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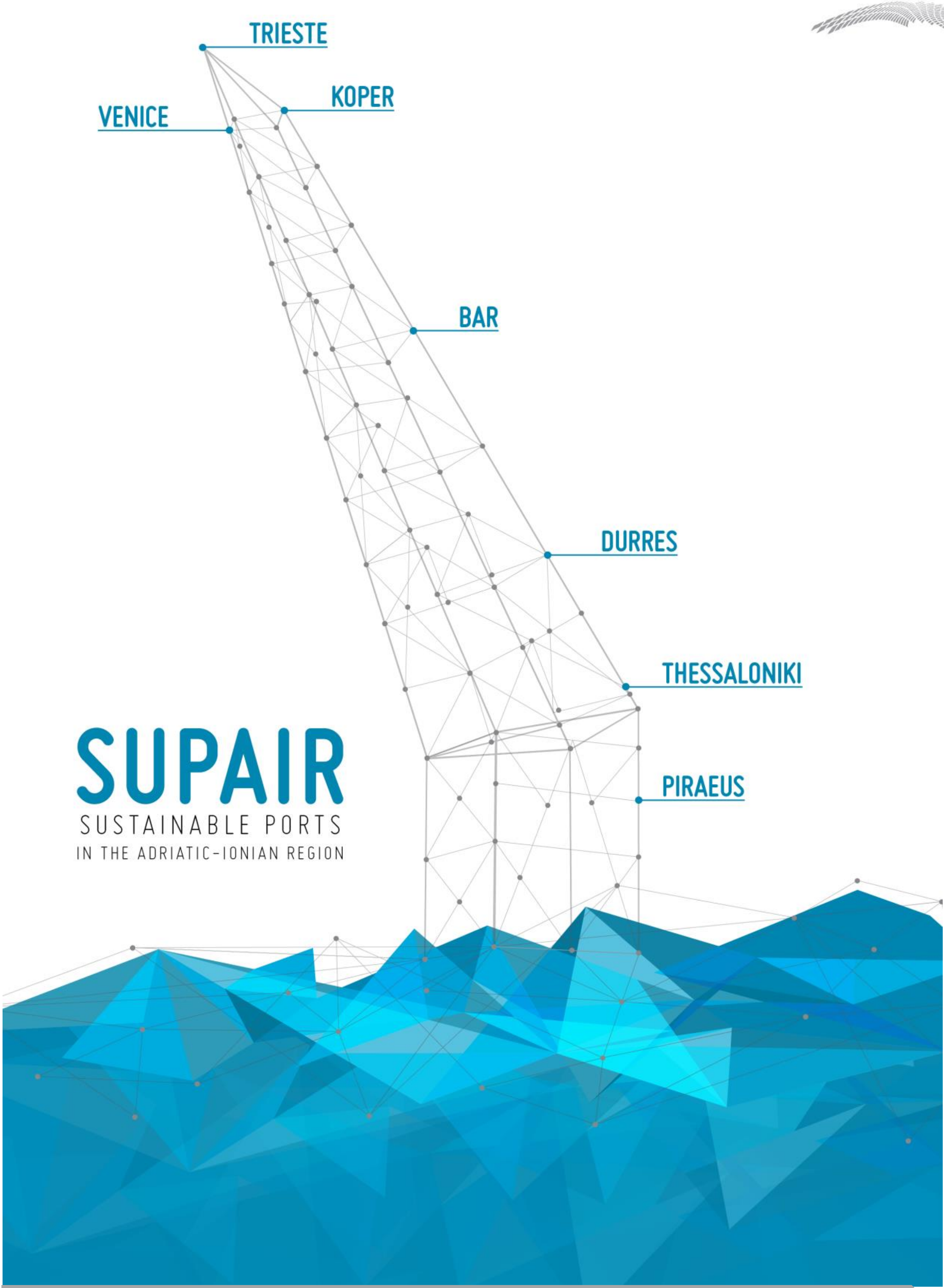

Action Plan for a Sustainable and Low carbon Port of Trieste

WPT1

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Within the SUPAIR project, the Port aims to develop an action plan addressing the most significant reduction in energy consumption of Ro-Ro vessels focusing on the main energy consumption items of the port authority and on the deployment of an onshore power supply system (OPS) to be implemented on the port's berths.

Partner responsible for the deliverable: Port Network Authority of the Eastern Adriatic Sea, Port of Trieste

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1. Definition of "sustainable port as a key element of wider low carbon strategies"

Following the general definition of a sustainable port agreed between SUPAIR project partners, in this section the Port of Trieste will provide highlights on key aspects pertaining to the specificities of its maritime industry domain. Indeed, an effective port environmental management system requires the identification of environmental components of concern in each port, based on its legal liabilities and responsibilities, governance profile, geography and operations framework, to determine what can be managed from the sustainability perspective. This section will then be a useful premise to ensure a deep understanding of the concepts discussed in the present report and connected with the Port' strategies to achieve the goal and targets set out in the national, EU, and international applicable rules.

To this end, among the most significant characteristics of the Port in terms of environmental protection policies and activities, it is important to highlight three main aspects, highly correlated with one another. These aspects represent the most important priorities where the Port is now concentrating its efforts and investments recognizing them as key driving factors addressing the Port sustainability in the long term perspective:

- proximity to the city center and urban areas (directly connected with the Port main objectives in developing the Plan focusing on emissions reduction, investigating several intervention on the main consumption items of the port authority, like buildings, public lighting, electric mobility, and infrastructural optimization, like OPS deployment, which is recognized as one of the best solutions in ports located close to urban areas, ensuring both air quality and reduce noise);

- leading position at national level in terms of rail based multimodal transport framework (directly connected to the enhancement of sustainable cargo flows towards the hinterland, ensuring relevant advantages e.g. CO_2 reduction-based bonuses);

- existing IT advanced managerial instruments harnessing new technologies and resource efficiency able to strengthen the holistic and integrated approach of the Port addressing the optimization of the entire supply chains (directly connected to the Port PCS -Port Community System – Sinfomar, and to the existing well-established links with a wide range of relevant stakeholders at local, regional, national, EU and international levels).

2. Understanding current port operations and management models

2.1 General overview of the Port

Main characteristics. Located in the heart of Europe, at the intersection between shipping routes and the Baltic-Adriatic and Mediterranean TEN-T core network corridors, the Port of Trieste is an international hub for overland and sea trade with the dynamic market of Central and Eastern Europe.

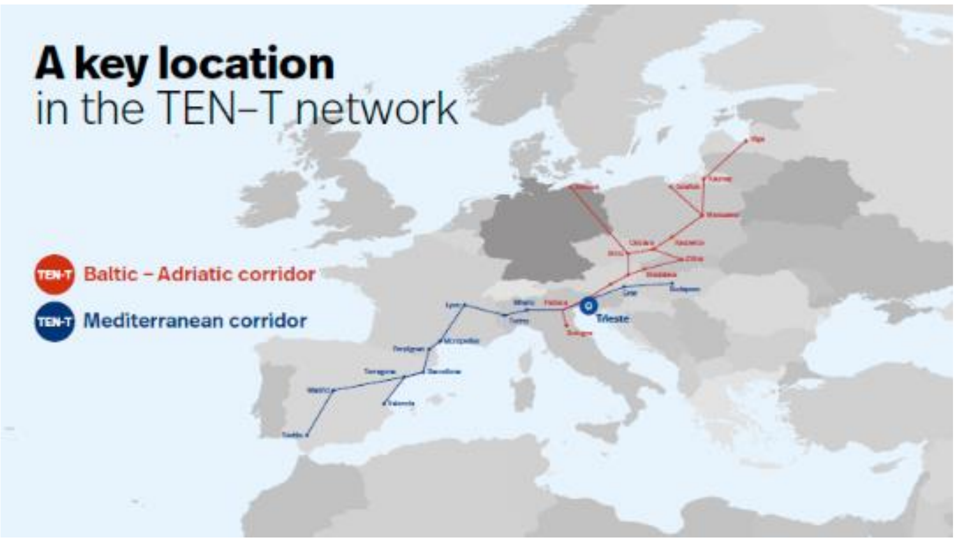


Fig. 1 - The Port of Trieste and TEN-T Corridors

The intensification of trade and maritime traffic between the Far East and Europe along with the EU enlargement process have revived the importance of the Upper Adriatic, opening up new growth and development opportunities for Trieste maritime industry. In this context, Trieste plays a decisive role in two separate supply chains: long-distance intercontinental maritime transportation and short/medium-distance intra-Mediterranean trade. The convergence of the TEN-T strategic axes of the “East Mediterranean Motorways of the Sea” with the “Baltic-Adriatic and Mediterranean Corridors” is resulting in the growth of port multimodal services and the development of innovative solutions in the field of rail-based intermodal transport nodes and operations.

The Port of Trieste in numbers

Port areas: about 2.3 million m2 of which about 1.8 million of free zones

Storage areas: about 925,000 m2 of which about 500,000 under cover

Length of docks: 12 km

Number of berths: 58 (for break bulks, multi-purpose vessels, container ships, Ro-Ro ferries, oil tankers, chemical tankers, passenger ships)

Maximum depth: 18 meters

Length of rail track: 70 km

Fig. 2 - The Port in numbers

With regard to the medium and long-term development and sustainable strategies, the Port of Trieste, as a key node of the EU's TEN-T, has the ultimate objective to fully integrate its maritime industry into the local, regional, EU and global multimodal logistics service network.

In light of this objective, and having regard to the current exceptional port traffic positive growing trend, the Port is focusing on the enhancement of its multimodal related infrastructures and management procedures. The ultimate objective of this effort is the full integration with the Port regional inland node terminals, using to the maximum extent existing inland facilities and designing innovative IT based solutions able to ensure additional advantage in terms of port efficiency and sustainability.

	2015	2016	2017	2018	Δ % 2015/2017	Δ % 2016/2017	Δ % 2017/2018
TOTAL THROUGHPUT [t]	57,132,878	59,244,255	61,947,454	**62,676,502**	8.46%	4.58%	**1.18%**
Liquid Bulk	41,286,761	42,756,341	43,750,555	**43,234,735**	5.97%	2.33%	**-1.18%**
Dry Bulk	1,607,232	1,971,001	1,639,595	**1,665,508**	2.01%	-16.81%	**1.58%**
General Cargo	14,238,885	14,516,913	16,557,304	**17,776,259**	16.40%	14.11%	**7.36%**
Number of vehicles [n]	301,494	302,619	314,705	**309,424**	4.43%	3.99%	**-1.68%**
Number of containers (n. TEUs)	501,222	486,462	616,153	**725,426**	22.95%	26.66%	**17.73%**
Total TEUs (n. CTNRs, vehicles)	1,165,431	1,158,329	1,314,950	**1,416,104**	12.87%	13.52%	**7.69%**

Total trains (Industrial Port/New Free Port)	2,980	7,631	8,682	**9,732**	156.07%	13.77%	**12.09%**

Table 1 - Port of Trieste - total throughput 2015-2018

2.2 Integrated Multimodal Connection Framework. The European Union's vision for an integrated multimodal freight transport network is a key element of its plans to transition to a modern and low-carbon economy. Enhancing rail freight's market share is a central pillar of this strategy[1].

Indeed, multimodality and optimized connections to the inland terminals concept can help improve logistics solutions, increase throughput by reducing the port areas/terminal yard occupancy ratio, reduce road problem on congestion in the area around the port, help move modes of transport to become more environmentally friendly[2].

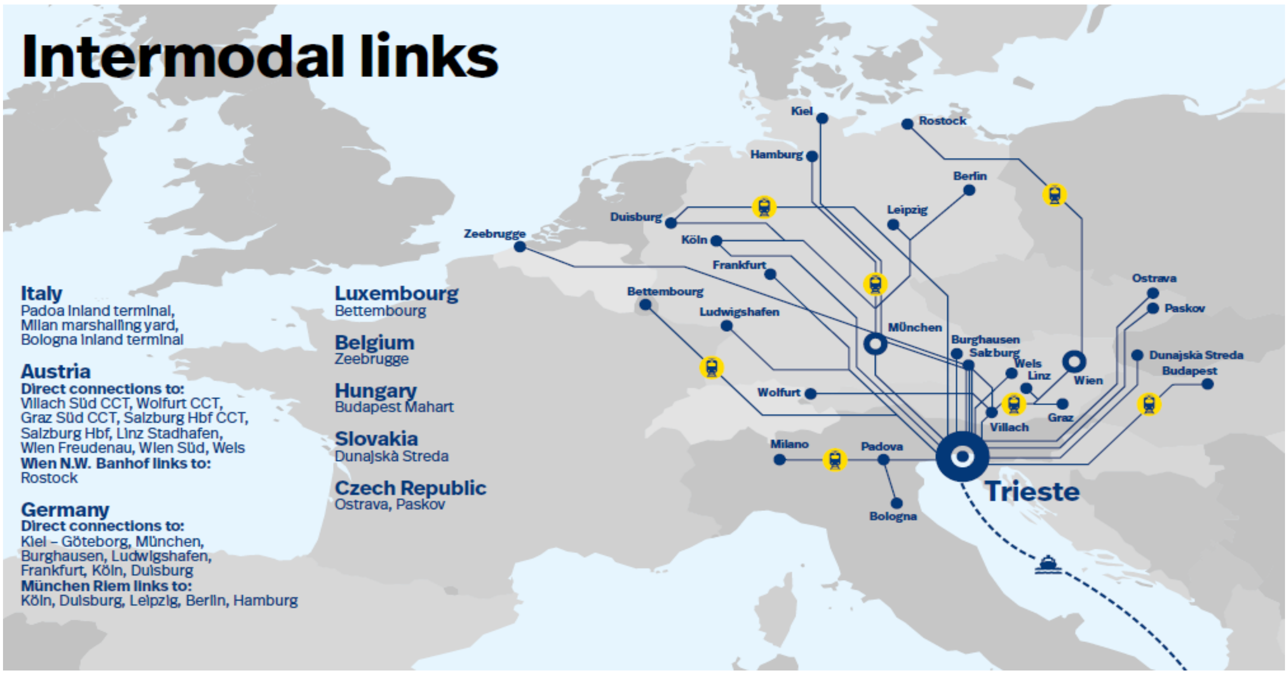


Fig.3- Port of Trieste - intermodal connections

In this respect, the Port of Trieste has a relevant advantage due to its excellent multimodal connections to major mainland centers of consumption and production including local, regional and EU inland logistics systems and multimodal links.

Moreover, the Port owes its leading position as the first Italian port for intermodal connections, with more than 200 trains a week connecting Trieste port to the Italian North-East industrial sites, Belgium, Luxembourg, Germany, Austria, Hungary, Slovakia and Czech Republic, with a total numbers of 9,732 trains in 2018. Thus, the railway connections represent one of the fastest growing freight transport segment and the most important priority sector of the Port of Trieste maritime industry. Indeed, the intermodal sector is one of the most significant competitive asset

1 EC, Logistics and multimodal transport, 2018 - https://ec.europa.eu/transport/themes/logistics_multimodal_es

EC, Logistics and multimodal transport, 2018 - Year of Multimodality https://ec.europa.eu/transport/themes/logistics-and-multimodal-transport/2018-year-multimodality_en

2 EC report, Making the Transport of Goods More sustainable, Delivering on the European Strategy for low-emission mobility, 2017 - https://ec.europa.eu/transport/sites/transport/files/2017-11-08-mobility-package-two/combined_transport_clean_mob.pdf

to further enhance the Port potentialities in expanding its catchment area while, at the same time, contributing to limiting port operations negative impacts on the environment and reducing congestion in the urban roads.

Figure 4 depicts the hinterland and the geographical configuration of the Port within the Friuli Venezia Giulia Region. The Region boasts the presence of several multimodal logistic nodes - as defined in Article 3 (r) of the TEN-T Guidelines – i.e. four railroad terminals (RRTs) and three ports representing a significant infrastructural endowment for a region with a total population of 1.2 million.

In particular, the Port of Trieste contribute to 92% of the total maritime traffic generated within the Region. Here below data related to 2018.

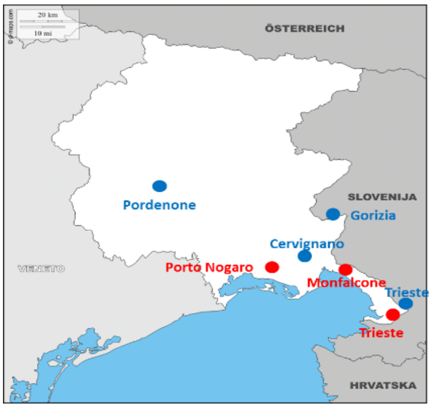


Fig. 4 - Port of Trieste - intermodal connections

PORT	TOTAL THROUGHPUT IN TONS (2018)	%	VAR % 2017/2018
Trieste	62,676,502	91.5	1.18
Monfalcone	4,537,278	6.6	-2.07
Porto Nogaro	1,343,600	1.9	12.41
TOTAL	68.557.380	100	1.43

Table 2- Ports of Friuli Venezia Giulia - total throughput 2018

Having regard to the technical specifications of the intermodal framework, the Port of Trieste has an internal rail network (70 km of tracks) that connects with the national and international network.

The existing framework allows all the docks to be served by rail with the possibility of shunting and/or assembling freight trains directly in the various terminals; a direct junction and a flyover (within the Port) connect to the outside road system, which leads directly to the motorway network, ensuring ease of access to the national road network.

	2015	2016	2017	**2018**	Δ % 2015/2017	Δ % 2016/2017	**Δ % 2017/2018**
Total trains (Industrial Port/New Free Port)	2,980	7,631	8,682	**9,732**	+156.07%	+13.77%	**+12.09%**

Table 3 - Port of Trieste - number of trains 2015-2018

2.3 Main terminal operators and intermodal connections framework. The main Port terminals of reference in terms of intermodal connections, where the Port is concentrating its investment priorities, are located in the New Free Zone area connected to the Campo Marzio railway station:

- Ro-Ro Terminal, Pier V, Samer Seaports & Terminals S.r.l.;
- Ro-Ro Terminal, Pier VI, Europe Multipurpose Terminal (EMT);
- Container Terminal, Pier VII, Trieste Marine Terminal (TMT).

These three private operators have independent movement of trains and they are all equipped with modern technology for handling, transportation and storage at the service of all types of traffic: Ro-Ro, Ro-La, containerized cargo, fruit and vegetables (potatoes, onions, oranges, and nuts), coffee, grains, metals, engines, steel and chemical products, timber, dry and liquid bulk, crude oil and derivative products. A detailed description of these terminal operators is provided within the following sections describing the TMT container terminal the two Ro-Ro terminal (Samer and EMT).

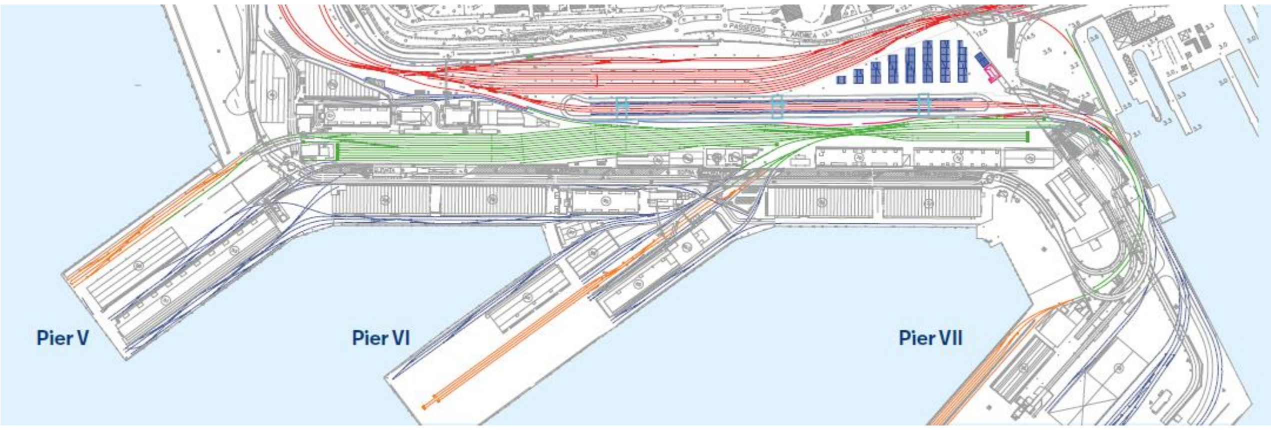


Fig.5 - Map of the Port railway station at Trieste Campo Marzio

General overview Ro-Ro Terminal – Pier V. The terminal can host three vessels simultaneously with a 12 meters natural draft and a storage area of 150,000 m^2. Operations are carried out 365 days a year with no interruption, including customs formalities enabling a movement of over 200,000 heavy units per year to be managed seamlessly.

A section of this terminal is devoted to rail operations, with regular services to strategic destinations in central Europe and the target enabling efficient movement of cargo to/from the terminal by train, with a significant reduction of carbon dioxide emissions and the consequent lower carbon footprint.

Railway traffic origin/destination 2015 - 2018			
Pier V			
2015	2016	2017	2018
Wels	Wels	Wels	Lambach
Krefeld	Krefeld	Bettembourg	Wels
Fernetti	Salzburg	Krefeld	Krefeld-Uerdingen
Duisburg	Bettembourg	Ludwigshafen	Ludwigshafen
	Novara	München	München
			Bettembourg

Table 4 - Port of Trieste - Rail destinations 2015-2018 - Pier V

Europe Multipurpose Terminal (EMT) - Pier VI. Pier VI is located in the center of the Port of Trieste with a total area of 70,000 m^2, 1,500 meters berths, one Ro-Ro berth, draft between 9 and 10 meters, four rail tracks and one 5,000 m^2 warehouse. It is equipped with four reach stackers with piggy-back, 10 tug-master Ro-Ro tractors and over 20 forks lifts.

The main connection involved in the service line of Ro-Ro services leave from Pier VI of Trieste heading to Istanbul.

Railway traffic origin/destination 2015 - 2018			
Pier VI			
2015	2016	2017	2018
Ludwigshafen	Köln	Wels	Wels
Ostrava	Ludwigshafen	Bettembourg	Zeebrugge
Köln	Ostrava	Krefeld	Ostrava
	München	Ludwigshafen	Köln
	Novara	München	Karlsruhe
	Bettembourg	Krefeld-Uerdingen	Kiel
		Zeebrugge	Ludwigshafen
		Ostrava	München
		Köln	
		Karlsruhe	
		Kiel	

Table 5- Port of Trieste - Rail destinations 2015-2018 - Pier VI

Container Terminal (Trieste Marine Terminal, TMT) - Pier VII. Pier VII is equipped with an internal Rail Park that guarantees trains loading and discharging during the vessels operations offering all the services of a modern Container terminal. The Rail Park consists of five rail tracks of 600 meters each served with three rail mounted stacking cranes able to operate up to five trains at the same time, ensuring the efficiency of the terminal rail connections.

Trieste Marine Terminal has a capacity of 11,500 trains per year granting a further opportunity to achieve a strong growth of the rail traffic volumes in the coming years.

Railway traffic origin/destination 2015 - 2018			
Pier VII			
2015	**2016**	**2017**	**2018**
Bologna	Villach	Budapest	Villach
Padova	Padova	München	Salzburg
Milano	Milano	Villach	Graz
Budapest	Budapest	Melzo	Paskov
München	Salzburg	Salzburg	Ostrava
	Melzo	Padova	Burghausen
	Dunajská Streda	Ostrava	Geingen
	München	Dunajská Streda	München
	Burghausen	Burghausen	Budapest
	Bologna	Bratislava	Cervignano del Friuli
	Ulm	Štúrovo	Milano
		Paskov	Melzo
			Novara
			Rubiera
			Sona
			Dunajská Streda

Table 6 - Port of Trieste - Rail destinations 2015-2018 - Pier VII

2.4 The Port operations management model

Management processes overview. This section is dedicated to the "soft" instruments adopted by the Port regarding the information provision, standards and IT technologies for optimizing the logistics administrative procedures and traffic flow. In the following scheme (fig.6) the logistics units flow is provided with a general overview of the cargo units that arrive and depart by ship, train and road.

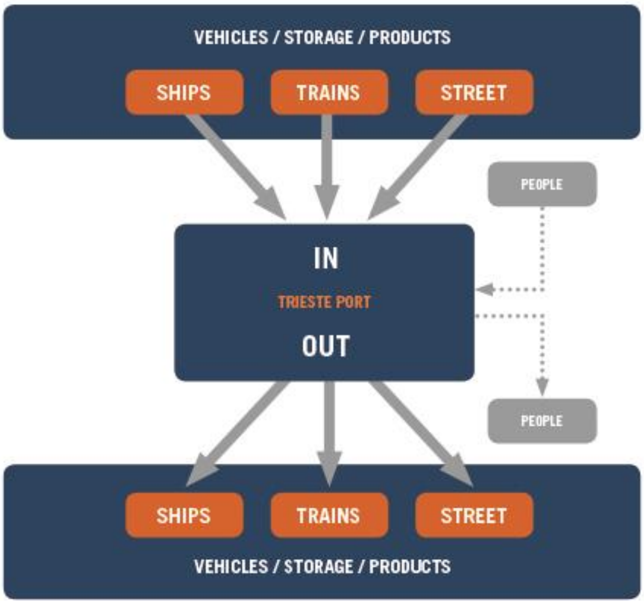


Fig. 6 - Cargo and logistics units flow

As widely recognized in relevant policies, technology and advanced IT management tools deployment form part of the necessary "holistic" energy efficiency concept for the whole transport system[3]. Accordingly, a number of international organizations (EU, OECD, IMO, and ESPO) and international ports have recommended the adoption of IT technologies as essential tools to optimize internal procedures, ensure stakeholder cooperation and communication activities[4]. As far as ports sustainability is concerned, apart from equipment procurement, infrastructure development and their upgrades, also efficient and standardized communications among port stakeholders, improved and faster processes, streamlined and coordinated activities, reduced administrative and procedural inefficiencies are important factors to determine port environmental performance.

In this direction, PCSs are widely recognized as essential IT tools to contribute to ensure a sustainable transport logistics framework and support the ambitions to meet global carbon reduction requirements[5].

3 Council conclusions on the digitalization of transport adopted by the Council at on 5 December 2017, http://data.consilium.europa.eu/doc/document/ST-15431-2017-INIT/en/pdf

4 Third IMO Greenhouse Gas Study 2014 https://gmn.imo.org/wp-content/uploads/2017/05/GHG3-Executive-Summary-and-Report_web.pdf

IPCSA, Port Community Systems – Tools for Trade Facilitation, 2015 - https://www.unece.org/fileadmin/DAM/trade/workshop/2015_SingleWingow_Shanghai/S04_01-RichardMorton.pdf

5 ESPO, THE INFRASTRUCTURE INVESTMENT NEEDS AND FINANCING CHALLENGE OF EUROPEAN PORTS, 2018 - https://www.espo.be/media/Port%20Investment%20Study%202018_FINAL_1.pdf

ESPO ENVIRONMENTAL REPORT 2018 EcoPortsinSights, 2018, https://www.espo.be/media/ESPO%20Environmental%20Report%202018.pdf

PCS Sinfomar System Features and Components. In light of the above, the Port Network Authority recognizes the development of ICT and digitization as a crucial mean to face the challenges associated to enabling optimization of the port management system and to facilitate the full integration of port' multimodal nodes and services.

Since its launch in 2014, Sinfomar has been constantly adapted and developed from the four original modules to arrive to the current 11-module configuration. From a technological standpoint, Sinfomar acts as trusted interface being an open platform that enables the intelligent and secure exchange of information between public and private stakeholders. Its interoperability with platforms operated by other organizations within the port community allows the electronic exchange of information, facilitating administrative and procedural requirements through easy access and sharing of data acting as a "National Single Maritime Window" in accordance with the EU legal and policy framework[6].

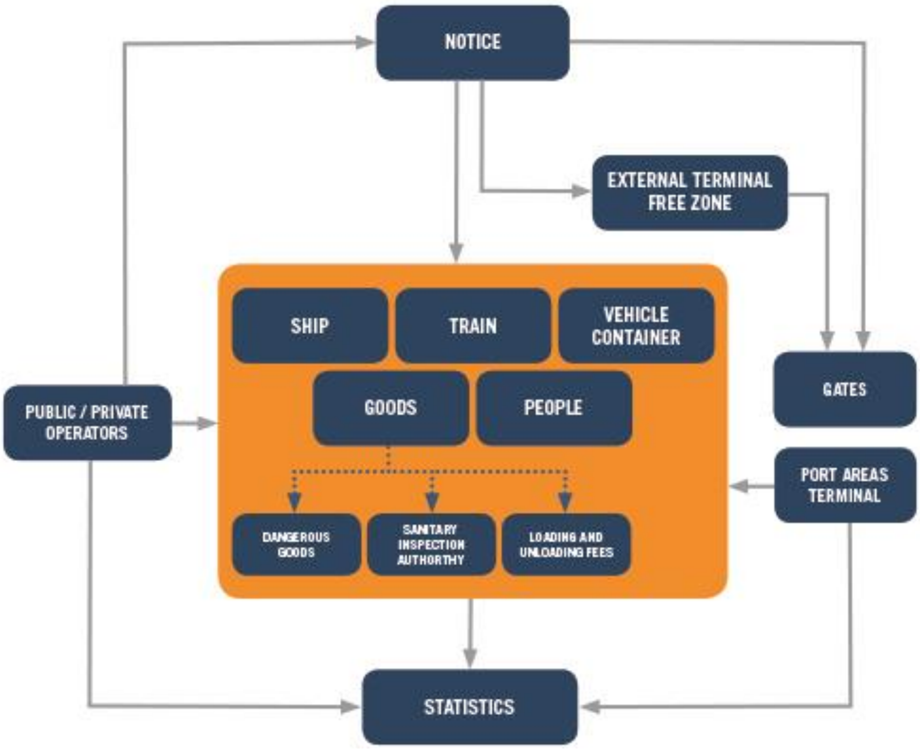


Fig. 7- Sinfomar Software Architecture

Private operators (e.g. maritime agents, freight forwarders etc.) enter the data related to their operations in real time, which are then validated and approved by competent public authorities (i.e. Customs Agency and Financial Police). The same data are collected and made available through Sinfomar for statistical and analytical purposes.

6 Directive 2010/65/EU of the European Parliament and of the Council of 20 October 2010 on reporting formalities for ships arriving in and/or departing from ports of the Member States and repealing Directive 2002/6/EC - https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX:32010L0065

The 'Sinfomar' Architecture - 11 main operating modules:

1.Pre-Arrival-Departure Notification Module
2. Ship Module
3. Cargo Module
4. Vehicle Module
5. Trains Module
6. Statistics/Analysis Module
7. People Module
8. Maritime Heath Authority Module
9. Dangerous Goods Module
10. Taxes on Loading and Unloading Procedures Module
11. External Free Zone Terminal-Area Module.

Fig. 8 – Sinfomar Operating Modules

All the Sinfomar modules are integrated with the maritime fees sub-module, which elaborates the official ship-related data also communicated to AIDA, the IT platform of the Italian Customs Agency, including modified or updated data related to the formal declarations whether they are canceled, corrected or added.

More in detail, having regard to the Goods Module, it allows to streamline the process linked to the execution of administrative procedures in regard to each phase of goods handling and a significant saving for operators in terms of time and "paper based reporting" to be presented to the Customs Agency with significant advantages for all parties. In particular, while the Custom Agency is relieved from the complex task of administrative checks regarding the calculation of the fees to be charged to individual operators, the private actors are facilitated in the preparation of customs formalities and in providing the certification of payments.

Other relevant module has been developed to rail traffic management. The train's module is responsible for managing trains arriving or departing from the Port of Trieste and is fully integrated with the other modules involved in rail traffic. On January 1st, 2018, a further step was taken towards the full dematerialization of control and authorization operations for the railway traffic, equalizing the movement of trains to that of ships and standardizing the customs, logistical and security management through the automatic generation of arrival and departure notice documents.

Considering the general architecture, the software is constantly under development in order to guarantee the full adaptation of its functionalities/features to the dynamics of constant change related to the global international maritime transport domain as well as its capability to elaborate the increasing volumes of data associated with the Port of Trieste traffic growth rates.

A relevant example of the efforts for continuous improvements derives following the recent changes in the national legislation concerning the port sector and the regulations on free zone status applicable to the areas of the Port, bringing to the further improvement in the PCS functionalities. These innovations are mainly connected with the introduction of a module for the integrated management of freight traffic from and to inland infrastructures such as Trieste RRT.

The time factor. Focusing on Custom formalities procedures and Sinfomar. To improve port environmentally sustainable performance and competitiveness, it is necessary to have a better understanding of the various components of cargo delays and problem of traffic congestions inside as well as outside the port areas to effectively address the underlying causes. Indeed, the waiting times significantly harm transit traffic and international trade regulatory procedures. This perspective of analysis is tightly connected with the fact that the global maritime industry and its operators face a wide range of administrative and legal formalities requirements each time a ship arrives at or leaves a port[7].

In this perspective, the Customs plays a critical role. The World Customs Organization, with the active involvement of Customs experts and trade partners from around the world, has been striving to achieve the balance between trade facilitation and compliance with statutory requirements[8].

As illustrated in the previous section describing the functionalities of the PCS Sinfomar, the Port of Trieste, in synergy with the policies promoted by the competent international organizations and the European Union, is already investing its efforts to identify IT solutions that can help reduce time necessary for the release of goods. In particular, the effort in this direction is related to the *single window* concept enhancement supporting further the overall system interoperability. This ambition seeks the improvement in terms of transactional efficiency, reduce costs and enhance reliability, ensuring advancement of customs formalities automation that can support faster cargo clearance and reduce dwell time.

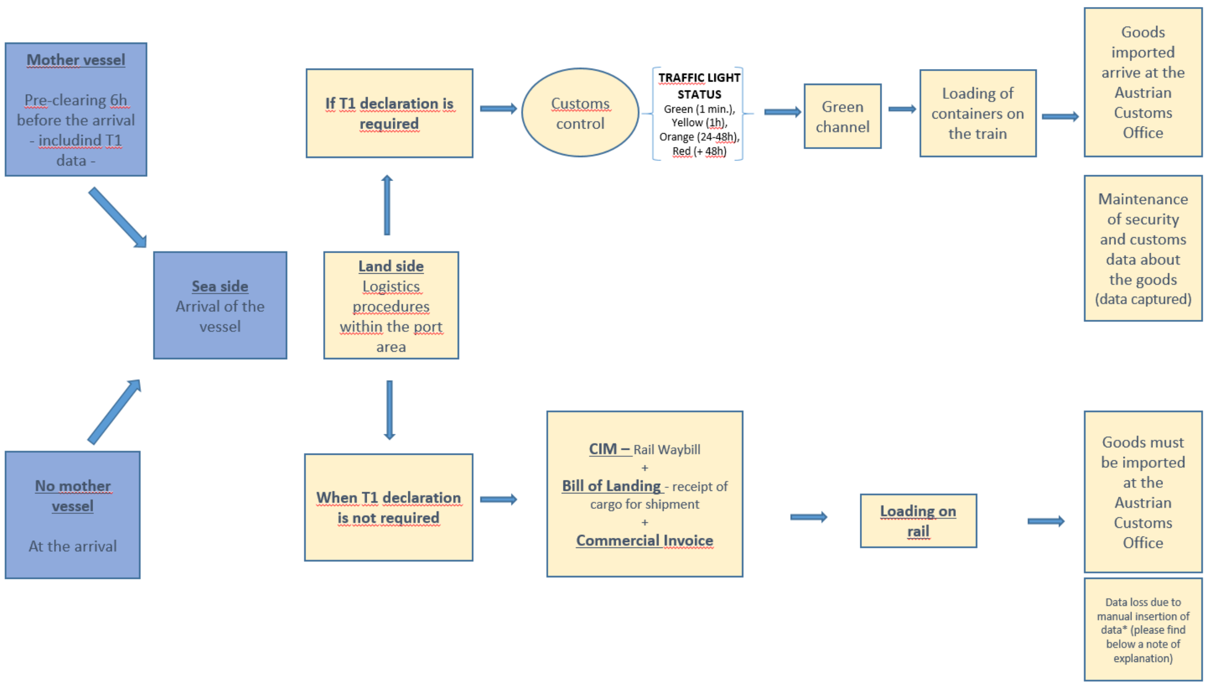


Fig.9 – Customs procedures diagram

7 Regulation of the European Parliament and the Council, "Establishing a European Maritime Single Window environment and repealing Directive 2010/65/EU", 17/05/2018
https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=COM:2018:0278:FIN
World Customs Organization, SMART Customs: The Gateway to High Performance and Sustainability, 2018 -
http://www.wcoomd.org/en/media/newsroom/2018/march/successful-9th-session-of-the-capacity-building-committee.aspx
8 World Customs Organization, Guidelines on Application of Information and Communication Technologies, 2017
http://www.wcoomd.org/-/media/wco/public/global/pdf/topics/facilitation/instruments-and-tools/tools/ict-guidelines/ict-guidelines.pdf?db=web

Terms of reference - Customs procedures diagram	
Acronyms and definitions	**Specifications**
Bill of Landing	The Bill of Landing is a document issued by the shipping company to the operating shipper, which acknowledge that the goods have been received on board. In this way the Bill of Landing serves as proof of receipt of goods by carrier obliging him to deliver the goods to the consignee. It contains the details of goods, the vessel and the port of destination. It evidences the contract of carriage and conveys title to the goods, meaning that the bearer of the Bill of Landing is the owner of the goods.
CIM - Rail Waybill	The rail waybill – CIM is a documentation of goods by rail. It is regulated by the Convention concerning International Carriage by Rail 1980 (COTIF-CIM). The CIM is issued by the carrier in five copies, the original accompanies the goods, the duplicate of the original is kept by the consignor and the three remaining copies by the carrier for internal purposes. It is considered the rail transport contract.
Commercial invoice	The commercial invoice is a record or evidence of the transaction between the exporter and the importer. Once the goods are available, the exporter issues a commercial invoice to the importer in order to charge him for the goods. The commercial invoice contains the information on the transaction and it is always required for customs clearance.
Mother vessel	Mother vessels have the capacity to carry thousands of containers and calls only a main port without intermediate stop on her route.
T1	Transit document referred to non-EU goods transported from one location in the EU to another location in the EU. The T1 declaration is used to transport goods from the customs office at the place of departure to the customs office at the destination without paying customs duties and taxes within the territories of the countries included in the transit agreement.
Traffic light status	Data validation signal of the Customs Authorities to indicate the status of the formalities and procedures for movements of goods.

Table 7 – Terms of reference on Customs procedures diagram

2.5 Energy consumption and energy performance indicators

State of the art analysis – statistical data. The objective of this section tackles the first step to be taken as to reduce the impact of energy consumption, i.e. the calculation of the demand for electricity by the port – port energy audit. To this end, it is important to highlight the fact that today methods for calculation of CO_2 vary in each Member State. Indeed, the need to establish a harmonized energy data and calculation CO_2 emission is one of the priorities of EU energy policies[9].

Therefore, the analysis provided within the next paragraphs summarizes the main energy needs originated by the different port activities, and where the gathered data makes it possible, the breakdown of energy consumption is related to the different final use or user.

The analysis below tries to distinguish for each final use three different levels, depending on the user:

- **Direct consumption**: it refers to the consumption of the Port Authority (AdSPMAO) for its buildings, car fleet, lighting, etc.
- **1st level indirect consumption**: it refers to the consumption accounted for the port services, namely attributable to PTS (Trieste Port Services S.p.A.), Adriafer (Adriafer S.r.l.), TTP (Trieste Passenger Terminal S.r.l) and buildings owned by AdSPMAO but used and managed by other port service entities.
- **2nd level indirect consumption**: this level accounts for the consumption caused by all private companies and commercial terminal operators.

2.5.1 Electricity

The tables shown below concern the electric consumption occurring in the port highlighting the most energy-intensive processes on the basis of the method suggested by the Italian Institute for Environmental Protection and Research in 2018[10].

The Port power grid is in Medium Voltage underground and there are approximately 30 transformer substations that provide to distribute low voltage electricity to port users and naval units.

The table below summarizes electric energy consumption in 2016-2018 related to the buildings managed by the Port and to the lighting of common areas.

As can be observed, the highest consumption (and the major increase in comparison to 2016) is due to external lighting (1,551,238 kWh); far beyond is the main building, the so called Torre del Lloyd with a minor increase since 2016 (468,978 kWh). Overall, consumption related to the Port corresponds to a total of 2,525,547 kWh electric (2018).

The increased consumption for lighting purposes depends partly to the enhancement of the existing network, both with the realization of new illuminated areas and the increase of the light level.

9 REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on the monitoring, reporting and verification of carbon dioxide emissions from maritime transport and amending Regulation (EU) No 525/2013

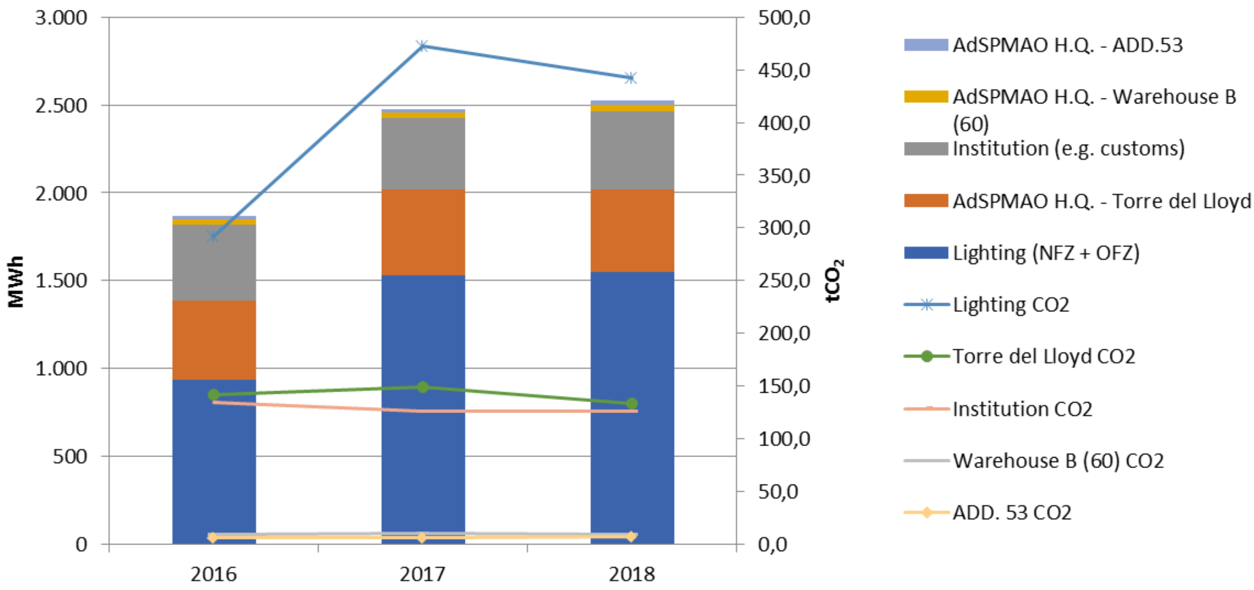
https://ec.europa.eu/clima/sites/clima/files/transport/shipping/docs/com_2013_480_en.pdf

10 Rapporto ISPRA 303/2019 "Fattori di emissione atmosferica di CO2 e altri gas a effetto serra nel settore elettrico",

http://www.isprambiente.gov.it/files2019/pubblicazioni/rapporti/R_303_19_gas_serra_settore_elettrico.pdf

Direct Electricity Consumption	Electric Energy Consumption			Primary Energy Consumption			Emissions		
	2016	2017	2018	2016	2017	2018	2016	2017	2018
	kWh	kWh	kWh	TOE	TOE	TOE	tCO_2	tCO_2	tCO_2
Lighting (NFZ + OFZ)	933.201	1.532.172	1.551.238	174,5	286,5	290,1	292,2	472,1	441,8
AdSPMAO H.Q. - Torre del Lloyd	453.405	485.057	468.978	84,8	90,7	87,7	142,0	149,4	133,6
Institution (e.g. customs)	428.873	408.069	444.731	80,2	76,3	83,2	134,3	125,7	126,7
AdSPMAO H.Q. - Warehouse B (60)	31.196	32.530	34.141	5,8	6,1	6,4	9,8	10,0	9,7
AdSPMAO H.Q. - ADD.53	19.566	19.746	25.915	3,7	3,7	4,8	6,1	6,1	7,4
Other AdSPMAO buildings			544	3,7	0,0	0,1	0,0	0,0	0,2
Total	1.866.241	2.477.573	2.525.547	349	463	472	584	763	719

Table 8 – Electric Energy consumption of AdSPMAO, directly utilized (in period 2016-18)

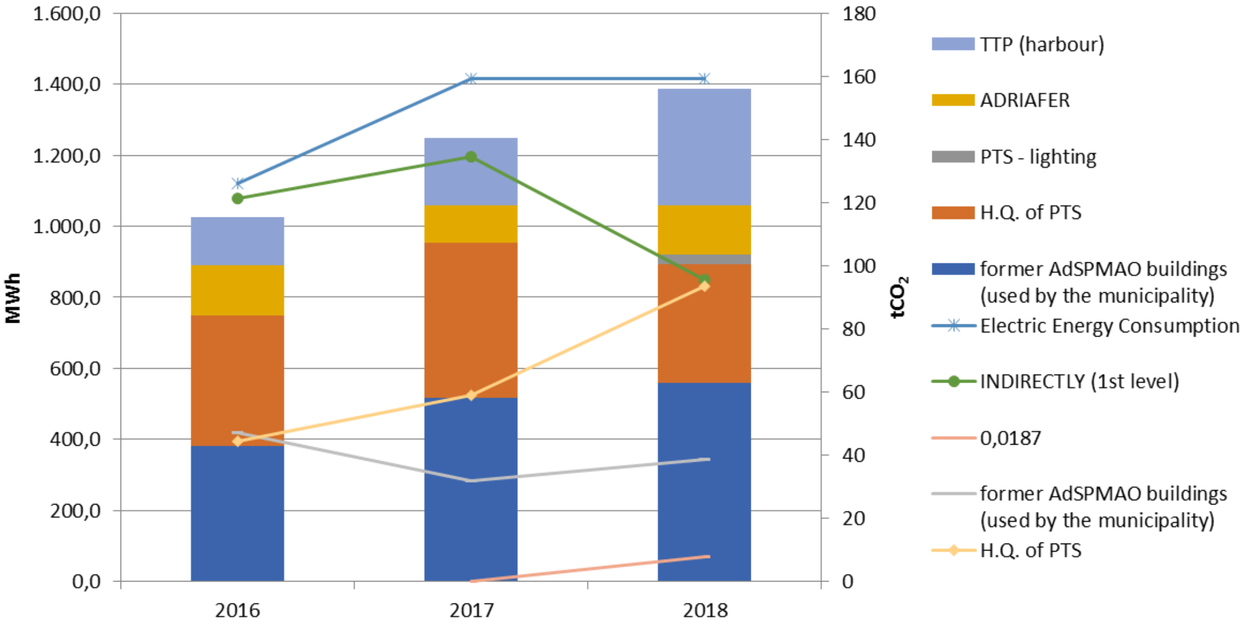


Graph. 1, Electric Energy consumption and CO2 emissions of AdSPMAO, directly utilized (in period 2016-18)

The calculation of CO_2 emissions, reported in the Table 8, is based on the emissions factors defined by the Italian Institute for Environmental Protection and Research quoted before. For 2018 the indicated emission factor is not yet definitive, whilst it is for 2016 and 2017.Electric energy consumption of the buildings and services made by companies under the direct management of the Port (1st level indirect consumption) corresponds to 1,100,749 kWh in 2018 (Table 9).

Electric Energy Consumption INDIRECTLY (1st level)	Electric Energy Consumption			Primary Energy Consumption			Emissions		
	2016	2017	2018	2016	2017	2018	2016	2017	2018
	kWh	kWh	kWh	TOE	TOE	TOE	tCO_2	tCO_2	tCO_2
H.Q. of PTS and other buildings	748.970	954.264	335.161	140,1	178,4	62,7	234,5	294,0	95,5
PTS - Ormeggio 57			166.710			31,2			47,5
Offices of PTS (add. 53+ex csd)	18.683	18.240	106.899	3,5	3,4	20,0	5,8	5,6	30,4
PTS - lighting			27.456		0,0	5,1		0,0	7,8
ADRIAFER	142.074	103.814	135.648	26,6	19,4	25,4	44,5	32,0	38,6
TTP (harbour)	134.296	191.296	328.875	25,1	35,8	61,5	42,0	58,9	93,7
Total	1.044.022	1.267.614	1.100.749	195	237	206	327	391	313

Table 9 – Electric Energy consumption of AdSPMAO, indirectly utilized (2016-18)



Graph. 2, Electric Energy consumption and CO2 emissions indirectly utilized (in period 2016-18)

In the overall port area, including the main mooring - New Free Zone and Old Free Zone – but also TTP (Maritime Station), Timber terminal, Oil terminal and the AdSPMAO buildings outside the port area, electricity consumption was recorded for about 8,550,000 kWh (Table 10). For 2018 the data collection has been realized with a deeper detail as for the previous years, trying to reach a more complete consumption framework. As for the reported data, the consumption of AdSPMAO and the 1st indirect level is approximately 43 % of the total consumption, and the remaining 57 % is related to the concessionaires and the terminal operators.

Data related to existing indirect consumption (2nd level) are note complete, as the activities managed by concessionaires have not yet been systematically gathered so far. A new system for the collection of these data is actually under development, therefore it will be possible in the next future to have a broader comprehension of the energy related activities. The complete information about the landside consumption will enable the Port Authority to develop environmental policies among the private port operators. The red cells in the tables below are meant as a placeholder for the next steps.

There is also an electricity generation from renewables, namely PV, in the port area. The PV plant has a peak power of 8,622 kWp, and a yearly production between 8,500 and 9,400 MWh. The plant is located in the New Free Port area, on the roofs of 14 warehouses owned by the Authority, but the PV plant is owned by a private company. Although it has no direct influence on the energy consumption of the port operators, and on their energy costs, nevertheless the full generated energy amount is consumed in the port area, with an emission reduction due to the missing production of this energy quantity to the national grid.

	2016	2017	2018
Total RES electricity MWh	*8.680*	*8.800*	*9.262*
Total RES electricity tCO_2	*2.718*	*2.711*	*2.638*

Table 10 – PV- Generation [MWh] and related CO2 emissions avoided in the Port Area (in 2016-18)

Electric Energy Consumption overview	Electric Energy Consumption							
	2017	2017	2018	2018	2018		2017	2018
	AdSPMAO (MV)	Concessionaires	AdSPMAO (direct)	Indirect 1st Level	Indirect 2nd Level		Total	Total
	kWh	*kWh*	*kWh*	*kWh*	*kWh*		*kWh*	*kWh*
Old Free Zone (OFZ)	1.189.801	1.110.899	563.504	17.538	1.698.261		2.300.700	2.279.303
New Free Zone (NFZ)	2.263.955	2.640.036	1.401.525	639.230	2.869.931		4.903.991	4.910.686
TTP (Maritime Station)	n.a.	n.a.	2.138	328.875	360.269		n.a.	691.282
Scalo Legnami	n.a.	n.a.	31.404	13.256	n.a.		n.a.	44.660
Oil terminal	n.a.	n.a.	43.031	3.978	n.a.		n.a.	47.009
Extra harbour	485.057	n.a.	483.945	97.872	39		485.057	581.856
Total Port Area	3.938.813	3.750.935	2.525.547	1.100.749	4.928.500		7.689.748	8.554.796

Table 11 – Electric Energy consumption [kWh] of the Port Area (in 2017-18)

Electric Energy Consumption overview	Primary Energy Consumption							
	2017	2017	2018	2018	2018		2017	2018
	AdSPMAO (MV)	Concessionaires	AdSPMAO (direct)	Indirect 1st Level	Indirect 2nd Level		Total	Total
	TOE	*TOE*	*TOE*	*TOE*	*TOE*		*TOE*	*TOE*
Old Free Zone (OFZ)	222,5	207,7	105,4	3,3	317,6		430	426
New Free Zone (NFZ)	423,4	493,7	262,1	119,5	536,7		917	918
TTP (Maritime Station)	n.a.	n.a.	0,4	61,5	67,4		n.a.	129
Scalo Legnami	n.a.	n.a.	5,9	2,5	n.a.		n.a.	8
Oil terminal	n.a.	n.a.	8,0	0,7	n.a.		n.a.	9
Extra harbour	90,7	n.a.	90,5	18,3	0,007		91	109
Total Port Area	737	701	472	206	922		1.438	1.600

Table 12 – Electric Primary Energy consumption [toe] of the Port Area (in 2017-18)

Electric Energy Consumption overview	Emissions							
	2017	2017	2018	2018	2018		2017	2018
	AdSPMAO (MV)	Concessionaires	AdSPMAO (direct)	Indirect 1st Level	Indirect 2nd Level		Total	Total
	tCO_2	*tCO_2*	*tCO_2*	*tCO_2*	*tCO_2*		*tCO_2*	*tCO_2*
Old Free Zone (OFZ)	366,6	342,3	160,5	5,0	483,7		709	649
New Free Zone (NFZ)	697,5	813,4	399,2	182,1	817,4		1.511	1.399
TTP (Maritime Station)	n.a.	n.a.	0,6	93,7	102,6		n.a.	197
Scalo Legnami	n.a.	n.a.	8,9	3,8	n.a.		n.a.	13
Oil terminal	n.a.	n.a.	12,3	1,1	n.a.		n.a.	13
Extra harbour	149,4	n.a.	137,8	27,9	0,011		149,4	166
Total Port Area	1.214	1.156	719	313	1.404		2.369	2.436

Table 13 – CO_2 emissions from electric energy consumption [tCO_2] of the Port Area (in 2017-18)

With specific regard to the maritime transport, the following tables identify with the calculation of energy performance indicators specific energy consumption and emissions.

Description	AdSPMAO	INDIRECT 1st LEVEL	INDIRECT 2nd LEVEL	Total	*u.m.*
specific consumption per vessel	1.114,54	485,77	2.174,98	**3.775,29**	*(kWh/vessel)*
specific consumption per passenger	22,64	9,87	44,19	**76,70**	*(kWh/passenger)*
specific consumption per ton of wares	0,04	0,02	0,08	**0,14**	*(kWh/t)*
specific consumption per worker	1.426,06	621,54	2.782,89	**4.830,49**	*(kWh/worker)*
specific consumption per TEU	1,78	0,78	3,48	**6,04**	*(kWh/TEU)*

Table 14 – Performance Indicators – 2018

Description	AdSPMAO	INDIRECT 1st LEVEL	INDIRECT 2nd LEVEL	Total	u.m.
specific emission per vessel	317,42	138,35	619,43	**1.075,20**	*(kgCO2/ vessel)*
specific emission per passenger	6,45	2,81	12,58	**21,84**	*(kgCO2/passenger)*
specific emission per ton of wares	0,01	0,01	0,02	**0,04**	*(kgCO2/t)*
specific emission per worker	406,14	177,01	792,57	**1.375,72**	*(kgCO2/worker)*
specific emission per TEU	0,51	0,22	0,99	**1,72**	*(kgCO2/TEU)*

Table - 15 - Carbon Footprint – 2018

2.5.2 Space Heating

The AdSPMAO owns several buildings located in the port area or close to it. Some of them are used as warehouse or storage area, and therefore no heating is required, but few of them are used by the Authority itself, by PTS, Adriafer and TTP.

The main fuel used for the heating purpose is oil, only few buildings are connected to the natural gas city grid. This fact leads to an uncertainty, indeed limited but still existing, in the definition of the yearly consumption for each building, and to what is more important, to a major level of CO2 emissions.

At the other end, energy efficiency measures can be advantageously introduced, not only as refurbishment of envelope and plants, but also introducing a fuel switch, trying to cut off the large use of gas oil, preferring low carbon fuels or even electricity, with a major impact on the local emission level.

The main building is the headquarter of the AdSPMAO, and is located outside the port area, but close to it. It was built around 1850 and is under protection by the architectural heritage authority, making hard to realize a deep refurbishment of the building envelope.

Among the buildings listed in the table below, the ownership of the Corso Cavour building (located outside the port area) has been transferred to the municipality during 2019, and it will be no longer used by the Port Authority.

Buildings		Volume	2016	2017	2018	2016	2017	2018
space heating	fuel type	[m3]	[l or m3]	[l or m3]	[l or m3]	[kWh/m3]	[kWh/m3]	[kWh/m3]
direct								
AdSP MAO (Torre del Lloyd, Pal.60 e Pa	oil	26.096	46.000	71.500	68.500	17,46	27,13	26,00
VARCO 10 DOGANA - PFV	oil	2.400	13.300	7.800	1.500	54,88	32,19	6,19
DOGANA - PFN	oil	4.774	7.000	4.000	n.a.	14,52	8,30	n.a.
EDIFICIO EX CULP - PFN	oil	n.a.	57.000	60.000	63.000	n.a.	n.a.	n.a.
PAL. EX CSD - PFN	oil	3.150	9.500	11.000	9.500	29,87	34,58	29,87
PALAZZINA MOLO F.LLI BANDIERA - RI\	oil	n.a.	8.500	9.500	10.500	n.a.	n.a.	n.a.
STAZIONE PROSECCO GPL	lpg	n.a.	0	1.400	6.400	n.a.	n.a.	n.a.
PAL. CORSO CAVOUR	natural gas	10.635	9.140	12.207	7.420	8,24	11,01	6,69
SCALO LEGNAMI 12 (VARCO DOGANA)	natural gas	2.574	2.560	6.542	6.899	9,54	24,38	25,71
indirect								
PTS	oil	n.a.	2.815	2.750	n.a.	n.a.	n.a.	n.a.
Adriafer	oil	n.a.	7.100	7.300	n.a.	n.a.	n.a.	n.a.
TTP (Stazione Marittima)	oil	55.200	40.000	51.500	54.000	7,18	9,24	9,69
TTP (MOLO BERSAGLIERI)	natural gas	32.400	15.232	14.211	n.a.	4,51	4,21	n.a.

Table 16 – Space heating consumption 2016– 2018

Buildings	2016	2017	2018	2016	2017	2018	2016	2017	2018
space heating	[kWh]	[kWh]	[kWh]	[toe]	[toe]	[toe]	[tCO2]	[tCO2]	[tCO2]
direct									
AdSP MAO (Torre del Lloyd, Pal.60 e Pa	455.560	708.099	678.389	40	61	58,91	121,63	189,06	181,1299
VARCO 10 DOGANA - PFV	131.716	77.247	14.855	11	7	1,29	35,17	20,63	4
DOGANA - PFN	69.324	39.614	n.a.	6	3	n.a.	18,51	10,58	n.a.
EDIFICIO EX CULP - PFN	564.499	594.209	623.920	49	52	54,18	150,72	159	167
PAL. EX CSD - PFN	94.083	108.938	94.083	8	9	8,17	25,12	29,09	25
PALAZZINA MOLO F.LLI BANDIERA - RI	84.180	94.083	103.987	7	8	9,03	22,48	25	28
STAZIONE PROSECCO GPL	0	10.117	46.251	0	1	3,94	0,00	2	10
PAL. CORSO CAVOUR	87.680	117.102	71.180	8	10	6,20	17,71	23,65	14
SCALO LEGNAMI 12 (VARCO DOGANA)	24.558	62.758	66.182	2	5	5,77	4,96	12,68	13
indirect									
PTS	27.878	27.235	n.a.	2	2	n.a.	7,44	7	n.a.
Adriafer	70.315	72.295	n.a.	6	6	n.a.	18,77	19	n.a.
TTP (Stazione Marittima)	396.140	510.030	534.788	34	44	46,44	105,77	136,18	143
TTP (MOLO BERSAGLIERI)	146.121	136.326	n.a.	13	12	n.a.	29,52	28	n.a.
total									
total direct	**1511601,279**	**1812168,43**	**1698847,38**	**131,2992**	**157,404564**	**147,493084**	**396,3020473**	**471,7533997**	**442,814**
total indirect	640453,5523	745886,163	534788,372	55,660852	64,813396	46,44	161,503238	190,290386	***142,788***
total	2.152.055	2.558.055	2.233.636	187	222	193,93	557,81	662,04	585,6021

Table 17 – Space heating consumption and emissions 2016– 2018

Buildings	2016	2017	2018	2016	2017	2018
space heating	[kWh]	[kWh]	[kWh]	[tCO2]	[tCO2]	[tCO2]
direct+indirect						
Old free port	219.397	194.349	86.035	53	44	18,34
New Free port	826.099	842.292	718.003	221	225	191,71
Maritime Station (TTP)	626.440	740.439	638.775	158	189	170,55
Scalo Legnami	24.558	62.758	66.182	5	13	13,37
Oil Port						
extra harbour	455.560	718.217	724.640	122	191	191,63

Table 18 – Space heating consumption and emissions breakdown by zone 2016– 2018

2nd level indirect consumption has not been gathered so far: in the definition of the new data collection structure, the consumption for space heating in buildings used by private port operators and concessionaires not yet inserted in the list above will be added in the relevant zone.

Within this new structure, the possibility to insert georeferenced information could be a big improvement towards the construction of a monitoring tool, comprehending all warehouses and buildings.

2.5.3 Vehicles fleet

To the energy consumption is accounted fuels used for the transport of personnel within the port area but also outside it. The Authority fleet consists in 22 vehicles: two of them are EURO2 (one is used as shuttle service within the port area), the remaining 45 % are EURO4, 40 % EURO5 and 15 % EURO6.

PTS and Adriafer own or rent about 40 vehicles, but the most fuel used in the port is needed to feed the five diesel locomotives, handling the freight train within the port, representing about 82% of the oil used and 78% of the total fuel used (oil and gasoline).

A combined estimation matching fuel consumption, age of the vehicle and distance ridden so far by the vehicle, allows to state that the Authority fleet (without cars used by PTS) have a total of about 100.000 km driven in 2018. According to these assumptions, the average fuel consumption is by 6,88 l/100km.

In the table below, the consumption trend 2016-2018, showing the figures described before.

Car fleet	2016	2017	2018	2016	2017	2018
	[l]	[l]	[l]	[kWh]	[kWh]	[kWh]
direct						
oil	1.180	1.866	1.942	11.658	18.436	19.185
gasoline	1.609	3.128	5.040	14.419	28.032	45.167
indirect 1st level						
oil	245.114	310.894	284.826	2.421.669	3.071.560	2.814.015
gasoline	436	356	1.586	3.907	3.190	14.213
total						
oil	246.294	312.760	286.768	2.433.327	3.089.996	2.833.200
gasoline	2.045	3.484	6.626	18.327	31.222	59.380
total fuel	**248.339**	**316.244**	**293.394**	**2.451.654**	**3.121.218**	**2.892.580**

Table 19 – Vehicles fleet consumption in liter fuel and conversion in kWh2016– 2018

Car fleet	2016	2017	2018	2016	2017	2018
	[toe]	[toe]	[toe]	[CO2]	[CO2]	[CO2]
direct						
oil	10	16	16	3.113	4.922	5.122
gasoline	12	24	39	3.590	6.980	11.246
indirect 1st level						
oil	2.083	2.642	2.420	646.586	820.107	751.342
gasoline	3	3	12	973	794	3.539
total						
oil	2.093	2.657	2.437	649.698	825.029	756.464
gasoline	16	27	51	4.563	7.774	14.786
total fuel	**2.108**	**2.684**	**2.488**	**654.262**	**832.803**	**771.250**

Table 20 – Vehicles fleet consumption in toe and related emissions in tCO_2 2016– 2018

No breakdown by zone is provided, as the single vehicles consumption is not linked to a specific port area. There are no data on the 2nd level indirect fuel consumption, although it is existing. The collection of these data will be started with the improvement of the existing data bank structure.

2.5.5 Vessels

With regard to the shipping sector, based on relevant data collected at local level detailed within the above tables as well as in the supporting documentation and analysis conducted by AREA Science Park attached to the present Plan (see annex I), the purpose of the Port is to develop a comprehensive strategy on the reduction of emissions abiding by the Directive 94/2014/EU on the deployment of alternative fuels infrastructure and art. 4bis of the Italian D.Lgs. 169/2016 on the reform of the national port sector[11].

Average duration of a vessel's stay in port (per type)										
Period	01/01/2015 - 31/12/2016			01/01/2016 - 31/12/2017			01/01/2018 - 31/12/2018*			
Type of vessel	Transit time (hh:mm)	Waiting time (hh:mm)	Tot. n° of vessels	Transit time (hh:mm)	Waiting time (hh:mm)	Tot. n° of vessels	Transit time (from ATA to ATS)			Tot. n° of vessels
							gg	hh	mm	
FULL CONTAINER	26:10:00	01:17	1,237	28:02:00	01:29	1,.226	0	22	37	582
GENERAL CARGO	55:16:00	05:42	332	53:03:00	07:10	313	2	12	11	173
TANKER	57:03:00	22:34	1,081	52:58:00	24:02:00	1,142	1	15	22	507
RO-RO	18:36	02:53	1,494	17:58	04:07	1,573	0	19	49	834
PASSENGER SHIP	18:52	00:24	107	22:27	00:10	117	1	16	12	61
RO-PAX	06:46	00:02	271	07:43	00:15	176	0	8	40	35
BULK CARRIER	137:32:00	09:29	88	125:30:00	11:19	110	5	12	10	51
TUG	127:46:00	00:00	30	158:21:00	00:01	28	13	7	17	19
OTHER	47:30:00	04:12	59	67:49:00	00:23	44	2	13	15	4
Tot. n° of Vessels			4,699			4,729				2,266
*Please pay attention: data for 2018 are referred to one single year, data for 2015-2017 are calculated in a two-year period										

Table 21 - Duration of a vessel's stay in port (per type)

Moreover, the Port aims at addressing the most significant reduction in energy consumption of Ro-Ro vessels focusing the deployment of an onshore power supply (OPS) to be later implemented on the port's berths. Thus, this step envisages the replacement of on board-generated power systems from diesel auxiliary engines with electricity generated onshore, which involves the vessels that have the characteristic of having precise schedules and routes and suitable dimensions in order not to burden on the port electricity grid.

11 Directive 2014/94/EU of the European Parliament and of the Council of 22 October 2014 on the deployment of alternative fuels infrastructure, https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX%3A32014L0094
Legislative Decree 4 August 2016, n.169, Riorganizzazione, razionalizzazione, semplificazione della disciplina concernente le Autorità portuali, http://www.mit.gov.it/sites/default/files/media/notizia/2016-09/Testo%20Decreto%20riorganizzazione%20porti%2031_8_16.pdf

2.6 Overview of the global scenario, main regulatory framework and Port vision. The main regulatory framework of reference in developing the present Port action plan derived from the EU Directive 2014/94/EU12 and from the art. 4bis of the Italian D.Lgs. 169/2016 on the reform of the national Port sector currently under preparation13. Having regard to the addressed needs and the global scenario of reference, the maritime transport emits around 1000 million tonnes of CO2 annually and is responsible for about 2.5% of global greenhouse gas emissions. Shipping emissions are predicted to increase between 50% and 250% by 2050. In 2016 the IMO in its MEPC 70 meeting reached an agreement on a global data collection system as the next step in their action to tackle CO2 emissions. As set out in IMO third study, aligned with the EU regulatory framework, developed countries should reduce their emissions by 80 to 95% by 2050 compared to 1990. In the medium term, the EU has committed to reduce its greenhouse gas emissions by 20% below 1990 levels by 2020, and by 30% if conditions are right. In the view of contributing to the EU 2020 Strategy, the 2011 Commission White Paper on Transport states that EU CO2 emissions from maritime transport should be reduced by 40% (if feasible 50%) from 2005 levels by 2050[14].

In order to effectively achieve these objectives, a number of studies promoted by the EC recommended that ports and / or national authorities consider introducing service charges or other financial incentives that reward port service providers based on their environmental performance. As more detailed in the next section, in the specific case of OPS, EC reports highlight that this could be addressed either by a tax reduction on electricity or by incentives taxes on maritime shipping fuels15 . Indeed, as reported in the following paragraphs, some Member States have already used this possibility to promote OPS. While this practice is worth being further investigated in each Member States framework, it is clear that it has enormous potential to improve significant environmental aspects in the port area, as well as the quality of life of the people living nearby[16].

The Port of Trieste has already adopted a "green procurement" initiative in order to introduce criteria aimed at reducing environmental impacts in the purchasing policies of goods and services both by own and by terminal operators and operators of the port. This topic is of specific importance for the Port of Trieste and its attention towards the environment is translated in the certification ISO 14001, whereby all port-related activities under the competence of the Port Network Authority need to adhere to the principles of environmental sustainability. Moreover, the Port Authority Decree n.1493/2016 establishes an incentive scheme to support operators inside the Port areas who invest in less energy-intensive equipment and / or renewable energy sources and environmental certification, in force from 1st January 2017[17]According to the international stakeholder lessons learned, as reported by one of the most relevant player in this scenario, the Port of Rotterdam, the valuable contribution of OPS, and at the same time the challenge of it, is the fact that two parties are involved, the ship and the shore facility.

12 Directive 2014/94/EU of the European Parliament and of the Council of 22 October 2014 on the deployment of alternative fuels infrastructure, https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX%3A32014L0094

13 Legislative Decree 4 August 2016, n.169, Riorganizzazione, razionalizzazione, semplificazione della disciplina concernente le Autorità portuali, http://www.mit.gov.it/sites/default/files/media/notizia/2016-09/Testo%20Decreto%20riorganizzazione%20porti%2031_8_16.pdf

14 IMO, Third IMO Greenhouse Gas Study 2014, https://gmn.imo.org/wp-content/uploads/2017/05/GHG3-Executive-Summary-and-Report_web.pdf
WHITE PAPER Roadmap to a Single European Transport Area – Towards a competitive and resource efficient transport system, https://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX:52011DC0144

15 EC, Shore side electricity: key policy recommendations for uptake, http://ec.europa.eu/environment/integration/research/newsalert/pdf/shore_side_electricity_key_policy_recommendations_for_uptake_431na1_en.pdf

16 EC, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions - Strategic goals and recommendations for the EU's maritime transport policy until 2018, https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=CELEX:52009DC0008:EN:HTML

17 Port Authority Decree n.1493/2016, art.8, http://www.porto.trieste.it/wp-content/uploads/2017/05/Decreto-n-1493-2016-con-regolamento.pdf

On one hand it is expensive for a port to invest in it, on the other hand it is necessary to have enough vessels with OPS connections to have a viable business case. In addition to these challenging aspects, ship owners will only invest in such a connection when there are enough ports offering OPS[18].

From the experience of another relevant port, the Port of Amsterdam, next to the high investment costs and the difference in vessel type and call frequencies, is highly connected to the incentives scheme. In particular, the fact that the OPS deployment requires an expensive frequency converter, as well as the tax on energy, but not on fuel cause problems.

To address this issue Denmark has successfully asked the European Commission for exemption as the Commission considers OPS an innovative technology[19].

The Spanish experience can also be relevant in selecting solid benchmarking. Indeed, in the Spanish context ship owners and port authorities can negotiate an agreement that entitles to rebates, provided that the agreement fulfils certain conditions defined at the central level by a State agency[20].

In light of the above and matching the outcomes of the Port focus group discussion, all these aspects are synthetized in the following table dedicated to the SWOT analysis and will be further discussed in the next section dedicated to the preliminary evaluation framework.

2.7 SWOT Analysis

SWOT	Negative	Positive
Internal	• High costs for the deployment of OPS infrastructures	• The benefit of OPS to society will be highest - Average time of stay of Ro-Ro vessels can be adequately covered impacting positively • Ro-Ro traffic has been progressively growing in the last years and represent the most relevant segment of Trieste maritime traffic
External	• Market immaturity as most of the fleets must be properly adapted - built • No common technical specifications and national legislation for the Italian ports energy plan and interface of ship to infrastructure	• Reduced emissions in terms reducing air pollution from ships and noise • Evolution of regulation and availability of technology - further impulse to the development of demand for OPS

Table 22 – SWOT Analysis

18 World Maritime News, In Depth: Onshore Power Supply, https://worldmaritimenews.com/archives/162146/onshore-power-supply/
https://www.portofrotterdam.com/en/our-port/our-themes/a-sustainable-port/sustainability

19 COMMISSION RECOMMENDATION of 8 May 2006 on the promotion of shore-side electricity for use by ships at berth in Community ports (Text with EEA relevance), https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2006:125:0038:0042:EN:PDF
https://ec.europa.eu/transport/sites/transport/files/2017-06-differentiated-port-infrastructure-charges-report.pdf https://ec.europa.eu/info/law/better-regulation/feedback/2141/attachment/090166e5b3d1e000_en

20 Port of Barcelona, CLEANPORT CEF Project, http://www.portdebarcelona.cat/en/web/el-port/cleanport

3. Stakeholder consultation

STAKEHOLDER CATEGORY (i.e Privates: Shipper; Logistics operator; Forwarders; Carrier (road/rail/shipping); Terminal operator i.e. Public: Regional authority, Transport agency, etc.)	RELEVANT STAKEHOLDERS (Name of the Organization)	INVOLVED IN THE FOCUS GROUP (Yes or not)	Contribution of the Sustainable and Low-carbon Port	
			NEEDS (list 2/3 of the main relevant needs)	INVOLVEMENT IMPACT (Involvement: indicate if easy, medium, difficult Impact on the sector: indicate if small, medium, large)
Local authority	Municipality of Trieste	**Yes**	- Enhanced coordination for improving the city's overall sustainability	Involvement: easy Impact: large
Regional authority	ARPA FVG	**Yes**	- Complete support and alignment of ARPA FVG to the mission of SUPAIR	Involvement: easy Impact: large
National authority	Harbour Master	**Yes**	- Complete support and alignment of HB to the mission of SUPAIR - Need to think in a long-term perspective	Involvement: easy Impact: large
Logistic operator	Association of terminal operators	**Yes**	- Check the maturity and demand of OPS vs. other technologies (LNG) - Potential risk of moving the pollution for power generation if insufficient use of renewables	Involvement: easy Impact: large
Logistic operator	Freight forwarders Association	**Yes**	- On OPS, need to involve also ship owners	Involvement: easy Impact: large

Table 23 – Main results of the Port Stakeholders Consultation

3.1 Short summary of the meeting. The purpose of the meeting focused on the importance of a collaborative framework in order to ensure the Port growth combined with environmental sustainability. In this perspective, as synthetized in the above table, the stakeholders discussed the general concept of the SUPAIR project regarding the partnership, activities and specific objectives identified, analysing all these concepts toward the design of the Port of Trieste action plan.

A great deal of attention has been devoted to the current regulatory framework of reference, discussing the recent document of Assoporti – the Association of Italian Ports - titled 'Green Ports' as essential document able to illustrate the current most relevant issues and specific legal aspects about challenges and opportunities towards a more efficient and sustainable ports in the national context[21].

21 ASSOPORTI, I Porti Verdi – Stato dell'arte, parametri di riferimento e prospettive, http://www.assoporti.it/media/1335/porti-verdi.pdf

In particular, Trieste stakeholders discussed key aspects regarding the expected publication of the "Port energy plan", as envisaged by art. 4 bis of Legislative Decree 169/2016[22], and on the main EU legal obligations related to ports environmental practices in towards the benefits and challenges related to potential deployment of liquefied natural gas and shore-side electricity infrastructures (Directive 2014/94/EU)[23].

Positive findings:

- Evolution of regulation and technology readiness to further support the development of effective low-carbon solutions for maritime transport;
- Existing stable cooperation among all public and private stakeholders and reciprocal supportive dialogue;
- Shared common interest and objectives among stakeholders;
- Relevant previous and on-going experiences from other EU projects > key lessons learnt to be re-used.

Challenges:

- Still on-going preparation of the national guidelines for the development of the Port Energy Plan;
- Need to integrate incentives and disincentives in national policies, including regulatory, economic and fiscal measures;
- Lack of national dedicated funding scheme.

Outcomes:

Key stakeholders are interested in innovative technologies, are considering their involvement, but high investments happen to be slower without incentives.

The discussion about actions inserted in a wider planning framework within the port but also within the strategic policies of municipality and region ease the understanding and is the first step toward the implementation of energy efficiency measures, at different levels.

22 DECRETO LEGISLATIVO 4 agosto 2016, n. 169 - Riorganizzazione, razionalizzazione e semplificazione della disciplina concernente le Autorita' portuali di cui alla legge 28 gennaio 1994, n. 84, http://www.gazzettaufficiale.it/eli/id/2016/08/31/16G00182/sg

23 Directive 2014/94/EU of the European Parliament and of the Council of 22 October 2014 on the deployment of alternative fuels infrastructure, https://eur-lex.europa.eu/legal-content/en/TXT/?uri=CELEX%3A32014L0094

4. Evaluation framework

4.1 Preliminary evaluation framework of costs and benefits of OPS. As emerged in reporting the evaluation of the Port of Rotterdam experience and international studies regarding the OPS deployment, an effective evaluation scheme can be achieved only after the identification of a specific user in order to collect the necessary energy consumption and specification data[24]. In light of these considerations, and following the provided Guidelines structure, the present preliminary evaluation will represent a general framework of reference to highlight the most important evaluation issues reported by EU and international stakeholders. This step is necessary to evaluate the best practices and lessons learnt from other relevant ports to then assess, in the "Action Plan Solution Design" section, a detailed framework based on the analysis of the selected users' requirements, reporting the specific outcomes and the evaluation on the correspondent data collection.

Therefore, based on the lesson learnt from the benchmarking step, the present section consists in a preliminary identification of the evaluation framework, considering two main aspects of reference:

- Costs and the role of incentives, to assess the business feasibility evaluation approach taking into account the effects of possible incentivises for ship owners to use OPS while at berth – on the basis of the EC studies and evaluation on the deployment of onshore power[25]
- Environmental benefits – a preliminary evaluation assessment taking into account potential emissions reduction estimated at EU TENT-T ports level - based on a tool developed by the World Ports Climate Initiative (WPCI)[26].

4.2 A potential evaluation framework of costs for implementation, incentives and environmental benefits. The investigation promoted by the EC and a report of WPCI providing estimated data have been selected with the perspective to further assess, with the same bases, the Port final evaluation structure. More specifically, the analysis of reference in the selected studies can be of valuable contribution on the data and lessons learnt reported by Eurostat considering the TEN-T core ports and relating calculation on costs and benefits of OPS[27].

Since OPS requires an investment both on the side of the port and the shipping company, the considered scenario on cost effectiveness is evaluated for the integral OPS deployment project, and not for individual parties. Subsequently, the main scope is to understand whether and how environmental charging can be used as a leverage by ports to convince shipping lines to invest in OPS.

Significantly, in line with the vessels type selected by the Port and discussed above, the WPCI's analysis focused on the business case for OPS which is more attractive for ships that have a high

24 Onshore power supply Case study – Port of Helsinki, 2015 - http://www.bpoports.com/OPS_Seminar/Rantio.pdf

Case Study Onshore Power Supply Facility at the Cruise Terminal Altona in Hamburg, 2014- http://archive.northsearegion.eu/files/repository/20150309115942_TEN-TaNS_CaseStudy_OnshorePowerSupplyFacilityinHamburg.pdf

Case study Onshore power supply at the Port of Gothenburg, 2014, http://www.ops.wpci.nl/_images/_downloads/_original/1370345459_a9rc82a.pdf

Electrification of harbours – Project report, Icelandic New Energy, 2017 - https://orkustofnun.is/gogn/IslenskNyOrka/Electrification-of-harbours-2017.pdf

25 COMMISSION RECOMMENDATION of 8 May 2006 on the promotion of shore-side electricity for use by ships at berth in Community ports (Text with EEA relevance), https://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=OJ:L:2006:125:0038:0042:EN:PDF

26EC Studies, Study on differentiated port infrastructure charges to promote environmentally friendly maritime transport activities and sustainable transportation, Final Report, 2017, https://ec.europa.eu/transport/sites/transport/files/2017-06-differentiated-port-infrastructure-charges-report.pdf

27 OPS calculation tool, http://wpci.iaphworldports.org/onshore-power-supply/implementation/ops-calculation-tool.html

electricity demand per berthing. Thus, the business case is concentrated on a RoRo vessel with a characteristic of a 25.000-GT that requires a 1,5 MVA connection.

In the selected study, as estimation bases, it was assumed that a RoRo vessel calls a port 30 times a year and spends an average time of 24 hours at berth per call. Considering an interest rate at 6% and a depreciation period of 10 years, the total yearly costs can be broken down as follows.

Investment costs terminal:

1. High voltage connection from grid (including transformer): € 200.000
2. Cable installation: € 225.000
3. Total investment: € 425.000
4. Maintenance, contract and electricity transport costs (15%): € 63.750
5. **Total yearly investment costs for terminal: € 121.494**

Investment costs ship:

1. Transformer: € 200.000
2. Main switchboard control panel: € 100.000
3. Cabling: € 3.000
4. Cable reel system: € 152.000
5. Total investment: € 455.000
6. **Total yearly investment costs for ship: € 61.820**

In the first phase of the study, the following estimation emerged taking in consideration a port offering rebates up to 50% of total port dues to vessels that use OPS rather than auxiliary engines at berth.

Average considering the TEN-T core ports of the EU (2017)							
Comparison between OPS payback periods with and without incentives from a 50% rebate on port dues for a ship that calls 30 ports a year							
Year	Annual investment costs	Operating costs OPS	Savings from saved maintenance	Rebates from green charging	Saving from fuel	Payback	Payback without rebates
0	€ 455.000	€ 60.480	€ 3.456	€ 80.400	€ 29.272	€ 402.352	€ 482.752
1		€ 120.960	€ 6.912	€ 160.800	€ 58.544	€ 349.704	€ 510.504
2		€ 181.440	€ 10.368	€ 241.200	€ 87.816	€ 297.056	€ 538.256
3		€ 241.920	€ 13.824	€ 321.600	€ 117.088	€ 244.408	€ 566.008
4		€ 302.400	€ 17.280	€ 402.000	€ 146.360	€ 191.760	€ 593.760
5		€ 362.880	€ 20.736	€ 482.400	€ 175.632	€ 139.112	€ 621.512
6		€ 423.360	€ 24.192	€ 562.800	€ 204.904	€ 86.464	€ 649.264
7		€ 483.840	€ 27.648	€ 643.200	€ 234.176	€ 33.816	€ 677.016
8		€ 544.320	€ 31.104	€ 723.600	€ 263.448	-€ 18.832	€ 704.768
9		€ 604.800	€ 34.560	€ 804.000	€ 292.720	-€ 71.480	€ 732.520

Table 24 - Comparison between OPS payback periods with and without incentives from a 50% rebate on port dues for a ship that calls 30 ports a year – source EC study on WPCI tool - 2017

However, considering that port dues are the main source of revenue for ports and the related interest in not exceeding their economic sustainability, the following analysis was developed considering a 30% rebate to RoRo vessels that use OPS.

For the ship owner, the resulting incentives would change the situation as follows:

Average considering the TEN-T core ports of the EU (2017) Comparison between OPS payback periods with and without incentives from a 30% rebate on port dues for a ship that calls 30 ports a year							
Year	Annual investment costs	Operating costs OPS	Savings from saved maintenance	Rebates from green charging	Saving from fuel	Payback	Payback without rebates
0	€ 455.000	€ 60.480	€ 3.456	€ 48.240	€ 29.272	€ 434.512	€ 482.752
1		€ 120.960	€ 6.912	€ 96.480	€ 58.544	€ 414.024	€ 510.504
2		€ 181.440	€ 10.368	€ 144.720	€ 87.816	€ 393.536	€ 538.256
3		€ 241.920	€ 13.824	€ 192.960	€ 117.088	€ 373.048	€ 566.008
4		€ 302.400	€ 17.280	€ 241.200	€ 146.360	€ 352.560	€ 593.760
5		€ 362.880	€ 20.736	€ 289.440	€ 175.632	€ 332.072	€ 621.512
6		€ 423.360	€ 24.192	€ 337.680	€ 204.904	€ 311.584	€ 649.264
7		€ 483.840	€ 27.648	€ 385.920	€ 234.176	€ 291.096	€ 677.016
8		€ 544.320	€ 31.104	€ 434.160	€ 263.448	€ 270.608	€ 704.768
9		€ 604.800	€ 34.560	€ 482.400	€ 292.720	€ 250.120	€ 732.520
10		€ 665.280	€ 38.016	€ 530.640	€ 321.992	€ 225.368	€ 305.272

Table 25 - Comparison between OPS payback periods with and without incentives from a 30% rebate on port dues for a ship that calls 30 ports a year - source EC study on WPCI tool - 2017

A rebate of 30% is estimated to result in € 48.240 saved by the ship owner every year. In other words, the rebate is tantamount to lowering the operating costs of OPS to the point of making it less expensive than generating electricity through auxiliary engines.

The total cost for the port would correspond to € 121.494 on yearly basis (425.000 € in tot), while is undoubtable that it corresponds to a significant investment, since the use of OPS significantly cuts emissions in the port area, the encouraging projection on the economic benefits from cleaner air in the port and its environment contribute to the growing interests towards its deployment.

In this respect, the study estimates the following emission cut per year for ten RoRo vessels that use OPS in a EU port:

Pollutants - GHG	Tons emitted with OPS	Tones emitted with Diesel
CO_2	2.016,00	4.055,04
NOx	2,02	86,17
PM	0,02	2,66
SO_2	2,65	6,34

Table 26 - Comparison between emissions generated at berth with and without OPS – source EC study on WPCI tool – 2017

The preliminary evaluation scheme of reference presented above with the estimation of costs for implementation, as well as the quantity of the level of pollutants potentially saved, may vary to a great extent in the further analysis to be developed on the following steps of the analysis. Nonetheless, these examples represent important preliminary evaluation framework and relevant references that can give a rough estimate of the benefits from the adoption of OPS solution in the Port of Trieste.

Taking in consideration the economic feasibility of OPS estimated emissions at TEN-T core ports and the related comparison provided above, with the aim to define a broader and more holistic approach to the evaluation framework, which considers the impact of the key topics discussed during the previous sections, the following table is provided to summarize the relevant indicators for the Port of Trieste.

Assessment of OPS solution sustainability issues	**Indicator**
CO_2	Calculate estimated on the amount of CO_2 - Comparison between emissions generated at berth with and without OPS
NOx	Calculate estimated on the amount of NOx - Comparison between emissions generated at berth with and without OPS
PM	Calculate estimated on the amount of PM - Comparison between emissions generated at berth with and without OPS
SO_2	Calculate estimated on the amount of SO_2 - Comparison between emissions generated at berth with and without OPS
Holistic evaluation of sustainability	**Indicator**
Improve energy efficiency in Port's buildings	Amount of building's energy consumption
Port intermodal connections	Improvement of intermodal links - Modal shift %
IT management system improvement	Number of existing module and/or new modules/functionalities dedicated to optimize traffic flow
Time performance for Customs	Time needed to finalize Customs procedures

Table 27 – OPS and Holistic Evaluation of Sustainability Issues Indicators

5. Action plan solutions design

5.1. Concept document and emissions inventory

On the bases of the data provided within the energy consumption data in chapter 2, there are a number of possibilities to introduce energy efficiency measures at different levels, continuing the path already traced by Port Authority towards sustainability and empowering the involvement of the stakeholder.

Some interventions are only responsibility of the Port Authority, and they can be integrated in the operative plan, according to the strategic priorities individuated by the Authority itself.

The development of a larger plan needs a larger involvement of the stakeholder not only for the definition of port-wide strategic priorities but also for the completion of the port energy balance. Relevant stakeholder is anyone who might contribute, has an interest in or is affected by a more efficient way to use energy resources.

The standard indicators link the energy consumption to the amount of carried freights or TEUs handled. For a more complete comparison in the following steps of the monitoring plan, indicators are provided in relationship to six factors:

- Tons of total throughput [t]
- N. of vessels calls in the port
- N. of passengers carried
- Nr. of TEUs handled
- Nr. of vehicles loaded or unloaded
- Nr. of workers in the whole area

The specific data in the years of the analysis (2016-2018) are listed in the following table:

	2016	2017	2018
total throughput [t]	59,244,255	61,947,454	62.676.502
vessels	2.394	2.339	2.266
pax	199.372	133.329	111.539
TEU	1.158.329	1.314.950	1.416.104
vehicles	302.619	314.705	306.424
authority workers	150	212	257
port companies	1.341	1.474	1.514
port workers	1.491	1.686	1.771

Table 28 – Quantitative figures for the definition of KPIs in the years 2016-2018

The three main consumption categories (Electricity, Space heating, Fuel), articulated in the three level of responsibility of the Port Authority (Direct, indirect 1st level, indirect 2nd level) are here reported. After each table the KPIs are calculated both for the energy performance and the emission level. Table 29 and 30 summarize all consumptions and calculate the KPIs on the overall consumption. In the electricity consumption a new column is added for 2018 (named '2018 new') where the final energy consumptions are recalculated according to the real use of the buildings, while the 2018 column respects the same distribution as the years before also if a change in the building use has occurred. Moreover, the "2018 new" column collects additional indirect energy consumption 2nd level, not considered in the previous years.

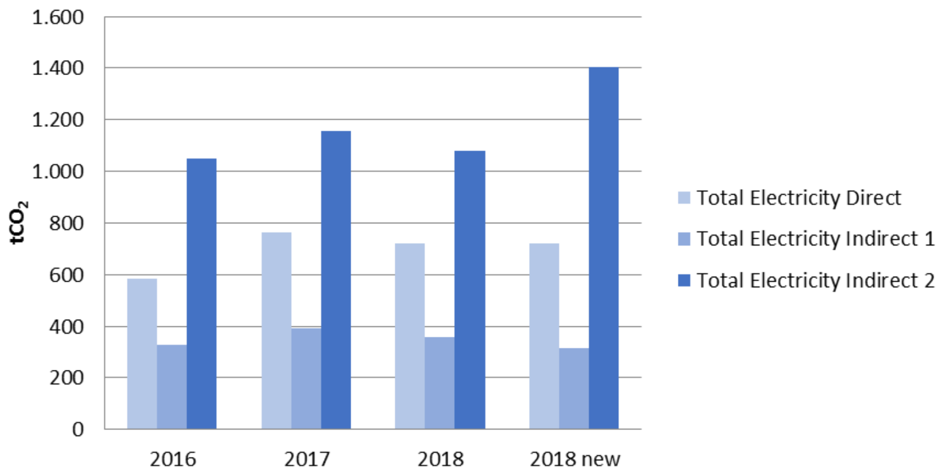
In order to have a reference here below the summary of direct and indirect consumption items, the related CO2 emissions and the KPIs.

		2016	2017	2018	2018 new	
electricity	Total Electricity Direct	1.866.241	2.477.573	2.525.547	2.525.547	kWh
	Total Electricity Indirect 1	1.044.022	1.267.614	1.254.924	1.100.749	kWh
	Total Electricity Indirect 2	3.359.348	3.750.935	3.783.509	4.928.500	kWh
	Total electricity kWh	**6.269.611**	**7.496.122**	**7.563.980**	**8.554.796**	
	kWhel/t	0,106	0,121	0,121	0,136	
	kWhel/vessel	2619	3205	3338	3775	
	kWhel/pax	31	56	68	77	
	kWhel/TEU	5	6	5	6	
	kWhel/vehicle	21	24	25	28	
	kWhel/worker	4205	4446	4271	4830	

Table 29 – Electricity consumption and energy performance indicators 2016-2018

		2016	2017	2018	2018 new	
electricity	Total Electricity Direct	584	763	719	719	tCO_2
	Total Electricity Indirect 1	327	391	357	313	tCO_2
	Total Electricity Indirect 2	1.052	1.156	1.078	1.404	tCO_2
	Total electricity CO_2	**1.963**	**2.310**	**2.154**	**2.436**	tCO_2
	$kgCO_2$/t	0,010	0,012	0,011	0,011	
	$kgCO_2$/vessel	820	987	951	1075	
	$kgCO_2$/pax	10	17	19	22	
	$kgCO_2$/TEU	2	2	2	2	
	$kgCO_2$/vehicle	6	7	7	8	
	$kgCO_2$/worker	1317	1370	1216	1376	

Table 30 – Total CO_2 emissions from electricity consumption and CO2 indicators 2016-2018



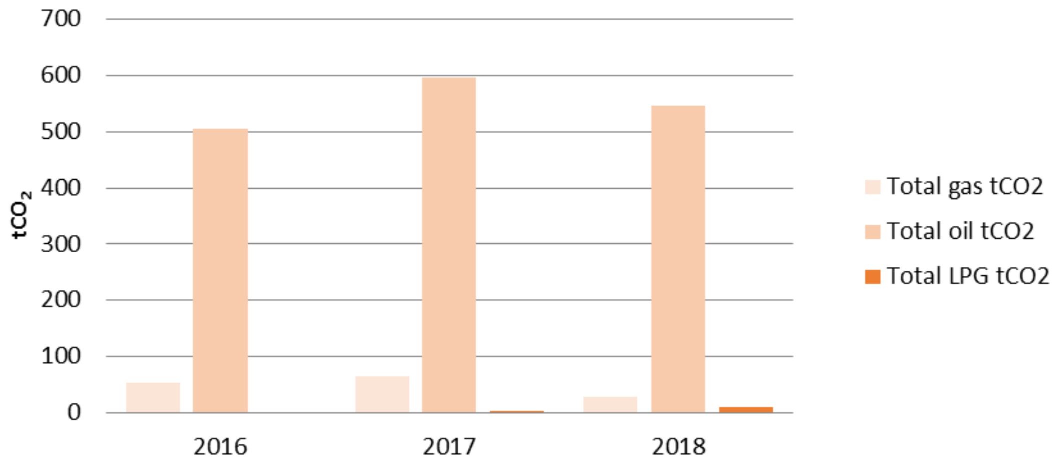
Graph. 3 – CO_2 emissions from electricity consumption with breakdown Direct, Indirect 1st L, Indirect 2nd L 2016-2018

		2016	2017	2018	
heat	Total Heat Direct	11.700	18.749	14.319	m^3
	oil	141.300	163.800	153.000	l
	lpg		1.400	6.400	l
	Total Heat Indirect 1	15.232	14.211	n.a.	m^3
	oil	49.915	61.550	54.000	l
	Total Heat Indirect 2				
	Total heat per fuel type	**26.932**	**32.960**	**14.319**	m^3
	oil	**191.215**	**225.350**	**207.000**	l
	lpg	**0**	**1.400**	**6.400**	l
	Total gas kWh	***258.359***	***316.186***	***137.363***	
	Total oil kWh	***1.893.696***	***2.231.751***	***2.050.022***	
	Total LPG kWh	***0***	***10.117***	***46.251***	
	Total heat kWh	**2.152.055**	**2.558.055**	**2.233.636**	
	kWhth/t	0,0363	0,0413	0,0356	
	kWhth/vessel	899	1094	986	
	kWhth/pax	11	19	20	
	kWhth/TEU	2	2	2	
	kWhth/vehicle	7	8	7	
	kWhth/worker	1443	1517	1261	

Table 31 – Energy consumption for space heating and energy performance indicators 2016-2018

		2016	2017	2018	
heat	Total Heat Direct	11.700	18.749	14.319	m3
	oil	141.300	164.800	153.000	l
	lpg		1.400	6.400	l
	Total Heat Indirect 1	15.232	14.211		m3
	oil	49.915	61.550	54.000	l
	Total Heat Indirect 2				m3
					l
	Total heat per fuel type	**26.932**	**61.550**	**54.000**	m3
	oil	**191.215**	**226.350**	**207.000**	l
	lpg	**0**	**1.400**	**6.400**	l
	Total gas tCO_2	***52***	***64***	***28***	
	Total oil tCO_2	***506***	***596***	***547***	
	Total LPG tCO_2	***0***	***2***	***10***	
	Total heat tCO_2	**558**	**662**	**586**	
	$kgCO_2$/t	0,0094	0,0107	0,0093	
	$kgCO_2$/vessel	233	283	258	
	$kgCO_2$/pax	3	5	5	
	$kgCO_2$/TEU	0	1	0	
	$kgCO_2$/vehicle	2	2	2	
	$kgCO_2$/worker	374	393	331	

Table 32 – Total CO_2 emissions from space heating consumption and CO2 indicators 2016-2018



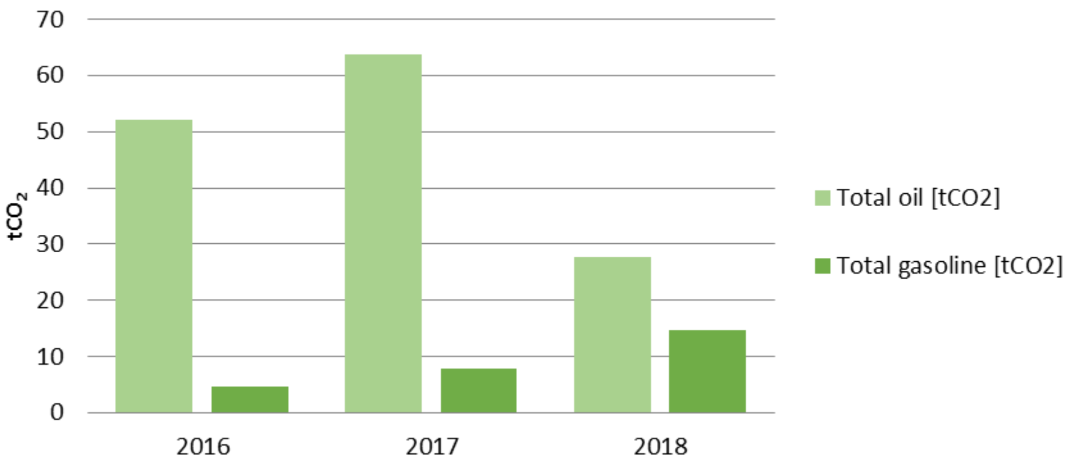
Graph. 4 – CO2 emissions from space heating consumption with breakdown Direct, Indirect 1st L, Indirect 2nd L 2016-2018

		2016	2017	2018	
	Total Fuel Direct				
	oil [l]	1.180	1.866	1.942	l
	gasoline [l]	1.609	3.128	5.040	l
	Total Fuel Indirect 1				
	oil [l]	245.114	310.894	284.826	l
	gasoline [l]	436	356	1.586	l
	Total Fuel Indirect 2				
	Total Fuel per fuel type				
	oil [l]	**246.294**	**312.760**	**286.768**	l
	gasoline [l]	**2.045**	**3.484**	**6.626**	l
	Total oil kWh	***2.433.327***	***3.089.996***	***2.833.200***	
	Total gasoline kWh	***18.327***	***31.222***	***59.380***	
	Total Fuel kWh	**2.451.654**	**3.121.218**	**2.892.580**	
	kWhfuel/t	0,0414	0,0504	0,0462	
	kWhfuel/vessel	1024	1334	1277	
	kWhfuel/pax	12	23	26	
	kWhfuel/TEU	2	2	2	
	kWhfuel/vehicle	8	10	9	
car fleet	kWhfuel/worker	1644	1851	1633	

Table 33 – Vehicle fleet energy consumption and energy performance indicators 2016-2018

		2016	2017	2018	
car fleet	Total Fuel Direct				
	oil	1.180	1.866	1.942	l
	gasoline	1.609	3.128	5.040	l
	Total Fuel Indirect 1				
	oil	245.114	310.894	284.826	l
	gasoline	436	356	1.586	l
	Total Fuel Indirect 2				
	Total Fuel per fuel type				
	oil	**246.294**	**312.760**	**286.768**	l
	gasoline	**2.045**	**3.484**	**6.626**	l
	Total oil [tCO_2]	***650***	***825***	***756***	
	Total gasoline [tCO_2]	***5***	***8***	***15***	
	Total Fuel [tCO_2]	**654**	**833**	**771**	
	$kgCO_2$/t	0,011	0,013	0,012	
	$kgCO_2$/vessel	273,3	356,1	340,4	
	$kgCO_2$/pax	3,282	6,246	6,915	
	$kgCO_2$/TEU	0,565	0,633	0,545	
	$kgCO_2$/vehicle	2,162	2,646	2,517	
	$kgCO_2$/worker	438,8	494,0	435,5	

Table 34 – Total CO2 emissions from vehicle fleet fuel consumption and CO2 indicators 2016-2018



Graph. 5 - CO_2 emissions from fuel consumption with breakdown Direct, Indirect 1st L, Indirect 2nd L 2016-2018

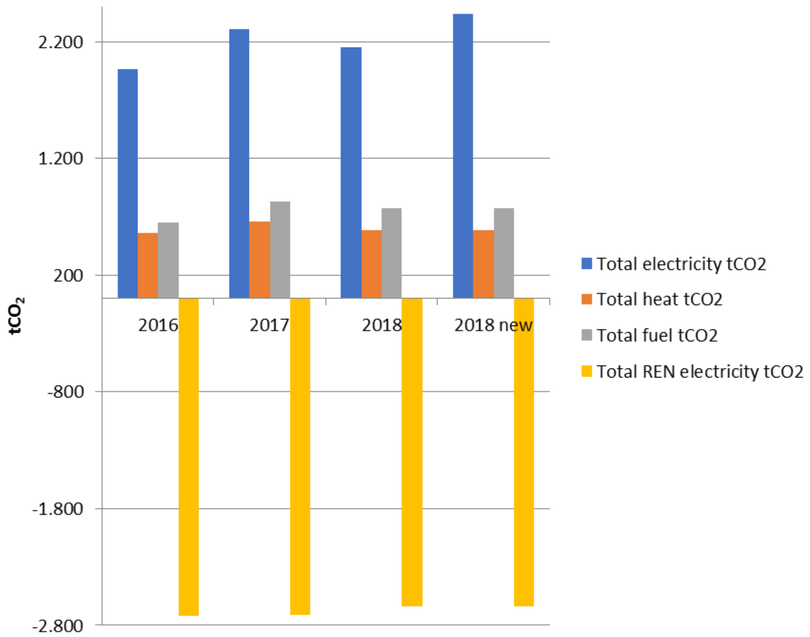
	2016	2017	2018	2018 new
Total electricity kWh	6.269.611	7.496.122	7.563.980	8.554.796
Total heat kWh	2.152.055	2.558.055	2.233.636	2.233.636
Total Fuel kWh	2.451.654	3.121.218	2.892.580	2.892.580
Total energy kWh	10.873.320	13.175.395	12.690.195	13.681.011
kWhtot/t	0,184	0,213	0,202	0,218
kWhtot/vessel	4.542	5.633	5.600	6.038
kWhtot/pax	54,5	98,8	113,8	122,7
kWhtot/TEU	9,4	10,0	9,0	9,7
kWhtot/vehicle	35,9	41,9	41,4	44,6
kWhtot/worker	7.293	7.815	7.166	7.725

Table 35 – Overview energy consumption and energy performance indicators 2016-2018

In the energy consumption overview the PV energy produced within the port area isn't listed, but, as seen in the next table, it is accounted in the emission calculation:

	2016	2017	2018	2018 new
Total electricity tCO2	1.963	2.310	2.154	2.436
Total REN electricity tCO2	-2.718	-2.711	-2.638	-2.638
Total heat tCO2	558	662	586	586
Total fuel tCO2	654	833	771	771
Total energy tCO2	**458**	**1.093**	**873**	**1.155**
kgCO2/t	0,008	0,018	0,014	0,018
kgCO2/vessel	191	467	385	510
kgCO2/pax	2,3	8,2	7,8	10,4
kgCO2/TEU	0,4	0,8	0,6	0,8
kgCO2/vehicle	1,5	3,5	2,8	3,8
kgCO2/worker	307	648	493	652

Table 36 - Overview total CO_2 emissions from energy consumption and CO2 indicators 2016-2018



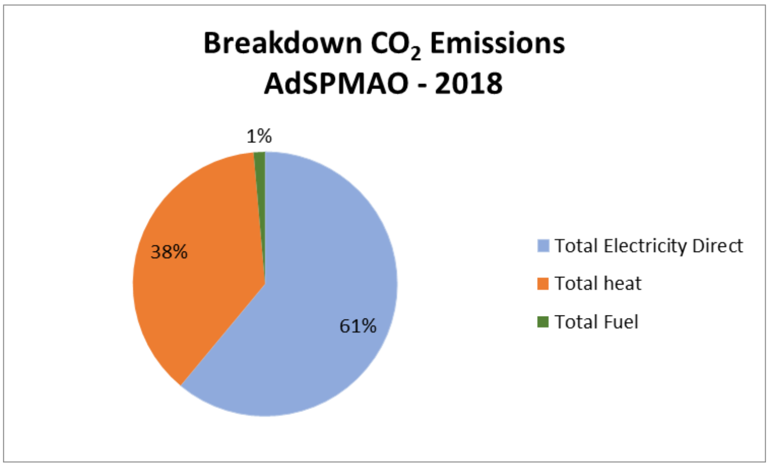
Graph. 6 - CO_2 emissions from energy consumption with breakdown by final use 2016-2018

5.2. Proposed actions

As listed in the emissions inventory paragraph, direct CO2 emissions of AdSPMAO can be summarized as follows, articulated in the three main uses, electricity, space heating, fuel for the car fleet. The main increase in the last years (2016-2018) is due to an increase in the energy consumption for the external lighting (+170 tCO2 only for this purpose).

	2016	2017	2018	
Total Electricity Direct	584	763	719	tCO_2
Total Heat Direct	11.700	18.749	14.319	m^3
oil	141.300	163.800	153.000	l
lpg		1.400	6.400	l
Total gas	*23*	*36*	*28*	tCO_2
Total oil	*374*	*433*	*405*	tCO_2
Total LPG	*0*	*2*	*10*	tCO_2
Total heat	396	472	443	tCO_2
Total Fuel Direct				
oil [l]	1.180	1.866	1.942	l
gasoline [l]	1.609	3.128	5.040	l
Total oil	*3*	*5*	*5*	tCO_2
Total gasoline	*4*	*7*	*11*	tCO_2
Total Fuel	7	12	16	tCO_2
Total Emissions	987	1.247	1.178	tCO_2

Table 37 – Breakdown of total direct CO_2 Emissions of ADSPMAO



Graph 7 – Breakdown of total direct CO_2 Emissions of ADSPMAO

The AdSPMAO emissions represent about 33 % of the total emissions accounted so far in the port area, but the real share is far lower, being many emissions caused by private port operators not yet gathered. A deeper investigation on the share of the AdSPMAO emissions make sense only once the total framework has been completed. It could be worth then to set separate targets of emissions reduction on the single port zone.

According to the assessment framework, there are several fields where implementation can reduce CO2 emissions of the Port, with environmental and local impact on the air quality, as well as on general comfort. More intervention with long term impact be developed together with the definition of port-wide targets.

5.2.1 Direct impact

As for the Port Authority and its direct energy use, there are energy efficiency measures which can actually be implemented. The already evaluated measures are:

- Buildings refurbishment
- Retrofitting of the external lighting plant
- Retrofitting of the vehicle fleet/substitution with e-vehicles
- Onshore Supply Power (OPS)

Buildings refurbishment

One of the major consumptions item is related to space heating, in the buildings of the AdSPMAO. In fact, there are only few buildings used directly by the Authority, being many premises located as offices to port operators.

Here are analysed the main buildings, which are representatives and cover a large part of the heating consumption.

Few buildings outside the Free Port Area, like the Palazzina Corso Cavour 2/2, were owned (still in 2018) by the Port Authority, but they hosted activities related to the Municipality. The costs for the space heating were paid at the end by the Municipality itself, but first accounted in the balance of the Port Authority. Now, in 2018 the ownership of these buildings was transferred to the Municipality, getting out from the energy balance of the Port Authority. These buildings will not be part of the retrofitting analysis.

There are five buildings worth to be analysed, on which several renewal measures are planned or already set in place, with impact on the energy needs.

- **Torre del Lloyd – AdSPMAO headquarter**
- **Palazzina Addossato 53 - offices**
- Palazzina 60 - offices
- Building Ex Culp – mixed use
- Building CSD (ex Geofisico) – offices

The first two, Torre del Lloyd and Addossato 53, are used directly by the Port Authority, while the others are located to port operators and on these are addressed further analysis. The Ex-Culp building is the largest building in the port area and the one with the higher energy consumption, while a lower one is expected, having been refurbished during the last decade: a complete metering system should be put in place

In the following are summarized the actual information on the buildings and the impacts deriving from possible interventions.

Torre del Lloyd - AdSPMAO headquarter

The AdSPMAO headquarter has been built in the years around 1850, and remains one of the oldest buildings of the port. Therefore, any change of the building envelope has to be discussed and agreed with the Architectural heritage authority.
Possible interventions consist in the retrofitting of the thermal plant with fuel switch from oil to natural gas, the substitution of windows and the installation of a PV plant. A larger intervention with thermal insulation is possible only in the internal side of the outer walls, reaching lower savings results.

Heaters [kW]	546
Net heated volume [m³]	14,365
Net heated area è[m²]	3,900
Fuel	Oil
Specific real consumption [kWh/m³]	26.83

Energy consumption	2016	2017	2018
Electricity [MWh]	453	485	469
Oil [l]	39,500	40,000	38,000
Oil [MWh]	394	396	381
Degree days	1704	1851	1772
Normalised heat consumption (ref 2018)	407	379	**381**

CO_2 Emissions	2016	2017	2018
Electricity [tCO_2]	141.8	149.4	133.6
Oil [tCO_2]	104.4	105.8	101.8

Energy costs	2016	2017	2018
Electricity [€]	72,480	77,600	75,040
Oil [€]	34,720	34,890	33,570

Data from Energy Performance Certificate

Name and cadastral address	Net Area [m²]	Gross Volume [m³]	EPC Class	Specific Consumption [kWh/m³y]
torre orologio SV, F34, P6195	43.89	384	D	23.75
palazzina centrale SV,F34,P6167	1804.19	10,159	F	34.54
palazzina APT_91 SV,F34,P6190	673.94	4,296	F	31.98
palazzina APT_90 SV,F34,P6166	664.14	3,797	F	33.61
SUM/AVERAGE	(S) 3,190	(S) 18,636		(A) 30.97

Interventions

	Actual consumption [kWh]	Estimated consumption [kWh]	Energy savings [kWh]	emissions savings [tCO_2]	economic savings [€]	investment [€]	PBT
Heater substitution with fuel switch	381,284	329,580	51,327	35	7,698	50,000	6.49
Windows substitution	381,284	311,748	69,536	19	6,109	300,000	49.11
			Energy production [kWh]				
PV plant 250 kWpeak			250,800	71.42	37,620	205,200	5.75

Table 38 – Data sheet on the Torre del Lloyd Building

Here below a short description of the considered intervention measures and of the rationale used for the calculation.

Torre del Lloyd - Heater substitution with fuel switch
This intervention has a high feasibility and an important impact on the emissions reduction and a contribution also to a slightly lower energy consumption. The energy consumption is reduced due to the higher energy efficiency of the heaters (the two existing heaters are both older than 30 years, having been installed in 1987, for a total 556 kW – 326 kW the bigger one, 220 kW the small one, although in the EPC the declared heater size is 468 kW), which imply a reduction in the related CO_2 emissions, and an additional emission reduction due to the lower carbonium content of the natural gas. The existing oil heaters can be replaced by a modular condensing boiler system, and the investment cost for the power range 550 kW is estimated in 30.000 €. Additional costs cover the new inverter pumps, estimated in 10.000 €, and the new chimney, estimated in 10.000 €. The energy savings are about 50.000 kWh/y (13,5 % of the consumption), based on the assumption that the global seasonal efficiency could have an increase of 9 percentage points, from 0,81 to 0,9. Energy costs base on the real values in 2018, 0,87 €/l for oil and 0,75 €/m^3 for natural gas. Simple pay-back time is calculated in 6,5 years. These figures are not the results of an energy audit, which is needed to have more detailed and accurate results, but derives from a matching between real data of the building and benchmark values.

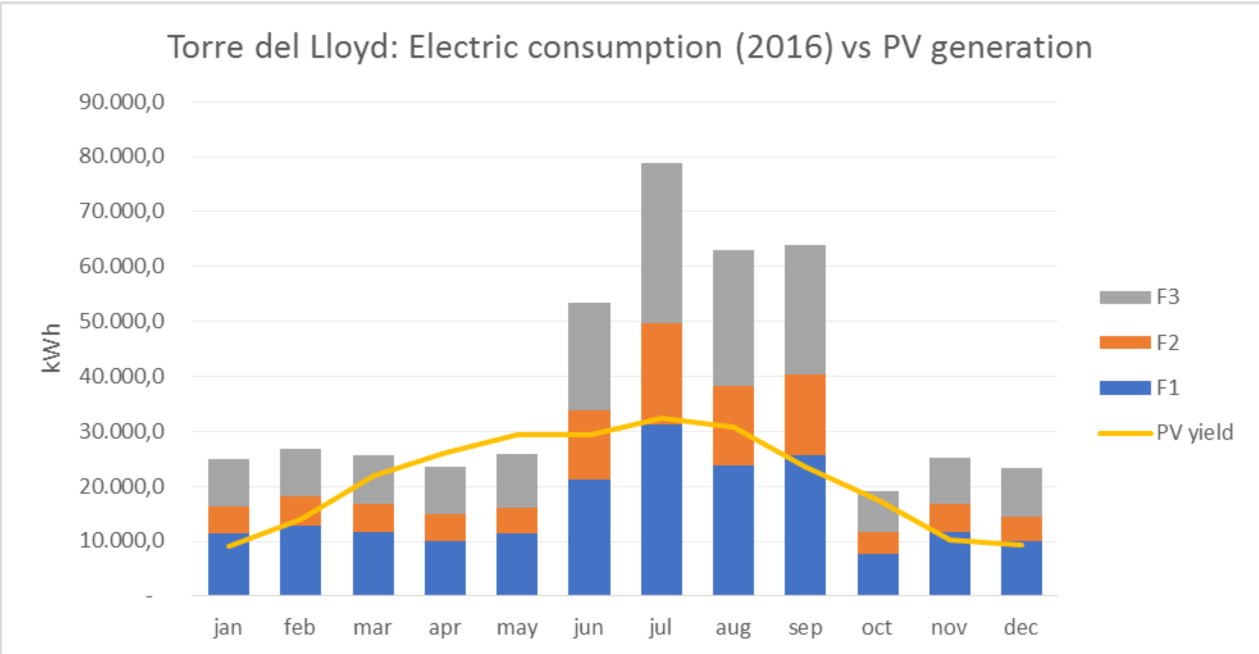
Torre del Lloyd - Windows substitution
Any intervention on the envelope of the building has a double effect, representing a refurbishment of the functional use of the building and in the meanwhile a contribution to the reduction of the energy needs. If energy efficiency measures on the building envelope are planned, it is worth to realize any plant retrofitting after the envelope measures or at least taking them into account: this can lead to a reduction of the plant costs and to a better design of the building-plant system. Windows substitution can be realized maintaining the use of the building with a low impact on the working activities. A thermal insulation of the internal side of the outer walls has a much bigger impact on the continuity of the existing activities and the impact on the savings is reduced, due to the fact that this kind of insulation allows only maximum 5 cm thermal insulation instead of 15-17 cm, which are the standard in northern Italy when put on the external part of the walls. As a standard value, the extent of windows in a masonry building with office activities are about 11% of the total outer envelope of the building. This would mind here a glazed area of about 700-1000 m^2, with a substitution cost varying from 180.000 to 300.000 €. The energy savings are about 70.000 kWh/y (18 % of the actual consumption), based on the assumption that the U-value of the windows decrease from 3,2 W/m^2K to 1,1 W/m^2K. Energy costs are taken from the real values in 2018, 0,87 €/l considering an economical saving about 6,100 €/y. Simple pay-back time is calculated in 49 years. Possible national subsidies covering 50-65% of the investment costs would squeeze the pay-back time to 17-20 years. These figures are not the results of an energy audit, which is needed to

have more detailed and accurate results but derives from a matching between real data of the building and benchmark values.

Torre del Lloyd - PV plant

The roof of the AdSPMAO headquarter could host a PV plant. The area of the roof has been calculated in about 2,200 m^2, while the area available for the PV-module has been reduced to 1,800 m^2, representing a possible installation of about 230 kW_{peak}.
Azimuth orientation is optimal, tilt is calculated by 25°, which is not optimal for a maximal yield during the year but is quite good.
Nowadays the cost of monocrystalline PV module is quite advantageous making possible the realization of a plant in these size with a total cost of about 200,000 €.

In this case there are no energy savings but only renewable energy generation, reaching about 250,000 kWh/y (50 % of the actual electricity consumption), while it determines a big emissions reduction of about 71.65 tCO^2/y.
The economical savings depends on the possibility to self-consume the whole amount of generated energy, because this is the most valuable use of the produced energy. The feed-in tariffs are usually much lower and would increase the payback time.
In the graph below the electric consumption in the AdSPMAO building (monthly data from 2016) is compared to the PV generation.



Graph 8 – Electric Consumption AdSPMAO (2016) vs potential PV generation

The produced energy is about 50 % of the total consumption, but it is necessary to further investigate the load profile. In summer, when the cooling needs are very high, the production is similar to the consumption in F1 time, corresponding to 8-19 from Monday to Friday), but in spring the energy generation is much larger than the needs.

By the next retrofitting of the chiller, the cooling consumption will be lower, due to a higher energy efficiency of the cooler, so possible efficiency interventions during the lifetime of the PV plant could have an impact on the economic forecast of the PV plant and its business plan.

Before deciding to sell the energy overproduction to the grid, it is important to define a consumption strategy, which could consist in the individuation of additional uses to be fed (e.g. charging columns for the electrical car fleet, heat pumps of near AdSPMAO buildings…) or in the redistribution of the loads during the day, adopting a prosuming approach. A storage pack could be an option, but the technology is still very expensive, and the market not really mature.
The economic savings, considering a complete self-consumption would be about 36,500 €/y, by an electricity cost of 0.15 €/kWh.
Simple pay-back time is calculated in 5.75 years.

Palazzina 53 – Offices

The Building near the Warehouse 53, the so-called Addossato 53, has been built in 1950, as an L-shaped building with 6 floors, including the ground floor. It hosts offices of AdSPMAO and PTS.

It is a masonry building with concrete floor and a flat roof. The heater in the thermal power plant station has been installed in 1990 and provides 258.4 kW power, oil fueled. The switch to natural gas is not possible in this area, not reached by the city gas network. Therefore, it is possible to plan a complete refurbishment of the building and then proceed with the heater substitution with a heat pump.

Heaters [kW]	258
Net heated volume [m^3]	4,125
Net heated area [m^3]	1,269
Fuel	Oil
Specific real consumption [kWh/m^3]	38.41

Energy consumption	2016	2017	2018
Electricity [MWh]	47.14	45.14	54.55
Oil [l]	17,500	18,000	16,000
Oil [MWh]	173.3	178.3	158.5
Degree days	1704	1851	1772
Normalised heat consumption (ref 2018)	180.2	170.7	**158.5**

CO_2 Emissions	2016	2017	2018
Electricity [tCO_2]	14.8	13.9	15.5
Oil [tCO_2]	48.1	45.6	42.3

Energy costs	2016	2017	2018
Electricity [€]	7,542	7,222	8,728
Oil [€]	15,225	15,660	13,920

Data from Energy Performance Certificate

Name and cadastral address		Net Area [m^2]	Gross Volume [m^3]	EPC Class	Specific Consumption [kWh/m^3y]	
palazzina APT_53 SV,F26,M5833, sub 32		1269.32	5864.80	G	71.15	

Interventions

	Actual consumption [kWh]	Estimated consumption [kWh]	Energy savings [kWh]	emissions savings [tCO_2]	economic savings [€]	investment [€]	PBT

Thermal insulation walls, roof and basement	158,456	85,742	72,714	19	6,388	370,000	57.92
Windows substitution	158,456	131,479	26,977	7	2,370	134,000	56.54
Heater substitution Heat Pump	158,456	67,075	91,391	23	3,860	72,800	18.86
Sum of all previous measures	158,456	30,436	128,020	34	9,355	458,400	49.00

Table 39 – Data sheet on the Addossato 53 Building

Addossato 53 – Thermal insulation

The thermal insulation of the building reduces its losses and increase the internal thermal comfort, which is important to guarantee good working conditions.
The realization of a layer of insulation about 15 cm on the outer walls, 17 on the roof and 14 on the lower side of the ceiling over the entrance portal reduce the energy consumption of the building about 45 %.
The intervention costs (2.500 m^2 external walls, about 600 m^3 roof and basement are estimated in 370.000 €.
The energy savings are about 86.000 kWh/y (45 % of the actual consumption), based on the assumption that the U-value of the windows decrease from 0,80 W/m^2K to 0,20 W/m^2K.

Energy costs base on real values in 2018, 0,87 €/l considering an economical saving about 6,400 €/y.
Simple pay-back time is calculated in 58 years.
Possible national subsidies covering 50-65% of the investment costs would squeeze the pay-back time to 23-28 years. These figures are not the results of an energy audit, which is needed to have more detailed and accurate results but derives from a matching between real data of the building and benchmark values.

Addossato 53 - Windows substitution

Windows substitution can be realized maintaining the use of the building with a low impact on the working activities.
As a standard value, the extent of windows in a masonry building with office activities are about 11% of the total outer envelope of the building. This would mind here a glazed area of about 500 m^2, with a substitution cost about 135.000 €.
The energy savings are about 27.000 kWh/y (17 % of the actual consumption), based on the assumption that the U-value of the windows decrease from 3,2 W/m^2K to 1,1 W/m^2K.
Energy costs base on the real values in 2018, 0,87 €/l considering an economical saving about 2,400 €/y.
Simple pay-back time is calculated in 56 years.
Possible national subsidies covering 50-65% of the investment costs would squeeze the pay-back time to 23-28 years. These figures are not the results of an energy audit, which is needed to have more detailed and accurate results but derives from a matching between real data of the building and benchmark values.

Addossato 53 – Heat Pump
The substitution of the old oil fueled heater with a heat pump is a good solution, as no connection to the gas network is feasible, but the thermal conditions could determine a very low efficiency of the heat pump during cold winters. A deep refurbishment of the building done before the heater substitution reducing dramatically the energy needs for space heating is a crucial condition to make possible the achievement of high COP. Both situations are here estimated: - the first one foresees the substitution of the existing boiler with a heat pump without any other intervention on the building - the second one includes the whole insulation of the building, with windows substitution. In the second case the HP is sized on the new heating need conditions, with a strong reduction in the investment, which is in any case a small part of the investment for the refurbishment of the envelope. Here below a comparison between the two operative cases. 1) - Estimated energy savings: approx. 67,000 kWh - Economic savings: approx. 90,000 kWh - Investment: approx. 73,000 € - PBT: 18.8 2) - Estimated energy savings: about 128,000 kWh - Economic savings: approx. 128,000 kWh - Investment: approx. 450,000 € (for the heat pump just 30,800 €) - PBT: 49 In this case too, the possibility to consider the contribution of subsidies has to be further investigated. These figures are not the results of an energy audit, which is needed to have more detailed and accurate results but derives from a matching between real data of the building and benchmark values.

List of technical regulations and reference standards concerning buildings refurbishment

Energy audit, Thermal performance windows, Buildings energy performance, Measurement and verification protocols

- UNI CEI/TR 11428:2011, Energy management- Energy audits- General requirements of energy audits
- UNI CEI EN 16247-1:2012, Energy audits- Part 1: Requirements
- UNI CEI EN 16247-2:2014, Energy audits - Part 2: Buildings
- UNI CEI EN 16247-3:2014, Energy audits - Part 3: Processes
- UNI CEI EN 16247-4:2014, Energy audits - Part 4: Transport

- UNI EN ISO 10077-1:2018. Thermal performance of windows, doors and shutters -- Calculation of thermal transmittance -Part 1: General
- UNI EN ISO 10077-2:2018. Thermal performance of windows, doors and shutters -- Calculation of thermal transmittance -Part 2: Numerical method for frames

- UNI EN ISO 13370:2018Thermal performance of buildings -- Heat transfer via the ground -- Calculation methods
- UNI EN ISO 13789:2018. Thermal performance of buildings -- Transmission and ventilation heat transfer coefficients -- Calculation method
- UNI EN ISO 52010-1:2018. Energy performance of buildings -- External climatic conditions Conversion of climatic data for energy calculations
- UNI EN ISO 52022-1:2018. Energy performance of buildings -- Thermal, solar and daylight properties of building components and elements Part 1: Simplified calculation method of the solar and daylight characteristics for solar protection devices combined with glazing
- UNI EN ISO 52022-3:2018. Energy performance of buildings -- Thermal, solar and daylight properties of building components and elements Part 3: Detailed calculation method of the solar and daylight characteristics for solar protection devices combined with glazing
- UNI EN ISO 52017-1:2018. Energy performance of buildings -- Sensible and latent heat loads and internal temperatures -Part 1: Generic calculation procedures
- UNI EN ISO 52016-1:2018. Energy performance of buildings -- Energy needs for heating and cooling, internal temperatures and sensible and latent heat loads -Part 1: Calculation procedures
- UNI EN ISO 52018-1:2018. Energy performance of buildings -- Indicators for partial EPB requirements related to thermal energy balance and fabric features - Part 1: Overview of options
- UNI EN ISO 52003-1:2018. Energy performance of buildings -- Indicators, requirements, ratings and certificates -Part 1: General aspects and application to the overall energy performance
- UNI CEN/TR 15459-2:2018. Energy performance of buildings - Economic evaluation procedure for energy systems in buildings - Parte 2: Explanation and justification of EN 15459-1, Module M1-14
- UNI EN 15459-1:2018. Energy performance of buildings - Economic evaluation procedure for energy systems in buildings - Part 1 Calculation procedures, Module M1-14
- EVO – International Performance Measurement and Verification Protocol (IPMVP) – Core Concepts 2017
- EVO – International Performance Measurement and Verification Protocol (IPMVP) – Uncertainty assessment for IMPVP

Lighting retrofitting

The lighting system consists of a total of about 700 light towers and light poles; the most used lamp typology is high-pressure sodium (HPS), but a recent lighting retrofitting has introduced a small amount of LED. The following table shows the details of the characteristics and power of existing lamps, with a zone breakdown, combining the data bank gathered in 2011 for the whole port with the state of the art verified in 2018 in the New Free Port area.

Port Zone	Light Poles	number of lamps	Type of lamps	Power [W]	Total power [kW]
Old Free Port	171	11	high pressure sodium	1000	11.0
		160	high pressure sodium	250	40.0
New Free Port	458	78	high pressure sodium	1000	78.0
		314	high pressure sodium	250	78.5
		36	high pressure sodium	125	4.5
		5	neon	58	0.29
		30	led	250	7,5
Maritime Station	7	7	high pressure sodium	250	1.75
Scalo Legnami	20	20	high pressure sodium	250	5.0
Oil Port	7	4	high pressure sodium	400	1.6
		3	high pressure sodium	400	1.2
Extra	17	17	high pressure sodium	250	4.2

Table 40 – overview of the existing lighting systems

The existing data about the New Free Port allow to proceed with a more detailed analysis.

In the New Free Port area are 458 lamps with a total power of 167 kW. Among them, 233 street lamps (250 W each, for a total 58,25 kW) are dedicated to the lighting of the flyover leading to the ramp in Pier VII. As can be noticed in the following table, the level of lighting has changed fundamentally, increasing the installed lighting power in the remaining area of the New Free Port from 33,12 kW in 2011 to 109 kW in 2018, while energy efficiency level has remained almost the same.

	installed power [kW]	Luminous flux [kilolumen]	Efficiency [lumen/W]
New Free Port - 2011	33,12	3885	117,29
New Free Port - 2018	108,79	12759	117,30

Table 41 – comparison between old an new lighting asset

A substitution of the existing high-pressure sodium lamps, having already a very good efficiency level, could be suggested only with high efficiency LED lamps, i.e. higher than 150 lumen/W. Comparing the installed power with the final consumption, the average working hours are quite high, considering that to reaching this value 50 % of the existing lamps are working through day and night while the remaining 50 % are switched on during the standard 4200 hours (11,5 hours/day), and both categories with their full power, thus without any dimmering regulation.

	lighting consumption [kWh/y]	installed power [kW]	average working hours [h/y]
New Free Port - 2018	1070167,61	167	6406,65

Table 42 – average working hours of the lighting system in the New Free Port area

LED is dimmable in a wider range than high-pressure sodium lamps, therefore a fine regulation based on the lighting needs could lead to a significant reduction of the working hours at maximum power, and consequently translated in an energy consumption abatement.

The large increase of the installed lighting power during the last decade consists in an increase of service, guaranteeing more security, more safety and a more articulated possibility to use the outer spaces. The introduction of a regulation and control system with the task to dimmer the lighting power of each lamp or of each lamps group in relation to the natural light and to the typology of the space use in different time zones allows to reach a consumption reduction up to 50%, depending on the possibility to provide a lower lighting level in some areas.

The intervention on a lighting system should be made only after a specific lighting plan, making sure that all functional and regulation needs are met, but the information about the possible energy and emission savings helps to the development of an intervention plan.

In the table below, all high-pressure sodium lamps are substituted with LED. The efficiency of the existing sodium lamps varies between 100 and 120 lm/W, and are substituted by high efficiency LED, with 160 lm/W. The final wattage of the lamps is than rounded by excess, to be on the safe side and guaranteeing the desired level of illuminance.

	Light Poles	number of lamps	Type of lamps	Power [W]	Total power [kW]
New Free Port	458,00	78	high pressure sodium	**1000**	78,00
		314	high pressure sodium	250	78,5
state of the art		36	high pressure sodium	**125**	4,50
		30	led	250	7,5
New Free Port	458	78	led	750	58,5
		314	led	**200**	62,80
intervention proposal		36	led	100	3,6
		30	led	**250**	7,50

Table 43– Intervention proposal for LED installation

Here in the following are described the energetic and the economic impact of a complete substitution of the sodium lamps in LED. As already said and shown in table 43, the substitution determines a power reduction, due to a major efficiency of the LED lamps. Here are not calculated the possible additional savings, which a dimmer-based regulation could achieve. To introduce this factor it is necessary to have an detailed analysis on the elements causing the high amount of working hours, and to double check the feasibility of their reduction, and the illuminance really needed during the night.

In the table is assumed to exchange all lamps at the beginning of 2020: the average life of a LED lamp is about 50.000 hours, thus it can vary between 8 and 12 years, depending on the working hours, which are here assumed to fluctuate between 4000 and 6400. Therefore, it is foreseen that a share of lamps, the most used, could start to need a substitution after 8 years. Within the 10-year period used for this analysis, 40 % of the lamps are substituted, but their price is slightly reduced, in line with the usual price shrinking with the maturity of the technology.

Year	investment costs [€]	energy savings [€]	maintenance savings [€]	Payback	Energy savings [MWh]	Energy savings [toe]	CO2 Emissions [tCO2]	CO2 Emission savings [tCO2]
2020	249.800 €	36.966 €	4.562 €	- 208.272 €	231,04	43,20	241,33	65,80
2021	- €	36.966 €	- €	- 171.305 €	231,04	43,20	241,33	65,80
2022	- €	36.966 €	4.562 €	- 129.777 €	231,04	43,20	241,33	65,80
2023	- €	36.966 €	- €	- 92.810 €	231,04	43,20	241,33	65,80
2024	- €	36.966 €	4.425 €	- 51.419 €	231,04	43,20	241,33	65,80
2025	- €	36.966 €	- €	- 14.452 €	231,04	43,20	241,33	65,80
2026		36.966 €	4.334 €	26.848 €	231,04	43,20	241,33	65,80
2027	18.735 €	36.966 €	- €	45.079 €	231,04	43,20	241,33	65,80
2028	37.470 €	36.966 €	4.243 €	48.818 €	231,04	43,20	241,33	65,80
2029	16.237 €	36.966 €	- €	69.548 €	231,04	43,20	241,33	65,80
2030	- €	36.966 €	4.106 €	110.620 €	231,04	43,20	241,33	65,80

Table 44 – Overview of the investment costs and impacts of a complete switch to LED

As a term of confrontation in the table 44 are described the needed interventions, energy costs and CO_2 emissions, considering not only operation costs, but also the investment needed for the substitution of sodium lamps, which have an average lifetime of about 5000-8000 hours. In the case described below, it is considered to need a complete substitution of the whole lamp asset every two years. It is considered also to have a saving contribution due to technology improvement.

Year	investment costs	energy savings [€]	maintenance costs[€]	energy consumption [MWh]	CO2 emissions [tCO2]	CO2 emission savings [tCO2]
2020	22.810 €	- €	4.562 €	1.078 €	307,13	0,00
2021	- €	- €	- €	1.078 €	307,13	0,00
2022	22.810 €	3 €	4.562 €	1.057 €	300,99	6,14
2023	- €	3 €	- €	1.057 €	300,99	6,14
2024	22.126 €	7 €	4.425 €	1.036 €	294,97	12,16
2025	- €	7 €	- €	1.036 €	294,97	12,16
2026	21.670 €	10 €	4.334 €	1.015 €	289,07	18,06
2027	- €	10 €	- €	1.015 €	289,07	18,06
2028	21.213 €	13 €	4.243 €	995 €	289,07	18,06
2029	- €	13 €	- €	995 €	289,07	18,06
2030	20.529 €	17 €	4.106 €	975 €	283,29	23,84

Table 45 – Overview of the investment costs and impacts without a switch to LED

Technical regulations and reference standards concerning lighting using LED technology

- UNI EN 12464-2 Lighting requirements for outdoor work places
- UNI 13201-2:2015 Road Lighting. Part 2: Performance requirements
- UNI 13201-3:2015 Road Lighting. Part 3: Calculation of performance
- UNI 13201-4:2015 Road Lighting. Part 4: Methods of measuring lighting performance
- UNI 13201-5:2015 Road Lighting. Part 5: Energy performance indicators
- ISO/CIE 8995-3:2018 Lighting of work places Lighting requirements for safety and security of outdoor work places

Specific regulations and standards concerning light pollution

- Regional Law Friuli-Venezia Giulia 15/2007
- UNI10819 Light and lighting - Impianti di illuminazione esterna - Requisiti per la limitazione della dispersione verso l'alto del flusso luminoso
- UNI 11248:2016 Road Lighting – Selection of lighting categories

International standards currently under discussion

- UNI1605901 Light and lighting – Road lighting enforcement of luminous flux regulation (Replaces UNI 11431:2011)
- UNI1605902 Characterization of the performance of illuminance meters and luminance meters.
- UNI1606444 Statutory photometric requirements and calculation procedures for outdoor lighting, (Replaces UNI 10819:1999)

It is worth to mention that the substitution of existing lamps with LED could be subsidized with the White Certificates system, if they are considered as a public lighting. For this reason in table 44 the energy savings are reported also as toe, to have a gross size of the achievable results, even if the calculation of the savings is more complex and depend in any way on the real final use.

Car fleet retrofitting

One of the most important field where AdSPMAO can reduce CO_2 emissions through implementation of energy efficiency measures, with environmental and local impact on the air quality, is the car fleet retrofitting.

AdSPMAO car fleet is composed by 22 cars, 11 of them belonging to EURO2 & EURO4 emissions category (among the remaining ones there are 3 EURO6 vehicles). They are mainly Fiat Panda Van (petrol-fueled) and most of them is used for inspection in port area. Only two vehicles are used in a 50 km zone around Port, one of them for business trip (a diesel Lancia Voyager). Just this one rides more than 20,000 km in a year while year's average distance for the fleet car is slightly more than 6,500 km.

The car fleet's CO_2 emissions are about 23 tons a year and the fuel cost about 15,630 € (plus an amount about 1,585 € for car annual tax).

According to this proposal, car fleet retrofitting happens in two steps, in order to change cars only if they are older than 10 years: the first immediate investment concerns the retrofitting of all 11 cars belonging to EURO4 and to all classes below and another investment in 5 years for the remaining cars (except for three EURO6 cars).

Year	Annual investment costs	Saving from fuel	Savings from car tax	Payback	Payback with PV system
2020	309,446 €	8,695 €	760 €	- 299,992 €	- 298,563 €
2021	0	8,673 €	760 €	- 290,559 €	- 287,702 €
2022	0	8,652 €	760 €	- 281,147 €	- 276,862 €
2023	0	8,630 €	760 €	- 271,758 €	- 266,043 €
2024	0	8,608 €	760 €	- 262,389 €	- 255,247 €
2025	185,167 €	11,211 €	1,433 €	- 434,912 €	- 425,459 €
2026	0	11,205 €	1,433 €	- 422,274 €	- 410,512 €
2027	0	11,199 €	1,433 €	- 409,642 €	- 395,570 €
2028	0	11,192 €	1,433 €	- 397,017 €	- 380,635 €
2029	0	11,186 €	1,433 €	- 384,397 €	- 365,705 €
2030	0	11,180 €	1,433 €	- 371,784 €	- 350,782 €

Table 46 – 2030 Payback prevision with and without PV system

The first annual investment covers the replacement of the first eleven cars with similar models: Panda Van are replaced by Renault Kangoo Z.E. (current price 30,000 €) and the Mercedes V220 shuttle is replaced by a Nissan E-NV200 Evalia, (current price 45,521 €); in addition, it covers three recharge columns as well, provided with two location each, (current price about 3,500 € for each column). Among the investment assumptions is calculated a discount of 15 % on the price of the 10 electric small vans and recharge columns.

As a base for the consumption calculation the official datasheet from Renault and Nissan (0.14 kWh/km and 0.16 kWh/km) are used, applied on the same annual distance in km ridden by the actual fleet, leading than to the determination of annual energy costs. As energy price it has been used 0,12 €/kWh. An annual increase of 0,05% on fuel costs for the reduction of efficiency of petrol and diesel cars is foreseen. The annual free car tax for electric vehicles is assumed as free also for the following years.

The second annual investment (in 2025) is set up with the same costs as the first investment, with a predicted reduction of 20 % on the batteries and cars price. Also in this case is foreseen the same replacement as in the first phase is (Renault Kangoo instead of Panda Van and Nissan e220 instead the diesel Lancia Voyager for business use).

A calculation of the possible payback in the case in which recharge columns are fed by solar cells (annual fuel saving is about 15 % in the first 5 years, then 18 %).

Retrofitting car fleet would produce a reduction of about 150 tCO_2 in 2030 using network energy and about 250 tCO_2 using a PV system.

Assuming retrofitting car fleet not with electrical cars but with cars of the same typology (petrol and diesel) we have calculated adjusted payback. We have used Fiat Panda Van and Mercedes V220 list price and consumption (mixed type).

Year	Investments [€]	Saving from fuel	Savings from car tax	Payback	Payback with solar cells
2020	154.902 €	7.379 €	760 €	- 146.763 €	- 145.335 €
2021	- €	7.413 €	760 €	- 138.591 €	- 135.734 €
2022	- €	7.447 €	760 €	- 130.384 €	- 126.098 €
2023	- €	7.481 €	760 €	- 122.143 €	- 116.429 €
2024	- €	7.516 €	760 €	- 113.867 €	- 106.724 €
2025	60.733 €	10.198 €	1.433 €	- 162.968 €	- 153.516 €
2026	- €	10.249 €	1.433 €	- 151.286 €	- 139.524 €
2027	- €	10.300 €	1.433 €	- 139.553 €	- 125.481 €
2028	- €	10.352 €	1.433 €	- 127.768 €	- 111.386 €
2029	- €	10.404 €	1.433 €	- 115.931 €	- 97.239 €
2030	- €	10.456 €	1.433 €	- 104.042 €	- 83.040 €

Table 47 – 2030 Payback prevision with and without PV system

Beside the CO_2 reduction car fleet retrofitting will reduce all pollutant emissions (NO_x about - 90%, VOC, CO and SO_x about - 99%, PM2,5 -81%, PM10 -57%) and noise and it means more healthy conditions within the port as well for workers as for passengers.

Technical regulations of reference concerning electric vehicles

- 61851-1 “Electric vehicle conductive charging system – Part 1: General requirements”
- IEC 62196-3 “Plugs, socket-outlets, vehicle connectors and vehicle inlets – Conductive charging of electric vehicles – Part 3: Dimensional compatibility and interchangeability requirements for d.c. and a.c./d.c. pin and contact-tube vehicle couplers

5.2.2 Indirect impact

The port authority has a role in the involvement the awareness of all port operators, public and private, defining target and goals to achieve a more sustainable port.

One of the activities undertaken by the Authority is the creation of a databank for the collection of consumption and emission data for each port operator. This is one definitive step for the development of energy efficiency and low emission strategies.

The feasibility study of an OPS (Onshore Power Supply) also belongs to this type of activity, since the presence of such an infrastructure can greatly influence, even if on the long term, the behaviour of the ship-owners.

OPS

One of the most effective solution identified is the OPS, which in the Port of Trieste could be advantageously applied to the RoRo Terminals. In this respect, having regard to the regulatory framework of reference, the Directive 2014/94/EU15 highlights positive effects related to shore power utilization. More specifically, the main content related to shore power is[28]:

> "Member States shall ensure that the need for shore-side electricity supply for inland waterway vessels and seagoing ships in maritime and inland ports is assessed in their national policy frameworks. Such shore-side electricity supply shall be installed as a priority in ports of the TEN-T Core Network, and in other ports, by 31 December 2025, unless there is no demand and the costs are disproportionate to the benefits, including environmental benefits."

Identifying best practice through benchmarking and outcomes measurement. From the analysis carried out at EU and international level, OPS emerged as a complex issue involving a large number of diverse stakeholders at various levels in the shipping supply chain[29]. Even although not technically complicated, the question of whether to invest in OPS or not depends on a large number of interrelated issues that ports and ship owners must evaluate. These aspects must be analysed with specific reference to each port domain, i.e. commercial viability of the investment, environmental impact, rate of utilisation as well as impacts of future emission reduction regulations on the maritime trade[30].

Taking in consideration the international framework of reference, nowadays it is calculated that about 30 ports worldwide offer OPS, of which 14 in Europe, and 9 in the United States of America. Considering the shipping industry, it is estimated that about 300 vessels have OPS connection possibilities[31].

28 COMMISSION STAFF WORKING DOCUMENT - Towards the broadest use of alternative fuels an Action Plan for Alternative Fuels Infrastructure under Article 10(6) of Directive 201/94/EU, including the assessment of national policy frameworks under Article 10(2) of Directive 2014/94/EU,

https://eur-lex.europa.eu/resource.html?uri=cellar:d80ea8e8-c559-11e7-9b01-01aa75ed71a1.0001.02/DOC_3&format=PDF

IMO, International Convention for the Prevention of Pollution from Ships

http://www.imo.org/KnowledgeCentre/ReferencesAndArchives/HistoryofMARPOL/Documents/MARPOL%201973%20-%20Final%20Act%20and%20Convention.pd

29 Onshore power supply Case study – Port of Helsinki, 2015 - http://www.bpoports.com/OPS_Seminar/Rantio.pdf

Case Study Onshore Power Supply Facility at the Cruise Terminal Altona in Hamburg, 2014- http://archive.northsearegion.eu/files/repository/20150309115942_TEN-TaNS_CaseStudy_OnshorePowerSupplyFacilityinHamburg.pdf

Case study Onshore power supply at the Port of Gothenburg, 2014, http://www.ops.wpci.nl/_images/_downloads/_original/1370345459_a9rc82a.pdf

Electrification of harbours – Project report, Icelandic New Energy, 2017 - https://orkustofnun.is/gogn/IslenskNyOrka/Electrification-of-harbours-2017.pdf

30 On Shore Power Supply, Harbours Review, 2017 - http://harboursreview.com/e-zine-17.pdf

31Ports - UNCTAD, 2017 - https://unctad.org/en/PublicationChapters/rmt2017ch4_en.pdf

Recent years have shown an advancement and closer collaboration of port and shipping company actors towards the OPS, which is globally recognized as a positive solution for the further identification, development and selection of practicable options that may lead to green shipping and cleaner port areas.

Main results of the study.
The Port Authority, technically supported by Fincantieri SI, has developed a feasibility study to verify and calculate the advantages of the presence of this infrastructure and the possible impact.

The port area involved in the intervention consists of the two berthing slots dedicated to Ro-Ro between Pier V and Pier VI, of the Punto Franco Nuovo (Mooring 38 and Mooring 39), where an enlargement of the port quay is foreseen at the root of Pier VI.

The intervention would offer electricity to the berthing vessels, for about 6200 hours/year, and this offer could cover 90 % of the cruises above 40.000 tons and 73 % of all cruises, even smaller.

In the project, two of the five existing quays for Ro-Ro are provided with Onshore power supply.

As assumption is considered that in the next 15 years the number of vessels able to connect to the OPS will increase, starting from a 30% base assumed for 2020.

In 2020, according to the study, 98 of the 326 berthing vessels at the 2 electrified quays could be direct supplied with electricity, and in 2035 these could increase to 438 of 438 vessels.

In this scenario, the OPS would supply 739 MWh in 2020, increasing constantly to reach 3317 MWh in 2035. The study does not report calculations on the quantification of energy savings that can qualitatively be said to be determined by the replacement of the electricity generation system. Basically the efficiency level of the national electric mix is higher than the average efficiency of the auxiliary engines of the ships in mooring

Although the CO_2 emissions related to the generation of these energy are quite existing (99.4 tCO_2 in 2020 and 446.1 tCO2 in 2035) these figures are a minor share of the emissions from HFO or MGO. The emissions produced instead from the vessels engine, calculated with the average values for HFO and MGO[32] would amount respectively to 457 tCO_2 in 2020 and 2048 tCo_2 in 2035.

32 Source: Particle emissions from Ships: Dependence on fuel Type

5.3. Overview of energy and CO_2 emissions savings scenarios

To get a better understanding of the proposed measures, the main results are listed here below.

In the first table all energy efficiency measures are considered in their yearly contribution. All payback time are simple, and do not consider possible subsidies: in some cases subsidies could make the investment much more valuable. The savings calculated here are referring to the situation in 2018.

n.	Measure description	Investment [€]	Energy savings [MWh/y]	Energy savings [€/y]	Emission savings [tCO₂/y]	PBT [y]	Lifetime [y]
A1	Torre del Lloyd refurbishment	350.000	106,95	12.047	73,2	29,1	15-50
A2	Addossato 53 refurbishment	458.400	128,02	9.355	33,6	49	15-50
B1	Public lighting	322.242	231,04	36.966	65,8	8,7	08-dic
C1	Car fleet	215.635	33,44	12.613	12,3	17,1	ott-15
D1	OSP	3.000.000	n.a.	n.a.	357	4	15
TOT	**TOTAL**	**1.346.277**	**499**	**70.981**	**185**	**19**	

Table 48– Overview of the proposed measures

Table 48describes the cumulated savings, generated in a 10-years period: they are calculated here as a difference between the proposed situation and a 'business as usual' trend.

	Measure	Investment [€]	Cumuled energy savings 2030 [MWh]	Cumuled CO_2 emission savings 2030 [tCO_2]	Cumuled economic savings 2030
A1	Torre del Lloyd refurbishment	350.000	1069,5	732	120467
A2	Addossato 53 refurbishment	458.400	1280,2	336	93546
B1	Public lighting	322.242	2541,4	724	406630
C1	Car fleet	215.635	477,4	115	111593
D1	OSP	3.000.000	-	7860.3	-
TOT	**TOTAL**	**1.346.277**	**5369**	**1.908**	**732237**

Table 49– Overview of the cumulated savings of the proposed measures

5.4. Workplan

The time schedule is projected over the next 10 years, including the different phases of the investments. Monitoring activities on single interventions are planned as continuous, in order to make available measured and reliable information needed for the set-up of the global consumption framework and for a more detailed estimation of the impact of future interventions on a reliable baseline, reducing - even if not eliminating - the uncertainty related to energy behaviour after the implementation.

Phase	Years	1	2	3	4	5	6	7	8	9	10
0	**Whole Port Energy Database**										
0.1	Design, implementation and update of all energy uses within the port area										
1	**Buildings Refurbishment**										
2.1	Energy audit										
1.2	Design and procurement										
1.3	Implementation										
1.4	Monitoring										
2	**Retrofit lighting**										
2.1	Lighting plan										
2.2	Design and procurement										
2.3	Implementation										
2.4	Monitoring										
3	**Retrofit car fleet**										
3.1	Procurement, phase 1										
3.2	Procurement, phase 2										
3.3	Implementation										
3.4	Monitoring										
4	**OPS**										
4.1	Executive Design										
4.2	Procurement										
4.3	Implementation										
4.4	Monitoring										
5	**Plan revision and individuation new actions**										

Table 50– Gantt diagram of the proposed actions

6. Actions and solutions deployment

One of the crucial issues for the development of energy efficiency actions lies in finding the funds needed to start the investments. In the following are described the most important reference schemes developed to achieve the strategic targets of reducing climate-changing emissions and developing energy efficiency in which Italy has committed itself.

For the proposed actions, in reality, incentives schemes already exist, which can reduce the payback time of the measures, thus reducing the risks and reducing the obstacles to financing that may be necessary.

National Energy Efficiency Fund - FNEE

The National Fund for energy efficiency, established in 2014 with Legislative Decree 102, but activated only in 2019, favors the necessary interventions for the achievement of national energy efficiency targets by means of the granting of revolving guarantees or the granting of subsidized loans. It promotes the involvement of national and EU financial institutions and private investors on the basis of adequate risk sharing.

The Fund, managed by Invitalia, supports energy efficiency measures implemented by companies and by the Public Administration on buildings, plants and industrial processes. In the case of the Port Authority it is possible to apply for the realization of measures to improve the efficiency of public services and infrastructures, including public lighting and energy upgrading of buildings. The financial resources allocated for the incentive amount to about 310 million euros.

The new Conto Energia Termico (CET 2.0)

The Conto energia termico is an incentivising scheme derived from Decree 28/2012: started in 2013 it has encouraged energy performance improvements in private and public buildings. Since June 2016, the revised CET 2.0 came into force, with an allocation of 900 million € per year, 200 of them dedicated to buildings owned by the public administration: in 2019 are so far distributed 153 million €, 58 for the public administration. The incentive promotes the achievement of NZEB standard, granting up to 575 €/m^2 over a maximum 5-year period and covering up to 65% expenses. Generally, if the NZEB standard is not reached, a grant of 40% of the total investments is provided with monthly instalments for 2 to 5 years depending on intervention type, with a cap on specific costs, e.g. 100 €/m^2 for external walls insulation. Moreover, 100% of the costs for energy audit and energy performance certificate are covered. This incentive can be combined with other grants (i.e., regional ones) up to 100% of eligible costs.

White certificates (Titoli di efficienza energetica, TEE)

White certificates were introduced in Italy in 2005, as one of the first incentivising mechanisms for energy efficiency market based, with ambitious targets, covering all sectors and energy efficiency solutions, and with many flexibility options in place (e.g. non-obliged parties, tradable market, bankability, etc.). In its first phase, most of the projects were related to buildings and to simplified final use energy savings assessment method. The industrial sector was arising constantly, for interventions mostly assessed through metered savings procedures, as in many industrial activities the saving potential is very high and the investment can be multiplied by the incentive existence. Despite some operational bottleneck in the last years, it remains a very useful instrument to incentive energy efficiency. In the case of the proposed measures, it could contribute to reduce the payback of the street lamps substitution with LED.

This incentives scheme is not combinable with other grants, but it can gather up to 250€/saved toe.

For lighting interventions, the calculation method is dynamic, and it bases on the installed power and on the working hours, taking into account some technological additions related to lighting conditions. As it is defined, the algorithm of calculation of the saved energy penalizes the installation of dimming systems.

Main regulatory framework of reference and standards for the proposed actions

- Law nr. 84 - 28.01.1994 “Reorganization of port legislation” and subsequent additions and modifications (art. 1, subsection 577, L. 27 December 2017, n. 205]
- Legislative Decree169 - 4.08.2016, “Reorganization, rationalization and simplification of the regulations concerning the Port Authorities pursuant to the law 28 January 1994, nr. 84”
- ISO 14064: 2018 Greenhouse gasses

Specific regulatory framework references on energy refurbishment of buildings

- Ministerial Decree 11.03.08, Implementation of art. 1 subsection 24 letter a) of the law 24.02.07/244 for the definition of the limit values of annual primary energy demand and thermal transmittance for the purposes of application of par. 344 and 345 of art.1 Law 27.12.06/296, 2008
- Ministerial Decree 26.06.09, National guidelines for energy certification of buildings, 2009
- Republic President Decree nr. 59/2009, Implementation regulation of art. 4, par. 1, letters a) and b) od legislative decree 19 August 2005, nr. 192, concerning the implementation of the directive and subsequent additions and modifications
- Legislative Decree 3 March 2011, nr 28 Implementation of the directive 2009/28/EC on promotion of the use of renewable energy sources, modifying and subsequently repealing the directives 2001/77/EC and 2003/30/EC.
- Legislative Decree 4 July 2014, nr. 102 Implementation of the directive 2012/27/EU on energy efficiency, which amends directives 2009/125/EC AND 2010/30/EU and repeals the directives 2004/8/EC and 2006/32/EC e s.m.i.
- Ministerial Decree 16 February 2016 Update of the regulations for encouraging small-scale interventions to increase energy efficiency and to produce thermal energy from renewable sources.
- Ministerial Decree 11 January 2017, Determination of the national quantitative energy saving targets that must be pursued by electricity and gas utilities for the years 2017 to 2020 and for the approval of the new Guidelines for the preparation, execution and evaluation of energy efficiency projects

- Ministerial Decree 10 May 2018, Modification and updating of the decree 11 january 2017, concerning the determination of the national quantitative energy saving targets that must be pursued by electricity and gas utilities for the years 2017 to 2020 and for the approval of the new Guidelines for the preparation, execution and evaluation of energy efficiency projects
- Interministerial Decree 26 June 2015 – Minimum requirements - " Application of energy performance calculation methods and definition of minimum building requirements"
- Interministerial Decree 26 June 2015 - "Technical report - Schemes and reference methods for the compilation of the technical project report for the purposes of the application of the minimum energy performance requirements in buildings
- Interministerial Decree 26 June 2015 -"Energy certification"-"Adaptation of the decree of Minister of Economic Development, 26 June 2009 - National guidelines for energy certification of buildings"

Specific regulatory framework references on E-Mobility

- National Infrastructure Plan for the recharging of vehicles powered by electricity (PNiRE), approved by Decree of the President of the Council of Ministers on 26 September 2014

Specific regulatory framework references on energy efficiency

National Energy Efficiency Fund - FNEE

- Legislative Decree 4 July 2014, nr. 102
- Interministerial Decree 22 December 2017
- Interministerial Decree 5 April 2019

Thermal Energy Incentives (Conto energia Termico)

- Interministerial Decree 16 February 2016 - Update Conto termico
- Ministerial Decree 28/12/2012. Incentives for the production of thermal energy from renewable sources and small-scale energy efficiency measures.

White Certificates

- Directorial decree 30 April 2019 - White certificates. Operational guide (Ministry of Economic Development in agreement with the Ministry of the Environment and the Protection of the Territory and the Sea)
- Ministerial Decree 10 May 2018, Modification and updating of the decree 11 January 2017, concerning the determination of the national quantitative energy saving targets that must be pursued by electricity and gas utilities for the years 2017 to 2020 and for the approval of the new Guidelines for the preparation, execution and evaluation of energy efficiency projects, Ministry of Economic Development
  - Ministerial Decree 20 July 2004 New identification of national quantitative targets for energy saving and development of renewable sources, as per art. 16, paragraph 4, of Legislative Decree 23 May 2000, n. 164

7. Coordination with relevant plans

The presence of targets for the reduction of greenhouse emissions agreed at international and national level, as well as adherence to these objectives by regional and local authorities is also reflected in the strategic choices of the Port Authority, which has developed the present action plan. The increase of energy efficiency level and the CO_2 emissions reduction defined in the proposed actions is aligned with the global and local targets defined in the following relevant plans.

NECP (National Energy and Climate Plan)

The implementation of energy efficiency actions is a contribution to the achievement of local set target but also to national binding energy efficiency target as foreseen in the draft NECP (National Energy and Climate Plan) transmitted to the European Commission, where a reduction of 33% of global greenhouse emissions, compared to 2005, and a share of 30% of renewable energies in gross final energy is targeted. The final NECP should be completed by the end of 2019, the main strategies are considered confirmed.

A strong action stream herein individuated involve a transition to e-mobility, where Italy is also setting a target of 6 million electric cars by 2030.

These targets cannot be reached with a ‘business as usual’ development, therefore instruments are currently developed in order to ease the achievement of that important results, both acting on reducing barriers and introducing new subsidy models, with a special attention to the public administration.

Regional planning document - Friuli Venezia Giulia Region: The strategic plan 2018-2023

The strategic objectives of the region underline the importance of sectorial action plans for the realization of interventions towards a sustainable development: “Environmental protection represents today one of the great challenges for Europe and is among the priority objectives of the EU which is addressing environmental problems according to an overall sustainable development strategy. In the wake of the transversal integration of environmental protection targets, the Region intends to equip itself with a global and coherent sustainable development strategy, which will contribute to achieving the objectives of the national strategy. The priority is to overcome the current fragmentation in planning and manage the development of the territory with a unified government plan, which integrates environmental, territorial and sector plans. In general, the conservation of resources and the reduction of waste will be encouraged through the adoption of circular economy principles: actions will be strengthened that encourage lifestyles and coherent individual and collective behaviours for recovery, reuse and recycling waste and the efficient use of energy”[33].

Sustainable Energy Action Plan – SEAP, Municipality of Trieste

The contribution of the Port Authority is considered also in the SEAP of the municipality of Trieste, as an important stakeholder for the realization of the targets defined by the municipality. The SEAP, dated 2014, integrate the reduction in energy consumptions and in

33 http://www.regione.fvg.it/rafvg/export/sites/default/RAFVG/GEN/piano-strategico-2018/allegati/PianoStrategico_2018_2023.pdf

emissions provided by the Port Authority, listing different intervention, already realized by the port authority:

- Iso 14001
- Energy demand reduction by 15 % on 2011 consumptions
- PV plant for the generation of estimated 7,000 MWh renewable energy (measured 8500-9300 MWh/y)
- CO_2 emissions reduction

It is worth to mention that the SEAP target set in 2014 have been already reached, and that new target can be considered for the port area, having started a path towards a more sustainable port. Port Authority can motivate and engage all the port operators to develop measures contributing to more effective emission reduction, in line with the new goals of the EU and the national energy planning.

Three-years Operative Plan, Port Master Plan

In regards to the Port vision, it is included into two main documents: the Port Master Plan (Piano Regolatore Portuale - PRP) and the Three-year Operational Plan (Piano Operativo Triennale - POT). The PRP refers to the long-term planning of the Port of Trieste, while the POT gives a view of the effective operational development covering a period of three years. Moreover, the Monitoring Plan “Piano di Monitoraggio Integrato VIA-VAS (PMI)” was written following the “Piano Regolatore del Porto di Trieste (PRP)”. The Plan establishes to perform activities “in situ” concerning the following topics:

- atmosphere;
- hydraulic - groundwater;
- hydraulic - coastal marine waters and marine biocenosis;
- terrestrial - vegetation, flora, fauna and ecosystems;
- noise;
- landscape;
- energy;
- waste.

Furthermore, the monitoring system aims at monitoring the evolution of the environmental performance, identifying the negative impacts not foreseen and adopting appropriate corrective measures, defining the mechanisms for reorienting the Plan in case of unexpected negative effects.

8. Assessment design

Data collection

First steps for the collection of energy related data from concessionaires are already started, and it is crucial to communicate the impact that a complete energy use framework can have in order to redefine and improve the energy services in the port area.

Responsibility for defining the baseline lies with the Port Authority, as does the involvement of the stakeholder. Best results are commonly obtained with a participating approach, more than with the introduction of an obligation. A timeline of 6-8 months should be headed in order to have a first draft. A procedure for the continuous updating of this data bank has to be developed at the same time.

The collection of georeferenced data enriches the existing GIS, and can contribute to the communication goals.

The stakeholder engagement strategy must be developed paying a particular attention to the balance between interest and availability of the specific stakeholder. Engagement strategy can base on two-way engagement (face to face meetings, emails, phone calls) or on a sharing approach where views and project progresses are commented and updated for the definition of new targets. Where a complete involvement is not possible it is important to keep a communication channel open to provide continuous information about the project progresses and the new redefinition of goals and standards.

Issues selection

The energy framework makes it possible to identify the major consumptions and which could be the more effective intervention fields for energy efficiency. A parallel investigation should pick up possible issues or process transformations already in development by each company working in the port area, in order to consider possible synergies and to ease a switch to energy efficiency by each occurring transformation.

The optimization, in terms of energy efficiency, of existing transformation plans allows generally to reach a better cost benefit result.

Working plan

Definition of the implementation steps, times and responsibilities. Definition of transparent criteria and procedures, goals to be reached. Good communication of all these is needed in order to make a real participation possible and to highlight the results reached or the barriers encountered.

Delivering viable projects is a good step towards success.

Cost-Benefit Analysis

The decision on what to implement must be taken on the base of an evaluation of the impact on each individuated energy efficiency measure. The actual tool to achieve this goal is the realization of a Cost-Benefit Analysis (CBA).

CBA is a tool for assessing the viability of different investments that considers the future realization of costs and benefits. This approach is adopted in the methodology described here. In this sense, evaluating an investment in energy efficient or environmentally sound measure is no different from evaluating any other type of capital project. The CBA should be realized following the indication provided within the Guide to Cost-Benefit Analysis (CBA) of investment projects, published in 2008 and updated in 2014 by the European Commission.

The project CBA involves two main phases: the financial analysis, through which the profitability is evaluated, and the economic-social analysis which, starting from the economic-financial plan data of the project and transforming them into social costs and benefits, analyzes the socio-economic and environmental effects of the project, quantifying the costs and benefits for the community. The CBA requires the adoption of a common unit of measurement, of a monetary type, and concludes with the calculation of indicators such as the benefits-cost ratio (B/C), the net economic present value (NEPV) and the internal rate of economic and social performance (IRER).

In its most complex form, the CBA also includes the execution of a quantitative risk analysis (both financial and economic-social) of the project. In its simplified forms, the CBA can consist in the calculation of an indicator that summarizes only some of the most important economic items (e.g. "simplified" benefits - costs ratio) or that reports the costs expressed in physical terms (in this case it is more appropriate to speak of "cost-effectiveness analysis").

The form to be chosen depends on the nature of the investment, if public or private, on the investment amount and on the possibility to have a positive cash flow during the operational phase, coming from fees paid by customers.

Use of energy performance and emissions indicators, yearly confrontation.

Risk Assessment

In the evaluation of energy efficiency projects, it is common practice to consider the quality of the project in terms of capacity to generate sufficient income to guarantee payment of the debt.

The results of an energy efficiency intervention, however, may be affected by deviations, once achieved, compared to what was calculated in the theoretical ex-ante evaluation model. These deviations are real internal risks and it is appropriate to consider their effect in the analysis of the project, similarly to the other types of risk.

It is not possible to define with a precise quantification the level of risk, but the application of a risk assessment method allows to estimate whether this level of unpredictability can put at risk the economic sustainability of the initiative.

The risk may concern four risk components:

- Increase in the initial investment cost
- Energy savings lower than expected
- Energy production lower than expected
- Increase in management and maintenance costs.

Applying these risk components to any efficiency improvement action (both on the energy efficiency side and on the production of energy from renewable or low impact sources) it is possible to identify a first assessment threshold.

For each component, two independent risk variables are considered:

- Probability of occurrence (Very unlikely; Unlikely; Probable; Very likely)
- Impact (Low; Medium; High).

The crossing of the two independent risk variables determines the potential risk linked to a specific energy efficiency action.

The levels associated with the two risk components are given the percentage values whose intersection unambiguously defines the potential risk associated with the action to improve efficiency.

Risk	Impact		
Probability of occurrence	Low (1%)	Medium (6%)	High (17,5%)
Very unlikely (5%)	0,05%	0,30%	0,88%
Unlikely (15%)	0,15%	0,90%	2,63%
Probable (35%)	0,35%	2,10%	6,13%
Very likely (75%)	0,75%	4,50%	13,13%

Table 51- Enhancement of risk and impact levels

The percentages attributed are not absolute values, but relative indices of comparison between one action and the other.

There is a certain discretion in attributing to a power efficiency action a certain level of probability of occurrence and impact. The method adopted is based on the experience of evaluating actions to improve energy performance.

For each action, the weighed risk associated with a given component is calculated as the product between the potential risk associated with the same action and the weight of the action on the overall intervention. The reduction of the incidence of risk to a numerical value makes it possible, in fact, to construct a sensitivity analysis which, in a complex intervention, takes into account in an articulated manner the specific risks relating to the different technologies.

This generally occurs by recalculating the values relating to the investment cost, management and maintenance cost, energy saving and energy production based on the risk percentages and reconstructing, consequently, worst-case scenarios around the base scenario regarding the financial parameters.

Policies development

Following the evolution of the international and national strategies, it is important to introduce an evaluation procedure and a continuous verification/update of the energy efficiency target set, adapting the action plan to the new conditions.

9. Monitoring Plan

In order to assess the proportion of existing or planned actions aiming at improving energy rationalization and to understand thoroughly the real state of energy flows, the Port Authority needs to carry out an overall monitoring procedure, involving the entire port area.

As a matter of fact, savings cannot be directly measured, and it is fundamental to define a baseline which represents the state of the art "before" the implementation of energy efficiency interventions: the baseline is not only the gathering of energy quantity used in a defined period (one year, usually), it needs also the recording of collateral information that make possible the interpretation of the information about the energy quantities.

The calculation of savings can be expressed as follows:

Savings = (Baseline Period Energy – Reporting Period Energy) ± Adjustments

The first two values (Baseline Period Energy and Reporting Period Energy) are easy to be collected, the quality of the performance assessment is in the adjustment process.

The analysis of a building should consider a number of variables which affect the building consumption (size of the heated volume, weather and climate conditions -degree days-, occupancy level, operation period, just to mention few of them) while the analysis of a complex system like an international commercial, industrial and touristic port should consider its own affecting elements.

To clean up the data, to make them comparable in the following periods, it is necessary to investigate all the independent variables and define which final energy use they can affect.

Well selected indicators relating to the main functional unit, i.e. transported goods or passengers, can help to the normalization of the values, step needed to make any comparison possible.

Monitoring is fundamental for the definition and setting of quantitative goals, which represent the improvement targets of the local energy system, since such targets have to represent a realistic situation, reachable within a defined time frame. A continuous monitoring procedure is needed to follow progresses towards the defined targets, starting from the present situation, and eventually to make corrections in case the real evolution of the Port energy system is not moving in the defined targets direction.

A monitoring plan should achieve as an output a monitoring report with the following characteristics:

- **Accurate**: the accuracy level depends on the system which has to be monitored, and the efforts needed should be adequate to the value of the savings.
- **Complete**: the analysis of energy savings should consider all effects of a measure, taking into account also all cross effects occurring.
- **Conservative**: it is not possible to measure everything, but every estimation should avoid an overstating. The calculated benefits of energy saving should be reasonable.
- **Consistent**: the impact of the energy savings should be comparable across different evaluations periods or different evaluators.
- **Relevant**: the measurement should produce relevant information; it has to be chosen what are the main performances to be directly measured and what can be estimated.
- **Transparent**: all activities needed for the monitoring are to be reported, and all the assumptions described.

In order to implement a monitoring strategy, it is often very useful to use proper software tools, even in a simple worksheet form. Such tools should allow to track the energy balance of the port community, considering its historical trend. Both the actions and the tools necessary for their implementation need to be taken into account by the software.

Tools can be described considering their development phases, while actions can be described with respect to quantitative parameters. According to these parameters, the new energy consumption will be estimated. It is important that beside the target scenario based on the energy rationalization actions, the business as usual scenario is represented. This allows to make a comparison and evaluate the real advantage of the planned actions with respect to a standard trend.

At the end of the analysis, a summarizing table will show the evolution of the energy system of the community according to the BAU scenario and according to the target scenario. At this point it will be important to compare the target scenario to the real consumption of the community. In such a way, differences will be highlighted and corrections will be possible.

Each selected action/tool will first be described according to the reference following scheme:

Actions (A) / Tools (T)	Type of action/tool	Time horizont	Final users involved	Involved stakeholders	Type of financing

Table 52. Scheme for the monitoring plan

Actions /tools results shall be then qualitatively and/or quantitatively evaluated and monitored with respect to defined targets, through:

- the definition of one or more specific "performing indicator", like the proposed KPIs;
- the evaluation of the correlated final energy consumptions (MWh) and CO_2 emissions reduction

The monitoring frequency in time will be strictly related to the type and complexity of the action/tool analysed, but a yearly evaluation is considered as an appropriated measure, good enough to evaluate possible internal trends and to contribute to monitoring processes defined at an higher level, as municipal or regional, or even national level.

Summary of Figures

Summary of Graphs

Summary of Tables

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European Regional Development Fund - Instrument for Pre-Accession II Fund
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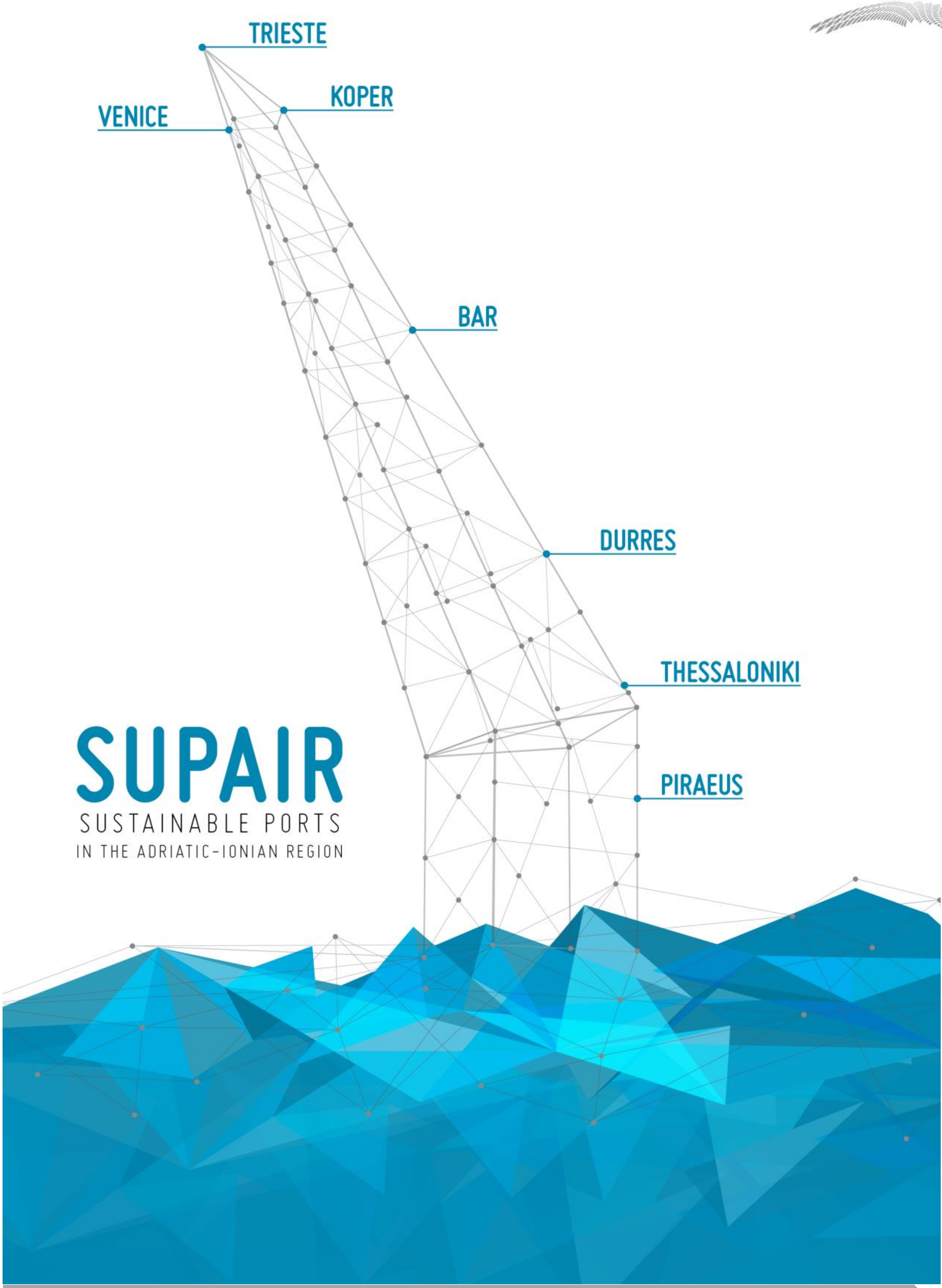

Annex I
Calculation of atmospheric emissions deriving from naval activities in the Port of Trieste

Area Science Park – International Projects Office

10th January 2020

Project co-funded by ERDF and IPA II fund

Index

1. Introduction

Energy consumption is one of the most significant environmental impacts deriving from naval activity. The production of combustion gasses comes from the use of fossil fuels that locally alter air quality and contribute to global climate-changing action. One possible way to limit the greenhouse effect is to restrict the introduction of climate-altering gasses into the atmosphere, or to reduce energy production from combustion processes.

This study is a technical supporting annex connected to the SUPAIR project deliverable DT 1.3.1 "Action Plan for a Sustainable and Low Carbon Port of Trieste". It aims to provide the Port of Trieste with a calculation of the carbon footprint related to the vessel sector emissions, also considering the main pollutants produced in the port of Trieste due to the sources directly attributable to the shipping activities nearby the port. In order to proceed with the calculation a study has been conducted aiming at defying the best methodological process for the calculation itself. Different existing methodologies has been assessed and a new tailor-made calculation approach has been developed in order to provide a useful instrument for the future monitoring process.

In line with the Port of Trieste main regulatory framework of reference, this analysis is based on what the Ministry of the Environment and the Protection of the Land and the Sea requires with the "Guidelines of for the preparation of the DEASP[1]".

The carbon footprint method re-elaborates energy consumption transforming it into equivalent carbon dioxide emitted and integrates it into the DEASP as an aid tool for planning in terms of energy supply and consumption within the port area.

With the calculation results presented in this study it will be possible to estimate the present levels of polluting emissions in the Port of Trieste with specific regard to the shipping sector.

The calculation of the polluting emissions produced by the naval activities in the ports is very complex and articulated due to the high heterogeneity of the ship types, their mechanical characteristics, the operations, the engine power and the times used for the various operations.

This document is divided into two main sections.

In the first one the working methodology will be described according to the main consulted sources, the databases that have been purchased and the calculation assumptions that have been adopted.

In the second part the carried-out elaborations, various statistics and the main results of the carbon footprint will be reported.

[1] "*Documenti di Pianificazione Energetico Ambientale dei Sistemi Portuali" that is Environmental Energy Planning Documents for Port Systems, see more at* *https://www.minambiente.it/sites/default/files/archivio/notizie/CLE/lg_deaspfinale.pdf*

2. Work methodology

2.1 Ship classification

AdSPMAO provided the list of the ships that entered the Port of Trieste in 2018 and the related hotelling time at berth. The data source in this case was the Port Community System of the Port of Trieste named "Sinfomar", which is based on customs declarations

As a preliminary statistical study, the ships were divided into categories according to their main technical characteristics, in order to produce graphs and tables that illustrate various aspects of the naval traffic in 2018 (year of construction, ship type, type of fuels, dimensions, type of propulsion, type of engines, ESI index[2]).

The ship types examined in this study are the following with their respective classifications:

- **Bulk carriers:**
  - Bulk dry;
  - Other bulk dry.
- **Dry Cargo/Passenger:**
  - Container;
  - General Cargo and other dry cargo;
  - Passenger;
  - Passenger Cruise;
  - Passenger/Ro-Ro cargo;
  - Ro-Ro cargo.
- **Miscellaneous:**
  - Tug.
- **Tankers:**
  - Chemical;
  - Oil.

Some of them are characterized by a high number of arrivals, prolonged dwell times and high installed power.

Data on average monthly fuel consumption and the quantity of fuel purchased in 2018 were also received from the companies operating with the tugs.

We also followed the IMO Ship Number Scheme according to Statcode 5 shiptype coding system. In fact to maintain comprehensive and accurate databases IHS Markit has developed over a period of time a number of key strategic agreements with governmental and inter-governmental organisations. IHS Markit has recently launched a new, versatile and expandable shiptype coding system. The new system takes coding to a new level of detail and was created to meet the demands of both a changing industry and the requirements of those wishing to perform either aggregated analysis or analysis on individual vessel types(*see more at https://ihsmarkit.com/products/imo-ship-company.html*).

[2] ESI - Environmental Ship Index which, among other emission factors (NO_x, SO_x and CO_2 emissions), also indicates the existence of the OPS - On-shore Power Supply electrical interface. http://www.environmentalshipindex.org/Public/Home/ESIFormulas

There are multiple different vessel type data coding systems in use today. Of all the systems currently existing, no one completely meets the desired requirements. Many coding systems are now out of date and too inflexible to meet the ever-changing technological face of shipping.

Following to this classification, we have also divided the ships according to the capacity bin.

Please refer to the two tables below.

Ship group	Class	Subclass	Statcode5 designations	
Cargo-carrying transport ships	Bulk carrier	Bulk Dry	A21A2BC	Bulk Carrier
			A21A2BG	Bulk Carrier, Laker Only
			A21A2BV	Bulk Carrier (with Vehicle Decks)
			A21B2BO	Ore Carrier
		Other Bulk Dry	A24A2BT	Cement Carrier
			A24B2BW	Wood Chips Carrier
			A24B2BW	Wood Chips Carrier, Self-unloading
			A24C2BU	Urea Carrier
			A24D2BA	Aggregates Carrier
			A24E2BL	Limestone Carrier
			A24G2BS	Refined Sugar Carrier
			A24H2BZ	Powder Carrier
		Self-discharging Bulk Dry	A23A2BD	Bulk Cargo Carrier, Self-discharging
			A23A2BD	Bulk Carrier, Self-discharging
			A23A2BK	Bulk Carrier, Self-discharging, Laker
		Bulk Dry/Oil	A22A2BB	Bulk/Oil Carrier (OBO)
			A22B2BR	Ore/Oil Carrier
	Chemical Tanker	Chemical	A12A2TC	Chemical Tanker
			A12B2TR	Chemical/Products Tanker
			A12E2LE	Edible Oil Tanker
			A12H2LJ	Fruit Juice Tanker
			A12G2LT	Latex Tanker
			A12A2LP	Molten Sulphur Tanker
			A12D2LV	Vegetable Oil Tanker
			A12C2LW	Wine Tanker
	Container	Container	A33A2CR	Container Ship (Fully Cellular with Ro-Ro Facility)
			A33A2CC	Container Ship (Fully Cellular)
			A33B2CP	Passenger/Container Ship
	General cargo	General cargo	A31A2GA	General Cargo Ship (with Ro-Ro facility)
			A31A2GE	General Cargo Ship, Self-discharging
			A31A2GO	Open Hatch Cargo Ship
			A31A2GT	General Cargo/Tanker
			A31A2GX	General Cargo Ship
			A31B2GP	Palletised Cargo Ship
			A31C2GD	Deck Cargo Ship
		Other Dry Cargo	A38A2GL	Livestock Carrier
			A38B2GB	Barge Carrier
			A38C2GH	Heavy Load Carrier
			A38C3GH	Heavy Load Carrier, semi submersible
			A38C3GY	Yacht Carrier, semi submersible
			A38D2GN	Nuclear Fuel Carrier
			A38D2GZ	Nuclear Fuel Carrier (with Ro-Ro facility)
		Passenger/General Cargo	A32A2GF	General Cargo/Passenger Ship
	Liquefied gas tanker	Liquefied Gas	A11C2LC	CO_2 Tanker
			A11A2TN	LNG Tanker
			A11B2TG	LPG Tanker
			A11B2TH	LPG/Chemical Tanker
	Oil tanker	Oil	A13C2LA	Asphalt/Bitumen Tanker
			A13E2LD	Coal/Oil Mixture Tanker
			A13A2TV	Crude Oil Tanker
			A13A2TW	Crude/Oil Products Tanker
			A13B2TP	Products Tanker
			A13A2TS	Shuttle Tanker
			A13B2TU	Tanker (unspecified)
	Other liquids tanker	Other liquids	A14H2LH	Alcohol Tanker
			A14N2LL	Caprolactam Tanker
			A14F2LM	Molasses Tanker
			A14A2LO	Water Tanker
	Ferry – pax only	Passenger	A37B2PS	Passenger Ship
	Cruise	Passenger	A37A2PC	Passenger/Cruise
	Ferry – ro-pax	Passenger/Ro-Ro Cargo	A36B2PL	Passenger/Landing Craft
			A36A2PR	Passenger/Ro-Ro Ship (Vehicles)
			A36A2PT	Passenger/Ro-Ro Ship (Vehicles/Rail)
	Refrigerated cargo	Refrigerated Cargo	A34A2GR	Refrigerated Cargo Ship
	Ro-ro	Ro-Ro Cargo	A35C2RC	Container/Ro-Ro Cargo Ship
			A35D2RL	Landing Craft
			A35A2RT	Rail Vehicles Carrier
			A35A2RR	Ro-Ro Cargo Ship
	Vehicle	Ro-Ro Cargo	A35B2RV	Vehicles Carrier
Non-merchant ships	Yacht			
	Miscellaneous - fishing			
Non-seagoing merchant ships	Miscellaneous - other			
Work ships	Service - tug			
	Offshore			
	Service - other			

Statcode	Class	Capacity bin	Values		Units
A2	Bulk carrier	0 - 9999	0	9.999	dwt
		10000 - 34999	10.000	34.999	
		35000 - 59999	35.000	59.999	
		60000 - 99999	60.000	99.999	
		100000 - 199999	100.000	199.999	
		200000 - +	200.000	∞	
A12	Chemical Tanker	0 - 4999	0	4.999	dwt
		5000 - 9999	5.000	9.999	
		10000 - 19999	10.000	19.999	
		20000 - +	20.000	∞	
A33	Container	0 - 999	0	999	TEU
		1000 - 1999	1.000	1.999	
		2000 - 2999	2.000	2.999	
		3000 - 4999	3.000	4.999	
		5000 - 7999	5.000	7.999	
		8000 - 11999	8.000	11.999	
		12000 - 14500	12.000	14.500	
		14500 - +	14.500	∞	
A3	General cargo	0 - 4999	0	4.999	dwt
		5000 - 9999	5.000	9.999	
		10000 - +	10.000	∞	
A11	Liquefied gas tanker	0 - 49999	0	49.999	cubic metres (cbm)
		50000 - 199999	50.000	199.999	
		200000 - +	200.000	∞	
A13	Oil tanker	0 - 4999	0	4.999	dwt
		5000 - 9999	5.000	9.999	
		10000 - 19999	10.000	19.999	
		20000 - 59999	20.000	59.999	
		60000 - 79999	60.000	79.999	
		80000 - 119999	80.000	119.999	
		120000 - 199999	120.000	199.999	
		200000 - +	200.000	∞	
A14	Other liquids tanker	All sizes	0	∞	dwt
A37B2PS	Ferry – pax only	0 - 1999	0	1.999	gt
		2000 - +	2.000	∞	
A37A2PC	Cruise	0 - 1999	0	1.999	gt
		2000 - 9999	2.000	9.999	
		10000 - 59999	10.000	59.999	
		60000 - 99999	60.000	99.999	
		100000 - +	100.000	∞	
A37A2P*	Ferry – ro-pax	0 - 1999	0	1.999	gt
		2000 - +	2.000	∞	
A34A2GR	Refrigerated cargo	0 - 1999	0	1.999	dwt
A35	Ro-ro	0 - 4999	0	4.999	gt
		5000 - +	5.000	∞	
A35B2RV	Vehicle	0 - 3999	0	3.999	vehicles
		4000 - +	4.000	∞	
-	Yacht	All sizes	0	∞	gt
-	Miscellaneous - fishing	All sizes	0	∞	gt
-	Miscellaneous - other	All sizes	0	∞	gt
-	Service - tug	All sizes	0	∞	gt
-	Offshore	All sizes	0	∞	gt
-	Service - other	All sizes	0	∞	gt

2.1.1 ESI - Environmental Ship Index

The Environmental Ship Index (ESI) identifies seagoing ships that perform better in reducing air emissions than required by the current emission standards of the International Maritime Organization (IMO).

The ESI evaluates the amount of nitrogen oxide (NO_x) and sulphur oxide (SO_x) that is emitted by a ship; it includes a reporting scheme on the greenhouse gas emission of the ship. The ESI is a perfect indicator of the environmental performance of the vessels and will assist in identifying cleaner ships in a general way.

ESI is completely voluntary: the index is intended to be used by ports to reward ships when they participate in the ESI and will promote clean ships, but can also be used by shippers and ship owners as their own promotional instrument. It should be noted that while the ESI database will provide a total score, the rewards can either be based on that total or on each of its constituent parts separately; for that purpose, those parts are appearing in the ship details. (*see more at https://www.environmentalshipindex.org/Public/Home*).

We made a request directly to ESI organization and we found that 196 ships out of 581 have an ESI score. It is interesting to note that the ESI index provides information on the possibility to power the ship at berth through the on-shore power supply (OPS) system: 19 ships (out of the 198 that have the ESI score) have this feature[3].

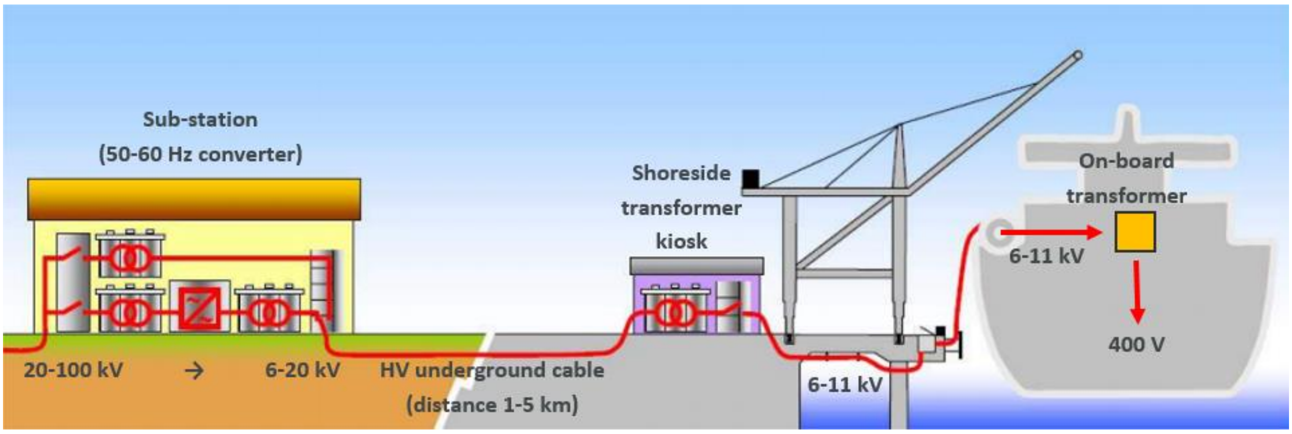

Figure 1 - OPS system (source: onthemosway.eu)

Please note that data we received were referred to the first six months of 2019, and not to 2018 (as the ships' data provided by AdSPMAO).

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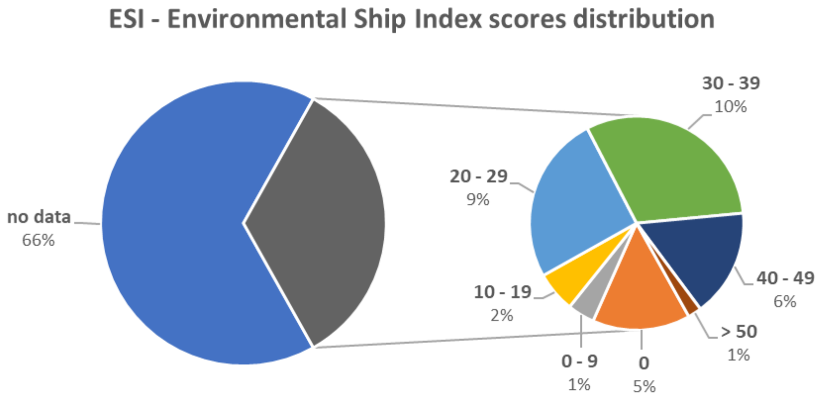
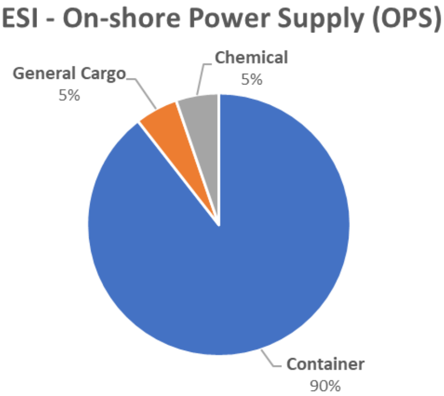
[3] *The "zero" value does not mean a bad score but could be related to a lack of data.*

ESI score	n° of vessels
no data	385
0	29
0 - 9	8
10 - 19	12
20 - 29	50
30 - 39	61
40 - 49	32
> 50	4
TOTAL:	**581**



OPS - On-shore Power Supply		
Shiptype Level 2	**Shiptype Level 3**	**N° of vessels**
Dry Cargo/Passenger	Container	17
	General Cargo	1
Tankers	Chemical	1
	Total:	**19**



2.2 Instruments and bibliography

UNI EN ISO 14064 norm was purchased. For the purpose of this study UNI EN ISO 14064-1:2019 ("*Greenhouse gases - Part 1: Specification with guidance at the organization level for quantification and reporting of greenhouse gas emissions and removals*") was mainly consulted.

A research on the methods for calculating the atmospheric emissions (both climate-altered and polluting) of the ships was carried out. Many documents were found, in particular:

- EMEP/EEA Air Pollutant Emission Inventory Guidebook 2016, from European Energy Agency,
- Ship Emission Toolkit from IMO,
- Fifth Assessment Report (2014) and others from IPCC,

together with many documents from other port authorities related to energy efficiency and carbon footprint.

A deep search for a database with technical ship data (type of engine, type of used fuel, year of construction...) has been conducted. Several sources have been evaluated (Lloyd Register, Marine Traffic and IHS Markit) and at the end the ship dataset from IHS Markit was purchased as it is considered the most complete and reliable. In fact, IHS Markit issues IMO numbers on behalf of the United Nations and collects all the information necessary to issue this unique identification number from the shipowners. Moreover, also the IMO 3rd Greenhouse Gas Study 2014 used this database as a source for the technical specifications of the ships of the world fleet.

2.3 Timing of port movements

The stationing times in harbor, collected using the Sinfomar system, have been provided by AdSPMAO, while manoeuvring times have been provided by the Association of Pilots of the Gulf of Trieste.

Arrival, manoeuvering and departure times of each ship are known. Starting from these data, we can define:

- Arrival time, i.e. the time that elapses between the time of entry into port and the time of mooring at the assigned berth;
- Maneuvering or internal movement time, i.e. the time that elapses between unmooring from the approach and mooring to the new berth;
- Hotelling time, i.e. the time that elapses between the time of mooring and that of unmooring;
- Departure time, i.e. the time that elapses between the time of unmooring and the time the ship leaves the port.

These calculations were carried out for each ship operating in the port of Trieste and were filtered based on the ship type.

2.4 Power and Energy calculation

Three modes of operations are commonly included in seagoing vessel emissions inventories: transit, manoeuvring and hoteling, but in this report the carbon footprint calculation is referred only to manoeuvring and hoteling within the port area of Trieste leaving out the navigation phase that takes place outside the area of competence of the port.

Descriptions of these modes are provided below.

- *Manoeuvring* – during this mode, a ship is operating within confined channels and within the harbor approaching or departing its assigned berth. The distance of this mode is unique for each port depending on geographical configuration of the port:
  - Ship is transiting at its slowest speeds;
  - Propulsion engines are operating at low loads;
  - Auxiliary engine loads are at their highest load of any mode as additional on-board equipment such as thrusters, air scavengers/blowers and additional generators are online in case an auxiliary engine/generator fails;
  - Auxiliary boilers are on because the economisers are not functioning due to low propulsion engine loads; this may not apply to large diesel-electric vessels, which produce sufficient exhaust heat to power economisers at manoeuvring speeds; and
  - Fuel consumption is very low for the propulsion system, is highest for the auxiliary engines and low for the auxiliary boilers.
- *Hotelling* – during this mode, a ship is either docked at a berth (at-berth) or anchored (at-anchorage):
  - Ship is not moving;
  - Propulsion engines are off;
  - Auxiliary engine loads can be high if the ship is self-discharging its cargo at-berth, as with self-discharging general cargo vessels, bulk liquids, auto carriers and RoRos or at-anchorage at a loading tanker buoy or during mid-stream operations;20
  - Auxiliary boilers are usually operated at-berth to keep the propulsion engine and fuel systems warm in case the ship is ordered to leave port on short notice, for crew amenities and, for certain

types of tanker, for off-loading cargo through the use of steam-powered pumps at-berth or at-anchorage loading buoys;

- Fuel consumption can be medium to high for auxiliary engines and can be medium to very high for boilers.

The ships are then divided by type and size following the methodology used by the 3rd IMO GHG Study 2014 and in particular following the "*Ship Type Level 3 classification*" so as to be able to assign them the values of average power generated by the auxiliary engines and on-board boilers in the phases of maneuvering and hoteling.

Furthermore, the ships are subdivided according to the year of construction in order to calculate more accurately the values for NOx emissions following the IMO classification for engines (IMO Level 0, I, II, III).

To do this a *.xls* file was created for each ship type together with a sheet for each type of engine (SSD MSD/HSD[4]) and size class (GT/dwt/TEU[5]).

The energies that are absorbed by the ships during each phase are calculated following the methodology described by the IMO toolkits, multiplying the maximum power of the main engine and of the generators by specific power coefficients for the times of each phase. The maximum powers of the main engines and generators of all the ships operating in the port under study were obtained from the IHS Markit database.

The energies absorbed by the main engines of the ships have been calculated by multiplying the maximum powers of the prime engines for the duration of each phase, by a load factor depending on the speed of the ship during the specific phase.

The energies of the auxiliary generators have been calculated by multiplying the maximum power absorbed by these for the duration time of each phase by another load coefficient. This calculation has been very complex because of the heterogeneity of the plant configurations and the management of loads used by fleets worldwide.

Phase	% load of MCR Main Engine	% time all Main Engine Operating	% load of MCR Auxiliary Engine
Cruise	80	100	30
Manoeuvring	20	100	50
Hotelling (except tankers)	20	5	40
Hotelling (tankers)	20	100	60

Estimated % load of MCR (maximum Continuous Rating) of Main and Auxiliary Engine for different ship activity (Source: Entec (2002) according to EEA Report No 21/2016 "EMEP/EEA air pollutant emission inventory guidebook 2016")

2.5 Polluting emissions and greenhouse gases calculation

The greater level of detail proposed by the guidelines (Tier 3) has been used in this document, therefore the total emissions that will be calculated will be the sum of different emission contributions.

$$E = E_{\text{Manouvering}} + E_{\text{Hotelling}} \ (+ E_{Anchorage})$$

[4] *SSD – Slow Speed Diesel, MSD – Medium Speed Diesel, HSD – High Speed Diesel*

[5] *GT (Gross Tonnage) and TEU (Twenty-foot Equivalent Unit) is a measure of size, while DWT (Dead Weight Tonnage) is a measure of mass.*

Two different procedures are available for Tier 3 methodology: the first is based on fuel consumption and the second one on engine power. Since the data provided by the AdSPMAO do not include the fuel consumption of the ships that transited through the port of Trieste in 2018, the procedure "*Estimate of emissions based on engine power*" was used. Instead the calculation procedure based on fuel consumption was used for the tugs.

Each ship was characterized by category and type of engine and fuel class; the installed power of the main and the auxiliary engines was recorded. The source of all the technical specifications was IHS Markit database, a ship register which provides the size and type of engine of the individual ships.

All emissions analyzed here, except for HFC, PFC and SF_6, result from fuel combustion and are therefore calculated by multiplying fuel consumption (or energy consumption) with an emissions factor. The emissions factors depend on the type of fuel and may also be affected by engine modifications.

The following pollutants were estimated as part of this study:

- **CARBON DIOXIDE (CO_2):** the carbon content of each fuel type is constant and is not affected by engine type, duty cycle or other parameters when looking based on kg CO_2 per tonne fuel. The fuel-based CO2 emissions factors for main and auxiliary engines at slow, medium and high speeds are based on ME PC 63/23, annex 8;
- **NITROGEN OXIDES (NO_X):** Nitrogen oxide is formed when oxygen and nitrogen react under high pressure or at high temperatures, such as in engines. NO_x emissions from marine engines are regulated in terms of g/kWh and depend on the date of the construction of a ship and on the engine's rated speed (according to three levels: Tier 1, Tier 2 and Tier 3).
- **SULPHUR OXIDES (SO_X):** The emissions of SO2 result from the combustion of sulphur that is present in petroleum-derived fuels. Emissions factors will decrease as a result of MAR POL Annex VI regulations.
- **PARTICULATE MATTER (PM):** The emissions of particulate matter result from incomplete combustion of fuels and from the formation of sulphate particles, which is a result of sulphur emissions. They are assumed to be constant over time.
- **CARBON MONOXIDE (CO):** The emissions of carbon monoxide result from incomplete combustion of fuels. They are assumed to be constant over time.
- **METHANE (CH_4)**: Methane emissions result from combustion of heavy fuel oils and distillates and from incomplete emissions of LNG. The emissions factors are constant over time.CH_4 emissions are approximately 2% magnitude of VOC. Therefore, the $EF_{baseline}$ is derived from multiplying the NM VOC $EF_{baseline}$ by 2%. This pollutant is affected by neither fuel type nor fuel sulphur content and therefore FCFs (Fuel Correction Factors) are not used for it.
- **NITROUS OXIDE (N_2O):** Nitrous oxide results from the combustion of fuels. Its emissions factors are constant over time.
- **NON-METHANE VOLATILE ORGANIC COMPOUNDS (NM VOC):** The emissions of non-methane volatile organic compounds result from incomplete combustion of fuels. They are assumed to be constant over time.

Exhaust gas emissions from ships are generated by on-board boilers that serve different purposes depending on the type of ship.

The assumed baseline fuel for the Emission Factors baseline ($EF_{baseline}$) is Heavy Fuel Oil (*HFO*) with 2,7% Sulphur content.

Emissions factors come in two groups: energy-based in $g_{pollutant}$/kWh and fuel-based in $g_{pollutant}/g_{fuel\ consumed}$.

The chosen methodology for large ships is based on the calculation of emissions based on the absorbed energy (g/kWh) according to Tier 3 of EMEP/EEA and the IMO GHG Study methodology.

GHG / Pollutant	Engine Type	Main EF g/kWh	Aux EF (average) g/kWh	Boilers EF g/kWh
CO_2	SSD	620	na	970
	MSD	683	706	
	HSD			
CH_4	SSD	0,012	na	0,00
	MSD	0,010	0,008	
	HSD			
N_2O	SSD	0,031	na	0,08
	MSD	0,034	0,036	
	HSD			

NO_x	SSD	Tier 0	18,1	na		2,1
		Tier I	17,0			
		Tier II	15,3			
		Tier III	3,6			
	MSD HSD	Tier 0	14,0	Tier 0	13,15	
		Tier I	13,0	Tier I	11,7	
		Tier II	11,2	Tier II	9,7	
		Tier III	2,8	Tier III	2,45	
SO_x	SSD		10,29	na		16,10
	MSD		11,35	11,98		
	HSD					
PM_{10}	SSD		1,42	na		0,93
	MSD		1,43	1,44		
	HSD					
$PM_{2,5}$	SSD		1,34			0,87
	MSD			1,35		
	HSD					
CO	SSD		1,40	na		0,20
	MSD		1,10	1,00		
	HSD					
VOC	SSD		0,60	na		0,10
	MSD		0,50	0,40		
	HSD					

Polluting emissions based on energy consumption

The same table is shown below with all the sources:

GHG / Pollutant	Engine Type	Tier	Main EF g/kWh	Source	Aux Engine	Aux Tier	Aux EF g/kWh	Source	Aux Tier (average)	Aux EF (average) g/kWh	Boilers EF g/kWh	Source
CO_2	SSD		620	Port Emissions Toolkit			na	MEPC 63/23, Annex 8		na	970	Port Emissions Toolkit
	MSD		683	Port Emissions Toolkit			722	Port Emissions Toolkit		706		
	HSD						690	Port Emissions Toolkit				
NO_x	SSD	Tier 0	18,1	Port Emissions Toolkit			na	IMO Standard		na	2,1	Port Emissions Toolkit
	SSD	Tier I	17,0	Port Emissions Toolkit								
	SSD	Tier II	15,3	Port Emissions Toolkit								
	SSD	Tier III	3,6	Port Emissions Toolkit								
	MSD HSD	Tier 0	14,0	Port Emissions Toolkit	MSD	Tier 0	14,7	Port Emissions Toolkit	Tier 0	13,15		
					MSD	Tier I	13,0	Port Emissions Toolkit				
	MSD HSD	Tier I	13,0	Port Emissions Toolkit	MSD	Tier II	11,2	Port Emissions Toolkit	Tier I	11,7		
					MSD	Tier III	2,8	Port Emissions Toolkit				
	MSD HSD	Tier II	11,2	Port Emissions Toolkit	HSD	Tier 0	11,6	Port Emissions Toolkit	Tier II	9,7		
					HSD	Tier I	10,4	Port Emissions Toolkit				
	MSD HSD	Tier III	2,8	Port Emissions Toolkit	HSD	Tier II	8,2	Port Emissions Toolkit	Tier III	2,45		
					HSD	Tier III	2,1	Port Emissions Toolkit				
SO_x	SSD		10,29	Port Emissions Toolkit			na	Mass balance		na	16,10	Port Emissions Toolkit
	MSD		11,35	Port Emissions Toolkit			11,98	Port Emissions Toolkit		11,98		
	HSD						11,98	Port Emissions Toolkit				
PM_{10}	SSD		1,42	USEPA 2007			na	USEPA 2007		na	0,93	Port Emissions Toolkit
	MSD		1,43	USEPA 2007			1,44	USEPA 2007		1,44		
	HSD						1,44	USEPA 2007				
$PM_{2,5}$	SSD		1,34	Port Emissions Toolkit							0,87	Port Emissions Toolkit
	MSD						1,35	Port Emissions Toolkit		1,35		
	HSD						1,35	Port Emissions Toolkit				
CO	SSD		1,40	Port Emissions Toolkit			na	Sarvi et al. 2008		na	0,20	Port Emissions Toolkit
	MSD		1,10	Port Emissions Toolkit			1,10	Port Emissions Toolkit		1,00		
	HSD						0,90	Port Emissions Toolkit				
CH_4	SSD		0,012	IVL 2004			na	IVL 2004		na	0,00	Port Emissions Toolkit
	MSD		0,010	IVL 2004			0,008	IVL 2004		0,008		
	HSD						0,008	IVL 2004				
N_2O	SSD		0,031	USEPA 2014			na	USEPA 2014		na	0,08	Port Emissions Toolkit
	MSD		0,034	USEPA 2014			0,036	USEPA 2014		0,036		
	HSD						0,036	USEPA 2014				
VOC	SSD		0,60	Port Emissions Toolkit			na	ENTEC 2002		na	0,10	Port Emissions Toolkit
	MSD		0,50	Port Emissions Toolkit			0,40	Port Emissions Toolkit		0,40		
	HSD						0,40	Port Emissions Toolkit				

Polluting emissions based on energy consumption with all the bibliographical references

Please note that the average Aux EF (for auxiliary engine) is classified only according to the Tier (it is an average value between MSD e HSD) as the kind of engine is unknown (MSD/HSD).

For tugboats the chosen methodology is based on the fuel consumption (kg/t_{fuel}) with a Tier 1 level.

GHG/Pollutant	kg/t fuel	Source
CO_2	3,206	3rd IMO GreenHouse Gas Study 2014. Annex 6
CH_4	0,056	
N_2O	0,16	

NO_x	78,5	EMEP EEA air pollutant emission inventory guidebook 2016. 1.A.3.d Navigation (shipping) 2016 - Table 3-2 - pag. 14
SO_x	20,0	
PM_{10}	1,5	
$PM_{2,5}$	1,4	
CO	7,4	
VOC	2,8	

Polluting emissions based on fuel consumption

The final emission results consist in the calculation of the emissions for each ship category and type of engine / fuel class by multiplying the total time elapsed in each phase by the installed power of the main and auxiliary engine, for each ship category, for the load factors and for the emission factors.

The conversion table from kWh or from t_{fuel} to kg of GHG or pollutants was constructed according to available data from technical literature, while the values relating to the Global Warming Potential (GWP) derive from Table 8.A.1 of the Annex 8. A "*Lifetimes, Radiative Efficiencies and Metric Values*" of the 5th IPCC Assessment Report.

Gas	GWP_{100}	Source
CO_2	1	Appendix 8.A: Lifetimes, Radiative Efficiencies and Metric Values - Table 8.A.1 - IPCC 5AR - WGI
CH_4	28	
N_2O	265	

Global Warming Potential of Greenhouse gasses

2.5.1 What is CO_2-equivalent (CO_2-eq) emission

The amount of carbon dioxide (CO_2) emission that would cause the same integrated *radiative forcing*, over a given time horizon, as an emitted amount of a greenhouse gas (GHG) or a mixture of GHGs. The CO_2-equivalent emission is obtained by multiplying the emission of a GHG by its Global Warming Potential (GWP) for the given time horizon (see WGI Chapter 8, Table 8.A.1 and WGIII Annex II.9.1 for GWP values of the different GHG_s used here). For a mix of GHGs it is obtained by summing the CO_2-equivalent emissions of each gas. CO_2-equivalent emission is a common scale for comparing emissions of different GHG_s but does not imply equivalence of the corresponding climate change responses. There is generally no connection between CO_2-equivalent emissions and resulting CO_2-equivalent concentrations. {WGI, III} (*source: IPCC Fifth Assessment Report (AR5) - Synthesis Report: Climate Change 2014 - Annex II - Glossary (page 121*).

2.5.2 Non combustion emissions

Emissions from HFCs (Hydrofluorocarbons) result from leaks from cooling systems and air conditioners. They do not emerge from fuel combustion but are assumed to be driven by the number of ships. There are several HFCs with different GWPs. The most relevant are presented in the following table.

R-22	R-22 (chlorodifluoromethane) has been the dominant refrigerant in air conditioners used on board
R-134a	R134a (1,1,1,2-Tetrafluoroethane) is used as a **replacement for R-22 in vessels built from 2000 onwards**
R-404a	R404a is a mixture of R125, R143a and R134a. **It is used predominantly in fishing vessels but also in freezing and cooling equipment in other vessels.**

Most relevant HFCs

Assuming that ships built before 2000 have a 25-year lifetime, R-22 will have become obsolete in shipping by 2025. We do not model that other HFCs will be phased out, that air conditioner leakage rates will change or that other coolants will replace HFCs.

	2012		
	before	after	after
	2000	2000	2000
Ship class	R-22	R-134a	R-404a
Bulk carrier	0,031	0,031	0,002
Chemical tanker	0,024	0,038	0,003
Container	0,027	0,035	0,002
General Cargo	0,037	0,025	0,002
Liquified gas tanker	0,031	0,031	0,002
Oil tanker	0,023	0,039	0,003
Other liquid tankers	0,023	0,039	0,003
Ferry - pax only	0,061	0,041	0,002
Cruise	0,76	0,488	0,033
Ferry - ro-pax	0,071	0,032	0,001
Refrigerated bulk	0,935	0,007	0,118
Ro-ro	0,075	0,028	0,001
Vehicle	0,027	0,034	0,002

HFC emissions per ship (tons per year)

PFC: The main application of PFCs on board ships that is of relevance is fire-fighting foams of the type AFFF (aqueous film-forming foam). In recent years, PFCs have been phased out by major manufacturers. Therefore, and because leakage from remaining stockpiles is regarded as negligible*, we do not project PFC emissions from international shipping.

SF6: Sulphur hexafluoride is not used on board ships to any significant degree. Supplies of SF6 are distributed and transported in compressed gas cylinders. Significant emissions of SF6 from shipping are not expected.

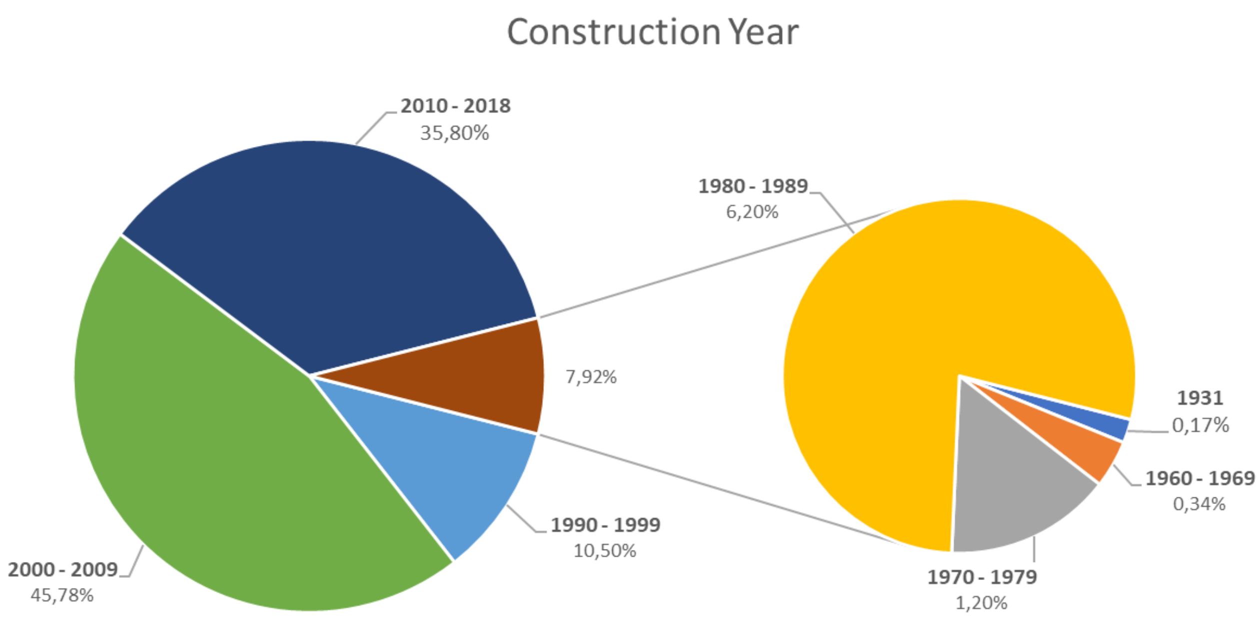
3. Calculations and results

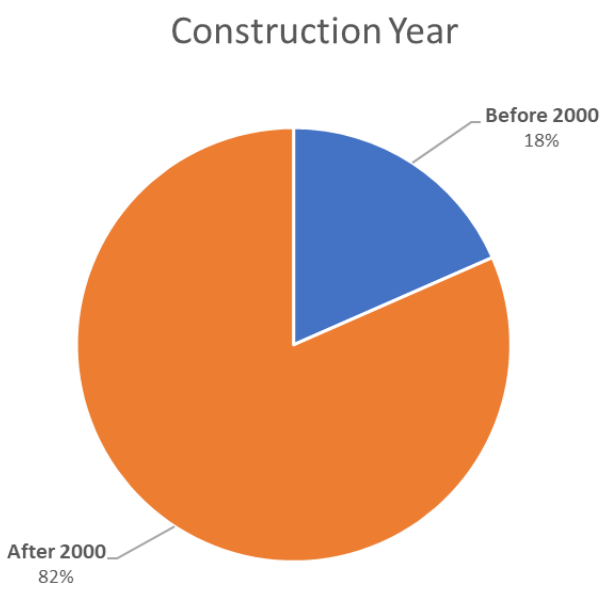
3.1 Statistics on the naval fleet under study

All the following elaborations regarding the statistics of the reference naval fleet derive from the database IHS Maritime Bespoke data.

3.1.1 Year of build

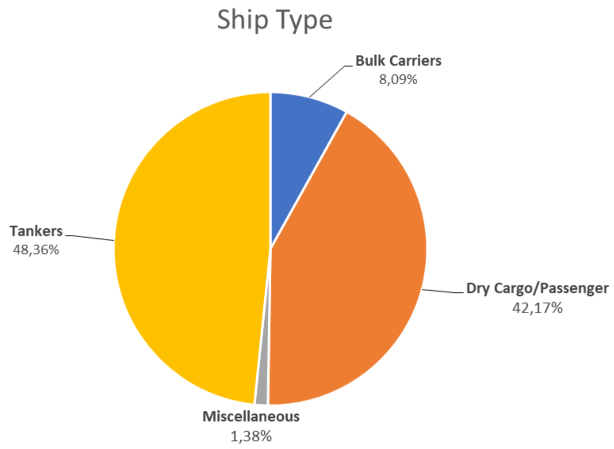
Year of build	Shiptype Level 3	Shiptype Level 5	N° of vessels	%	total	% decade	% before/after 2000
1931	Passenger	Passenger/Cruise	1	100%	1	0,17%	18,42%
1960 - 1969	Other Bulk Dry	Cement Carrier	1	50%	2	0,34%	
	Towing / Pushing	Tug	1	50%			
1970 - 1979	Bulk Dry	Bulk Carrier	2	29%	7	1,20%	
	General Cargo	General Cargo Ship	1	14%			
	Other Bulk Dry	Cement Carrier	2	29%			
	Passenger	Passenger Ship	1	14%			
		Passenger/Cruise	1	14%			
1980 - 1989	Bulk Dry	Bulk Carrier	1	3%	36	6,20%	
	Container	Container Ship (Fully Cellular)	1	3%			
	General Cargo	General Cargo Ship	25	69%			
	Oil	Products Tanker	1	3%			
	Other Bulk Dry	Cement Carrier	2	6%			
	Passenger	Passenger Ship	2	6%			
		Passenger/Cruise	1	3%			
	Ro-Ro Cargo	Ro-Ro Cargo Ship	2	6%			
	Towing / Pushing	Tug	1	3%			
1990 - 1999	Bulk Dry	Bulk Carrier	4	7%	61	10,50%	
	Chemical	Chemical/Products Tanker	3	5%			
	Container	Container Ship (Fully Cellular)	17	28%			
	General Cargo	General Cargo Ship	28	46%			
	Oil	Crude Oil Tanker	2	3%			
		Crude/Oil Products Tanker	2	3%			
	Other Bulk Dry	Aggregates Carrier	1	2%			
	Passenger	Passenger/Cruise	3	5%			
	Passenger/Ro-Ro Cargo	Passenger/Ro-Ro Ship (Vehicles)	1	2%			
2000 - 2009	Bulk Dry	Bulk Carrier	11	4%	266	45,78%	81,58%
	Chemical	Chemical/Products Tanker	29	11%			
	Container	Container Ship (Fully Cellular)	32	12%			
	General Cargo	General Cargo Ship	39	15%			
	Oil	Crude Oil Tanker	114	43%			
		Crude/Oil Products Tanker	13	5%			
		Products Tanker	6	2%			
	Other Dry Cargo	Heavy Load Carrier	2	1%			
	Passenger	Passenger/Cruise	4	2%			
	Passenger/Ro-Ro Cargo	Passenger/Ro-Ro Ship (Vehicles)	2	1%			
	Ro-Ro Cargo	Ro-Ro Cargo Ship	11	4%			
	Towing / Pushing	Tug	3	1%			
2010 - 2018	Bulk Dry	Bulk Carrier	23	11%	208	35,80%	
	Chemical	Chemical/Products Tanker	5	2%			
	Container	Container Ship (Fully Cellular)	26	13%			
	General Cargo	General Cargo Ship	30	14%			
		Open Hatch Cargo Ship	2	1%			
	Oil	Crude Oil Tanker	88	42%			
		Crude/Oil Products Tanker	17	8%			
		Products Tanker	1	0%			
	Passenger	Passenger/Cruise	2	1%			
	Ro-Ro Cargo	Ro-Ro Cargo Ship	11	5%			
	Towing / Pushing	Tug	3	1%			
		TOTAL:			**581**		**100,00%**

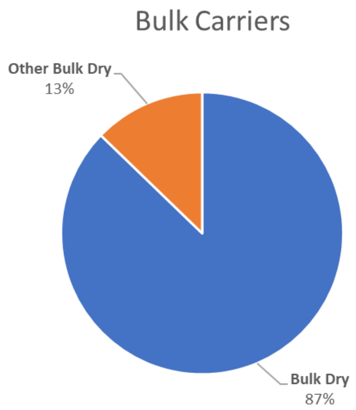


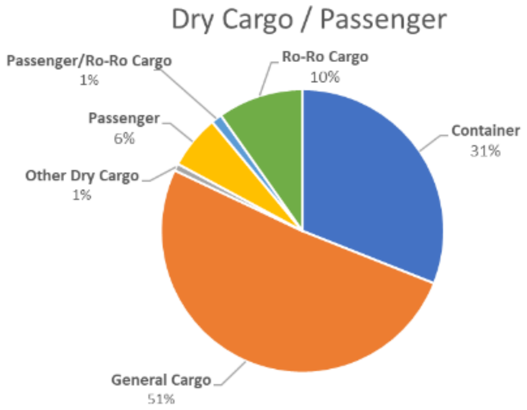


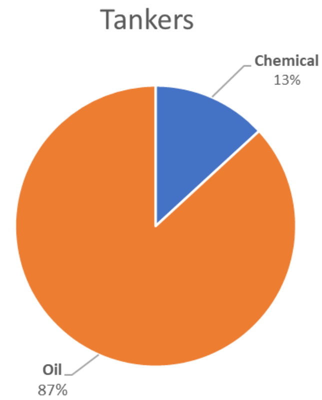
3.1.2 Ship Types

Shiptype Level2	Number	%	Shiptype Level3	Number	%	Shiptype Level5 SubType	Number	%
Bulk Carriers	47	8,09%	Bulk Dry	41	7,06%	Bulk Carrier	41	7,06%
			Other Bulk Dry	6	1,03%	Aggregates Carrier	1	0,17%
						Cement Carrier	5	0,86%
Dry Cargo/Passenger	245	42,17%	Container	76	13,08%	Container Ship (Fully Cellular)	76	13,08%
			General Cargo	125	21,51%	General Cargo	123	21,17%
						Open Hatch Cargo Ship	2	0,34%
			Other Dry Cargo	2	0,34%	Heavy Load Carrier	2	0,34%
			Passenger	15	2,58%	Cruise Ship	12	2,07%
						Passenger Ship	3	0,52%
			Passenger/Ro-Ro Cargo	3	0,52%	Passenger/Ro-Ro Ship (Vehicles)	3	0,52%
			Ro-Ro Cargo	24	4,13%	Ro-Ro Cargo Ship	24	4,13%
Miscellaneous	8	1,38%	Towing / Pushing	8	1,38%	Tug	8	1,38%
Tankers	281	48,36%	Chemical	37	6,37%	Chemical/Products Tanker	37	6,37%
			Oil	244	42,00%	Crude Oil Tanker	204	35,11%
						Crude/Oil Products Tanker	32	5,51%
						Products Tanker	8	1,38%
						TOTAL:	**581**	**100,00%**





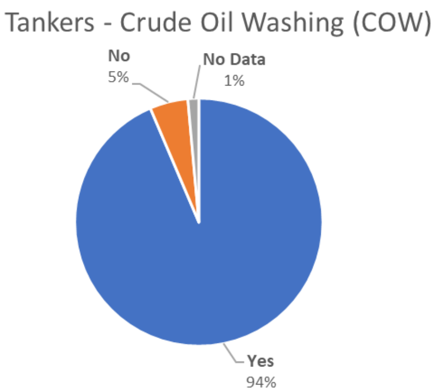




3.1.3 Characteristics of Tankers

All the vessels classified as Oil Tankers in Shiptype Level 3 can perform Crude Oil Washing (COW) except for a vessel (8004090 - MARISA N) whose information is missing (COW field is blank). There are 20 vessels classified as Chemical/Oil Products Tankers that can perform COW as well. The total number of vessels classified as Tankers in Shiptype Level 2 able to perform COW is 263. 14 vessels classified as Chemical/Oil Products Taker in Shiptype Level 4 are not equipped for COW, 4 vessels have no data available.

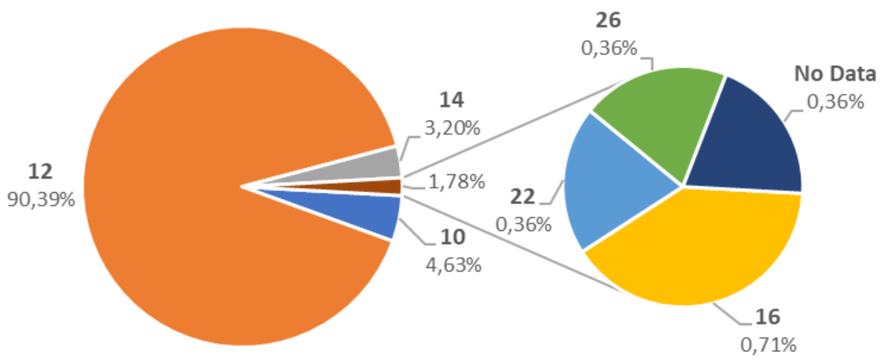
COW	
Yes	263
No	14
No Data	4
Total:	**281**



Shiptype Level2	Number	Shiptype Level3	Number	%	Shiptype Level5 SubType	COW	Number	%
Tankers	281	Chemical	37	13%	Chemical/Products Tanker	Yes	20	7,12%
						No	14	4,98%
						No data	3	1,07%
		Oil	244	87%	Crude Oil Tanker	Yes	204	72,60%
					Crude/Oil Products Tanker	Yes	32	11,39%
					Products Tanker	Yes	7	2,49%
						No Data	1	0,36%

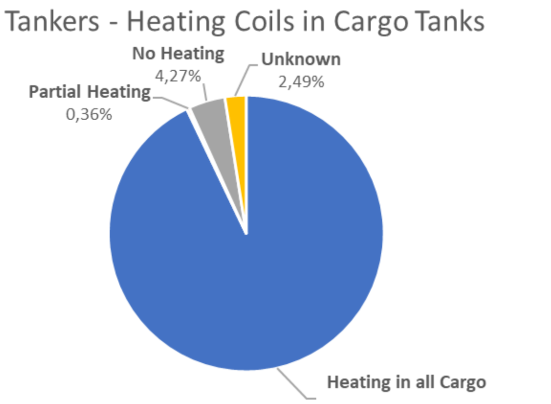
All the vessels classified as Tankers in Shiptype Level 2 are equipped with the Closed Loading System.

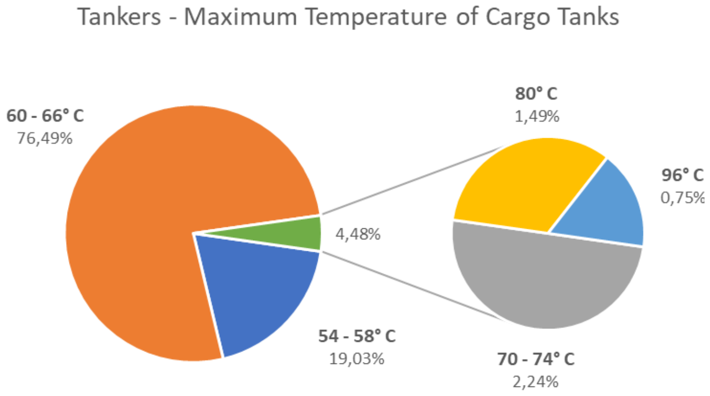
N° of Cargo Tanks	N° of vessels	%	Heating coils in Cargo Tanks	N° of vessels	%
10	13	4,63%	Heating in all Cargo	11	84,62%
			Partial Heating	0	0,00%
			No Heating	1	7,69%
			Unknown	1	7,69%
12	254	90,39%	Heating in all Cargo	238	93,70%
			Partial Heating	1	0,39%
			No Heating	10	3,94%
			Unknown	5	1,97%
14	9	3,20%	Heating in all Cargo	8	88,89%
			Partial Heating	0	0,00%
			No Heating	1	11,11%
16	2	0,71%	Heating in all Cargo	2	
22	1	0,36%	Heating in all Cargo	1	
26	1	0,36%	Heating in all Cargo	1	
No Data	1	0,36%	Unknown	1	
Total:	**281**	**100,00%**		**281**	



Heating coils in Cargo Tanks	N° of vessels	%
Heating in all Cargo	261	92,88%
Partial Heating	1	0,36%
No Heating	12	4,27%
Unknown	7	2,49%
Total:	**281**	**100,00%**

Maximum Temperature	N° of vessels	%
54 - 58° C	51	19,03%
60 - 66° C	205	76,49%
70 - 74° C	6	2,24%
80° C	4	1,49%
96° C	2	0,75%
Total:	**268**	**100,00%**





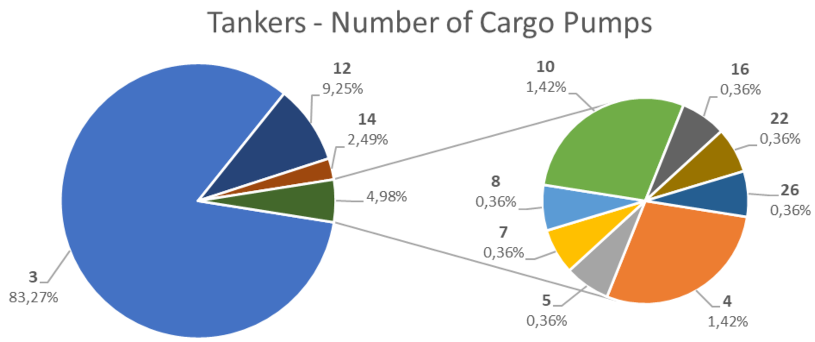
Inert Gas system allows a cargo tank void space above cargo to be made inert so as to reduce risk of explosion.

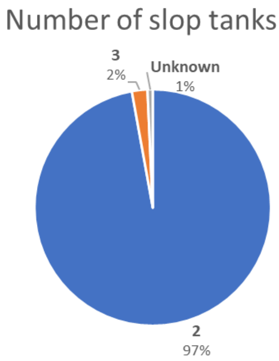
Shiptype Level2	Number	Inert Gas System	Number
Tankers	281	Yes	279
		Unknown	2

Tankers' liquid cargo capacity (98%) vary between 2256 and 177223 cubic metres. The 98% is used to allow for cargo expansion.

Total number of cargo pumps on tankers used for loading and unloading of cargo.

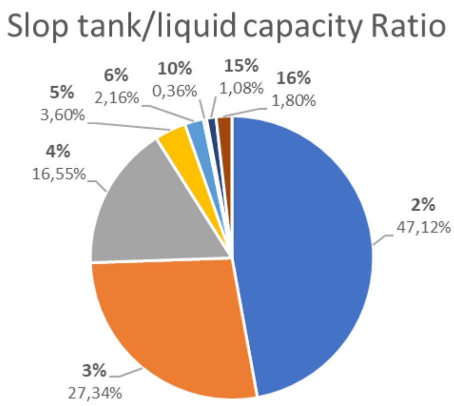
Number of Cargo Pumps	Number of vessels	%
3	234	83,27%
4	4	1,42%
5	1	0,36%
7	1	0,36%
8	1	0,36%
10	4	1,42%
12	26	9,25%
14	7	2,49%
16	1	0,36%
22	1	0,36%
26	1	0,36%
Total:	**281**	**100,00%**





Number of Slop Tanks	Number of vessels	%
2	273	97,15%
3	6	2,14%
Unknown	2	0,71%
Total:	**281**	**100,00%**

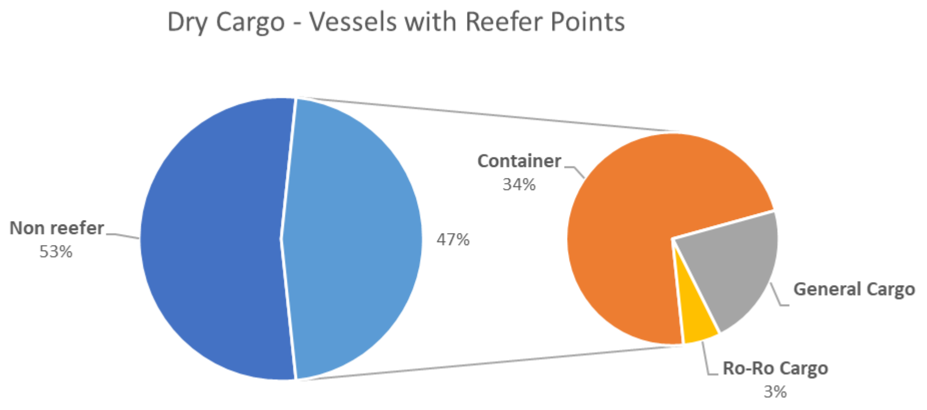
Number of Slop Tanks	Capacity (m^3)	Number of vessels	%
2	< 1000	14	5,04%
	1000 - 4999	233	83,81%
	5000 - 10000	19	6,83%
	> 15000	5	1,80%
3	1000 - 4999	4	1,44%
	> 15000	2	0,72%
Unknown	1000 - 4999	1	0,36%
Total:		278	**95,68%**



Slop tank/liquid capacity ratio	Number of vessels
2%	131
3%	76
4%	46
5%	10
6%	6
10%	1
15%	3
16%	5

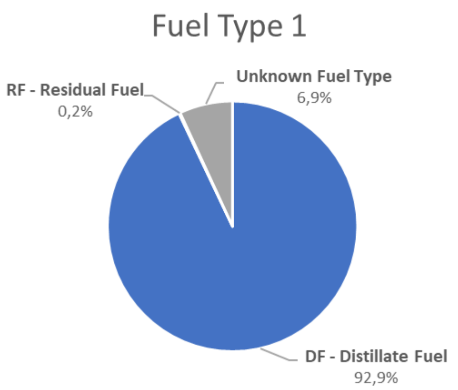
3.1.4 Dry Cargo - Vessels with Reefer Points

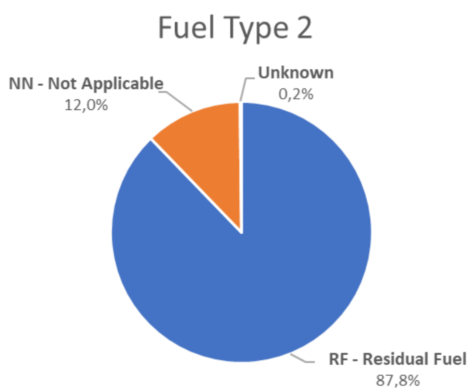
Shiptype Level2	Shiptype Level3	Number	Reefer	%
Dry Cargo/Passenger	Container	76	76	100,00%
	General Cargo	125	23	18,40%
	Ro-Ro Cargo	24	6	25,00%
	Total:	**225**	**105**	**46,67%**

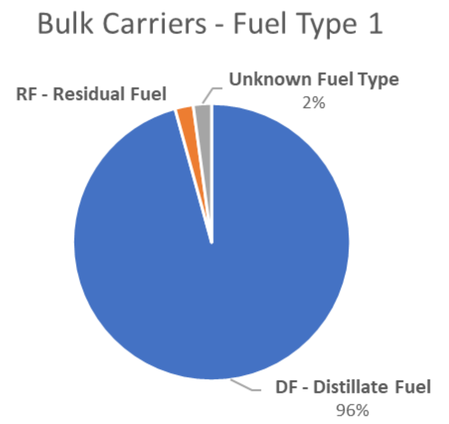


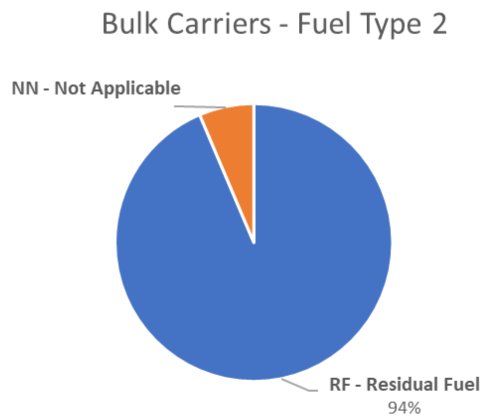
3.1.5 Fuel type

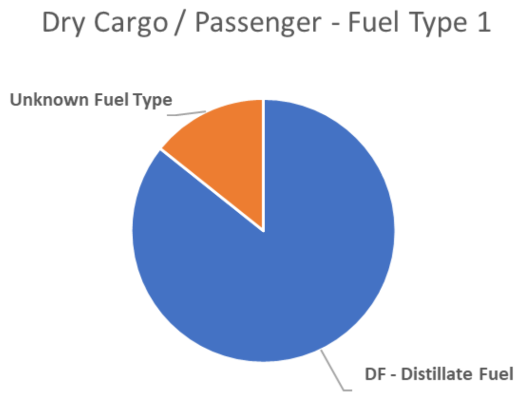
Shiptype Level2	Fuel Type 1	N° of vessels	Fuel Type 2	N° of vessels
Bulk Carriers	DF - Distillate Fuel	45	RF - Residual Fuel	44
			NN - Not Applicable	1
	RF - Residual Fuel	1	NN - Not Applicable	1
	Unknown Fuel Type	1	NN - Not Applicable	1
Dry Cargo/Passenger	DF - Distillate Fuel	210	RF - Residual Fuel	186
			NN - Not Applicable	24
	Unknown Fuel Type	35	NN - Not Applicable	34
			Unknown	1
Miscellaneous	DF - Distillate Fuel	4	NN - Not Applicable	4
	Unknown Fuel Type	4	NN - Not Applicable	4
Tankers	DF - Distillate Fuel	281	RF - Residual Fuel	280
			NN - Not Applicable	1

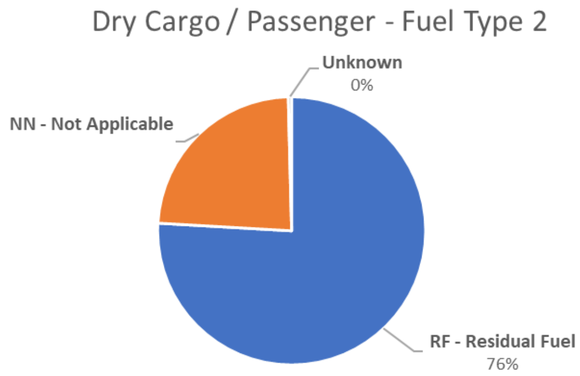


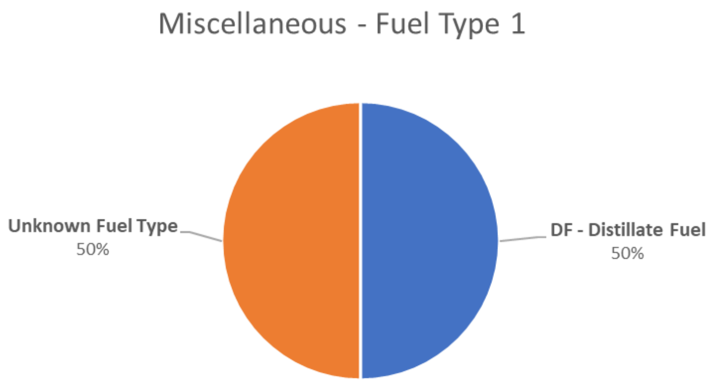



Bulk Carriers - Fuel Type 1
RF - Residual Fuel
Unknown Fuel Type
2%
DF - Distillate Fuel
96%


Bulk Carriers - Fuel Type 2
NN - Not Applicable
RF - Residual Fuel
94%

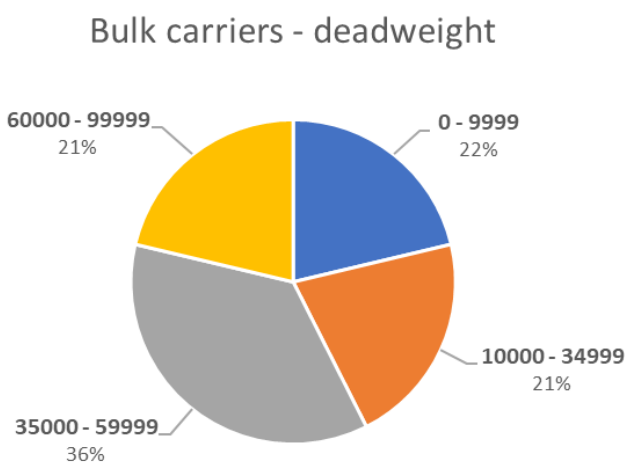

Dry Cargo / Passenger - Fuel Type 1
Unknown Fuel Type
DF - Distillate Fuel

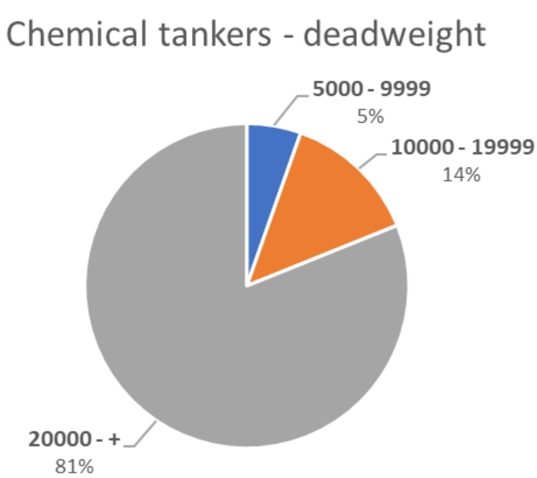

Dry Cargo / Passenger - Fuel Type 2
Unknown
0%
NN - Not Applicable
RF - Residual Fuel
76%

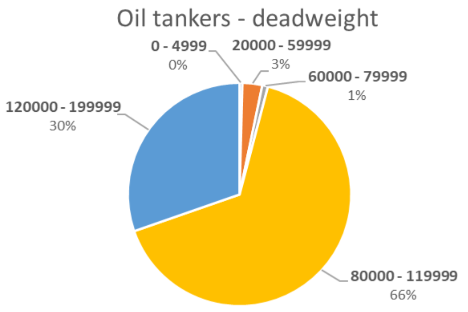

Miscellaneous - Fuel Type 1
Unknown Fuel Type
50%
DF - Distillate Fuel
50%

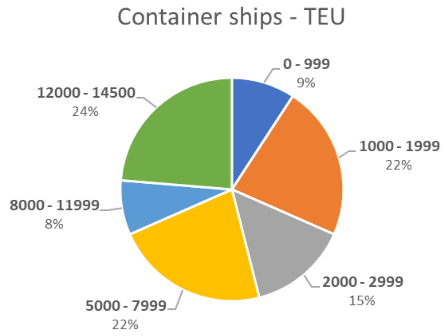
3.1.6 TEU – dwt – GT

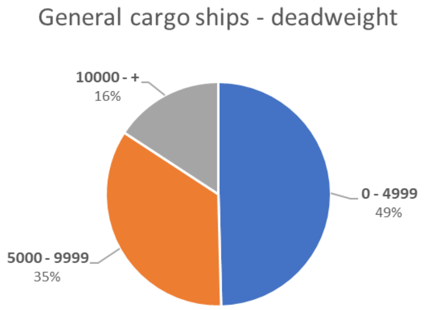
Shiptype Level 2	Shiptype Level 3	Capacity bin	Units	N° of vessels	%	subtotal
Bulk carrier	Bulk carrier	0 - 9999	dwt	10	21%	47
		10000 - 34999		10	21%	
		35000 - 59999		17	36%	
		60000 - 99999		10	21%	
		100000 - 199999		0	0%	
		200000 - +		0	0%	
Tankers	Chemical Tanker	0 - 4999	dwt	0	0%	37
		5000 - 9999		2	5%	
		10000 - 19999		5	14%	
		20000 - +		30	81%	
	Oil tanker	0 - 4999	dwt	1	0%	244
		5000 - 9999		0	0%	
		10000 - 19999		0	0%	
		20000 - 59999		7	3%	
		60000 - 79999		2	1%	
		80000 - 119999		160	66%	
		120000 - 199999		74	30%	
		200000 - +		0	0%	
Dry cargo/passenger	Container	0 - 999	TEU	7	9%	76
		1000 - 1999		17	22%	
		2000 - 2999		11	14%	
		3000 - 4999		0	0%	
		5000 - 7999		17	22%	
		8000 - 11999		6	8%	
		12000 - 14500		18	24%	
		14500 - +		0	0%	
	General cargo	0 - 4999	dwt	63	50%	127
		5000 - 9999		44	35%	
		10000 - +		20	16%	
	Cruise	0 - 1999	gt	4	27%	15
		2000 - 9999		3	20%	
		10000 - 59999		5	33%	
		60000 - 99999		3	20%	
		100000 - +		0	0%	
	Ferry – ro-pax	0 - 1999	gt	0	0%	3
		2000 - +		3	100%	
	Ro-ro	0 - 4999	gt	0	0%	24
		5000 - +		24	100%	
Miscellaneous	Service - tug	All sizes	gt	8	100%	8

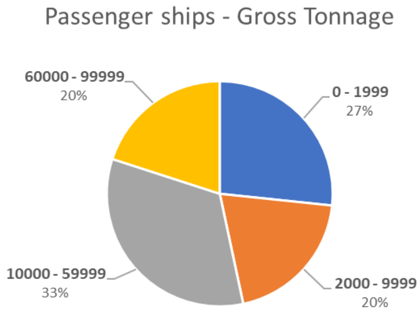




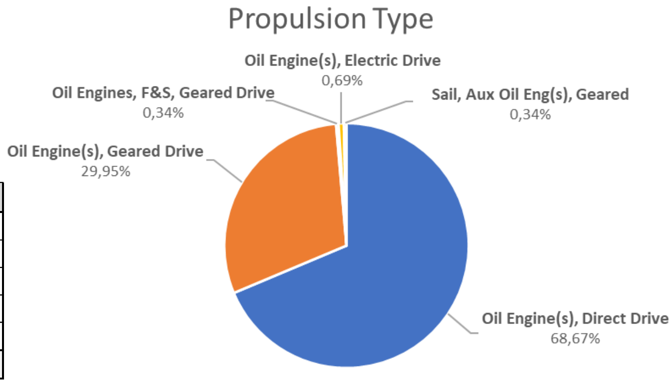




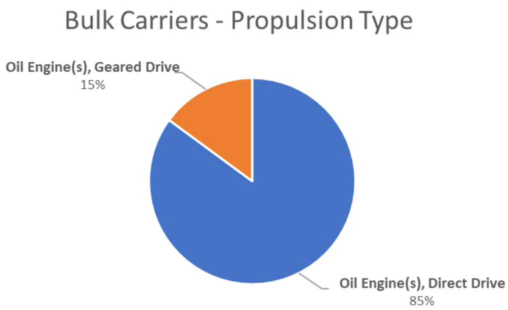


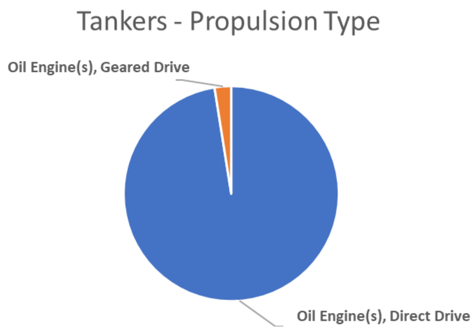


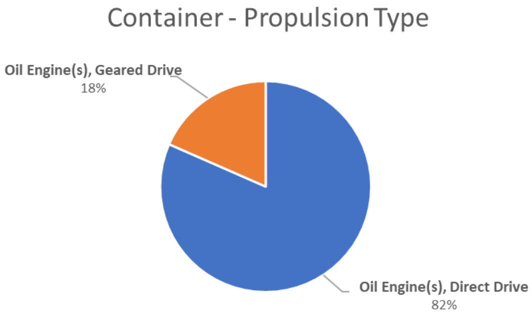
3.1.7 Propulsion

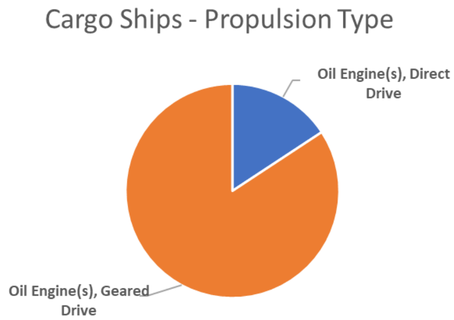


Propulsion Type	N° of vessels	%
Oil Engine(s), Direct Drive	399	68,67%
Oil Engine(s), Geared Drive	174	29,95%
Oil Engines, F&S, Geared Drive	2	0,34%
Oil Engine(s), Electric Drive	4	0,69%
Sail, Aux Oil Eng(s), Geared	2	0,34%
Total:	581	100,00%

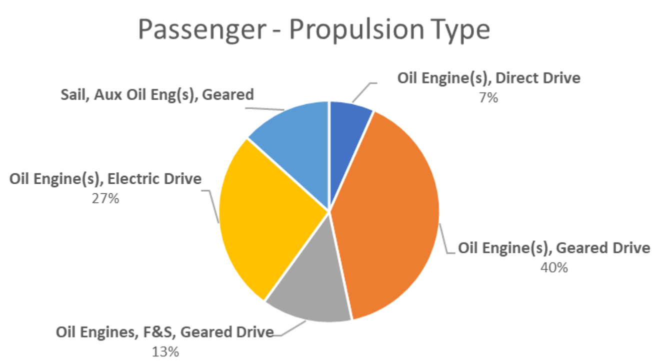






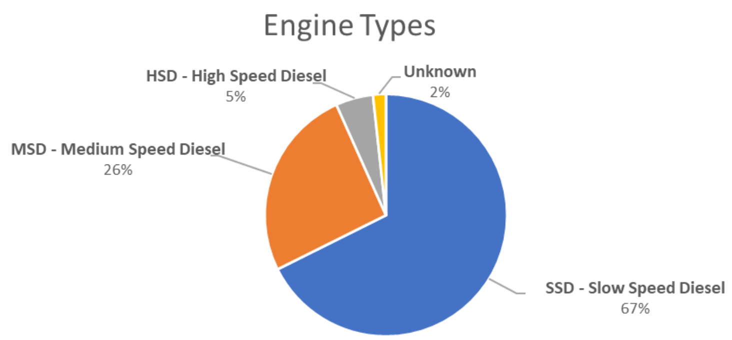


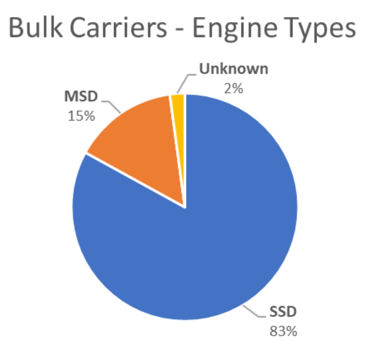
Shiptype Level 2	Shiptype Level 3	Propulsion Type	N° of vessels
Bulk carrier	Bulk Dry	Oil Engine(s), Direct Drive	37
		Oil Engine(s), Geared Drive	4
	Other Bulk Dry	Oil Engine(s), Direct Drive	3
		Oil Engine(s), Geared Drive	3
Tankers	Chemical Tanker	Oil Engine(s), Direct Drive	31
		Oil Engine(s), Geared Drive	6
	Oil tanker	Oil Engine(s), Direct Drive	243
		Oil Engine(s), Geared Drive	1
Dry cargo/passenger	Container	Oil Engine(s), Direct Drive	62
		Oil Engine(s), Geared Drive	14
	General cargo	Oil Engine(s), Direct Drive	19
		Oil Engine(s), Geared Drive	106
	Other Dry Cargo	Oil Engine(s), Direct Drive	1
		Oil Engine(s), Geared Drive	1
	Cruise	Oil Engine(s), Direct Drive	1
		Oil Engine(s), Geared Drive	6
		Oil Engines, F&S, Geared Drive	2
		Oil Engine(s), Electric Drive	4
		Sail, Aux Oil Eng(s), Geared	2
	Ferry – ro-pax	Oil Engine(s), Geared Drive	3
	Ro-ro	Oil Engine(s), Direct Drive	2
		Oil Engine(s), Geared Drive	22
Miscellaneous	Service - tug	Oil Engine(s), Geared Drive	8
		Total:	**581**

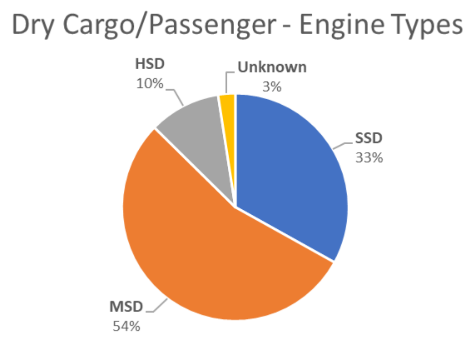


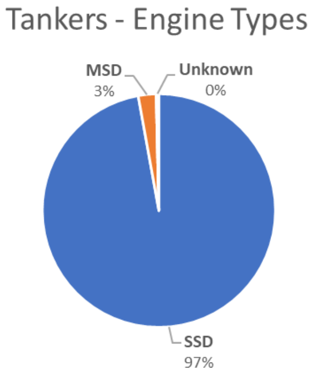
3.1.8 Engine Type

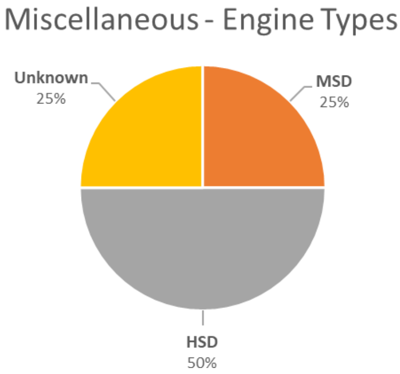
Engine Type	N° of vessels	%	Shiptype Level 2	N° of vessels	%	Shiptype Level 3	N° of vessels	%
SSD - Slow Speed Diesel	393	68%	Bulk Carriers	39	7%	Bulk Dry	37	6%
						Other Bulk Dry	2	0%
			Dry Cargo/Passenger	81	14%	Container	62	11%
						General Cargo	15	3%
						Other Dry Cargo	1	0%
						Passenger	1	0%
						Ro-Ro Cargo	2	0%
			Tankers	273	47%	Chemical	30	5%
					0%	Oil	243	42%
			Miscellaneous				0	0%
MSD - Medium Speed Diesel	149	26%	Bulk Carriers	7	1%	Bulk Dry	4	1%
						Other Bulk Dry	3	1%
			Dry Cargo/Passenger	133	23%	Container	13	2%
						General Cargo	87	15%
						Other Dry Cargo	1	0%
						Passenger	7	1%
						Passenger/Ro-Ro Cargo	3	1%
						Ro-Ro Cargo	22	4%
			Tankers	7	1%	Chemical	6	1%
						Oil	1	0%
			Miscellaneous	2	0%	Towing/Pushing	2	0%
HSD - High Speed Diesel	29	5%	Bulk Carriers				0	0%
			Dry Cargo/Passenger	25	4%	General Cargo	19	3%
						Passenger	6	1%
			Tankers				0	0%
			Miscellaneous	4	1%	Towing/Pushing	4	1%
Unknown	10	2%	Bulk Carriers	1	0%	Other Bulk Dry	1	0%
			Dry Cargo/Passenger	6	1%	Container	1	0%
						General Cargo	4	1%
						Passenger	1	0%
			Tankers	1	0%	Chemical	1	0%
			Miscellaneous	2	0%	Towing/Pushing	2	0%
Total:	581	100%		581	100%		581	100%

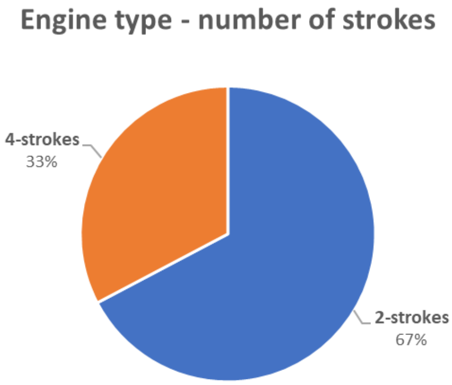








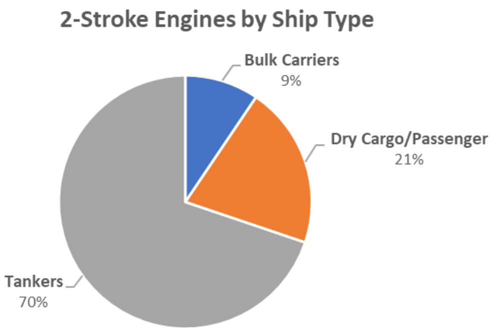


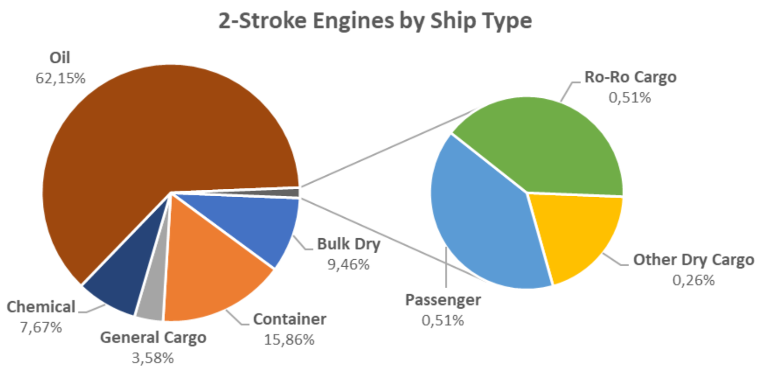


Engine type	N° of vessels	%
2-strokes	391	67%
4-strokes	190	33%
TOTAL:	**581**	**100%**

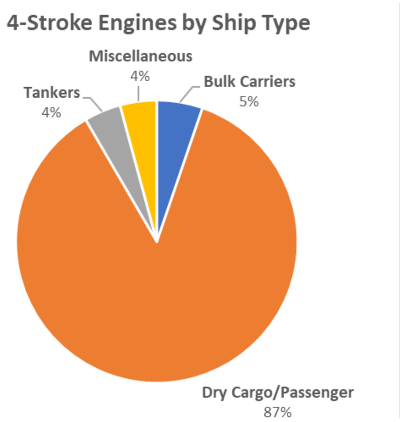
2-stroke engines

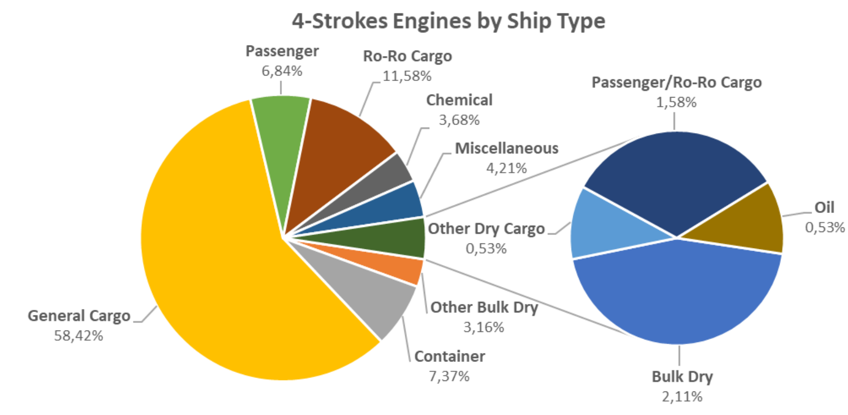
Shiptype level 2	N° of vessels	%	Shiptype level 3	N° of vessels	%
Bulk Carriers	37	9%	Bulk Dry	37	9%
			Other Bulk Dry	0	0%
Dry Cargo/Passenger	81	21%	Container	62	16%
			General Cargo	14	4%
			Other Dry Cargo	1	0%
			Passenger	2	1%
			Passenger/Ro-Ro Cargo	0	0%
			Ro-Ro Cargo	2	1%
Tankers	273	70%	Chemical	30	8%
			Oil	243	62%
Miscellaneous				0	0%
			Total:	**391**	**100%**





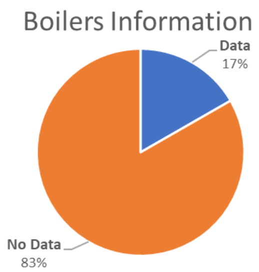
4-stroke engines					
Shiptype level 2	**N° of vessels**	**%**	**Shiptype level 3**	**N° of vessels**	**%**
Bulk Carriers	10	3%	Bulk Dry	4	1%
			Other Bulk Dry	6	2%
Dry Cargo/Passenger	164	42%	Container	14	4%
			General Cargo	111	28%
			Other Dry Cargo	1	0%
			Passenger	13	3%
			Passenger/Ro-Ro Cargo	3	1%
			Ro-Ro Cargo	22	6%
Tankers	8	2%	Chemical	7	2%
			Oil	1	0%
Miscellaneous				8	2%
			Total:	**190**	**49%**

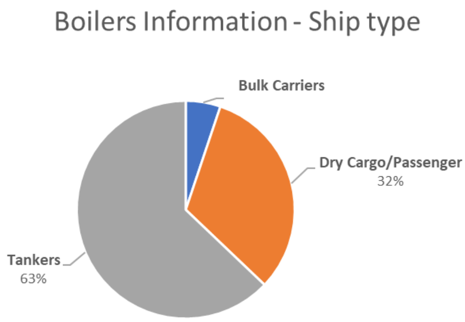


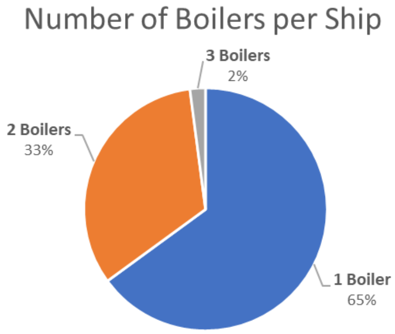


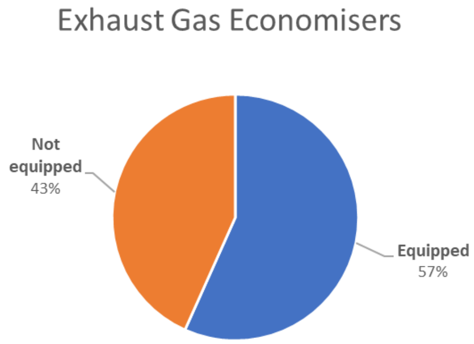
3.1.9 Boilers on board

Boilers Data		
Data	97	17%
No Data	484	83%









Shiptype Level 2	Shiptype Level 3	Boiler	N° of boilers	Economisers	N° of vessels
Bulk Carriers	Bulk Dry	1 x Auxiliary boiler	1	N	5
Dry Cargo/Passenger	Container	1 x Auxiliary boiler	1	N	2
		1 x Exhaust gas eEconomiser, 1 x Auxiliary boiler	1	Y	5
		1 x Exhaust gas eEconomiser, 1 x Water tube auxiliary boiler	1	Y	8
	General Cargo	1 x Auxiliary boiler	1	N	3
		1 x Hot water heater	1	N	2
		2 x Hot water heaters	2	N	1
		2 x Thermal oil heaters	2	N	2
		2 x Water tube auxiliary boilers	2	N	1
	Other Dry Cargo	2 x Thermal oil heaters	2	N	2
	Passenger	2 x Auxiliary boiler	2	N	1
		5 x Exhaust gas eEconomisers, 2 x Auxiliary boilers	2	Y	1
		6 x Exhaust gas eEconomisers, 2 x Auxiliary boilers, 1 x Unknown type of boiler	3	Y	1
	Passenger/Ro-Ro Cargo	2 x Exhaust gas eEconomisers, 2 x Auxiliary boilers	2	Y	1
	Ro-Ro Cargo	1 x Auxiliary boiler	1	N	1
Tankers	Chemical	1 x Auxiliary boiler, 1 x Water tube auxiliary boiler	2	N	1
		1 x Exhaust gas eEconomiser, 1 x Water tube auxiliary boiler	1	Y	1
		2 x Auxiliary boilers	2	N	2
	Oil	1 x Auxiliary boiler, 1 x Water tube auxiliary boiler	2	N	12
		1 x Exhaust gas eEconomiser, 1 x Auxiliary boiler	1	Y	7
		1 x Exhaust gas eEconomiser, 1 x Auxiliary boiler, 1 x Water tube auxiliary boiler	2	Y	1
		1 x Exhaust gas eEconomiser, 1 x Water tube auxiliary boiler	1	Y	27
		1 x Exhaust gas eEconomiser, 2 x Auxiliary boilers	2	Y	1
		2 x Auxiliary boilers	2	N	5
		2 x Exhaust gas eEconomisers, 1 x Water tube auxiliary boiler	1	Y	2
		2 x Water tube auxiliary boilers	2	N	1
		3 x Auxiliary boilers	3	N	1
Miscellaneous	Towing/Pushing	---		N	0

3.2 Ship movement times in the port of Trieste

Two categories of time were clustered for all the ships indicated by the port authority:

- times at berth,
- maneuvering times.

Anchorage times have not been considered in this study since that operation takes place outside the area of the Port of Trieste.

3.3 Emission calculation results

The tables and the summary graphs of the main results concerning the emissions are shown in the following paragraphs.

As said before in the methodology section, when fuel consumption per phase is unknown, another methodology is proposed to calculate the emissions, based on the installed power and the time spent in the different navigation phases. Emissions can be calculated from a detailed knowledge of the installed main and auxiliary engine power, the load factor and the total elapsed time, in hours, for each phase using the following equation.

$$E_{Trip,i,j,m} = \sum_{p}\left[T_{P}\sum_{e}\left(P_{e} \times LF_{e} \times EF_{e,i,j,m,p}\right)\right]$$

where:

E_{Trip} = emission over a complete trip (tonnes),
EF = emission factor (kg/tonne) from Table 3-10, depending on type of vessel,
LF = engine load factor (%)
P = engine nominal power (kW)
T = time (hours),
e = engine category (main, auxiliary)
i = pollutant (NO_x, NMVOC, PM)
j = engine type (slow-, medium-, and high-speed diesel, gas turbine and steam turbine).
m = fuel type (bunker fuel oil, marine diesel oil/marine gas oil, gasoline),
p = the different phase of trip (cruise, hotelling, manoeuvring).

3.3.1. Bulk Carriers

BULK DRY

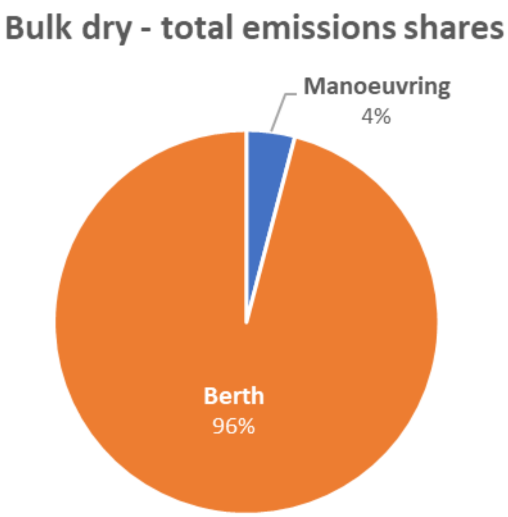
The Bulk Dry emissions summary is reported below:

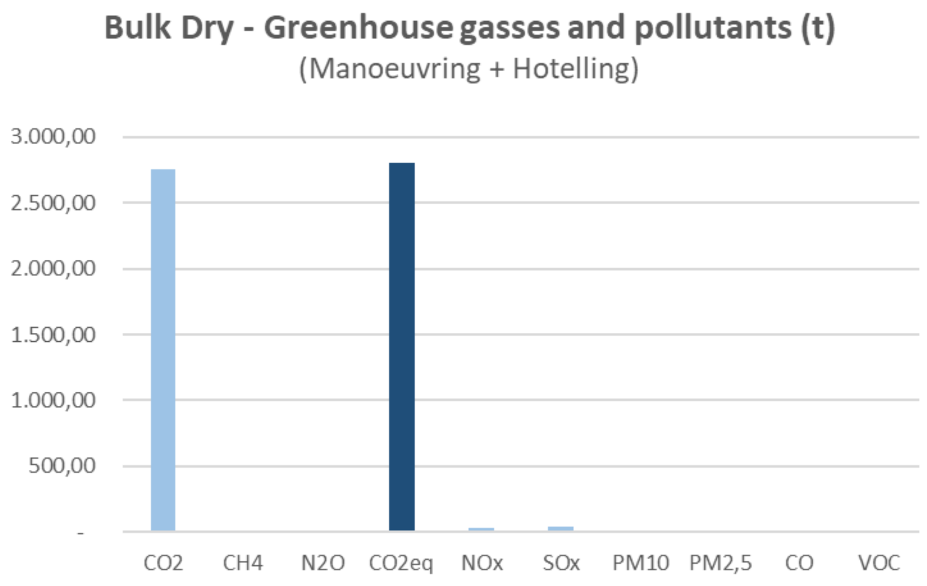
	Manoeuvring	%	Berth	%	Total
kWh	168.625	5%	3.452.719	95%	**3.621.344**
CO_2	110,77	4%	2.642,72	96%	**2.753,49**
CH_4	0,00	8%	0,02	92%	**0,02**
N_2O	0,01	4%	0,16	96%	**0,16**
t CO_2e *	112,36	4%	2.685,32	96%	**2.797,68**
R-22 (AC+ref)	-	-	-	-	**0,01**
R-134a (AC)	-	-	-	-	**0,04**
R-404a (ref)	-	-	-	-	**0,00**
t CO_2e **					**2.875,57**
NO_x	2,29	7%	28,91	93%	**31,20**
SO_x	1,85	4%	44,56	96%	**46,41**
PM_{10}	0,24	5%	4,58	95%	**4,81**
$PM_{2,5}$	0,22	5%	4,29	95%	**4,51**
CO	0,21	7%	2,83	93%	**3,04**
VOC	0,09	7%	1,15	93%	**1,24**

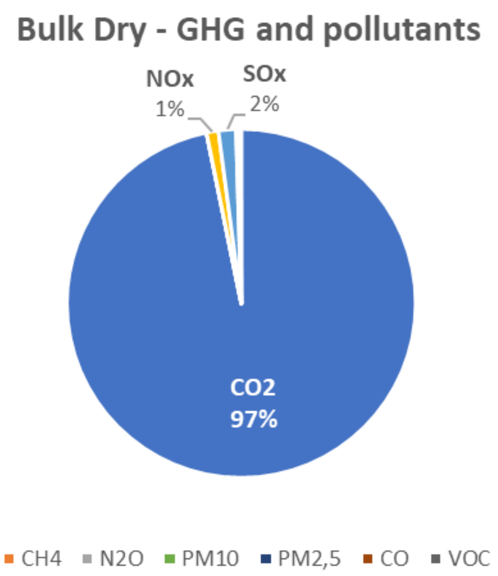
TOT	**115,67**	**4%**	**2.729,22**	**96%**	**2.844,89**

* ($CO_2 + CH_4 + N_2O$)

** ($CO_2 + CH_4 + N_2O$ + R-22 + R134a + R404a)




Bulk Dry - Greenhouse gasses and pollutants (t)
(Manoeuvring + Hotelling)
3.000,00
2.500,00
2.000,00
1.500,00
1.000,00
500,00
-
CO2
CH4
N2O
CO2eq
NOx
SOx
PM10
PM2,5
CO
VOC


Bulk Dry - GHG and pollutants
NOx
1%
SOx
2%
CO2
97%
CH4
N2O
PM10
PM2,5
CO
VOC

OTHER BULK DRY

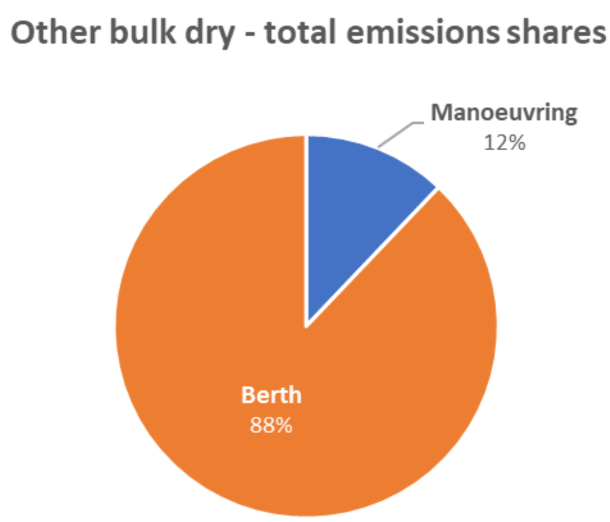
The Other Bulk Dry emissions summary is reported below:

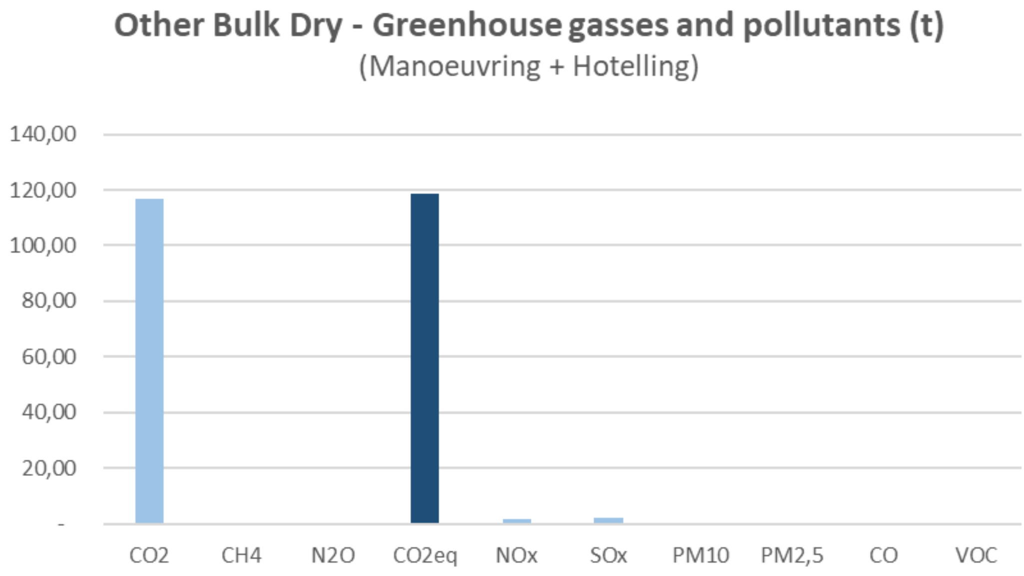
	Manoeuvring	%	Berth	%	Total
kWh	20.154	13%	137.229	87%	**157.384**
CO_2	14,10	12%	102,86	88%	**116,96**
CH_4	0,00	16%	0,00	84%	**0,00**
N_2O	0,00	11%	0,01	89%	**0,01**
t CO_2e *	14,30	12%	104,46	88%	**118,76**
R-22 (AC+ref)	-	-	-	-	**0,00**
R-134a (AC)	-	-	-	-	**0,00**
R-404a (ref)	-	-	-	-	**0,00**
t CO_2e **					**124,94**
NO_x	0,28	15%	1,55	85%	**1,83**
SO_x	0,24	12%	1,74	88%	**1,97**
PM_{10}	0,03	13%	0,19	87%	**0,21**
$PM_{2,5}$	0,03	13%	0,17	87%	**0,20**
CO	0,02	15%	0,12	85%	**0,14**
VOC	0,01	16%	0,05	84%	**0,06**

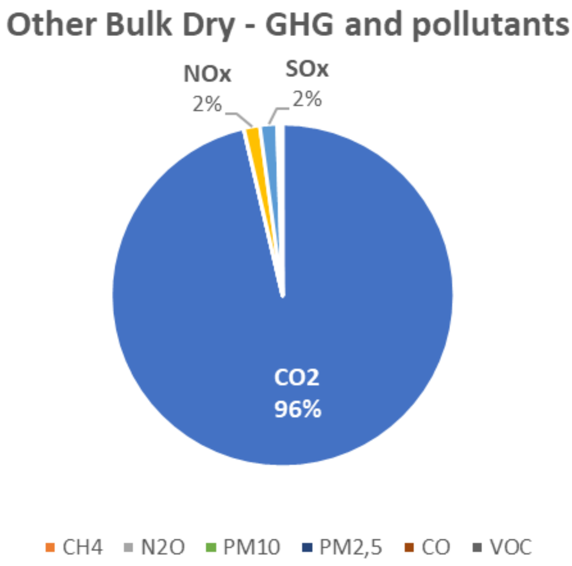
TOT	**14,69**	**12%**	**106,69**	**88%**	**121,38**

* ($CO_2 + CH_4 + N_2O$)

** ($CO_2 + CH_4 + N_2O$ + R-22 + R134a + R404a)




Other Bulk Dry - Greenhouse gasses and pollutants (t)
(Manoeuvring + Hotelling)
140,00
120,00
100,00
80,00
60,00
40,00
20,00
-
CO2
CH4
N2O
CO2eq
NOx
SOx
PM10
PM2,5
CO
VOC


Other Bulk Dry - GHG and pollutants
NOx 2%
SOx 2%
CO2 96%
CH4
N2O
PM10
PM2,5
CO
VOC

3.3.2. Dry Cargo/Passenger

CONTAINER

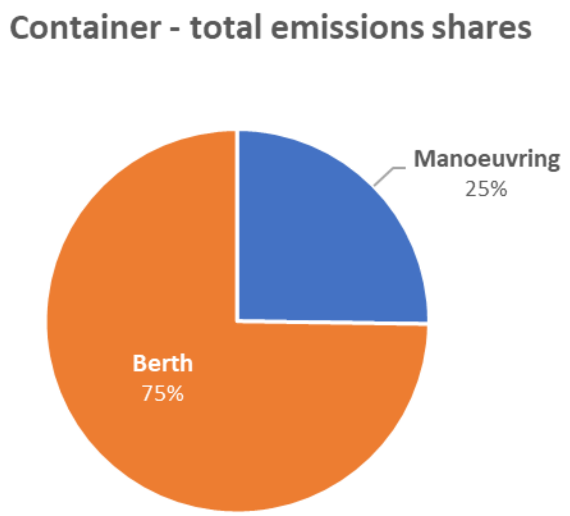
The Container Cargo emissions summary is reported below:

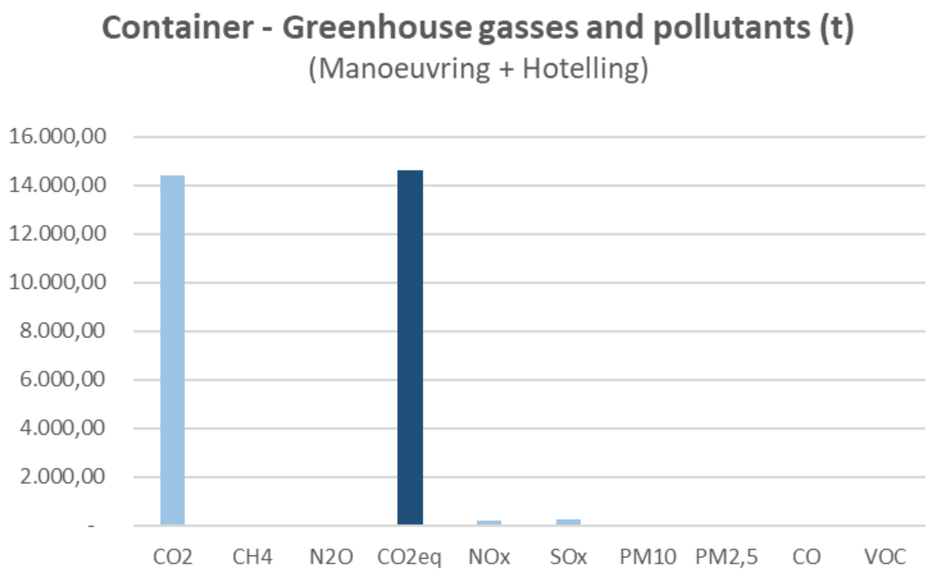
	Manoeuvring	%	Berth	%	Total
kWh	5.457.976	29%	13.646.553	71%	19.104.529
CO_2	3.599,04	25%	10.802,42	75%	14.401,47
CH_4	0,06	44%	0,07	56%	0,13
N_2O	0,19	21%	0,69	79%	0,87
t CO_2e *	3.650,12	25%	10.986,26	75%	14.636,38
R-22 (AC+ref)	-	-	-	-	0,05
R-134a (AC)	-	-	-	-	0,05
R-404a (ref)	-	-	-	-	0,00
t CO_2e **					14.801,86
NO_x	78,34	41%	113,58	59%	191,93
SO_x	60,07	25%	181,71	75%	241,79
PM_{10}	7,69	31%	17,39	69%	25,08
$PM_{2,5}$	7,24	31%	16,30	69%	23,54
CO	6,72	40%	10,11	60%	16,82
VOC	2,86	41%	4,13	59%	7,00

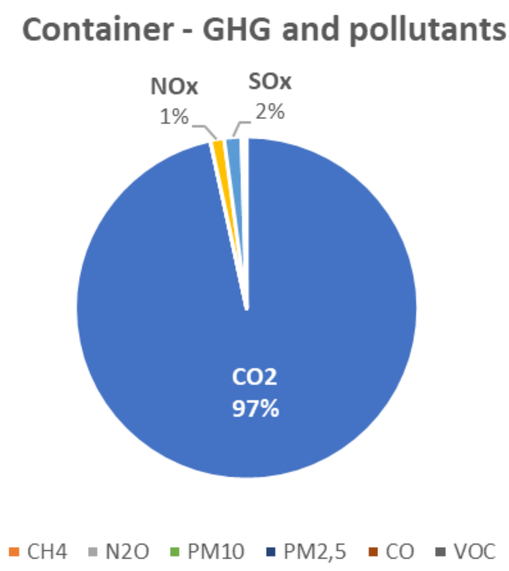
TOT	**3.762,21**	**25%**	**11.146,41**	**75%**	**14.908,62**

* (CO_2 + CH_4 + N_2O)

** (CO_2 + CH_4 + N_2O + R-22 + R134a + R404a)




Container - Greenhouse gasses and pollutants (t)
(Manoeuvring + Hotelling)
16.000,00
14.000,00
12.000,00
10.000,00
8.000,00
6.000,00
4.000,00
2.000,00
-
CO2
CH4
N2O
CO2eq
NOx
SOx
PM10
PM2,5
CO
VOC


Container - GHG and pollutants
NOx
1%
SOx
2%
CO2
97%
CH4
N2O
PM10
PM2,5
CO
VOC

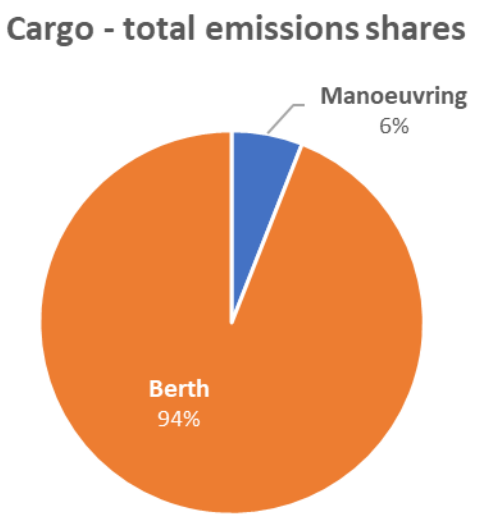
GENERAL CARGO

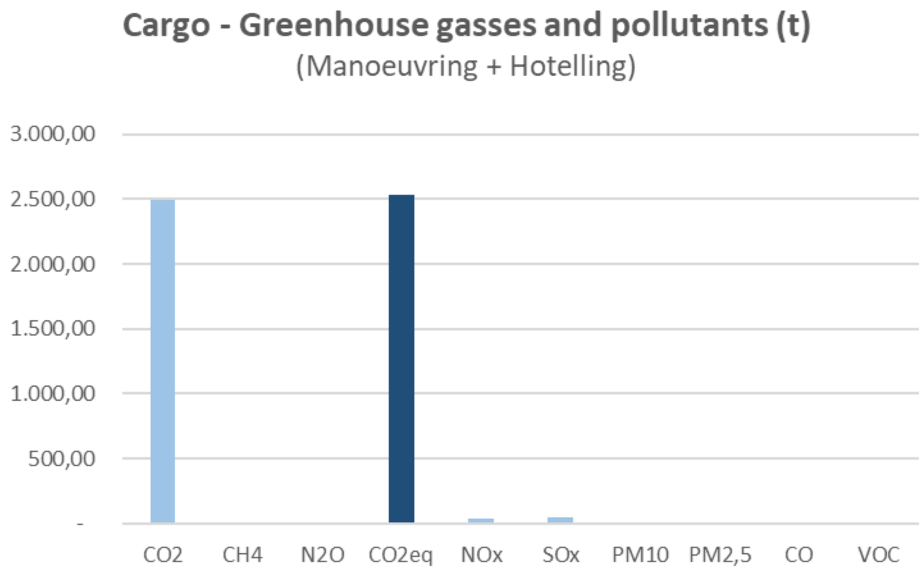
The General Cargo emissions summary is reported below:

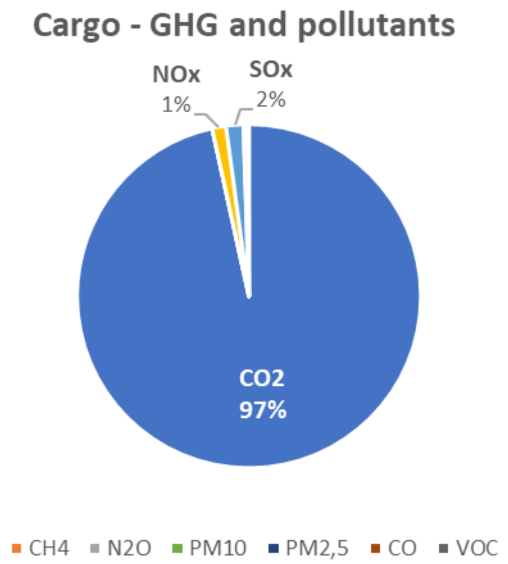
	Manoeuvring	%	Berth	%	Total
kWh	213.368	6%	3.157.187	94%	**3.370.555**
CO_2	147,80	6%	2.342,60	94%	**2.490,41**
CH_4	0,00	8%	0,02	92%	**0,02**
N_2O	0,01	5%	0,13	95%	**0,14**
t CO_2e *	149,90	6%	2.378,35	94%	**2.528,26**
R-22 (AC+ref)	-	-	-	-	**0,03**
R-134a (AC)	-	-	-	-	**0,04**
R-404a (ref)	-	-	-	-	**0,00**
t CO_2e **					**2.639,81**
NO_x	2,62	8%	30,79	92%	**33,41**
SO_x	2,47	6%	39,60	94%	**42,07**
PM_{10}	0,30	6%	4,33	94%	**4,63**
$PM_{2,5}$	0,28	7%	4,06	93%	**4,34**
CO	0,23	8%	2,81	92%	**3,04**
VOC	0,10	8%	1,13	92%	**1,23**
TOT	**153,81**	**6%**	**2.425,47**	**94%**	**2.579,28**

* (CO_2 + CH_4 + N_2O)

** (CO_2 + CH_4 + N_2O + R-22 + R134a + R404a)




Cargo - Greenhouse gasses and pollutants (t)
(Manoeuvring + Hotelling)
3.000,00
2.500,00
2.000,00
1.500,00
1.000,00
500,00
-
CO2
CH4
N2O
CO2eq
NOx
SOx
PM10
PM2,5
CO
VOC


Cargo - GHG and pollutants
NOx
1%
SOx
2%
CO2
97%
CH4
N2O
PM10
PM2,5
CO
VOC

PASSENGER

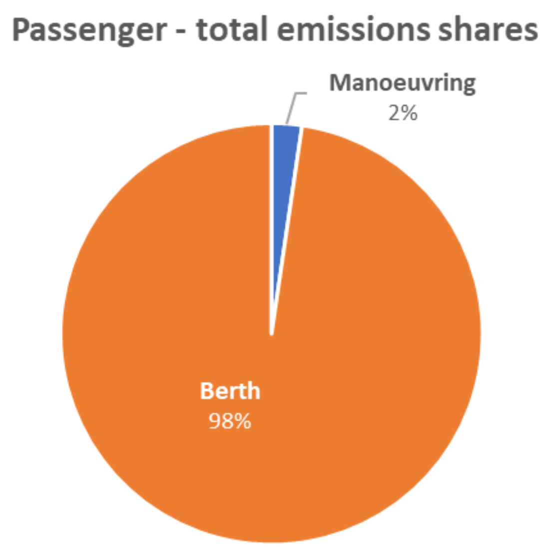
The Passenger Cargo emissions summary is reported below:

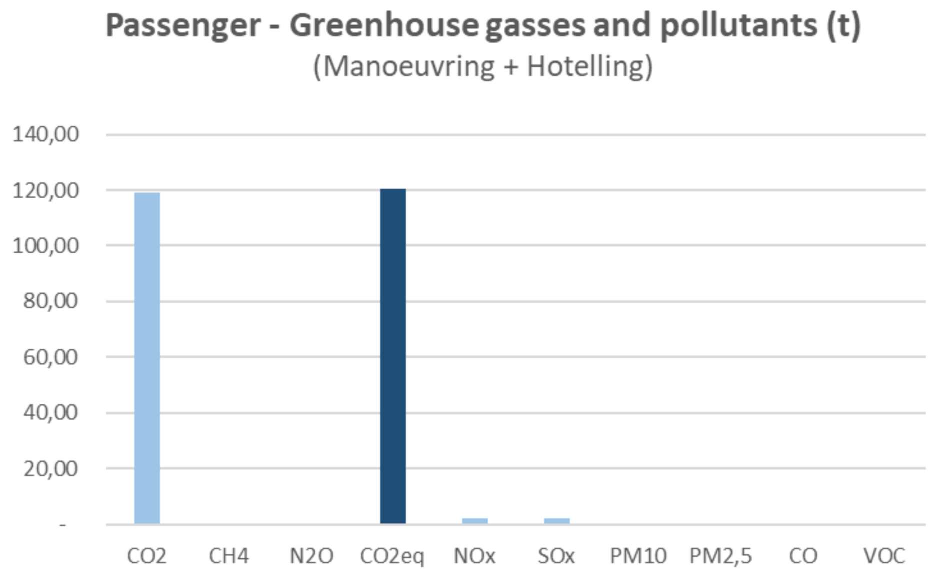
	Manoeuvring	%	Berth	%	Total
kWh	3.985	2%	164.486	98%	**168.471**
CO_2	2,75	2%	116,13	98%	**118,88**
CH_4	0,00	3%	0,00	97%	**0,00**
N_2O	0,00	2%	0,01	98%	**0,01**
t CO_2e *	2,79	2%	117,73	98%	**120,52**
R-22 (AC+ref)	-	-	-	-	**0,01**
R-134a (AC)	-	-	-	-	**0,00**
R-404a (ref)	-	-	-	-	**0,00**
t CO_2e **					**139,13**
NO_x	0,05	2%	2,16	98%	**2,22**
SO_x	0,05	2%	1,97	98%	**2,02**
PM_{10}	0,01	2%	0,24	98%	**0,24**
$PM_{2,5}$	0,01	2%	0,22	98%	**0,23**
CO	0,00	3%	0,16	97%	**0,17**
VOC	0,00	3%	0,07	97%	**0,07**

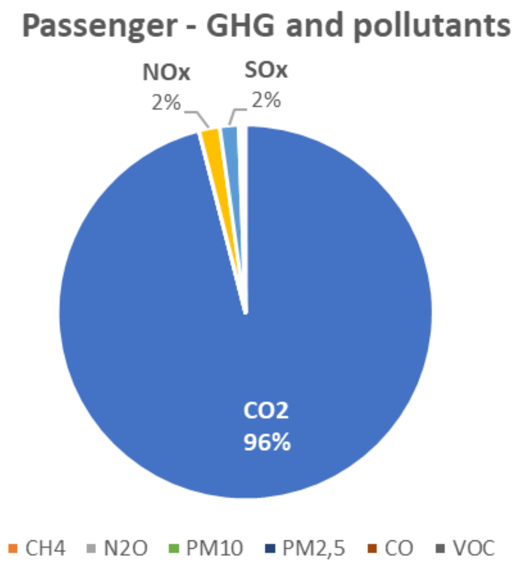
TOT	**2,87**	**2%**	**120,96**	**98%**	**123,82**

* (CO_2 + CH_4 + N_2O)

** (CO_2 + CH_4 + N_2O + R-22 + R134a + R404a)




Passenger - Greenhouse gasses and pollutants (t)
(Manoeuvring + Hotelling)
140,00
120,00
100,00
80,00
60,00
40,00
20,00
-
CO2
CH4
N2O
CO2eq
NOx
SOx
PM10
PM2,5
CO
VOC


Passenger - GHG and pollutants
NOx
2%
SOx
2%
CO2
96%
CH4
N2O
PM10
PM2,5
CO
VOC

PASSENGER CRUISE

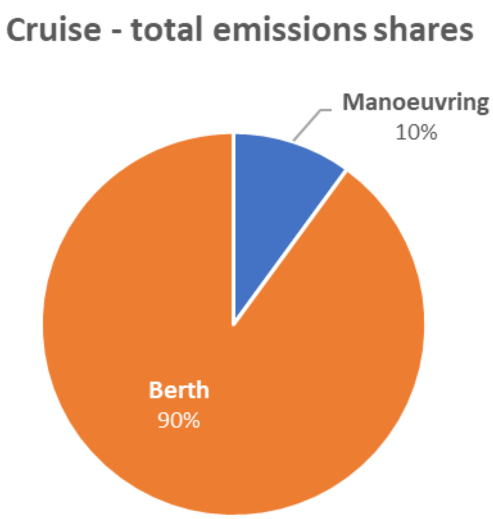
The Passenger Cruise Cargo emissions summary is reported below:

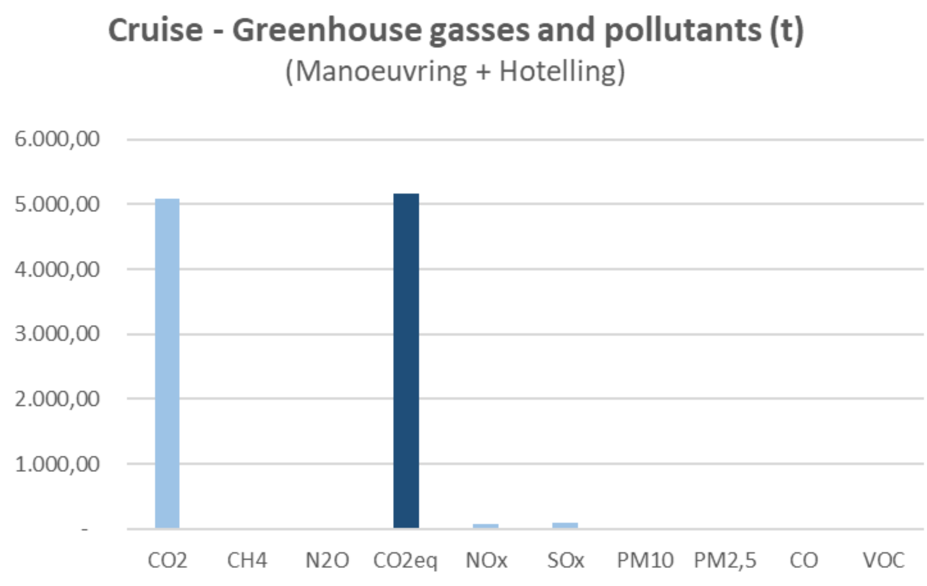
	Manoeuvring	%	Berth	%	Total
kWh	717.832	10%	6.201.633	90%	**6.919.465**
CO_2	508,84	10%	4.572,71	90%	**5.081,55**
CH_4	0,01	12%	0,04	88%	**0,05**
N_2O	0,03	10%	0,26	90%	**0,28**
t CO_2e *	516,14	10%	4.641,68	90%	**5.157,81**
R-22 (AC+ref)	-	-	-	-	**0,10**
R-134a (AC)	-	-	-	-	**0,12**
R-404a (ref)	-	-	-	-	**0,01**
t CO_2e **					**5.511,84**
NO_x	9,00	11%	70,42	89%	**79,42**
SO_x	8,56	10%	77,33	90%	**85,89**
PM_{10}	1,01	11%	8,55	89%	**9,57**
$PM_{2,5}$	0,95	11%	8,02	89%	**8,97**
CO	0,72	11%	5,61	89%	**6,34**
VOC	0,30	12%	2,26	88%	**2,56**

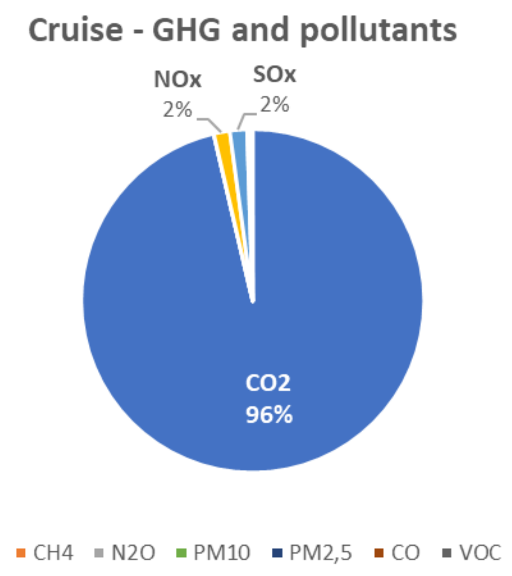
TOT	**529,43**	**10%**	**4.745,20**	**90%**	**5.274,63**

* (CO_2 + CH_4 + N_2O)

** (CO_2 + CH_4 + N_2O + R-22 + R134a + R404a)




Cruise - Greenhouse gasses and pollutants (t)
(Manoeuvring + Hotelling)
6.000,00
5.000,00
4.000,00
3.000,00
2.000,00
1.000,00
-
CO2
CH4
N2O
CO2eq
NOx
SOx
PM10
PM2,5
CO
VOC


Cruise - GHG and pollutants
NOx
2%
SOx
2%
CO2
96%
CH4
N2O
PM10
PM2,5
CO
VOC

PASSENGER/RO-RO CARGO

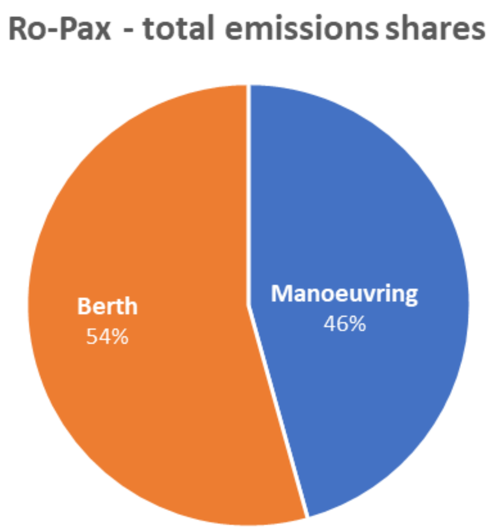
The Ro-Pax Cargo emissions summary is reported below:

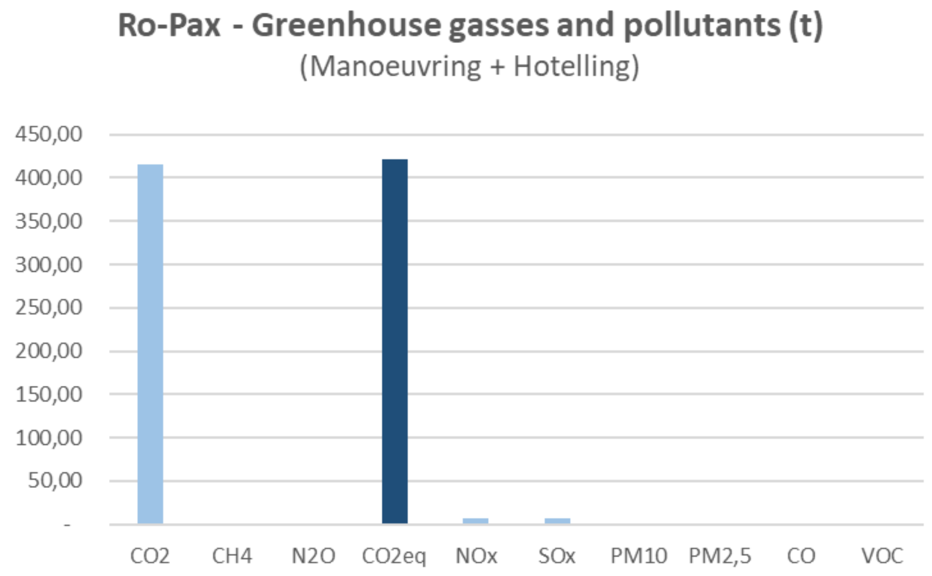
	Manoeuvring	%	Berth	%	Total
kWh	276.627	46%	320.305	54%	**596.931**
CO_2	189,92	46%	226,14	54%	**416,06**
CH_4	0,00	51%	0,00	49%	**0,01**
N_2O	0,01	45%	0,01	55%	**0,02**
t CO_2e *	192,51	46%	229,26	54%	**421,77**
R-22 (AC+ref)	-	-	-	-	**0,00**
R-134a (AC)	-	-	-	-	**0,01**
R-404a (ref)	-	-	-	-	**0,00**
t CO_2e **					**435,05**
NO_x	3,57	48%	3,82	52%	**7,39**
SO_x	3,17	45%	3,84	55%	**7,00**
PM_{10}	0,40	46%	0,46	54%	**0,86**
$PM_{2,5}$	0,37	46%	0,43	54%	**0,80**
CO	0,30	48%	0,32	52%	**0,62**
VOC	0,13	51%	0,13	49%	**0,26**

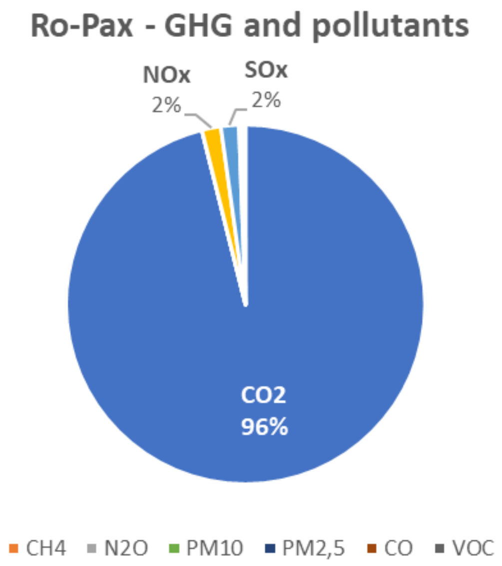
TOT	**197,87**	**46%**	**235,15**	**54%**	**433,02**

* ($CO_2 + CH_4 + N_2O$)

** ($CO_2 + CH_4 + N_2O$ + R-22 + R134a + R404a)




Ro-Pax - Greenhouse gasses and pollutants (t)
(Manoeuvring + Hotelling)
450,00
400,00
350,00
300,00
250,00
200,00
150,00
100,00
50,00
-
CO2
CH4
N2O
CO2eq
NOx
SOx
PM10
PM2,5
CO
VOC


Ro-Pax - GHG and pollutants
NOx
2%
SOx
2%
CO2
96%
CH4
N2O
PM10
PM2,5
CO
VOC

RO-RO CARGO

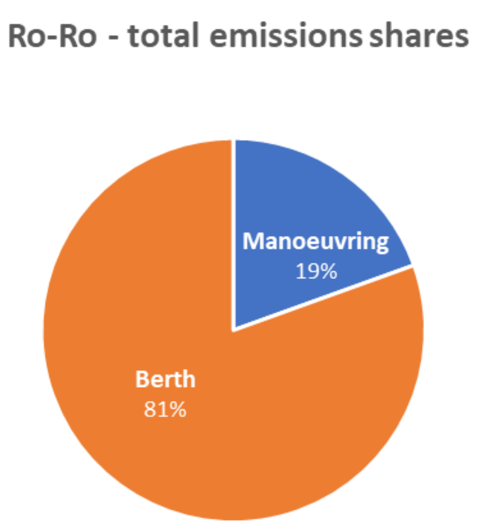
The Ro-Ro Cargo emissions summary is reported below:

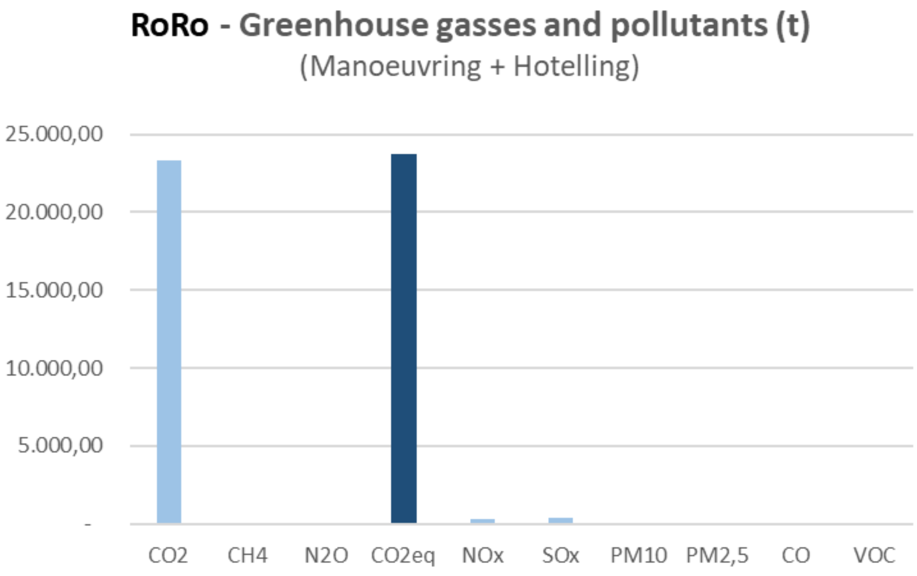
	Manoeuvring	%	Berth	%	Total
kWh	6.450.284	21%	24.791.275	79%	**31.241.559**
CO_2	4.537,92	19%	18.811,62	81%	**23.349,54**
CH_4	0,06	26%	0,16	74%	**0,22**
N_2O	0,24	18%	1,11	82%	**1,35**
t CO_2e *	4.602,49	19%	19.110,38	81%	**23.712,87**
R-22 (AC+ref)	-	-	-	-	**0,01**
R-134a (AC)	-	-	-	-	**0,39**
R-404a (ref)	-	-	-	-	**0,02**
t CO_2e **					**24.299,57**
NO_x	66,50	24%	213,89	76%	**280,39**
SO_x	76,07	19%	317,43	81%	**393,50**
PM_{10}	9,10	22%	33,17	78%	**42,27**
$PM_{2,5}$	8,53	22%	31,09	78%	**39,62**
CO	6,63	24%	20,82	76%	**27,45**
VOC	2,86	25%	8,43	75%	**11,29**

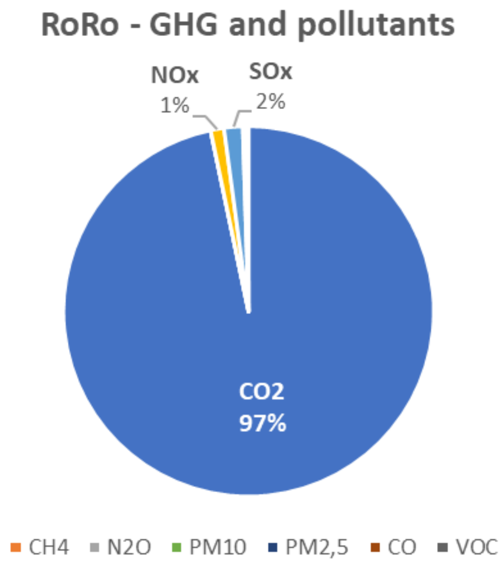
TOT	**4.707,91**	**19%**	**19.437,72**	**81%**	**24.145,63**

* (CO_2 + CH_4 + N_2O)

** (CO_2 + CH_4 + N_2O + R-22 + R134a + R404a)




RoRo - Greenhouse gasses and pollutants (t)
(Manoeuvring + Hotelling)
25.000,00
20.000,00
15.000,00
10.000,00
5.000,00
-
CO2
CH4
N2O
CO2eq
NOx
SOx
PM10
PM2,5
CO
VOC


RoRo - GHG and pollutants
NOx
1%
SOx
2%
CO2
97%
CH4
N2O
PM10
PM2,5
CO
VOC

3.3.3. Miscellaneous

TUG

This section is divided into two parts: the first one refers to tugs not operating in the port of Trieste that entered the port during international navigation (and for this reason are recorded in the Sinfomar system); the second part of the section reports the emissions produced by tugs operating in the port of Trieste in order to assist the seagoing vessels entering the harbour. The emissions proeduced by the assisting tugs of the port of Trieste are not calculated with the ship movements methodology (Tier III), but based on the yearly fuel consumption (Tier I).

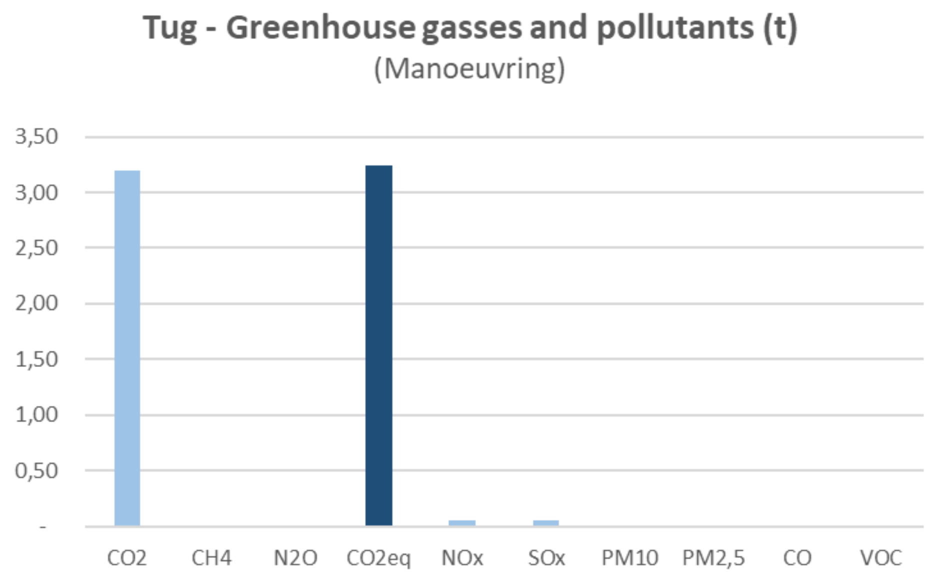
Seagoing tugs (international navigation)

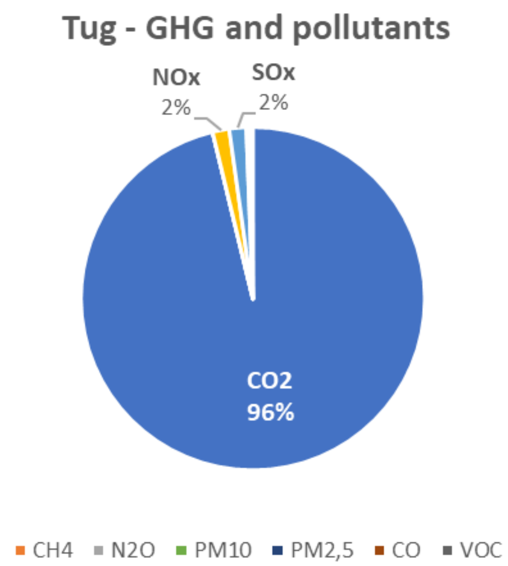
It has been assumed that tugs don't need energy during the hotelling phase, so auxiliary engines are turned off at berth. Moreover they don't have boilers. As far as non combustion emissions are concerned (cooling and refrigerant gasses), their contribution is negligible, so they're not calculated at all during hotelling phase.

The seagoing tug emissions summary is reported below:

	Manoeuvring	
kWh	4.664	
CO_2	3,19	
CH_4	0,00	
N_2O	0,00	
t CO_2e *	3,24	* ($CO_2 + CH_4 + N_2O$)
R-22 (AC+ref)	0,00	
R-134a (AC)	0,00	
R-404a (ref)	0,00	
t CO_2e **	3,31	** ($CO_2 + CH_4 + N_2O$ + R-22 + R134a + R404a)
NO_x	0,05	
SO_x	0,05	
PM_{10}	0,01	
$PM_{2,5}$	0,01	
CO	0,01	
VOC	0,00	

TOT	3,32





Domestic tugs (port assistence service)

These are the annual consumptions of marine diesel oil (MDO) deriving from TRIPMARE data:

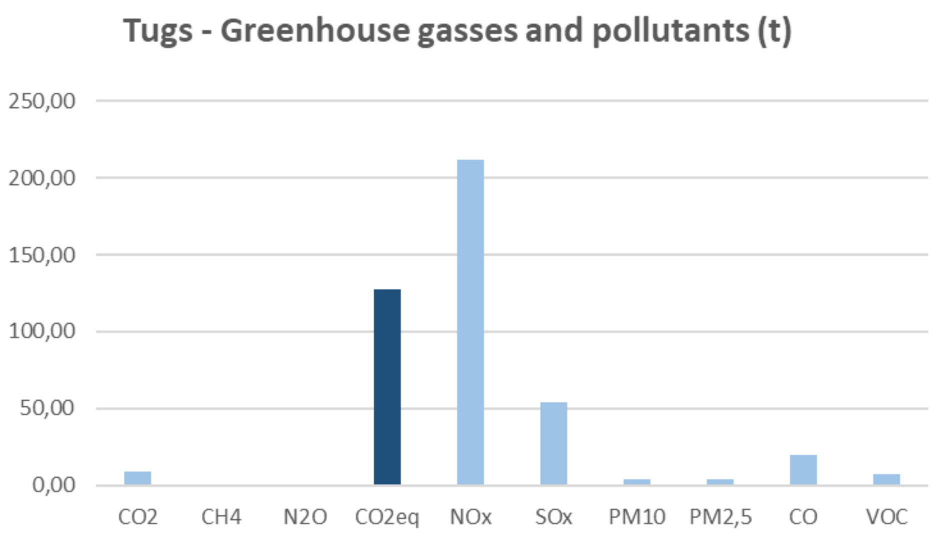
Year 2018	Average monthly consumption in kg
Altair	31.763,00
Centurion	23.659,00
Davide	16.618,00
Deneb	6.744,00
Gladiator	15.803,00
Taur	29.650,00
Vega	652,00
TOTAL (kg):	**124.889,00**
TOTAL per year (tons):	**1.498,67**

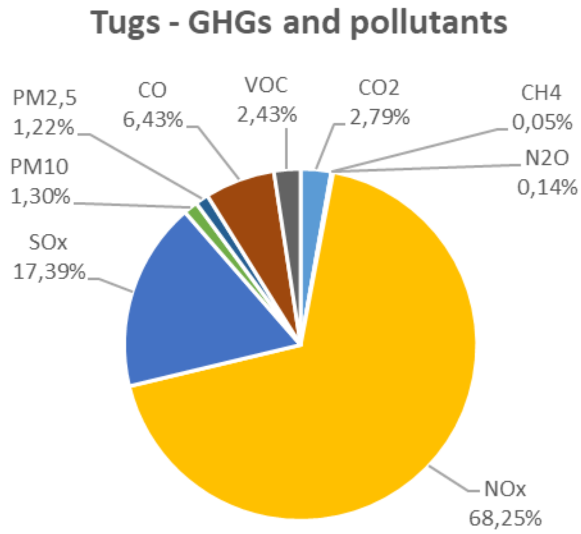
These are the annual consumptions of marine diesel oil (MDO) deriving from OCEAN data:

Annual Consumption of MDO in tons	**1.200,00**

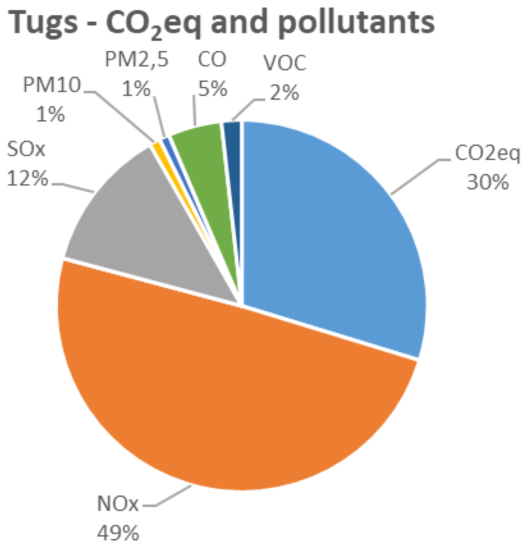
The Tugs emissions summary is reported below:

GHG/Pollutant	kg
CO_2	8.651,93
CH_4	151,13
N_2O	431,79
kg CO_2eq	**127.306,96**
NO_x	211.845,44
SO_x	53.973,36
PM_{10}	4.048,00
$PM_{2,5}$	3.778,14
CO	19.970,14
VOC	7.556,27





Tugs - GHGs and pollutants
PM2,5
1,22%
CO
6,43%
VOC
2,43%
CO2
2,79%
CH4
0,05%
N2O
0,14%
PM10
1,30%
SOx
17,39%
NOx
68,25%



Tugs - CO_2eq and pollutants
PM2,5
1%
CO
5%
VOC
2%
PM10
1%
SOx
12%
CO2eq
30%
NOx
49%

3.3.4. Tankers

CHEMICAL

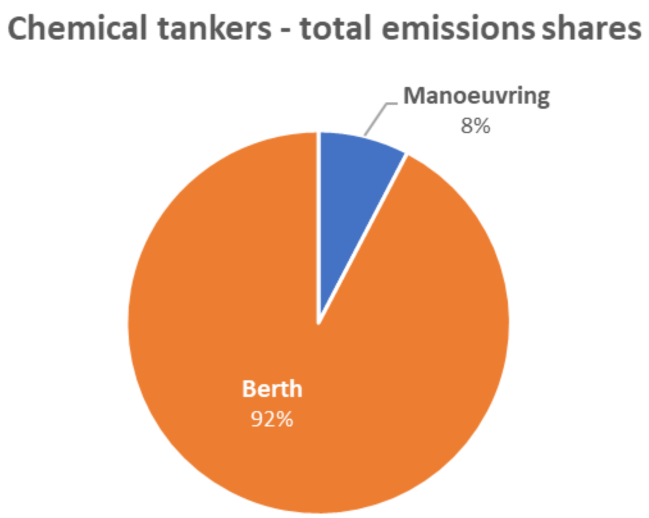
The Chemical Tankers emissions summary is reported below:

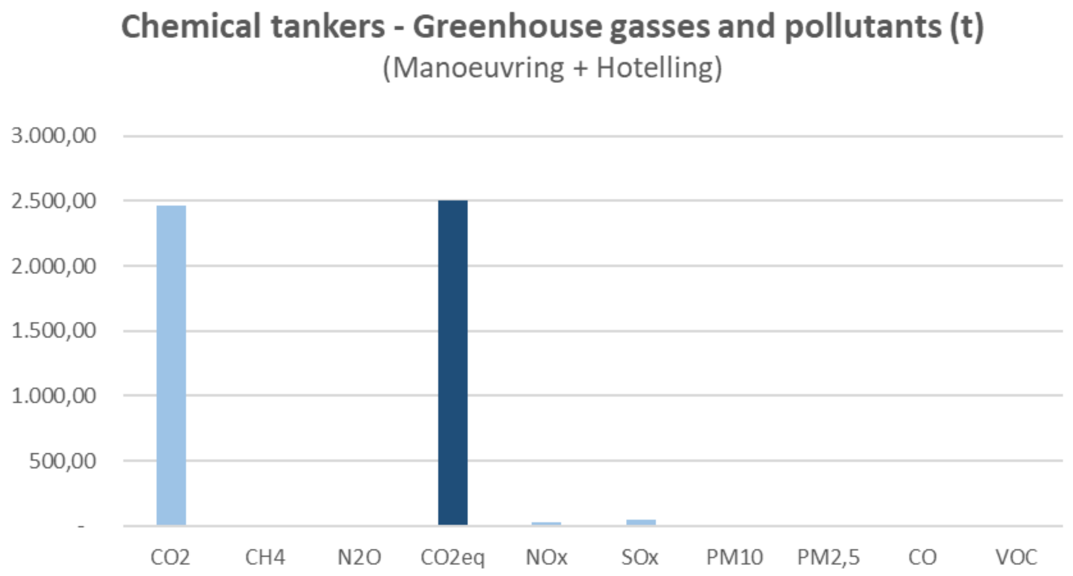
	Manoeuvring	%	Berth	%	Total
kWh	274.495	8%	3.008.967	92%	**3.283.462**
CO_2	187,23	8%	2.273,68	92%	**2.460,91**
CH_4	0,00	12%	0,02	88%	**0,02**
N_2O	0,01	7%	0,13	93%	**0,14**
t CO_2e *	190,03	8%	2.309,53	92%	**2.499,56**
R-22 (AC+ref)	-	-	-	-	**0,00**
R-134a (AC)	-	-	-	-	**0,02**
R-404a (ref)	-	-	-	-	**0,00**
t CO_2e **					**2.525,10**
NO_x	3,43	11%	27,37	89%	**30,81**
SO_x	3,13	8%	38,38	92%	**41,51**
PM_{10}	0,38	9%	4,04	91%	**4,42**
$PM_{2,5}$	0,36	9%	3,79	91%	**4,15**
CO	0,32	11%	2,56	89%	**2,87**
VOC	0,13	11%	1,03	89%	**1,17**

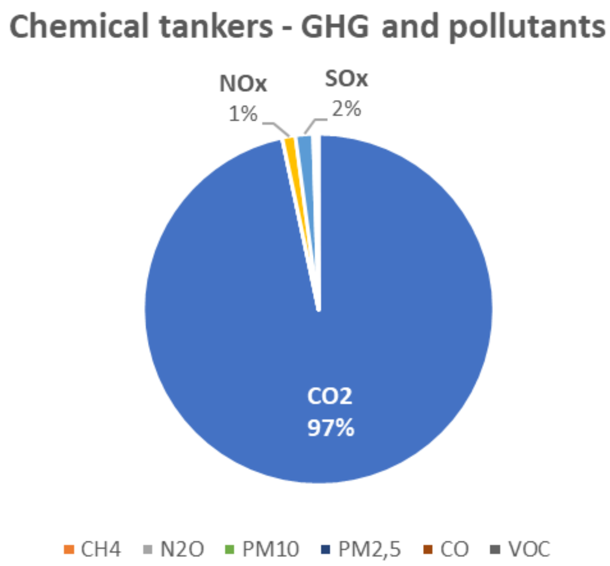
TOT	**194,99**	**8%**	**2.351,01**	**92%**	**2.546,00**

* (CO_2 + CH_4 + N_2O)

** (CO_2 + CH_4 + N_2O + R-22 + R134a + R404a)




Chemical tankers - Greenhouse gasses and pollutants (t)
(Manoeuvring + Hotelling)
3.000,00
2.500,00
2.000,00
1.500,00
1.000,00
500,00
-
CO2
CH4
N2O
CO2eq
NOx
SOx
PM10
PM2,5
CO
VOC


Chemical tankers - GHG and pollutants
NOx
1%
SOx
2%
CO2
97%
CH4
N2O
PM10
PM2,5
CO
VOC

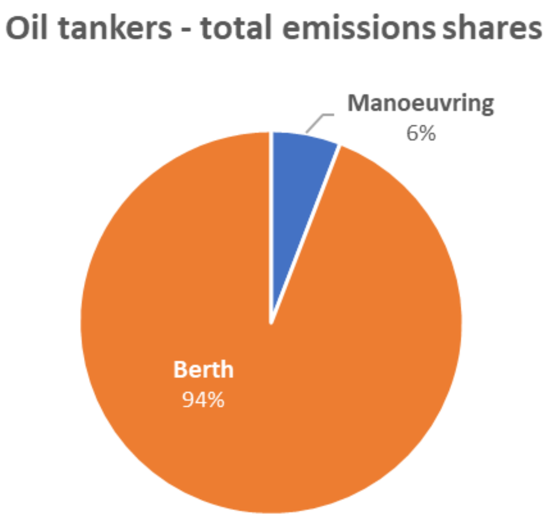
OIL

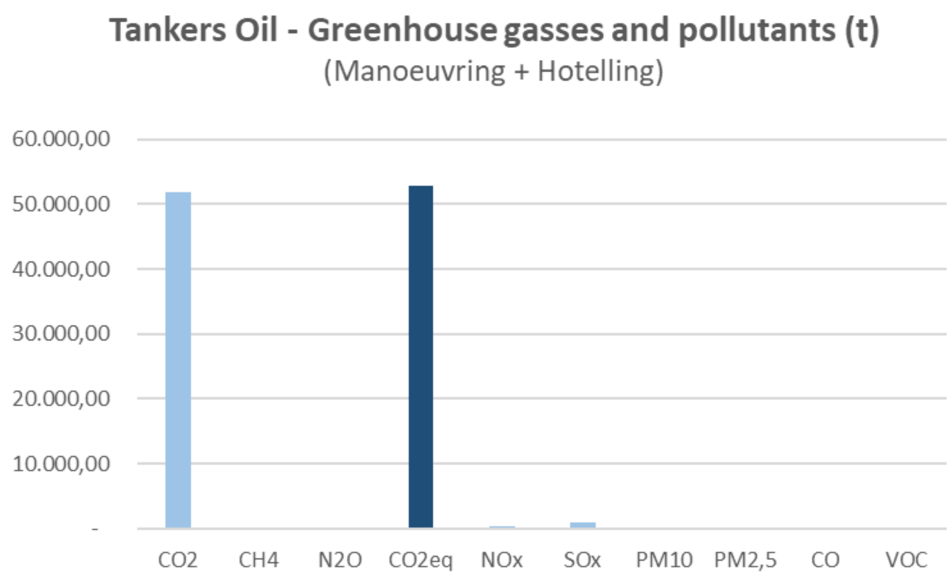
The Oil Tankers emissions summary is reported below:

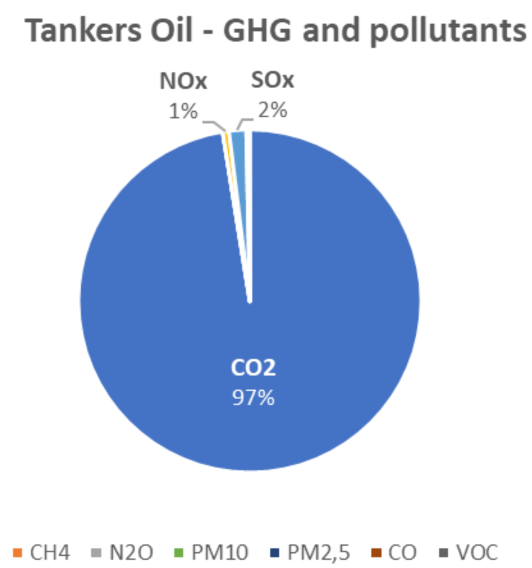
	Manoeuvring	%	Berth	%	Total
kWh	4.407.037	7%	55.399.083	93%	**59.806.120**
CO_2	2.989,92	6%	48.849,50	94%	**51.839,42**
CH_4	0,04	22%	0,15	78%	**0,19**
N_2O	0,16	4%	3,62	96%	**3,78**
t CO_2e *	3.034,18	6%	49.812,24	94%	**52.846,42**
R-22 (AC+ref)	-	-	-	-	**0,00**
R-134a (AC)	-	-	-	-	**0,13**
R-404a (ref)	-	-	-	-	**0,01**
t CO_2e **					**53.048,35**
NO_x	53,36	17%	256,87	83%	**310,23**
SO_x	50,00	6%	815,65	94%	**865,65**
PM_{10}	6,10	9%	60,96	91%	**67,06**
$PM_{2,5}$	5,74	9%	57,08	91%	**62,82**
CO	5,14	17%	25,89	83%	**31,03**
VOC	2,17	16%	11,09	84%	**13,26**
TOT	**3.112,63**	**6%**	**50.080,81**	**94%**	**53.193,45**

* (CO_2 + CH_4 + N_2O)

** (CO_2 + CH_4 + N_2O + R-22 + R134a + R404a)




Tankers Oil - Greenhouse gasses and pollutants (t)
(Manoeuvring + Hotelling)
60.000,00
50.000,00
40.000,00
30.000,00
20.000,00
10.000,00
-
CO2
CH4
N2O
CO2eq
NOx
SOx
PM10
PM2,5
CO
VOC


Tankers Oil - GHG and pollutants
NOx
1%
SOx
2%
CO2
97%
CH4
N2O
PM10
PM2,5
CO
VOC

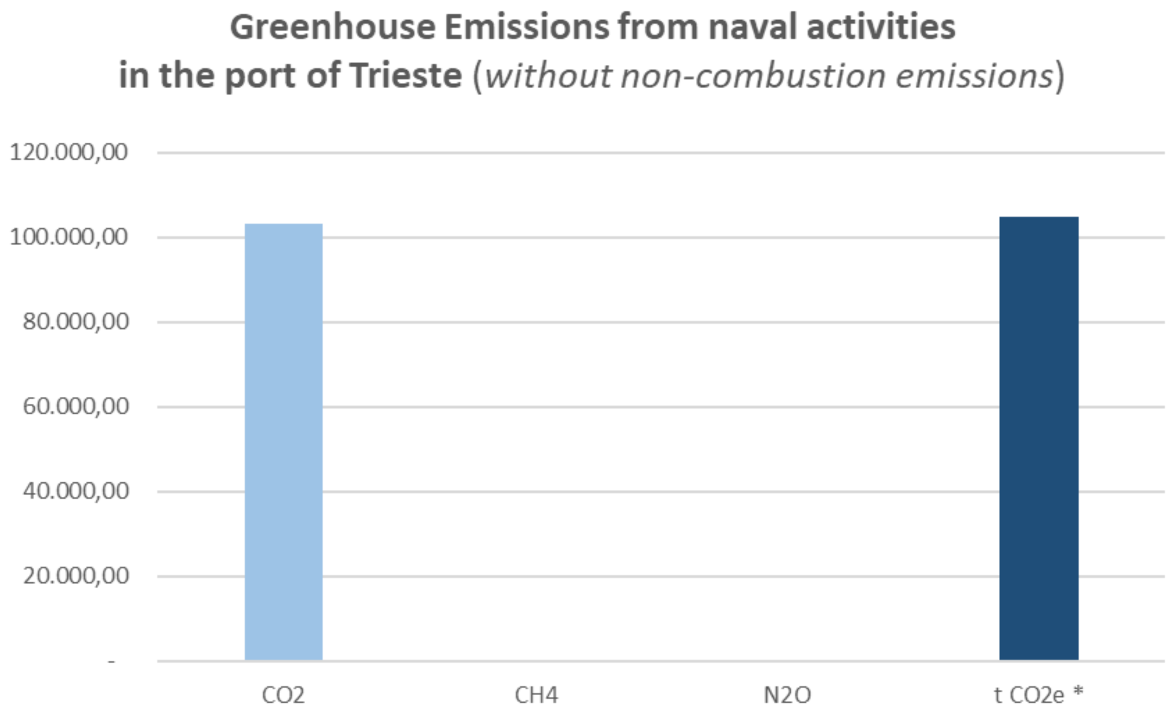
4. Conclusions

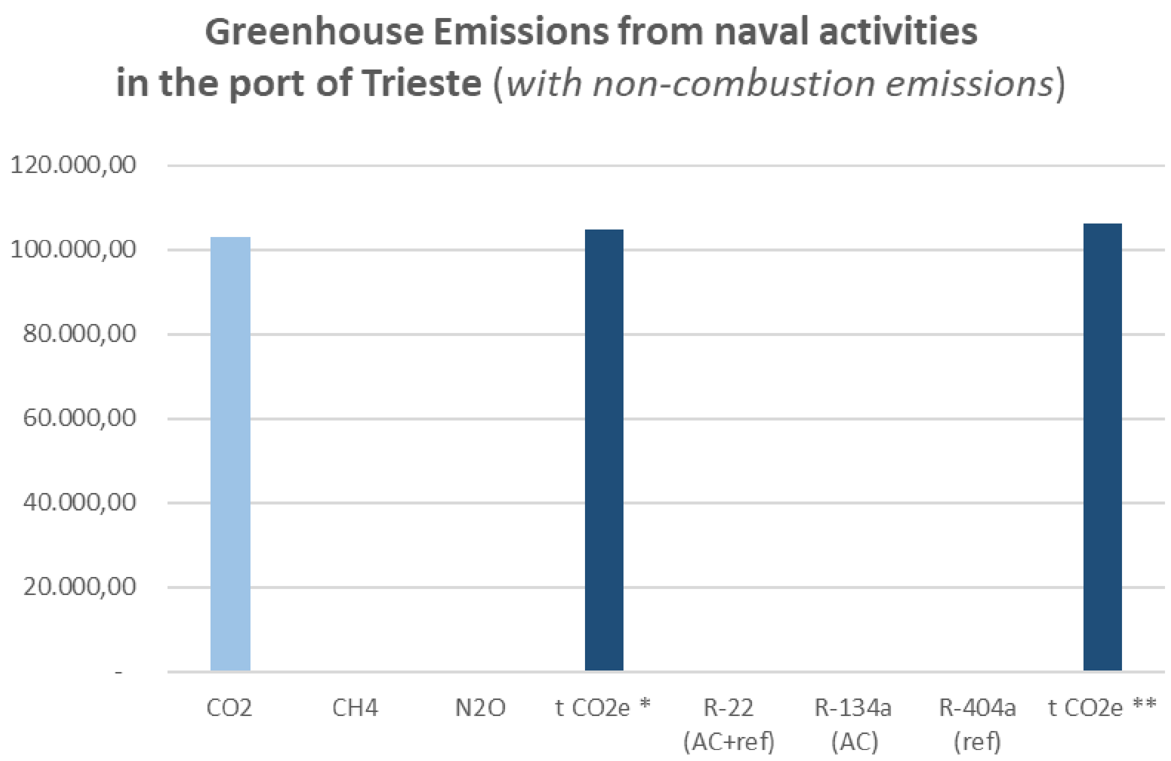
To conclude this work, the total summary tables of polluting and climate-altering emissions that contribute to defining the carbon footprint of the naval activities of the port of Trieste are estimated and reported. The related graphs are also shown below.

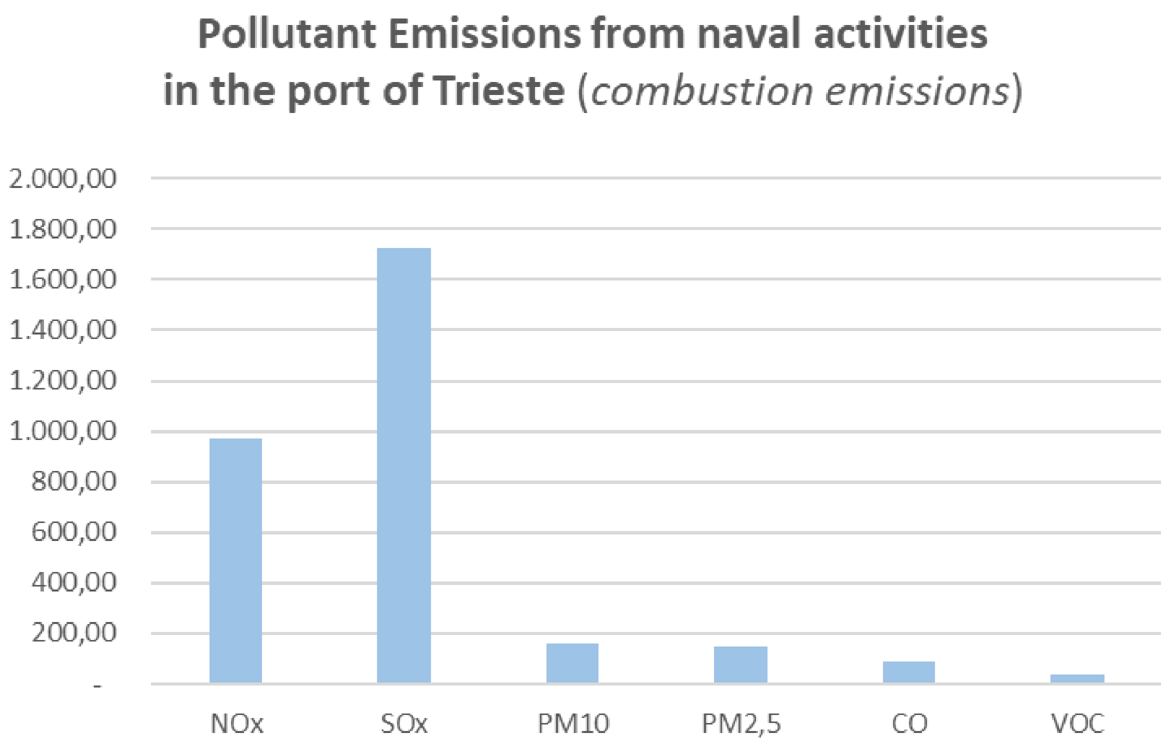
	Manoeuvring	%	Berth	%	Total
kWh	17.995.047,13	14%	110.279.436,75	86%	**128.274.484**
CO2	12.291,50	12%	90.740,38	88%	**103.031,87**
CH4	0,17	26%	0,49	74%	**0,66**
N2O	0,65	10%	6,12	90%	**6,77**
t CO2e *	12.468,05	12%	92.375,22	88%	**104.843,27**
R-22 (AC+ref)	-	-	-	-	**0,22**
R-134a (AC)	-	-	-	-	**0,78**
R-404a (ref)	-	-	-	-	**0,04**
t CO2e **					**106.404,53**
NOx	219,49	23%	749,38	77%	**968,87**
SOx	205,65	12%	1.522,20	88%	**1.727,85**
PM10	25,25	16%	133,91	84%	**159,17**
PM2,5	23,73	16%	125,45	84%	**149,18**
CO	20,29	22%	71,24	78%	**91,53**
VOC	8,67	23%	29,47	77%	**38,14**

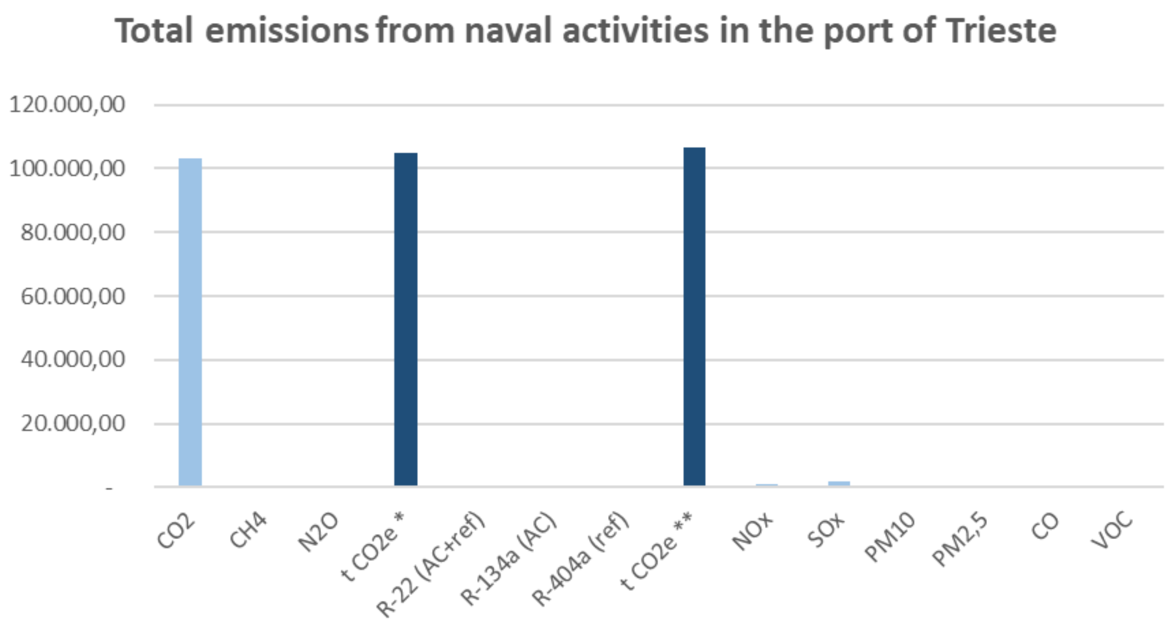
TOT	**12.795,39**	**12%**	**93.378,65**	**88%**	**106.174,04**

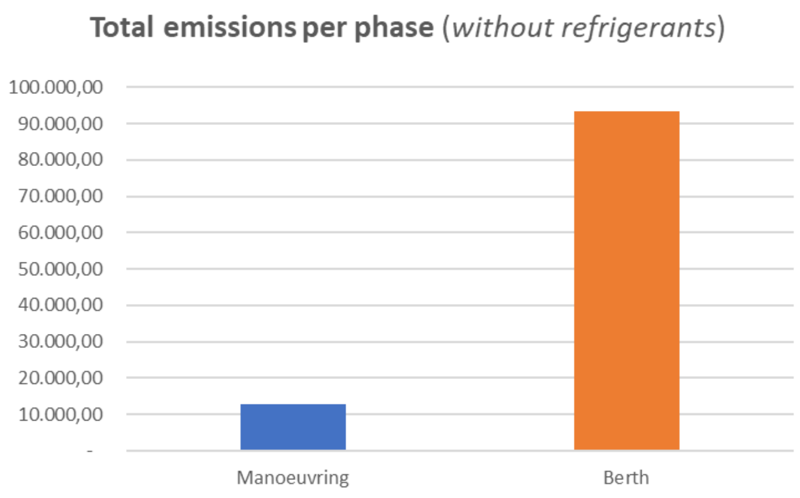
* (CO2 + CH4 + N2O)
** (CO2 + CH4 + N2O + R-22 + R134a + R404a)

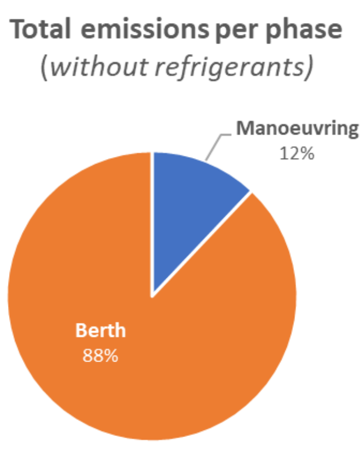



Greenhouse Emissions from naval activities
in the port of Trieste (*with non-combustion emissions*)
120.000,00
100.000,00
80.000,00
60.000,00
40.000,00
20.000,00
-
CO2
CH4
N2O
t CO2e *
R-22 (AC+ref)
R-134a (AC)
R-404a (ref)
t CO2e **

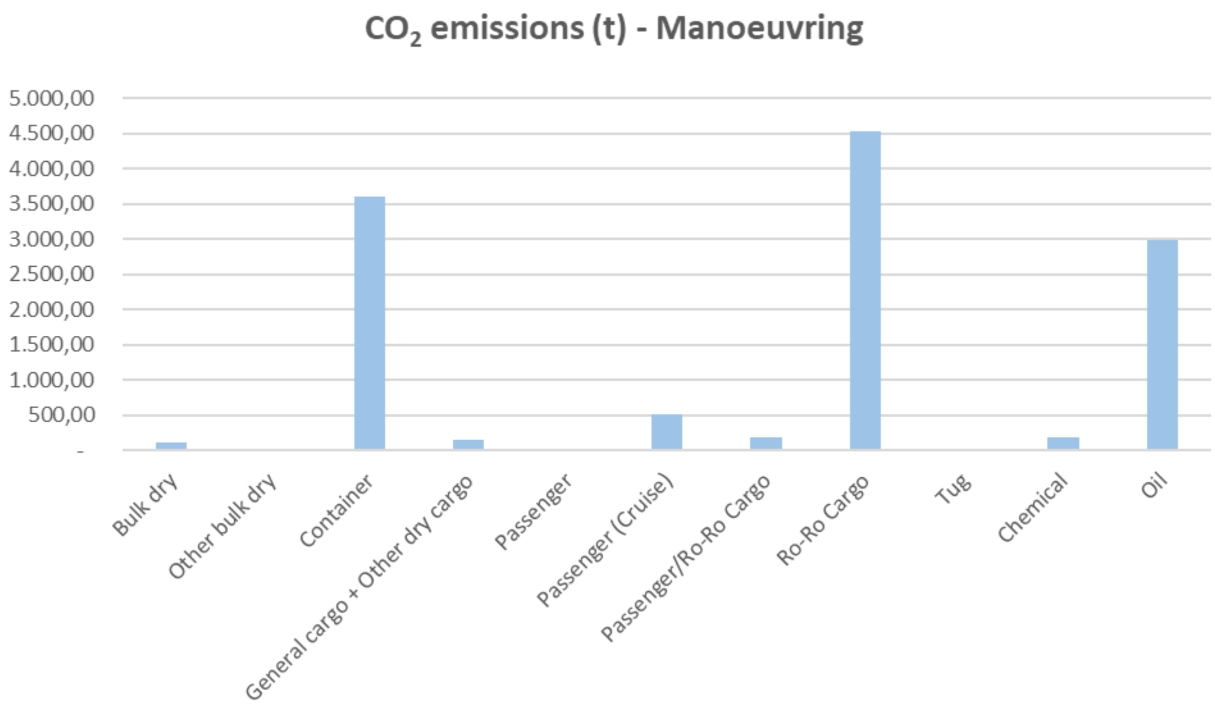

Pollutant Emissions from naval activities
in the port of Trieste (*combustion emissions*)
2.000,00
1.800,00
1.600,00
1.400,00
1.200,00
1.000,00
800,00
600,00
400,00
200,00
-
NOx
SOx
PM10
PM2,5
CO
VOC

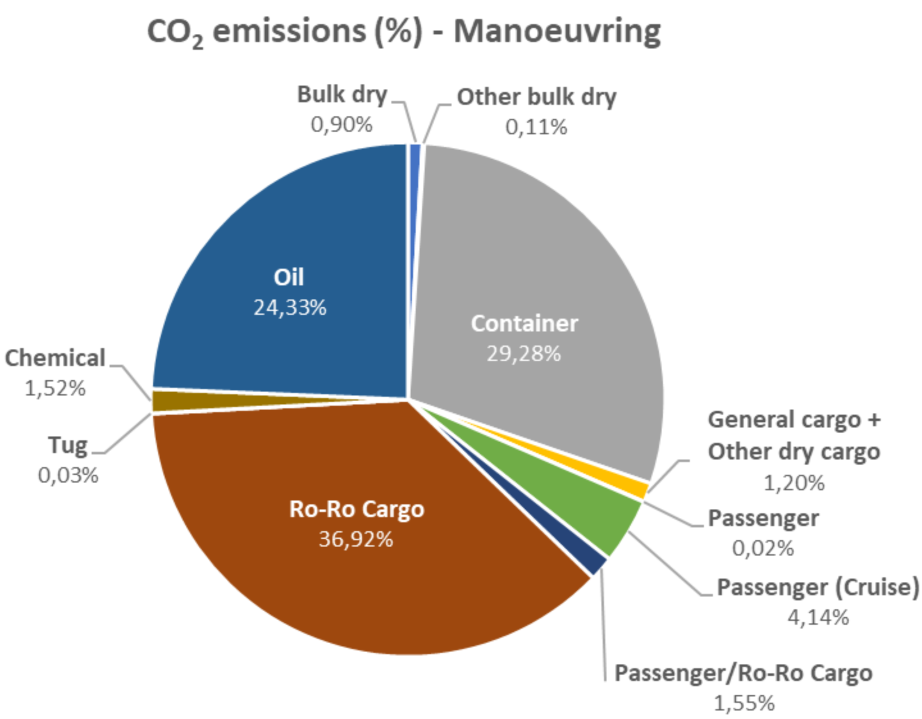

Total emissions from naval activities in the port of Trieste
120.000,00
100.000,00
80.000,00
60.000,00
40.000,00
20.000,00
-
CO2
CH4
N2O
t CO2e *
R-22 (AC+ref)
R-134a (AC)
R-404a (ref)
t CO2e **
NOx
SOx
PM10
PM2,5
CO
VOC

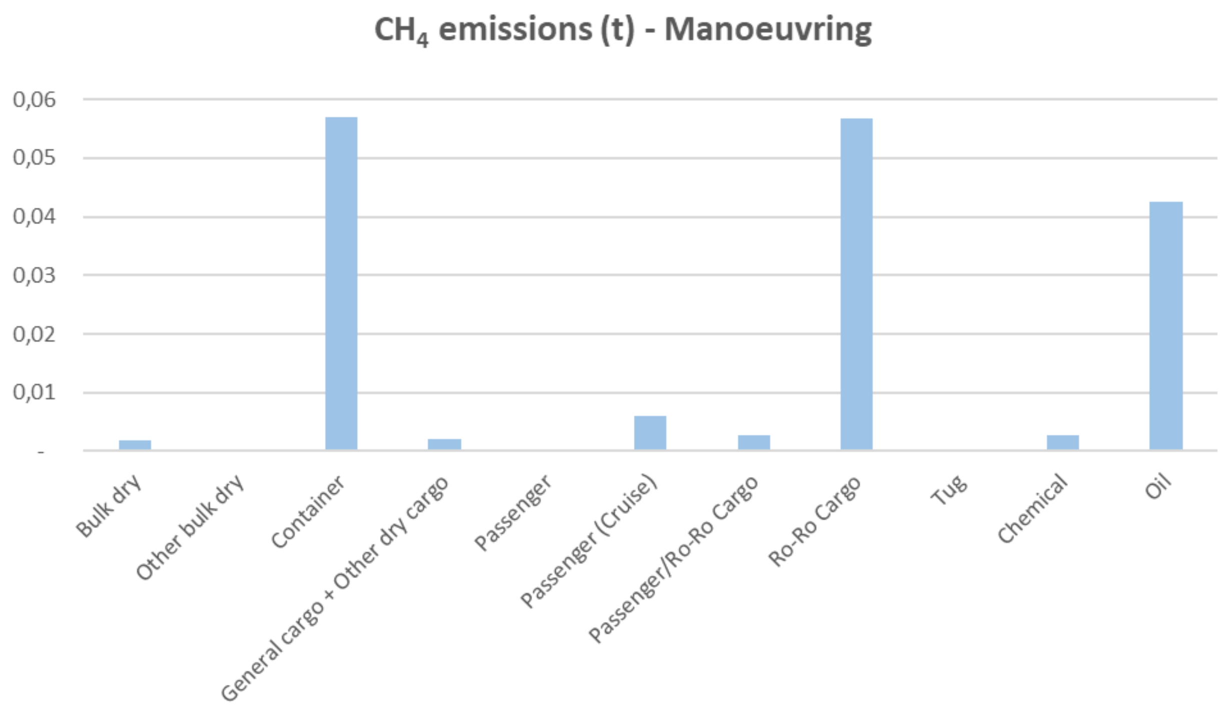

Total emissions per phase (without refrigerants)
100.000,00
90.000,00
80.000,00
70.000,00
60.000,00
50.000,00
40.000,00
30.000,00
20.000,00
10.000,00
-
Manoeuvring
Berth


Total emissions per phase (without refrigerants)
Manoeuvring 12%
Berth 88%

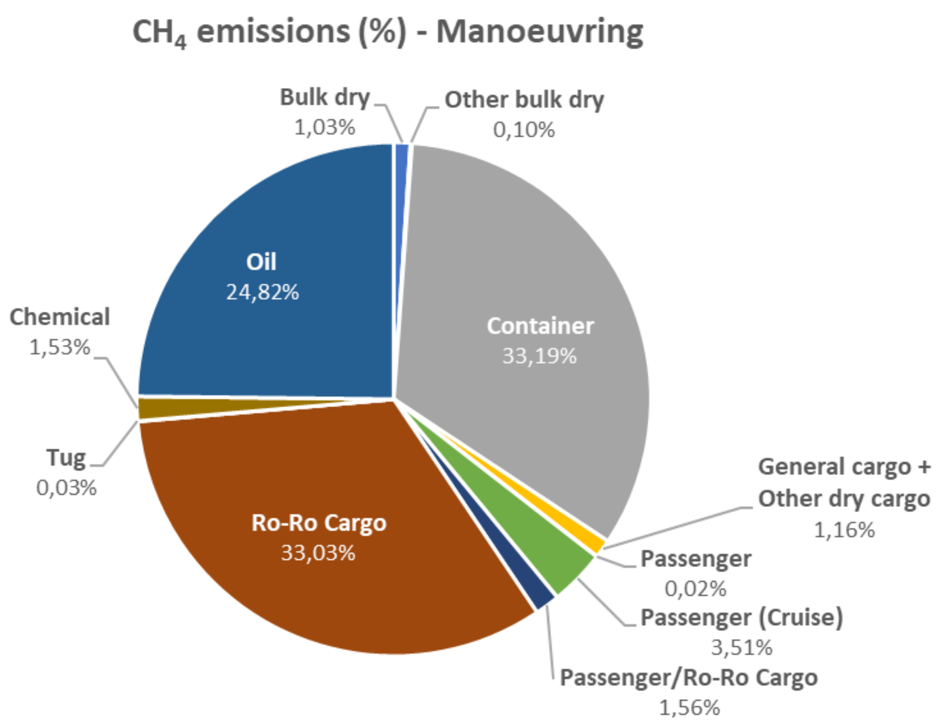
Emissions during manoeuvring phase



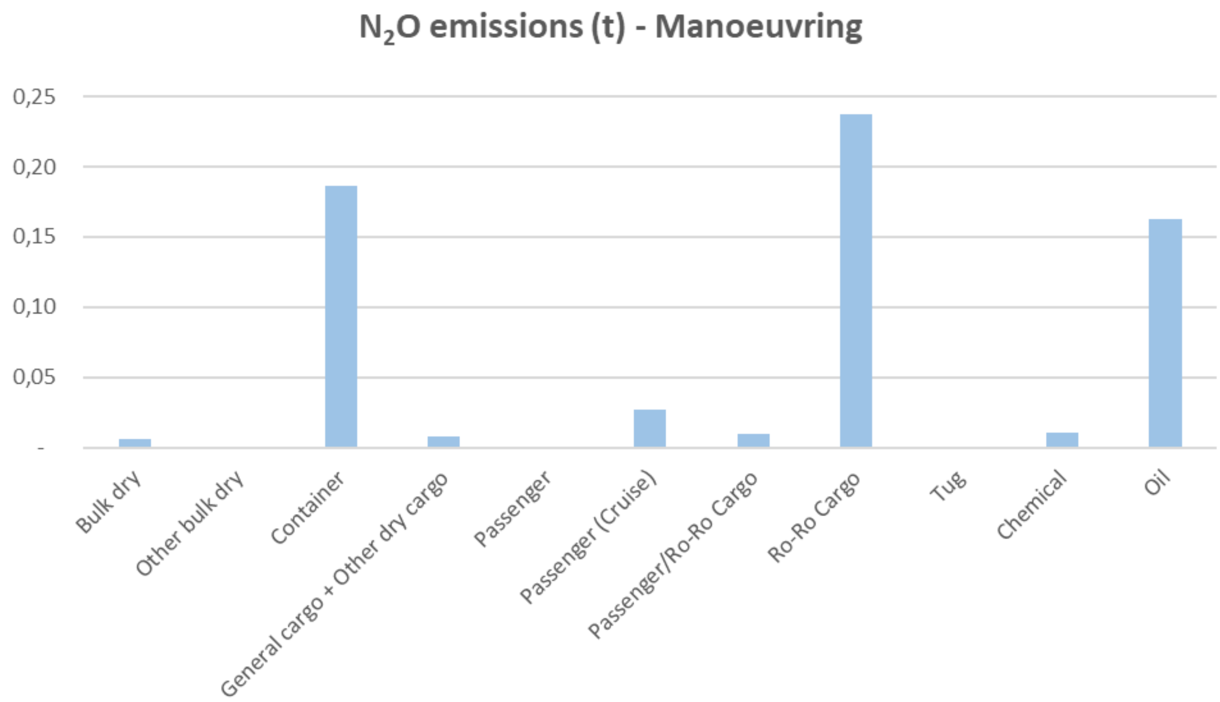


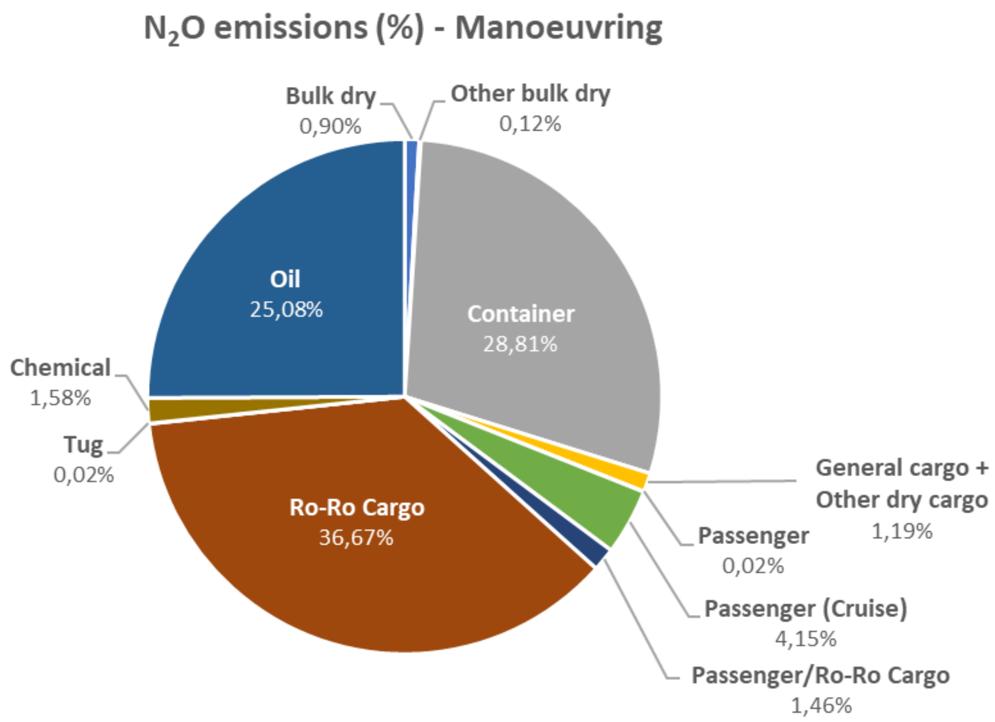


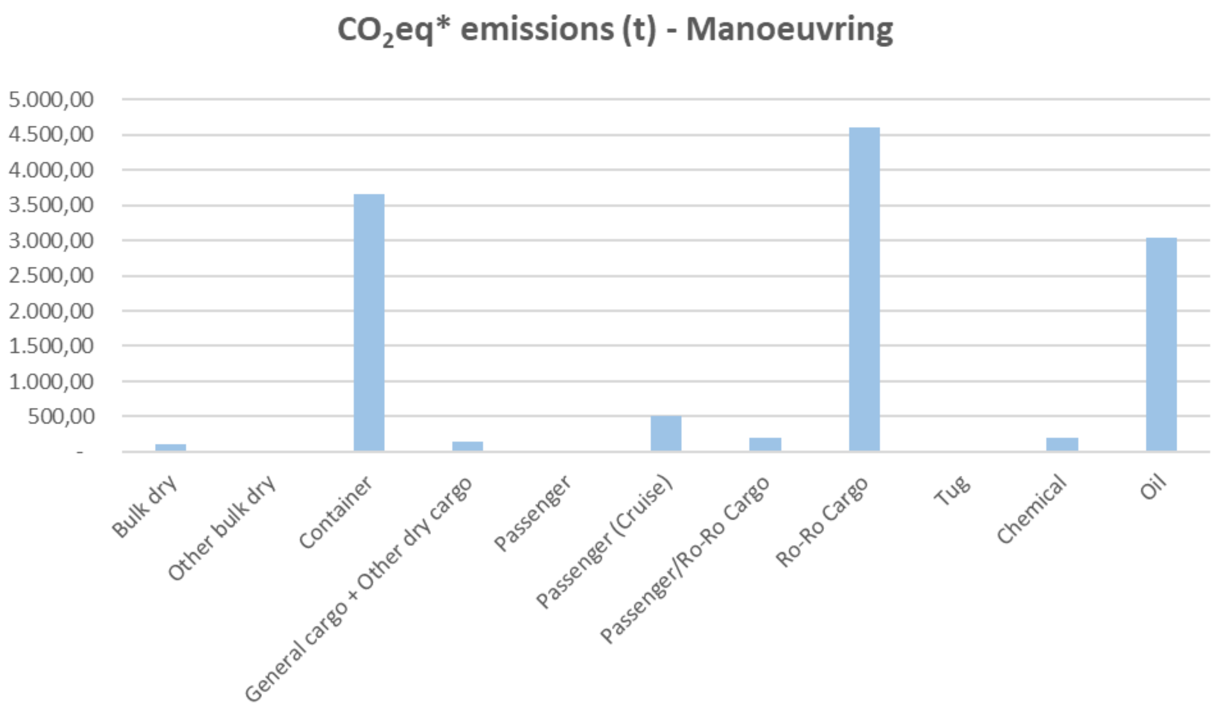
CH_4 emissions (t) - Manoeuvring
0,06
0,05
0,04
0,03
0,02
0,01
-
Bulk dry
Other bulk dry
Container
General cargo + Other dry cargo
Passenger
Passenger (Cruise)
Passenger/Ro-Ro Cargo
Ro-Ro Cargo
Tug
Chemical
Oil

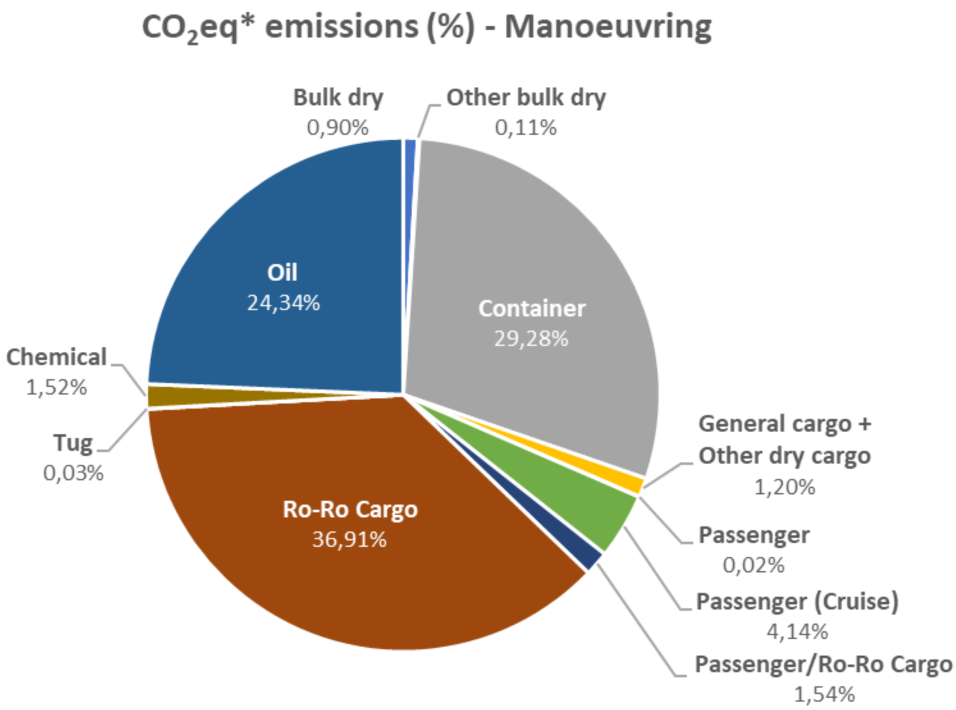


CH_4 emissions (%) - Manoeuvring
Bulk dry 1,03%
Other bulk dry 0,10%
Oil 24,82%
Container 33,19%
Chemical 1,53%
Tug 0,03%
Ro-Ro Cargo 33,03%
General cargo + Other dry cargo 1,16%
Passenger 0,02%
Passenger (Cruise) 3,51%
Passenger/Ro-Ro Cargo 1,56%

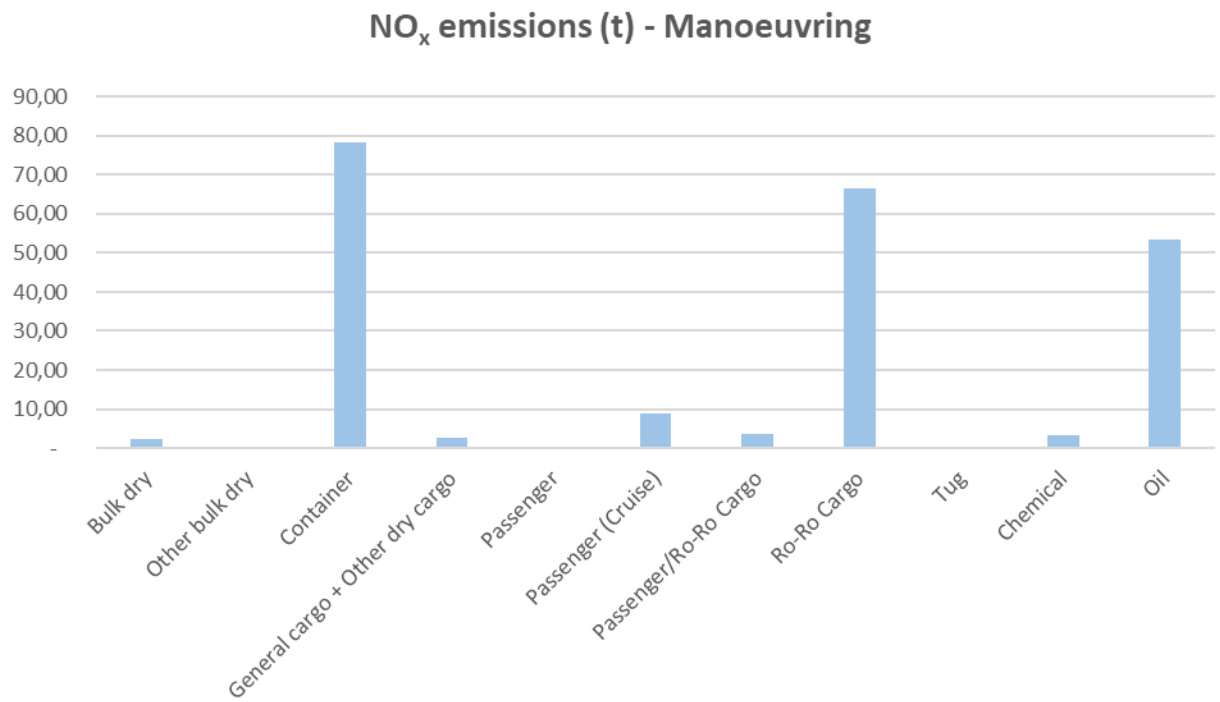

N$_2$O emissions (t) - Manoeuvring
0,25
0,20
0,15
0,10
0,05
-
Bulk dry
Other bulk dry
Container
General cargo + Other dry cargo
Passenger
Passenger (Cruise)
Passenger/Ro-Ro Cargo
Ro-Ro Cargo
Tug
Chemical
Oil

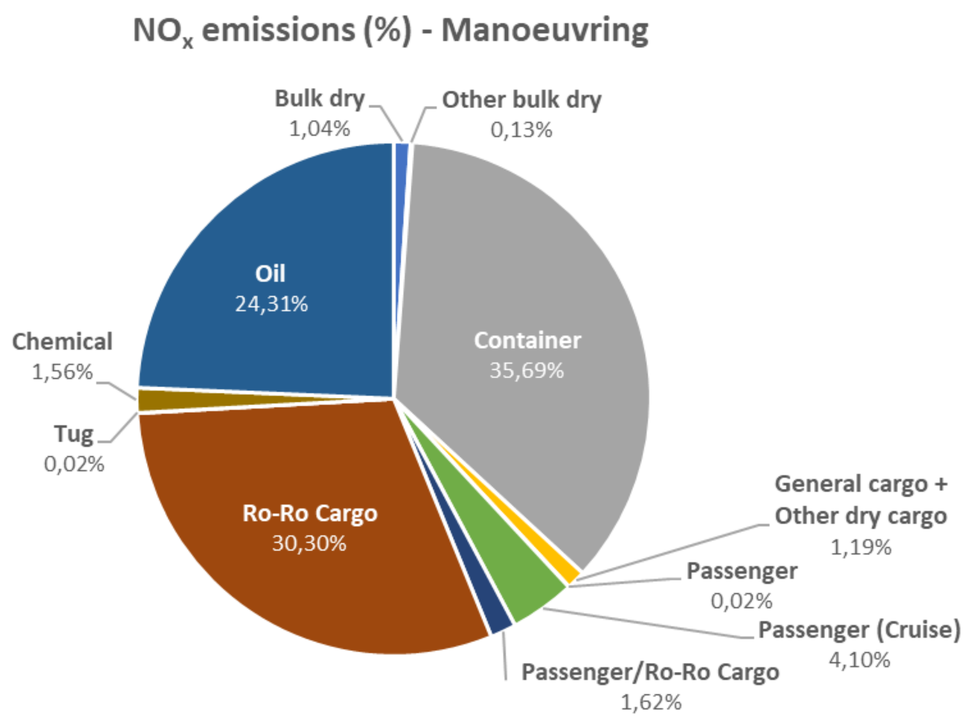

N$_2$O emissions (%) - Manoeuvring
Bulk dry 0,90%
Other bulk dry 0,12%
Container 28,81%
General cargo + Other dry cargo 1,19%
Passenger 0,02%
Passenger (Cruise) 4,15%
Passenger/Ro-Ro Cargo 1,46%
Ro-Ro Cargo 36,67%
Tug 0,02%
Chemical 1,58%
Oil 25,08%

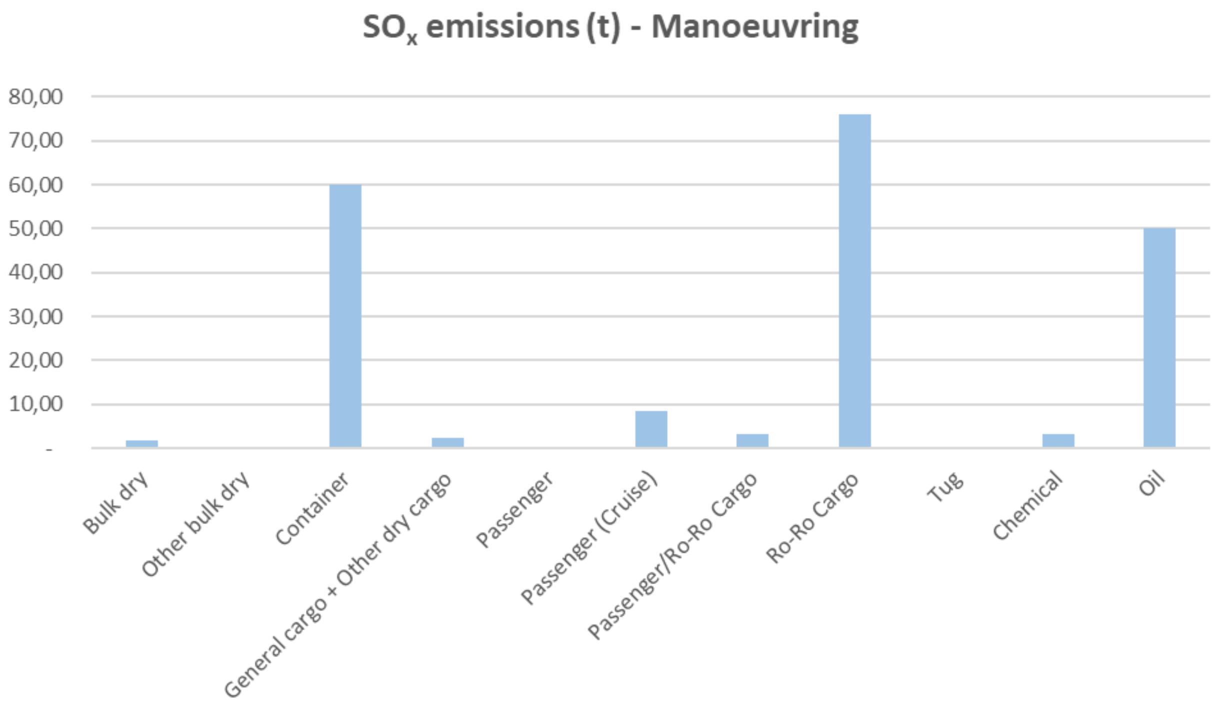

CO2eq* emissions (t) - Manoeuvring
5.000,00
4.500,00
4.000,00
3.500,00
3.000,00
2.500,00
2.000,00
1.500,00
1.000,00
500,00
-
Bulk dry
Other bulk dry
Container
General cargo + Other dry cargo
Passenger
Passenger (Cruise)
Passenger/Ro-Ro Cargo
Ro-Ro Cargo
Tug
Chemical
Oil

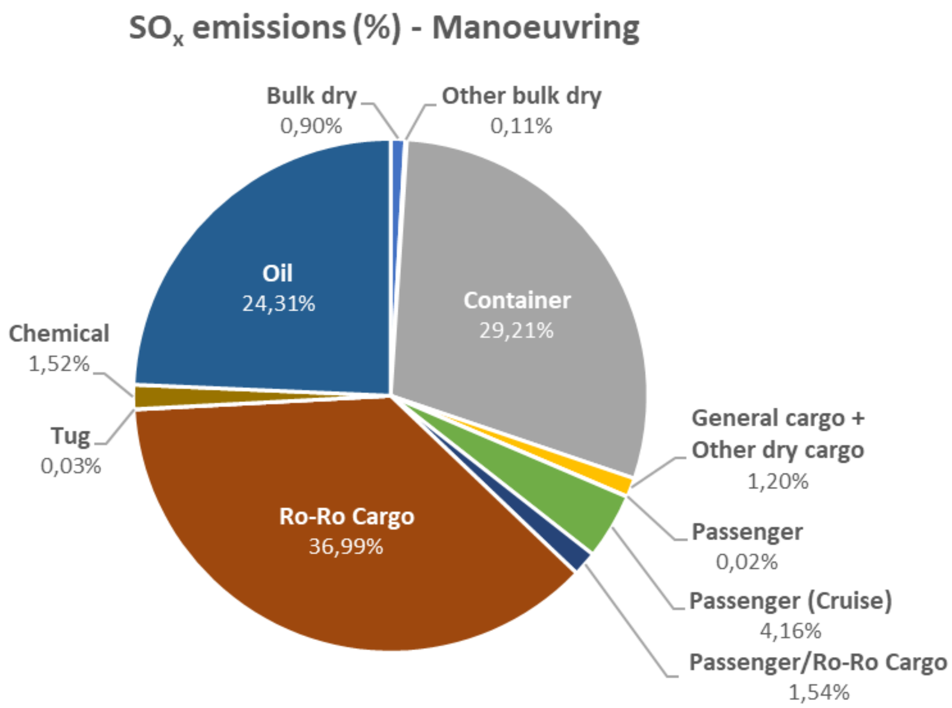

CO2eq* emissions (%) - Manoeuvring
Bulk dry 0,90%
Other bulk dry 0,11%
Oil 24,34%
Container 29,28%
Chemical 1,52%
Tug 0,03%
General cargo + Other dry cargo 1,20%
Passenger 0,02%
Ro-Ro Cargo 36,91%
Passenger (Cruise) 4,14%
Passenger/Ro-Ro Cargo 1,54%

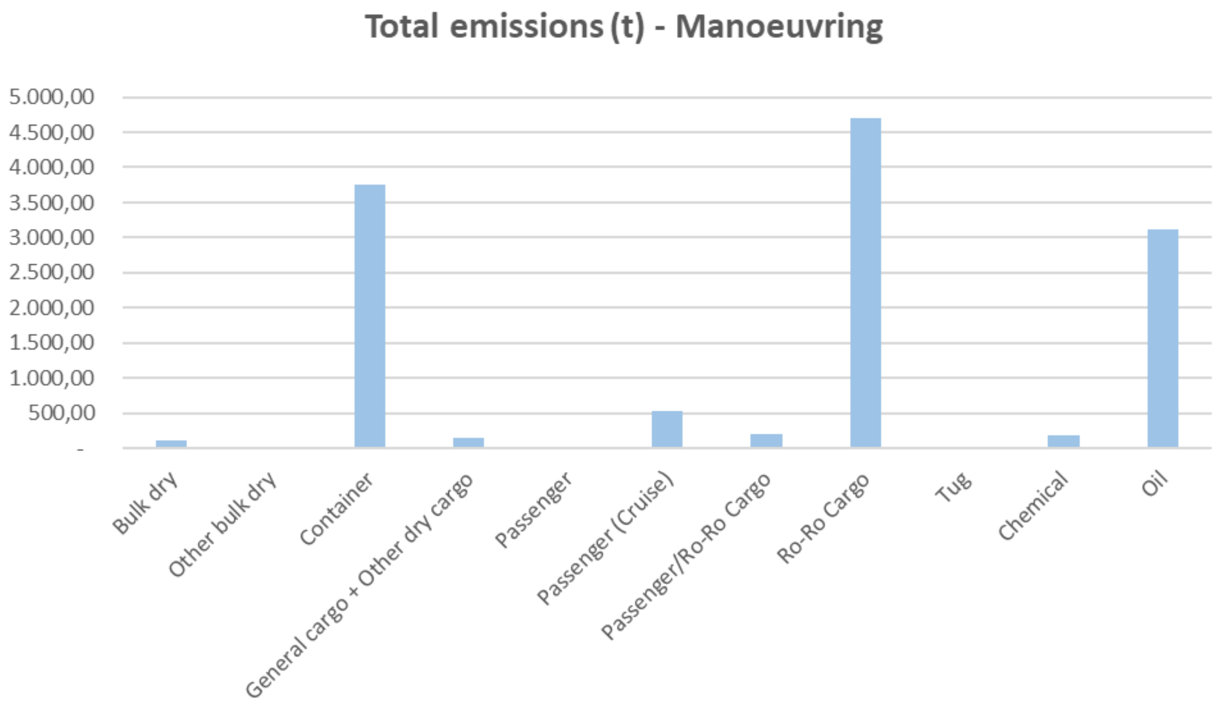
*** (CO_2 + CH_4 + N_2O)**

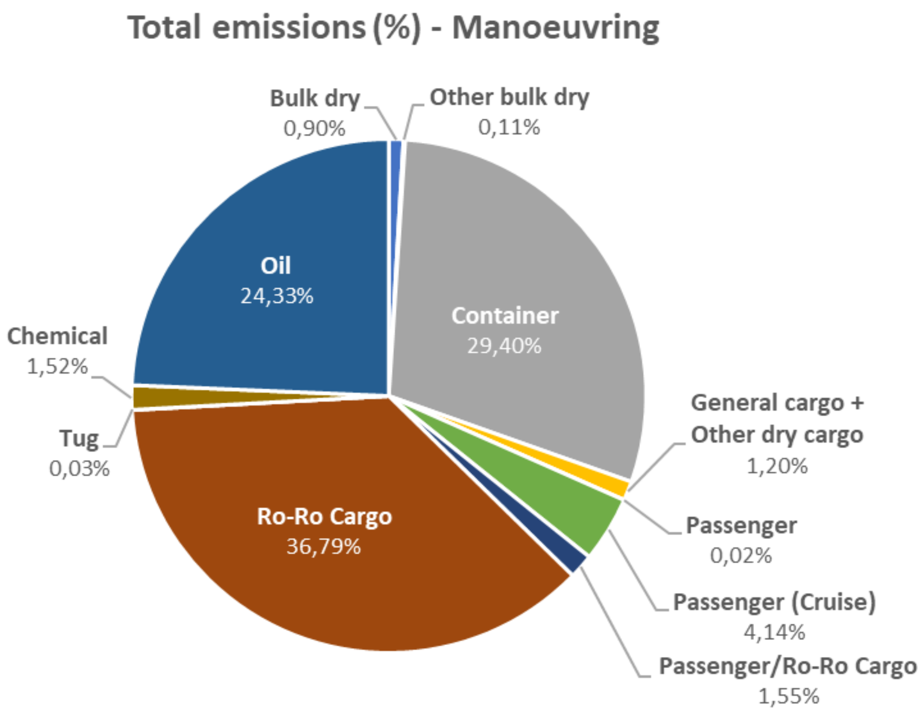

NOx emissions (t) - Manoeuvring
90,00
80,00
70,00
60,00
50,00
40,00
30,00
20,00
10,00
-
Bulk dry
Other bulk dry
Container
General cargo + Other dry cargo
Passenger
Passenger (Cruise)
Passenger/Ro-Ro Cargo
Ro-Ro Cargo
Tug
Chemical
Oil


NOx emissions (%) - Manoeuvring
Bulk dry 1,04%
Other bulk dry 0,13%
Oil 24,31%
Container 35,69%
Chemical 1,56%
Tug 0,02%
Ro-Ro Cargo 30,30%
General cargo + Other dry cargo 1,19%
Passenger 0,02%
Passenger (Cruise) 4,10%
Passenger/Ro-Ro Cargo 1,62%

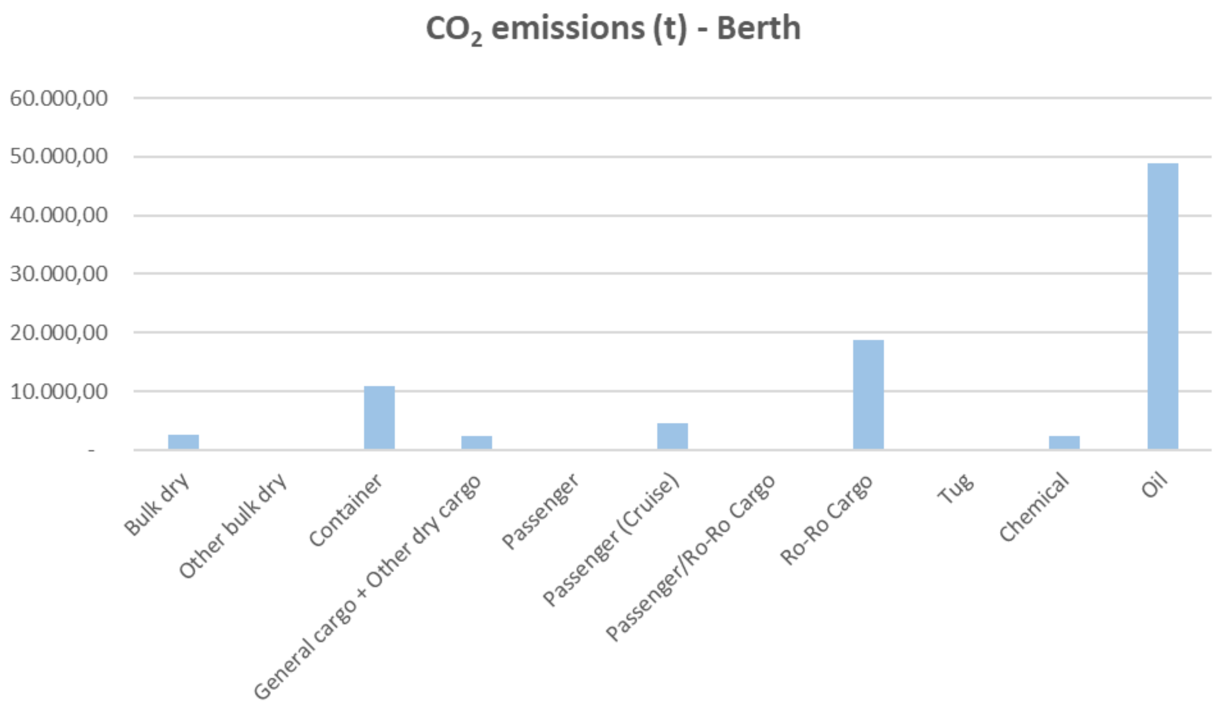

SO_x emissions (t) - Manoeuvring
80,00
70,00
60,00
50,00
40,00
30,00
20,00
10,00
-
Bulk dry
Other bulk dry
Container
General cargo + Other dry cargo
Passenger
Passenger (Cruise)
Passenger/Ro-Ro Cargo
Ro-Ro Cargo
Tug
Chemical
Oil

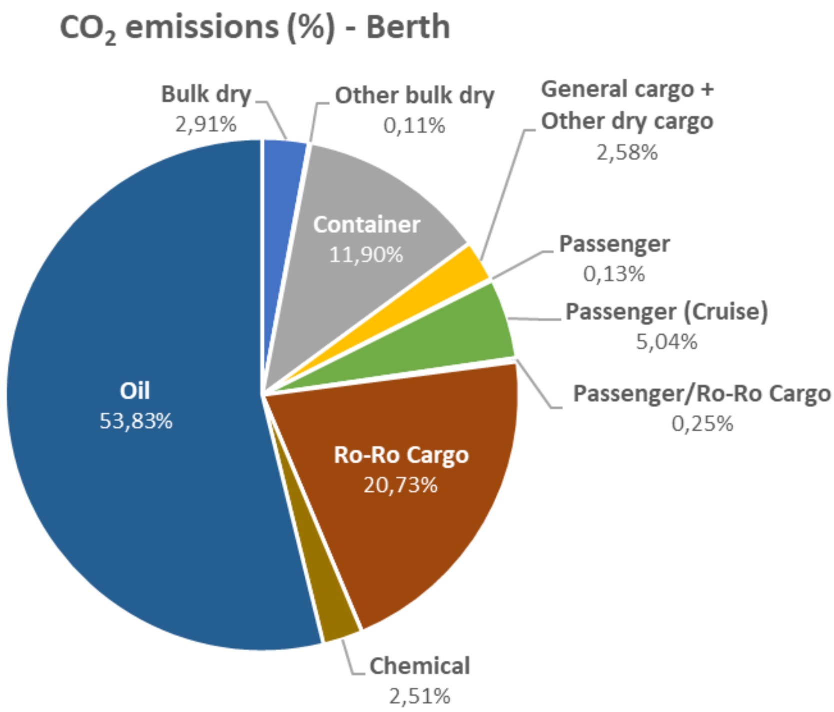

SO_x emissions (%) - Manoeuvring
Bulk dry 0,90%
Other bulk dry 0,11%
Container 29,21%
General cargo + Other dry cargo 1,20%
Passenger 0,02%
Passenger (Cruise) 4,16%
Passenger/Ro-Ro Cargo 1,54%
Ro-Ro Cargo 36,99%
Tug 0,03%
Chemical 1,52%
Oil 24,31%

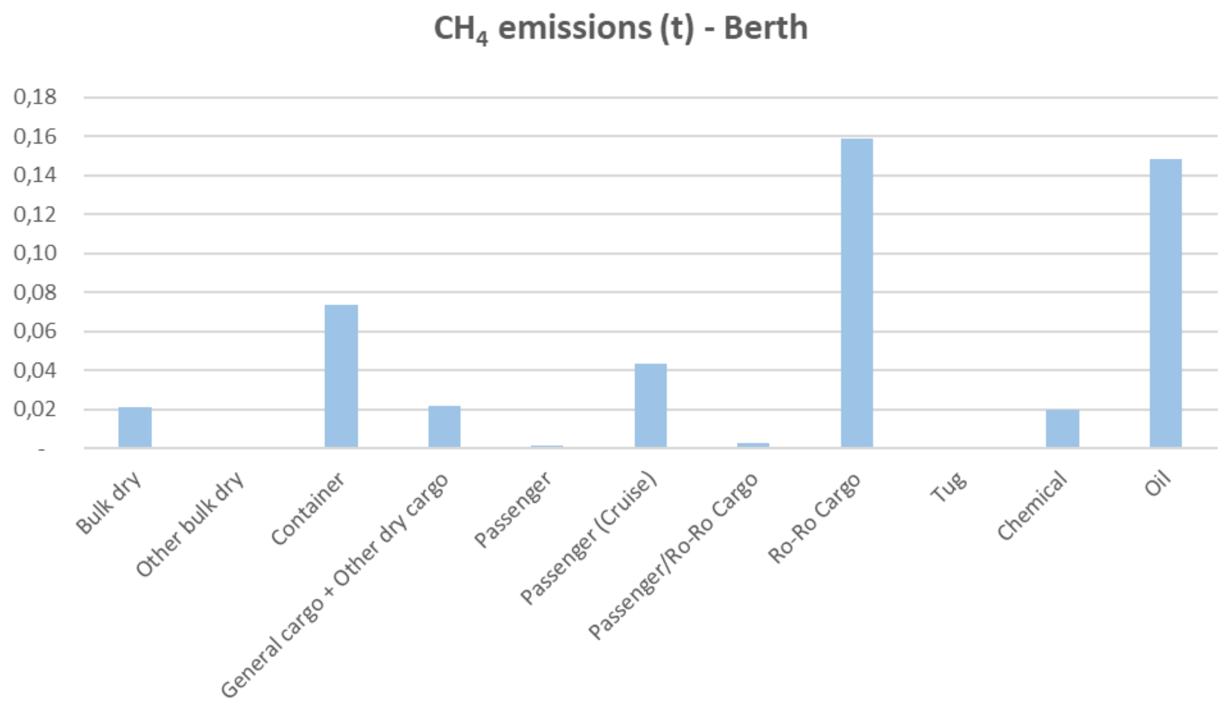

Total emissions (t) - Manoeuvring
5.000,00
4.500,00
4.000,00
3.500,00
3.000,00
2.500,00
2.000,00
1.500,00
1.000,00
500,00
-
Bulk dry
Other bulk dry
Container
General cargo + Other dry cargo
Passenger
Passenger (Cruise)
Passenger/Ro-Ro Cargo
Ro-Ro Cargo
Tug
Chemical
Oil


Total emissions (%) - Manoeuvring
Bulk dry 0,90%
Other bulk dry 0,11%
Oil 24,33%
Container 29,40%
Chemical 1,52%
Tug 0,03%
General cargo + Other dry cargo 1,20%
Ro-Ro Cargo 36,79%
Passenger 0,02%
Passenger (Cruise) 4,14%
Passenger/Ro-Ro Cargo 1,55%

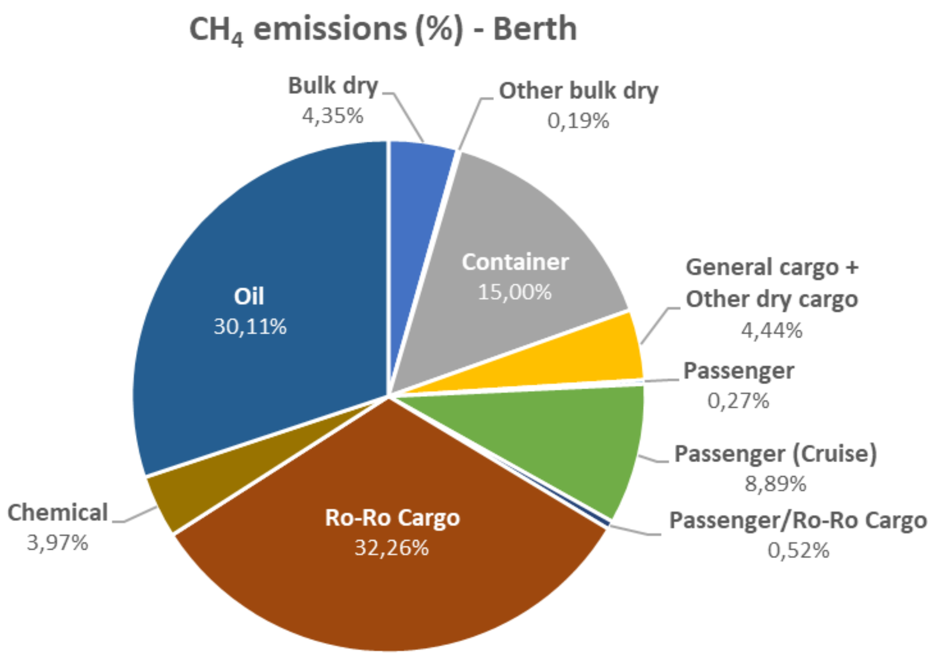
Emissions during hotelling phase (at berth)



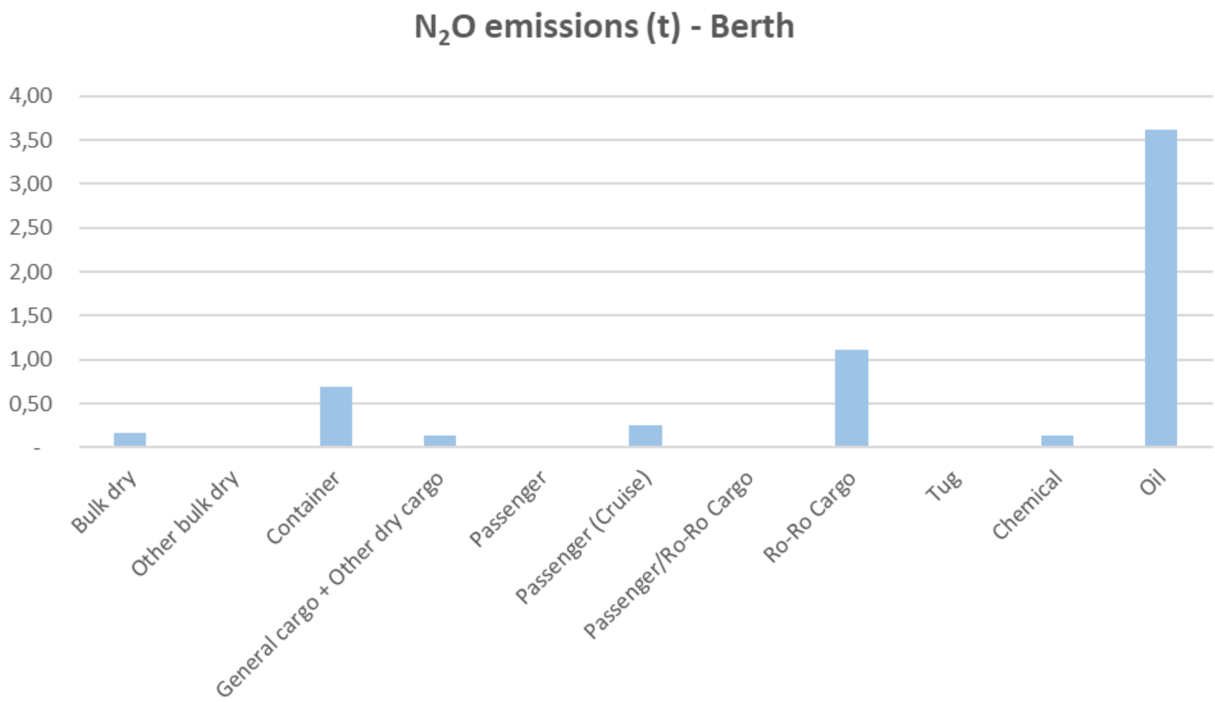




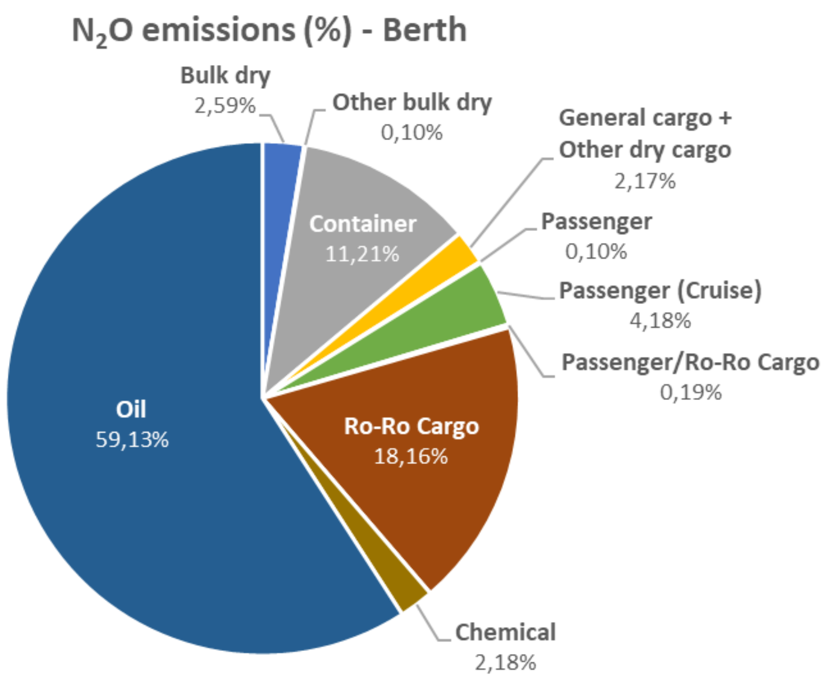
CH_4 emissions (t) - Berth
0,18
0,16
0,14
0,12
0,10
0,08
0,06
0,04
0,02
-
Bulk dry
Other bulk dry
Container
General cargo + Other dry cargo
Passenger
Passenger (Cruise)
Passenger/Ro-Ro Cargo
Ro-Ro Cargo
Tug
Chemical
Oil



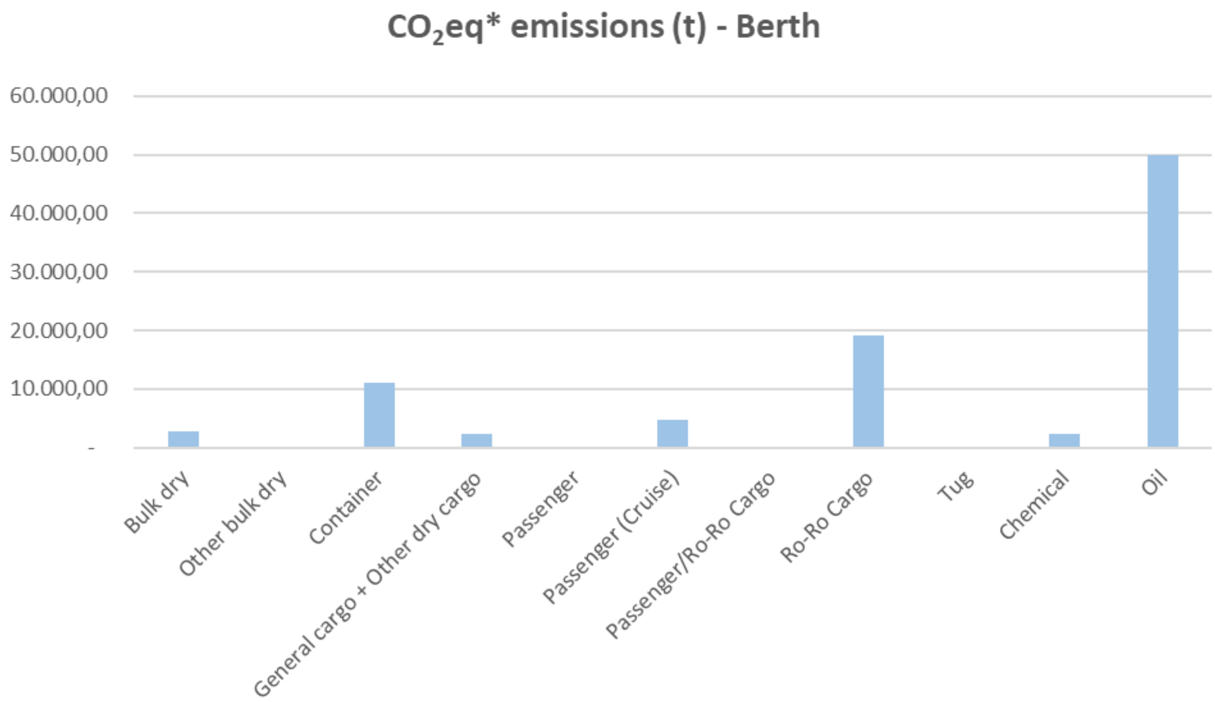
CH_4 emissions (%) - Berth
Bulk dry 4,35%
Other bulk dry 0,19%
Container 15,00%
General cargo + Other dry cargo 4,44%
Passenger 0,27%
Passenger (Cruise) 8,89%
Passenger/Ro-Ro Cargo 0,52%
Ro-Ro Cargo 32,26%
Chemical 3,97%
Oil 30,11%

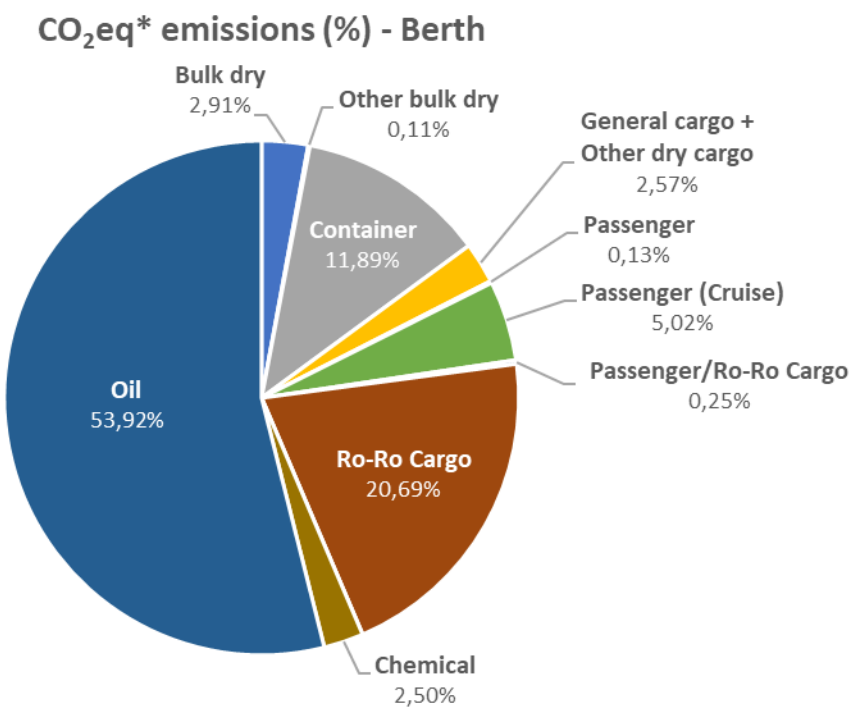


N_2O emissions (t) - Berth
4,00
3,50
3,00
2,50
2,00
1,50
1,00
0,50
-
Bulk dry
Other bulk dry
Container
General cargo + Other dry cargo
Passenger
Passenger (Cruise)
Passenger/Ro-Ro Cargo
Ro-Ro Cargo
Tug
Chemical
Oil

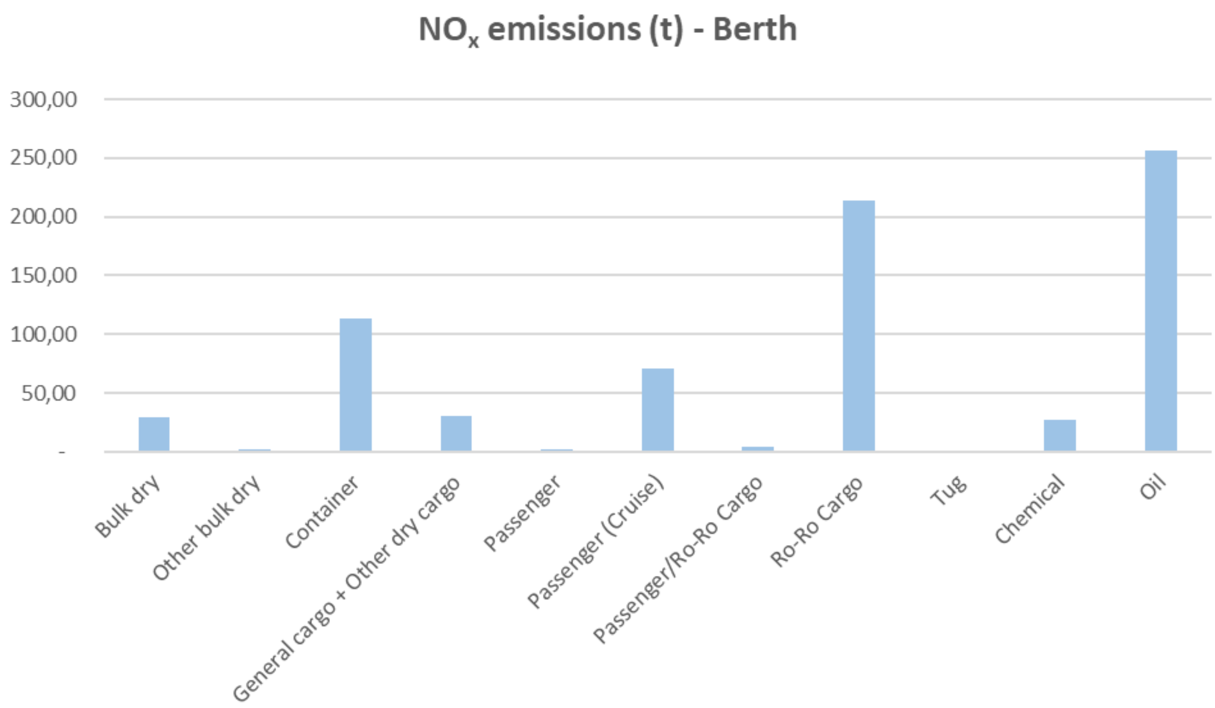


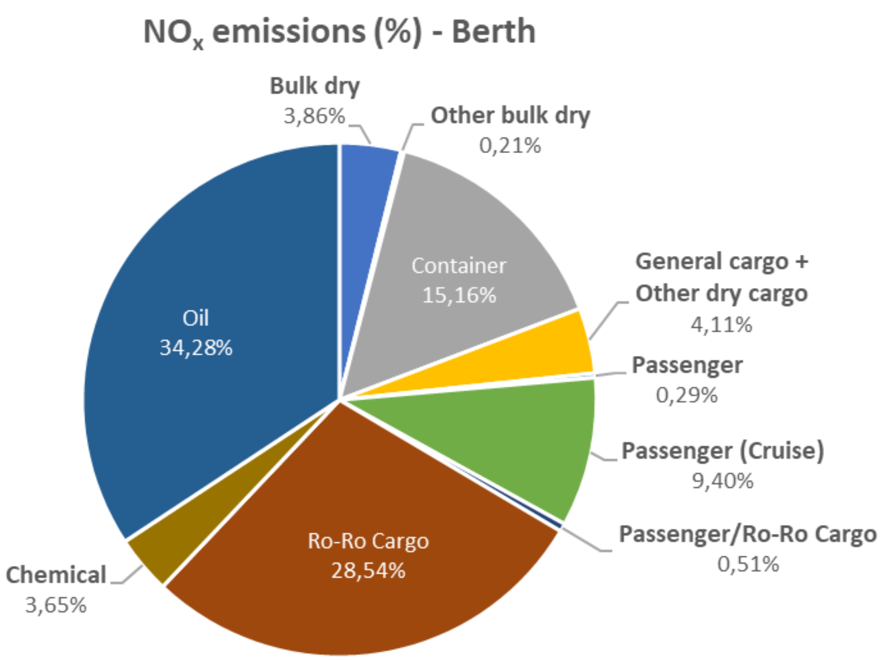
N_2O emissions (%) - Berth
Bulk dry 2,59%
Other bulk dry 0,10%
General cargo + Other dry cargo 2,17%
Container 11,21%
Passenger 0,10%
Passenger (Cruise) 4,18%
Passenger/Ro-Ro Cargo 0,19%
Oil 59,13%
Ro-Ro Cargo 18,16%
Chemical 2,18%

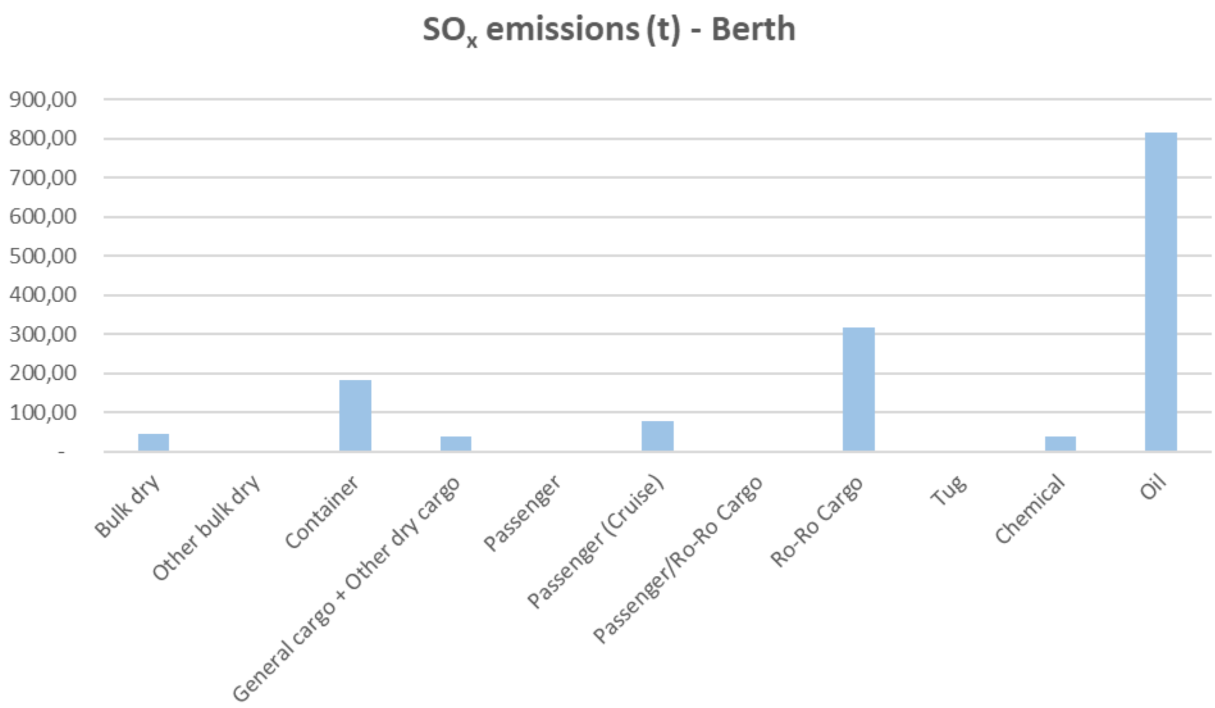

CO_2eq* emissions (t) - Berth
60.000,00
50.000,00
40.000,00
30.000,00
20.000,00
10.000,00
-
Bulk dry
Other bulk dry
Container
General cargo + Other dry cargo
Passenger
Passenger (Cruise)
Passenger/Ro-Ro Cargo
Ro-Ro Cargo
Tug
Chemical
Oil

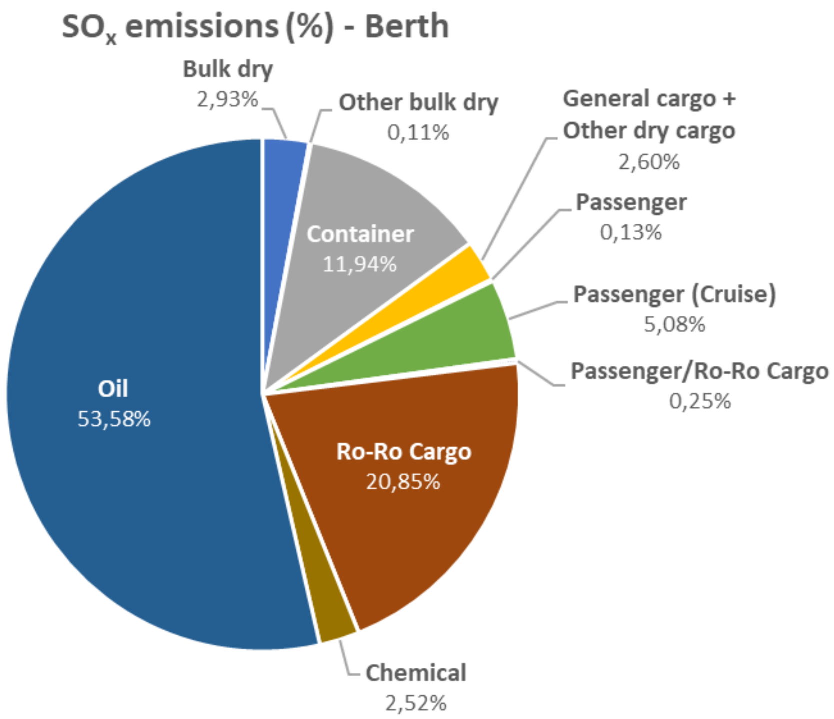

CO_2eq* emissions (%) - Berth
Bulk dry 2,91%
Other bulk dry 0,11%
General cargo + Other dry cargo 2,57%
Passenger 0,13%
Passenger (Cruise) 5,02%
Passenger/Ro-Ro Cargo 0,25%
Container 11,89%
Oil 53,92%
Ro-Ro Cargo 20,69%
Chemical 2,50%

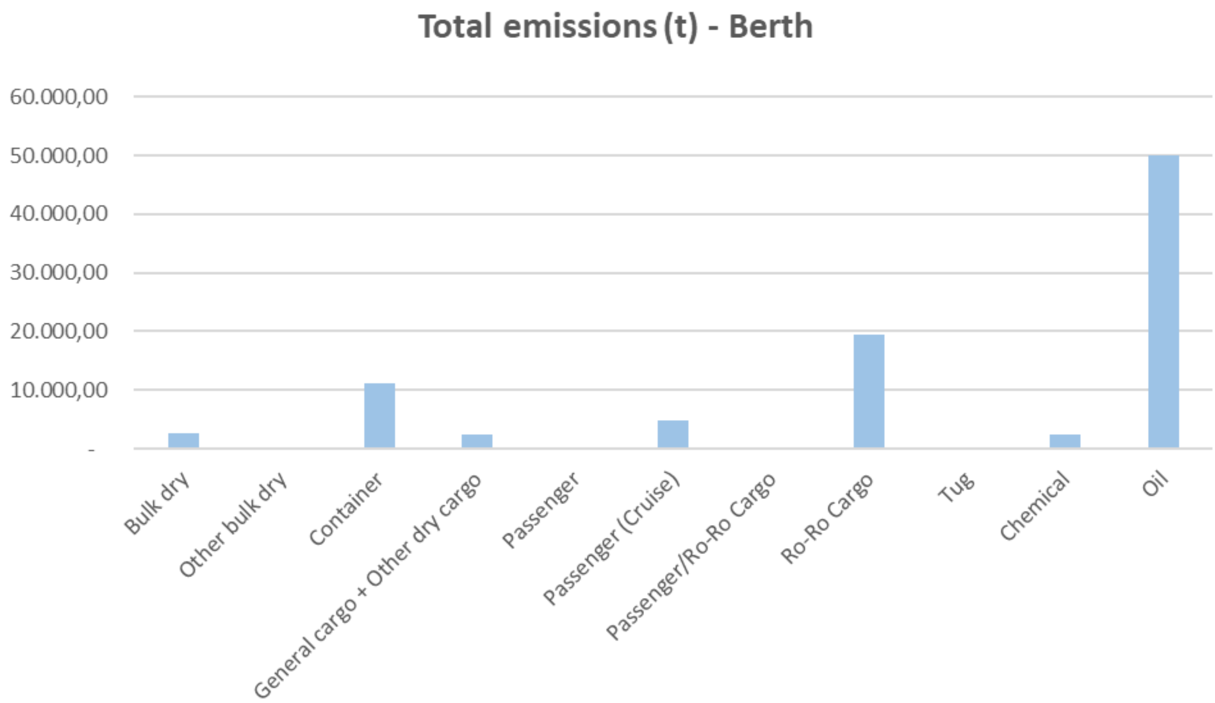
*** (CO_2 + CH_4 + N_2O)**

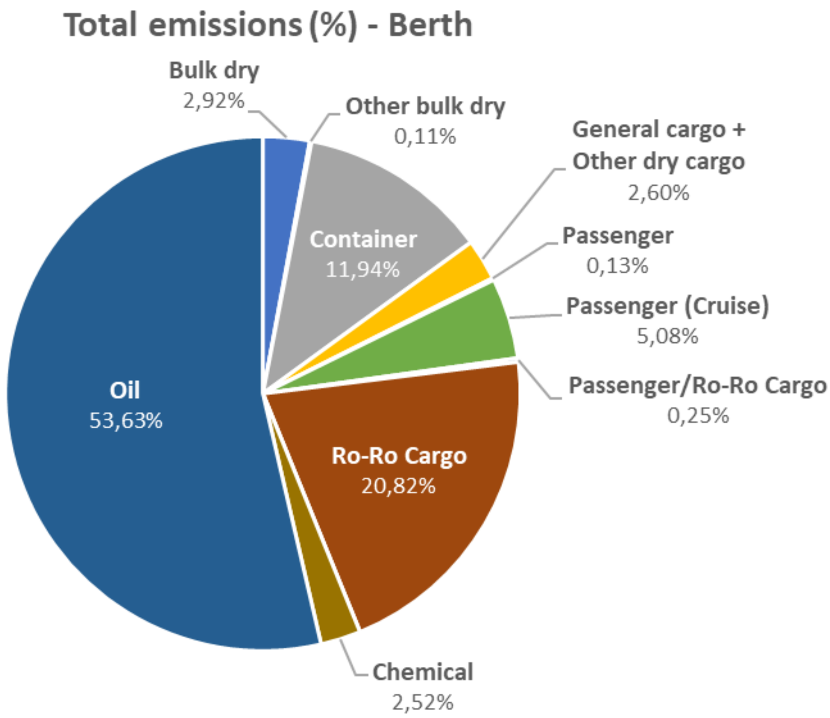

NOx emissions (t) - Berth
300,00
250,00
200,00
150,00
100,00
50,00
-
Bulk dry
Other bulk dry
Container
General cargo + Other dry cargo
Passenger
Passenger (Cruise)
Passenger/Ro-Ro Cargo
Ro-Ro Cargo
Tug
Chemical
Oil


NOx emissions (%) - Berth
Bulk dry 3,86%
Other bulk dry 0,21%
Container 15,16%
General cargo + Other dry cargo 4,11%
Passenger 0,29%
Passenger (Cruise) 9,40%
Passenger/Ro-Ro Cargo 0,51%
Ro-Ro Cargo 28,54%
Chemical 3,65%
Oil 34,28%


SOx emissions (t) - Berth
900,00
800,00
700,00
600,00
500,00
400,00
300,00
200,00
100,00
-
Bulk dry
Other bulk dry
Container
General cargo + Other dry cargo
Passenger
Passenger (Cruise)
Passenger/Ro-Ro Cargo
Ro-Ro Cargo
Tug
Chemical
Oil


SOx emissions (%) - Berth
Bulk dry
2,93%
Other bulk dry
0,11%
General cargo +
Other dry cargo
2,60%
Passenger
0,13%
Container
11,94%
Passenger (Cruise)
5,08%
Passenger/Ro-Ro Cargo
0,25%
Oil
53,58%
Ro-Ro Cargo
20,85%
Chemical
2,52%


Total emissions (t) - Berth
60.000,00
50.000,00
40.000,00
30.000,00
20.000,00
10.000,00
-
Bulk dry
Other bulk dry
Container
General cargo + Other dry cargo
Passenger
Passenger (Cruise)
Passenger/Ro-Ro Cargo
Ro-Ro Cargo
Tug
Chemical
Oil


Total emissions (%) - Berth
Bulk dry 2,92%
Other bulk dry 0,11%
General cargo + Other dry cargo 2,60%
Passenger 0,13%
Passenger (Cruise) 5,08%
Passenger/Ro-Ro Cargo 0,25%
Container 11,94%
Oil 53,63%
Ro-Ro Cargo 20,82%
Chemical 2,52%