
UK	162	75,670	378,715	31,834	19,627,351	2%
IS	72	19,396	164,450	240	--	--
DK	107	29,547	139,399	2,466	1,120,451	11%
AL	67	5,460	121,677	436	0	--
MT	83	7,490	82,407	283	255,951	30%
IE	71	6,687	78,799	2,049	689,619	11%
SE	80	34,780	76,145	4,768	2,504,444	3%
DE	92	21,692	65,285	45,804	16,275,692	0%
NL	97	19,612	60,148	8,223	3,946,470	1%
ME	62	3,830	50,608	193	--	--
CY	34	8,192	39,294	508	390,211	9%
FI	72	11,823	33,132	3,346	2,059,426	1%

Country	Number of cruise ships**	Sailing time (hours)	PM from cruise ships* (kg)	Number of registered LDVs (thousand)	PM 2.5 from registered LDVs† (kg)	Cruise ship PM2.5 vs. LDVs†† (%)
EE	71	8,509	29,339	703	327,295	8%
BE	86	2,990	11,836	5,731	1,620,883	1%
LV	43	3,288	7,183	664	208,927	3%
PL	41	3,123	5,606	21,675	19,624,461	0%
SI	33	1,228	2,484	1,097	522,984	0%
LT	36	974	1,724	1,299	332,776	0%
BG	3	126	647	3,144	1,058,342	0%
RO	3	62	171	5,472	2,341,336	0%
CZ*	0	0	0	5,308	2,721,813	0%
LU*	0	0	0	391	70,931	0%
HU*	0	0	0	3,313	1,922,878	0%
AT*	0	0	0	4,822	2,805,553	0%
SK*	0	0	0	2,122	863,975	0%
TOTAL	**203**	**932,491**	**10,357,785**	**263,019**	**136,728,184**	**7%**

** refers to landlocked countries with no coastline; hence, no maritime emissions.*

*** the sum of cruise ships in each country is larger than total 203 ships in European EEZ, because the same cruise ships travel across multiple EEZs.*

† PM emissions from LDVs are also estimated by T&E. Number of registered can be found in the EU Statistical pocketbook, 2018.

†† The majority (about 92%) of ship PM is PM 2.5. This has been taken into account when comparing to car PM 2.5.

Appendix 3 – Projected impact of 2020 standard on SO_X emissions

In 2020, sulphur standard for marine fuels will be tightened under the MARPOL Annex VI and EU Sulphur Directive. For cruise ships sailing in the EU EEZ outside the ports and SECAs, this will be a three-fold improvement – from 1.5% down to 0.5%. Anticipating this change in legislation, this report also estimated the potential impact of the 2020 sulphur standard on emissions. As the results presented in Table A.3.1 demonstrate, even after the new sulphur standard, cruise ships will remain a huge source of SO_X emissions in almost all Europe countries. In the most cruise SO_X polluted European countries, namely, Spain, Italy and Greece, cruise ships will keep exceeding domestic LDV fleets by a factor of 10-40.

Table A.3.1: Projected emissions of SO_X from cruise ships and LDVs in European countries in 2020.

Country	**Number of cruise ships****	**Sailing time** (hours)	**SO_X from cruise ships** (kg)	**Number of registered LDVs** (thousand)	**SO_X from registered LDVs** (kg)	**Ratio of SO_X from cruise ships and LDVs**
ES	172	129,742	4,936,254	22,877	278,818	17.7
IT	141	128,164	4,732,440	37,876	461,627	10.3
EL	115	97,949	2,607,930	5,236	63,814	40.9
FR	162	63,541	2,085,453	32,074	390,914	5.3
NO	110	160,253	1,992,580	2,663	32,455	61.4
PT	154	46,042	1,730,602	4,850	59,114	29.3
HR	78	42,324	1,214,178	1,553	18,926	64.2
UK	162	75,670	818,063	31,834	387,991	2.1
IS	72	19,396	338,450	240	2,931	115.5
DK	107	5,460	316,869	2,466	30,049	10.5
AL	67	29,547	261,759	436	5,314	49.3
SE	80	7,490	182,034	4,768	58,112	3.1
MT	83	6,687	175,944	283	3,448	51.0
DE	92	3,830	157,366	45,804	558,245	0.3
IR	71	8,192	154,721	2,049	24,969	6.2
NL	97	34,780	146,228	8,223	100,220	1.5
ME	62	21,692	107,882	193	2,355	45.8
CY	34	19,612	79,942	508	6,195	12.9
FI	72	11,823	79,355	3,346	40,780	1.9
EE	71	8,509	70,904	703	8,569	8.3
BE	86	2,990	28,461	5,731	69,848	0.4
LV	43	3,288	17,033	664	8,095	2.1

Country	**Number of cruise ships****	**Sailing time** (hours)	**SO_x from cruise ships** (kg)	**Number of registered LDVs** (thousand)	**SO_x from registered LDVs** (kg)	**Ratio of SO_x from cruise ships and LDVs**
PL	41	3,123	13,513	21,675	264,175	0.1
SI	33	1,228	5,541	1,097	13,364	0.4
LT	36	974	4,183	1,299	15,829	0.3
BG	3	126	1,350	3,144	38,312	0.0
RO	3	62	360	5,472	66,697	0.0
CZ*	0	0	0	5,308	64,691	0.0
LU*	0	0	0	391	4,765	0.0
HU*	0	0	0	3,313	40,381	0.0
AT*	0	0	0	4,822	58,764	0.0
SK*	0	0	0	2,122	25,860	0.0
TOTAL	**203**	**932,491**	**22,259,396**	**263,019**	3,205,628	6.9

** refers to landlocked countries with no coastline; hence, no maritime emissions.*
*** the sum of cruise ships in each country is larger than the total of the 203 ships in European EEZs, because the same cruise ships travel across multiple EEZs.*

Appendix 4 – Passenger car fleet in port cities

The table A.4.1. summarises the passenger car fleet numbers in major touristic port cities based on desk research. In some cases, the numbers refer to the size of the car fleet in regions, as opposed to individual cities. Wherever possible, we have aimed to exclude electric vehicles.

Table A.4.1: Passenger car fleet in major touristic port cities, compiled by T&E.

Port city name	Country	Number of registered passenger cars	Source	Year	Source
Palma Mallorca	ES	245,005	Ministerio del interior, Dirección General de Tráfico	2019	https://sedeapl.dgt.gob.es/WEB_IEST_CONSULTA/
Marseille	FR	339,987	Ministère de la Transition écologique et solidaire	2019	
Barcelona	ES	558,920	Ministerio del interior, Dirección General de Tráfico	2019	https://sedeapl.dgt.gob.es/WEB_IEST_CONSULTA/
Venezia	IT	111,712	Automobile Club D'Italia	2017	http://www.aci.it/laci/studi-e-ricerche/dati-e-statistiche/autoritratto/autoritratto-2017.html
Rijeka	HR	67,792	Ministarstvo Unutarnjih Poslova	2019	
Genova	IT	271,943	Automobile Club D'Italia	2017	http://www.aci.it/laci/studi-e-ricerche/dati-e-statistiche/autoritratto/autoritratto-2017.html
Savona	IT	33,813	Automobile Club D'Italia	2017	http://www.aci.it/laci/studi-e-ricerche/dati-e-statistiche/autoritratto/autoritratto-2017.html
Hamburg	DE	767,202	Statistisches Amt für Hamburg und Schleswig-Holstein	2017	https://www.statistik-nord.de/fileadmin/Dokumente/Statistische_Berichte/verkehr_umwelt_und_energie/H_I_2_j_HuS/H_I_2_j-17_HH.pdf
Civitavecchia	IT	33,591	Automobile Club D'Italia	2017	http://www.aci.it/laci/studi-e-ricerche/dati-e-statistiche/autoritratto/autoritratto-2017.html
Las Palmas	ES	183,913	Ministerio del interior, Dirección General de Tráfico	2019	https://sedeapl.dgt.gob.es/WEB_IEST_CONSULTA/
Santa Cruz de Tenerife	ES	115,574	Ministerio del interior, Dirección General de Tráfico	2019	https://sedeapl.dgt.gob.es/WEB_IEST_CONSULTA/
Palermo	IT	388,986	Automobile Club D'Italia	2017	http://www.aci.it/laci/studi-e-ricerche/dati-e-statistiche/autoritratto/autoritratto-2017.html
Rotterdam	NL	225,210	Centraal Bureau voor de Statistiek	2019	https://statline.cbs.nl/Statweb/publication/?DM=SLNL&PA=37209hvv&D1=0-17&D2=80,241,489,500&D3=15-19&HDR=T&STB=G1,G2&VW=T
Lisbon	PT	374,855	Diario de Noticias	2017	https://www.dn.pt/sociedade/interior/lisboa-vai-ter-84-mil-lugares-de-estacionamento-pago-8656670.html
Arrecife de Lanzarote	ES	30,353	Ministerio del interior, Dirección General de Tráfico	2019	https://sedeapl.dgt.gob.es/WEB_IEST_CONSULTA/

Southampton	UK	261,696	UK Government, Department for Transport	2018	https://www.dft.gov.uk/traffic-counts/area/regions/South+East/local-authorities/Southampton
Warnemunde	DE	122,514	Kraftahrt-Bundesamt	2017	https://www.kba.de/DE/Statistik/Produktkatalog/produkte/Fahrzeuge/fz3_b_uebersicht.html
Kobenhavns Havn	DK	206,054	Danmarks statistik	2019	http://www.statbank.dk/statbank5a/default.asp?w=1920
Le Havre	FR	65,546	Ministère de la Transition écologique et solidaire	2019	
Cagliari	IT	100,600	Automobile Club D'Italia	2017	http://www.aci.it/laci/studi-e-ricerche/dati-e-statistiche/autoritratto/autoritratto-2017.html
Ibiza	ES	89,569	Ministerio del interior, Dirección General de Tráfico	2019	https://www.diariodeibiza.es/pitiuses-balears/2018/02/24/eivissa-soporta-113-vehiculos-motor/971933.html
Livorno	IT	86,497	Automobile Club D'Italia	2017	http://www.aci.it/laci/studi-e-ricerche/dati-e-statistiche/autoritratto/autoritratto-2017.html
Amsterdam	NL	235,026	Centraal Bureau voor de Statistiek	2019	https://statline.cbs.nl/Statweb/publication/?DM=SLNL&PA=37209hvv&D1=0-17&D2=80,241,489,500&D3=15-19&HDR=T&STB=G1,G2&VW=T
Bari	IT	178,521	Automobile Club D'Italia	2017	http://www.aci.it/laci/studi-e-ricerche/dati-e-statistiche/autoritratto/autoritratto-2017.html
La Spezia	IT	47,563	Automobile Club D'Italia	2017	http://www.aci.it/laci/studi-e-ricerche/dati-e-statistiche/autoritratto/autoritratto-2017.html
Stockholm	SE	356,236	SCB	2019	https://www.scb.se/en/finding-statistics/statistics-by-subject-area/transport-and-communications/road-traffic/registered-vehicles/
Kiel	DE	109,052	Kraftahrt-Bundesamt	2019	https://www.kba.de/DE/Statistik/Produktkatalog/produkte/Fahrzeuge/fz3_b_uebersicht.html
Tallinn	EE	135,733	Tallinn City Office	2019	https://www.tallinn.ee/eng/Yearbooks-and-Statistics
Trieste	IT	107,265	Automobile Club D'Italia	2017	http://www.aci.it/laci/studi-e-ricerche/dati-e-statistiche/autoritratto/autoritratto-2017.html
Napoli	IT	540,385	Automobile Club D'Italia	2017	http://www.aci.it/laci/studi-e-ricerche/dati-e-statistiche/autoritratto/autoritratto-2017.html
Puerto del Rosario	ES	19,856	Ministerio del interior, Dirección General de Tráfico	2019	https://sedeapl.dgt.gob.es/WEB_IEST_CONSULTA/
Cadiz	ES	44,695	Ministerio del interior, Dirección General de Tráfico	2019	https://sedeapl.dgt.gob.es/WEB_IEST_CONSULTA/
Schiedam	NL	30,167	Centraal Bureau voor de Statistiek	2019	https://statline.cbs.nl/Statweb/publication/?DM=SLNL&PA=37209hvv&D1=0-17&D2=80,241,489,500&D3=15-19&HDR=T&STB=G1,G2&VW=T
Zeebrugge	BE	57,049	Statbel	2018	https://statbel.fgov.be/fr/themes/mobilite/circulation/parc-de-vehicules#figures
Helsinski	FI	243,000	Helsingin kaupunki	2017	https://www.hel.fi/helsinki/fi/kartat-ja-liikenne/kadut-ja-liikennesuunnittelu/tutkimus-ja-tilastot/moottoriajoneuvoliikenteen-maarat/
Monfacolne	IT	15,451	Automobile Club D'Italia	2017	http://www.aci.it/laci/studi-e-ricerche/dati-e-statistiche/autoritratto/autoritratto-2017.html
Messina	IT	144,546	Automobile Club D'Italia	2017	http://www.aci.it/laci/studi-e-ricerche/dati-e-statistiche/autoritratto/autoritratto-2017.html
Split	HR	89,473	Ministarstvo Unutarnjih Poslova	2019	
Gravesend	UK				
Reykjavik	IS	79,887	Icelandic Transport Authority	2019	

Ballstaviken	SE	356,236	SCB	2019	https://www.scb.se/TK1001-en
Valencia	ES	359,938	Ministerio del interior, Dirección General de Tráfico	2019	https://sedeapl.dgt.gob.es/WEB_IEST_CONSULTA
Malaga	ES	269,170	Ministerio del interior, Dirección General de Tráfico	2019	https://sedeapl.dgt.gob.es/WEB_IEST_CONSULTA
Cannes	FR	36,556	Ministère de la Transition écologique et solidaire	2019	
Ajaccio	FR	35,722	Ministère de la Transition écologique et solidaire	2019	
Loudden	SE	356,236	SCB	2019	https://www.scb.se/TK1001-en
Gibraltar	GI	17,000	Government of Gibraltar	2016	https://www.gibraltar.gov.gi/new/sites/default/files/press/2016/Press%20Releases/641-2016.pdf
Santa Cruz de la Palma	ES	7,213	Ministerio del interior, Dirección General de Tráfico	2019	https://sedeapl.dgt.gob.es/WEB_IEST_CONSULTA
Dubrovnik - Gruz Passenger port	HR	27,173	Ministarstvo Unutarnjih Poslova	2019	
Kirkwall	UK	35,873	UK Government, Department for Transport	2018	https://www.dft.gov.uk/traffic-counts/area/regions/Scotland/local-authorities/Orkney+Islands
Mariehamn	FI	7,856	Tilastokeskus	2018	http://pxnet2.stat.fi/PXWeb/pxweb/en/StatFin/StatFin__lii__mkan/statfin_mkan_pxt_11ic.px/table/tableViewLayout1/?loadedQueryId=eeb4b53e-e0ca-463c-bed5-59de16a3b709&timeType=from&timeValue=2014
Olbia	IT	42,130	Automobile Club D'Italia	2017	http://www.aci.it/laci/studi-e-ricerche/dati-e-statistiche/autoritratto/autoritratto-2017.html
Antwerp	BE	204,641	Statbel	2018	https://statbel.fgov.be/fr/themes/mobilite/circulation/parc-de-vehicules#figures

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