Feasibility of LNG as a Fuel for the Mediterranean SSS Fleet: Profitability, Facts and Figures

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FOREWORD

Rafael Aznar Garrigues

CHAIRMAN OF THE PORT AUTHORITY OF VALENCIA

As Chairman of the Port Authority of Valencia and Fundación Valenciaport, it has been an honour to participate in the European Union (EU) co-funded project "CO2 and ship transport emission abatement by LNG" (the COSTA Action). I would like to thank the Italian Ministry of Infrastructure and Transport for coordinating this eye-opening project, the EU's Trans-European Network for Transport (TEN-T) Programme for their co-financing of this Action and, extensively, for all their efforts in the improvement of the efficiency and sustainability of the European Transport System.

So far, most projects and activity on liquefied natural gas (LNG) as an alternative marine fuel have been focused in Northern Europe, particularly in the Baltic countries, with many of these projects having been boosted by a strong government and EU support. However, it has been highlighted in the COSTA Action that there is a huge potential for this sector in the Mediterranean and us, transport infrastructure managers, sea carriers and policy-makers should start to define the best strategy to comply with environmental regulation and then taking the necessary steps to develop the designed course of action.

Changes in international environmental regulations pose several challenges for the shipping and port sectors and we simply cannot afford the cost of inaction as not doing anything would have serious repercussions on the European transport sustainability and would affect significantly the competitiveness of the shipping industry. The time to deal with existing problems and uncertainty and start planning strategically is now.

In the Port of Valencia, we are following the developments in this field with great interest and our port cluster is initiating actions to prepare for the future. Terminal operators, LNG suppliers, engineering companies and sea carriers are beginning to work together. There have been some promising results that have already been obtained in the field of energy efficiency at container terminals using LNG for port equipment and we hope to continue with more successful pilots and projects in the coming months.

Timeliness and relevance of the results published in this report present a notable contribution to the state-of-the-art knowledge in this field in the Mediterranean and I hope this publication will help to shorten the initial learning curve for many members of our shipping and port communities.

Finally, I would like to thank the team of analysts in Fundación Valenciaport who have dedicated their time and effort to produce this work. We hope this report will contribute to stimulate discussion and ultimately help to advance the competitiveness of the European shipping and shipbuilding industries. Last but not least, I hope that you will find this publication both interesting and helpful.

PROLOGUE

Enrico Maria Pujia
DIRECTOR GENERAL
DG FOR THE SUPERVISION OF PORT AUTHORITIES, PORT INFRASTRUCTURES AND FOR MARITIME TRANSPORT AND INLAND NAVIGATION
ITALIAN MINISTRY OF INFRASTRUCTURES AND TRANSPORT

Within the next few years, stricter sulphur, nitrogen and carbon dioxide emission limits from ships will be enforced both locally (already in SECA zones and from 2020 in the rest of the EU) and worldwide (from 2025). Simultaneously, the European Commission is stimulating the use of alternative fuels in the transport sector. Directive 2014/94/EU requires the development in each Member State of the Union, in the period 2017-2025, of a network of infrastructures allowing the use of natural gas, hydrogen, electricity and other sources of power for transport.

We, the Transport Administrations of EU and non EU Countries, have a common challenge ahead of us: Making maritime transport more environmentally friendly without compromising its economic competitiveness. In order to comply with the incumbent regulatory regime, three solutions are available:

- To use low sulphur content fuels such as Marine Gas Oil (MGO) in combination with Selective Catalytic Reducers (SCR) (for new vessels) to limit NOx emissions. However, this solution involves a significant increase in the operational cost of maritime transport. **In the period 2020-2025, such costs will only apply to a limited part of the Mediterranean (the EU one) and Atlantic Seas, hence a significant risk exists of distorting competition in these areas until 2025.**
- To use traditional heavy fuel oil (HFO) in combination with Exhaust Gas Cleaning Systems – EGCS (e.g. Scrubbers) to limit SOx emissions and Selective Catalytic Reducers – SCR to limit NOx emissions. **This solution requires a greater amount of fuel consumption and requires a network of "reception facilities" for scrubbers' residues (dangerous wastes). However, no such facility is currently available.**
- To use alternative fuels such as Liquefied Natural Gas (LNG). This is, from an economic point of view, the most appealing solution (this is already used in the Baltic area). However, **it requires a network of LNG refueling stations in the area. It is also noted that this type of network is one of the aims of the previously mentioned Directive 2014/94/UE.**

The current situation requires the preparation of solutions to prevent damage in the EU's shipping economy due to the double regime in the Mediterranean in 2020-2025. However, **too many factors are still unknown, preventing an immediate deployment of these solutions.**

As part of a comprehensive green shipping pre-deployment strategy, in my capacity of Director General for Maritime Transport and Ports, I wholeheartedly supported the establishment of the COSTA Action as a think tank to provide me and my colleagues in other countries with the elements to shape our strategy for the years 2015-2030.

I am therefore proud to introduce this technical report, which summarises a major piece of work carried out within the COSTA Action. Thanks to this work, we have been able to identify the major factors influencing the costs (hence the likelihood of success) of using LNG as a marine fuel and to estimate them as opposed to the costs of the other possible solutions.
This work is so important and useful that I totally supported the idea of Fundación Valenciaport to make this report publicly available. It will be instrumental to the decisions that, in less than 18 months, I and other Directors General for Maritime Transport in Europe will have to take concerning, as requested by Directive 2014/94/EU:

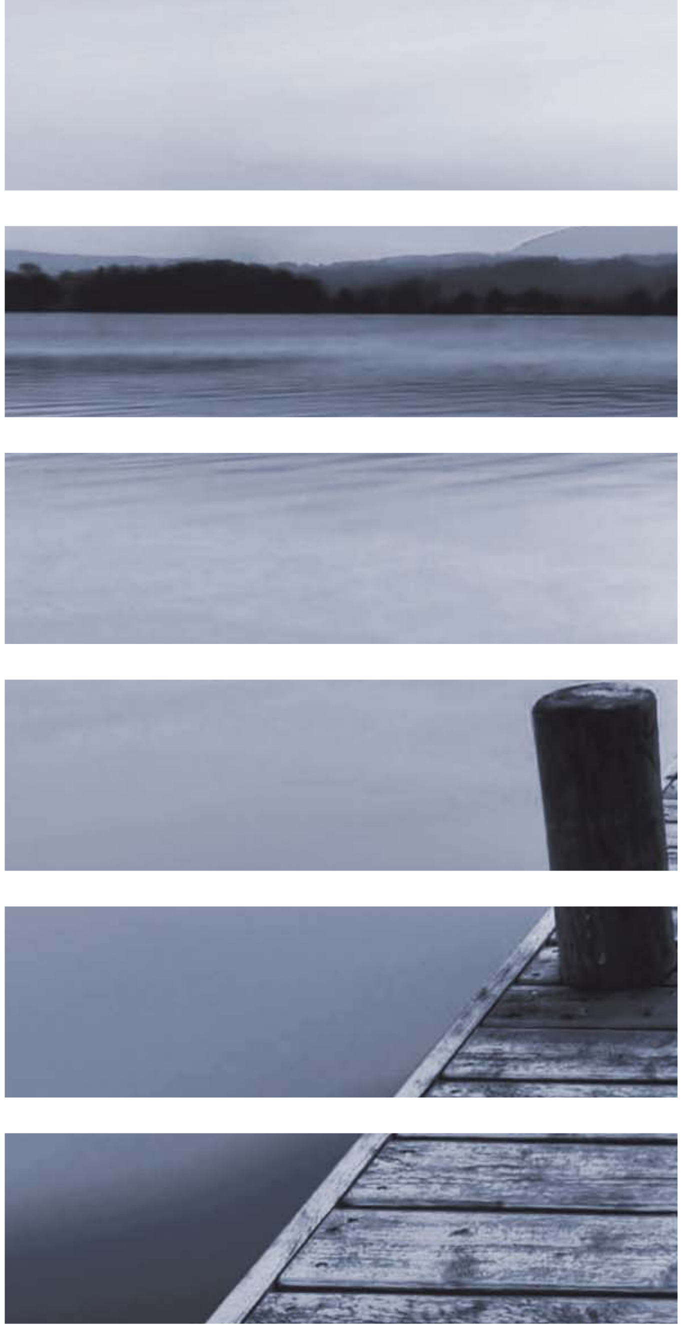
- Which, where and by when alternative fuel infrastructures will be located in each EU Country
- Who and how (e.g. national law and/or guidelines) will be in charge of giving authorisations (so called "permitting") to operate alternative fuel infrastructures.

No matter how many other pre-deployment studies and pilot refueling infrastructures will be developed in the next few years, this book will be a "bestseller" within my General Directorate and I believe, in many other Public Administrations across Europe.

While acknowledging the whole COSTA Action team for 30 months of excellent work, I would like to specially thank the authors of this publication for their dedication.

Roma
March 2015

CONTENTS



INTRODUCTION

Forthcoming implementation of international and European environmental regulations, namely Marpol Annex VI and Directive 2012/33/EU, will force ship owners to assess technologies that can allow them to comply with regulation whilst helping them to improve their position in an increasingly competitive market.

Given the European economy's fragile condition, prevailing uncertainty about its future and about the future evolution of key factors affecting the outcome of the ship owners' decisions, making the right choice among the multiple feasible technologies available becomes a considerable challenge.

For the past two years, the undersigned team of analysts have worked together in a study leading towards the publication of this report. This analysis has been the Fundación Valenciaport's contribution to the European Union (EU) co-funded project "CO2 and ship transport emission abatement by LNG" (the COSTA Action). The COSTA project has been coordinated by the Italian Ministry of Infrastructure and Transport and co-financed by the EU's Trans-European Network for Transport (TEN-T) Programme under the Motorways of the Sea Call 2011.

Our objective has been to analyse which technology would give the best results for the ship owner to comply with environmental regulations concerning emissions from a financial point of view. This has been done for those vessels that are particularly affected by this regulation, that is, each of the 658 vessels deployed in short-sea shipping (SSS) lines calling at core ports in the Mediterranean and Black Sea EU countries and Portugal. Additionally, a cost-benefit analysis including externalities has been conducted.

As a result of this study, different scenarios on technology uptake towards 2030 for the Southern European SSS fleet have been defined. Needless to say, there is no certainty of how many of the driving factors will behave in the next 15 years. The results published in this report are not definitive predictions of the Mediterranean shipping sector in 2030. Instead, our main findings are intended to stimulate discussions about available options for the industry. By examining the entire SSS fleet operating in the Mediterranean, Black Sea and Portuguese core ports, we hope to portray a general picture of the most convenient technological options for different kinds of vessels. In addition, we hope to draw attention to the factors explaining most of the uncertainty over future results and provide useful information for both ship owners and policy-makers who may be evaluating policies to foster the adoption of the technologies that are most environmentally friendly and contribute the most to the competitiveness of the shipping and shipbuilding sectors in Europe.

Financial feasibility and cost-benefit analyses for the conversion of each vessel deployed in short-sea services in the studied area have been validated with the collaboration of prominent industrial companies. We would like to thank experts working for MAN Diesel & Turbo, Caterpillar, Wärtsilä, Ros Roca Indox Cryo Energy, S.L., Boluda Corporación Marítima, RINA and Bureau Veritas for the information provided and for their help validating the results on the investment required for each ship in the SSS fleet to install scrubbers, be retrofitted to LNG dual fuel or be substituted by a newly built vessel of similar characteristics and operating with LNG dual fuel engines, tanks and all the necessary installations for this newbuilding to be LNG-compatible. Their support has also been crucial to check the operational costs of the ship for each pair of alternative options (the options compared have been: installing scrubbers, retrofitting to LNG dual fuel, newbuilding with HFO engines plus scrubbers, newbuilding with MGO engines (no scrubbers) and newbuilding with LNG engines and other LNG-related installations).

We share this report openly and free of charge to enhance the understanding of some of the challenges the shipping sector is facing, to encourage comprehension of the driving factors that affect the future competitiveness of short-sea shipping in the South of Europe and grasp the potential consequences that a "do nothing" scenario would bring in terms of modal backshift and increase in the use of road transport for intra-European trade flows. We hope you find this report useful and informative; and that it helps to stimulate discussion and thinking of the challenges, solutions and potential incentives to be put in place to favour the adoption of the technological options that will foster the competitiveness of the European shipping and shipbuilding industries. We sincerely hope you will enjoy reading the following pages.

2 METHODOLOGY

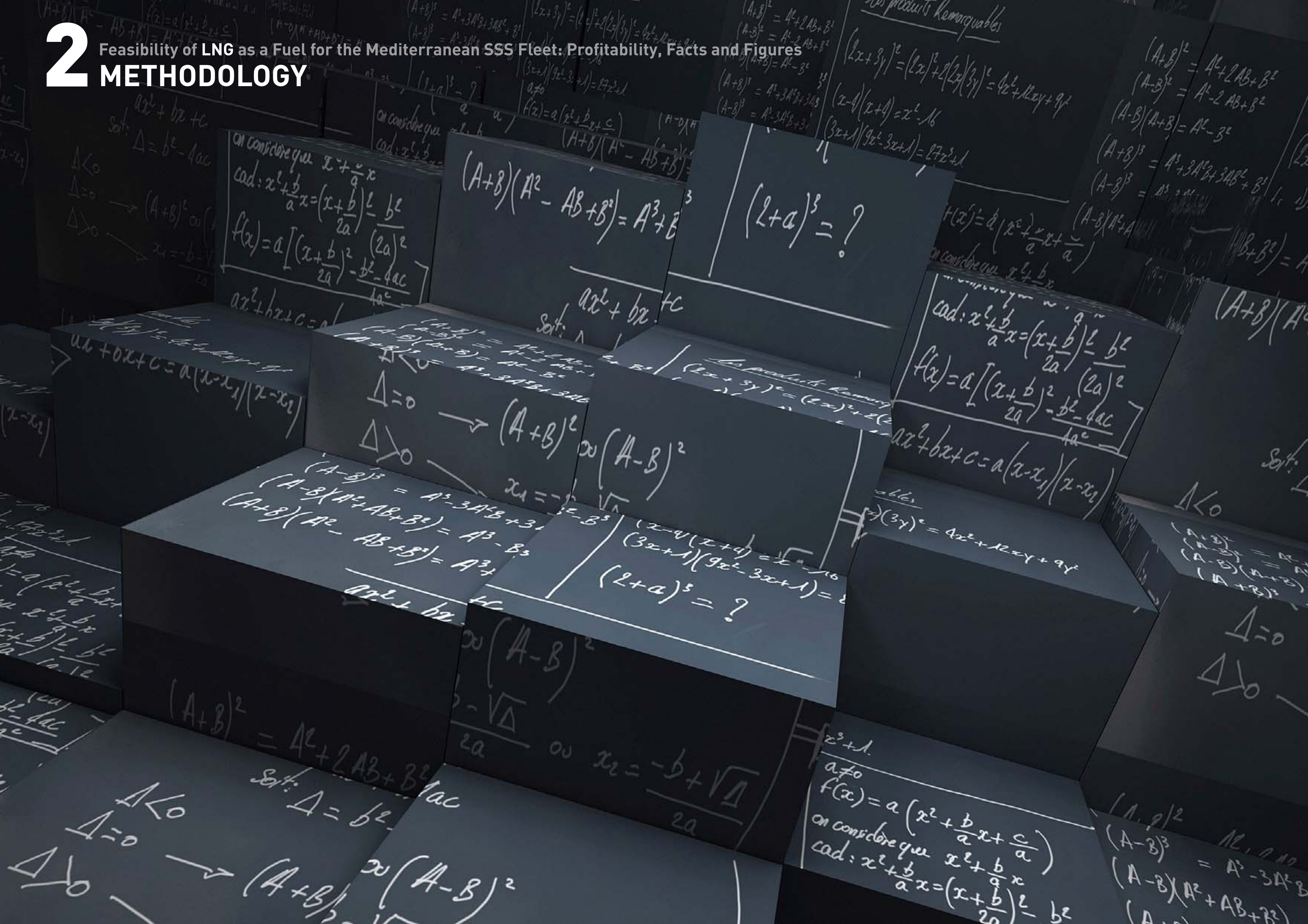


Figure 1: Countries included in the COSTA study

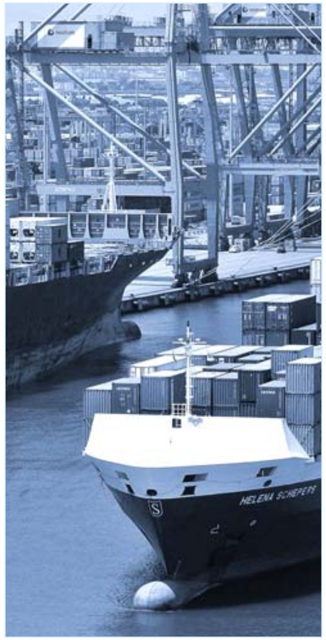
Source: Fundación Valenciaport, 2014

2.1 DATABASE: SCOPE, SPECIFICATION OF VARIABLES AND INFORMATION COLLECTION PROCESS

2.1.1 Scope: conceptual framework and geographical area

The first input to the model was the creation of a database featuring information about all the Short Sea Shipping (SSS) regular lines that called at any core port in Europe having a Mediterranean coastline, as well as the characteristics of the ships used on these routes. In addition, the geographical area was extended to include countries such as Portugal that are of special interest within the COSTA project. The timeframe used for the database spanned the first six months of 2013 and included all lines that were active at the end of this period.

The criteria used to define SSS were in concordance with the definition of SSS provided by the European Short Sea Network, which states that Short Sea Shipping is defined as the movement of cargo and passengers by sea between ports situated in geographical Europe or between those ports and ports situated in non-European countries which have a coastline on the enclosed seas bordering Europe.



The abovementioned group of countries is intrinsically related to the area of activity of the COSTA project. The main focus in this project is the Mediterranean, where action towards the reduction of polluting emissions from ships and the use of alternative energy sources has not been developed as much as in other areas of Europe.

In addition, the study was restricted to the fleet of ships used on regular lines in a particular area, given that the investment envisaged in the proposed scenario is more likely to take place in regular line operations as these are more stable services. Specifically, countries and **core ports** included in the model are:

- **Bulgaria:** Bourgas
- **Cyprus:** Limassol
- **Slovenia:** Koper
- **Spain:** Algeciras, Barcelona, Bilbao, Cartagena, Gijón, A Coruña, Las Palmas, Palma de Mallorca, Seville, Tarragona and Valencia
- **France:** Ports on the Mediterranean coast, Fos-sur-Mer and Marseilles
- **Greece:** Igoumenitsa, Patras, Thessaloniki and Piraeus
- **Italy:** Ancona, Bari, Genoa, Gioia Tauro, Naples, La Spezia, Livorno, Palermo, Ravenna, Taranto, Trieste, and Venice
- **Malta:** Valletta and Marsaxlokk
- **Portugal:** Leixoes, Lisbon and Sines
- **Romania:** Constantza

The lines that connect the following ports were also included as partners or stakeholders in the COSTA project:

- Spain's connections to the Canary Islands and the Balearic Islands, and inter-island traffic from the core ports of Las Palmas and Palma de Mallorca, respectively.
- Spain's connections to the territories of Ceuta and Melilla.
- Portugal's connections to Madeira and the Azores, and inter-island traffic from their major ports.

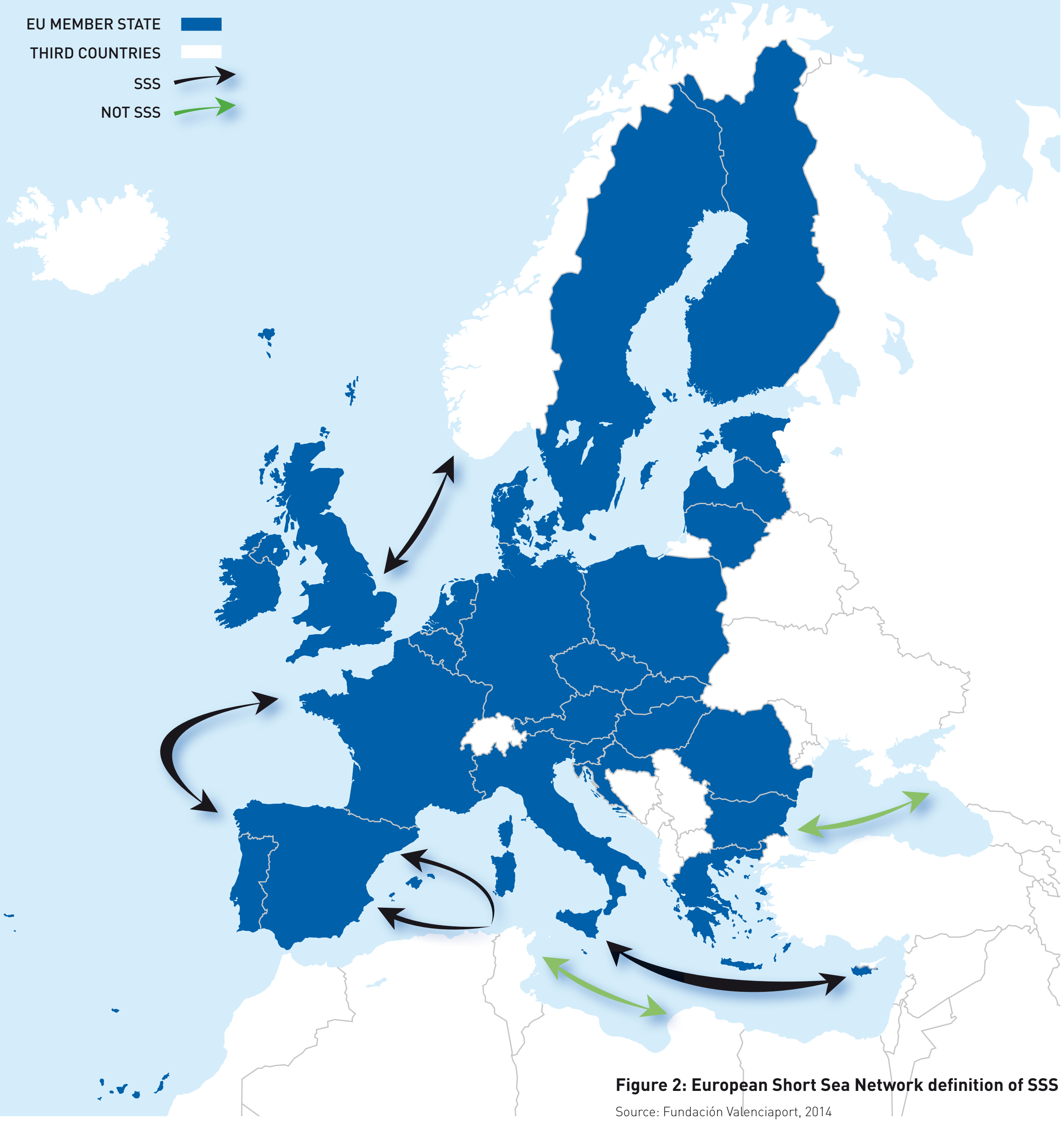


Figure 2: European Short Sea Network definition of SSS

Source: Fundación Valenciaport, 2014

Furthermore, taking services originating from a core port as a geographical criterion is perfectly in line with the Directive 2014/94/EU of the European Parliament and of the Council on the deployment of alternative fuels infrastructure, which sets out minimum requirements for the building-up of alternative fuels infrastructure. In terms of maritime transport, Member States shall ensure, by means of their national policy frameworks, that an appropriate number of refuelling points for LNG are put in place at maritime ports, to enable LNG seagoing ships to circulate throughout the entire TEN-T Core Network by 31 December 2025.

The use of core ports as a selection criterion for the lines guarantees that data are representative and describe the current situation in the Mediterranean, as long as the network of core ports accounts for the majority of transport flows. This was checked by comparing the information available in the Fundación Valenciaport's LinePort database, which contains data about the regular SSS services operating out of all Spanish ports, with the information obtained through the COSTA project. The result showed that 75% of Spanish SSS supply is included in this study.

Figure 3: Trans-European Transport Network

Source: European Commission

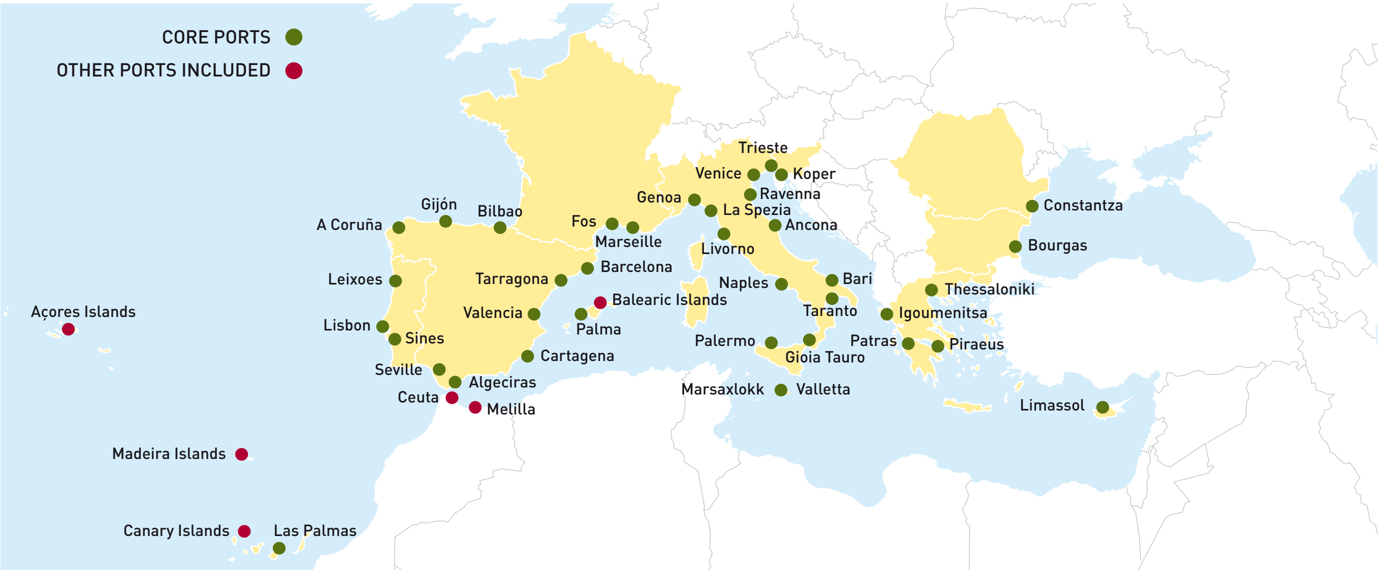


Figure 4: Ports included in the MED Short-Sea Lines database

Source: Fundación Valenciaport, 2014

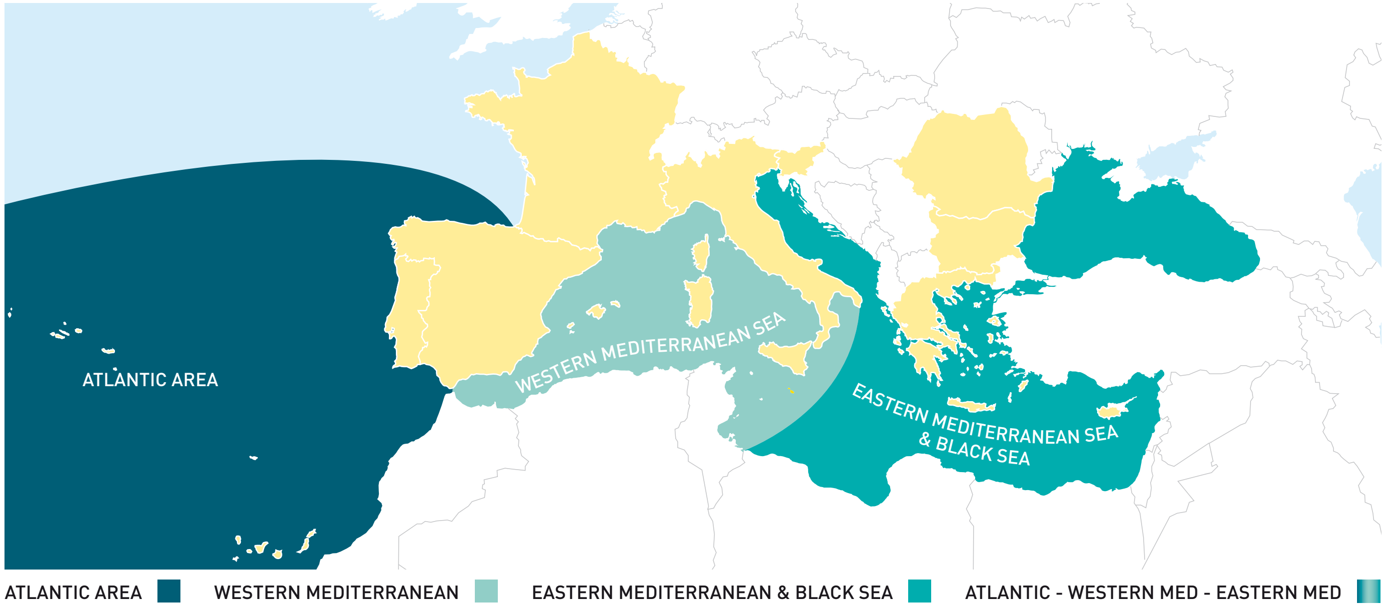


Figure 5: Areas defined in the MED Short-Sea Lines database

Source: Fundación Valenciaport, 2014

The core ports in European countries which have a Mediterranean coastline, along with Portugal, which is a partner in the COSTA project, are shown in the figure, based on the geographical scope of the database.

Croatia became a member of the European Union on 1st July 2013. However, this incorporation was outside the timeframe established for this project and as a result, Croatia was not included in the database. However, these countries which come under the SSS definition, are partially included in the study because the lines of the **10 countries** featured in the study call at their ports. These countries are:

- **12 Atlantic coast countries:**
  Germany, Belgium, Denmark, Finland, France (Atlantic), the Netherlands, Ireland, Morocco, Poland, the United Kingdom, Russia and Sweden.
- **15 Mediterranean and Black Sea countries:**
  Albania, Algeria, Croatia, Egypt, Georgia, Israel, Lebanon, Libya, Morocco, Montenegro, Russia, Syria, Tunisia, Turkey, and Ukraine.

Four areas of study have been identified on the basis of this geographical division and are referred to in the presentation of results further on. The division is based on representative routes for each particular shipping service. The areas defined in the database are:

- The Atlantic area
- The Western Mediterranean Sea
- The Eastern Mediterranean & Black Sea
- The Mixed area: Those routes operating in more than one area

Finally, the database includes a specific focus on **Motorways of the Sea services (MoS)** that use the MoS corridors specified in the Trans-European Transport Network, in which the countries that come under the COSTA project are included: the Western Europe, the South-West Europe and South-East Europe Motorways of the Sea.

- **Western MoS:** SSS services established in the Western European corridor connecting the ports on Spain's Atlantic coastline with the North Sea and the Irish Sea, with the Port of Hamburg as the motorway's eastern boundary.
- **South-West Europe MoS:** SSS services established in the South-West European corridor connecting ports along the Spanish Mediterranean coastline to the Mediterranean coast of France, Italy and Malta.
- **South-East Europe MoS:** SSS services established in the South-West European corridor connecting ports on the Adriatic Sea to the Ionian Sea and the Eastern Mediterranean, including Cyprus.

The criteria used to define MoS services were as follows:

- **Minimum frequency:** 1 departure per week
- **Maximum number of port calls:** 3

In short, through the creation of this database, the Fundación Valenciaport is providing the Mediterranean ports and logistics community with comprehensive quality information on SSS services. This database enables users to tackle decision-making processes in their respective fields of work from a more informed standpoint. This tool is therefore extremely useful for transport policy-makers in Europe, since it provides them with not only a detailed picture of SSS services at any given time, but also with information about service developments over time. As a result, while current information enables the identification of critical SSS areas for government actions to focus on at any given time, the trends revealed by these services will enable policy-makers to assess the relative effectiveness of the different measures set or to be set in motion.

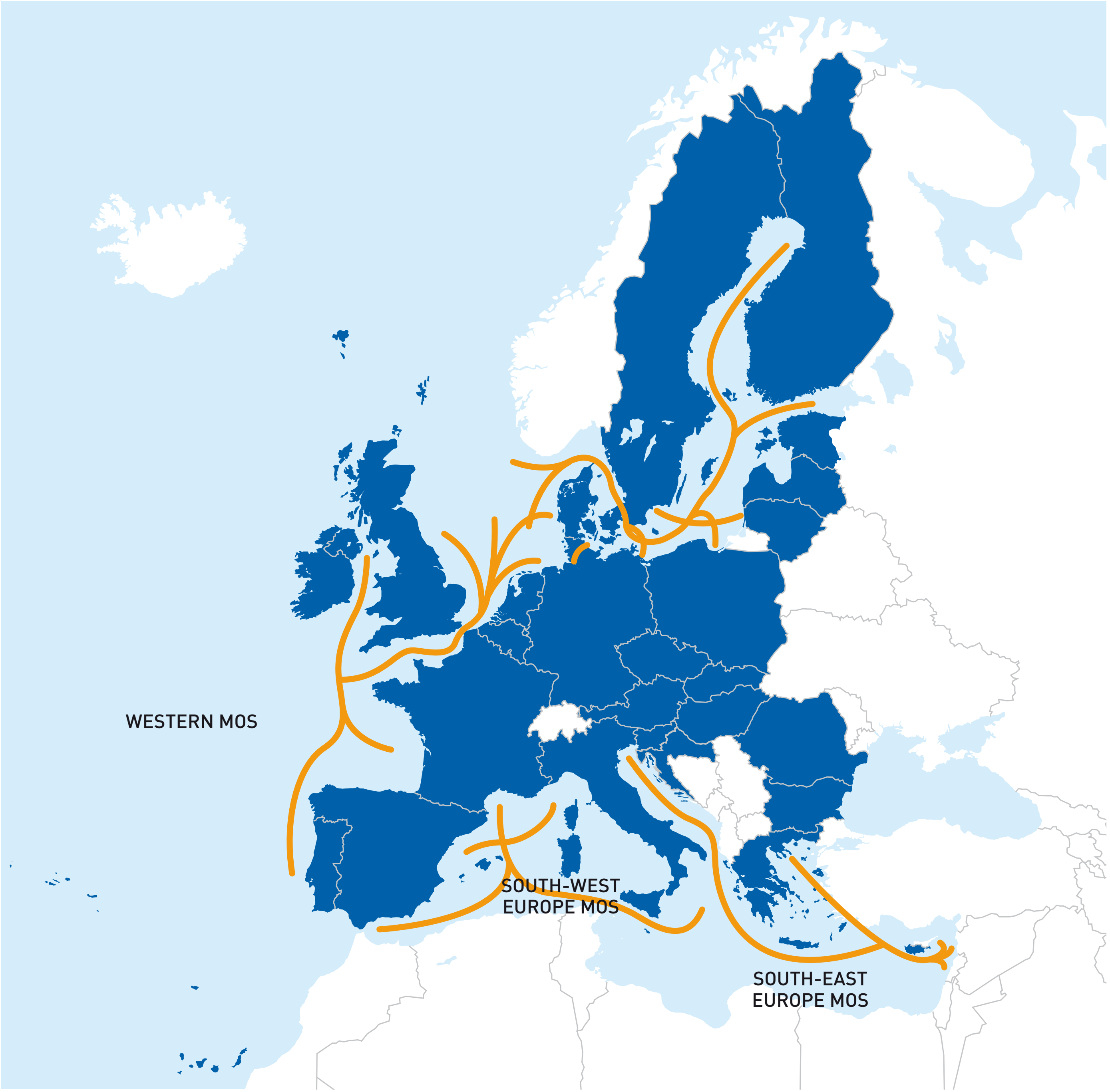


Figure 6: Motorways of the Sea corridors included in the COSTA study

Source: European Commission

2.1.2 Database: definition of fields of information

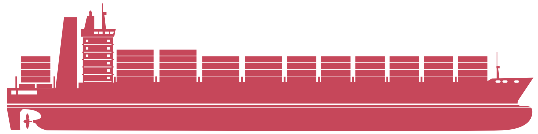
The database not only lists the lines in operation at each of the ports under study but it also provides highly detailed information about their characteristics, and data about regular services and vessel characteristics. Before defining the fields of information, it must be noted that multiple data sources were consulted to complete all the inputs required to run the model, giving the database considerable added value as a unique, highly detailed tool.

The following fields of information have been included in the database:

- **Regular lines:** Stable SSS services, in terms of frequency, route and transit times.
- **Type of lines:** The type of lines has been decided on the basis of the cargo transported by each service and the characteristics of the vessels used. According to these criteria, lines have been classified as car carrier, container, Pax, Ro-ro and Ro-pax services.
- **Shipping company:** Company or companies operating regular lines.
- **Route:** Most representative pattern of the line's movements during the period under study. When changes took place in a line over the period, the latest route that has represented a regular pattern have been chosen.
- **Geographical area:** Three different areas according to the line's route have been defined, i.e. Atlantic area, Western Mediterranean, or Eastern Mediterranean & Black Sea.
- **Number of calls:** Number of ports where the ship calls during a turnaround voyage.
- **Distance:** The number of nautical miles covered in each turnaround voyage. To calculate distance, complete rotations have been used, that is, the port of origin has been considered as the last stop so as to create a closed circle.
- **Port:** Ports where the service calls.
- **Frequency:** The number of voyages per week of said line. For seasonal lines, frequency has been weighted to obtain an approximate annual average.
- **Seasonality:** Regular lines that operate throughout the year as well as those that operate seasonally, that is, during a period of less than a year, have been included in this field.
- **Number of voyages per year:** The result of multiplying the frequency by the number of weeks in the year (52).
- **Average ship:** Vessel selected for its characteristics as the most representative of those used in the short-sea service.
- **Ships:** All the ships deployed in the short-sea service taking line frequency and transit times into account.
- **Types of vessel:** Lines were categorised based on the cargo transported by a particular service and the characteristics of the ships used. Thus, the lines studied were classified as follows:

- Car carrier:

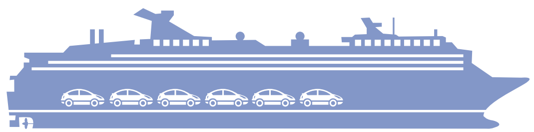
- Container ship:



- General cargo

- Passenger ship:

- Ro-pax (Roll on/Roll off passenger):



- Ro-ro (Roll on/Roll off):

- **Type of vessel according to engine: High-Speed Crafts** are defined according to SOLAS Chapter 10, Reg 1.3, as vessels which are capable of sailing at a maximum speed, in meters per second (m/s), equal to or exceeding:

$$v=3.7*\nabla^{0.1667}$$

Where:

∇= volume of displacement in cubic meters corresponding to the design waterline.

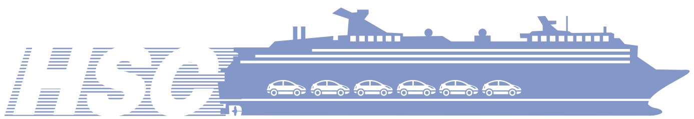
$$\nabla\sim\frac{\Delta}{1.025}$$

Considering that the displacement is unknown, it has been estimated using the following approximation:

$$\nabla_1\sim\frac{DWT}{1.025} \quad (*)$$

Comparing both values: $\nabla_1<\nabla$.

For ships complying with the statement (*), it has been checked that their Classification Society Certificate has the mark HSC (High Speed Craft) using the official website www.equasis.org.



The variables related to these vessels are: [1]

- **Name of ship:** Current name of the vessel, associated with the IMO number.
- **IMO number:** Unique identifier for ships, introduced under the SOLAS convention.
- **Type of vessel:** According to the classification of the vessel.
- **Year of construction:** Year of build.
- **Deadweight Tonnage (DWT):** The weight in tonnes of cargo, stores, fuel, passengers, and crew carried by the ship when loaded to her maximum summer loadline.
- **Gross Tonnage (GT):** Gross and net tonnages (GT and NT) are defined in the 1969 International Convention on Tonnage Measurement of Ships, which was adopted by the International Maritime Organisation in 1969, and came into force in July 1982. These measurements replaced Gross and Net Register Tonnage (GRT and NRT). Gross Tonnage (GT) is a unitless function calculated from the moulded volume of all enclosed spaces of the ship.
- **Lane metres:** For Ro-ro and Ro-pax vessels. The total maximum linear lane length, the maximum width of loadable cargo and the maximum deck head clearance between adjacent fixed or movable decks are displayed. The number and type of ramps and doors (number, position, length, width and safe working load) are displayed, where known.
- **Capacity in TEUs:** The number of containers and reefer containers the vessel is designed to carry in primary or alternative stowage.
- **Passenger capacity, besides crew:** Number of people the vessel is designed to carry.
- **Car capacity in the case of car carriers:** Number of cars the vessel is designed to carry.
- **Engine power in kW:** Total power installed in the vessel (including all engines).
- **Speed in knots:** Service speed registered in sea trials.
- **Strokes:** Indicator referred to the engine cycle (2 or 4 strokes).
- **Specific Fuel Consumption (SFC):** Term used to describe the degree of energy efficiency of an engine in relation to its output power. SFC can be expressed in different ways; in this text, SFC is expressed as the mass of fuel consumed (expressed in g) per unit of energy produced by the engine (expressed in kWh), that is, g/kWh. An intrinsic variable of all kinds of engines, SFC depends on many factors such as engine power, age, and the engine cycle (2 or 4 stroke).

Although in some studies a reference value is used for this variable, in this case, the SFC was identified according to the information that appears in the engine data sheet, provided by the engine manufacturer of each vessel. The SFC of an engine differs according to the kind of fuel used. SFC is usually expressed in terms of a reference marine fuel (marine diesel oil) whose low calorific value is 42,700 kJ/kg, which is in accordance with ISO standard 3046-1:2002. SFC varies when using a fuel with a different calorific value.

- **Fuel consumption (tonnes/day):** In this study, this is considered a key variable that represents the amount of fuel used by a ship, expressed in tonnes per day of navigation. In studying this variable, two methods were used to determine consumption. The first method has looked at the consumption register provided by the SeaWeb database. The second method has been used to calculate consumption using the following formula for the complete database:

$$FC(tonnes/day)=SFC(g/kWh)*Ep(kW)*\frac{24}{10^6}$$

where:

FC is the ship's fuel consumption in tonnes/day.

SFC is the specific fuel consumption of the engine in g/kWh.

Ep is engine power in kW.

The constant is a unit correcting factor.

The methodological criteria followed to determine fuel consumption gave priority to our own calculations, in the light of the scarcity of the information on this variable in the Seaweb database and the differences in the data supplied.

1 Definitions of the variables according to "Ship Navigation Trees Definition", by IHS Fairplay.

2.1.3 Information collection and validation

Collecting and validating information about regular lines and the fleets operated for their inclusion in the database has been a complex task because of the lack of uniform and comprehensive information. Data about the different aspects of SSS is available from different sources, but this information is often incomplete and outdated. In this context, the need to create a database including consistent, coherent and exhaustive information validated with sea carriers and classification societies has been clear.

Information collection has been divided into different stages. First, the lines have been identified and then, the information required for the model has been completed and validated.

Identification of lines

Lines have been identified by analysing each port and its short-sea services individually. The following search procedure has been followed:

1. Searches for links related to the ports under study.
   - Online information from the managing port authorities, and searches for information about the port's regular lines. In some cases, the information about regular lines provided by the port authorities is almost non-existent. This meant other alternatives need to be used. These are shown below.
   - Information about permits granted by terminals to the traffic under study, and an analysis of the terminal websites in each case. In some cases, these websites have provided information about the ships that called at certain terminals, and thus enabled the search for information a posteriori to complete the database model.
2. Port to port monitoring of vessel movements for six months in 2013 using AIS information. AIS is a compulsory standard for all vessels that are part of the SOLAS Convention.
3. Searches for information on specialised ferry and container ship websites.
4. Identification of ships, sea carriers and ship owners. Ships were allocated to specific services by monitoring their movements and contrasting this information with port authorities and sea carriers.

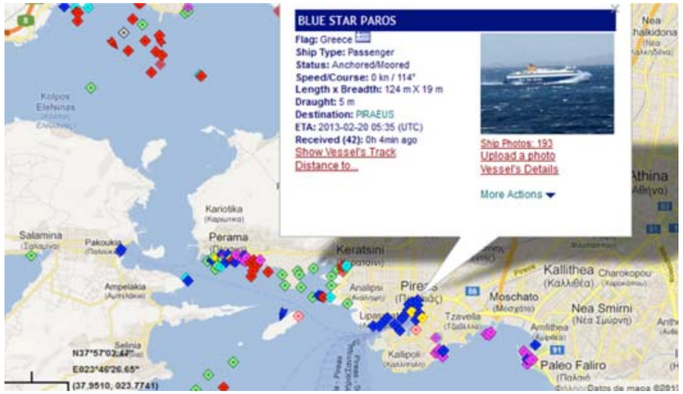


Figure 7: Example of information via AIS

Source: Screenshot from: http://www.marinetraffic.com

5. Identification of the sea carrier and download or request of the updated line schedules.
   - This information has then been processed in the database, and saved for each sea carrier.
   - When lines are shared by multiple sea carriers, the information has been downloaded for all the companies, and the most complete and reliable source has then been chosen.

AUTOMATIC IDENTIFICATION SYSTEM (AIS)

The AIS, a dissemination system for ships, operates within the maritime VHF bandwidth with the help of a transponder and can provide more than 4,500 reports per minute, updating them up to every two seconds.

The AIS on ships uses Self-Organizing Time Division Multiple Access (SOTDMA) or Carrier-Sense Time Division Multiple Access (CSTDMA) radio sets.

The AIS was adopted by the IMO (International Maritime Organisation) in 2002 with an implementation calendar based on vessel characteristics beginning on December 31st, 2004. Since 2007, the AIS standard is compulsory for ships that are part of the SOLAS Convention and fulfil any of the following characteristics:

- Ships with GT greater than 500.
- International voyage ships with GT greater than 300.
- All passenger ships, irrespective of size.

The main idea behind the AIS is to prevent ships from colliding and to assist the Port Authorities in monitoring maritime traffic. The on-board transponders are fitted with a GPS (Global Positioning System) receptor that collects data about the position, course and speed of the vessel as also other static information like the name of the ship, its dimensions or details about its route.

The received information is updated in real time and is thus immediately available on the map. Base stations fitted with receptors collect information from each of the ships and feed it into more generic information systems. Currently, there are a number of websites that compile and share this information while maintaining a high level of reliability.

Source: http://www.marinetraffic.com

Searching for information about ships

The second stage in creating the database has involved identifying the ships' characteristics and calculating the distances of the different turnaround voyages. Information on all ships operating on identified regular lines has been collected. It has been assumed that these ships could also be used on other services, thus, the most up-to-date ships in terms of number and characteristics have been included.

The following information has been collected for the identified ships:

- Name of the ship
- IMO number
- Type of cargo
- Year of construction
- Deadweight Tonnage (DWT)
- Gross Tonnage (GT)
- Lane metres: For Ro-ro and Ro-pax
- Capacity in TEUs: Container and mixed ships
- Passenger capacity, besides crew
- Car capacity in the case of car carriers
- Engine power in kW
- Service speed in knots
- Strokes
- Specific fuel consumption

The above mentioned information has been sourced from websites like IHS Fairplay and information provided by the different organisations that certify the studied ships (Classification Societies). The information on mechanical aspects has been checked with that obtained in the engine data sheet provided by the engine manufacturer.

When calculating distance, a complete turnaround voyage has been considered, i.e. from one core port until the vessel returned to the same port. In the case of figure-of-eight routes, the complete distance from port to port has been considered. Different tools and information from specialised websites for nautical distances have also been used. For example, much of the information about the distances between the Greek islands has been obtained from information provided on the websites of port authorities and sea carriers.

The main tool used has been the application World Shipping Encyclopedia by Fairplay that calculates the distance between ports. This has been complemented by other tools that calculate distances in nautical miles.

Both series of data have been included in the definitive database, in which the characteristics of every ship associated with each regular line can be consulted. In the case of multiple ships operating on a service, the line information contains as many rows as there are ships operating, and the characteristics and distance of the rotation covered by each ship have also been included.

Information validation and standardisation

The large number of ports under study and the vast amount of information and variables to be considered in the database has resulted in an exhaustive monitoring process of the information which has been essential in terms of possible changes and further processing. To this end, the information has been validated and standardised through regular reviews during the six-month data collection period, in parallel to the search for information.

Validations have been carried out by different analysts, and the information has been reviewed up to four times, carrying out a case-by-case discussion of any regular line that presented any deviation in terms of information or validation, within the model created for this study. As the information has been obtained from several sources, cross-check procedures have been defined during the whole period.

Finally, all the information collected regarding all of the core ports has been processed in accordance to standard procedures, to avoid the duplication of information. Some regular lines overlapped in different parts of the transport chain because of their rotation at core ports in the EU. This duplicity has been eliminated at a later stage.

2.2 MODEL SPECIFICATION HYPOTHESES

2.2.1 General hypotheses

- **Euro-dollar conversion rate** (€/$): According to data published by the Boletín Estadístico del Banco de España, the average euro-dollar exchange rate in 2013 was 1.3281.
- **Number of weeks per year:** All the calculations were carried out based on a 52-week year.
- **Discount rate:** 12%.

2.2.2 Vessel consumption hypotheses

As mentioned in the previous section, fuel consumption is one of the key variables in the model, and has been calculated according to the formula described before, which includes the following considerations.

- As a general hypothesis, it has been assumed that conventional vessels are fuelled by **HFO** while High-Speed Crafts (HSC) are propelled by **MDO**.
- **Low calorific value (kJ/kg):** The total amount of heat that results from the complete combustion of one volume unit of fuel, excluding the amount of latent heat generated in water steam during combustion, as this does not change state and is released as steam. This value is important for industrial uses, such as ovens and turbines, because the combustion gases are emitted at high temperatures and water steam does not condense. In this study, four types of fuel with different low calorific values are considered.
  - Marine Diesel Oil (42,700 kJ/kg)
  - Heavy Fuel Oil (40,600 kJ/kg)
  - Marine Gas Oil (42,800 kJ/kg)
  - Liquefied Natural Gas (49,200 kJ/kg)

  Low calorific value is an important value as it enables the Specific Fuel Consumption of all relevant fuels to be calculated through the Specific Fuel Consumption of reference fuel provided in the database and hence, the estimation of the daily fuel consumption of those fuels (HFO, MGO and LNG) per vessel.
- **Speed correction factor:** An 85% correction in the service speed published in the Fairplay database has been established based on common practises in the shipping industry.
- **Engine power correction factor:** An 85% correction in the engine power was defined, based on the assumption that vessels do not employ their total power during the whole voyage.
- **Fuel prices (average 2013):** Average prices of HFO, MDO and MGO in 2013 have been calculated to include them in the model, according to information provided by the BunkerIndex database. Concerning MGO and HFO, the average price in the Mediterranean has been selected, while in the case of MDO, this corresponds to North European ports due to the lack of information for the Mediterranean area.
- **Average price of LNG ($/MMBtu):** An average price of 10$/MMBtu has been used in the database. An increase of 15% to the final price has been added in order to include the logistics cost of LNG bunkering.

Fuel	($/Tonne)	(€/Tonne)
HFO (Average 2013)	618.19	465.47
LNG (Average 2013)	536.25	403.77
MGO (Average 2013)	963.57	725.53
MDO (Average 2013)	886.30	667.35

Table 1: Fuel prices included in the model
Source: BunkerIndex

2.2.3 GHG emission hypotheses

In order to estimate the greenhouse gas (GHG) emissions of the SSS fleet in the Mediterranean, fuel emission factors based on fuel consumption has been used. Reference values are based on the IMO (2009) Second IMO GHG Study, which compiled information in line with recognized standards (IPCC, UNECE/EMEP CORINAIR).

Emission factors (tonnes per fuel tonne)	HFO	MDO
CO_2	3.13	3.19
SO_x	0.054	0.01
NO_x	0.056	0.056
PM_x	0.0067	0.0011

Table 2: Emission factors included in the model
Source: Fundación Valenciaport, 2014 based on the IMO (2009) GHG Study

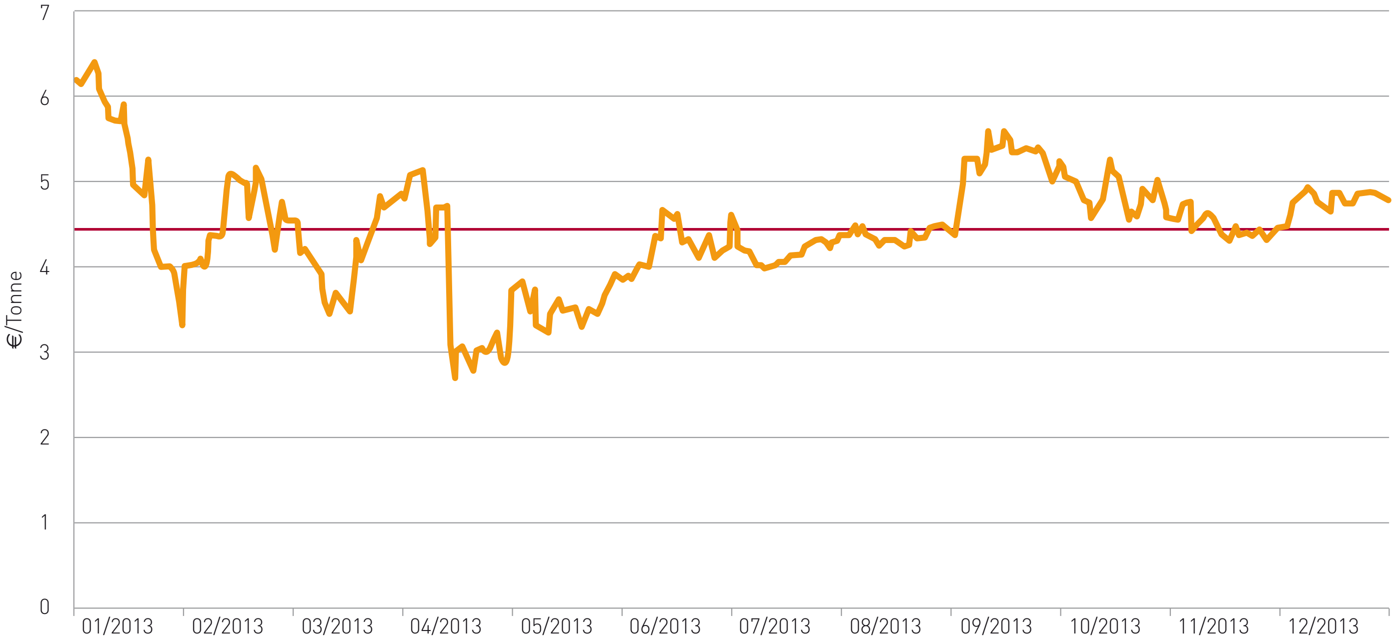
- **Percentage reduction in CO_2** when using LNG: A 25% reduction in CO_2 emissions has been assumed when using LNG.
- **Percentage reduction in SO_x** when using LNG: A 95% reduction in SO_2 emissions has been estimated when using LNG.
- **Percentage reduction in NO_x** when using LNG: An 85% reduction in NOx emissions has been assumed when using LNG.

The following table summarises the hypotheses adopted in terms of emission reductions when using LNG as marine fuel.

Emission reduction	%
CO_2	25%
SO_x	95%
NO_x	85%
PM_x	100%

Table 3: Hypotheses related to percentage reductions in environmental emissions when using LNG
Source: Fundación Valenciaport, 2014 based on literature review

- **Price of CO_2 (€/tonne) in 2013:** according to data published by SENDECO2, a stock exchange for CO_2 emission allowances, the average price of CO_2 in 2013 was €4.455 per tonne. The graph shows the variability of this price, and the average price in 2013.



CO_2 PRICES **AVERAGE VALUE 2013**

Graph 1: Evolution of CO_2 price (€/tonne) in 2013

Source: Fundación Valenciaport, 2014 based on SENDECO

- **Price of CO_2 (€/tonne) in 2020:** according to the literature review, a price of 23.5 (€/t) in 2020 has been taken as a point of reference.

- **Price of NO_x and SO_x (€/tonne) in 2013:** to estimate NO_x and SO_x prices, the evolution of American emission markets has been analysed, as in Europe there is only a trading scheme for CO_2 emissions. It has been assumed that the same relationship between emission prices in the USA, could be employed in the European market; this proportion was calculated and applied to European CO_2 prices. The results are shown in the table:

	$/short tonne (US market)	Price relation based on CO_2	EU prices (€)
SO_x	0.7	0.23	1.03
NO_x	39.6	13.11	58.42
CO_2	3.02	1	4.46

Table 4: CO_2, SO_x and NO_x prices

Source: Fundación Valenciaport, 2014 based on SENDECO2 and Argus Daily

- **Price of NO_x and SO_x (€/tonne) in 2020:** the uncertainty over the economic value of SO_x and NO_x has led us to adopt a conservative approach and maintain constant prices.
- **Price of PM_x:** due to the lack of relevant information on this matter, the economic value of PM_x has not been considered.






2.3 INVESTMENTS

This section aims to obtain an estimation of the cost of the installation required to power the fleet currently sailing in the Mediterranean with LNG. Both refurbishment of existing vessels and new builds have been considered.

As LNG is not the sole solution available to comply with the emissions limits fixed by Marpol Annex VI and Directive 2012/33/EU, the installation of exhaust gas treatment systems, such as scrubbers, has also been analysed.

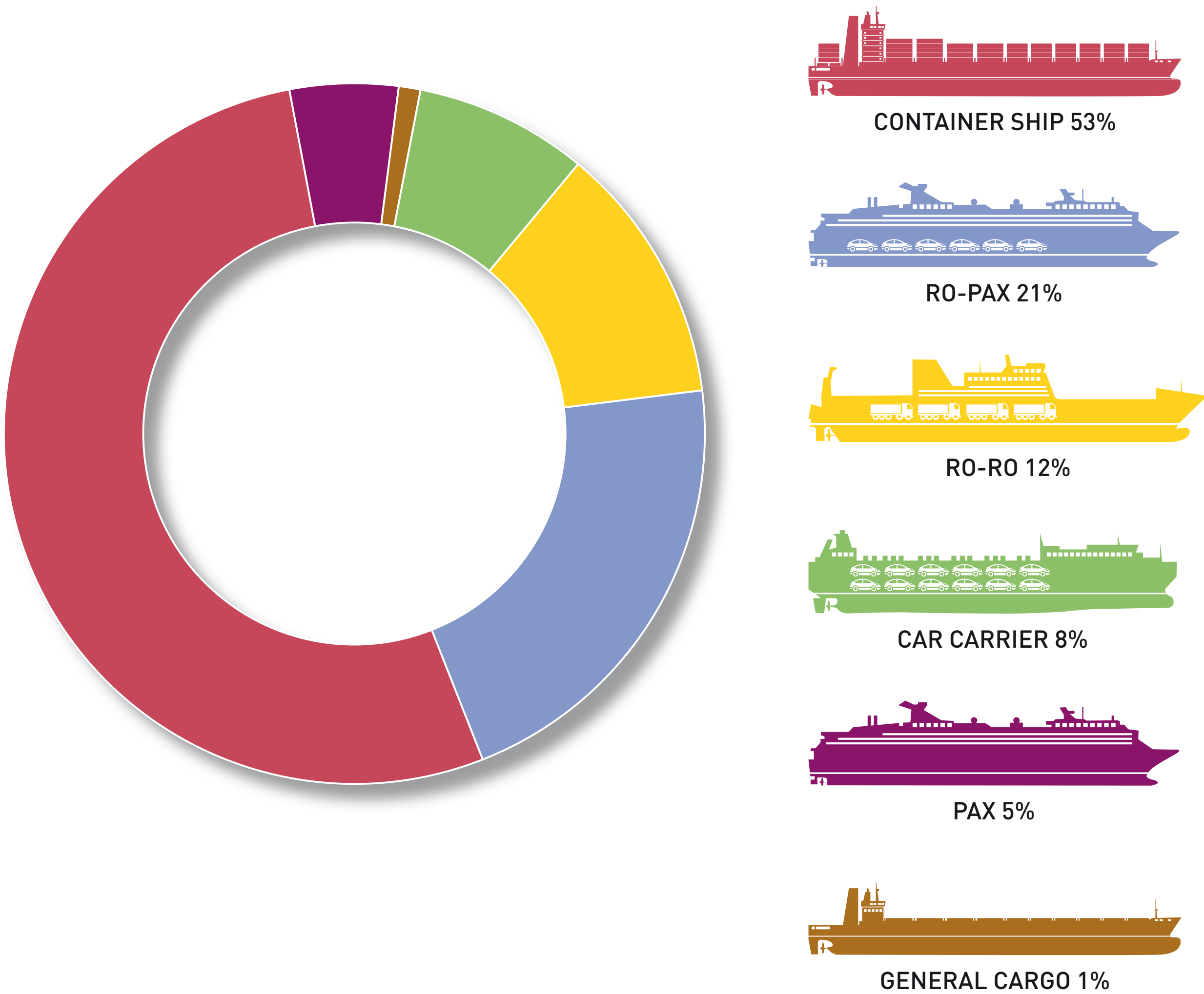
The final objective is to present a feasibility analysis of each solution to answer questions regarding the potential investments and possible benefits of using these technologies. For this reason, the study estimates the cost of implementing LNG and scrubbers when applied to different type of vessels, sized according to engine power.

Most of the existing fleet currently sailing on Short Sea Shipping lines in the Mediterranean Sea can be divided into different types of ships:

- **Car carrier (CC)**
- **Container ship (CONT-SHIP)**
- **General cargo (GC)**
- **Passenger ship (PAX)**
- **RO-PAX**
- **RO-RO**

2.3.1 Fleet Segmentation

In order to gain a clearer understanding of the problem, the fleet operating in the Mediterranean Sea during the first six months of 2013 has been classified by type of vessel.



Graph 2: Distribution of SSS fleet by type of vessel
Source: Fundación Valenciaport

Each type of vessel has been sized according to the commercial engine power ranges available on the market. Catalogues provided by Caterpillar, Man Diesel & Turbo and Wärtsilä have been used to establish these ranges. In general, each type of vessel complied with a commercial series of marine engines. The main advantage of this is that we have been able to assign a constant value in €/kW to the engine price.

There are two critical parameters in terms of LNG installation. The first, engine power, has been mentioned above, whilst the second is autonomy, which is also crucial when it comes to defining the installation, as there is a direct relationship between autonomy and LNG storage tank capacity. It is advisable that the future operability of the vessel is not compromised as a result of insufficient tank capacity that could prevent the ship from sailing on longer routes. This capacity has been estimated considering the route the vessel operated on from January to June 2013, and also taking into account the longest distance covered by this type of vessel during this period of time.

For instance, passenger vessels refer to ships whose primary function is to move passengers on short-sea voyages. As a rule, a representative vessel is approximately 40 m long, and operates on short routes, such as in the Gibraltar Strait, between islands, or connecting the mainland with islands (e.g. Greek Islands, Balearic Islands). Daily round distances range between 130-180 nautical miles (nm), with an average speed of 21 knots. These vessels are fitted with two high-speed engines, which can supply 4,000 kW of total power. This group includes a total of 27 ships, in which the line Naples-Ischia-Naples (180 nm per day), operated by a ship fitted with two high-speed engines of 2,000 kW each, epitomizes this type of vessel.

An in-depth analysis of car carriers shows that they can be divided into three different categories:

TYPE	CC1	CC2	CC3
POWER ENGINE (kW)	3,700-9,000	11,000-13,000	15,500-16,000
DISTANCE (nautical miles)	1,500-2,700	2,000-9,600	3,700-9,600

Table 5: Segmentation of car carrier vessels

Source: Fundación Valenciaport, 2014

The CC1 group includes nine car carriers which are equipped with one medium-speed engine of between 3,700-9,000 kW. The CC2 group is made up of 29 ships, fitted with low-speed engines, while there are seven car carriers in the CC3 group, with medium-speed engines. At this point, it should be highlighted that 69% of car carriers operating in the Mediterranean run on one low-speed engine between 11,000-13,000 kW.

Secondly, roll on-roll off vessels are designed to carry wheeled cargo, such as cars, trucks, and trailers that are driven on and off these vessels on their own wheels. Following the same process as the one set out above, the complete picture of Ro-ro vessels navigating in the Mediterranean can be summarised as:

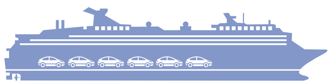
15 vessels, powered by medium-speed engines, come under the RO-RO1 classification; 16 ships, fitted with low-speed engines, are included in RO-RO 2, and 56% of the Ro-ro vessel fleet, i.e. 40 vessels, equipped with two medium-speed engines, come under RO-RO 3.

TYPE	RO-RO1	RO-RO2	RO-RO3
POWER ENGINE (kW)	4,800-6,600	8,600-13,000	+13,000
DISTANCE (nautical miles)	1,050-6,200	300-3,700	390-3,700

Table 6: Segmentation of Ro-ro vessels

Source: Fundación Valenciaport, 2014

Additionally, the acronym RO-PAX (Roll-on/Roll-off passenger) describes a Ro-ro vessel built for freight vehicle transport along with passenger accommodation. Technically, this encompasses all ferries with both a roll-on/roll-off car decks and passenger-carrying capacities, but in practice, ships with facilities for more than 500 passengers are often referred to as cruise ferries. Ro-pax vessels have different engine power capacities; as a consequence, these vessels have been categorised into six types:



TYPE	RO-PAX 1A	RO-PAX 1B	RO-PAX 2	RO-PAX 3	RO-PAX 4A	RO-PAX 4B	HSC
POWER ENGINE (kW)	5,800-10,800	10,800-14,000	14,000-25,000	25,000-34,000	34,000-48,000	48,000-67,200	4,000-36,400
DISTANCE (nautical miles)	26-900	26-1,200	26-1,800	26-1,800	350-1,800	280-1,000	26-300

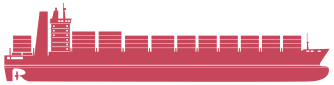
Table 7: Segmentation of Ro-pax vessels

Source: Fundación Valenciaport, 2014

According to the IMO SOLAS regulation, passenger vessels have to be fitted with at least two engines. In order to reach commercial speeds, these ships install medium-speed engines, with the exception of High-Speed Craft (HSC), which require high-speed engines to reach operational speeds. The main difference between medium and high-speed engines is that the latter run at variable rpm, reaching higher power/engine weight ratios. High-Speed Craft are propelled by water jets. To supply the vessel with enough power and manoeuvrability, at least four engines must be fitted. Conventional Ro-pax vessels up to 25,000 kW are equipped with two engines. More powerful vessels have four engines which are all equal power.

As per the classification set out above, 34 RO-PAX 1A, 16 RO-PAX 1B, 54 RO-PAX 2, 22 RO-PAX 3, 10 RO-PAX 4A and 23 RO-PAX 4B are in operation in the Mediterranean.

To conclude the segmentation of the fleet, container ships are the most common means of commercial intermodal freight transport and now carry most seagoing non-bulk cargo. In the first six months of 2013, container vessels made up 45% of the fleet operating on SSS services in the Mediterranean Sea. In accordance with total engine power, container ships have been divided into seven major categories, being CONT-SHIP 3 and CONT-SHIP 2 the most common segments used in the Mediterranean SSS lines.



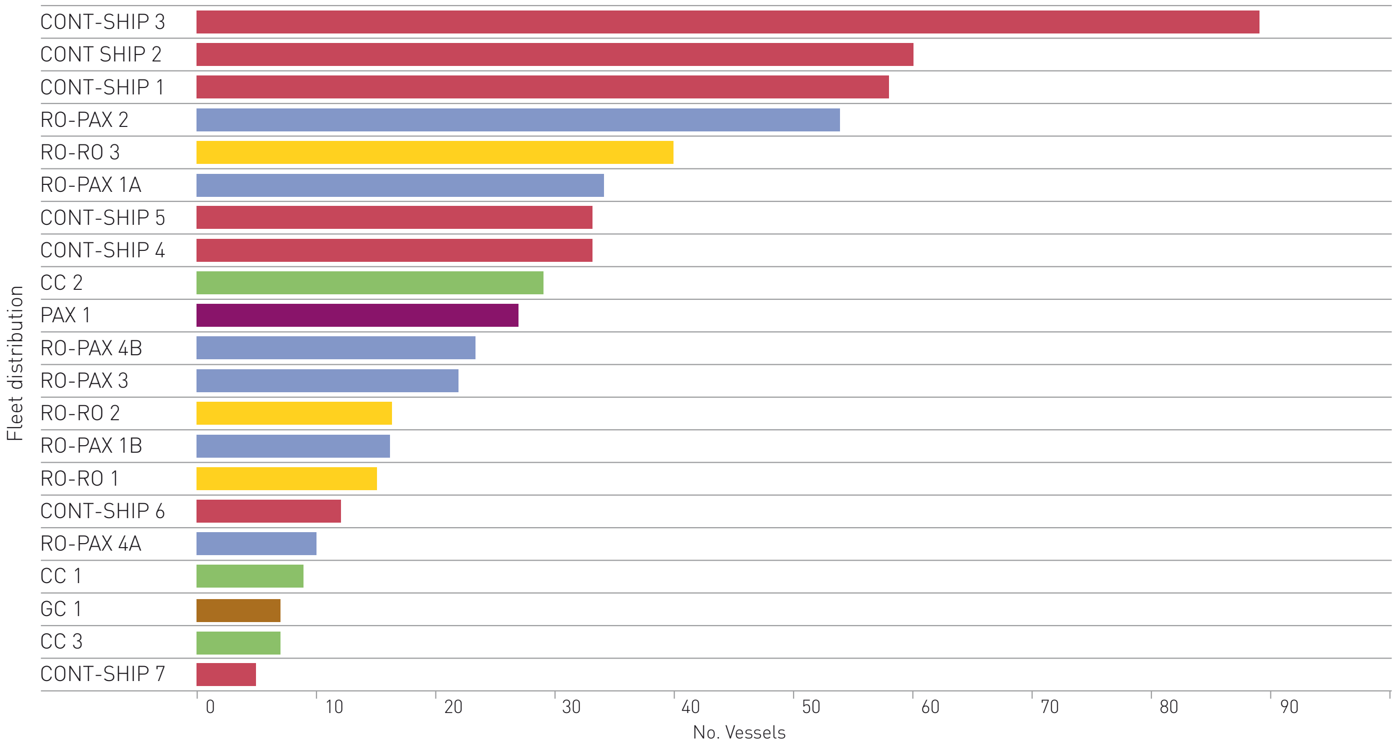
TYPE	CONT-SHIP1	CONT-SHIP2	CONT-SHIP3	CONT-SHIP4	CONT-SHIP5	CONT-SHIP6	CONT-SHIP7
POWER ENGINE (kW)	3,500-7,000	7,000-9,000	9,000-13,500	13,500-23,000	23,000-38,000	38,000-55,000	55,000-80,000
DISTANCE (nautical miles)	300-4,600	450-7,600	320-6,200	900-8,700	1,200-8,000	3,600-8,000	3,300-7,200

Table 8: Segmentation of container ship vessels

Source: Fundación Valenciaport, 2014

Regarding general cargo vessels, and although seven of them operated in the Mediterranean during the first six months of 2013, from the point of view of this study, their main characteristics were strikingly similar. General cargo vessels are equipped with one medium-speed engine of between 3,700-6,000 kW. In addition, routes covered round distances of between 1,000 nm to 3,900 nm. Therefore, a vessel designated as GC1, with 5,400 Kw of power, operating on the route "Bremen - Antwerp - Harwich - Leixoes - Oran - Mostaganem - Cartagena – Bremen" has been taken as a reference with all the critical parameters in account.

Taking into account the segmentation of the vessels defined previously, the existing fleet operating in the Mediterranean is represented in the following graph:



Graph 3: SSS Fleet distribution per type of vessel

CAR CARRIER | CONTAINER | GENERAL CARGO | PAX | RO-PAX | RO-RO

Source: Fundación Valenciaport, 2014

Furthermore, in each vessel segment it is possible to define a "representative vessel" which fits with the average characteristics of the vessels included in each category, not only in terms of technical issues but also according to service related aspects. The representative vessels have been summarised in the following table.

Table 9: Summary of the segmentations of the fleet

Source: Fundación Valenciaport, 2014

TYPE OF VESSEL	LENGTH	BEAM	DRAUGHT	TOTAL POWER kW	ROUND DISTANCE nm	EXAMPLE	
CC 1	130	22	6	6,000	2,700	Representative vessel example: NEPTUNE PLOES	
CC 2	176	31	8.7	12,600	7,700	Representative vessel example: CORAL LEADER	
CC 3	181	32.2	9.4	16,000	9,600	Representative vessel example: GRANDE ELLADE	
CONT-SHIP 1	121.8	18.8	6.7	5,300	1,500	Representative vessel example: WEC MAJORELLE	
CONT-SHIP 2	129	20.8	7.4	7,200	1,900	Representative vessel example: WMS HARLINGEN	
CONT-SHIP 3	166.2	25	9.5	11,120	3,370	Representative vessel example: WARNOW BELUGA	
CONT-SHIP 4	176	27	10.9	15,800	2,230	Representative vessel example: KONRAD SCHULTE	

Table 9: Summary of the segmentations of the fleet

Source: Fundación Valenciaport, 2014

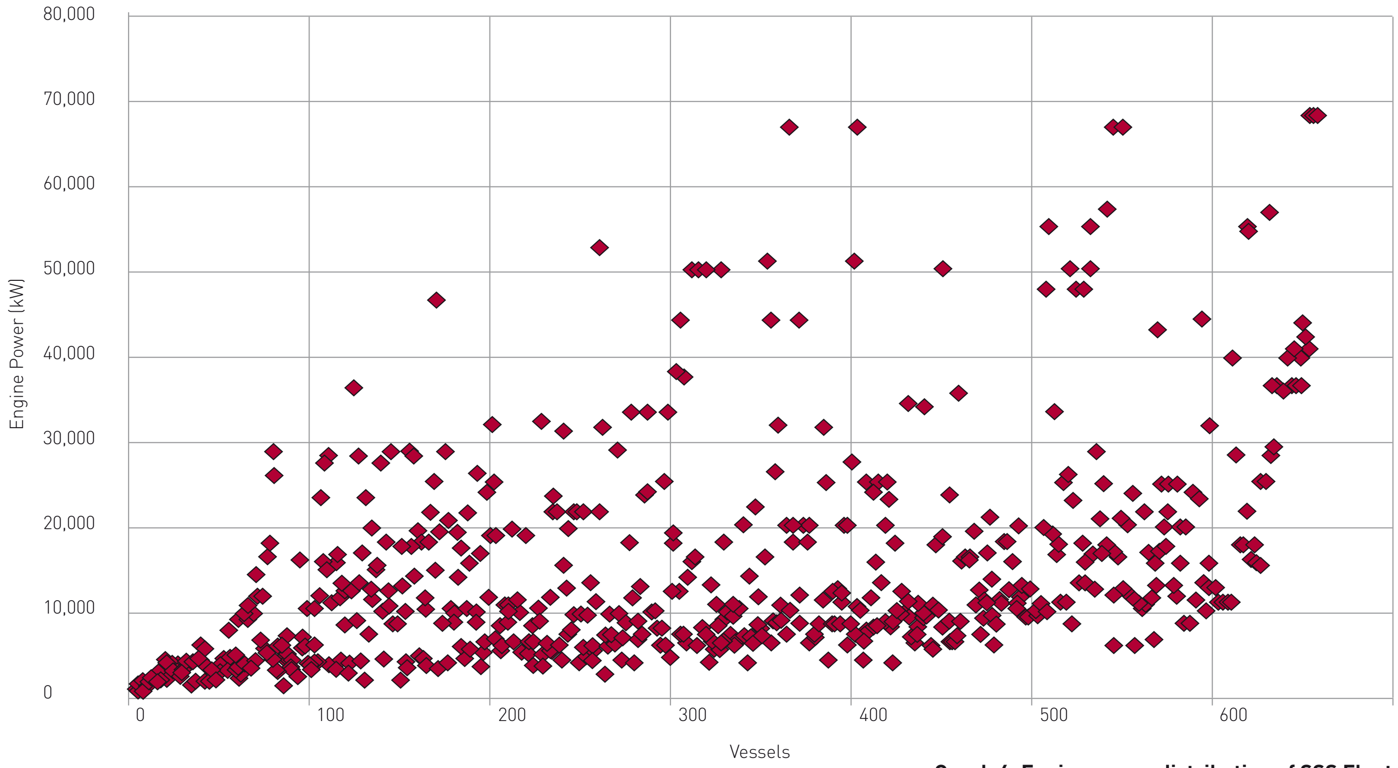
TYPE OF VESSEL	LENGTH	BEAM	DRAUGHT	TOTAL POWER kW	ROUND DISTANCE nm	EXAMPLE	
CONT-SHIP 5	216	26.7	8.7	25,000	2,920	Representative vessel example: MSC EDITH	
CONT-SHIP 6	227.4	40	14	55,000	3,600	Representative vessel example: MSC MIRA	
CONT-SHIP 7	294.1	32.2	12.2	68,640	7,200	Representative vessel example: SEAGO ANTWERP	
GC 1	138	21	8	5,400	3,900	Representative vessel example: SLOMAN DISCOVERER	
PAX 1	38	8	1.2	4,000	36	Representative vessel example: ACAPULCO JET	
RO-PAX 1A	101	17	4.3	9,000	26	Representative vessel example: PASSIO PER FORMENTERA	
RO-PAX 1B	150	23.4	5.7	1,150	1,200	Representative vessel example: PUGLIA	
RO-PAX 2	150	23.4	5.7	18,000	298	Representative vessel example: SCANDOLA	

Table 9: Summary of the segmentations of the fleet

Source: Fundación Valenciaport, 2014

TYPE OF VESSEL	LENGTH	BEAM	DRAUGHT	TOTAL POWER kW	ROUND DISTANCE nm	EXAMPLE	
RO-PAX 3	145	22	5.9	32,000	286	Representative vessel example: BLUE STAR DELOS	
RO-PAX 4A	200.6	25.8	6	44,500	1,820	Representative vessel example: IKARUS PALACE	
RO-PAX 4B	224	30.4	6.9	55,500	1,000	Representative vessel example: CRUISE OLYMPIA	
HSC	115.3	17	4.4	28,800	265	Representative vessel example: FEDERICO GARCIA LORCA	
RO-RO 1	122	19	6.2	6,000	1,800	Representative vessel example: AKNOUL	
RO-RO 2	195	25,2	6	12,600	3,650	Representative vessel example: EUROCARGO VALENCIA	
RO-RO 3	193	26	7	18,000	2,000	Representative vessel example: HATCHE	

From the perspective of LNG and scrubber retrofitting, RO-RO 3 vessels are similar to RO-PAX 2, to a certain extent in that both are equipped with similar power. The SSS fleet is mainly made up of container feeder ships and Ro-ro/Ro-pax vessels with similar engine power, which represented 65% of the total SSS fleet. When CC2 and PAX 1 type of vessels are added, this group accounts for 75% of the SSS fleet operating in the Mediterranean. In fact, a detailed study of the fleet reveals that most of the ships have less than 25,000 kW of engine power, which infers that efforts should concentrate on this segment.



Graph 4: Engine power distribution of SSS Fleet

Source: Fundación Valenciaport

2.3.2 Cost assumptions

Compliance with Marpol Annex VI and Directive 2012/33/EU can be achieved by using different technologies available on the market:

- **Fuelling by MGO**
- **Fuelling by LNG**
- **Installing scrubbers**
- **Among others**

As of 2020, ship operators that trade in European territorial seas and exclusive economic zones will be required to burn fuel which has less than 0.5% of sulphur content. A ship operator may meet this requirement by burning high-sulphur fuel at sea, and then switching to low-sulphur fuel within these areas. Other ship operators may choose to reduce operational efforts by converting their vessels so that they always run on low-sulphur fuel oil, or utilise natural gas, which has almost no sulphur content.

This study has analysed costs for key technologies when applied to different types of vessels which are considered to be representative of the Mediterranean fleet. Costs have been calculated for each type of vessel, based on the information supplied by the main engine manufacturers, such as Wärtsilä, MAN Diesel & Turbo, and Caterpillar, as well as the cryogenic tank manufacturer, Ros Roca Indox Cryo Energy S.L. The costs of scrubber installation and operation have been estimated according to the information provided by equipment suppliers. Scrubbering operational costs are available on Aalborg Industries self-certified data. Boiler units have not been considered in this survey, and specific fuel oil consumption has been based on current knowledge.

This study aims to answer questions regarding the cost/benefit ratio of using such technologies, and constitutes a general approach to the problem. In general, ships which may choose to engage in these technologies will have to pass a technical survey, ensuring that the technology can be integrated with ship arrangements, stability and operations.

In addition, it is necessary to highlight that the regulatory framework is defined by the IMO Interim Guidelines for gas as ship fuel (Resolution MSC. 285(86)), which contain the state-of-the-art on safety concepts. Classification Societies have issued their own rules, based on the IMO resolution mentioned above, and on their broad experience in both shipbuilding and LNG tanker operations. The IMO subcommittee on BLG has approved the International Gas as Fuel Code (IGF), which is scheduled to come into force in 2017. In parallel, ISO TC 67 is preparing standards for LNG bunkering. However, most systems are still close to their prototype development phase, and therefore involve technical risks.

LNG technology and modelling assumptions

Operating a ship on LNG is not a new technology; LNG tankers use the boil-off from the LNG tank as fuel. The technology exists, but making an existing ship run on LNG as a fuel requires a retrofit of the main engine, or the installation of a new engine, as well as the installation of a fuel system on board.
As ships have to comply with tight schedules, the main engine option was chosen, according to the following criteria:

- **Retrofit:** Installation of the immediately superior main engine (in terms of power) available on the market.

- **New build:** Engine power given by design speed.

For medium-speed engines, the installation of new engines seems to be the best option, as the difference in price is not significant, and removed engines can be sold in the second market.

Engine retrofitting is financially feasible for four-stroke engines and only for electronic two-stroke engines. Mechanical engines will need to be converted in two stages: in a first stage, an electronic fuel injection system will be installed and in a second phase, the engine will be converted to a dual-fuel engine.

For new builds, auxiliary engine power is taken as 20% of the main engine power. It has been assumed that auxiliary engines of existing vessels will still run on LSFO/MGO. A first rough estimate of the potential savings has dissuaded us from going straight on to retrofitting them to run on LNG in the model.

Apart from changing the main engines, LNG conversions require other major changes, such as:

- **LNG/Inner gas system**
- **Auxiliary systems**
- **LNG storage tanks**
- **Fuel supply systems. ATEX electrical installation**
- **Tank foundations**

Moreover, piping and equipment in existing vessels has to be removed. In addition, the vessel will be taken off hire for approximately 40 days.

The LNG tank volume chosen aims to give the vessel sufficient autonomy to avoid increasing exposure to volatile fuel prices. The LNG system includes tanks, a bunker station, gas preparation, a gas line, automation, electrical system compliance with ATEX regulations, double-wall pipes, etc. This study has chosen type C tanks for all types of vessels following the recommendations of the IGF code.

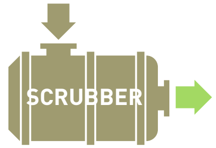
Tanks generally imply lost cargo capacity, roughly estimated at 3%. Other operational costs remain constant in terms of operations run on IFO. Even though crew costs are higher, these are compensated by reductions in maintenance costs, mainly because times between overhauls are extended.

Scrubber technology and modelling assumptions

Alfa Laval Aalborg has designed a hybrid scrubber that works both in open and closed loops, and uses water (seawater or freshwater) to wash out the sulphur from the exhaust gases. The scrubber only works in the main engine. Early estimates reveal that is more profitable to operate auxiliary engines with MGO/LSFO than to invest in scrubbers.

The conversion to the scrubber solution requires some important changes:

- **New funnel layout**
- **Scrubber**
- **Installation of scrubber auxiliary machinery**
- **Installation of sludge tanks**
- **Steel work**



The acquisition costs of scrubbing technologies have been broken down into equipment, engineering/certification, and installation / commissioning for each of the vessels.

Technically, each engine should have a single scrubber system installed on its exhaust pipe. Although the best solution from a technical point of view would be to have a single scrubber for each different engine, it is not feasible to install four scrubbers on four engines in a ship due to operational and financial reasons. So, following operational and financial criteria, it has been assumed that two scrubbers will be installed on four engines.

Installation and commissioning has been assumed to be 50% of the equipment cost. Engineering and certification has also been estimated as 7% of the equipment cost. Maintenance and repair expenses have been assumed to be 4% of the equipment cost on an annual basis.

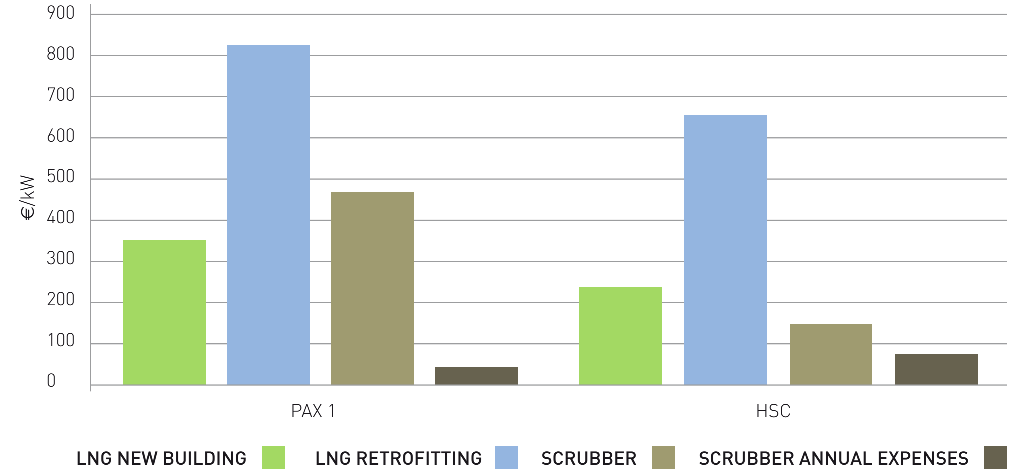
Consumables and parasitic loads as a result of the scrubber were converted to a percentage of fuel consumption. Burning residual fuel requires significant heating, purifying, and waste management efforts that require energy, maintenance and operational efforts. Typically, the tanks and combustion fuel lines are heated by waste heat-generated steam, meaning that energy costs are relatively low. A correction factor is applied to account for the difference in heating value of distillate on a weight basis, as compared to residual fuel. On the other hand, distillate is lighter, and therefore requires larger storage volumes, and is more important for piping work and mechanical systems. This volume difference results in a diesel engine loss. A 5% increase in fuel consumption is assumed to be a sum of the aforementioned losses.

Sludge residue quantities and equipment energy consumption have been gathered from self-certified data sheets provided by equipment suppliers. Marpol VI residue collection prices are around €185 per tonne according to rates published by some Spanish port authorities. Moreover, the piping and equipment in existing vessels has to be removed. In addition, the vessel will be taken off hire for approximately 20 days.

2.3.3 Cost estimates

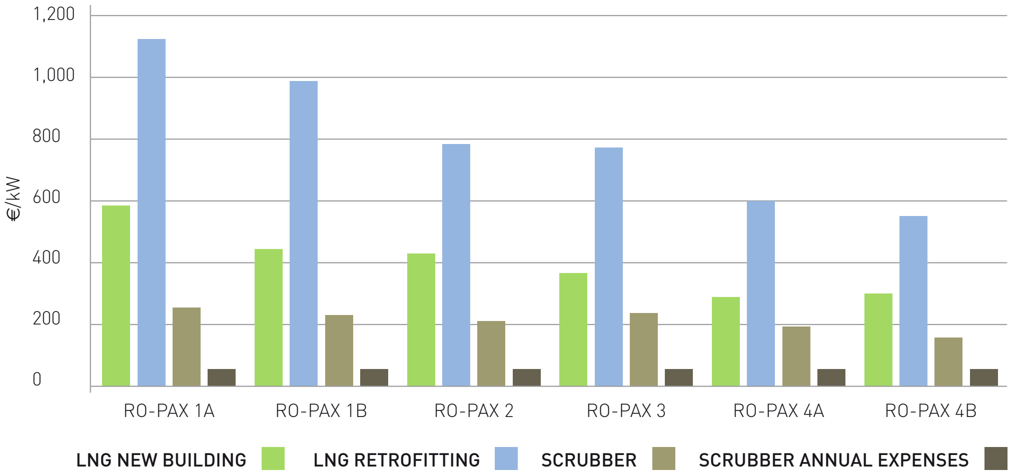
Investments for each type of vessel are provided in terms of €/kW. Three separate cases have been studied. Retrofitting investment represents the total investment required to propel existing ships using LNG as fuel, whereas newbuild investment refers to additional costs for LNG installation compared with a traditional diesel installation. On the other hand, scrubbers investments include two components: new build investment refers to the complete scrubber and auxiliary equipment installation as mentioned above while the annual expenses are referred to the maintenance and waste management costs of the scrubbers.

The following graphs provide an overall picture of the investments by type of vessel required to comply with environmental regulations, establishing a comparison between the different solutions.



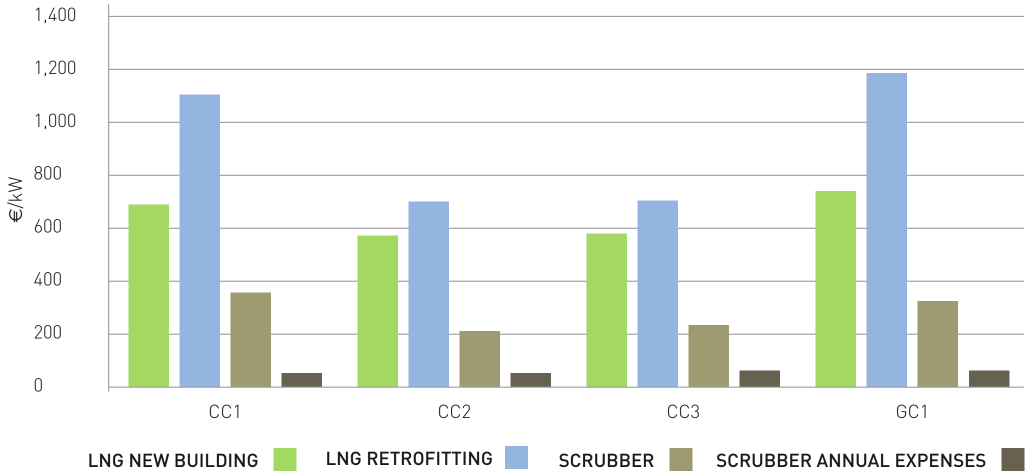
Graph 5: Comparative costs for passenger vessels and High-Speed Craft

Source: Fundación Valenciaport, 2014



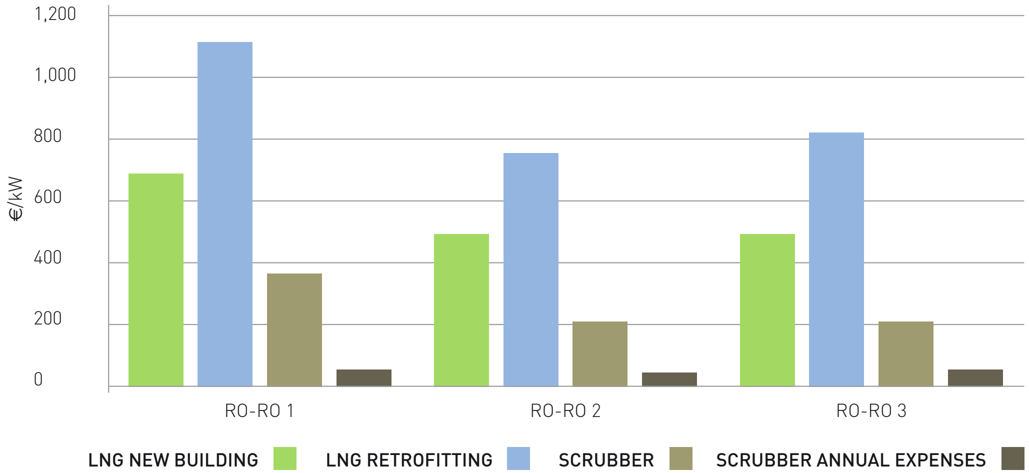
Graph 6: Comparative costs for Ro-pax ships

Source: Fundación Valenciaport, 2014



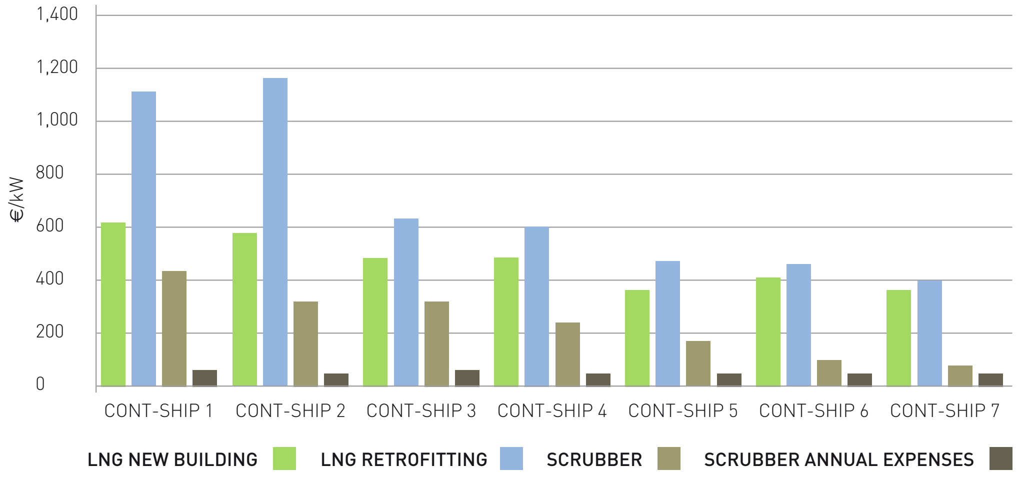
Graph 7: Comparative costs for general cargo and car carriers

Source: Fundación Valenciaport, 2014



Graph 8: Comparative costs for Ro-ro ships

Source: Fundación Valenciaport, 2014



Graph 9: Comparative costs for container ships

Source: Fundación Valenciaport, 2014

2.4 INDICATORS

This section explains the methodology used to calculate the indicators included in this publication. The indicators have been defined from different geographic points of view, which coincide with the presentation structure.

These groups of indicators are:

- **Global indicators:** The whole area of study
- **Indicators per area:** Atlantic area, Western Mediterranean, Eastern Mediterranean & Black Sea, and mixed area (routes that connect more than one area)
- **Indicators per country**
- **Indicators per port**
- **Indicators per Motorways of the Sea (MoS)**

The indicators have been calculated for an entire calendar year based on the in-depth analysis of a six month period and additional research carried out. Considering that not all the lines included in this database have been active during the entire period in question, calculations have been based on the period of activity of each line and scaled up to a year. For example, a line has been in service from January to March but has ceased to operate thereafter. The average indicators for this line have been calculated on the basis of the total number of voyages and by calculating a weekly frequency for the line.

2.4.1 SSS service indicators

- **Total number of ports:** Sum of the core ports and the ports added to the database (overseas areas and SSS connections).
- **Number of core ports:** Number of ports selected by the TEN-T as key ports in the Mediterranean. Only those that are within the studied area of the project have been included.
- **Number of ports with direct connections:** Total number of ports of destination connected with other ports without any intermediate calls.
- **Average number of ports connected per line:** Average number of calls for the total number of lines, considering all the stopovers on the line.
- **Number of ports of destination:** Total number of ports where all the lines stopped.
- **Number of lines:** The lines included in the database during the study period.
- **Number of shared lines per sea carrier:** Total number of lines operated by more than one sea carrier.
- **Number of shared lines per country:** Total number of lines that have operated in more than one country and included in the study.
- **Number of seasonal lines:** Total number of lines that have operated for a period of less than a year.

- **Number of sea carriers:** Total number of sea carriers providing services during the period under consideration.
- **Number of sea carriers per line:** Average number of sea carriers operating per line.
- **Average frequency (weekly departures):** Average frequency of all the lines, calculated on the basis of the number of departures per week during their period of activity.
- **Total lines per cargo type:** Total number of lines active during the study period, organised according to cargo type. The total of this classification coincides with the total number of lines.
- **Number of stops:** Number of ports called at per line.
- **Total lines per country and cargo type:** Total number of lines active in the study period, organised by country, grouped together according to cargo type. The total of this classification is different from the total number of lines, as one line has been counted in every country in which it has a port of call.
- **Total lines per port and cargo type:** Total number of lines active in the study period, organised by the core port of loading. The total of this classification is different from the total number of lines because one line has been counted for each core and each additional port in which it had a port of call.

2.4.2 SSS fleet indicators

- **Number of ships:** Total number of ships used in rotation for the total number of lines active in the study period.
- **Total GT capacity:** Total GT per line and per type of traffic, scaled up to a year.
- **Total DWT capacity:** Total DWT vessel capacity per line and per type of traffic.
- **Total TEU capacity:** Total number of TEUs that can be transported by the container ship lines under study.
- **Total lane metres capacity:** Total number of linear metres offered by wheeled cargo lines (Ro-ro and Ro-pax).
- **Total passenger capacity:** Total number of passengers carried by passenger lines.
- **Total car capacity:** Total number of cars that can be transported by car carrier lines.
- **Average DWT capacity of ship per cargo type:** Average DWT vessel capacity per cargo type.
- **Average speed according to cargo type:** Average maximum speed of the ships operating on each line, according to cargo type, expressed in knots.
- **Average engine power according to cargo type:** Average engine power of the ships operating on each line, according to cargo type, expressed in kW.
- **Average age of ships according to cargo type:** Average age of ships operating on each line, expressed in years. The year 2013 has been used to determine average ages, based on the ship's year of construction.
- **Total number of ships per age range:** Total number of ships per age range, according to year of construction.
- **Consumption in tonnes/day per cargo type:** Average consumption of ships per cargo type in tonnes per day of navigation.
- **Number of ships per country and cargo type:** Total number of ships per country, organised by cargo type. The total of this classification is different from the total number of ships as a line is counted in every country in which it has a port of call.
- **Total GT capacity per country and cargo type:** Total capacity offered per country according to cargo type. The total of this classification could be different from the general total.
- **Total DWT capacity per country and cargo type:** Derived from total GT capacity per country according to cargo type.
- **TEU capacity per country:** Total capacity of container transport supplied by country expressed in TEUs.
- **Lane metre capacity per country:** Total capacity of Ro-ro and Ro-pax transport supplied by country expressed in linear metres.
- **Passenger capacity per country:** Total capacity of passenger transport supplied by country expressed in number of passengers.
- **Car capacity per country:** Total capacity of car carrier tranport supplied by country expressed in number of cars.
- **Average age of ships per country:** Average age of ships, organised by country.
- **Number of ships per port and cargo type:** Total number of ships operating in each port, organised by cargo type.
- **GT capacity per port and cargo type:** Total capacity of each port according to cargo type. The total of this classification could be different from the general total.
- **DWT capacity per port and cargo type:** Derived from total DWT capacity per port, according to cargo type.
- **Average age of ships per port:** Average age of ships, organised by port.

2.4.3 SSS line fuel consumption indicators

The following indicators have been calculated for each shipping line:

- **Average specific fuel consumption of the ship in grams per kiloWatt/hour (SFC, kWh):** As explained in the previous stage in terms of the ships used to provide each service, information published by the Fairplay database about the average daily consumption of each ship has been used. However, this information is available across the board and therefore, theoretical formulae have been used first to calculate specific consumption in kilowatts/hour, and then, to obtain fuel consumption in tonnes per day for ships, when information was not available from Fairplay. As stated in the hypotheses section, the SFC of each ship has been based on the engine data sheet for each vessel.

- **Ship consumption in tonnes per day** *(FC,t/day)*: On the basis of the specific consumption *(SFC)* estimated earlier, the number of tonnes of fuel used per day by each of the lines has been calculated, based on engine power *(EP)* as shown below:

$$FC(tonnes/day) = \frac{SFC\left(\frac{g}{kWh}\right) * EP\ (kW) * 24\ (h/day)}{1{,}000{,}000\left(\frac{g}{tonne}\right)}$$

  These indicators have been calculated for those fuels used in the model, that is, HFO, MGO, MDO and LNG.

- **Average number of days per voyage** *(days)*: The average distance covered in each voyage *(D)* in nautical miles, and the average speed of each service *(v)* in knots, has been estimated using both parameters and taking into account an average speed reduction factor of 85%. Only sailing times have been used to estimate fuel consumption, as time spent in ports has not been considered relevant for the purpose of the model.

- **Average fuel consumption per voyage (tonnes):**

$$\begin{aligned}&Average\ fuel\ consumption\ per\ voyage\ (tonnes) =\\ &= fuel\ consumption\left(\frac{tonnes}{day}\right) * Average\ Voyage\ (days) *\\ &* Engine\ correction\ factor\ (85\%)\end{aligned}$$

- **Average current price of fuel per voyage (€):** The average price of fuel per voyage has been estimated using the formula below, using the average daily cost of bunkering and the calculation for the average number of days per voyage:

$$\begin{aligned}&Average\ price\ of\ fuel\ per\ voyage\ (€) =\\ &= fuel\ consumption\left(\frac{tonnes}{day}\right) * Average\ voyage\ (days) *\\ &* fuel\ price\left(\frac{€}{day}\right)\end{aligned}$$

- **Hypothetical LNG fuel consumption per voyage (tonnes):**

$$\begin{aligned}&Average\ consumption\ LNG\ per\ voyage\ (tonnes) =\\ &= LNG\ consumption\left(\frac{tonnes}{day}\right) * Average\ Voyage\ (days) *\\ &* Engine\ correction\ factor\ (85\%)\end{aligned}$$

- **Average price LNG per voyage (€):** The average price of LNG per voyage has been estimated using the following formula, using the average daily cost of bunkering and the calculation for the average number of days per voyage:

$$\begin{aligned}&Average\ price\ of\ LNG\ per\ voyage\ (€) =\\ &= LNG\ consumption\left(\frac{tonnes}{day}\right) * Average\ Voyage\ (days) *\\ &* LNG\ price\left(\frac{€}{tonne}\right)\end{aligned}$$

- **Average savings in bunkering per voyage in Euro (€):** Once the cost of traditional fuels (HFO and MDO) and the forecast cost per voyage for the line when using LNG have been calculated, the savings resulting from the change in fuel has been estimated:

$$\begin{aligned}&Average\ savings\ in\ bunkering\ per\ voyage\ (€) =\\ &= price\ of\ fuel\ per\ voyage\ (€) - price\ of\ LNG\ per\ voyage\ (€)\end{aligned}$$

- **Annual savings in bunkering (€):** To calculate the total annual savings in bunkering for each of the ships used in each service, we have calculated the number of voyages carried out by the line for each service, as well as the number of vessels required to cover each service. The formulae to obtain these values are as follows:

$$Nº\ voyages\ per\ year = Frequency\ (nº\ departures\ per\ week) * nº\ week\ /year$$

$$Nº\ voyages\ per\ vessel/year = Nº\ voyages\ per\ year\ /\ nº\ vessels$$

  Therefore,

$$\begin{aligned}&Average\ annual\ savings\ in\ bunkering\ by\ vessel\ (€/year) =\\ &= Nº\ voyages\ per\ vessel/year *\\ &* Average\ savings\ in\ bunkering\ per\ voyage\ (€)\end{aligned}$$

The next step in creating the model involved assigning a value to the environmental emissions (CO_2, SO_x and NO_x) produced by the use of fuel:

- **Total CO_2 emissions (tonnes/day):** In line with the IMO report mentioned above, total CO_2 emissions produced by the use of fossil fuels in maritime transport have been obtained by multiplying fuel consumption in tonnes per day, by a factor of 3.13 or 3.19 (depending on the type of fuel), as indicated in the hypotheses section:

$$Total\ CO_2\ Emissions\ (conventional\ fuels)\left(\frac{tonnes}{day}\right) = \\ = FC\left(\frac{tonnes}{day}\right) * CO_2\ emission\ factor$$

- **Total SO_x emissions (tonnes/day):** SO_x emissions from the combustion process have been calculated as follows, taking into account the different emission factors for each main fuel.

$$Total\ SO_x\ emissions\ \left(\frac{tonnes}{day}\right) = FC\left(\frac{tonnes}{day}\right) * SO_x\ emission\ factor$$

- **Total NO_x emissions (tonnes/day):** As explained above, the NO_x emission factor has been estimated at 0.056 (tonnes per tonne of fuel), which resulted in:

$$Total\ NO_x\ emissions\ \left(\frac{tonnes}{day}\right) = FC\left(\frac{tonnes}{day}\right) * NO_x\ emission\ factor$$

- **Total PM_x emissions (tonnes/day):** PM_x emissions from the combustion process have been calculated as follows, taking into account the different emission factors for each main fuel.

$$Total\ PM_x\ emissions\ \left(\frac{tonnes}{day}\right) = FC\left(\frac{tonnes}{day}\right) * PM_x\ emission\ factor$$

Thereafter, the same environmental parameters calculated for fuel have been also calculated for LNG use.

- **Total CO_2 emissions (LNG) (tonnes/day):** CO_2 emissions produced when using LNG have been estimated as being 25% lower than those produced when using current maritime fuels. On the basis of the value calculated in the previous step, emissions for LNG have been easily calculated as follows:

$$Total\ CO_2\ Emissions\ (LNG)\left(\frac{tonnes}{day}\right) = \\ = Total\ CO_2\ Emissions\ \left(\frac{tonnes}{day}\right) * (100\% - 25\%)$$

- **Total SO_x emissions (LNG) (tonnes/day):** Total SO_x emissions when using LNG have been calculated on the basis of the emissions calculated for traditional maritime fuels, applying a reduction factor of 95%:

$$Total\ SO_x\ Emissions\ (LNG)\left(\frac{tonnes}{day}\right) = \\ = Total\ SO_x\ Emissions\ \left(\frac{tonnes}{day}\right) * (100\% - 95\%)$$

- **Total NO_x emissions (LNG) (tonnes/day):** Similarly, a reduction factor of 85% has been applied to NO_x gas emission estimates:

$$Total\ NO_x\ Emissions\ (LNG)\left(\frac{tonnes}{day}\right) = \\ = Total\ NO_x\ Emissions\ \left(\frac{tonnes}{day}\right) * (100\% - 85\%)$$

- **Total PM_x emissions (LNG) (tonnes/day):** Similarly, a reduction factor of 100% has been applied to PM_x emission estimates:

$$Total\ PM_x\ Emissions\ (LNG)\left(\frac{tonnes}{day}\right) = \\ = Total\ PM_x\ Emissions\ \left(\frac{tonnes}{day}\right) * (100\% - 100\%)$$

- **Average annual savings in CO_2 emissions (tonnes/year):** Once CO_2 emissions for each type of fuel and for each line have been calculated in tonnes per day, the average savings in CO_2 emissions per year as a result of a change in fuel have been calculated by multiplying the average savings in tonnes per day, by the average number of days per voyage, and by the total number of voyages carried out by a line in a year:

$$Average\ annual\ savings\ in\ CO_2\ emissions\ \left(\frac{tonnes}{year}\right) = \\ = \left(Total\ CO_2\ Emissions\ (conventional\ fuels)\left(\frac{tonnes}{day}\right) - \\ - Total\ CO_2\ Emissions\ (LNG)\left(\frac{tonnes}{day}\right)\right) * Average\ Voyage\ (days) * \\ * \frac{Nº\ voyages}{year}$$

- **Average value of savings due to reduction of CO_2 emissions for the year 2013 (Euros/year):** Once the average annual reduction in total CO_2 emissions in tonnes per year has been calculated and using the price quoted on the CO_2 emissions trading market as a reference, the total savings in CO_2 from using LNG instead of conventional fuels has been estimated.

  As mentioned above, the average price of CO_2 for 2013 has been €4.55 per tonne, which results in:

$$Average\ value\ of\ the\ savings\ in\ CO_2\ emissions\ \left(\frac{€}{year}\right)_{2013} = Average\ annual\ savings\ in\ CO_2\ emissions\ \left(\frac{tonnes}{year}\right) * price\ CO_2\ \left(\frac{€}{tonne}\right)_{2013}$$

- **Average value of savings due to the reduction of CO_2 emissions for the year 2020 (Euros/year):** To calculate the savings in this scenario, estimations of future CO_2 prices in 2020 have been used , taking the price of CO_2 in 2020 as €23.50 per tonne:

$$Average\ value\ of\ the\ savings\ in\ CO_2\ emissions\ \left(\frac{€}{year}\right)_{2020} = Average\ annual\ savings\ in\ CO_2\ emissions\ \left(\frac{tonnes}{year}\right) * price\ CO_2\ \left(\frac{€}{tonne}\right)_{2020}$$

- **Annual conventional fuel consumption costs per vessel (Euros/year):** The average annual fuel consumption cost for each of the said vessels has been calculated using the value of annual fuel consumption per voyage and the number of voyages carried out by each vessel, based on the following formula:

$$Average\ annual\ consumption\ costs\ \left(\frac{Euros}{year}\right)(per\ vessel) = Average\ price\ of\ fuel\ per\ voyage\ (€)(conventional\ fuel) * Nº\ voyages\ per\ vessel\ /\ year$$

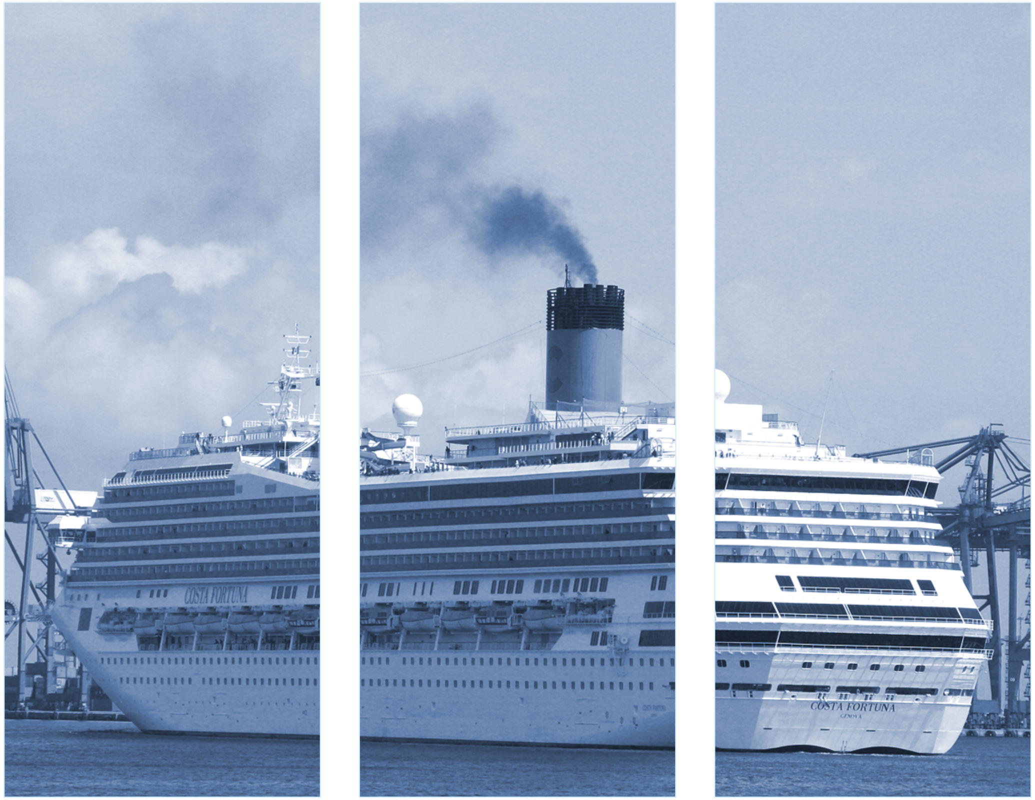
- **Annual LNG consumption costs (Euros/year):** Annual LNG consumption costs have been obtained in the same way:

$$Average\ annual\ LNG\ consumption\ costs\ \left(\frac{Euros}{year}\right)(per\ vessel) = Average\ price\ of\ fuel\ per\ voyage\ (€)(LNG) * Nº\ voyages\ per\ vessel\ /\ year$$

- **Average annual savings in bunkering per vessel (Euros/year):** Based on the above, the annual savings in bunkering per vessel from using LNG instead of conventional fuels have been calculated:

$$Average\ annual\ savings\ in\ bunkering\ \left(\frac{Euros}{year}\right) per\ vessel = Average\ annual\ current\ consumption\ costs\ \left(\frac{Euros}{year}\right)(per\ vessel) - Average\ annual\ LNG\ consumption\ costs\ \left(\frac{Euros}{year}\right)(per\ vessel)$$

The same analytical approach used in the sections that study the services and fleet has been employed to obtain all these indicators by different levels of aggregation: geographical area, country, shipping line, cargo type or traffic, etc.



2.4.4 Economic and financial indicators

- **Cash flow:** Difference between incoming flows and outflows in the period.
- **Net Present Value (NPV):** The present value of the cash flows generated by an investment project.
- **Internal Rate of Return (IRR):** Rate of interest where NPV=0.
- **Payback:** Period necessary to recover the investment associated with the project.
- **Total investment per line:** Sum of money required to adapt the fleet assigned to the line to run on LNG.

The NPV has been calculated by discounting the difference between costs and benefits cash flows back to the present and indicates how much the investor's wealth has increased after recovering their initial investment, that is similar to an extra amount on top of the minimum return such investments are expected to render. The minimum required return on the investment is implicit in the discount rate, which represents the cost of capital, or opportunity cost of relinquishing the return on alternatives involving the same level of risk.

NPV is calculated using the following formula:

$$NPV = -I_0 + \sum_{j=1}^{n} \frac{F_j}{(1+r)^j}$$

Where Fj is flow of net cash flows (inflows – outflows) for $t = j$; Io is the investment in $t = 0$; r is the discount rate and n is the time horizon or lifespan of the project (20 years in our study).

NPV is one of the most commonly used measures to decide whether or not to go ahead with a project. A project is profitable for an investor if NPV is greater than zero. Therefore, the decision making rule is as follows:

$NPV \rightarrow 0$	Profitable Project (go-ahead recommended)
$NPV \leftarrow 0$	NON Profitable Project (should be rejected)
$NPV = 0$	Going ahead with the project would yield the same return as the alternative that has been used to calculate the opportunity cost.

It is worth recalling that the discount rate is one of the parameters involved in calculating NPV. Therefore, if NPV is positive, the result reveals the extra return for investors in relation to what they expected to obtain from an alternative project. If NPV is zero, investors record the same return they expected to receive from undertaking an alternative project. And finally, if NPV is negative, the amount estimated would reveal the difference between the alternative project and the result of the project being evaluated; that is, the result is the amount that investors would no longer receive unless they opted for the alternative, which does not necessarily mean that the project would make a loss.

The second indicator used is the IRR, which is defined as the discount rate that produces a zero NPV. Mathematically speaking, the IRR is calculated on the basis of the following expression:

$$0 = -I_0 + \frac{F_1}{(1+IRR)^1} + \frac{F_2}{(1+IRR)^2} + \cdots + \frac{F_n}{(1+IRR)^n} = = -I_0 + \sum_{j=1}^{n} \frac{F_j}{(1+IRR)^j}$$

Where Fj is flow of net benefits in $t = j$; Io is investment in $t = 0$ and n is the time horizon or lifespan of the project.
The IRR is frequently used to evaluate projects. The decision making rule would be to give the go-ahead to a project if the IRR is higher than the opportunity cost of the investor (discount rate), but not to set the project in motion when the IRR is lower than the discount rate.
Generally speaking, the IRR and the NPV lead to the same decision:

- If NPV is positive, the IRR is higher than the discount rate and the investors are recommended to implement the initiative under study.
- If NPV is zero, the IRR is exactly the same as the discount rate and the investors would receive the same return as from an alternative project.
- If NPV is negative, the IRR is lower than the discount rate required by the investors. Therefore, the project is less profitable for the investor than the alternative, which leads to a recommendation not to undertake the initiative.

2.5 DEFINITION OF THE SCENARIOS

As mentioned above, the final objective of the model is to present a suitable and feasible situation for the 2020 and 2030 horizons, in terms of the fuel consumption pattern for Mediterranean SSS regular lines and the relevance of the use of LNG as a fuel for vessels in this framework. To achieve this, a scenario approach has been followed. The definition of the scenarios is analysed in section six.

3 ANALYSIS OF THE SUPPLY OF SHORT SEA SHIPPING SERVICES IN THE MEDITERRANEAN

ANALYSIS OF THE SUPPLY OF SHORT SEA SHIPPING SERVICES IN THE MEDITERRANEAN

The coming into force of international regulation on maritime transport emissions poses a challenge to the shipping sector, as this industry needs to take into account these new emission restrictions when creating their present and future strategic decisions concerning their fleet and services. These new constraints will be particularly relevant after the year 2020 for sea carriers deploying their vessels in short-sea services in the Mediterranean, as well as for ocean carriers whose ships spend most of their time in ECAs.

In these cases an in-depth analysis of the configuration and characteristics of services currently on offer and fleet deployed at present is vital as the fleet is relatively young with the year 2020 fast approaching. Most shipowners have to decide whether they should substitute some vessels and order newbuildings in the short term or to retrofit their vessels or to install scrubbers on them in the mid-term.

Although the rationale for carrying out this analysis is clear from the private point of view, this study is even more necessary from an institutional perspective. Public efforts guiding the shipping sector towards the most profitable solutions from a socio-economic viewpoint will need to go hand in hand with private initiatives. This course of action is only being possible after a comprehensive and consistent diagnosis of the current situation. Therefore, understanding the configuration of Short Sea Shipping (SSS) services in the Mediterranean has been the first step taken to achieve the general objective of this analysis: assessing the feasibility of the Med SSS fleet to run on LNG.

The results of an in-depth analysis of the Med SSS supply are provided in this section for the following types of traffic:

Global SSS fleet

SSS traffic by area

SSS traffic by country

SSS traffic by port

SSS traffic on Motorways of the Sea (MoS)

The analysis of the supply of SSS has been performed based on the data included in the MED Short-Sea Lines Database compiled by Fundación Valenciaport. For further information about the database, see the methodology section (Database: scope, specification of variables and information collection process). The indicators shown next include all the services active during 2013.

3.1 GLOBAL INDICATORS

According to the information included in the database for the reference period, the supply of SSS consists of 395 regular lines. These lines connect an average of 4 ports per voyage, and are provided by a total of 139 sea carriers. Out of the 395 lines, 72 are joint services. The 395 SSS lines connect 34 countries and 289 ports. On average, each line is operated by 1.3 sea carriers.

The following figure shows the importance of container traffic, with 162 regular lines, closely followed by 137 services deploying Ro–pax vessels. A total of 45 lines are used for Ro-ro freight, 30 for passengers, and 21 lines deploy car carriers. Passenger services are the most frequently operated services, with an average of 20.9 departures per week, followed by Ro-pax lines, with an average frequency of 7.8 weekly departures.

Seasonality affects 17% of the lines. Voyages are more common in the summer months than during the rest of the year, mainly due to the increase in frequency in passengers and Ro-pax lines.

PORTS

• No. of ports	62
• No. of Core ports	38
• No. of total ports of destinations	289

SHIPPING LINES

• No. of lines	395	• Weekly frequency	4.9
• Container	162	• Container	0.9
• Ro-pax	137	• Ro-pax	7.8
• Ro-ro	45	• Ro-ro	2
• Pax	30	• Pax	20.9
• Car carrier	21	• Car carrier	0.7
• No. of shared lines	72		
• No. of seasonal lines	67		
• No. of ports by line	4		

SEA CARRIERS

• No. of sea carriers	139
• No. of sea carriers by line	1.3

Figure 8: Global indicators of SSS services in the countries under study

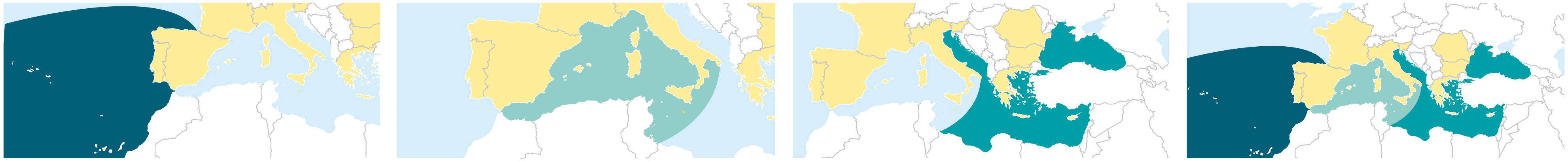
Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

3.2 INDICATORS BY AREA

The situation of the supply of SSS services in the areas included in the database: the Atlantic, Western Med, Eastern Med and Black Sea and the mixed area is described and compared in this sub-section.

The first feature worth highlighting is the concentration of lines in the Western Mediterranean: the supply of SSS services in the Western Mediterranean area (135 lines) is much higher than the supply in the other areas under study. However, the connectivity of ports in the Eastern Mediterranean and Black Sea is the best in terms of the number of ports of destination (126 in total).

As far as shipping specialisation is concerned, the Atlantic ports specialize in container cargo whilst the Mediterranean ports are clearly dominant in Ro-pax services. The high frequency of lines operating in the Western Mediterranean area is due to the Ro-pax lines linking ports such as Algeciras-Ceuta in Spain or Naples and Ischia in Italy. Finally, the high rate of seasonal services operating in the Eastern Mediterranean area is notable, a fact that is due to its relevance as a tourist area.



	ATLANTIC AREA	WESTERN MEDITERRANEAN SEA	EASTERN MEDITERRANEAN & BLACK SEA	ATLANTIC - WESTERN MED - EASTERN MED
• No. of ports	25	24	13	35
• No. of Core ports	8	17	13	32
• No. of total ports of destination	52	80	126	123
• No. of lines	45	135	120	95
• Container	25	33	34	70
• Ro-pax	13	69	53	2
• Ro-ro	5	20	10	10
• Pax	2	12	16	0
• Car carrier	0	1	7	13
• No. of shared lines	16	17	12	27
• No. of seasonal lines	3	13	51	0
• No. of ports by line	3.6	2.9	3.9	5.8
• Weekly frequency	3.5	8.2	4.9	0.9
• No. of sea carriers	33	53	58	43
• No. of sea carriers by line	1.6	1.2	1.1	1.5

ATLANTIC AREA ■ WESTERN MEDITERRANEAN ■ EASTERN MEDITERRANEAN & BLACK SEA ■ ATLANTIC - WESTERN MED - EASTERN MED ■

Figure 9: Characteristics of SSS services by area

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

3.3
INDICATORS BY COUNTRY

The supply of SSS services has also been analysed by country and the following figures in this sub-section are considered the most important in terms of supply capacity amongst the countries included in the study.

Graph 10 displays information about the number of SSS services which have been grouped according to the type of freight (car carrier, container, Pax, Ro-ro or Ro-pax). It must be taken into account that the sum of lines represented here does not coincide with the total mentioned previously (395), as the same service has been counted every time it calls into a different country. Italy is the country with the largest number of lines (158), closely followed by Spain (118 services), and Greece (108 services).

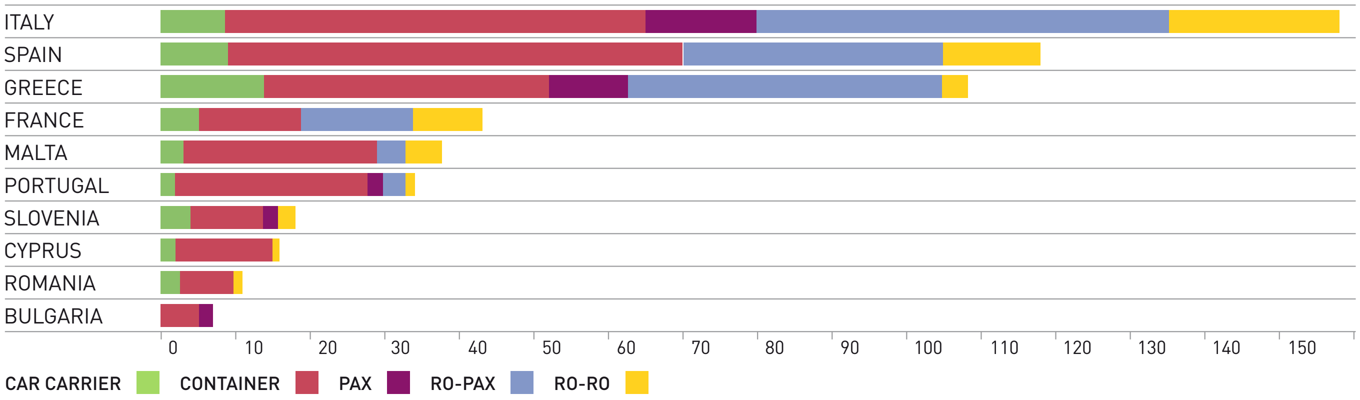
Italy, Spain and Greece also rank highly in terms of the total number of calls of SSS vessels at their ports.

Finally, a country profile providing detailed information about the supply of the SSS services has been created for all the countries included in the database, compiling the most relevant indicators mentioned above.

Italy is the country that provides the highest number of SSS services. Specifically, the 12 Italian core ports are served by 158 lines, operated by 67 sea carriers, followed closely by Spain (118 lines). However, despite having a lower number of services lines, Greece is the country that connects the largest number of ports, 162 ports of destination in total.

According to type of freight, Italy leads the table in Ro-pax (55 lines), Ro-ro (23 lines) and passenger services (15), Spain ranks higher in container services (61 lines), and Greece in car carrier connections (14). Furthermore, the connections available at Italian ports are more frequent due to the high number of Ro-pax and passenger services offered.

Additionally, the country profiles contain information about the map of connections of each country grouped by type of freight, that is, the ranking of countries of destination for each particular traffic.



Graph 10: Ranking of countries according to the number of SSS services by type of freight

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

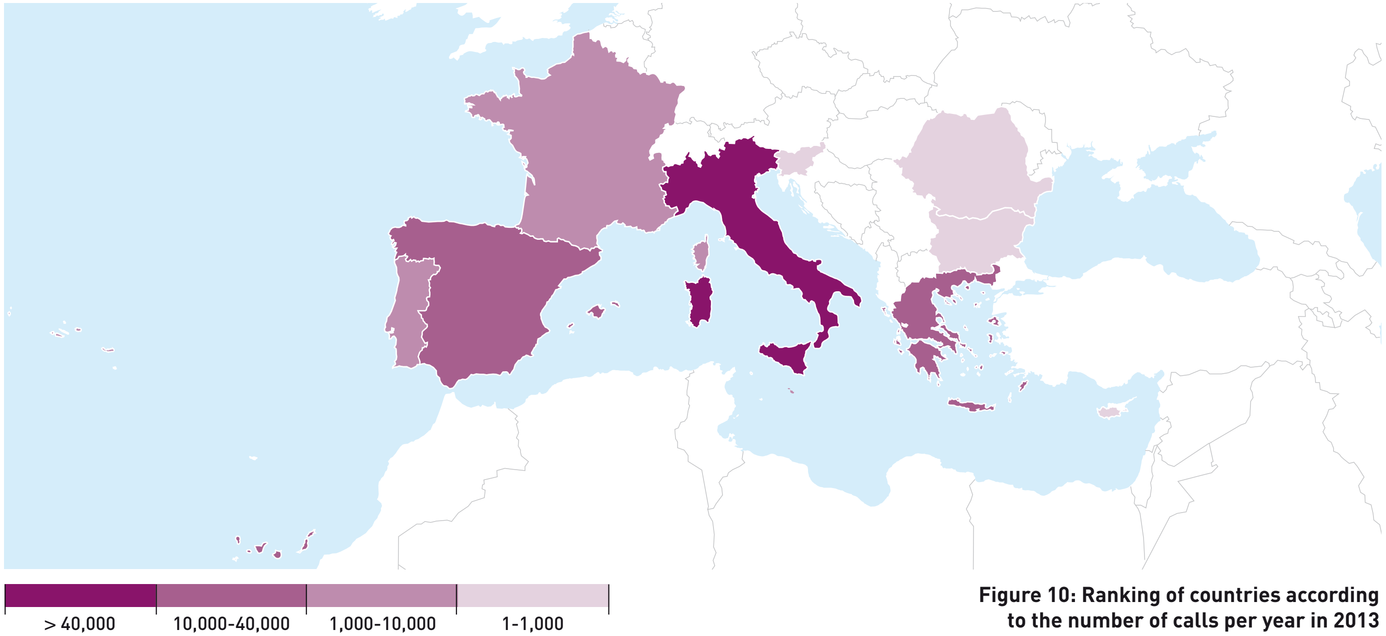


Figure 10: Ranking of countries according to the number of calls per year in 2013

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

ITALY | SPAIN | GREECE | PORTUGAL | FRANCE | MALTA | SLOVENIA | CYPRUS | ROMANIA | BULGARIA

- No. of ports 12
- No. of Core ports 12
- No. of total ports of destination 147

- No. of lines 158
  - Container 56
  - Ro-pax 55
  - Ro-ro 23
  - Pax 15
  - Car carrier 9
- No. of shared lines 26
- No. of seasonal lines 29
- No. of ports by line 4
- Weekly frequency 5.2

- No. of sea carriers 67
- No. of sea carriers by line 1.2

Ranking by country of destination according to the number of SSS services

Car carrier:

Country of destination	No. of lines
GREECE	7
TURKEY	6
SPAIN	4
UK	3
EGYPT	3

Container:

Country of destination	No. of lines
TURKEY	19
SPAIN	15
EGYPT	14
GREECE	12
SLOVENIA	10

Pax:

Country of destination	No. of lines
SLOVENIA	2
CROATIA	2
-	-
-	-
-	-

Ro-pax:

Country of destination	No. of lines
GREECE	7
CROATIA	6
FRANCE	5
ALBANIA	4
TUNISIA	3

Ro-ro:

Country of destination	No. of lines
TURKEY	6
SPAIN	4
LIBYA	4
TUNISIA	3
SLOVENIA	2

CAR CARRIER | CONTAINER | PAX | RO-PAX | RO-RO

Figure 11: Characteristics of SSS services in Italy

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

ITALY | **SPAIN** | GREECE | PORTUGAL | FRANCE | MALTA | SLOVENIA | CYPRUS | ROMANIA | BULGARIA

- No. of ports 22
- No. of Core ports 11
- No. of total ports of destination 120

- No. of lines 118
  - Container 61
  - Ro-pax 35
  - Ro-ro 13
  - Pax 0
  - Car carrier 9
- No. of shared lines 28
- No. of seasonal lines 0
- No. of ports by line 4.4
- Weekly frequency 4.9

- No. of sea carriers 60
- No. of sea carriers by line 1.5

Ranking by country of destination according to the number of SSS services

Country of destination	No. of lines
GREECE	6
TURKEY	5
FRANCE	4
MOROCCO	4
BELGIUM	3

Country of destination	No. of lines
ITALY	15
ALGERIA	14
MOROCCO	14
FRANCE	14
PORTUGAL	11

Country of destination	No. of lines
-	-
-	-
-	-
-	-
-	-

Country of destination	No. of lines
MOROCCO	6
ITALY	3
FRANCE	1
UK	1
TUNISIA	1

Country of destination	No. of lines
ITALY	4
BELGIUM	3
ALGERIA	2
FINLAND	1
PORTUGAL	1

CAR CARRIER | CONTAINER | PAX | RO-PAX | RO-RO

Figure 12: Characteristics of SSS services in Spain

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

ITALY | SPAIN | **GREECE** | PORTUGAL | FRANCE | MALTA | SLOVENIA | CYPRUS | ROMANIA | BULGARIA

- No. of ports 4
- No. of Core ports 4
- No. of total ports of destination 162

- No. of lines 108
  - Container 38
  - Ro-pax 42
  - Ro-ro 3
  - Pax 11
  - Car carrier 14
- No. of shared lines 52
- No. of seasonal lines 36
- No. of ports by line 5.1
- Weekly frequency 5.1

- No. of sea carriers 42
- No. of sea carriers by line 1.2

Ranking by country of destination according to the number of SSS services

Country of destination	No. of lines
TURKEY	10
ITALY	6
SPAIN	6
FRANCE	4
EGYPT	4

Country of destination	No. of lines
TURKEY	28
ITALY	12
EGYPT	11
SPAIN	6
CYPRUS	6

Country of destination	No. of lines
-	-
-	-
-	-
-	-
-	-

Country of destination	No. of lines
ITALY	7
-	-
-	-
-	-
-	-

Country of destination	No. of lines
ITALY	2
MONTENEGRO	1
CYPRUS	1
ISRAEL	1
-	-

CAR CARRIER | CONTAINER | PAX | RO-PAX | RO-RO

Figure 13: Characteristics of SSS services in Greece

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

- No. of ports 16
- No. of Core ports 3
- No. of total ports of destination 83

- No. of lines 34
  - Container 26
  - Ro-pax 3
  - Ro-ro 1
  - Pax 2
  - Car carrier 2
- No. of shared lines 15
- No. of seasonal lines 3
- No. of ports by line 5.7
- Weekly frequency 1.6

- No. of sea carriers 29
- No. of sea carriers by line 1.8

Ranking by country of destination according to the number of SSS services

Country of destination	No. of lines
BELGIUM	2
TURKEY	2
EGYPT	2
UK	2
GREECE	2

Country of destination	No. of lines
SPAIN	11
NETHERLANDS	6
UK	6
MOROCCO	5
TURKEY	3

Country of destination	No. of lines
-	-
-	-
-	-
-	-
-	-

Country of destination	No. of lines
-	-
-	-
-	-
-	-
-	-

Country of destination	No. of lines
ALGERIA	1
BELGIUM	1
GERMANY	1
SPAIN	1
UK	1

CAR CARRIER | CONTAINER | PAX | RO-PAX | RO-RO

Figure 14: Characteristics of SSS services in Portugal

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

- No. of ports 2
- No. of Core ports 2
- No. of total ports of destination 61

- No. of lines 43
  - Container 14
  - Ro-pax 15
  - Ro-ro 9
  - Pax 0
  - Car carrier 5
- No. of shared lines 8
- No. of seasonal lines 3
- No. of ports by line 4.2
- Weekly frequency 1.5

- No. of sea carriers 25
- No. of sea carriers by line 1.2

Ranking by country of destination according to the number of SSS services

Country of destination	No. of lines
SPAIN	4
GREECE	4
TURKEY	3
MOROCCO	3
ITALY	2

Country of destination	No. of lines
SPAIN	11
ITALY	7
ALGERIA	5
TURKEY	4
ISRAEL	4

Country of destination	No. of lines
-	-
-	-
-	-
-	-
-	-

Country of destination	No. of lines
ITALY	5
ALGERIA	3
TUNISIA	2
-	-
-	-

Country of destination	No. of lines
ALGERIA	5
TUNISIA	3
MOROCCO	1
ITALY	1
-	-

CAR CARRIER | CONTAINER | PAX | RO-PAX | RO-RO

Figure 15: Characteristics of SSS services in France

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

- No. of ports 2
- No. of Core ports 2
- No. of total ports of destination 84

- No. of lines 38
  - Container 26
  - Ro-pax 4
  - Ro-ro 5
  - Pax 0
  - Car carrier 3
- No. of shared lines 9
- No. of seasonal lines 2
- No. of ports by line 4.5
- Weekly frequency 1.2

- No. of sea carriers 18
- No. of sea carriers by line 1.3

Ranking by country of destination according to the number of SSS services

Country of destination	No. of lines
GREECE	3
ITALY	2
SLOVENIA	1
MOROCCO	1
DENMARK	1

Country of destination	No. of lines
ITALY	8
LIBYA	7
ALGERIA	6
TURKEY	5
SPAIN	4

Country of destination	No. of lines
-	-
-	-
-	-
-	-
-	-

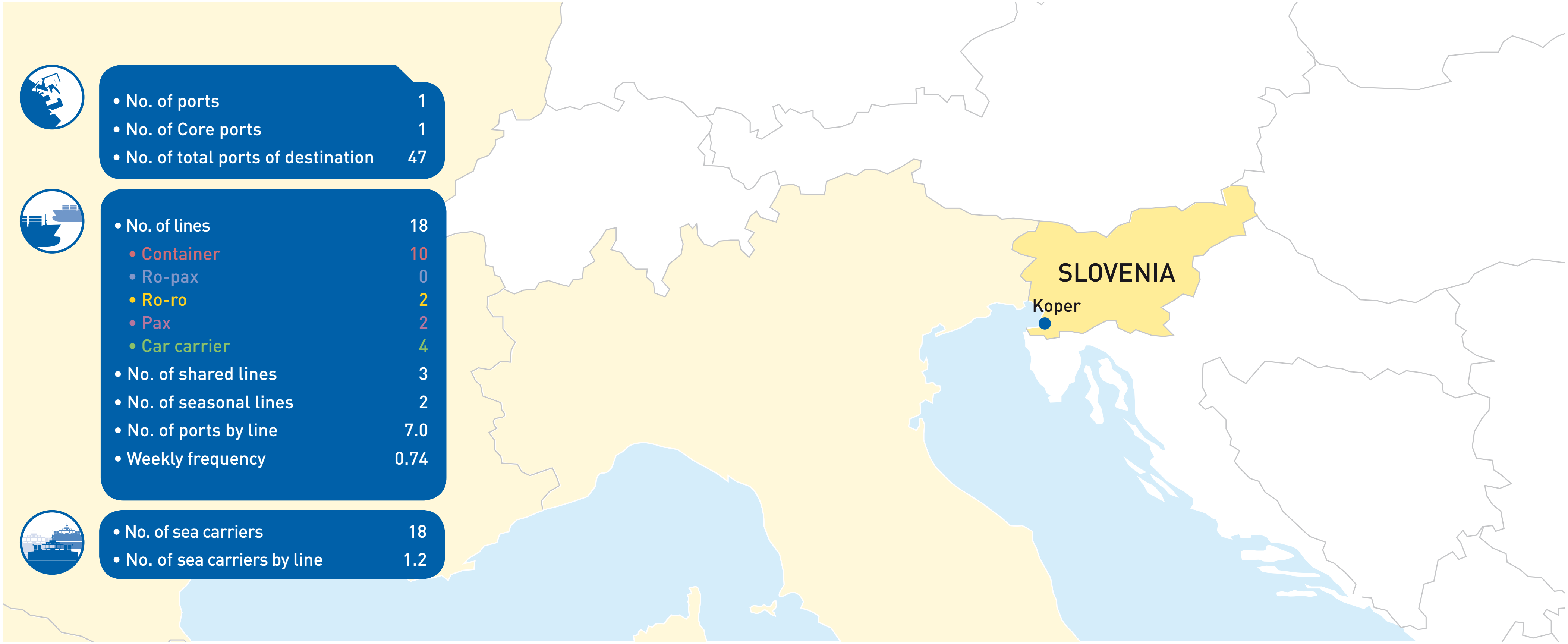
Country of destination	No. of lines
ITALY	2
LIBYA	1
-	-
-	-
-	-

Country of destination	No. of lines
LIBYA	3
ITALY	2
-	-
-	-
-	-

CAR CARRIER | CONTAINER | PAX | RO-PAX | RO-RO

Figure 16: Characteristics of SSS services in Malta

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database



- No. of ports 1
- No. of Core ports 1
- No. of total ports of destination 47

- No. of lines 18
  - Container 10
  - Ro-pax 0
  - Ro-ro 2
  - Pax 2
  - Car carrier 4
- No. of shared lines 3
- No. of seasonal lines 2
- No. of ports by line 7.0
- Weekly frequency 0.74

- No. of sea carriers 18
- No. of sea carriers by line 1.2

Ranking by country of destination according to the number of SSS services

Country of destination	No. of lines
GREECE	3
TURKEY	2
EGYPT	2
ROMANIA	1
MOROCCO	1

Country of destination	No. of lines
ITALY	10
EGYPT	5
TURKEY	4
CROATIA	4
GREECE	3

Country of destination	No. of lines
ITALY	2
CROATIA	1
-	-
-	-
-	-

Country of destination	No. of lines
-	-
-	-
-	-
-	-
-	-

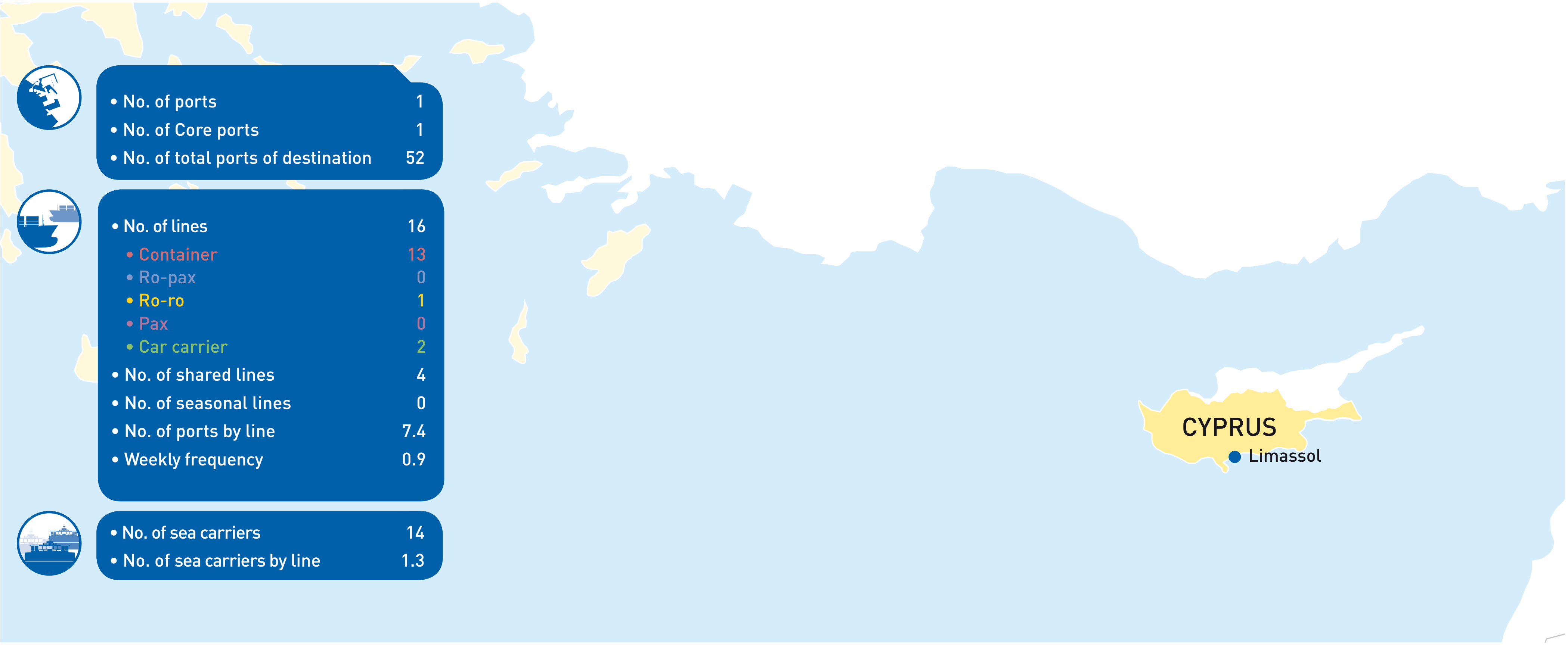
Country of destination	No. of lines
ITALY	2
TURKEY	1
EGYPT	1
ALBANIA	1
LIBYA	1

CAR CARRIER | CONTAINER | PAX | RO-PAX | RO-RO

Figure 17: Characteristics of SSS services in Slovenia

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

ANALYSIS OF THE SUPPLY OF SHORT SEA SHIPPING SERVICES IN THE MEDITERRANEAN



- No. of ports 1
- No. of Core ports 1
- No. of total ports of destination 52

- No. of lines 16
  - Container 13
  - Ro-pax 0
  - Ro-ro 1
  - Pax 0
  - Car carrier 2
- No. of shared lines 4
- No. of seasonal lines 0
- No. of ports by line 7.4
- Weekly frequency 0.9

- No. of sea carriers 14
- No. of sea carriers by line 1.3

Ranking by country of destination according to the number of SSS services

Country of destination	No. of lines
TURKEY	3
EGYPT	2
GREECE	2
BELGIUM	1
MALTA	1

Country of destination	No. of lines
EGYPT	8
TURKEY	7
ISRAEL	7
GREECE	6
ITALY	6

Country of destination	No. of lines
-	-
-	-
-	-
-	-
-	-

Country of destination	No. of lines
-	-
-	-
-	-
-	-
-	-

Country of destination	No. of lines
ISRAEL	1
GREECE	1
-	-
-	-
-	-

CAR CARRIER CONTAINER PAX RO-PAX RO-RO

Figure 18: Characteristics of SSS services in Cyprus

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

- No. of ports 1
- No. of Core ports 1
- No. of total ports of destination 32

- No. of lines 11
  - Container 7
  - Ro-pax 0
  - Ro-ro 1
  - Pax 0
  - Car carrier 3
- No. of shared lines 1
- No. of seasonal lines 0
- No. of ports by line 5.2
- Weekly frequency 0.79

- No. of sea carriers 8
- No. of sea carriers by line 1.1

Ranking by country of destination according to the number of SSS services

Car carrier:

Country of destination	No. of lines
TURKEY	2
FRANCE	1
RUSSIA	1
EGYPT	1
GREECE	1

Container:

Country of destination	No. of lines
TURKEY	6
RUSSIA	4
BULGARIA	3
GREECE	3
GEORGIA	2

Pax:

Country of destination	No. of lines
-	-
-	-
-	-
-	-
-	-

Ro-pax:

Country of destination	No. of lines
-	-
-	-
-	-
-	-
-	-

Ro-ro:

Country of destination	No. of lines
GEORGIA	1
-	-
-	-
-	-
-	-

CAR CARRIER | CONTAINER | PAX | RO-PAX | RO-RO

Figure 19: Characteristics of SSS services in Romania

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

ANALYSIS OF THE SUPPLY OF SHORT SEA SHIPPING SERVICES IN THE MEDITERRANEAN

- No. of ports 1
- No. of Core ports 1
- No. of total ports of destination 20

- No. of lines 7
  - Container 5
  - Ro-pax 0
  - Ro-ro 0
  - Pax 2
  - Car carrier 0
- No. of shared lines 1
- No. of seasonal lines 2
- No. of ports by line 5.7
- Weekly frequency 0.89

- No. of sea carriers 6
- No. of sea carriers by line 1.1

Ranking by country of destination according to the number of SSS services

Car carrier

Country of destination	No. of lines
-	-
-	-
-	-
-	-
-	-

Container

Country of destination	No. of lines
TURKEY	5
RUSSIA	3
ROMANIA	3
GREECE	2
UKRAINE	2

Pax

Country of destination	No. of lines
-	-
-	-
-	-
-	-
-	-

Ro-pax

Country of destination	No. of lines
-	-
-	-
-	-
-	-
-	-

Ro-ro

Country of destination	No. of lines
-	-
-	-
-	-
-	-
-	-

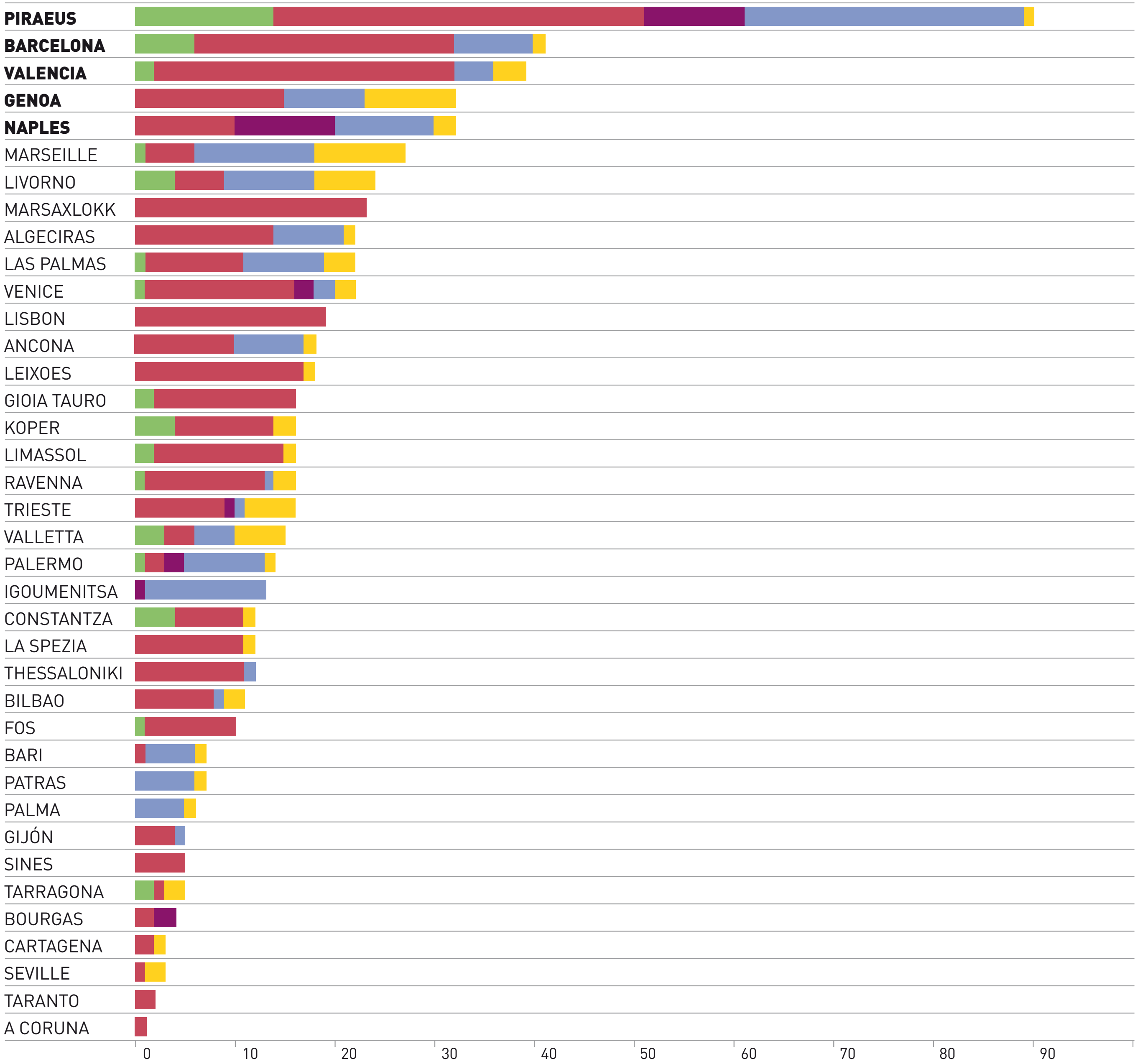
CAR CARRIER | CONTAINER | PAX | RO-PAX | RO-RO

Figure 20: Characteristics of SSS services in Bulgaria

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

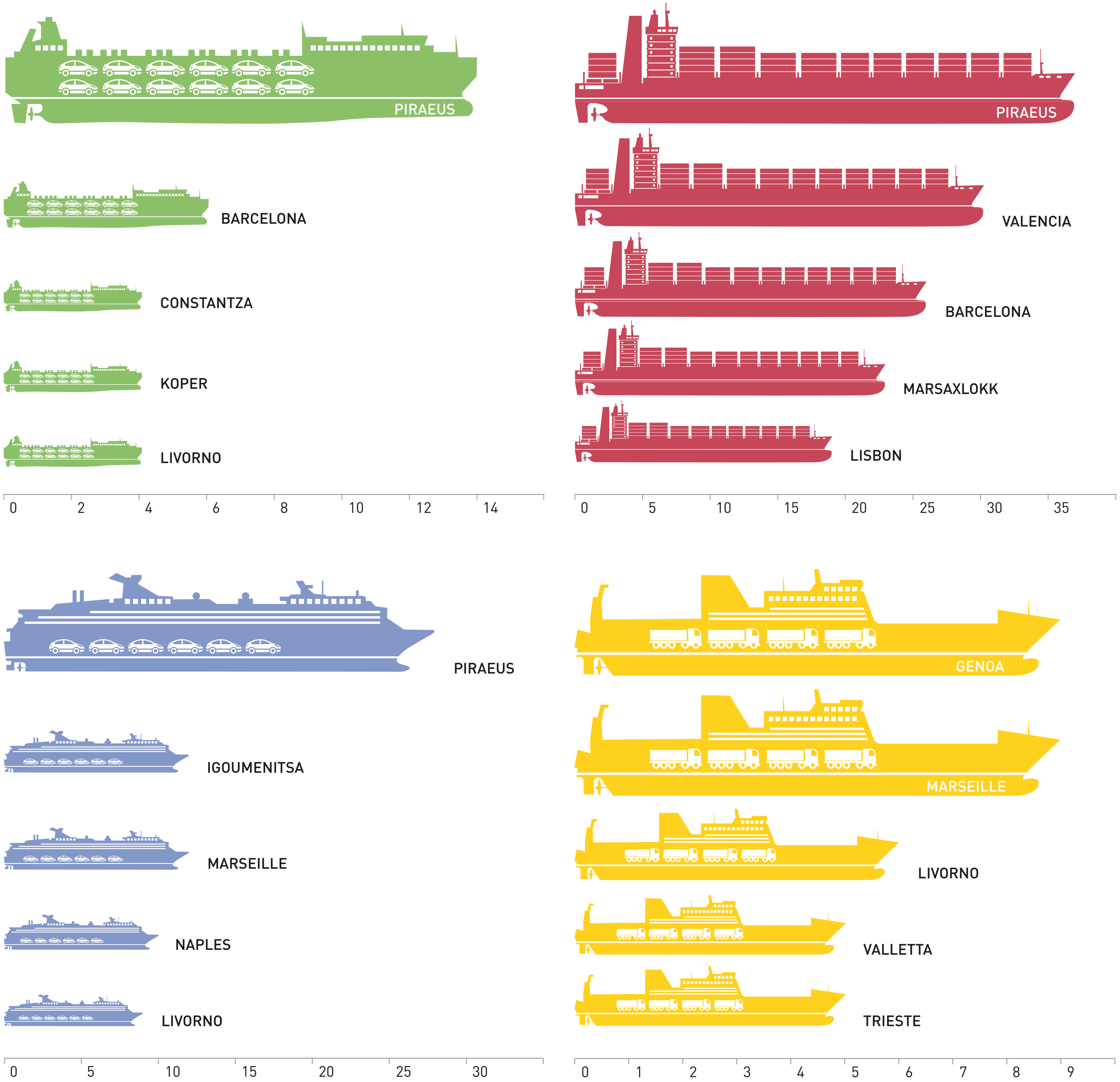
3.4 INDICATORS BY CORE PORT

The number of lines available from core ports have been classified by type of freight with the results being shown in the Graph 11. As mentioned before, it must be taken into account that the sum of lines represented here does not coincide with the total (395), as the same service has been counted every time it calls at a different core port. The port of Piraeus (Greece) has the greatest number of lines (90), followed by Barcelona (Spain) with 41 services. Container services represent a large share of the total number of services for most ports.



Graph 11: Ranking of core ports according to the number of SSS lines by type of freight

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

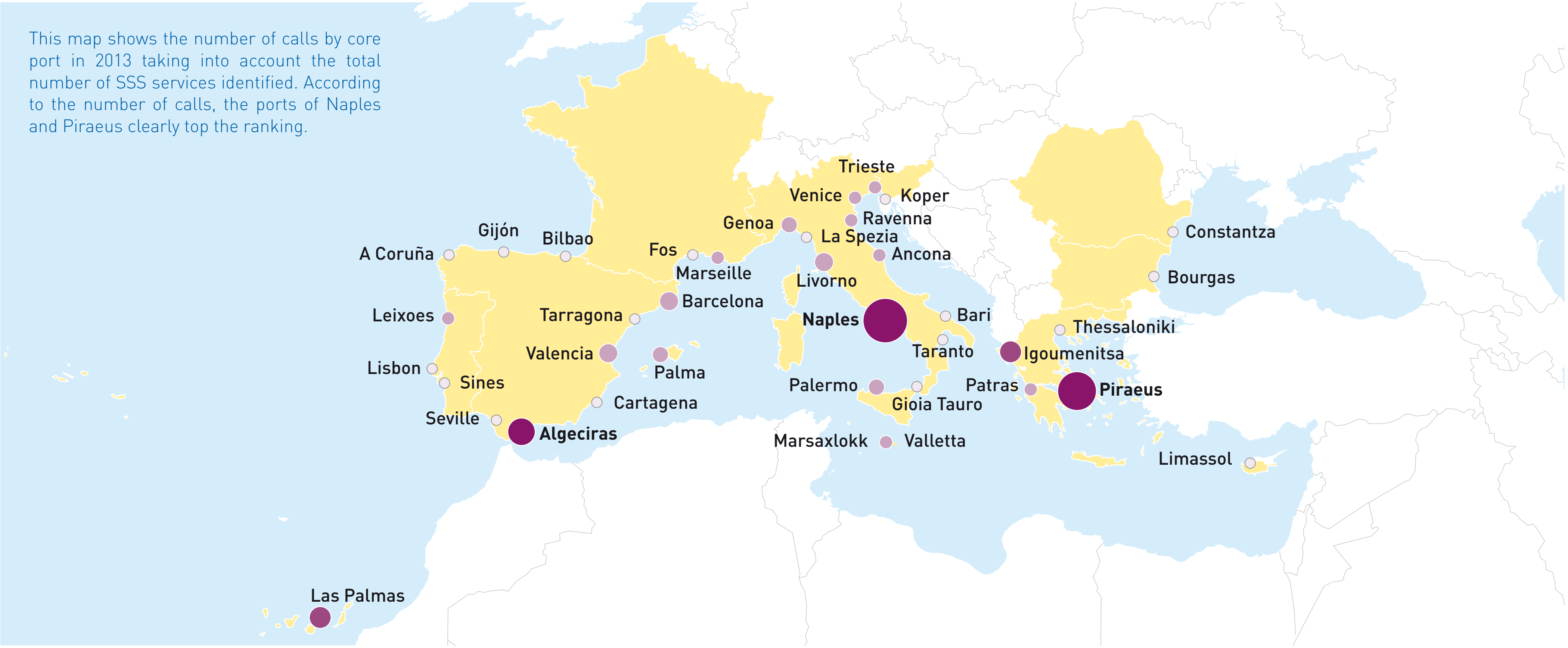


CAR CARRIER CONTAINER PAX RO-PAX RO-RO

Graph 12: Top five core ports in terms of SSS services by type of freight

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

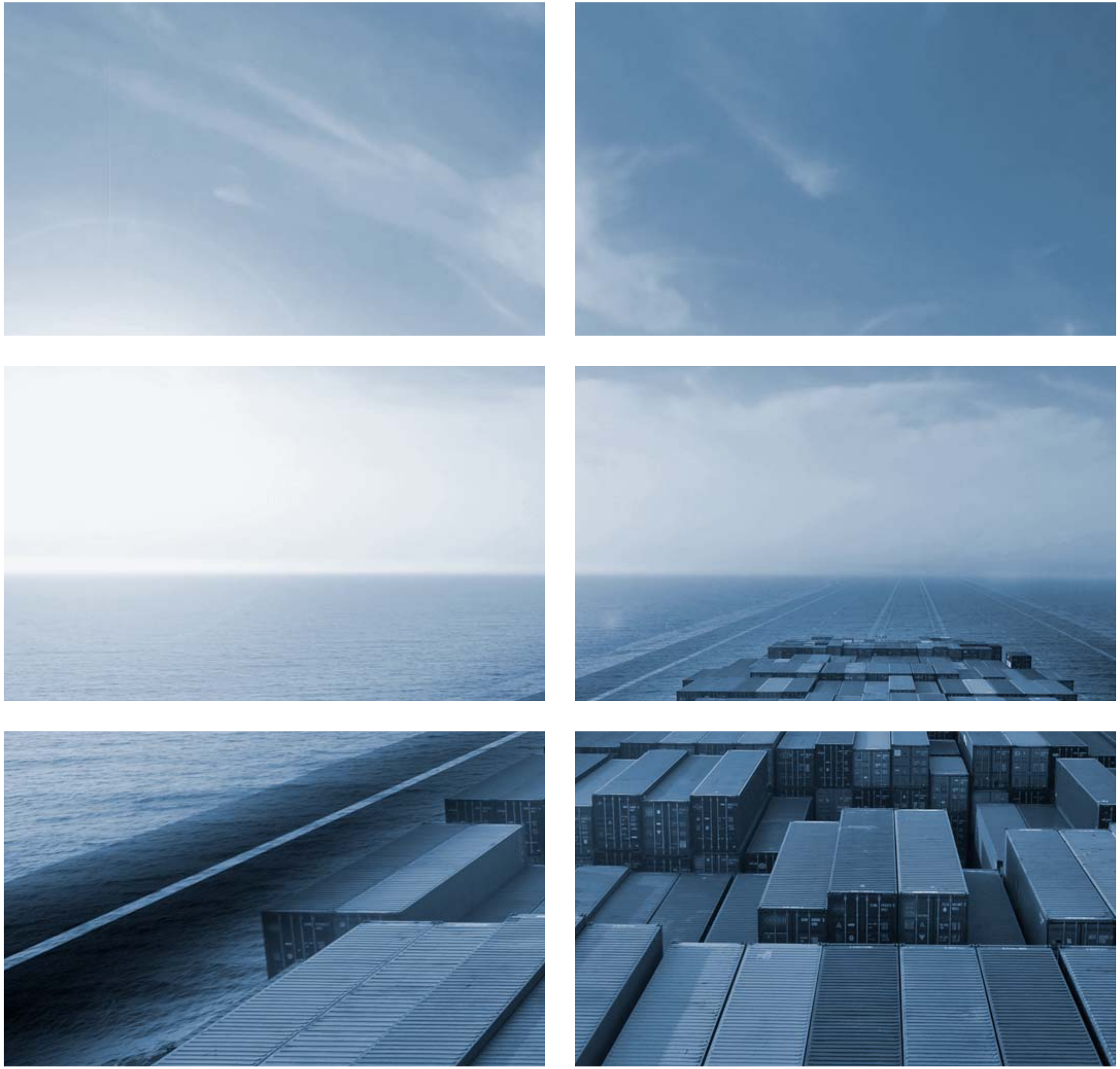
The top five core ports according to number of SSS services and broken down by type of traffic are ranked in Graph 12. According to the information gathered, the Port of Piraeus offered the largest number of SSS services for container, car carrier, and Ro-pax services, whilst the Italian ports of Naples and Genoa stand out from the rest in terms of passenger and Ro-ro services respectively.



15,000-30,000	5,000-15,000	1,000-5,000	1-1,000
Naples Piraeus Algeciras	Igoumenitsa Las Palmas	Barcelona Valencia Livorno Palma Genoa Palermo Marseille Patras Ancona Trieste Venice Valletta Marsaxlokk Leixoes Ravenna	Bari Limassol Lisbon Bilbao Gioia Tauro Koper Thessaloniki Constantza La Spezia Fos Gijón Sines Tarragona Bourgas Seville Cartagena Taranto A Coruña

Figure 21: Ranking of core ports according to the number of calls in 2013

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database



3.5 MOTORWAYS OF THE SEA

This sub-section focuses exclusively on the maritime connections that are compatible with the Motorway of the Sea (MoS) definition embraced in this report, which is, an intermodal logistics chain based on shipping with a level of service that is competitive with road haulage in terms of frequency and transit time.

The only MoS service offered in 2013 in the Western European corridor is a Ro-pax service linking the ports of Gijón (Spain) and Saint Nazaire (France), operated by a single ship (Figure 22). Three round trips are currently operated three times per week. The aim of this maritime motorway is to relieve congestion on the trans-Pyrenean road links and to reduce the environmental impact of freight transport by "transferring" lorries from roads to the sea. It is worth mentioning that this maritime connection that is established in the Atlantic is the only Spanish service that utilises the MoS status, granted by the European Commission, with its corresponding benefits and State funding.

Regarding the South-Western MoS, MoS services offered in 2013 connected two Spanish ports (Barcelona and Valencia), six Italian ports (Genoa, Livorno, Civitavecchia, Salerno, Cagliari and Porto Torres), one Maltese port (Valletta) and one French port (Marseille). The connections offered by the Port of Barcelona are the most frequent. Barcelona offers a maximum of six departures per week (the service connecting Barcelona to Civitavecchia), but in other cases, the frequency drops to three departures per week.

The Motorways of the Sea services in the South-Eastern Europe corridor connected 13 ports in six countries (Italy, Slovenia, Greece, Bulgaria, Romania and Cyprus). The most relevant countries in terms of the number of ports are Italy (five ports) followed by Greece (four ports).

Route	Sea carrier	Traffic	Frequency	No. Vessels
GIJÓN - SAINT NAZAIRE	LD LINES SUARDIAZ	RO-PAX	3 x week	1

RO-PAX

Figure 22: Western European Motorways of the Sea corridor

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

Route	Sea carrier	Traffic	Frequency	No. Vessels
BARCELONA - CIVITAVECCHIA	GRIMALDI	RO-PAX	6 x week	2
GENOA - CATANIA - VALLETTA - NAPLES	GRIMALDI & IGNACIO MESSINA LINES	RO-RO	4 x week	2
LIVORNO - CATANIA - VALLETTA	GRIMALDI & IGNACIO MESSINA LINES	RO-RO	3 x week	1
MARSEILLE - AJACCIO - PORTO TORRES	SNCN	RO-PAX	3 x week	1
MARSEILLE - PORTO TORRES - PROPIANO	LA MERIDIONALE	RO-PAX	3 x week	1
SALERNO - CATANIA - VALLETTA - CIVITAVECCHIA	GRIMALDI	RO-PAX	4 x week	1
VALENCIA - BARCELONA - LIVORNO - SAVONA	GRIMALDI	RO-RO	4 x week	3
VALENCIA - CAGLIARI - SALERNO	GRIMALDI	RO-RO	3 x week	1

RO-PAX RO-RO

Figure 23: South-Western European Motorways of the Sea corridor

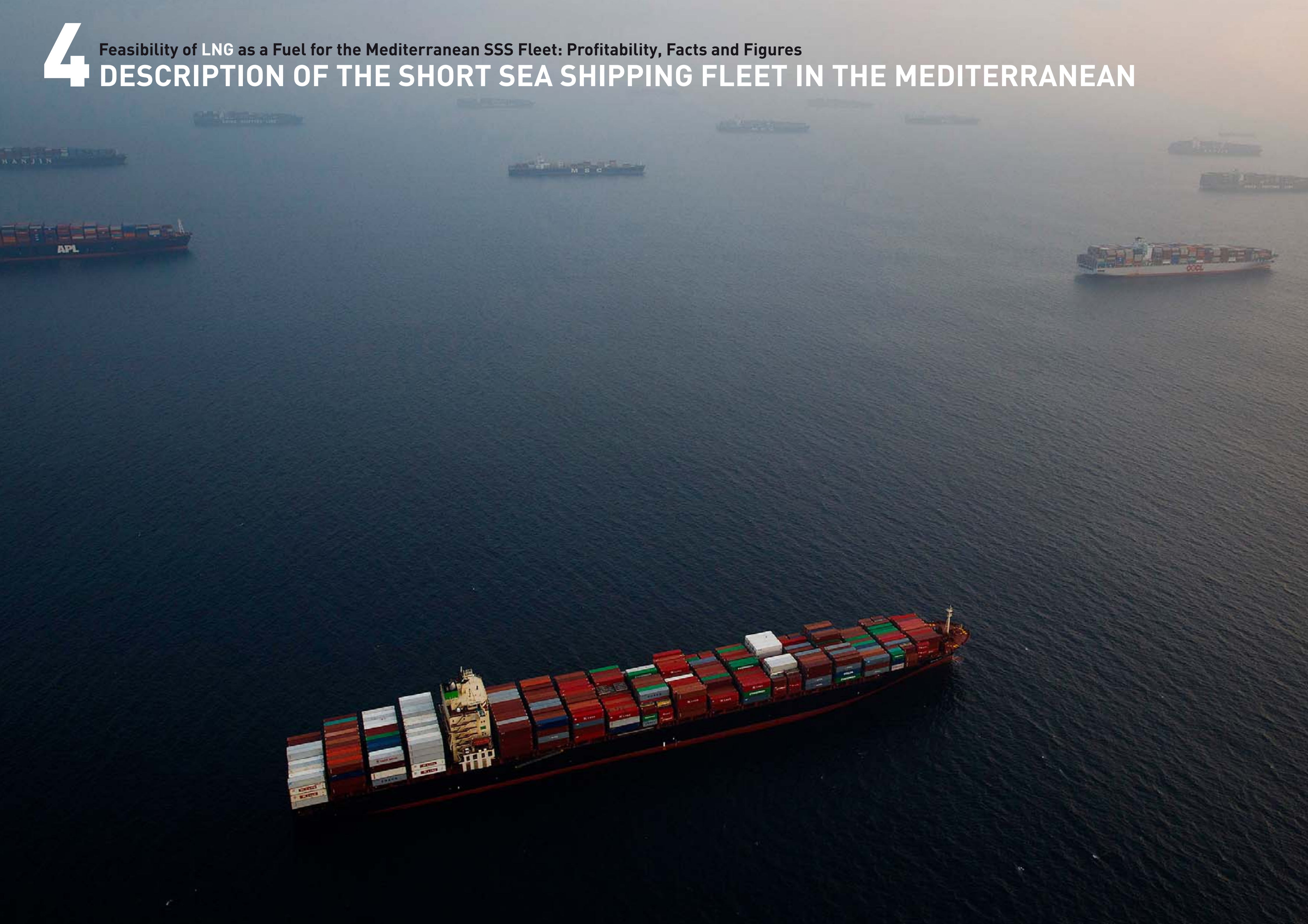
Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

Route	Sea carrier	Traffic	Frequency	No. Vessels
ANCONA - IGOUMENITSA - PATRAS - IGOUMENITSA	MINOAN LINES	RO-PAX	6 x week	3
BRINDISI - CORFU - IGOUMENITSA - PATRAS	GRIMALDI	RO-PAX	8 x week	2
PATRAS - IGOUMENITSA - BARI - IGOUMENITSA	SUPER FAST FERRIES & BLUE STAR FERRIES & ANEK FERRIES	RO-PAX	7 x week	2
TRIESTE - CESME	ULUSOY SEALINES	RO-RO	3 x week	4
TRIESTE - HAYDARPASA	COLBERT FERRIES	RO-RO	3 x week	3
TRIESTE - ISTANBUL	UN RORO	RO-RO	7 x week	7
VENICE - CORINTHOS	HELLENIC SEAWAYS	RO-RO	3 x week	2

RO-PAX RO-RO

Figure 24: South-Eastern European Motorways of the Sea corridor
Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

4 DESCRIPTION OF THE SHORT SEA SHIPPING FLEET IN THE MEDITERRANEAN



DESCRIPTION OF THE SHORT SEA SHIPPING FLEET IN THE MEDITERRANEAN

Once the regular SSS services operating in the Mediterranean during the period under study have been described, a detailed study of the vessels used on the aforementioned lines has been carried out. As mentioned in the supply section, the fleet is shaped according to market demand, which sea carriers try to cater for by assigning the best vessels to each service based on their capacity, speed and engine power. The introduction of new environmental laws limiting gas emissions presents new challenges when planning shipping services, although it should be said that the acute market uncertainty still surrounding the technical and economic aspects of the existing solutions makes it difficult to define business strategies. This is precisely why the assessment of fleet characteristics constitutes an extremely useful exercise as elements of certainty that can help sea carriers make investment decisions.

An example of this is the analysis of the average age of fleets in the different geographical areas under study. This exercise enabled us to pinpoint the geographical area in which investments to renew the fleet would be most pressing, taking into account that the age of the vessels determines whether they can be adapted to comply with new regulations, or whether they need to be replaced. This is an essential first step towards simulating the fleet for the 2020 and 2030 horizons, anticipating future shipping needs, and planning suitable solutions.

Given the complementary nature of the sections analysing regular services and the fleet, the latter has been presented in a similar way, thus enabling easy comprehension of both sets of data. Accordingly, the chapter has been divided into the following geographical and conceptual sections:

- **Global SSS fleet**
- **SSS fleet by area**
- **SSS fleet by country**
- **SSS fleet by port**
- **SSS fleet on Motorways of the Sea (MoS)**

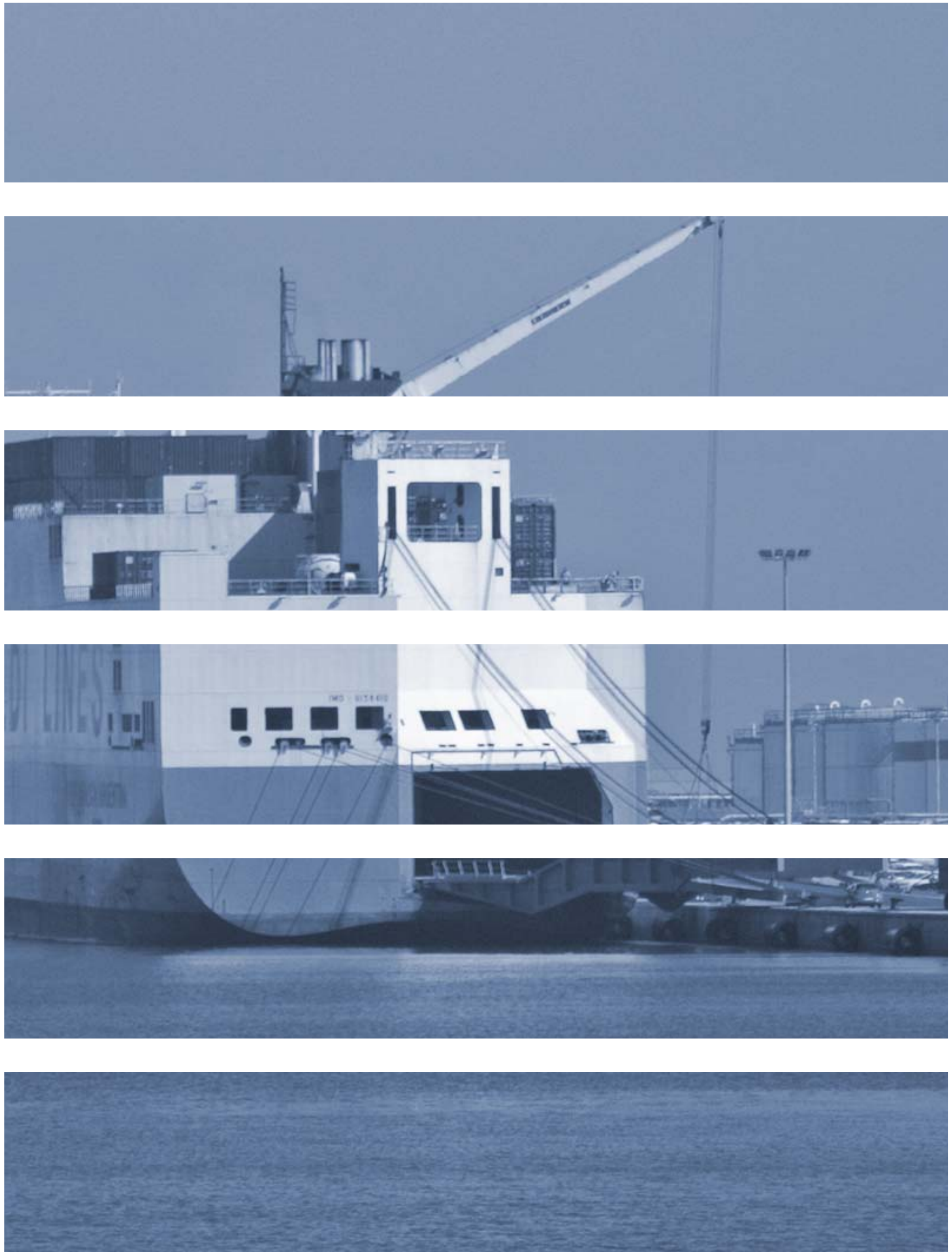
In the first four sections, the fleet has been studied according to the following parameters:

No. **Number of vessels deployed in SSS services and average characteristics**

Cap **Annual capacity offered**

Age **Average age**

However, it should be mentioned that, for presentation reasons, and given the volume of data used for each geographical area, the level of detail will vary in the different sections. In addition, the global analysis of the fleet features a special section on high-speed vessels and general vessel energy consumption. Finally, a special section on Classification Societies and their role in the Mediterranean fleet rounds off the chapter.



4.1 GLOBAL INDICATORS

A total of 658 vessels compose the fleet deployed in short sea shipping services calling at core ports in the Mediterranean, the majority of these vessels being container ships (299) and ro-pax (182 vessels).

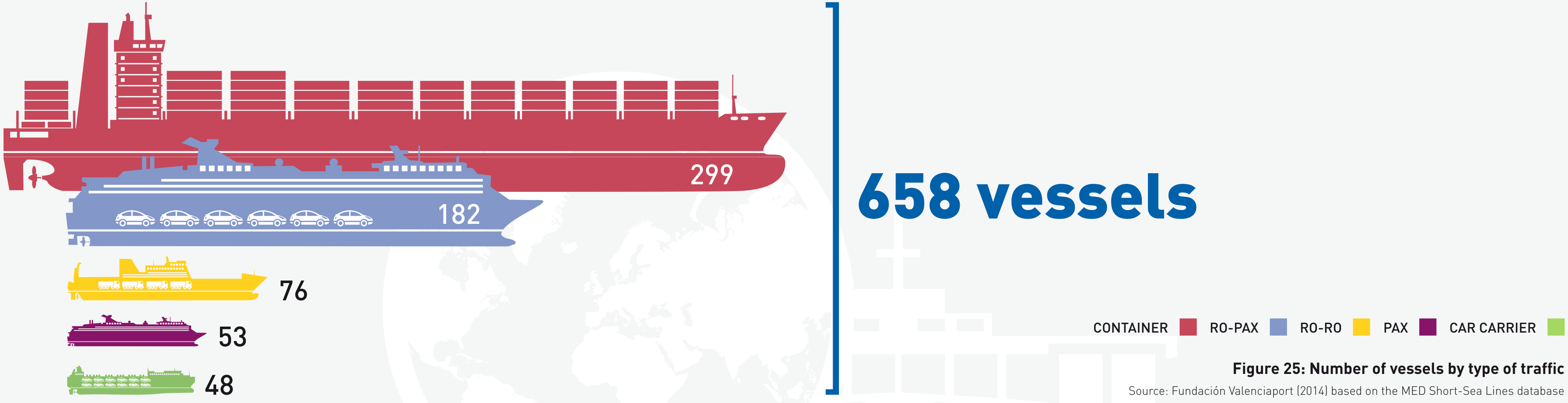


Figure 25: Number of vessels by type of traffic

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

	CONTAINER	RO-PAX	RO-RO	PAX	CAR CARRIER
GT	16,515	18,449	20,705	337	30,901
DWT	20,186	4,228	10,020	52	10,600
Service speed (knots)	17.00	19.40	17.00	22.80	17.00
Engine power (kw)	14,180	22,897	13,385	3,000	11,024
Consumption (Tonnes/day)	58.6	100	58.8	15.3	46.5

Table 10: Average characteristics of vessels operating SSS services

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

With regards to the average characteristics of the vessels deployed, the container, Ro-ro and car carrier vessels have higher deadweight tonnage (DWT) values than other types of vessels. Average high speed services are mostly operated with passenger and Ro-pax vessels. Ro-pax vessels have big engines in terms of engine power (kW). In all cases, fuel consumption is directly proportional to the type of engines fitted. Thus, Ro-pax vessels have higher consumption measured in tonnes/day, and have to comply with a fixed schedule, which involves sailing with a higher engine load. Finally, passenger vessels are the oldest type of vessel (22 years old on average) while container ships are relatively new (twelve years of age on average).

DESCRIPTION OF THE SHORT SEA SHIPPING FLEET IN THE MEDITERRANEAN

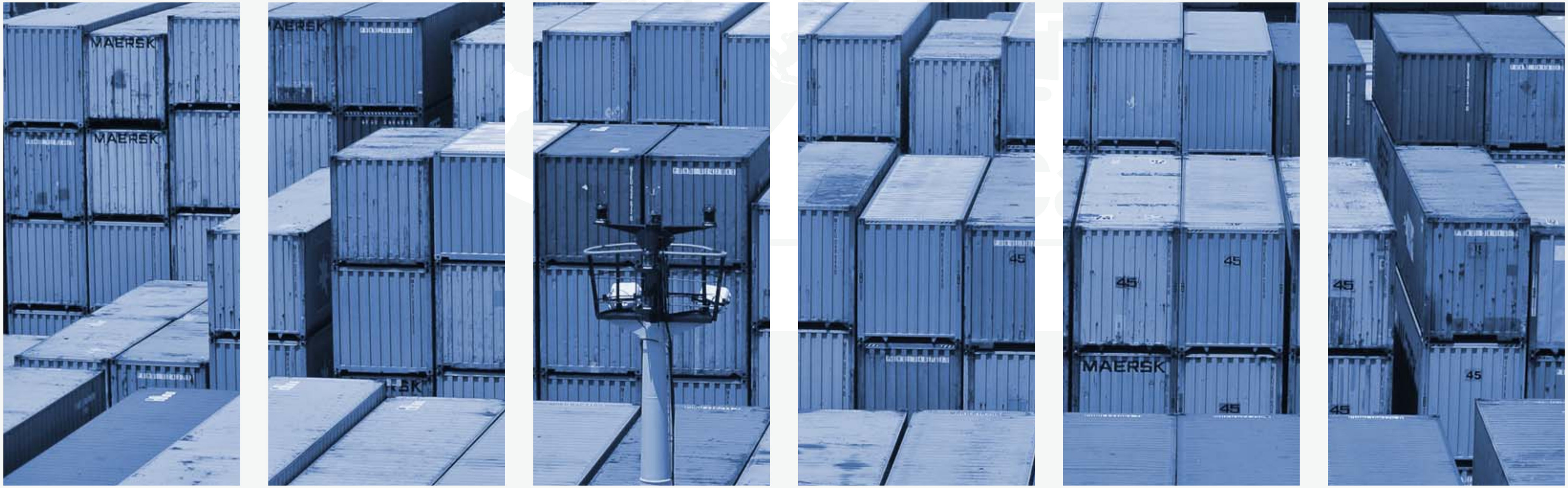
In terms of carrying capacity, 85% of the total annual DWT offered by short-sea shipping services in the Mediterranean is provided by Ro-pax and container ships. In the case of container ships, this equals an annual capacity to transport almost 10 million TEUs in short-sea services. If all the lane metres offered by Ro-pax and Ro-ro vessels were dedicated to transport unaccompanied conventional trucks, the total annual carrying capacity in these types of short-sea services would be over 4.5 million trailers. Regular passenger line vessels can carry an average of 60 million passengers per year and car-carrier vessels operating on regular lines can carry more than 1.5 million cars a year.

	CONTAINER	RO-PAX	RO-RO	PAX	CAR CARRIER	TOTAL
GT	106,691,841	672,393,740	101,052,613	11,268,429	18,316,152	909,722,773
DWT	130,326,401	152,476,202	44,027,878	1,287,925	6,385,102	334,503,508
TEUS	9,946,081	-	-	-	-	9,946,081
Lane metres	-	53,550,203	12,236,069	-	-	65,786,272
Passengers	-	49,923,344	142,965	9,637,493	-	59,703,803
Cars	-	-	-	-	1,673,281	1,673,281

CONTAINER RO-PAX RO-RO PAX CAR CARRIER

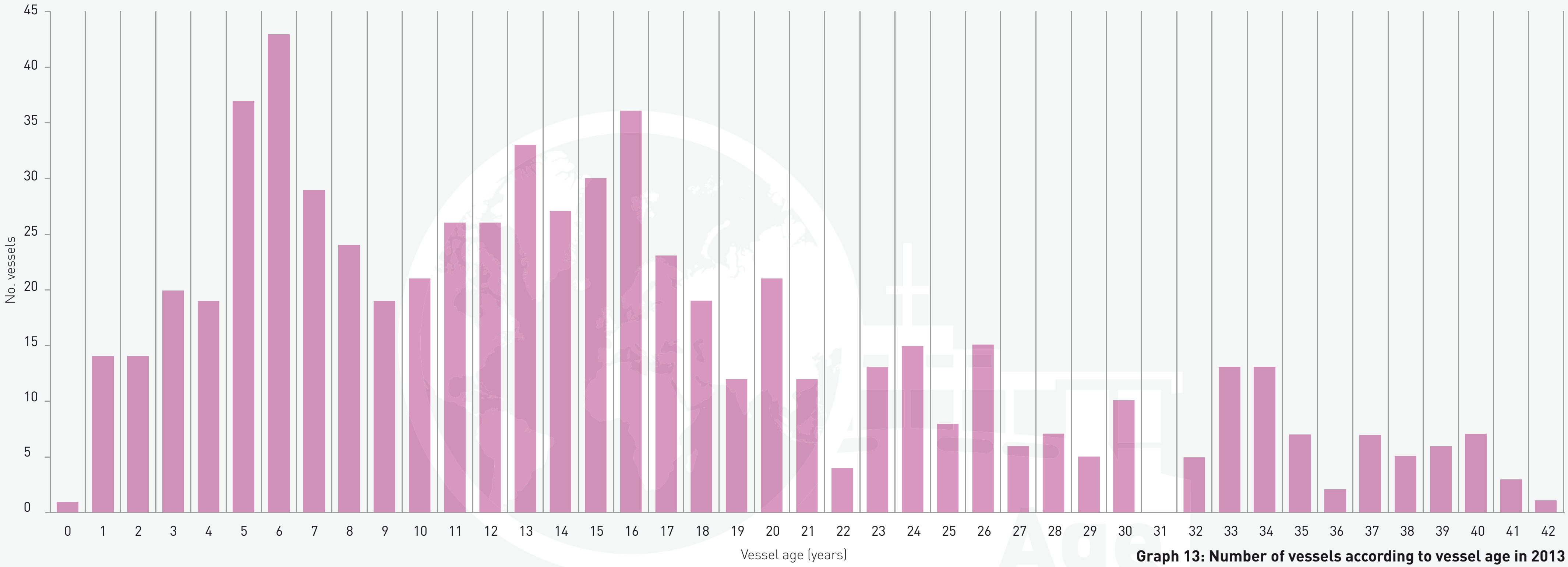
Table 11: Total annual capacity offered in 2013

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database



DESCRIPTION OF THE SHORT SEA SHIPPING FLEET IN THE MEDITERRANEAN

Most vessels that are integrated in the Mediterranean SSS fleet can be classified into two groups according to their age: 109 ships are between five and seven years old whilst 126 vessels are 13 to 16 years old. According to their age profile, 64% of all vessels are less than 16 years old.



Graph 13: Number of vessels according to vessel age in 2013

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

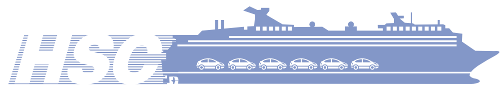
	CONTAINER	RO-PAX	RO-RO	PAX	CAR CARRIER
Vessel age (years)	12	18	14	22	14

CAR CARRIER CONTAINER PAX RO-PAX RO-RO

Table 12 : Average age of vessels by type of freight in 2013

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

High-Speed Crafts (HSC) have been analysed separately, including both hydrofoils and catamarans. With the development of many new types of HSC, the IMO decided to adopt new international regulations in 1994 and 2000, to cater for the special needs of this type of vessels. HSC operate as regular lines and are characterised by the high speeds they reach.



	RO-PAX	PAX	TOTAL
High-Speed Craft	50	20	70

RO-PAX ■ PAX ■

Table 13: Number of High-Speed Crafts (HSC) by type of traffic

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

	HIGH SPEED RO-PAX	HIGH SPEED PAX	TOTAL
GT	6,001	332	1,952
DWT	575	48	199
Service speed (knots)	25.80	23.40	24.10
Engine power (kw)	24,290	3,120	9,168
Consumption (Tonnes/day)	99.97	13.49	38.19
Vessel age (years)	13.4	22.7	20.0

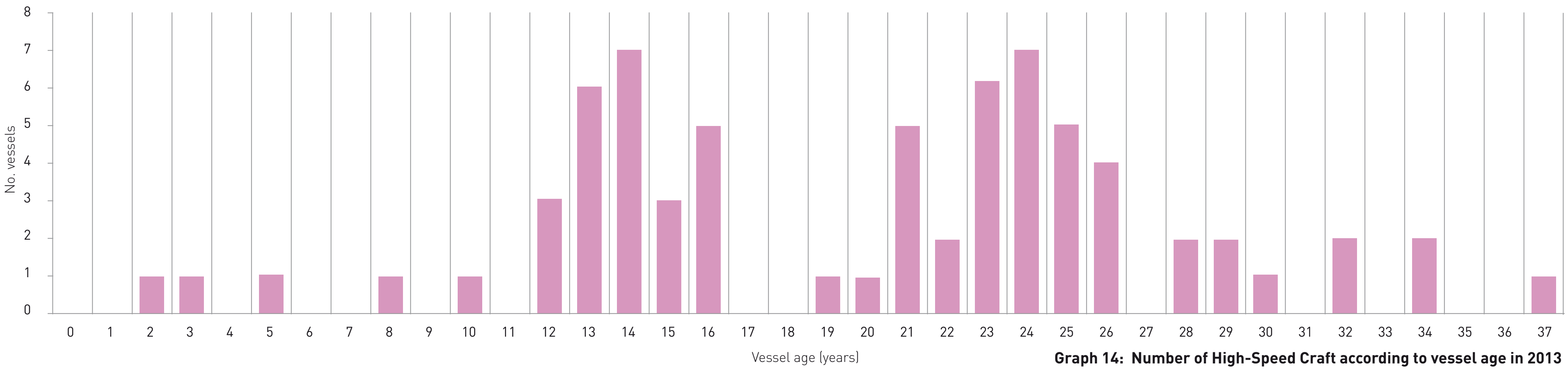
RO-PAX ■ PAX ■

Table 14: Average characteristics of HSC operating in SSS services

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

Comparing the average characteristics of HSC Ro-pax and passenger vessels, Ro-pax have on average more carrying capacity, are deployed in higher speed services and are fitted with larger engines, the consumption being five times that of passenger HSC. Additionally, passenger vessels are considerably old (22.7 years old on average) while HSC Ro-pax are relatively new (average age of 13). Nevertheless, as HSC are made of aluminium, their average economic life may not exceed 20 years.

From a geographical perspective, Italy is the country with the largest number of high speed vessels (40), followed by Greece (18), and Spain (5). Two vessels operate in services calling in Bulgaria and Slovenia whilst only one HSC calls in Malta and another one in Portugal. By port of call, 31 HSC call at the Port of Naples (Italy), followed by Piraeus (Greece) with 18 vessels. Palermo and Venice have four vessels each, followed by Spanish core ports such as Algeciras and Las Palmas (3), Bourgas with two vessels, and Valletta, Palma, Trieste and Valencia (one vessel each) complete the list.



Graph 14: Number of High-Speed Craft according to vessel age in 2013

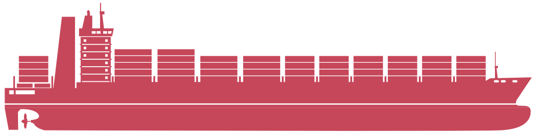
Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

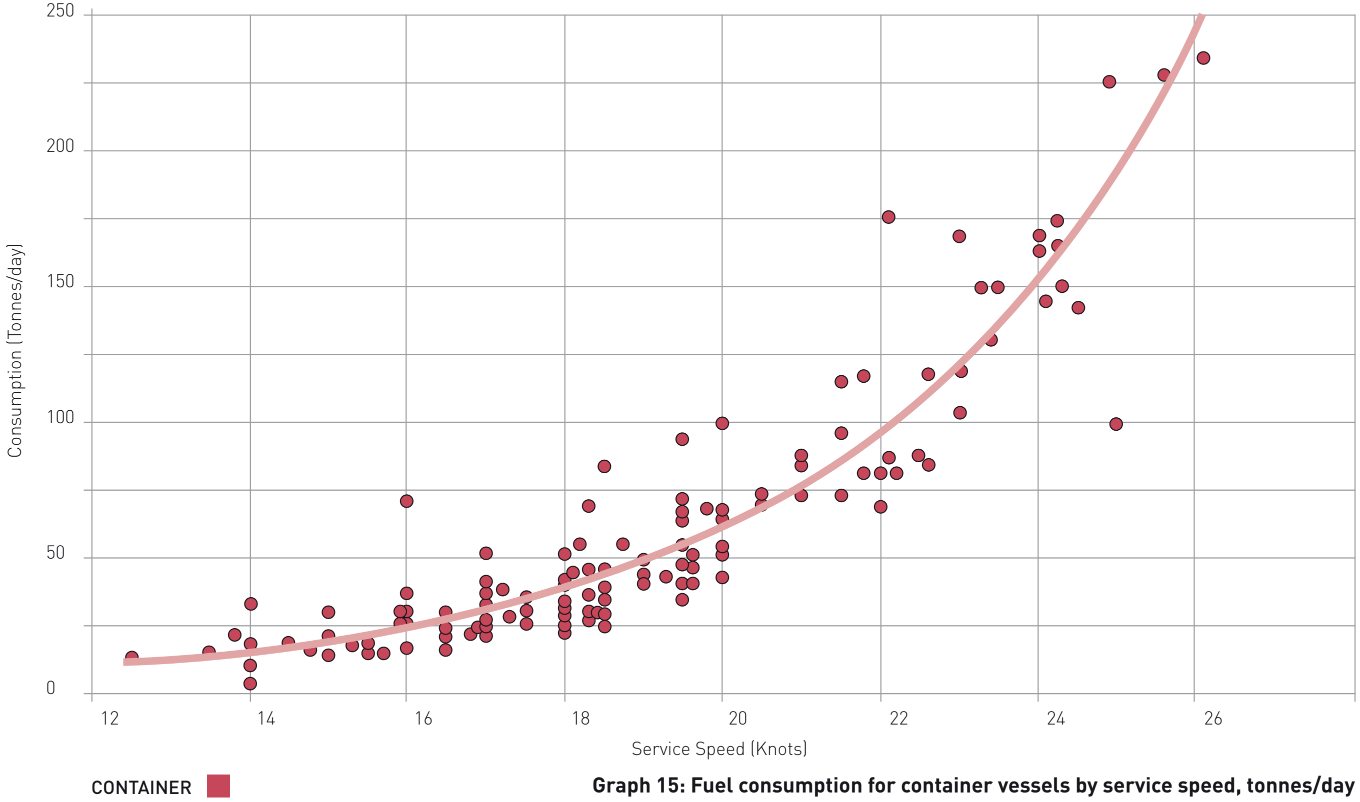
DESCRIPTION OF THE SHORT SEA SHIPPING FLEET IN THE MEDITERRANEAN

Finally, vessel fuel consumption and its determinant variable factors (vessel speed and engine power) have been analysed for each type of ship. The results for containerships, Ro-ro, and Ro-pax are shown in the next graphs.

High consumption in container vessels comes from service speeds of 20 knots or more. Fuel consumption in this type of vessel depends on its engine power, which is commonly a function of ship size. The main vessel speed ranges are:

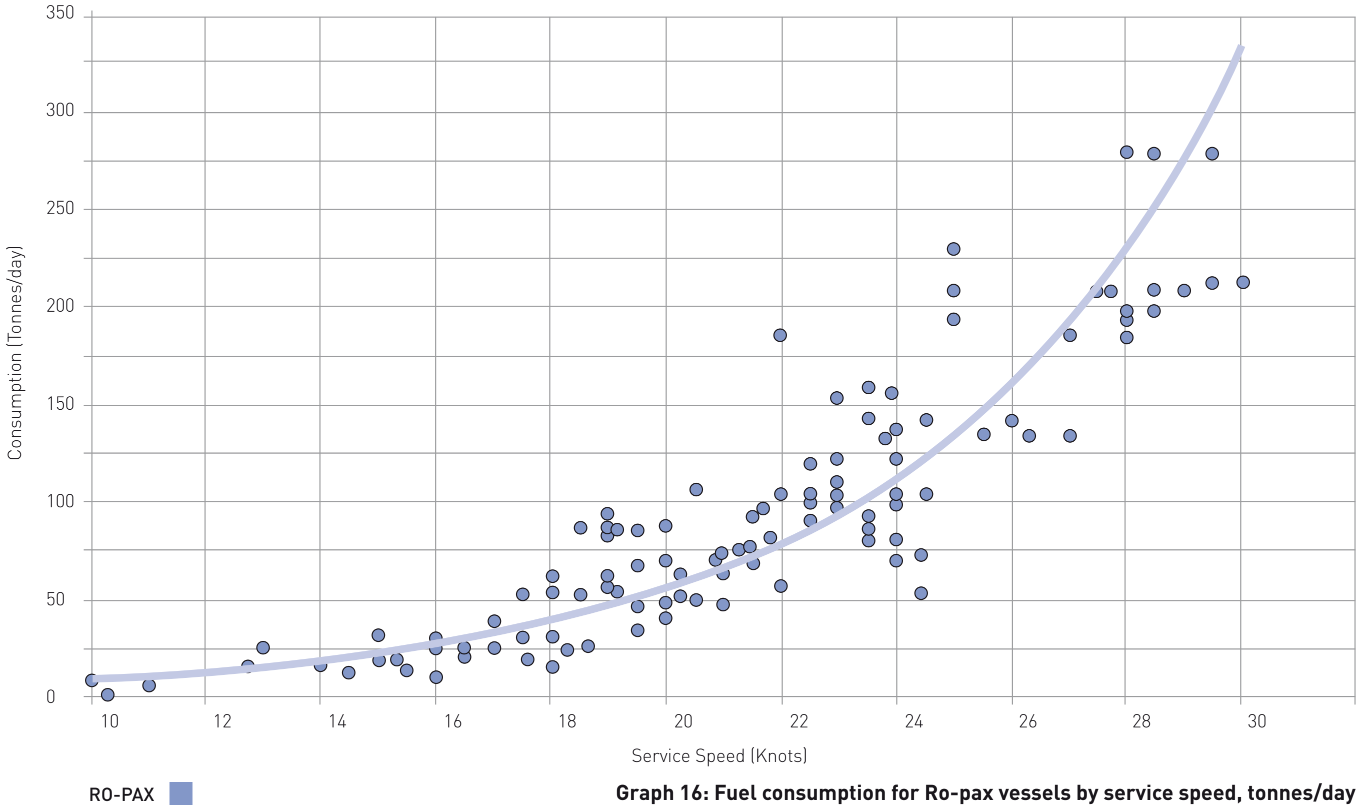
- **Normal – 20-25 knots.** The vessel's engine has been designed to travel at this optimal speed.
- **Slow steaming – 18-20 knots.** These speeds bring important savings in fuel consumption. More than 50% of the world's container shipping capacity operates in this range.
- **Extra slow steaming – 15-18 knots.** Economical speed that can be applied on specific short sea shipping routes.
- **Minimal cost – 12-15 knots.** This speed is not commercially accepted in most services.

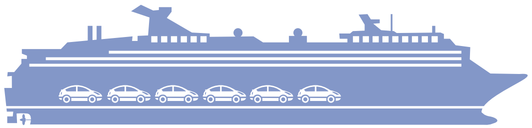




Graph 15: Fuel consumption for container vessels by service speed, tonnes/day

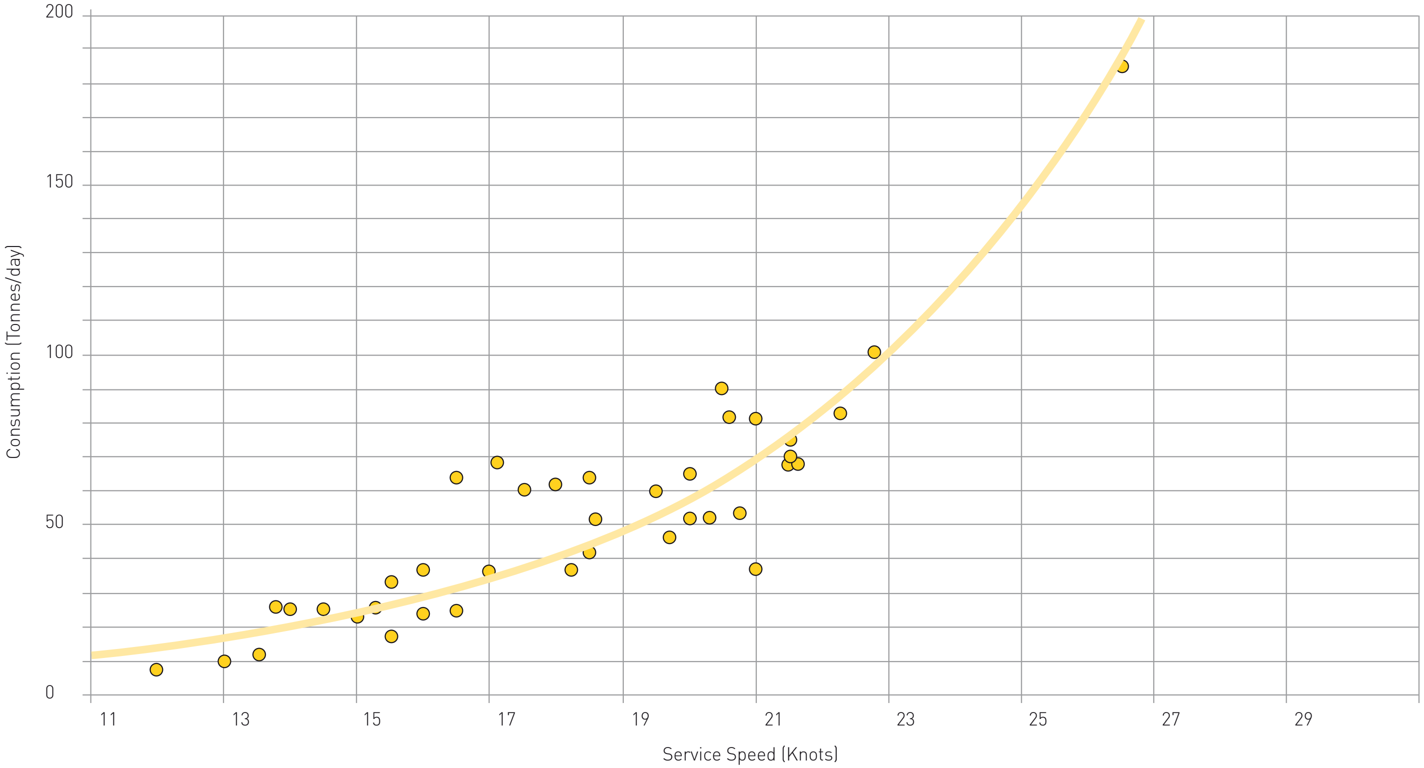
Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database





Graph 16: Fuel consumption for Ro-pax vessels by service speed, tonnes/day

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

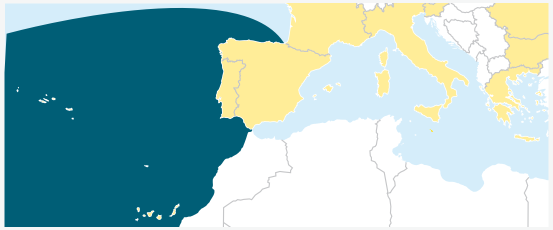


Graph 17: Fuel consumption for Ro-ro vessels by service speed, tonnes/day

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

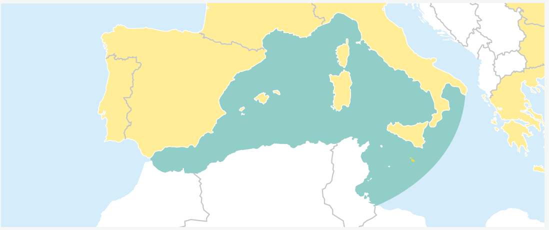
4.2 INDICATORS BY AREA

Figure 26 shows that the percentage of vessels in the Mediterranean area is higher than in the Atlantic zone under study. Container and car carrier vessels are highly concentrated in the mixed area. This is because the regular lines designed for this type of freight try to cover a large part of the Mediterranean. There is a high concentration of Ro-pax and passenger vessels in the Western and Eastern Mediterranean and the Black Sea areas. This is influenced by lines that operate to and from Greek and Italian islands, including Sardinia and Sicily. Spanish connections between the Balearic Islands and regular lines from Spanish ports to North Africa add data consistency. A total of 206 vessels operate in several areas, 73% of these vessels are container ships. There are no passenger vessels in this mixed area.



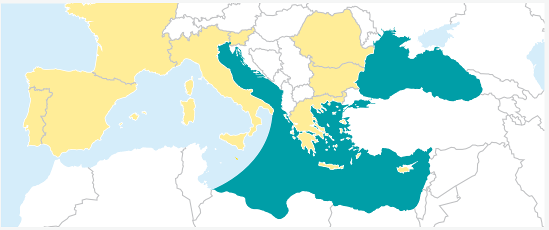
ATLANTIC AREA

AVERAGE VESSEL	CONTAINER	RO-PAX	RO-RO	PAX	CAR CARRIER
No. VESSELS	**44**	**13**	**9**	**3**	**0**
GT	7,458	15,621	21,644	150	-
DWT	8,876	3,439	9,291	30	-
SERVICE SPEED (knots)	17.12	27.30	20.30	15.70	-
ENGINE POWER (kW)	6,923	24,856	18,193	595	-
CONSUMPTION (tonnes/day)	29.55	109.49	77.41	3.02	-



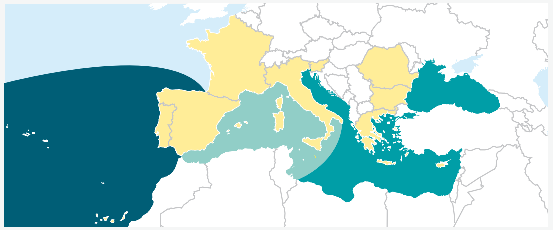
WESTERN MEDITERRANEAN SEA

AVERAGE VESSEL	CONTAINER	RO-PAX	RO-RO	PAX	CAR CARRIER
No. VESSELS	**49**	**93**	**26**	**30**	**2**
GT	8,915	21,567	21,036	379	9,110
DWT	11,284	4,671	8,401	55	2,953
SERVICE SPEED (knots)	17.50	23.40	19.40	31.90	16.80
ENGINE POWER (kW)	8,104	24,223	14,683	3,330	4,818
CONSUMPTION (tonnes/day)	34.15	105.31	61.85	16.67	19.83



EASTERN MEDITERRANEAN & BLACK SEA

AVERAGE VESSEL	CONTAINER	RO-PAX	RO-RO	PAX	CAR CARRIER
No. VESSELS	**56**	**73**	**23**	**20**	**11**
GT	14,726	15,046	24,615	303	24,736
DWT	17,399	3,625	11,915	49	10,280
SERVICE SPEED (knots)	18.60	22.60	20.20	33.90	17.90
ENGINE POWER (kW)	11,959	21,285	15,355	2,867	8,997
CONSUMPTION (tonnes/day)	49.70	93.35	65.88	14.97	38.88



ATLANTIC - WESTERN MED - EASTERN MED

AVERAGE VESSEL	CONTAINER	RO-PAX	RO-RO	PAX	CAR CARRIER
No. VESSELS	**150**	**3**	**18**	**-**	**35**
GT	22,323	16,820	14,760	-	34,084
DWT	27,453	8,608	10,303	-	11,137
SERVICE SPEED (knots)	19.90	19.20	16.30	-	19.30
ENGINE POWER (kW)	19,123	12,554	8,489	-	12,016
CONSUMPTION (tonnes/day)	78.37	58.76	35.96	-	50.42

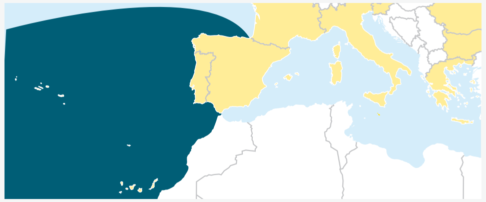
ATLANTIC AREA   WESTERN MEDITERRANEAN
EASTERN MEDITERRANEAN & BLACK SEA   ATLANTIC - WESTERN MED - EASTERN MED

Figure 26: Average characteristics of vessels operating in SSS services by area

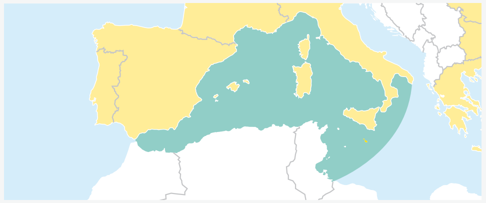
Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

DESCRIPTION OF THE SHORT SEA SHIPPING FLEET IN THE MEDITERRANEAN

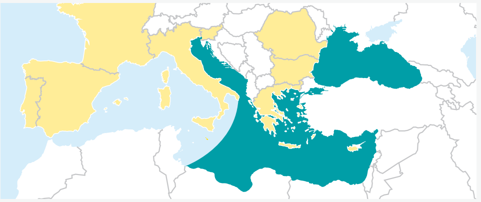
The following figure shows total annual capacity in terms of DWT, lane metres, passengers and cars. As mentioned before, total annual TEUs are highest in the mixed area. Moreover, the Western Mediterranean has double the amount of lane metres compared to the Eastern Mediterranean & Black Sea. The Western Mediterranean has also the greatest annual passenger capacity.



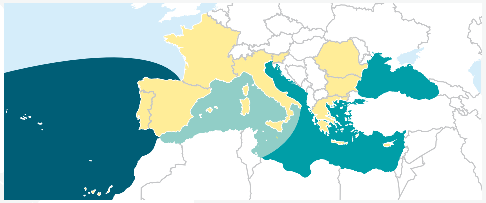
ATLANTIC AREA	
DWT	26,929,588
TEUS	1,157,393
LANE METRES	7,017,632
PAX	5,187,883
CARS	1,371,578



WESTERN MEDITERRANEAN SEA	
DWT	138,464,227
TEUS	2,249,348
LANE METRES	39,756,323
PAX	36,683,237
CARS	7,586,813



EASTERN MEDITERRANEAN & BLACK SEA	
DWT	81,940,787
TEUS	2,196,868
LANE METRES	17,588,336
PAX	17,829,787
CARS	2,794,057



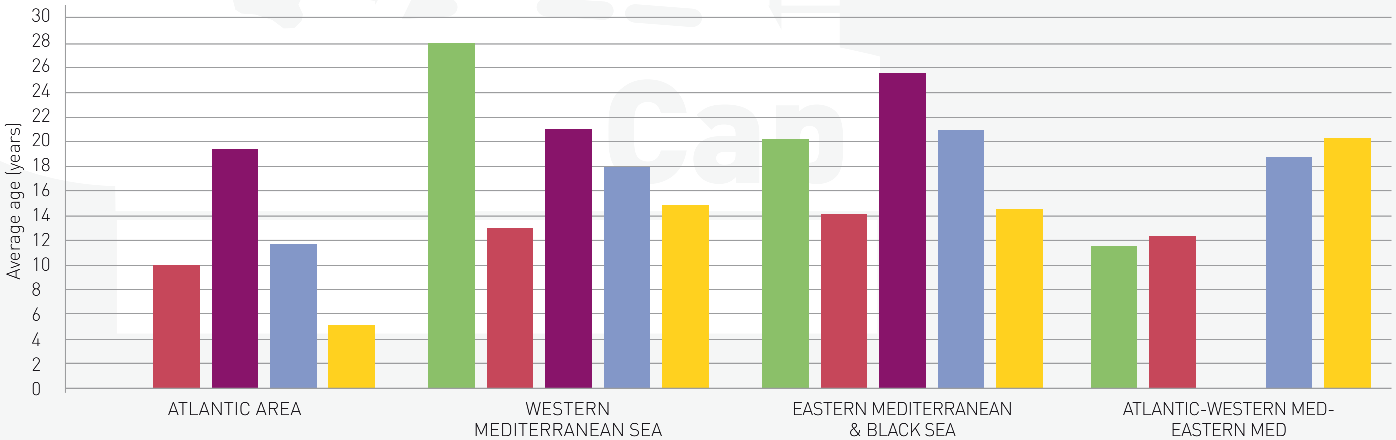
ATLANTIC - WESTERN MED - EASTERN MED	
DWT	87,168,905
TEUS	5,894,922
LANE METRES	2,372,776
PAX	2,896
CARS	1,392,364

ATLANTIC AREA WESTERN MEDITERRANEAN EASTERN MEDITERRANEAN & BLACK SEA ATLANTIC - WESTERN MED - EASTERN MED

Figure 27: Total annual capacity by area in 2013

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

Graph 18 shows the average age of vessels by area and type of freight. In the Eastern Mediterranean, the average age of vessels is greatest than in other areas. Car carriers in the Western Mediterranean are older on average than those in the Eastern Mediterranean & Black Sea. Container vessels are generally new in all the areas.



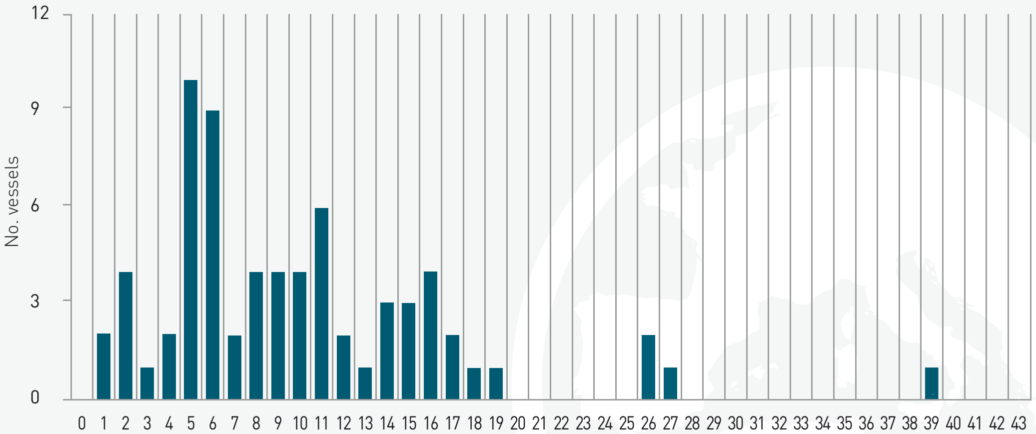
Graph 18: Average age of vessels by area and type of freight in 2013

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

DESCRIPTION OF THE SHORT SEA SHIPPING FLEET IN THE MEDITERRANEAN

Graphs 19-22 show the number of vessels by area and age in 2013. Graph 19 shows that the fleet operating in the Atlantic is relatively new. Vessels in the Western Mediterranean area show a more uniform distribution in terms of vessel age, with a high percentage in the 12-16 year-old range.

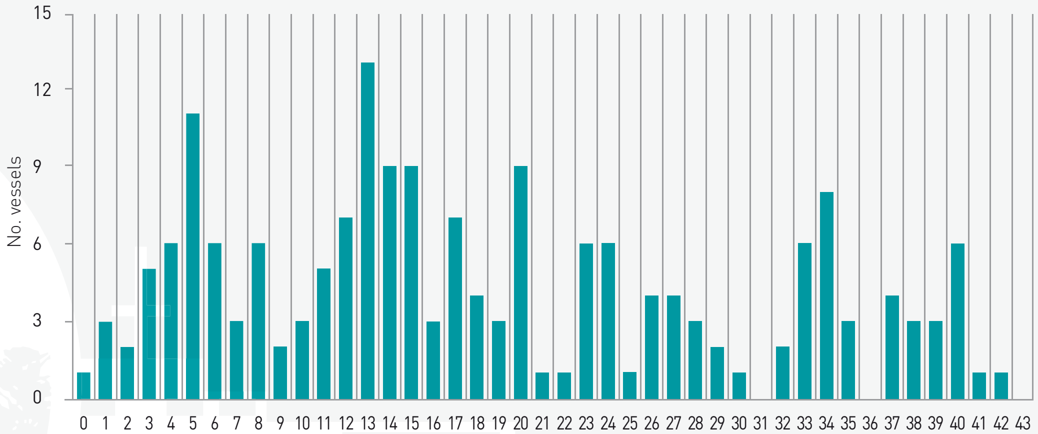
Vessels that operate in the Eastern Mediterranean and the Black Sea also have a uniform age distribution with vessels in the same range as those above. However, there are some vessels in the 30-40 year-old range, especially those operating in Greece on connections to the Greek Islands. Finally, in the mixed area the majority of vessels are relatively new (defined as 1-15 years old), similar to the Atlantic area fleet (see Graph 19).



Vessel age (years)

Graph 19: Number of vessels operating in the Atlantic area according to the vessel age

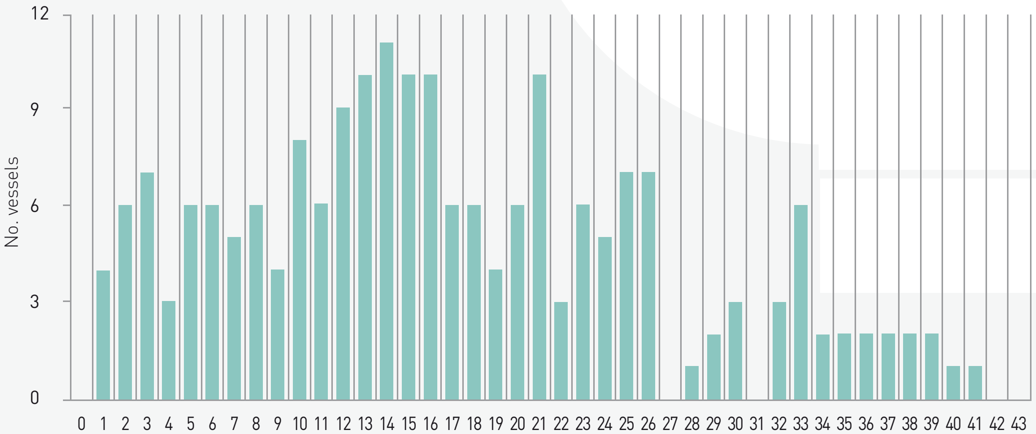
Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database



Vessel age (years)

Graph 21: Number of vessels operating in the Eastern Mediterranean and the Black Sea according to the vessel age

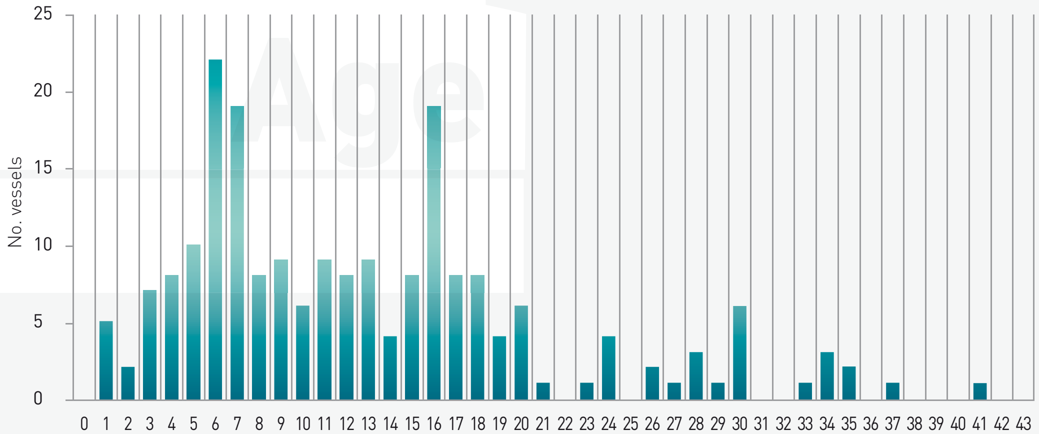
Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database



Vessel age (years)

Graph 20: Number of vessels operating in the Western Mediterranean according to the vessel age

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database



Vessel age (years)

Graph 22: Number of vessels operating in the mixed area according to the vessel age

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

ATLANTIC AREA   WESTERN MEDITERRANEAN   EASTERN MEDITERRANEAN & BLACK SEA   ATLANTIC - WESTERN MED - EASTERN MED

4.3 INDICATORS BY COUNTRY

This section provides information about the characteristics of the vessels deployed in SSS services for each of the countries in the database.

The following figure shows information about the number of vessels according to country and type of freight. Italy has the largest number of vessels calling at its ports (300), closely followed by Spain (217) and Greece (194). Both Italy and Spain had the largest number of container ships, followed by Greece. Italy also had the largest number of Ro-pax and Ro-ro vessels. Greece tops the ranking for the number of car carriers.

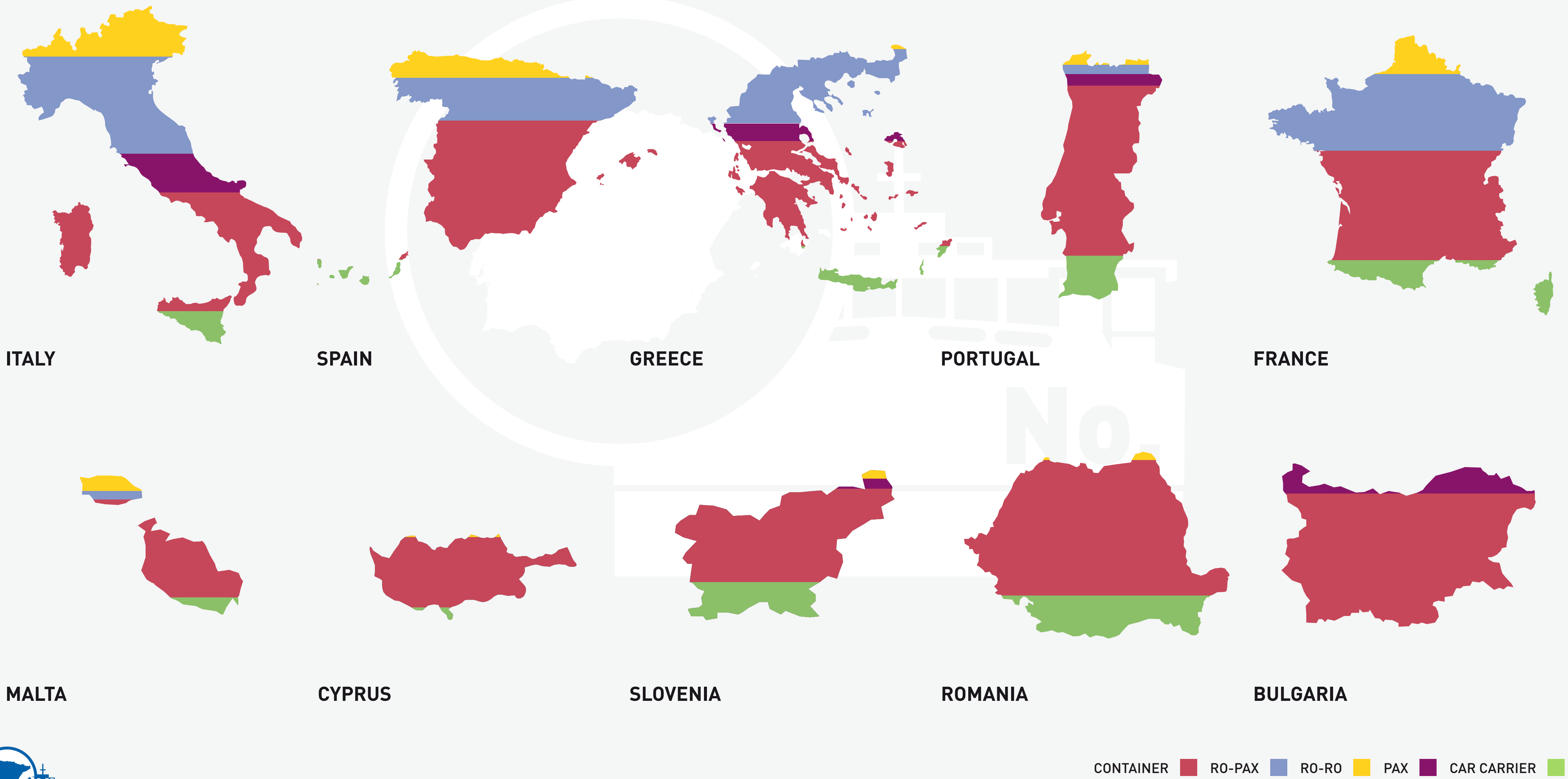


Figure 28: Number of vessels by country and type of traffic
Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

An analysis of the main characteristics of vessels by country and type of freight shows that container vessels from Greece and Cyprus have high fuel consumption due to their vessels' high engine power. Italian and Slovenian vessels are old on average, as are Ro-ro vessels from Romania and Cyprus. In terms of DWT, the Ro-ro vessels from Cyprus and Malta are the largest, while French and Maltese Ro-pax vessels have the highest values for this indicator. The newest vessels in all the countries are Ro-ro vessels from Portugal (six) whilst the average age of Ro-pax vessels from Malta and Spain is 13. Cyprus and Malta occupy the top positions in the DWT ranking for car carriers, whilst Romania and France are in the top positions concerning average age (eight and nine, respectively).Passenger vessels from Slovenia and Greece offer the highest speed. Bulgarian vessels are older than the rest of the vessels from the other countries.

ITALY	CONTAINER	RO-PAX	RO-RO	PAX	CAR CARRIER
GT	16,357	22,517	24,748	373	36,400
DWT	20,293	4,979	10,503	56	12,803
Service Speed (knots)	17.00	19.40	17.70	23.50	17.40
Engine power (kW)	12,745	25,020	15,552	3,289	11,840
Consumption (tonnes/day)	52.90	108.45	65.63	16.41	49.99

SPAIN	CONTAINER	RO-PAX	RO-RO	PAX	CAR CARRIER
GT	16,961	19,628	18,258	-	31,428
DWT	20,226	4,317	9,410	-	9,734
Service Speed (knots)	17.00	20.80	16.20	-	17.50
Engine power (kW)	15,697	22,902	12,790	-	11,413
Consumption (tonnes/day)	64.41	101.79	53.84	-	48.17

GREECE	CONTAINER	RO-PAX	RO-RO	PAX	CAR CARRIER
GT	21,775	15,814	18,839	320	35,074
DWT	26,676	3,729	11,260	45	12,038
Service Speed (knots)	17.80	19.00	17.10	23.30	17.40
Engine power (kW)	18,851	23,246	14,858	3,012	11,818
Consumption (tonnes/day)	76.66	100.88	66.44	16.01	49.78

PORTUGAL	CONTAINER	RO-PAX	RO-RO	PAX	CAR CARRIER
GT	12,105	6,855	8,436	150	44,466
DWT	14,743	1,040	10,134	30	15,113
Service Speed (knots)	16.30	21.30	13.60	14.10	17.60
Engine power (kW)	10,731	18,423	5,349	595	12,856
Consumption (tonnes/day)	44.51	81.15	22.59	3.02	53.38

FRANCE	CONTAINER	RO-PAX	RO-RO	PAX	CAR CARRIER
GT	14,644	25,757	13,161	-	31,457
DWT	17,712	5,506	7,082	-	9,434
Service Speed (knots)	17.00	19.60	15.80	-	17.40
Engine power (kW)	12,586	27,543	9,519	-	11,167
Consumption (tonnes/day)	52.10	116.77	41.30	-	47.08

CONTAINER RO-PAX RO-RO PAX CAR CARRIER

MALTA	CONTAINER	RO-PAX	RO-RO	PAX	CAR CARRIER
GT	16,814	13,990	24,803	-	41,427
DWT	21,508	6,029	13,077	-	14,444
Service Speed (knots)	17.30	18.50	17.40	-	17.40
Engine power (kW)	14,360	14,498	15,305	-	14,484
Consumption (tonnes/day)	59.46	65.03	64.14	-	60.00

CYPRUS	CONTAINER	RO-PAX	RO-RO	PAX	CAR CARRIER
GT	22,000	-	11,400	-	44,440
DWT	27,187	-	17,884	-	15,880
Service Speed (knots)	18.00	-	15.80	-	16.00
Engine power (kW)	18,198	-	12,000	-	13,757
Consumption (tonnes/day)	74.45	-	60.17	-	57.09

SLOVENIA	CONTAINER	RO-PAX	RO-RO	PAX	CAR CARRIER
GT	17,781	-	12,253	259	29,011
DWT	21,778	-	9,386	66	11,786
Service Speed (knots)	17.40	-	16.20	21.70	17.10
Engine power (kW)	13,801	-	12,213	2,680	11,105
Consumption (tonnes/day)	57.09	-	51.03	13.06	47.87

ROMANIA	CONTAINER	RO-PAX	RO-RO	PAX	CAR CARRIER
GT	13,271	-	20,000	-	30,900
DWT	16,500	-	12,889	-	9,527
Service Speed (knots)	17.00	-	18.70	-	16.40
Engine power (kW)	11,948	-	12,994	-	9,448
Consumption (tonnes/day)	49.62	-	53.12	-	39.30

BULGARIA	CONTAINER	RO-PAX	RO-RO	PAX	CAR CARRIER
GT	14,846	-	-	142	-
DWT	18,747	-	-	60	-
Service Speed (knots)	17.30	-	-	21.70	-
Engine power (kW)	12,705	-	-	1,622	-
Consumption (tonnes/day)	52.38	-	-	8.70	-

Table 15: Average characteristics of vessels operating SSS services by country

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

DESCRIPTION OF THE SHORT SEA SHIPPING FLEET IN THE MEDITERRANEAN

According to the total annual capacity offered by country in 2013, Italy offers the highest capacity in terms of DWT and passenger capacity, but Spain comes first in terms of TEUs, lane metres, and car capacity.

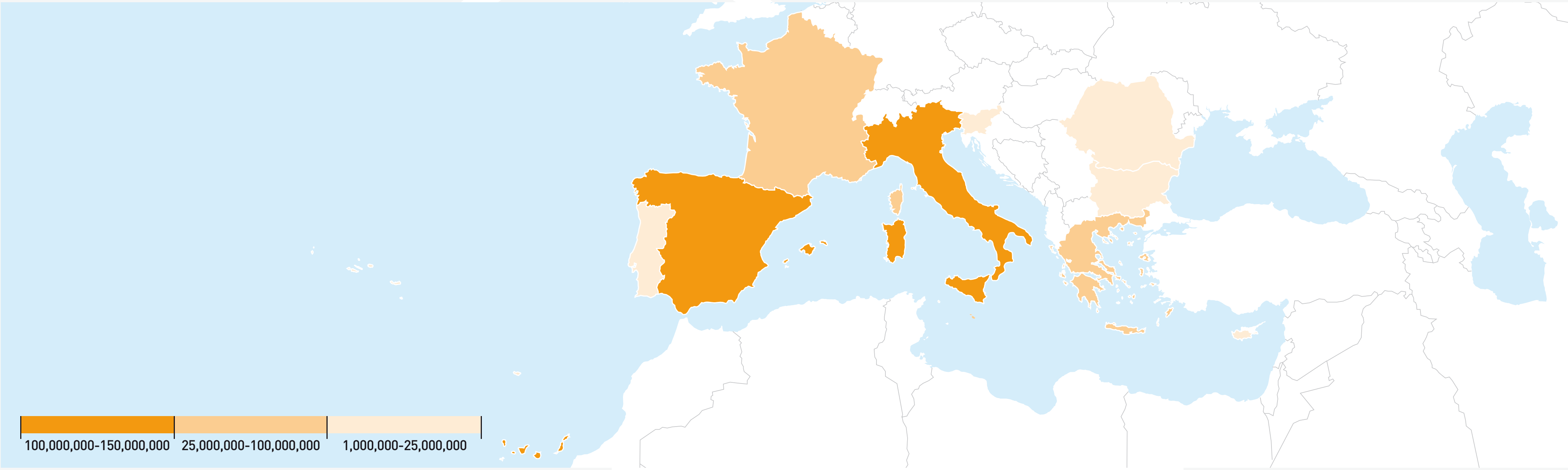
ITALY	
DWT	137,632,786
TEUS	3,991,283
LANE METERS	26,979,571
PASSENGERS	23,297,399
CARS	5,195,318

SPAIN	
DWT	134,765,179
TEUS	4,609,884
LANE METERS	31,090,000
PASSENGERS	20,887,682
CARS	6,533,082

GREECE	
DWT	86,574,163
TEUS	3,623,151
LANE METERS	3,783,292
PASSENGERS	16,640,056
CARS	3,481,445

MALTA	
DWT	30,426,327
TEUS	1,838,786
LANE METERS	2,466,731
PASSENGERS	203,720
CARS	871,216

FRANCE	
DWT	28,580,193
TEUS	1,031,301
LANE METERS	4,709,000
PASSENGERS	1,753,798
CARS	1,345,440



PORTUGAL	
DWT	18,008,697
TEUS	1,262,906
LANE METERS	482,059
PASSENGERS	610,545
CARS	563,063

CYPRUS	
DWT	15,492,935
TEUS	1,035,517
LANE METERS	205,764
PASSENGERS	-
CARS	311,397

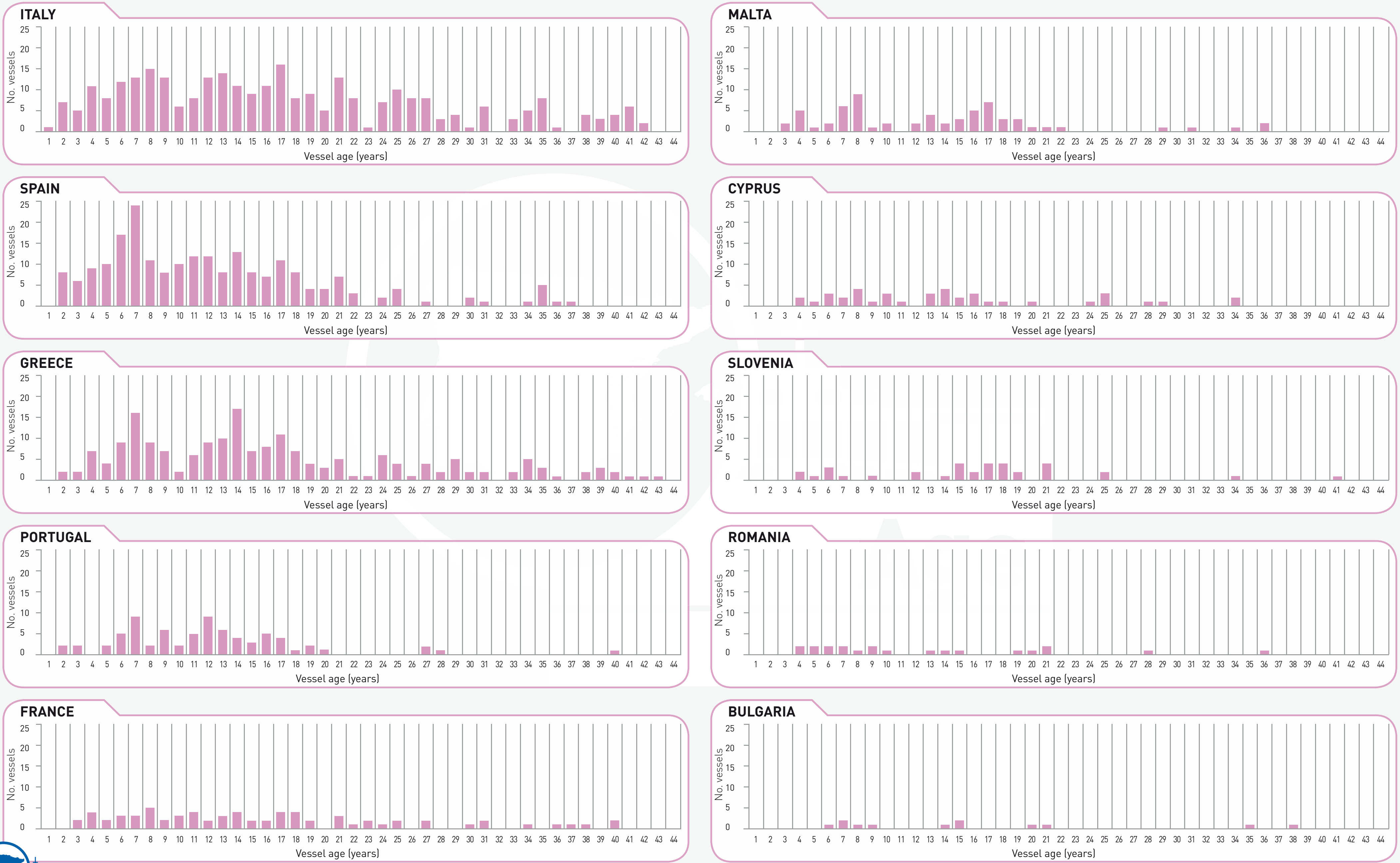
SLOVENIA	
DWT	10,798,671
TEUS	687,681
LANE METERS	226,001
PASSENGERS	21,863
CARS	254,228

ROMANIA	
DWT	6,428,946
TEUS	438,531
LANE METERS	50,267
PASSENGERS	1,300
CARS	157,442

BULGARIA	
DWT	4,290,328
TEUS	308,529
LANE METERS	-
PASSENGERS	9,000
CARS	-

Figure 29: Total annual capacity in DWT offered by country in 2013

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database



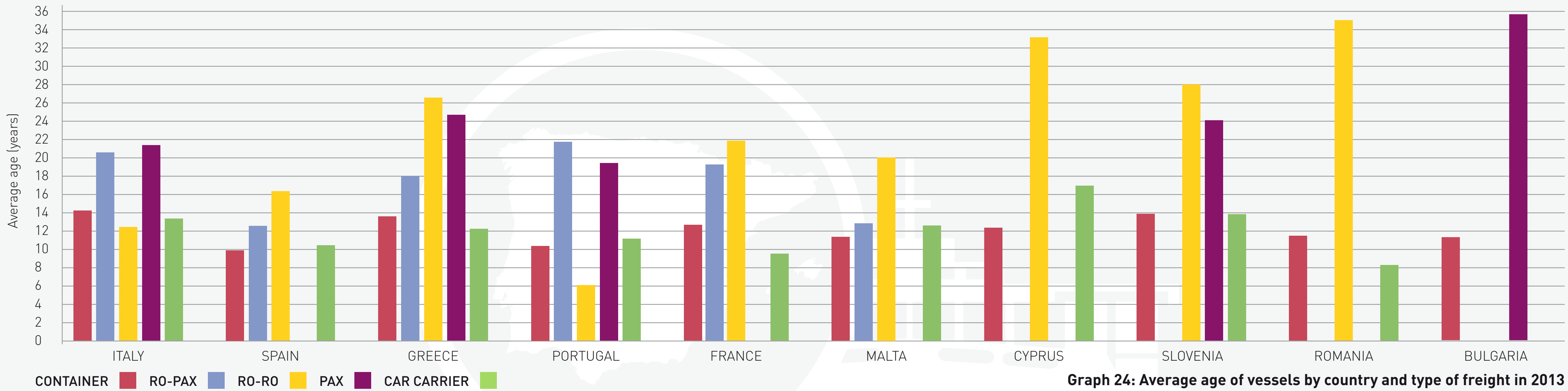
Graph 23: Number of vessels per country according to vessel age in 2013

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

The graph below provides more detailed information on the average age by country according to the different types of freight.

Ro-ro vessels that operate in Portuguese ports are quite new. By contrast, passenger vessels that call at Bulgarian ports are older, followed by Ro-ro vessels calling at Romanian ports.

Ro-ro and passenger vessels in Cyprus, Romania, Bulgaria and Greece are the oldest followed by Ro-pax vessels from Portugal and Italy (20 years old on average). Both container vessels and car carriers have a lower average (10-12 years old).

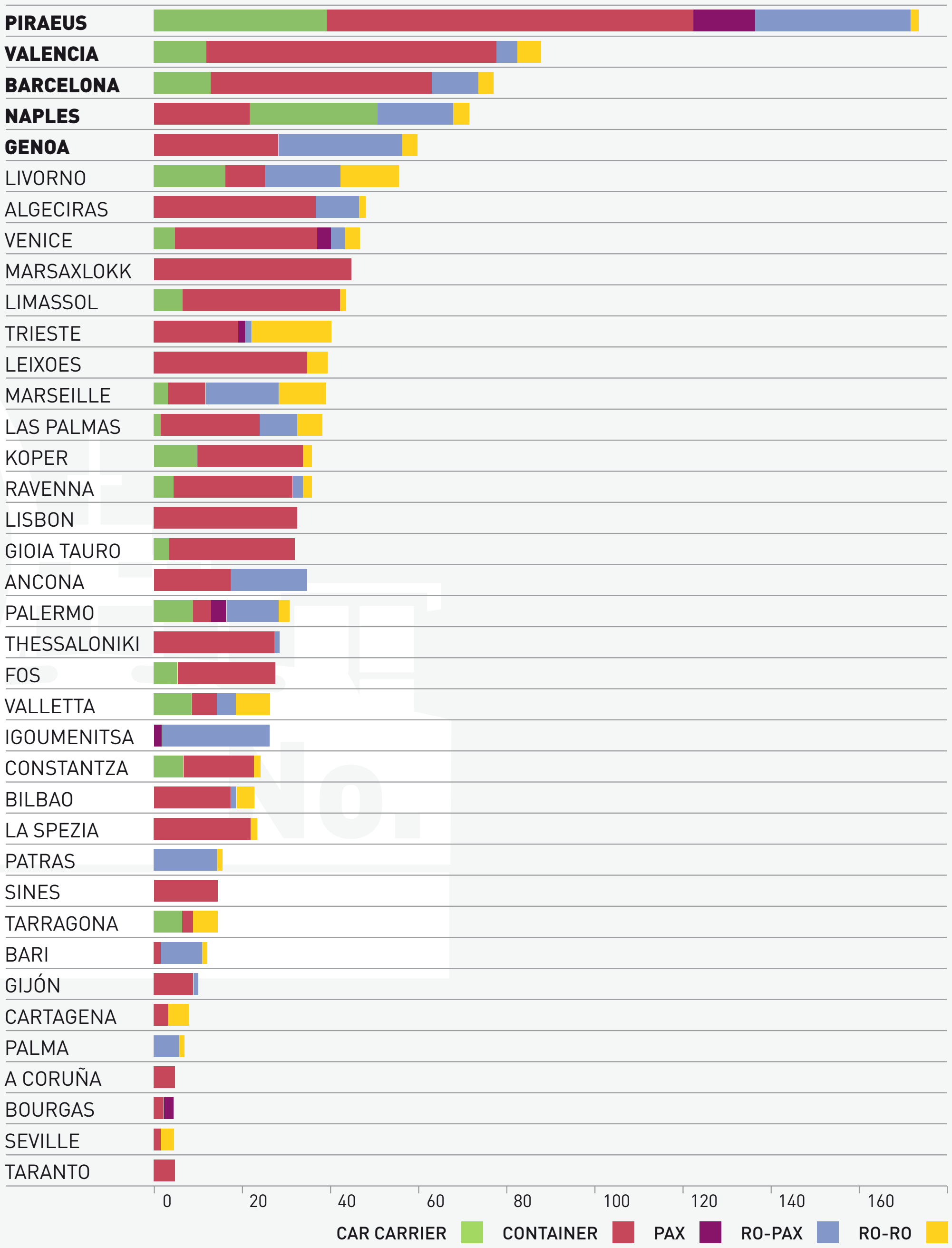


Graph 24: Average age of vessels by country and type of freight in 2013

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database0

4.4 INDICATORS BY CORE PORTS

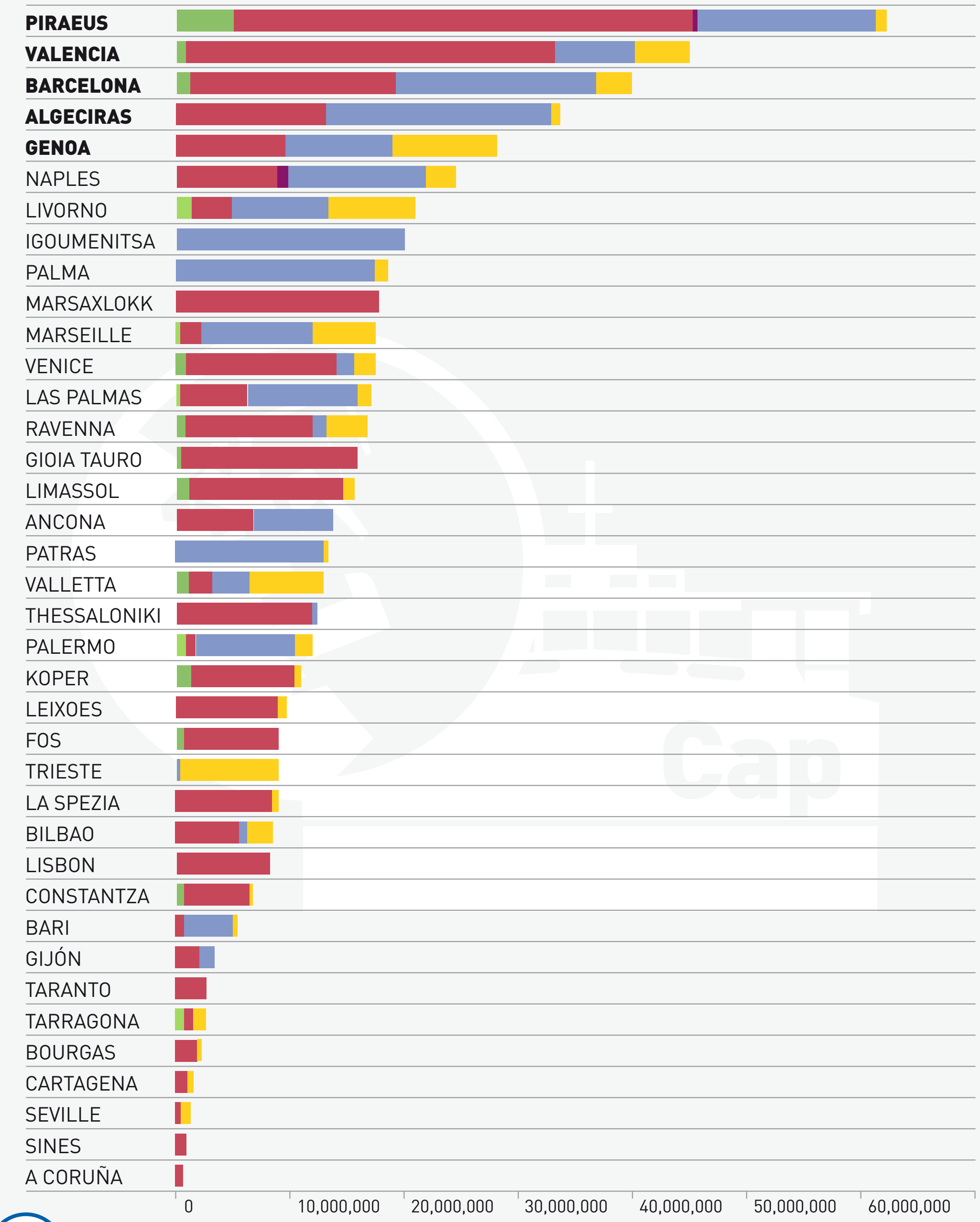
This section provides information on the SSS fleet in the Mediterranean by core port and type of freight. In total 160 vessels call at the Port of Piraeus (Greece), followed by Valencia (Spain) with 81 vessels. Ro-pax and car carrier vessels lead the ranking by type of traffic at the Port of Piraeus, followed by Livorno. Piraeus, Livorno, Barcelona, Valencia, Koper and Palermo are the main ports with car carrier vessels followed by Valletta in Malta. In terms of passenger vessels, Piraeus leads the way as a result of its connections with the Greek islands as does Naples with its Aeolian island connections. Concerning container traffic, the ranking is headed by Piraeus and Valencia, followed by Barcelona, Marsaxlokk, Algeciras and Limassol. In the Atlantic area, the main ports are Leixoes and Lisbon in Portugal and Las Palmas in Spain.



Graph 25: Ranking of core ports according to the number of vessels calling at them by type of freight

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

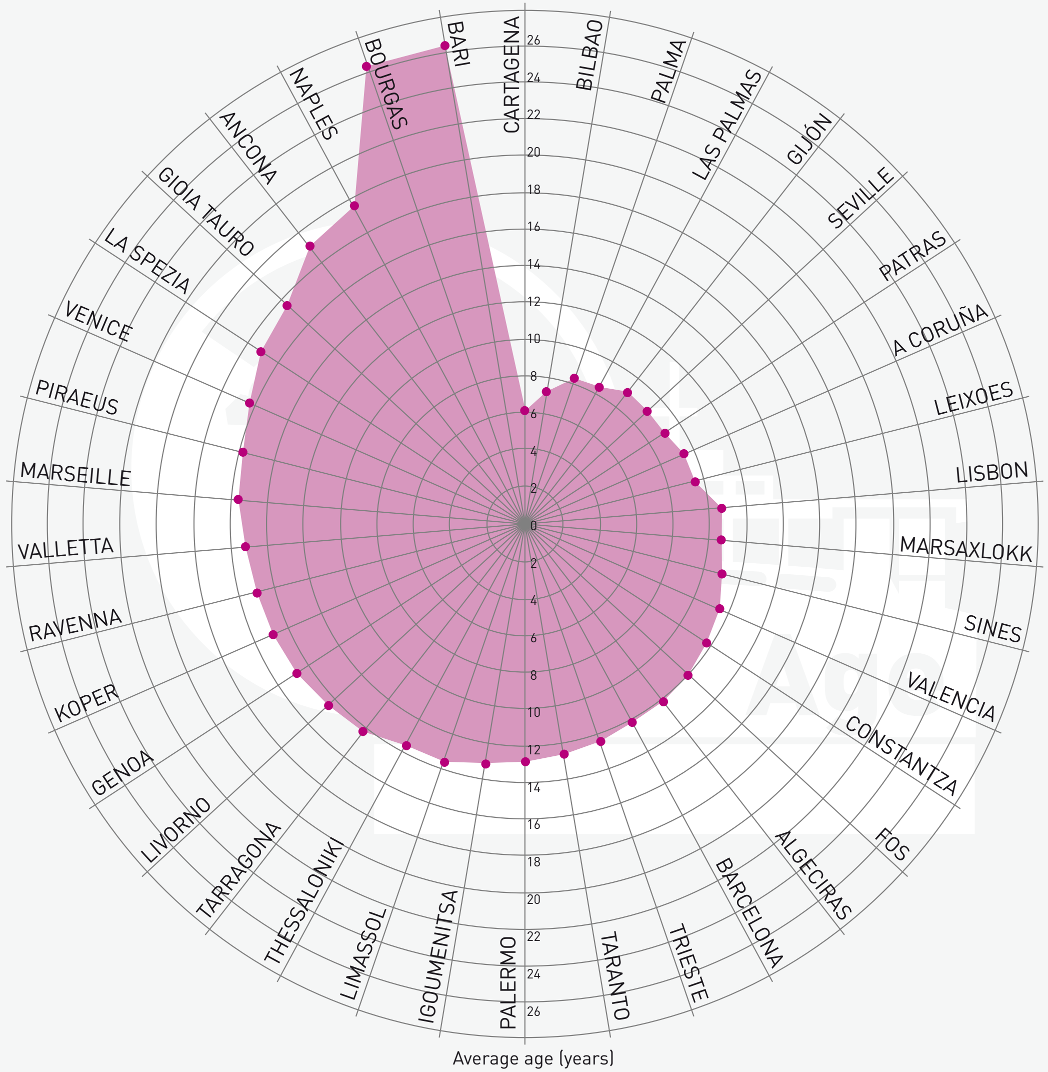
DESCRIPTION OF THE SHORT SEA SHIPPING FLEET IN THE MEDITERRANEAN



Graph 26: Total annual DWT capacity offered by core port and type of freight

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

Finally, the following graph shows the ranking of core ports according to the average age of vessels calling at it. The newest vessels call at three Spanish ports: Cartagena, Bilbao and Palma.



Graph 27: Average vessel age by core port in 2013

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

4.5 MOTORWAYS OF THE SEA

Route	Traffic	No. Vessels	GT	Lane Metres	Year Built	Service Speed (Knots)
GIJÓN - SAINT NAZAIRE	RO-PAX	1	27,414	2,250	2007	21.2

RO-PAX

Figure 30: Average characteristics of vessels in the Western European Motorways of the Sea corridor

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

Route	Traffic	No. Vessels	GT	Lane Metres	Year Built	Service Speed (Knots)
BARCELONA - CIVITAVECCHIA	RO-PAX	2	108,620	6,100	2008	22.5
GENOA - CATANIA - VALLETTA - NAPLES	RO-RO	2	65,294	7,620	2011	20.1
LIVORNO - CATANIA - VALLETTA	RO-RO	1	32,637	3,810	2010	20.1
MARSEILLE - AJACCIO - PORTO TORRES	RO-PAX	1	39,777	2,000	1999	21.6
MARSEILLE - PORTO TORRES - PROPIANO	RO-PAX	1	29,575	2,200	1993	17.1
SALERNO - CATANIA - VALLETTA - CIVITAVECCHIA	RO-PAX	1	21,357	1,960	1995	17.6
VALENCIA - BARCELONA - LIVORNO - SAVONA	RO-RO	3	97,939	11,447	2011	20.1
VALENCIA - CAGLIARI - SALERNO	RO-RO	1	32,632	3,810	2012	20.1

RO-PAX RO-RO

Figure 31: Average characteristics of vessels in the South-Western European Motorways of the Sea corridor

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

Route	Traffic	No. Vessels	GT	Lane Metres	Year Built	Service Speed (Knots)
ANCONA - IGOUMENITSA - PATRAS - IGOUMENITSA	RO-PAX	3	154,739	10,323	2008	22.5
BRINDISI - CORFU - IGOUMENITSA - PATRAS	RO-PAX	2	51,979	4,300	2003	21.2
PATRAS - IGOUMENITSA - BARI - IGOUMENITSA	RO-PAX	2	51,275	5,083	2008	21.6
TRIESTE - CESME	RO-RO	4	103,982	13,166	1992	16.0
TRIESTE - HAYDARPASA	RO-RO	3	87,437	10,989	2009	19.4
TRIESTE - ISTANBUL	RO-RO	7	200,949	25,426	2006	19.2
VENICE - CORINTHOS	RO-RO	2	31,325	2,959	1977	16.2

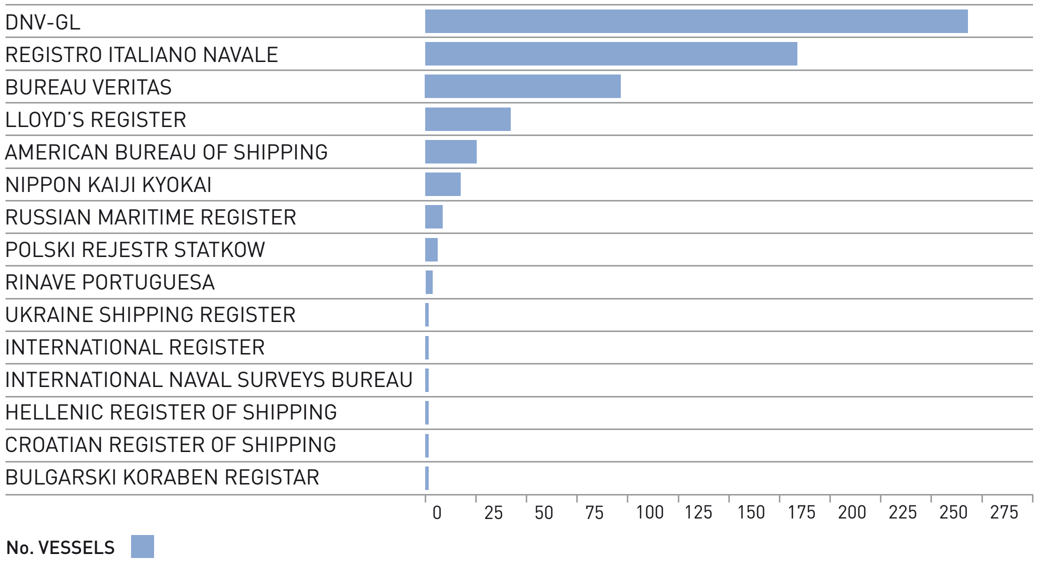
RO-PAX RO-RO

Figure 32: Average characteristics of vessels in the South-Eastern European Motorways of the Sea corridor

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

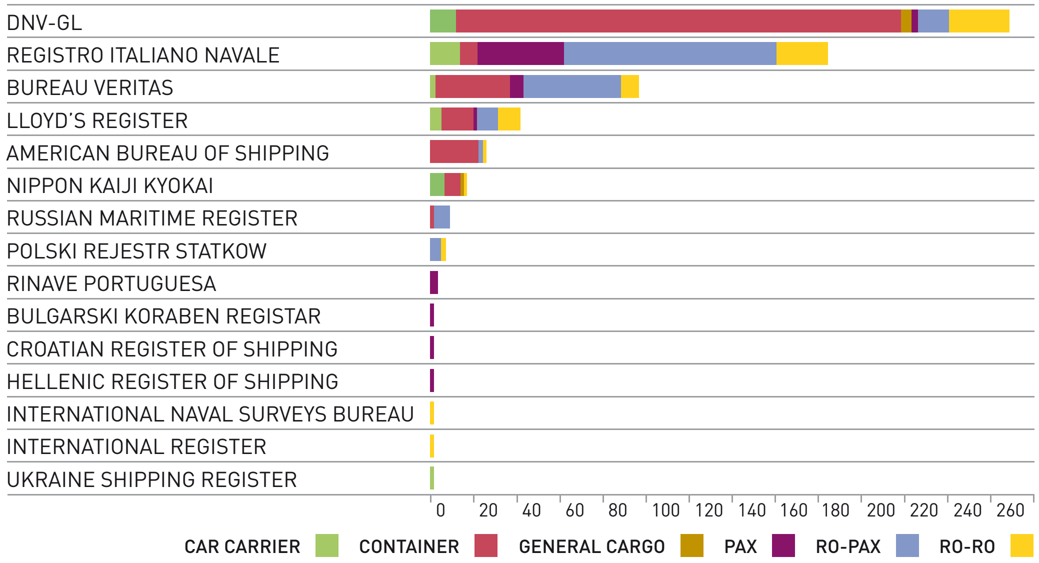
4.6 CLASSIFICATION SOCIETIES

The Classification Societies of SSS vessels operating in the Mediterranean Sea in 2013 have been studied and the results are shown below. DNV-GL has the largest number of SSS vessels operating in the Mediterranean sea. Approximately 41% of the SSS fleet is classified under its rules and standards. The major Classification Societies are DNV-GL, Registro Italiano Navale (RINA), Bureau Veritas (BV), Lloyd's Register, and the American Bureau of Shipping (ABS) as 90% of the fleet on SSS services is covered by one of these companies' rules. Classification societies and the certifications they issue tend to specialise in different types of vessels. DNV-GL mainly covers container ships, general cargo and Ro-ro vessels, whereas RINA leads the classification of passenger vessels, car carriers and Ro-pax vessels.



Graph 28: Classification societies according to number of vessels

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

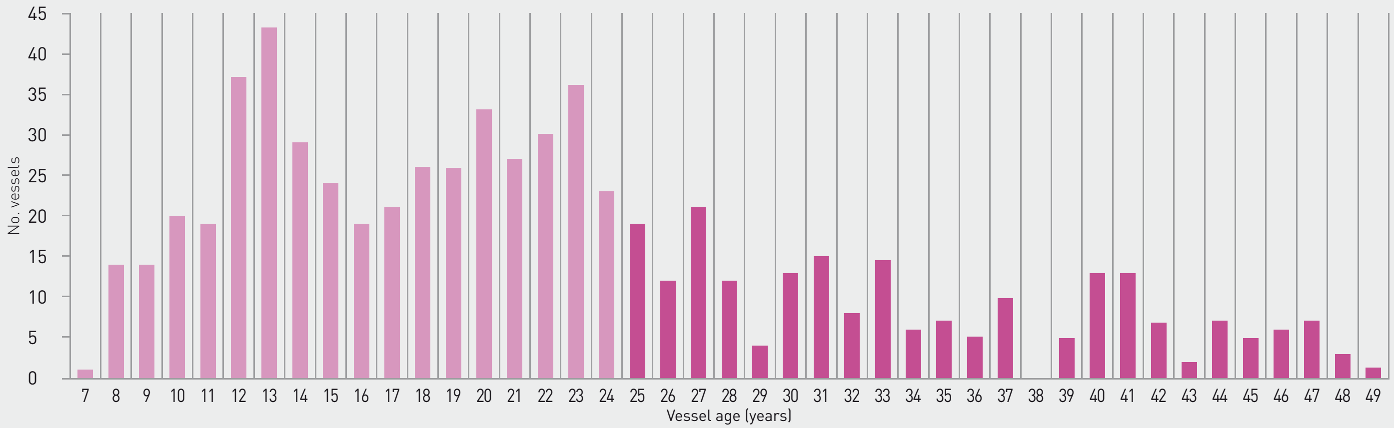


Graph 29: Number of vessels by vessel type and by classification society

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

4.7 AGE OF THE FLEET IN 2020

The following graph shows the number of vessels according to their age in 2020. Two age ranges were identified: 12 to 14 years old (109 vessels in total), and 20 to 23 years old (126 vessels). According to the results, 64% of the total number of vessels will be less than 23 years old by 2020.



Graph 30: Number of vessels according to vessel age in 2020

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

5 FUEL CONSUMPTIONS AND EMISSIONS IN THE MEDITERRANEAN

FUEL CONSUMPTIONS AND EMISSIONS IN THE MEDITERRANEAN

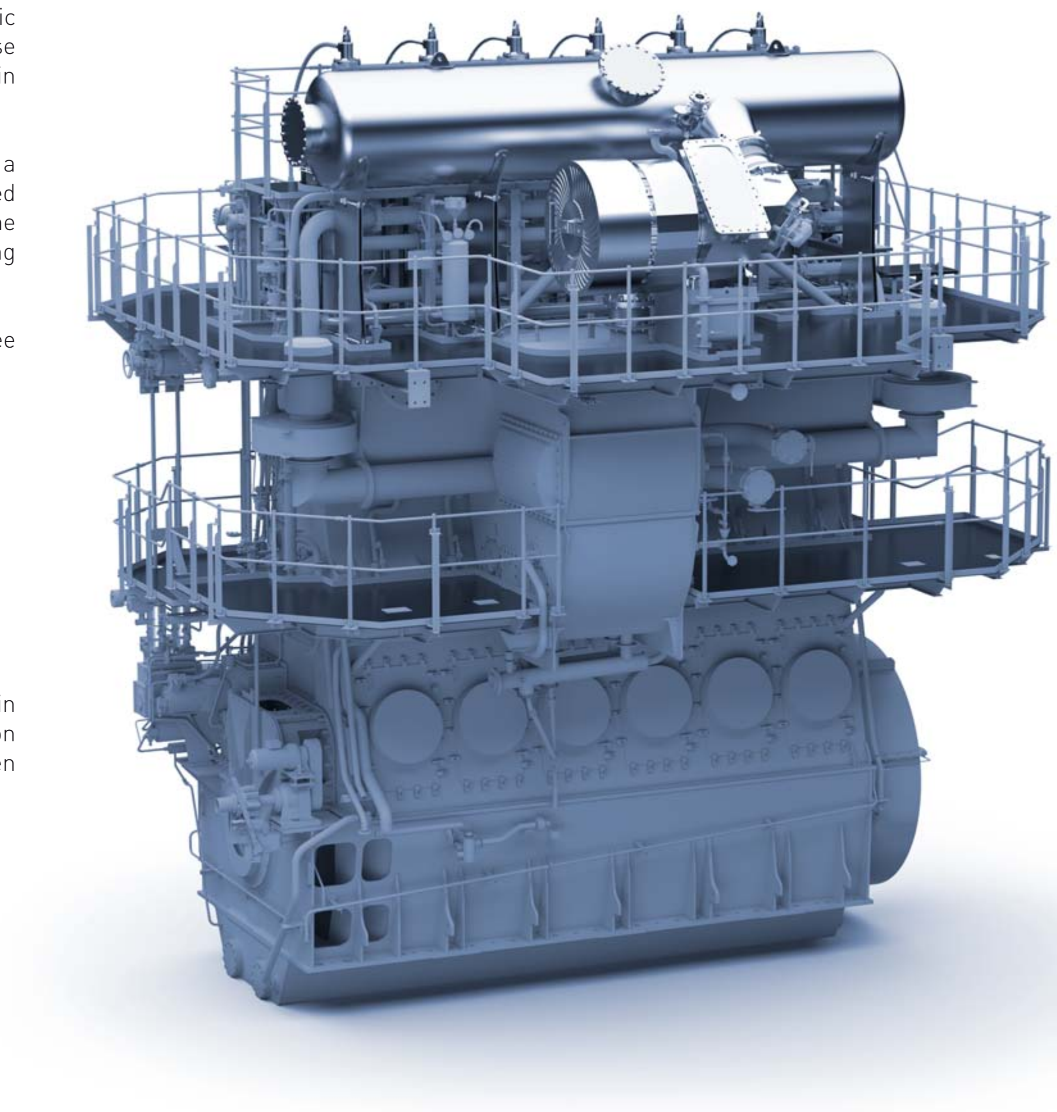
This chapter analyses the fuel consumption of vessels operating on the regular Short Sea Shipping services included in the study, both in the current situation, as well as in two "what-if" scenarios in which the entire fleet would be hypothetically powered by either LNG or by MGO fuels, which would enable the industry to comply with legislation on emissions in ECA areas[1]. This simulation enables a first approach for an analysis of sea carrier costs, calculating current expenditure on fuel, and estimating expenditure if LNG or MGO were to be used. In addition to showcasing the economic advantages of using LNG to power vessels in an initial approach, this will also serve as a base case to define foreseeable scenarios for the 2020 horizon, in which the advantages of using LNG in different market situations will be explored in greater depth.

The analysis of fuel consumption does not focus exclusively on fuel use. It is completed with a calculation of the emissions associated with this consumption, emphasising the estimated reductions that could be achieved by converting the fleet to LNG, the economic valuation of the externalities produced by the shipping industry, and the savings that could be generated by using LNG now, and in 2020.

The most significant results obtained for consumption and emissions are presented from three different perspectives:

- **Global indicators**
- **Indicator by area**
- **Indicators by shipping line**

In addition, a specific analysis of High-Speed Craft has been included, for the same reasons as in the fleet analysis, given their technical specificities. Finally, in the case of the fuel consumption analysis, a simulation of the potential LNG bunkering demand per port has been carried out, given shipping service supply conditions, and the technical requirements of the vessels.



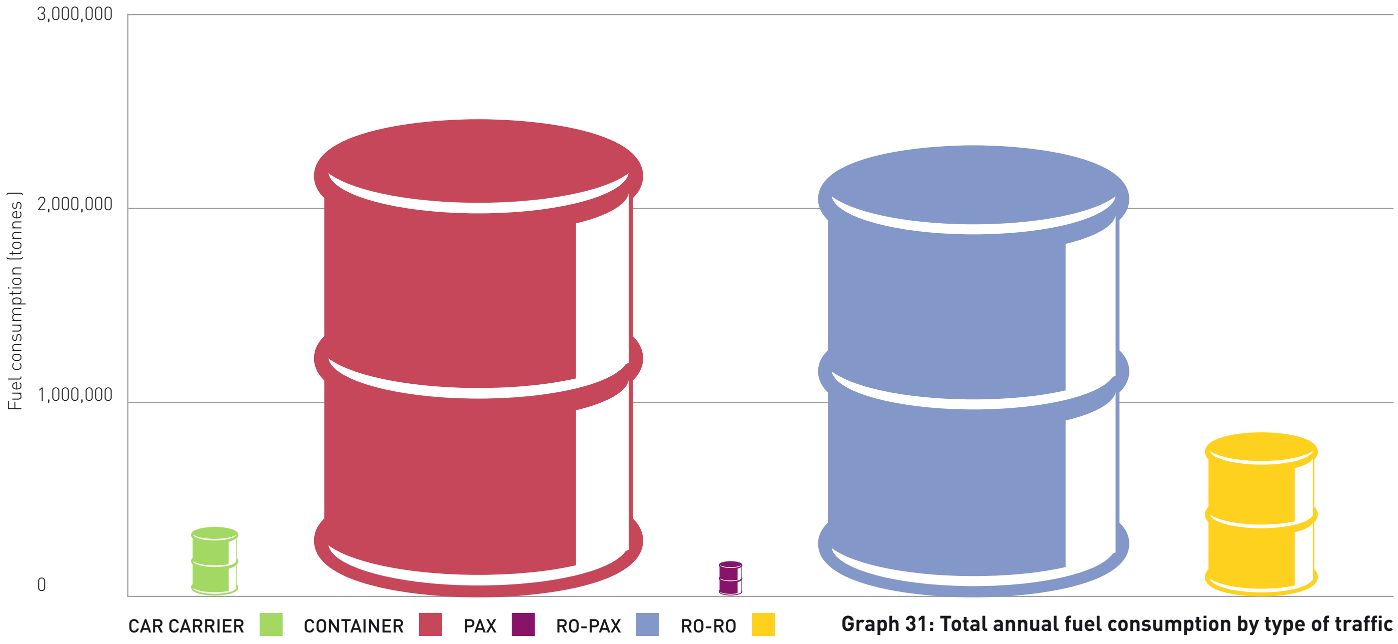
1 Therefore, and for the purposes of this section, when the expressions "LNG-case" or "MGO-case" are used, they shall refer to a hypothetical situation which sets out what would happen if the entire fleet analysed in the study were powered by LNG or MGO, respectively.

5.1 FUEL CONSUMPTION AND SAVINGS

5.1.1 Global indicators

The first step in this part of the study has been to calculate the amount of fuel consumed by ships operating on SSS services. According to the estimates, the total annual fuel consumption of the vessels included in the study stands at 5,965,576 tonnes. The largest consumers of fuel are container ships and Ro-pax ships, which together account for around 80% (40 and 40% respectively) of total fuel consumption. These types of ships also constitute the most numerous group of vessels in the database (73%) as analysed in previous sections.

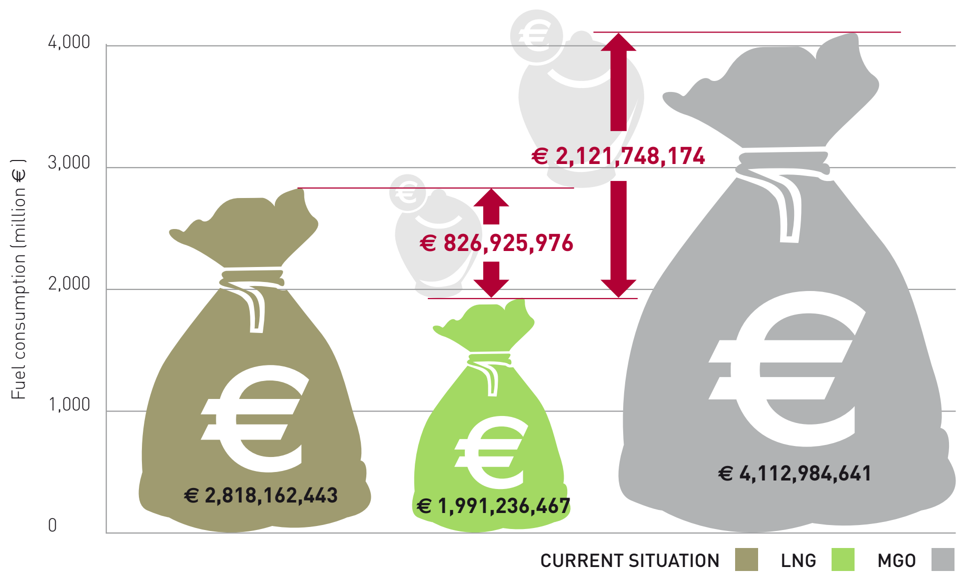
These figures show the global savings that the industry would make, ceteris paribus, in the hypothetical case were the fleet is propelled by LNG. This could be considered one of the key factors when choosing LNG as a fuel for vessels. As a result, it is convenient to conduct an in-depth analysis of this approach and the nature of those savings. Thus, the next part of the analysis establishes the value of cost savings resulting from using LNG instead of current fuels or MGO for services running on reference distance ranges, and for different types of freight. In general, the study reveals that Ro-pax ships mainly run on shorter distances, hence these vessels generate the greatest savings on shorter routes. Container ships account for the greatest share of savings on longer distances (over 1,500 nautical miles), explained by long sailing times associated with those routes.



Graph 31: Total annual fuel consumption by type of traffic

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

TOTAL ANNUAL FUEL CONSUMPTION 5,965,576 (Tonnes)



Graph 32: Total annual fuel consumption and potential savings by SSS services in the Mediterranean

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

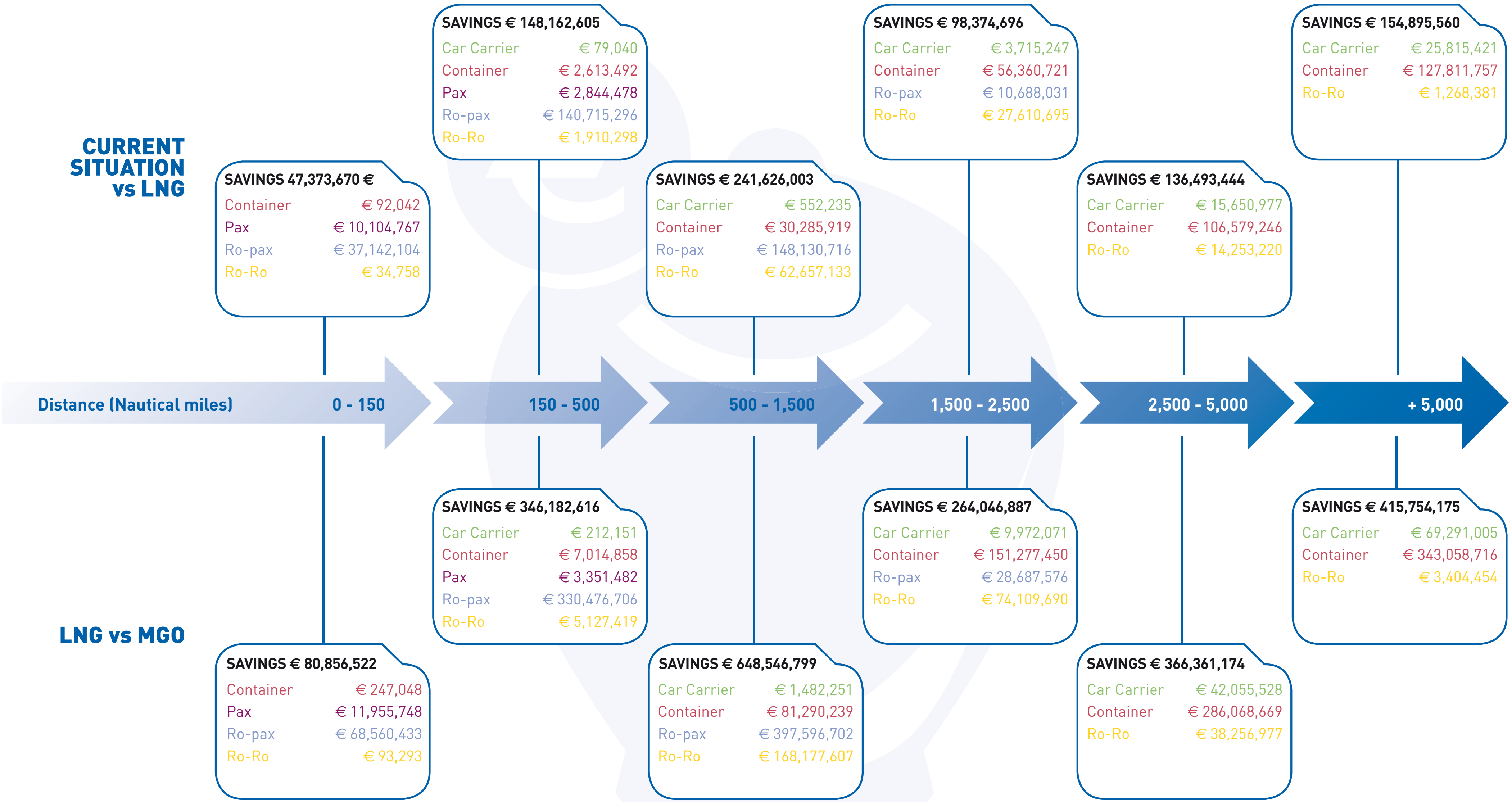
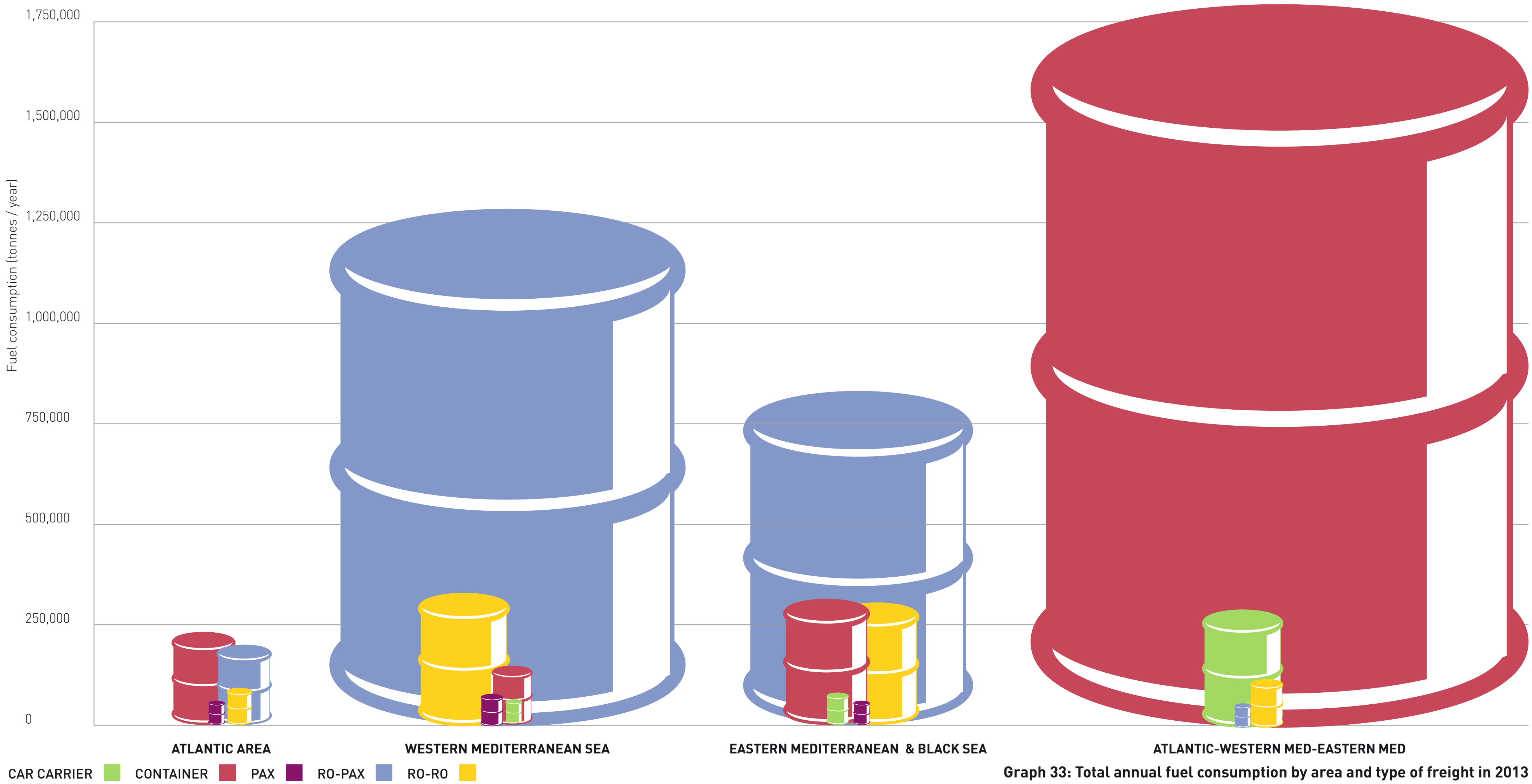


Figure 33: Total annual potential fuel savings "current fuels compared to LNG" and "LNG compared to MGO" by distance range and freight type

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

5.1.2 Indicators by area

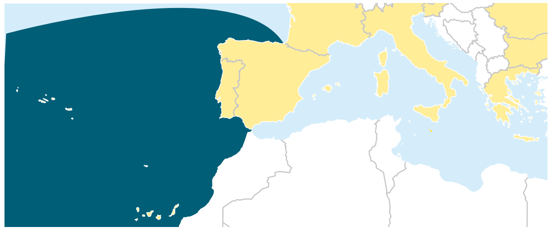
When dividing the entire region under study into four areas, it becomes evident that the largest consumers of fuel are ships operating on services in the Atlantic-Western Med-Eastern Med area. In this area, there are mainly container vessels covering long distance routes, which use over 1.79 million tonnes of fuel per year. Car carriers are the next most common freight type with around 0.29 million tonnes. The remaining types of ships (Ro-ro and Ro-pax) have only a marginal share of fuel consumption within this area. The second region in terms of fuel consumption is the Western Mediterranean. Ro-pax vessels dominate this area in terms of fuel consumption (› 1.27 million tonnes/year). The situation is similar in the Eastern Mediterranean & the Black Sea, with Ro-pax vessels that sail in this area consuming almost ~0.8 mt/year of fuel. The following graph shows that the highest costs are generated by ships operating on the services running through the Atlantic–Western Med–Eastern Med area, in line with previously mentioned results. In 2013, the total annual cost of fuel consumed by vessels operating in these areas was estimated at €1,031,140,004, which represents 37% of the total cost estimated for all the areas included in the study. The second region in terms of fuel cost is the Western Mediterranean (€837,952,652 in 2013), followed by the Eastern Mediterranean & Black Sea (€707,019,574), and finally, the Atlantic area (€242,050,213).



Graph 33: Total annual fuel consumption by area and type of freight in 2013

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

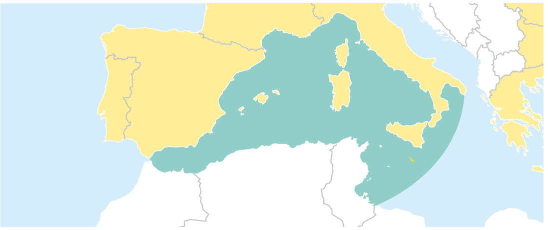
The savings generated by using LNG instead of the current fuels or MGO, are consistent with the previous analysis of total fuel costs generated by ships. This means that in the hypothetical cases, the greatest savings would be made in the areas where the total cost is the highest.



ATLANTIC AREA

FUEL CONSUMPTION	
CURRENT CONSUMPTION	€ 242,050,213
LNG CONSUMPTION	€ 165,472,114
MGO CONSUMPTION	€ 341,789,774

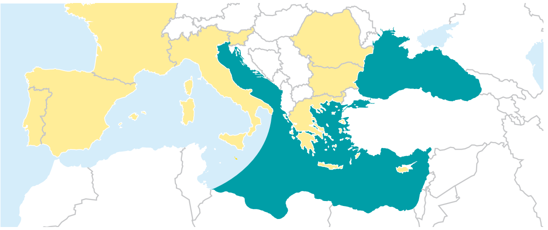
FUEL SAVINGS	
SAVINGS LNG vs. CURRENT FUELS	€ 76,578,099
SAVINGS LNG vs. MGO	€ 176,317,660



WESTERN MEDITERRANEAN SEA

FUEL CONSUMPTION	
CURRENT CONSUMPTION	€ 837,952,652
LNG CONSUMPTION	€ 589,666,406
MGO CONSUMPTION	€ 1,217,981,345

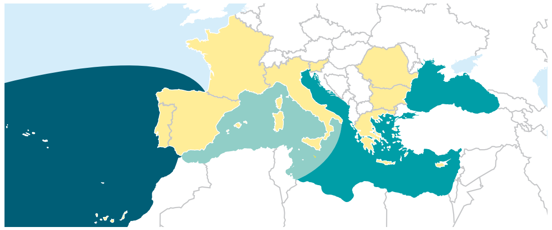
FUEL SAVINGS	
SAVINGS LNG vs. CURRENT FUELS	€ 248,286,246
SAVINGS LNG vs. MGO	€ 628,314,939



EASTERN MEDITERRANEAN & BLACK SEA

FUEL CONSUMPTION	
CURRENT CONSUMPTION	€ 707,019,574
LNG CONSUMPTION	€ 497,979,422
MGO CONSUMPTION	€ 1,028,597,933

FUEL SAVINGS	
SAVINGS LNG vs. CURRENT FUELS	€ 209,040,152
SAVINGS LNG vs. MGO	€ 530,618,511



ATLANTIC - WESTERN MED - EASTERN MED

FUEL CONSUMPTION	
CURRENT CONSUMPTION	€ 1,031,140,004
LNG CONSUMPTION	€ 738,118,526
MGO CONSUMPTION	€ 1,524,615,589

FUEL SAVINGS	
SAVINGS LNG vs. CURRENT FUELS	€ 293,021,478
SAVINGS LNG vs. MGO	€ 786,497,063

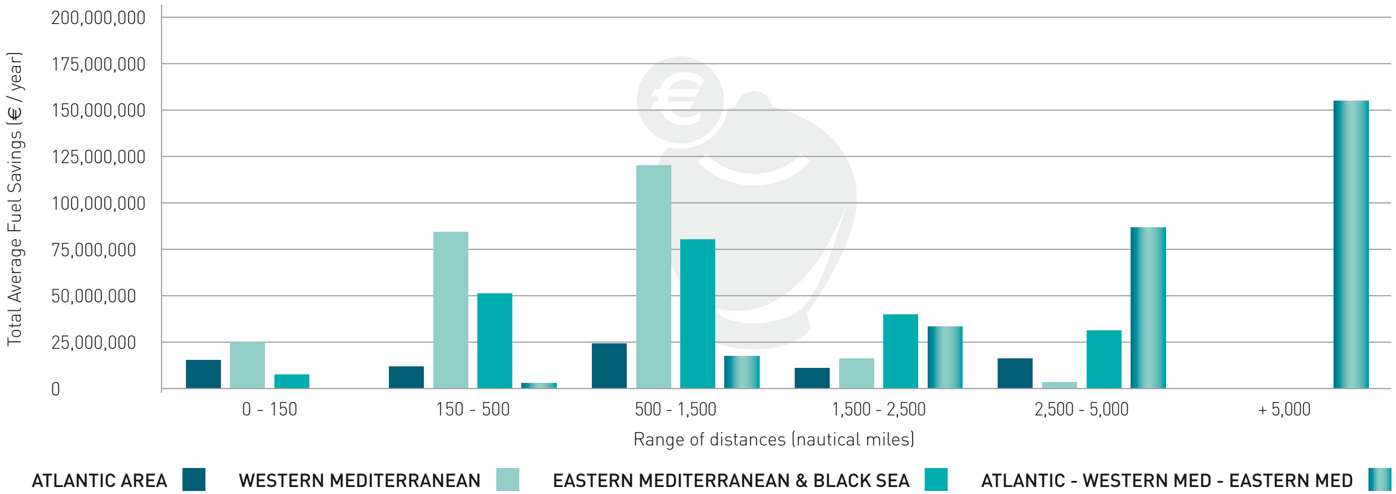
ATLANTIC AREA — WESTERN MEDITERRANEAN — EASTERN MEDITERRANEAN & BLACK SEA — ATLANTIC - WESTERN MED - EASTERN MED

Figure 34: Total annual fuel consumption by area and total annual potential fuel savings estimated by area in 2013

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

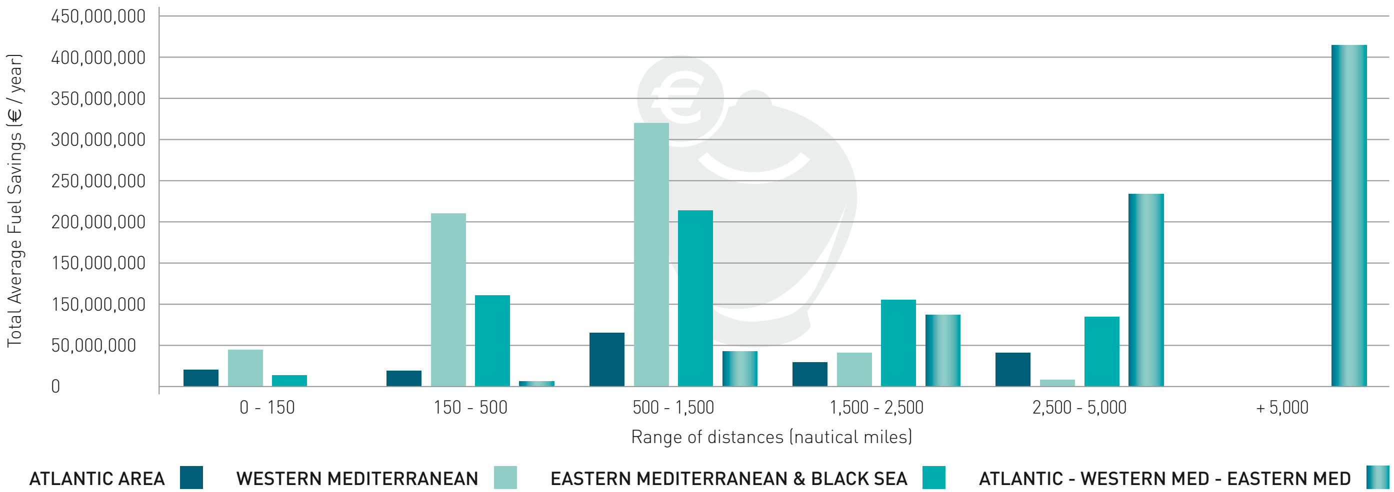
FUEL CONSUMPTIONS AND EMISSIONS IN THE MEDITERRANEAN

The comparison of the cost savings for different distance ranges in the four areas under study shows that for the Atlantic-Western-Eastern Mediterranean area, savings are greatest on routes longer than 5,000 nautical miles, although significant savings would also be achieved on routes ranging from 2,500 to 5,000 nautical miles. In the case of the Western and Eastern Mediterranean areas, the benefits would be especially high for routes between 500 to 1,500 nautical miles, and 150 to 500 nautical miles, as many vessels are deployed in SSS services within these distance ranges. In the case of the Atlantic area, the cost difference calculated between the LNG and MGO-case is highest for distances ranging from 500 to 1,500 nautical miles, and from 2,500 to 5,000 nautical miles.



Graph 34: LNG vs current situation savings in Euros by distance range according to the area

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database



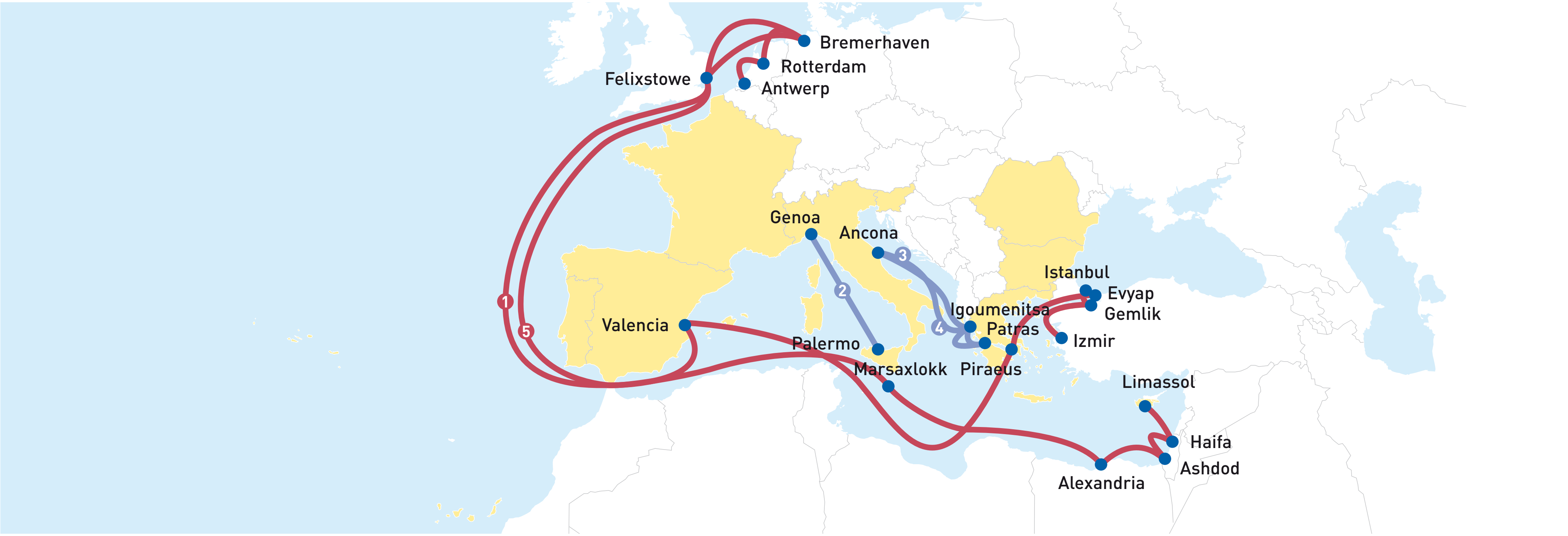
Graph 35: LNG vs MGO savings in Euros by distance range according to the area

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

5.1.3 Indicators by shipping line

The MED Short-Sea Lines database contains information about all regular SSS services and vessels operating in the area. This database permits the analysis of all those services as individual business cases, focusing in the interest of private companies in this issue. In this sense, the following section deals with cost savings for individual shipping lines. The following figure shows the five shipping lines, which would generate the greatest cost savings from using LNG instead of current fuels. This top five ranking is dominated by two container and three Ro-pax routes. As stated, it is worth noting that the container and Ro-pax services included in the study accounts for approximately 80% of the total savings calculated for all routes. Meanwhile, the annual potential savings for the top-ranked shipping lines amount to approximately €95 million.

Similarly, a comparison of fuel costs in the LNG and MGO-case indicates that the ranking of annual savings is similar to the one above (the same routes are in the same position on the ranking). However, the savings are even higher than in the comparison of LNG and current fuels. For the five shipping lines shown in the figure below annual fuel costs when using LNG are about €254 million lower than costs using MGO. In addition to container and Ro-pax connections, it could be highlighted that some car carrier services that cover the whole Mediterranean are also relevant savers in this issue. On the other hand, savings obtained by pax services are quite short compared to the rest of the lines due to their lower aggregated consumption.



Service	Annual savings Current fuels vs LNG (€)	Annual savings LNG vs MGO (€)
1 AEGEAN SEAGO	29,588,693	79,418,820
2 PALERMO - GENOA	18,567,560	49,837,069
3 ANCONA - IGOUMENITSA - PATRAS	15,625,264	41,939,670
4 PATRAS - IGOUMENITSA - ANCONA	15,479,624	41,548,760
5 EAST MED - NORTH EUROPE	15,239,776	40,904,985

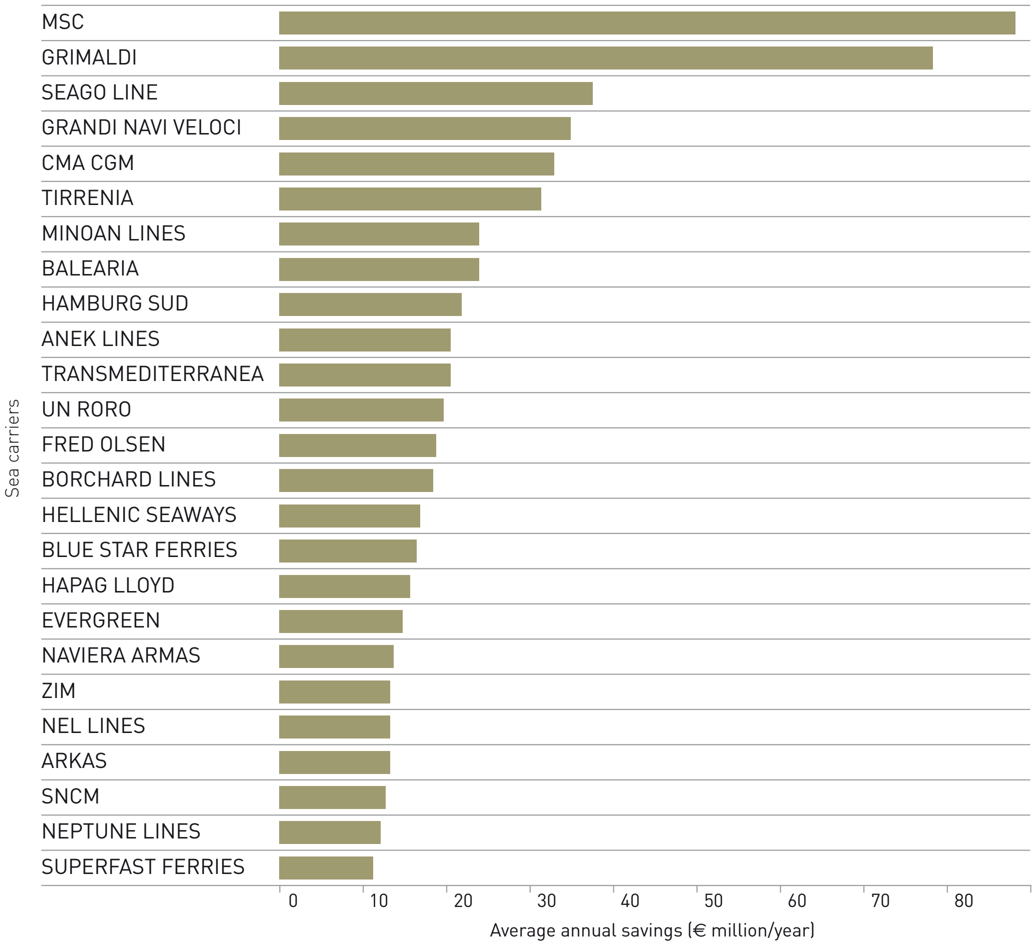
CONTAINER RO-PAX

Figure 35: LNG vs current fuels and LNG vs MGO – Ranking of annual potential savings in Euros by shipping line

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

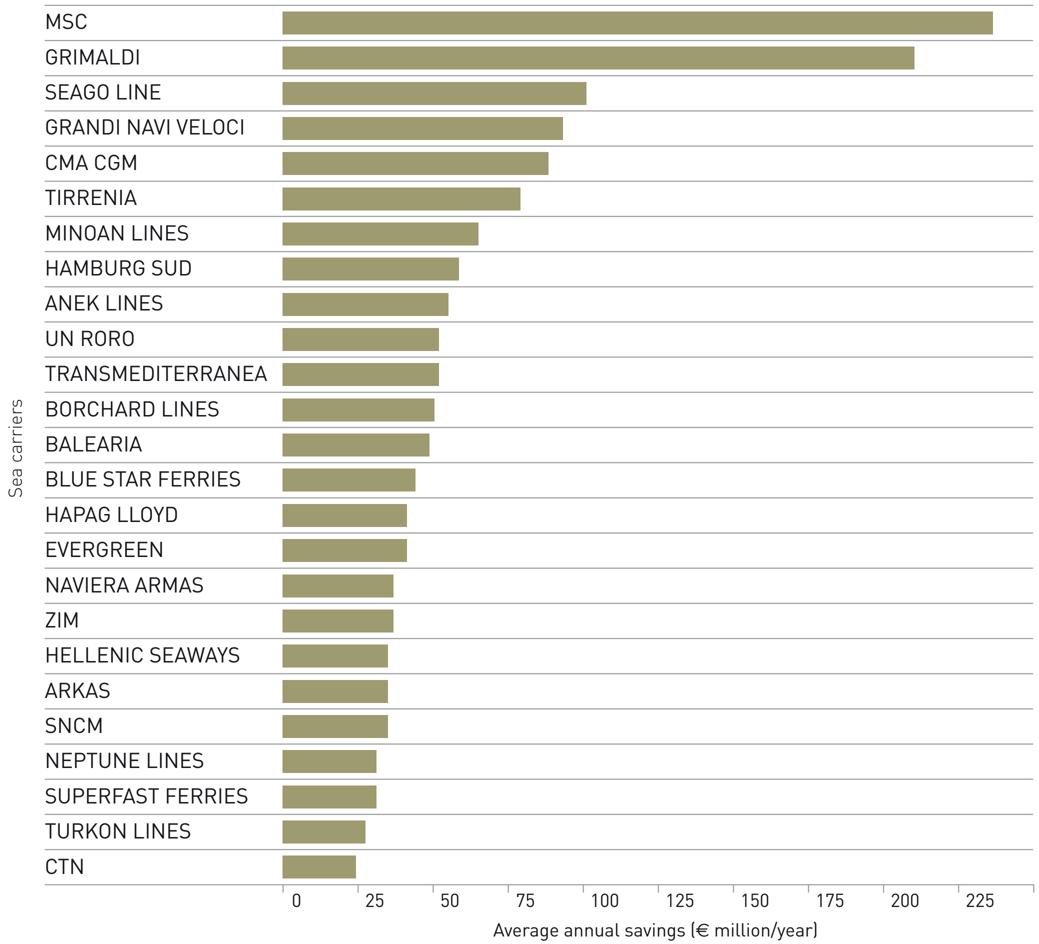
The ranking of savings from using LNG instead of traditional fuels has been also compiled for each sea carrier included in the study to complete the business perspective. From a total of 25 operators (those with higher benefits), the greatest savings from the comparison of annual fuel costs using LNG, current fuels, and the MGO-case are obtained by the container carrier, Mediterranean Shipping Company (over €88 million). Significant savings are also estimated for the short sea operator Grimaldi (€78,393,506). Savings ranged from €20-40 million for nine operators (three container operators, four Ro-pax operators and two Ro-ro operators), and €10-20 million for 14 operators (five container operators, six Ro-pax operators, two Ro-ro operators and one car carrier).

When the fuel costs for the LNG and the MGO-case are compared, the ranking of savings calculated for shipping companies is the same as the one before for the first seven companies on the list. Afterwards, the order of the companies changes, gaining importance, those companies specialised in container traffic, as the current costs are significantly smaller than in the case where distillate fuels are used to meet the emission requirements. The biggest cost savings are estimated for the same two companies as in the previous case: MSC (€236,458,662) and Grimaldi (€210,415,506). MSC and Grimaldi together accounted for around 12% of the total savings that could be made by all operators included in the study. Estimated savings for nine companies (three container operators and six Ro-ro and Ro-pax operators) were between €50-125 million, savings range from € 25-50 million in the case of 13 operators (six container operators, six Ro-ro and Ro-pax operators and one car carrier) , while for one operator (Ro-ro operator) savings are less than €25 million.



Graph 36: Ranking of annual savings in Euros by top sea carriers (Current fuels vs LNG)

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database



Graph 37: Ranking of annual savings in Euros by top sea carriers (LNG vs MGO case)

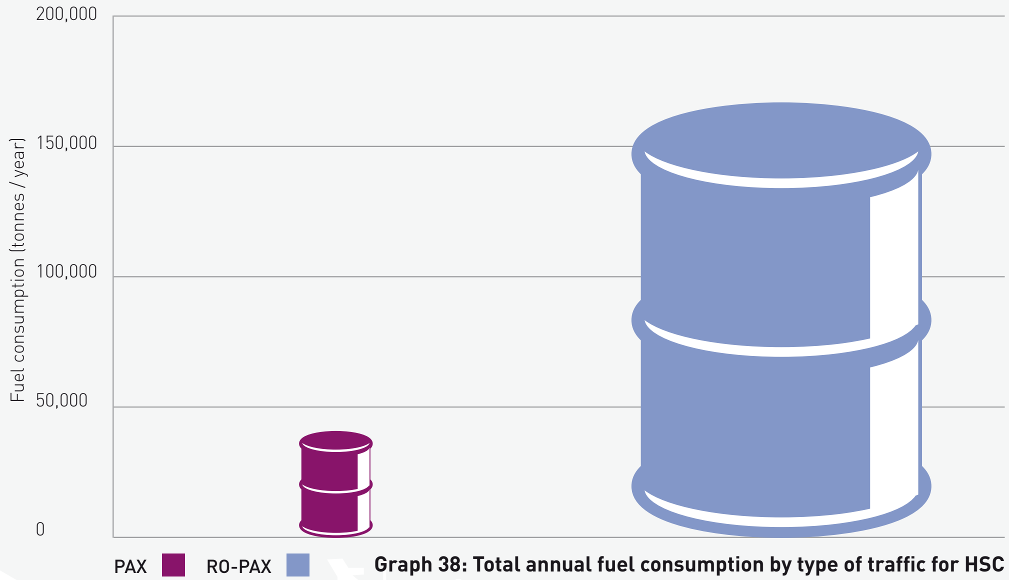
Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

FUEL CONSUMPTIONS AND EMISSIONS IN THE MEDITERRANEAN

A separate analysis has been conducted for High-Speed Craft (HSC), due to its major operational differences compared to traditional vessels that lies on the fact that the latter mainly use distillate fuels instead of heavy fuels. 70 HSC operating in this region represent 3% of the total annual fuel consumption, a percentage that grows up to 5% in monetary terms. The distribution of the total consumption depending on the type of vessels is clearly explained by the total number of each kind of vessel but also by the longer distances covered by Ro-pax services. This reason justifies the level of fuel consumption registered in each geographical area.

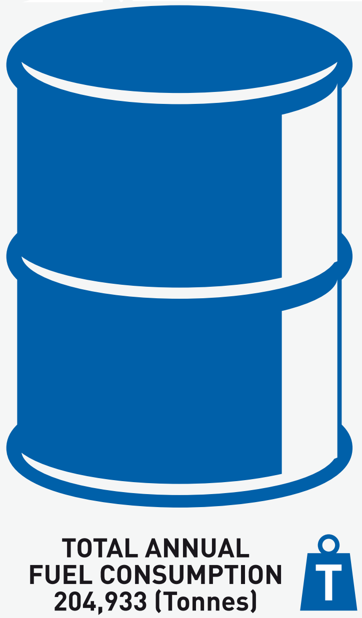
The three areas are quite similar in terms of volume consumption but they differ when the type of vessel is considered. The same circumstance is observed if the data is compiled in monetary terms.

From the cost savings point of view, it is worth noting that the differences between the estimated savings from the use of LNG compared to current fuels, and LNG compared to the MGO case are not very significant in the case of high-speed craft, as base prices present small differences given the current market situation. However, using LNG instead of the currently used fuels, or instead of MGO, would generate notable cost savings for companies operating in the HSC segment.

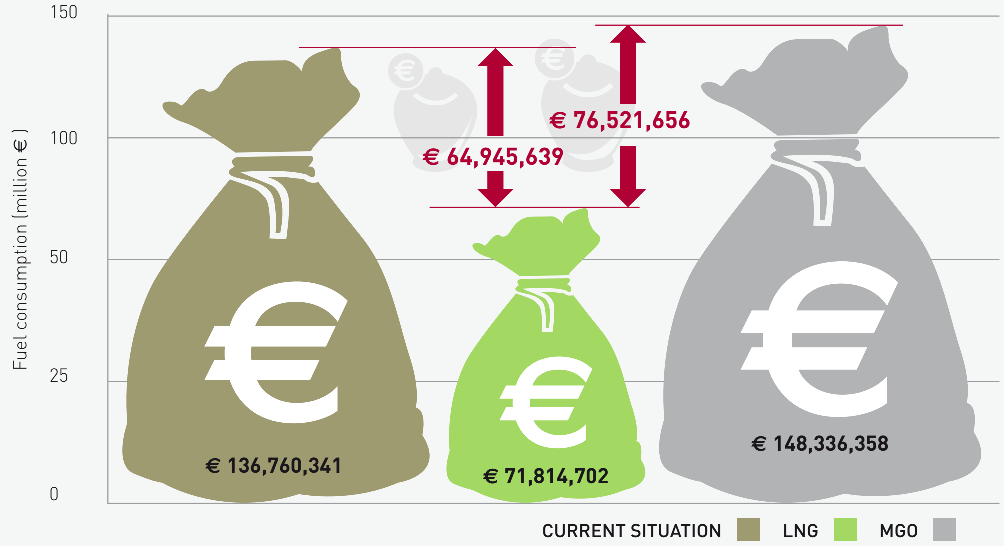


Graph 38: Total annual fuel consumption by type of traffic for HSC

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

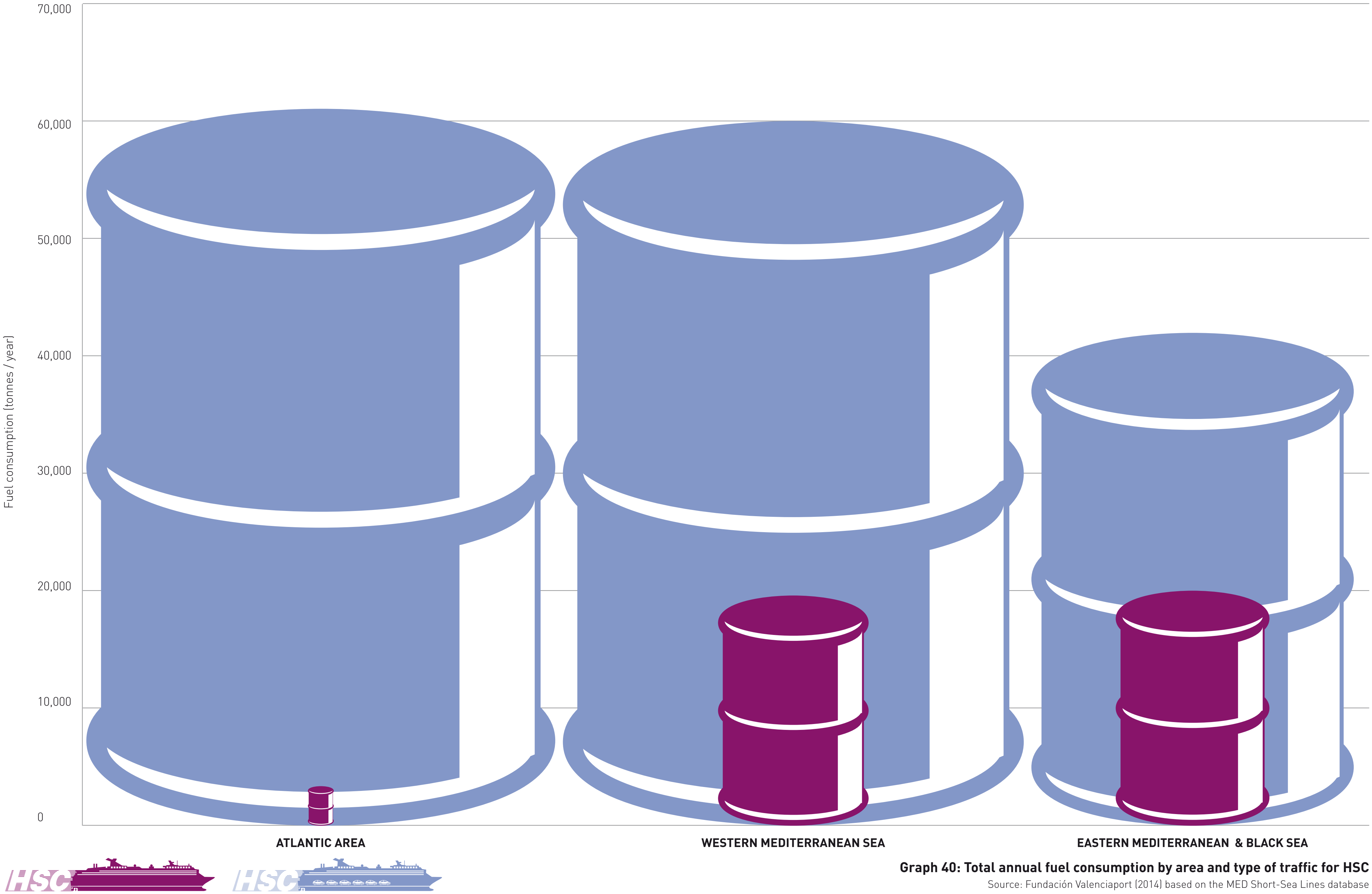


TOTAL ANNUAL FUEL CONSUMPTION 204,933 (Tonnes)



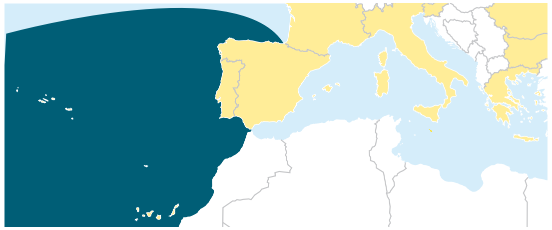
Graph 39: Total annual fuel consumption and potential savings for HSC

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database



Graph 40: Total annual fuel consumption by area and type of traffic for HSC

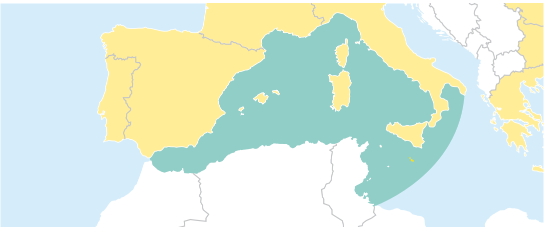
Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database



ATLANTIC AREA

FUEL CONSUMPTION	
CURRENT CONSUMPTION	€ 40,868,081
LNG CONSUMPTION	€ 21,460,381
MGO CONSUMPTION	€ 44,327,341

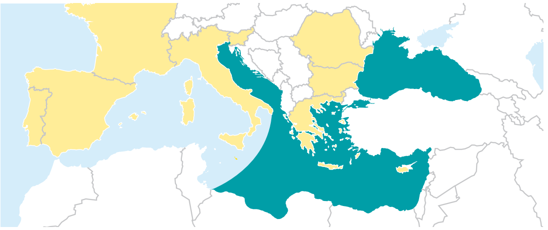
FUEL SAVINGS	
SAVINGS CURRENT FUELS vs. LNG	€ 19,407,700
SAVINGS LNG vs. MGO	€ 22,866,960



WESTERN MEDITERRANEAN SEA

FUEL CONSUMPTION	
CURRENT CONSUMPTION	€ 53,290,604
LNG CONSUMPTION	€ 27,983,616
MGO CONSUMPTION	€ 57,801,363

FUEL SAVINGS	
SAVINGS CURRENT FUELS vs. LNG	€ 25,306,988
SAVINGS LNG vs. MGO	€ 29,817,747



EASTERN MEDITERRANEAN & BLACK SEA

FUEL CONSUMPTION	
CURRENT CONSUMPTION	€ 42,601,656
LNG CONSUMPTION	€ 22,370,705
MGO CONSUMPTION	€ 46,207,654

FUEL SAVINGS	
SAVINGS CURRENT FUELS vs. LNG	€ 20,230,951
SAVINGS LNG vs. MGO	€ 23,836,949

ATLANTIC AREA WESTERN MEDITERRANEAN EASTERN MEDITERRANEAN & BLACK SEA

Figure 36: Total annual fuel consumptions and potential savings by area for High-Speed Craft (HSC) in 2013

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

5.1.4 LNG bunkering potential demand

Thorough analyses of regular shipping lines and vessels operating in the Mediterranean Sea and the Atlantic, as well as estimates of these ships' fuel consumption, have enabled the calculation of the potential LNG bunkering demand for SSS services. According to the estimate, the maximum annual LNG bunkering potential for SSS services in the Mediterranean Sea and Atlantic region is 10,959,135 m^3. This area covers the seaports located along the coasts of Spain, Portugal, Southern France, Italy, Greece, Bulgaria, Romania, Slovenia, Malta, and Cyprus. Core ports have been divided into five groups, according to potential LNG bunkering demand:

- › 500,000 m^3
- 350,000-500,000 m^3
- 150,000-350,000 m^3
- 0-150,000 m^3

The greatest potential demand for LNG is in those ports that have dense regular line networks. There is one port (Piraeus, 685,550 m^3) in the first group and one port (Valencia, 442,000 m^3) in the second group. These two ports have a combined potential of LNG bunkering demand of 10% of the total potential in the analysed regions. Potential in four core ports (Livorno, Limassol, Genoa, Barcelona) ranged from 200,000 to 350,000 m^3, whilst in nine ports (Marsaxlokk, Trieste, Palermo, Algeciras, Ancona, Patras, Naples, Igoumenitsa and Palma), potential was estimated at 150,000-200,000 m^3. The fourth group of ports was the largest with 24 core ports having potential LNG bunkering demand below 150,000 m^3.

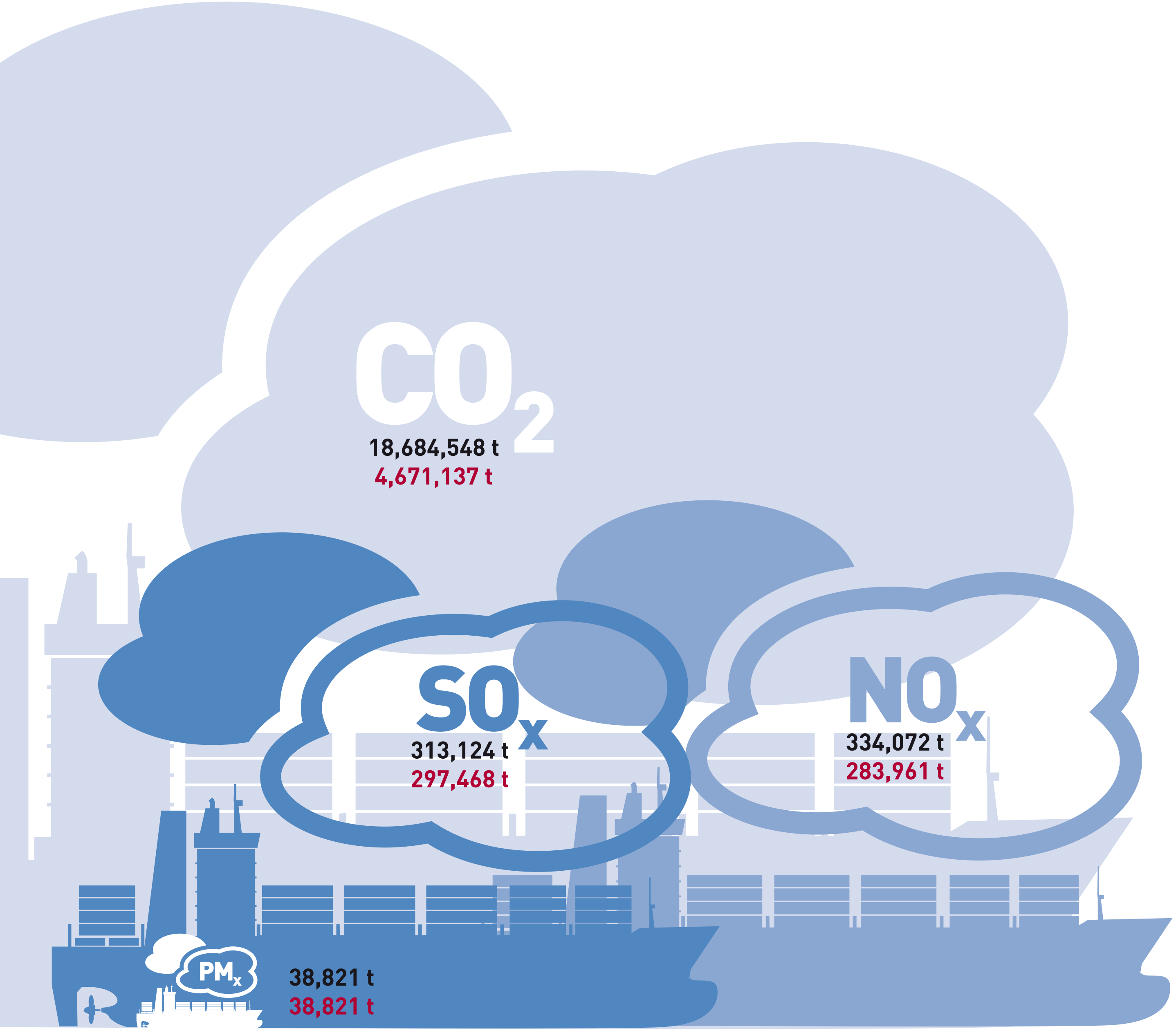
› 500,000	350,000-500,000	150,000-350,000	0-150,000
Piraeus	Valencia	Barcelona Genoa Limassol Livorno Palma Igoumenitsa Naples Patras Ancona Algeciras Palermo Trieste Marsaxlokk	Venice Marseille Las Palmas Ravenna Thessaloniki Valletta Koper Fos Bilbao Leixoes La Spezia Gioia Tauro Sines Palma Lisbon Constantza Tarragona Bari Gijón Cartagena Taranto Seville A Coruña Bourgas

Figure 37: Ranking of core ports according to the potential LNG maximum bunkering demand (m^3/year) in 2013

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

ANNUAL LNG MAXIMUM BUNKERING POTENTIAL DEMAND FOR SSS SERVICES (m^3/year):

10,959,135



5.2 ENVIRONMENTAL EMISSIONS AND SAVINGS

Fuel consumption and cost savings obtained from the use of LNG as marine fuel in Mediterranean shipping should be considered not only from a cost-effective point of view (positive effects of fuel savings for shipowners), but also as a way to limit external costs within the regional transport sector and to comply with international regulations. Decreasing CO_2, NO_x, SO_x and PM_x emissions would reduce the negative influence of shipping on the environment and society. Annual emissions for the shipping sector in the main areas of the Mediterranean Sea have been estimated based on the fuel consumption calculations provided in the previous section.

5.2.1 Global indicators

The total annual volume of emissions generated by ship engines equals 19.37 million tonnes. Over 96.5% of this total volume is composed of CO_2 (18.7 million tonnes), while NO_x accounts for 1.72% (334,072 tonnes) and SO_x for 1.62% (313,124 in tonnes). Container and Ro-pax ships are the main pollutants in the SSS network in the Mediterranean. According to the calculations, SO_x equals 313,124 tonnes and PM_x discharge is approximately 38,821 tonnes. It is evident that the reduction of pollutants emitted by ships constitutes a key challenge for the shipping sector and LNG is one of the most promising solutions that currently exists. It is theorised that global emissions could be decreased by up to 5.29 million tonnes (a decrease of 27.3%). It should be pointed out that using LNG as an alternative marine fuel will eliminate almost all NO_x, SO_x and PM_x emissions.

TOTAL ANNUAL EMISSIONS (Tonnes)

AVERAGE ANNUAL REDUCTIONS USING LNG (Tonnes)

Figure 38: Total annual emissions and potential reductions in SSS services in the Mediterranean

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

FUEL CONSUMPTIONS AND EMISSIONS IN THE MEDITERRANEAN

The estimates regarding emission costs indicate the main challenges for further development of a sustainable maritime transport system in the Mediterranean, with the major problem being high carbon dioxide emissions. It should also be emphasised that other types of discharge are harmful to society and the environment, and are also very costly. Although there is no real system to internalise external transport costs in Europe, a consistent, sustainable policy needs to be implemented. The best direction for the shipping industry to take is to implement a new and innovative source of ship propulsion, including alternative fuel technology. The implementation of LNG in the maritime transport sector can therefore be regarded as an important factor in further improving the environmental performance of shipping. Using this type of alternative fuel would decrease CO_2 emissions by 25% and could significantly lower the industry's external costs. Furthermore other types of pollution could also be radically decreased.

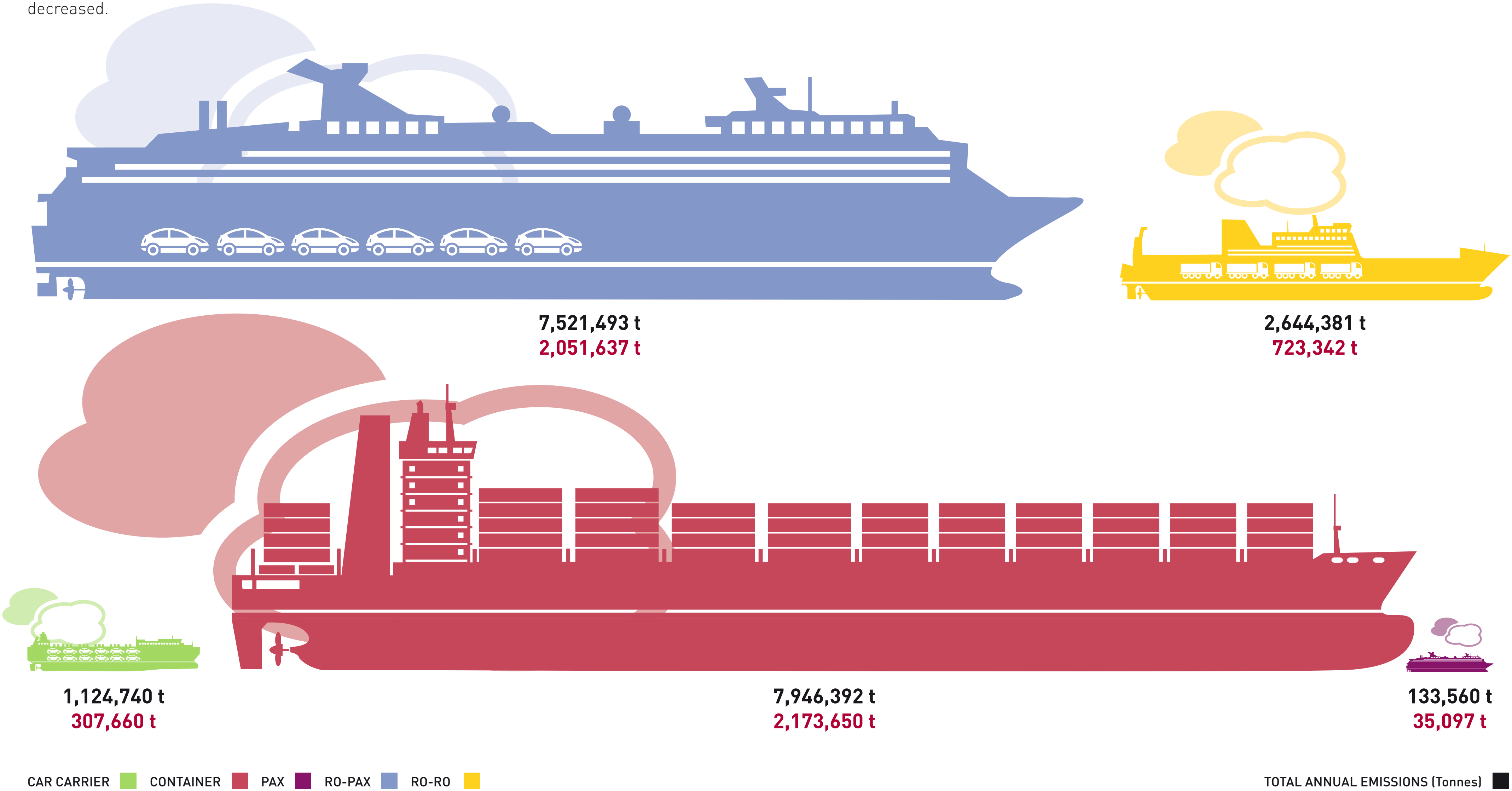


Figure 39: Total annual emissions by type of vessel in SSS services in the Mediterranean

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

The total value of emissions generated by the ships operating in the area of study totals €103,078,681 in a year. The emission cost structure is headed by CO_2 (81%). This result is mainly caused by the high volume of total CO_2 emissions, followed by nitrogen oxides, in this case explained by the high unit cost. Additionally, an initial estimate of the 2020 emission pattern has been calculated, only taking into account the expected variations in polluting substance prices.

TOTAL ANNUAL EMISSIONS 2013 (€)
TOTAL ANNUAL EMISSIONS 2020 (€)
AVERAGE ANNUAL REDUCTIONS USING LNG in 2013 (€)
AVERAGE ANNUAL REDUCTIONS USING LNG in 2020 (€)

Figure 40: Total annual emissions and potential reductions using LNG in SSS services in the Mediterranean

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

The distance range structure of potential emission savings has also been analysed. The largest part of the market navigates in the 500-1,500 nautical miles range and consequently total emission savings in this area of the market could reach the best results, reducing emissions by 1,610,067 tonnes per year. The results are as follows: 500-1,500 nm range (1,610,067 tonnes), +5,000 nm range (1,032,140 tonnes), 2,500-5,000 nm range (909,521 tonnes), 150-500 nm range (851,612 tonnes), 1,500-2,500 nm range (655,517 tonnes) and 0-150 nm range (193,709 tonnes).

Distance (Nautical miles): 0 - 150

FREIGHT TYPE	CO_2	NO_x	SO_x
Container	544	33	36
Pax	25,541	1,525	315
Ro-Pax	149,446	9,031	7,006
Ro-Ro	206	13	13

150 - 500

FREIGHT TYPE	CO_2	NO_x	SO_x
Car Carrier	468	28	31
Container	15,461	940	1,014
Pax	7,158	427	85
Ro-Pax	725,854	44,064	43,353
Ro-Ro	11,301	687	741

500 - 1,500

FREIGHT TYPE	CO_2	NO_x	SO_x
Car Carrier	3,267	199	214
Container	179,165	10,899	11,746
Ro-Pax	876,308	53,306	57,450
Ro-Ro	370,665	22,548	24,300

1,500 - 2,500

FREIGHT TYPE	CO_2	NO_x	SO_x
Car Carrier	21,979	1,337	1,441
Container	333,417	20,282	21,859
Ro-Pax	63,228	3,846	4,145
Ro-Ro	163,339	9,936	10,708

2,500 - 5,000

FREIGHT TYPE	CO_2	NO_x	SO_x
Car Carrier	92,647	5,636	6,074
Container	630,499	38,354	41,335
Ro-Ro	84,319	5,129	5,528

+ 5,000

FREIGHT TYPE	CO_2	NO_x	SO_x
Car Carrier	152,718	9,290	10,012
Container	756,105	45,994	49,570
Ro-Ro	7,503	456	492

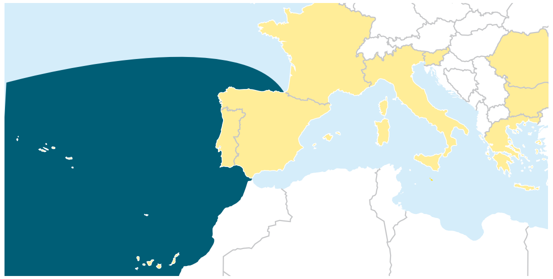
Figure 41: Total annual emission reductions in tonnes by distance range and freight type using LNG

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

5.2.2 Indicators by area

The volume of emissions is directly connected to fuel consumption in the four identified areas of shipping activity. Thus, the highest volume of emissions (CO_2, NO_x, SO_x and PM_x), is observed in the Atlantic-Western Med-Eastern Med area where container lines and car carrier traffic account for the largest part. CO_2 emissions reached 6.94 million tonnes in this area in 2013. In the other areas, the annual emission volume of carbon dioxide ranges from 5.54 to 1.55 million tonnes. Results were similar for other types of emissions such as NO_x, SO_x and PM_x.

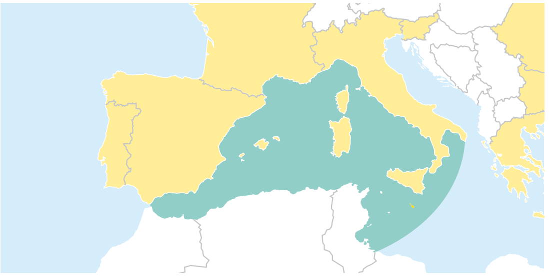
ATLANTIC AREA



Type of traffic	Total CO_2 emissions in tonnes	Total NO_x emissions in tonnes	Total SO_x emissions in tonnes	Total PM_x emissions in tonnes
CONTAINER	644,685	11,534	11,122	1,380
PAX	615	10	8	1
RO-PAX	608,072	10,814	7,735	951
RO-RO	294,811	5,274	5,086	631

CO_2 EMISSIONS	€ 6,897,162
NO_x EMISSIONS	€ 1,614,344
SO_x EMISSIONS	€ 24,670

WESTERN MEDITERRANEAN SEA



Type of traffic	Total CO_2 emissions in tonnes	Total NO_x emissions in tonnes	Total SO_x emissions in tonnes	Total PM_x emissions in tonnes
CAR CARRIER	29,202	522	504	62
CONTAINER	434,757	7,778	7,501	930
PAX	63,298	1,111	198	21
RO-PAX	3,986,604	71,261	66,076	8,189
RO-RO	1,017,253	18,200	17,550	2,177

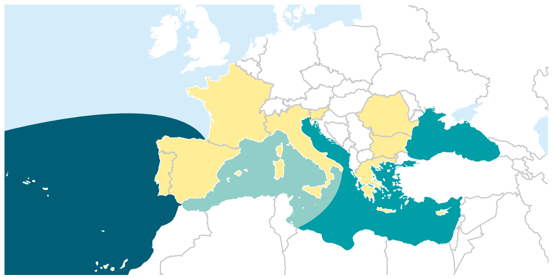
CO_2 EMISSIONS	€ 24,641,125
NO_x EMISSIONS	€ 5,776,193
SO_x EMISSIONS	€ 94,584

EASTERN MEDITERRANEAN & BLACK SEA

Type of traffic	Total CO_2 emissions in tonnes	Total NO_x emissions in tonnes	Total SO_x emissions in tonnes	Total PM_x emissions in tonnes
CAR CARRIER	148,689	2,660	2,565	318
CONTAINER	962,734	17,225	16,609	2,060
PAX	66,882	1,174	214	24
RO-PAX	2,564,017	45,828	42,299	5,242
RO-RO	929,129	16,623	16,030	1,989

CO_2 EMISSIONS	€ 20,811,321
NO_x EMISSIONS	€ 4,878,664
SO_x EMISSIONS	€ 80,050

ATLANTIC - WESTERN MED - EASTERN MED



Type of traffic	Total CO_2 emissions in tonnes	Total NO_x emissions in tonnes	Total SO_x emissions in tonnes	Total PM_x emissions in tonnes
CAR CARRIER	906,420	16,217	15,637	1,940
CONTAINER	5,618,588	100,524	96,934	12,027
RO-PAX	100,648	1,801	1,736	215
RO-RO	308,137	5,513	5,316	660

CO_2 EMISSIONS	€ 30,890,055
NO_x EMISSIONS	€ 7,247,300
SO_x EMISSIONS	€ 123,213

ATLANTIC AREA | WESTERN MEDITERRANEAN | EASTERN MEDITERRANEAN & BLACK SEA | ATLANTIC - WESTERN MED - EASTERN MED

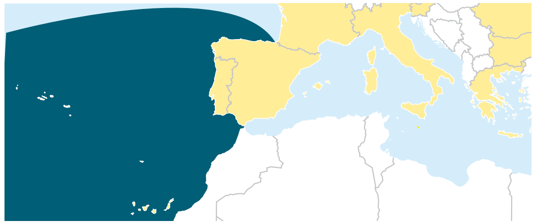
CAR CARRIER | CONTAINER | PAX | RO-PAX | RO-RO

Figure 42: Total annual emissions in tonnes and Euros by area in 2013

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

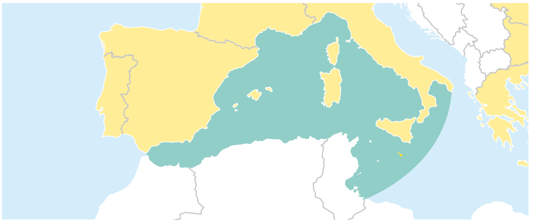
The cost savings by area associated with the use of LNG are consistent with the main pollutants, thus the main positive effect of LNG is the reduction of carbon dioxide emissions in the mixed area, where the costs of emissions could decrease by approximately €7.7 million. The largest part of these savings comes from reducing CO_2 and NO_x discharges. The Western Mediterranean market would see an important drop in emission costs by about €11.1 million. While €9.4 million in savings are also calculated for the Eastern Mediterranean and Black Sea region. The smallest change in costs would take place in the Atlantic area.

The distribution of savings related to the reduction of pollutant emissions due to the use of LNG as a fuel for vessels in the horizon 2020 is in line with the pattern shown for the different areas in 2013. It should be noted that the increase in the global reduction is explained by the evolution of CO_2 futures, which are expected to triple their unit price, increasing the value of CO_2 savings up to €110 million. Increasing interest in the internalisation of external transport costs as a concept, as well as the improvement of environmental awareness in Europe, should increase the price of externalities, including emissions. Thus, our results could end up becoming conservative and the amount of savings connected with the implementation of LNG as a fuel in the region would be even higher in the future.



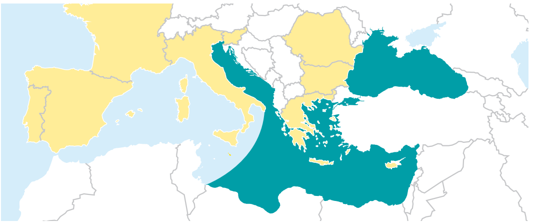
ATLANTIC AREA

2013		2020	
REDUCTIONS CO_2	€ 1,724,290.49	REDUCTIONS CO_2	€ 9,095,583.96
REDUCTIONS NO_x	€ 1,372,192.11	REDUCTIONS NO_x	NA
REDUCTIONS SO_x	€ 23,436.97	REDUCTIONS SO_x	NA



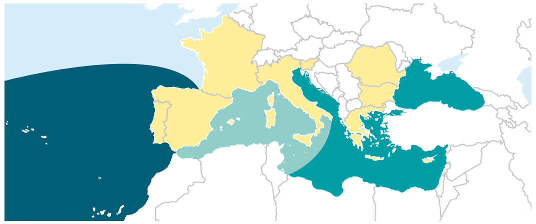
WESTERN MEDITERRANEAN SEA

2013		2020	
REDUCTIONS CO_2	€ 6,160,281.17	REDUCTIONS CO_2	€ 32,495,310.34
REDUCTIONS NO_x	€ 4,909,764.00	REDUCTIONS NO_x	NA
REDUCTIONS SO_x	€ 89,854.41	REDUCTIONS SO_x	NA



EASTERN MEDITERRANEAN & BLACK SEA

2013		2020	
REDUCTIONS CO_2	€ 5,202,830.24	REDUCTIONS CO_2	€ 27,444,783.51
REDUCTIONS NO_x	€ 4,146,864.72	REDUCTIONS NO_x	NA
REDUCTIONS SO_x	€ 76,047.85	REDUCTIONS SO_x	NA



ATLANTIC - WESTERN MED - EASTERN MED

2013		2020	
REDUCTIONS CO_2	€ 7,722,513.68	REDUCTIONS CO_2	€ 40,736,042.96
REDUCTIONS NO_x	€ 6,160,204.60	REDUCTIONS NO_x	NA
REDUCTIONS SO_x	€ 117,053.00	REDUCTIONS SO_x	NA

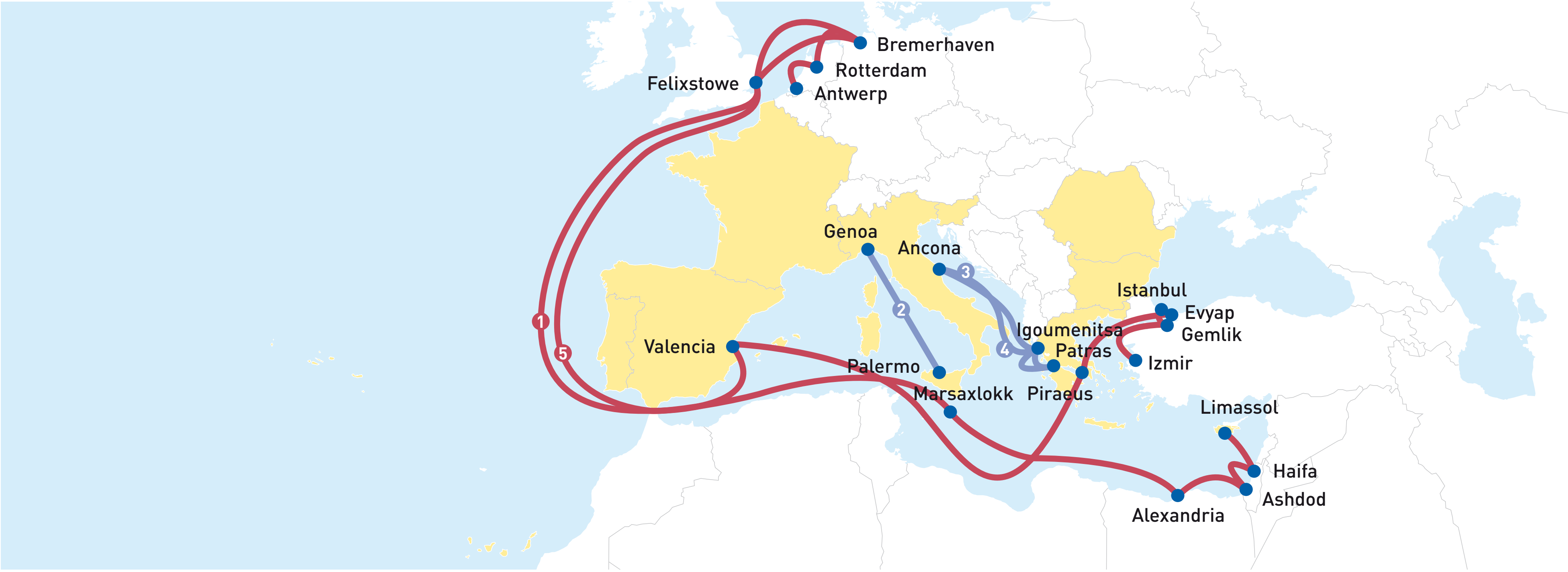
ATLANTIC AREA — WESTERN MEDITERRANEAN — EASTERN MEDITERRANEAN & BLACK SEA — ATLANTIC - WESTERN MED - EASTERN MED

Figure 43: Total average annual reductions using LNG in CO_2, NO_x and SO_x emissions by area in 2013 and 2020

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines Database

5.2.3 Indicators by shipping line

Finally, an analysis of the emission scheme of all shipping lines has been conducted on emissions which involves calculating the total amount of emission of CO_2, SO_x and NO_x as well as estimating the economic value of these emissions in the current situation and in the hypothetical case where all the fleet is fuelled by LNG. This has allowed the estimation of savings in emissions related to the use of LNG, which are represented in the following figure for the top five shipping lines that are mainly long-distance container connections and high frequency Ro-pax services.



Service	CO_2 (€)	NO_x (€)	SO_x (€)
1 AEGEAN SEAGO	779,803	622,044	11,820
2 PALERMO - GENOA	489,344	390,347	7,417
3 ANCONA - IGOUMENITSA - PATRAS	411,800	328,491	6,242
4 PATRAS - IGOUMENITSA - ANCONA	407,962	325,429	6,184
5 EAST MED - NORTH EUROPE	401,641	320,387	6,088

CONTAINER RO-PAX

Figure 44: Ranking of CO_2, NO_x and SO_x emission reductions (€) per shipping line when using LNG

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

To conclude this chapter, the methodology employed to calculate the emission of exhaust gases and their related costs and reductions has been applied to the specific case of HSC. CO_2, NO_x, SO_x and PM_x emissions caused by the HSC operating in the Mediterranean represent 3.5% of the global fleet emission in terms of annual tonnes and Euros. This percentage is slightly higher when CO_2 is considered individually due to the higher emission factor associated to related fuels. On the other hand, the opposite situation can be found in the case of SO_x emissions, as MDO can be considered as a cleaner fuel due to its low sulphur content. Furthermore, geographic and traffic segmentation breakdown provide similar conclusions, that is, the predominance of Ro-pax services marks their amount of emissions and also their potential savings derived from using LNG.

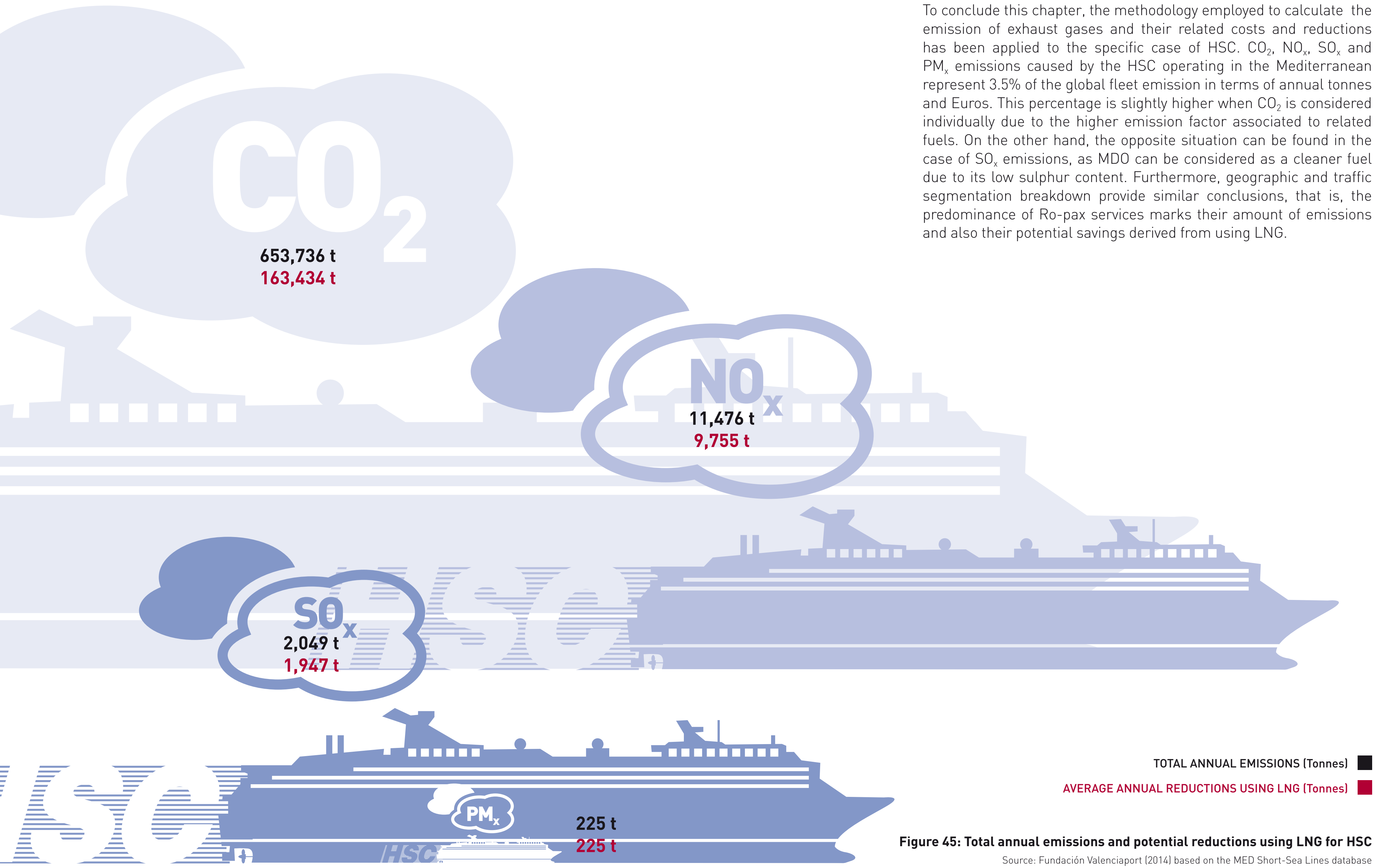


Figure 45: Total annual emissions and potential reductions using LNG for HSC

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

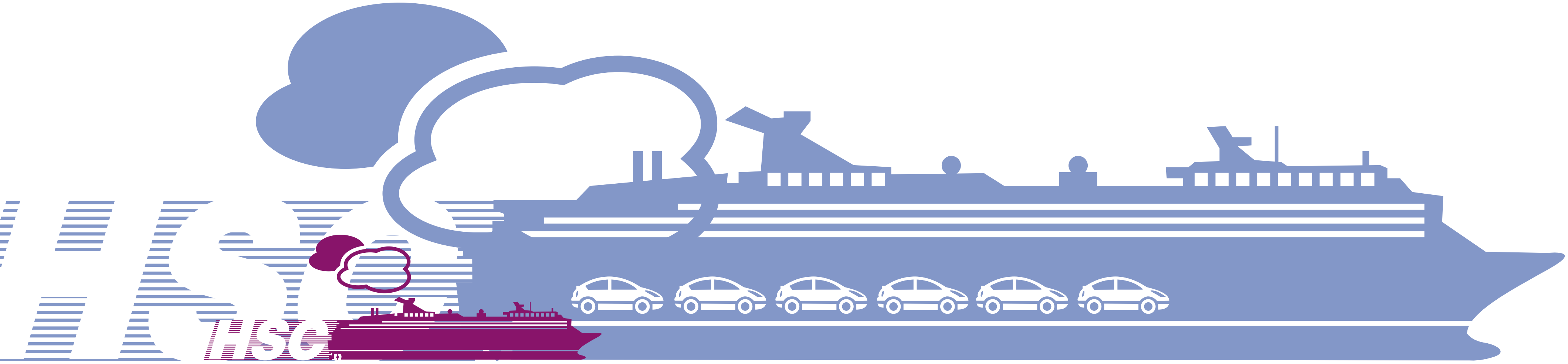


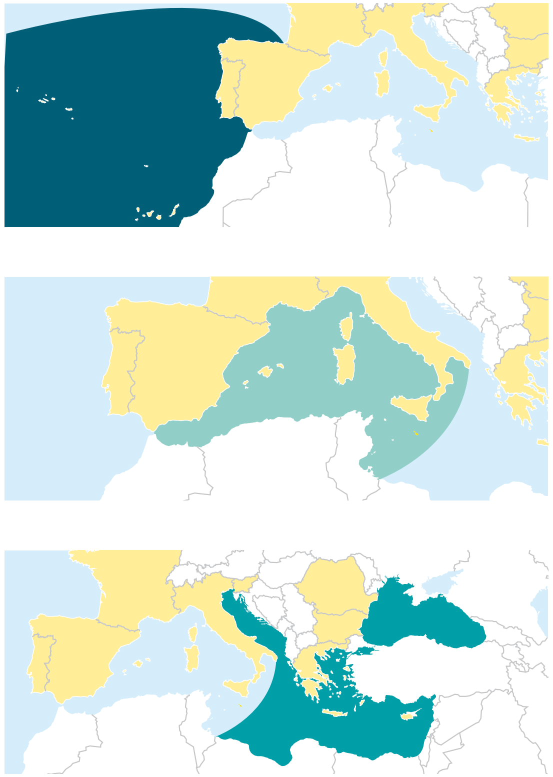
Figure 46: Total annual emissions by type of vessel for HSC

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

	CO_2	NO_x	SO_x
TOTAL ANNUAL EMISSIONS 2013	€ 2,912,369	€ 670,443	€ 2,111
TOTAL ANNUAL EMISSIONS 2020	€ 15,362,807	NA	NA
TOTAL ANNUAL REDUCTIONS 2013	€ 728,099	€ 569,876	€ 2,005
TOTAL ANNUAL REDUCTIONS 2020	€ 3,840,702	NA	NA

Figure 47: Total annual emissions and potential reductions using LNG for HSC

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database



ATLANTIC AREA

EMISSIONS IN TONNES	
CO_2	195,356
NO_x	3,429
SO_x	612
PM_x	67

EMISSIONS IN EUROS	
CO_2	€ 870,311
NO_x	€ 200,348
SO_x	€ 631

WESTERN MEDITERRANEAN SEA

EMISSIONS IN TONNES	
CO_2	254,738
NO_x	4,472
SO_x	799
PM_x	88

EMISSIONS IN EUROS	
CO_2	€ 1,134,856
NO_x	€ 261,247
SO_x	€ 823

EASTERN MEDITERRANEAN & BLACK SEA

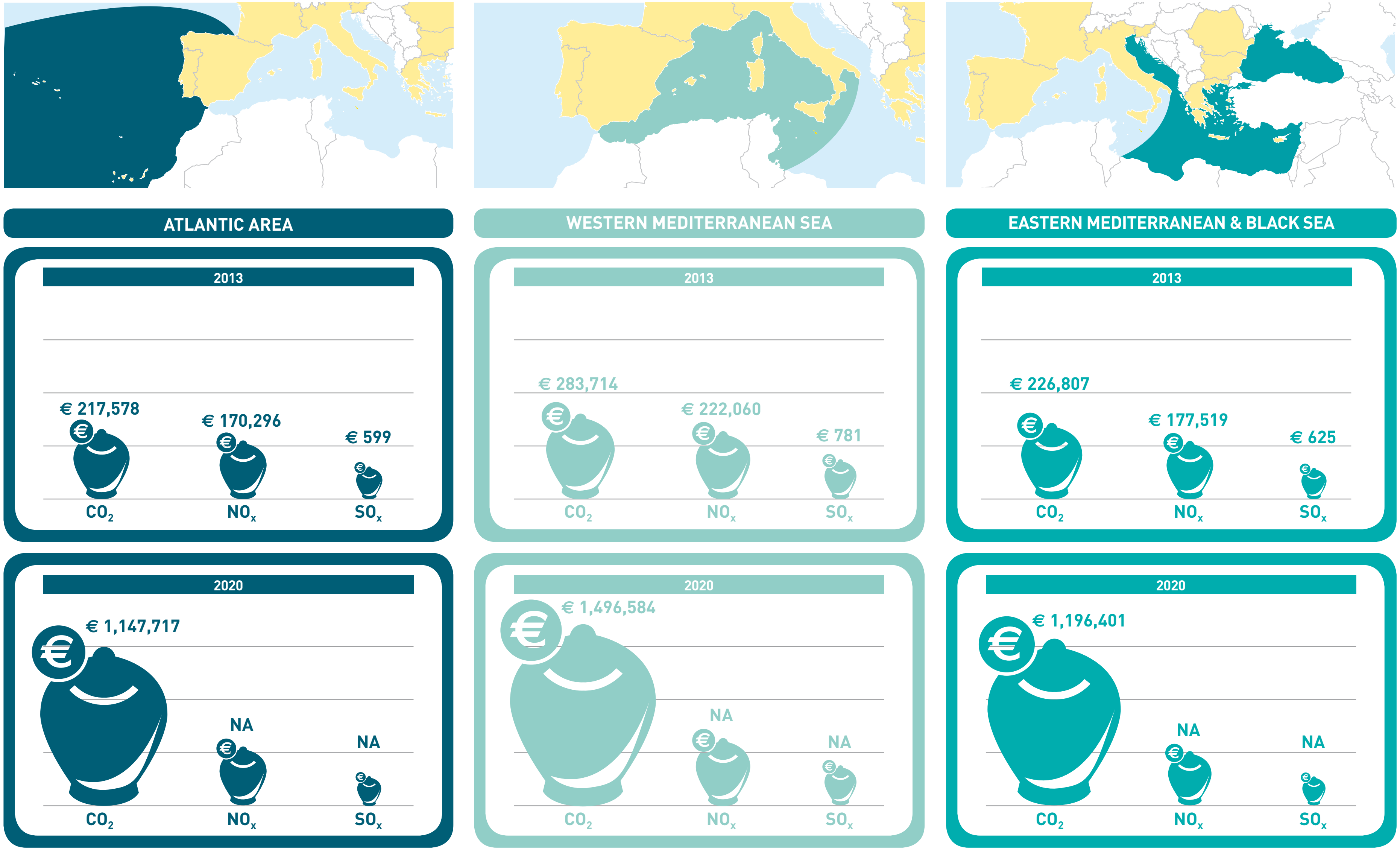
EMISSIONS IN TONNES	
CO_2	203,643
NO_x	3,575
SO_x	638
PM_x	70

EMISSIONS IN EUROS	
CO_2	€ 907,229
NO_x	€ 208,847
SO_x	€ 658

ATLANTIC AREA — WESTERN MEDITERRANEAN — EASTERN MEDITERRANEAN & BLACK SEA

Figure 48: Total annual emissions (tonnes) and cost (€) by area for High-Speed Craft (HSC) in 2013

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database



ATLANTIC AREA ■ WESTERN MEDITERRANEAN ■ EASTERN MEDITERRANEAN & BLACK SEA ■

Figure 49: Total average annual potential reductions in CO_2, NO_x and SO_x emissions using LNG by area for HSC in 2013 and 2020

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

6 INVESTMENTS AND FINANCIAL FEASIBILITY ANALYSES

6.1 INTRODUCTION

Financial feasibility and cost-benefit analyses have been carried out for the conversion of each vessel deployed in short-sea services in the area of study. Firstly, Fundación Valenciaport, with the collaboration of prominent industrial companies such as MAN Diesel & Turbo, Wärtsilä, Caterpillar, Ros Roca Indox Cryo Energy, S.L., Boluda Corporación Marítima, RINA, among others, has estimated the investment required for each ship in the SSS fleet to install scrubbers, their engines be retrofitted to LNG dual fuel or be substituted by a newly built vessel of similar characteristics and operating with LNG dual fuel engines, tanks and all the necessary installations for this newbuilding to be LNG-compatible. The difference in operational costs of the ship for each pair of alternative options (the options compared have been: installing scrubbers, retrofitting to LNG dual fuel, newbuilding with HFO engines plus scrubbers, newbuilding with MGO engines (no scrubbers) and newbuilding with LNG engines and other LNG-related installations) have been forecasted and fuel savings in Euros have been calculated.

This section presents the main results of these analyses.

The methodology used in these cost benefit analyses follows the basic principles outlined in the *Guide to Cost Benefit Analysis of Investment Projects* by the Evaluation Unit of the European Commission Directorate General of Regional Policy.

The forecasts for investments, costs and benefits have been incorporated into an *ad-hoc* tool that has been programmed to simulate the financial feasibility and cost-benefit socio-economic viability of each alternative option for a ship to comply with international environmental regulation.

In order to simulate the financial and socio-economic feasibility, the investment, differential costs and differential benefits that each ship owner would incur throughout the life-span of the project (27 years) have been studied for each set of alternative options. The main steps that have been taken to complete this analysis, together with an outline of the simulation programme are shown in the following figure.

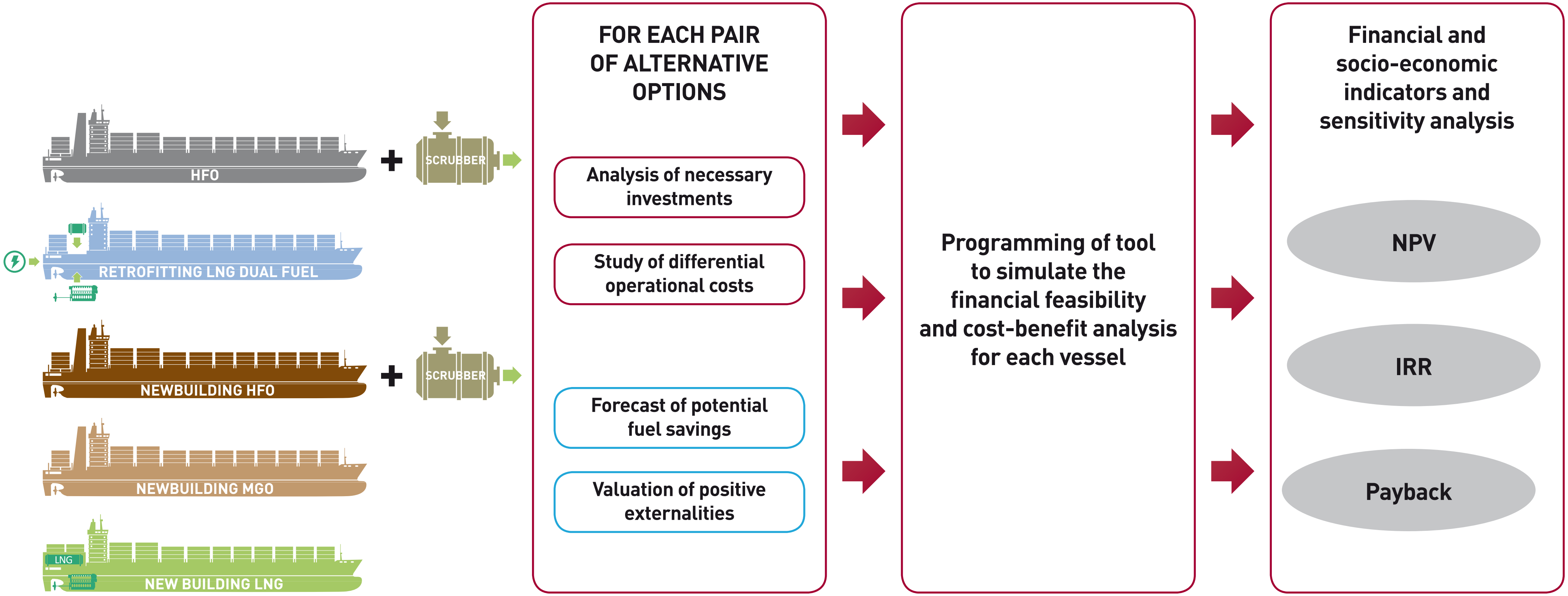


Figure 50: Programme outline for the simulation of financial and socio-economic feasibility of different alternative options for ships to comply with international environmental regulation

Source: Fundación Valenciaport (2014)

The steps below have been followed to carry out the financial feasibility and cost-benefit analysis of each pair of alternative options.

The main changes that the implementation of each option would bring to the current operation of the vessel have been analysed. The identified changes in the operational costs, fuel savings and environmental externalities have been calculated along with their expected evolution in the future for different scenarios. This has been carried out by performing stochastic simulation models, the results having been checked by key informants at several companies leaders and experts in the market. The average and standard deviation has been calculated for each input parameter of the different input data gathered.

An application has been programmed that is capable of dynamically calculating the main financial and cost-benefit results that would stem from the implementation of a specific option for a vessel. Such results include: financial and socio-economic Net Present Value (NPV), financial and socio-economic Internal Rate of Return (IRR) and payback. Various scenarios can be simulated, as the programme is able to introduce changes to the input variables and thus it is able to automatically recalculate results.

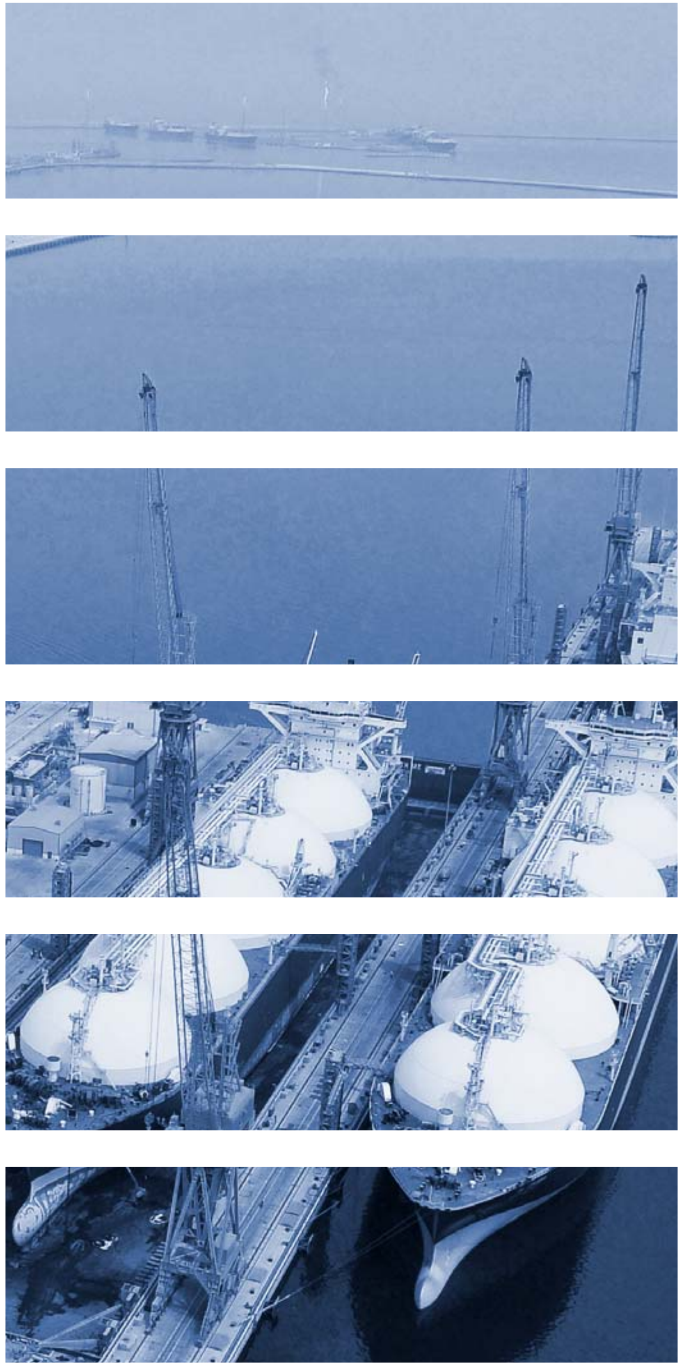
A stochastic model of the financial and cost-benefit analysis has been constructed. The average has been established for each parameter (the value that displays the highest expected frequency of occurrence) along with a confidence interval using the minimum and maximum expected values for this factor. Once the average, minimum and maximum values are obtained, the probability distribution of expected changes in the parameter is studied and a stochastic variability interval or margin for error is established with different levels of clearly defined probabilities.

By stochastically modelling each of the parameters (which affect the financial feasibility and cost-benefit analyses), it is possible to calculate how sensitive the final financial and socio-economic NPV, IRR and payback are to each and every factor included in the estimation. Final expected NPV will therefore be an average value inside a variability interval marked by the 10% (minimum expected value) and 90% (maximum expected value) percentiles. As a result, the confidence interval encompasses a probability of 80%. In other words, the analysis undertaken will render an average expected result in terms of NPV, IRR and payback for each vessel and alternative pair of options to comply with the sulphur emission regulation and will also produce a variability interval for each result, with a specific probability distribution of 80% that final NPV, IRR or payback will fall inside that interval. The method proposed is a considerable improvement of the traditional sensitivity analysis, which usually studies three scenarios; average, optimistic and pessimistic. Instead, this method studies the variability of each specific input factor, analyses the probability distribution that better fits the measurements obtained for that input factor and simulates a large number of iterations (1,000,000 different scenarios have been simulated for each initiative in this study), thereby producing a variability interval with an associated probability distribution for each result of NPV, IRR and payback.

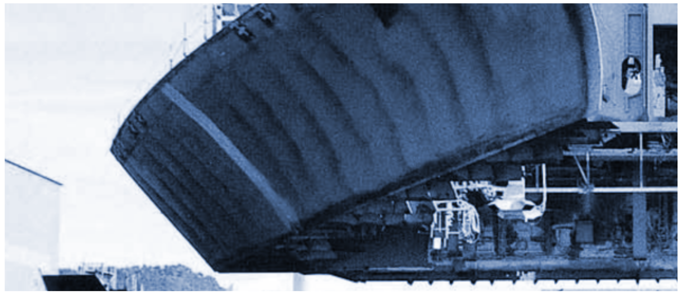
The following hypotheses have been used to forecast the differential costs and benefits (savings of fuel consumption and externalities) that would be generated by the deployment of different options available for ships to comply with MARPOL Annex VI:

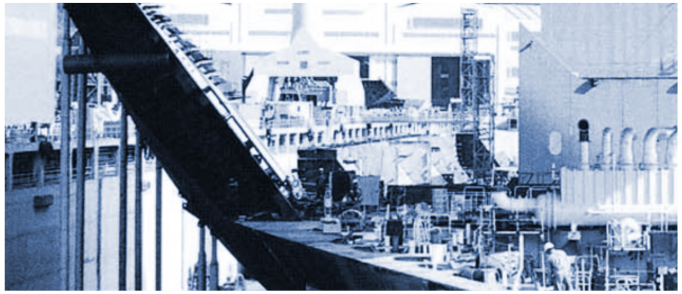
- The financial feasibility and cost-benefit analyses cover a period of 27 years, from 2020 until 2046.
- The average inflation rate for the period under study has been fixed at 2%. Ship operational costs have been updated applying this annual inflation rate.
- A discount rate of 12% has been estimated and incorporated to the model. This represents the opportunity cost for ship owners of carrying out the investment needed to implement a specific option (i.e. installing scrubbers) instead of investing in an alternative course of action (i.e. retrofitting to LNG dual fuel).
- Short-sea shipping traffic is assumed to grow at a 1% annual rate.
- The price gaps between LNG and MGO, between LNG and HFO and between MGO and HFO are supposed to remain the same in the future as in the base scenario. Variability intervals have been defined in order to carry out the sensitivity analysis. For instance, the price gap between LNG and HFO varies from -0.05% to 0.10% (with a 80% probability of occurrence), this meaning that when the price gap is -0.05%, the difference in price between LNG and HFO will progressively be reduced year after year at a 0.05% rate. On the contrary, when the price gap takes a value of 0.10%, the difference between LNG and HFO prices will gradually increase year after year at a rate of 0.10%.

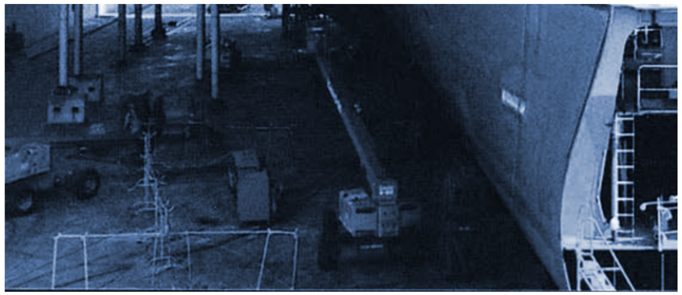
The following sub-sections include the results of the financial feasibility and cost-benefit analyses of the different pairs of alternative options available for ship owners to comply with international environmental regulation.



6.2 INVESTMENTS







This sub-section presents the estimated results of investments to be made by the owners of short-sea shipping vessels operating in the area of study in order for these ships to comply with environmental regulation. The different options available for ship owners to comply with MARPOL Annex VI and Directive 2012/33/EU have been compared from financial and socio-economic perspectives and the main results in terms of investments are shown below. Ultimately, the goal is to estimate the NPV, IRR and payback of each pair of alternative options.

Investments in key technologies adapted to the 22 different types of vessels defined in the methodology (representative of the SSS Mediterranean fleet) have been calculated. Next, the formulas for the calculation of investments for each ship type have been applied to each one of the 658 vessels deployed in short-sea services in the 10 countries under study. Investments have been estimated for each type of vessel based on the information supplied by main engine manufacturers, such as Wärtsilä, MAN Diesel & Turbo and Caterpillar, as well as the cryogenic tank manufacturer Ros Roca Indox Cryo Energy S.L. The cost of scrubber installation and operation have been estimated according to the information provided by the equipment suppliers. The operational costs of scrubbers are found on Aalborg Industries self-certificated data. Boiler units are not considered in this survey and specific fuel oil consumption is based on current knowledge.

This publication provides an approximation to the investments that sea carriers will have to make to implement each of the alternative courses of action available for them to comply with MARPOL Annex VI. Owners may directly contact suppliers for detailed integration and commercial discussions. In general, existing ship candidates for engaging in these technologies will have to pass a technical survey to ensure that the technology can be integrated with ship arrangements, stability and operations. Additionally, it must be noted that most systems are still in the pilot phase and therefore carry with them technical and subsequently financial risks.

The following table displays the average investment in Euros (2013 prices) that ship owners will need to make in order to:

- Install scrubbers systems on their ships
- Retrofit the vessel to make it LNG dual fuel compatible
- Substitute the ship by a new one with similar features but incorporating HFO engines plus scrubbers. In this case the figures shown in the sixth column correspond to the price of the new HFO engine plus scrubbers.
- Replace the ship by another vessel with similar characteristics operating with HFO/MGO engines and with no scrubbers installed.
- Substitute the vessel with a similar one operating with LNG dual fuel engines. In this case only the price of LNG dual fuel engines and all LNG related equipment are considered.

Examining the first row of results, the interpretation of the figures shown in Table 16 is as follows. The owner of a car carrier deployed in SSS services covering a voyage distance of less than 500 nautical miles (round trip distance, from first port of departure until the vessel returns to this port) and with less than 8,000 kW of engine power would have to invest an average of €2,124,812 to have scrubbers systems installed on the previously mentioned vessel (taking into account 2013 prices). If instead of installing scrubbers, the option of their choice is retrofitting the vessel so that it is made LNG compatible (with LNG dual fuel engines), the average investment for the car carrier (less than 8,000 kW and deployed in services covering a distance of less than 500 nm) would be €2,702,019. Alternatively, if the ship owner decides to substitute the vessel for a new one with similar characteristics and HFO engines plus scrubbers systems, then the average investment in the HFO engines plus scrubbers would be €2,887,093. Another possibility would be for the ship owner to replace the ship with a newbuilding of similar features, operating the same route with conventional engines and burning MGO. In the mentioned case, the average investment in the new engine would be €762,281. Finally, if the selected option is substituting the vessel for a newbuilding with LNG dual fuel engines, the necessary investment in the LNG dual fuel engines of the newbuilding would be €2,441,901on average for this specific type of vessel.

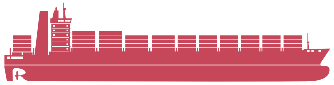
CAR CARRIER

AUTONOMY (ROUTE DISTANCE RANGE IN nm)	ENGINE POWER (kW)	SCRUBBER + HFO	RETROFITTING LNG DUAL FUEL	SCRUBBER + NEWBUILDING HFO	NEWBUILDING MGO	NEWBUILDING LNG
< 500 nm	< 8,000	2,124,812	2,702,019	2,887,093	762,281	2,441,901
500 - 2,000 nm	< 8,000	2,372,707	4,328,378	3,825,190	1,452,483	4,677,574
	8,000 - 16,000	2,620,602	7,527,153	5,369,786	2,749,184	8,873,482
2,000 - 4,000 nm	< 8,000	2,290,075	3,664,455	3,440,997	1,150,922	3,699,366
	8,000 - 16,000	2,738,647	8,483,362	5,823,975	3,085,328	9,981,502
4,000 - 10,000 nm	8,000 - 16,000	2,833,083	8,633,796	5,963,696	3,130,613	10,144,669
	16,000 - 26,000	3,683,008	11,415,931	7,731,536	4,048,529	13,280,295

Table 16: Average investments (€) in scrubbers, retrofitting and newbuilding engines by type of vessel, autonomy and engine power (base scenario, 2013 prices)

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

CONTAINER SHIP



AUTONOMY (ROUTE DISTANCE RANGE IN nm)	ENGINE POWER (kW)	SCRUBBER + HFO	RETROFITTING LNG DUAL FUEL	SCRUBBER + NEWBUILDING HFO	NEWBUILDING MGO	NEWBUILDING LNG
< 500 nm	< 8,000	2,266,466	4,025,338	3,559,601	1,293,134	3,526,123
	8,000 - 16,000	3,075,918	7,899,530	6,350,168	3,274,250	8,208,100
	16,000 - 26,000	3,683,008	10,068,809	7,998,290	4,315,282	12,403,439
500 - 2,000 nm	< 8,000	2,266,466	6,216,700	4,472,156	2,205,690	5,528,257
	8,000 - 16,000	3,305,263	7,646,177	6,495,682	3,190,419	8,342,116
	16,000 - 26,000	4,087,734	10,618,251	9,716,463	5,628,729	14,010,871
	> 26,000	4,249,624	13,429,969	11,895,800	7,646,176	18,175,871
2,000 - 4,000 nm	< 8,000	2,266,466	7,232,201	4,832,505	2,566,039	6,431,319
	8,000 - 16,000	3,323,587	7,728,379	6,552,277	3,228,690	8,491,828
	16,000 - 26,000	4,000,313	10,492,541	9,324,782	5,324,469	13,639,862
	> 26,000	5,156,211	26,295,559	17,447,328	12,291,117	36,099,396
4,000 - 10,000 nm	< 8,000	2,266,466	4,261,238	3,635,383	1,368,917	3,732,767
	8,000 - 16,000	3,039,125	8,322,531	6,488,463	3,449,338	8,642,924
	16,000 - 26,000	3,997,794	11,117,800	9,655,829	5,658,035	14,466,723
	> 26,000	4,740,692	21,704,118	15,597,990	10,857,298	29,613,457

Table 16: Average investments (€) in scrubbers, retrofitting and newbuilding engines by type of vessel, autonomy and engine power (base scenario, 2013 prices)

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

GENERAL CARGO

AUTONOMY (ROUTE DISTANCE RANGE IN nm)	ENGINE POWER (kW)	SCRUBBER + HFO	RETROFITTING LNG DUAL FUEL	SCRUBBER + NEWBUILDING HFO	NEWBUILDING MGO	NEWBUILDING LNG
< 500 - 2,000 nm	< 8,000	1,888,722	4,741,866	3,137,342	1,248,620	4,232,458
2,000 - 4,000 nm	< 8,000	1,888,722	5,893,692	3,440,639	1,551,917	5,260,547

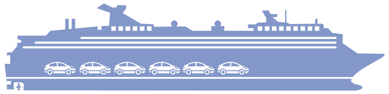
PAX

AUTONOMY (ROUTE DISTANCE RANGE IN nm)	ENGINE POWER (kW)	SCRUBBER + HFO	RETROFITTING LNG DUAL FUEL	SCRUBBER + NEWBUILDING HFO	NEWBUILDING MGO	NEWBUILDING LNG
< 500 nm	< 8,000	4,035,242	1,880,055	5,301,167	1,265,924	1,950,222
	8,000 - 16,000	4,249,624	5,825,158	8,203,797	3,954,172	6,060,135

Table 16: Average investments (€) in scrubbers, retrofitting and newbuilding engines by type of vessel, autonomy and engine power (base scenario, 2013 prices)

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

RO-PAX



AUTONOMY (ROUTE DISTANCE RANGE IN nm)	ENGINE POWER (kW)	SCRUBBER + HFO	RETROFITTING LNG DUAL FUEL	SCRUBBER + NEWBUILDING HFO	NEWBUILDING MGO	NEWBUILDING LNG
< 500 nm	< 8,000	2,266,466	4,866,855	4,297,744	2,031,278	4,569,438
	8,000 - 16,000	2,844,887	11,278,763	8,461,140	5,616,253	10,949,774
	16,000 - 26,000	3,984,023	15,220,687	11,508,147	7,524,124	15,380,279
	> 26,000	7,901,153	23,015,518	22,069,111	14,167,958	25,086,263
500 - 2,000 nm	< 8,000	2,266,466	4,778,491	4,213,586	1,947,120	4,468,128
	8,000 - 16,000	2,813,766	11,296,615	8,176,932	5,363,166	10,878,463
	16,000 - 26,000	4,929,564	16,000,220	13,461,622	8,532,058	16,596,773
	> 26,000	8,263,158	25,126,792	22,925,075	14,661,917	28,030,692

Table 16: Average investments (€) in scrubbers, retrofitting and newbuilding engines by type of vessel, autonomy and engine power (base scenario, 2013 prices)

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

RO-RO

AUTONOMY (ROUTE DISTANCE RANGE IN nm)	ENGINE POWER (kW)	SCRUBBER + HFO	RETROFITTING LNG DUAL FUEL	SCRUBBER + NEWBUILDING HFO	NEWBUILDING MGO	NEWBUILDING LNG
< 500 nm	< 8,000	2,124,812	2,997,102	2,970,341	845,529	2,708,577
	8,000 - 16,000	3,151,805	10,388,153	6,841,334	3,689,529	10,153,534
500 - 2,000 nm	< 8,000	2,223,970	6,074,657	3,973,622	1,749,652	5,556,701
	8,000 - 16,000	2,717,184	8,426,793	5,468,336	2,751,152	8,193,873
	16,000 - 26,000	3,683,008	15,330,129	9,486,932	5,803,924	15,047,180
	> 26,000	3,683,008	35,233,344	17,022,208	13,339,200	34,583,040
2,000 - 4,000 nm	< 8,000	2,124,812	5,539,250	3,687,520	1,562,708	5,005,997
	8,000 - 16,000	2,620,602	8,215,627	5,234,720	2,614,118	7,976,546
	16,000 - 26,000	3,683,008	14,484,579	9,166,810	5,483,803	14,217,237
4,000 - 10,000 nm	< 8,000	2,124,812	6,727,063	4,022,621	1,897,809	6,079,462
	8,000 - 16,000	3,683,008	12,723,152	8,499,941	4,816,933	12,488,320

Table 16: Average investments (€) in scrubbers, retrofitting and newbuilding engines by type of vessel, autonomy and engine power (base scenario, 2013 prices)

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

	SCRUBBER + HFO	RETROFITTING LNG DUAL FUEL	SCRUBBER + NEWBUILDING HFO	NEWBUILDING MGO	NEWBUILDING LNG
CC 1	2,345,163	4,160,291	3,720,141	1,374,978	4,426,085
CC 2	2,657,236	8,199,475	5,648,576	2,991,340	9,661,068
CC 3	3,683,008	11,190,810	7,651,700	3,968,693	13,018,410
CONT-SHIP 1	2,266,466	5,624,053	4,084,344	1,817,877	4,930,984
CONT-SHIP 2	2,266,466	9,265,243	6,045,877	3,779,411	8,433,933
CONT-SHIP 3	3,683,008	6,849,949	6,572,607	2,889,599	8,104,622
CONT-SHIP 4	3,860,075	10,115,797	8,619,587	4,759,512	12,827,434
CONT-SHIP 5	4,249,624	13,915,556	12,172,263	7,922,639	18,833,054
CONT-SHIP 6	5,382,857	26,680,579	16,552,210	11,169,353	35,725,614
CONT-SHIP 7	5,382,857	34,103,881	22,439,535	17,056,678	48,482,201
GC 1	1,888,722	5,235,506	3,267,326	1,378,605	4,673,068
PAX	3,968,886	1,508,188	4,979,204	1,010,318	1,561,600
HSC	5,753,856	16,359,880	16,419,989	10,666,133	16,976,614
RO-PAX 1A	2,266,466	6,377,366	4,865,089	2,598,623	5,963,157
RO-PAX 1B	2,620,602	11,843,016	8,722,881	6,102,279	11,337,459
RO-PAX 2	3,777,444	14,918,781	11,090,551	7,313,108	15,017,611
RO-PAX 3	7,366,015	16,927,398	17,625,305	10,259,290	18,531,854
RO-PAX 4A	8,499,248	22,037,233	21,287,218	12,787,969	24,652,120
RO-PAX 4B	8,499,248	29,754,129	25,765,250	17,266,001	33,284,685

Table 17. The average investment (€) for installing scrubbers, retrofitting or newbuilding engines for different types of vessels, (base scenario, 2013 prices)

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

	SCRUBBER + HFO	RETROFITTING LNG DUAL FUEL	SCRUBBER + NEWBUILDING HFO	NEWBUILDING MGO	NEWBUILDING LNG
RO-RO 1	2,174,391	5,536,087	3,754,155	1,579,764	5,036,558
RO-RO 2	2,620,602	8,059,692	5,185,103	2,564,502	7,825,148
RO-RO 3	3,683,008	15,207,286	9,440,424	5,757,416	14,926,604

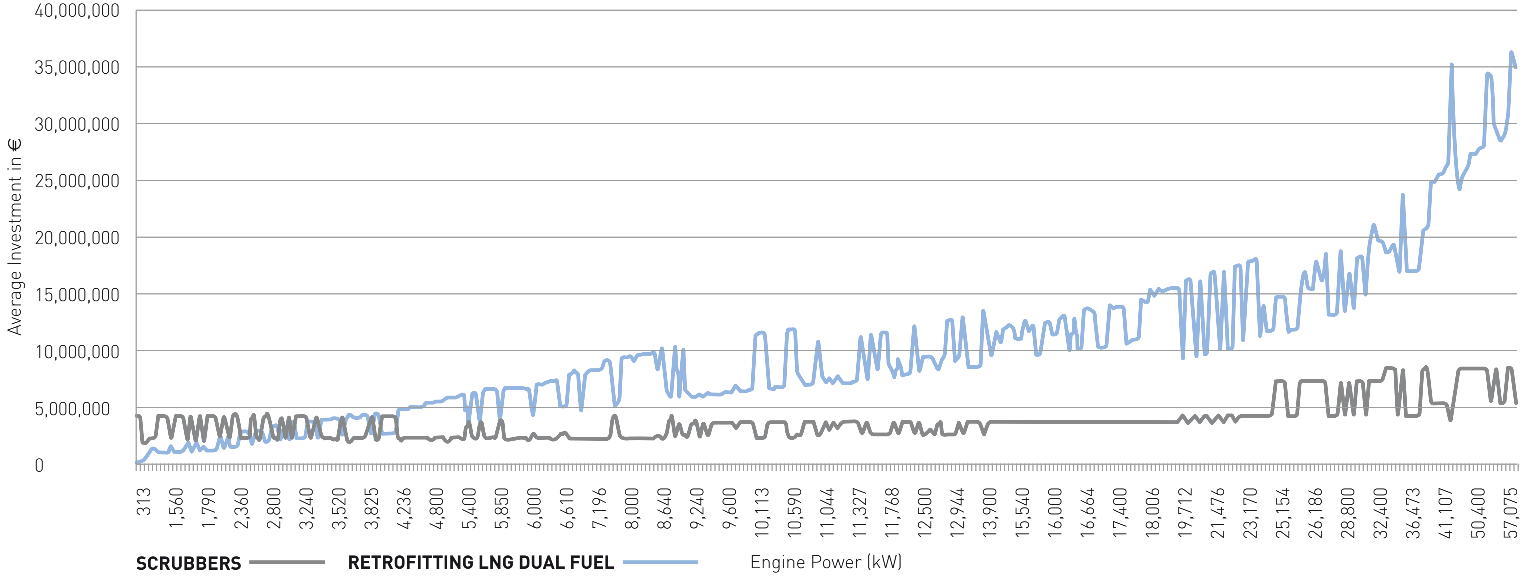
Table 17. The average investment (€) for installing scrubbers, retrofitting or newbuilding engines for different types of vessels, (base scenario, 2013 prices)

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

For existing vessels, the investment required for the retrofitting to LNG is approximately three times higher than installing scrubbers, with the exception of passenger vessels. In this case, the least expensive option is converting to LNG, depending of the availability of LNG engines.

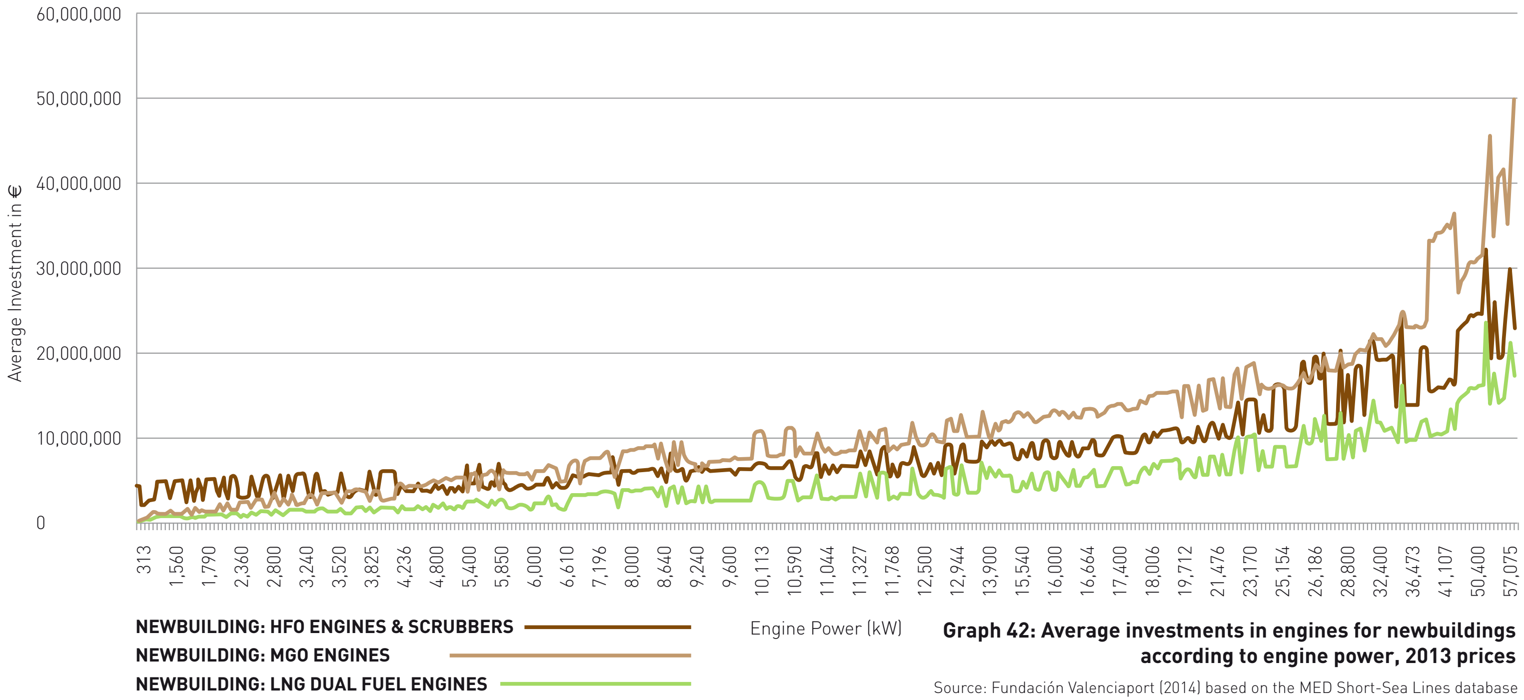
The average investments required to install scrubbers or to retrofit to LNG dual fuel the 658 vessels deployed in SSS services in the area are represented in the following graph. This graph shows the relationship between average investments in these two options and engine power of the vessel.

Similarly, the following graph displays how the average investments in newbuilding engines (HFO + scrubbers, MGO or LNG engines for a new ship) change depending on engine power.



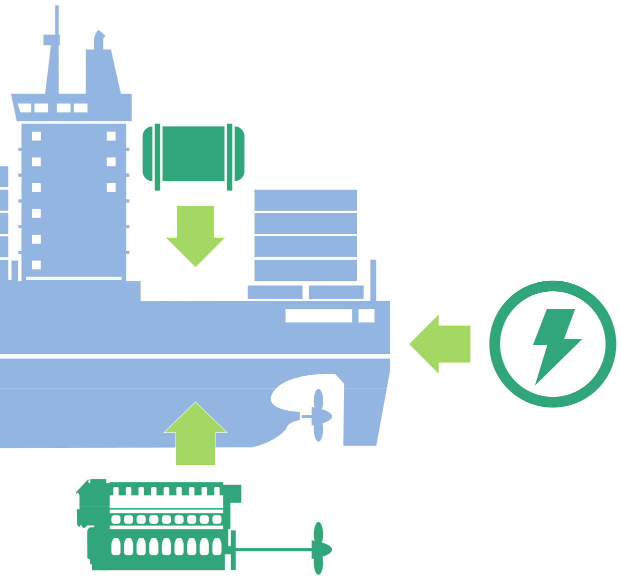
Graph 41: Average investments in scrubbers and retrofitting to LNG dual fuel according to engine power of the vessel, 2013 prices

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database



Graph 42: Average investments in engines for newbuildings according to engine power, 2013 prices

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database



The following table presents the sum of investments (in € million) if all vessels of a specific category opted for the same option to comply with sulphur emission regulation. Clearly, not all companies owning vessels of a specific type will opt for the same strategy, so these investment figures are only provided for comparative purposes. The figures provided should be interpreted as follows. If all car carriers in the SSS fleet were to have scrubbers systems installed on them, in the base scenario and taking into account 2013 prices, the investments that all the different ship owners deploying car carriers in SSS services would have to make are estimated to be €123.95 million. Alternatively, if all car carrier owners decide to retrofit their vessels to make then LNG compatible, the sum of investments would reach €353.56 million. This figure can be compared with the €250.85 million of investments that would be necessary for the new HFO engines plus scrubbers systems on the newbuildings that would replace the existing fleet of car carriers deployed in SSS services in the Mediterranean. The investments required for MGO engines (no scrubbers) for newbuildings for all car carriers would be €126.90 million and finally, if all these vessels were replaced by newbuildings with LNG dual fuel engines, the expected investments in the new LNG dual fuel engines and related LNG equipments would be €411.13 million.

Taking into account that part of the fleet will be scrapped by 2020, owners opting for LNG as fuel for newbuildings need to invest around 1.5 times more than if they choose the scrubber option. Due to the high power engines installed on board Ro-pax vessels, this ratio is reduced up to 1.2, this potentially being the most successful case for the use of LNG as fuel.

	SCRUBBER + HFO	RETROFITTING LNG DUAL FUEL	SCRUBBER + NEWBUILDING HFO	NEWBUILDING MGO	NEWBUILDING LNG
CAR CARRIER	123.95	353.56	250.85	126.9	411.13
CONTAINER SHIP	961.83	2,800.90	2,199.25	1,237.42	3,253.84
GENERAL CARGO	13.22	36.65	22.87	9.65	32.71
PAX	226.19	109.23	299.77	73.58	113.32
RO-PAX	886.33	2,832.61	2,441.92	1,555.59	2,971.38
RO-RO	232.74	847.97	535.66	302.92	823
TOTAL SSS FLEET	**€2,444.26M**	**€6,980.92M**	**€5,750.32M**	**€3,306.07M**	**€7,605.39M**

Table 18. Sum of investments (million €) in scrubbers, retrofitting and newbuilding engines if all vessels of a specific type opted for the same strategy (base scenario, 2013 prices)

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

INVESTMENTS AND FINANCIAL FEASIBILITY ANALYSES

The following table shows the sum of investments (million €) by geographical area if all vessels deployed in a specific zone opted for the same strategy. For example, if all ships deployed in SSS services in the East Mediterranean & Black Sea area were to have scrubbers installed, the total investment required would equal €710.1 million.

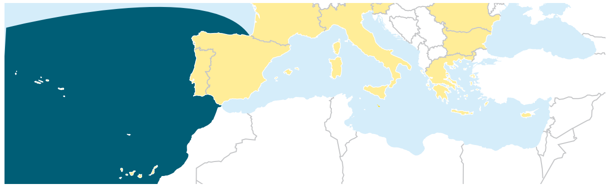
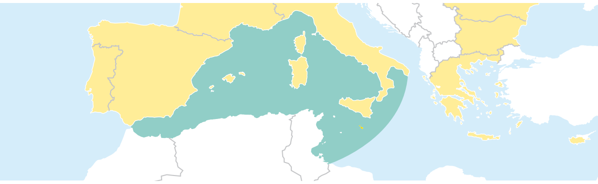
	SCRUBBER + HFO	RETROFITTING LNG DUAL FUEL	SCRUBBER + NEWBUILDING HFO	NEWBUILDING MGO	NEWBUILDING LNG
ATLANTIC AREA 	210.81	699.83	524.1	313.29	675.12
WESTERN MEDITERRANEAN SEA 	822.09	2,189.74	1,916.84	1,094.75	2,274.70
EASTERN MEDITERRANEAN & BLACK SEA 	710.1	1,891.22	1,639.30	929.2	2,008.04
ATLANTIC - WESTERN MED - EASTERN MED 	701.26	2,200.13	1,670.08	968.83	2,647.52
TOTAL SSS FLEET	**€2,444.26M**	**€6,980.92M**	**€5,750.32M**	**€3,306.07M**	**€7,605.39M**

Table 19. Sum of investments (million €) if all vessels of a specific type opted for the same strategy by geographical zone, base scenario, 2013 prices

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

6.3

FINANCIAL FEASIBILITY ANALYSIS

The next figure shows the two stages in the finantial feasibily analysis. In the three cases, were the existing vessel would be replaced by a newbuilding, only the price of the HFO engines plus scrubbers systems, MGO engines (no scrubbers) or the LNG dual fuel engines and LNG related equipment have been considered in the comparative financial analysis.

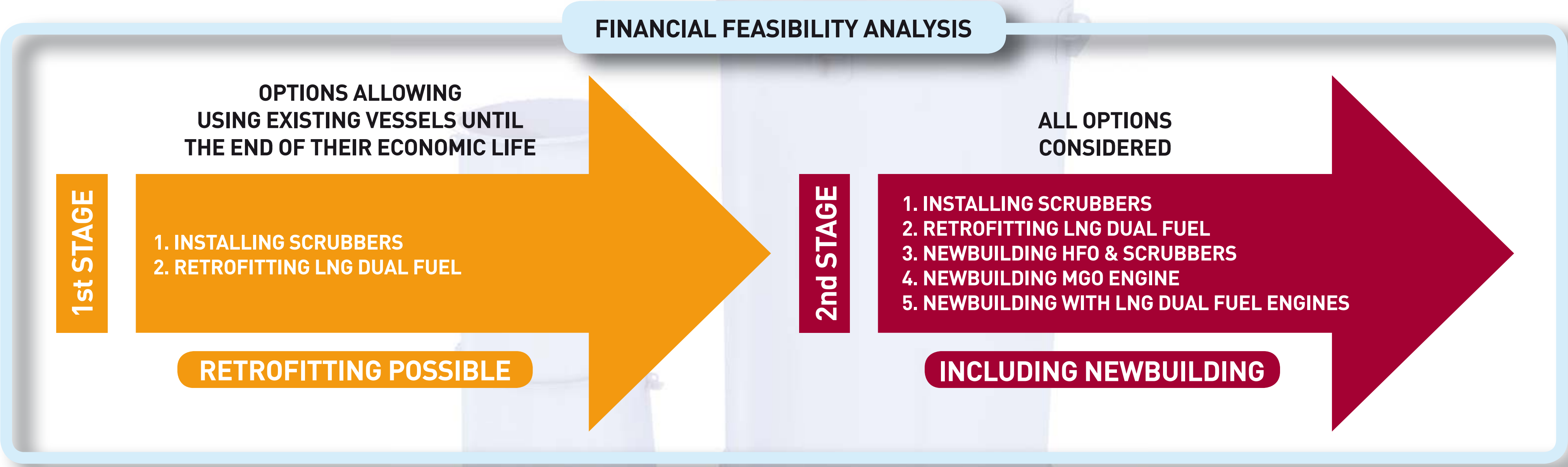


Figure 51. Financial feasibility analysis stages

Source: Fundación Valenciaport (2014)

The following figure shows that, out of the 658 vessels in the Mediterranean SSS fleet, retrofitting would not be an option for 197 ships that are over 30 years by 2020 (the average age of these 197 vessels will be 35 years old by then). For the remaining 461 vessels, two alternative options have been compared: (1) having scrubbers installed and (2) retrofitting to LNG dual fuel. The most profitable option in terms of NPV would be the installation of scrubbers for 121 ships, whilst for 340 would be being retrofitted. The average NPV for the project for those ships having scrubbers installed on them would be €1,454,479, whereas the average NPV of the retrofitting project is higher at €2.5 million. If retrofitting to LNG dual fuel is compared to burning HFO and having scrubbers installed, the NPV of doing the first option against the second would be €2,5 million, whilst the NPV would be €20.3 million if retrofitting to LNG dual fuel is measured up to burning MGO to operate.

The total investment required for 121 ships to have scrubbers installed on them would be €4,082.65 million. The sum of investments for the 340 vessels retrofitting to LNG dual fuel would amount to €4 billion.

The options available for ship owners that are required to comply with international environmental legislation increase in the second stage once the three newbuilding options are incorporated into the analysis. It must be stated that in these three cases where the existing vessel would be replaced by a newbuilding, the comparison of the financial indicators of the different options have been carried out by only considering the differential investments required (i.e. the price of the HFO engines plus scrubbers systems, the MGO engines without scrubbers, or the LNG dual fuel engines and LNG related equipment) as well as the differential costs and benefits expected.

Substituting existing vessels with newbuildings equipped with LNG dual fuel engines is the most profitable option for the majority of vessels (655 out of 658) as the average NPV for this option is €22 million with the average payback being 3.3 years. For the remaining three vessels, the most financially profitable option would be for them to be replaced by newbuildings with HFO engines and scrubbers, with their average NPV being €28,082 and average IRR equalling 12.55%.

The sum of investments for new HFO engines and scrubbers to be installed on newbuildings to replace existing vessels in 2020 would equal to €25.37 million (for three ships for which the best option would be to utilise HFO and scrubbers). Using the same calculation method, the sum of investments for the 655 vessels for replacing existing engines with LNG dual fuel engines equal to €7.5 billion.

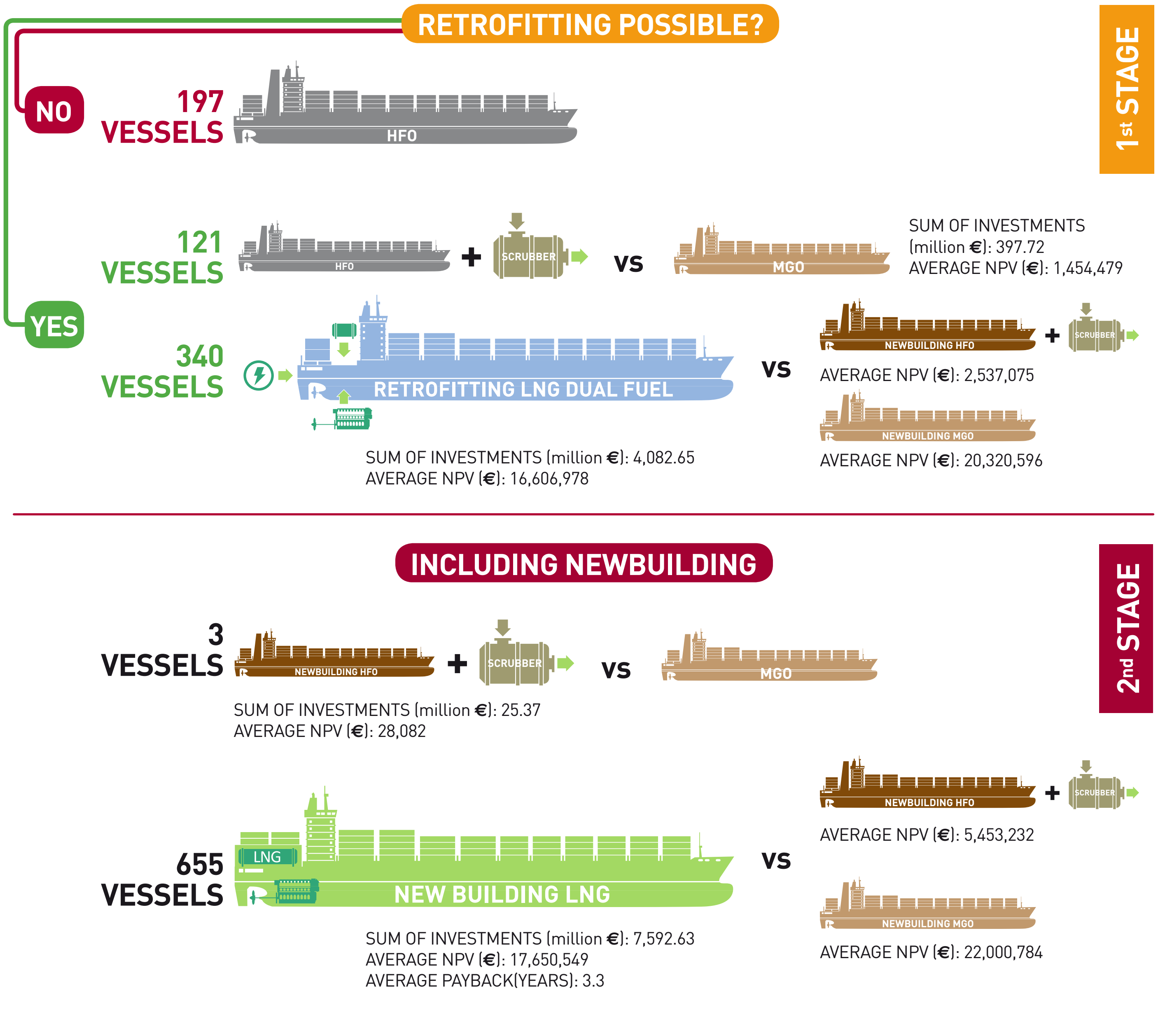
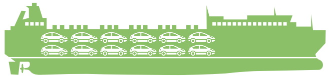


Figure 52: The best option to comply with international environmental legislation for each of the vessels deployed in the Med SSS fleet – First stage (assuming that vessels will be operational until the end of their economic lives) and second stage (including newbuilding options), (base scenario, 2013 prices)

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

The following table show the average NPV for each pair of alternative options by engine power and autonomy for each type of vessel. Results refer to the base scenario, have been calculated using 2013 prices as a reference and display the NPV of each investment option compared to another alternative.

CAR CARRIER



				1st STAGE	2nd STAGE	
AUTONOMY (ROUTE DISTANCE RANGE IN nm)	**ENGINE POWER (kW)**	**SCRUBBER + HFO vs MGO**	**RETROFITTING LNG DUAL FUEL vs HFO & Scrubbers**	**RETROFITTING LNG DUAL FUEL vs MGO**	**NEWBUILDING LNG vs HFO & Scrubbers**	**NEWBUILDING LNG vs MGO**
< 500 nm	< 8,000 kW	NA	NA	NA	1,610,450	-4,059
500 - 2,000 nm	< 8,000 kW	NA	NA	NA	2,148,901	2,006,558
	8,000 - 16,000 kW	NA	NA	NA	957,809	2,006,922
2,000 - 4,000 nm	< 8,000 kW	NA	NA	NA	5,132,128	7,613,608
	8,000 - 16,000 kW	5,272,928	2,124,368	7,397,296	6,286,467	13,888,754
4,000 - 10,000 nm	8,000 - 16,000 kW	5,786,916	2,948,504	8,735,420	6,600,375	14,406,552
	16,000 - 26,000 kW	11,177,175	6,646,892	17,824,066	13,344,979	29,015,794

Table 20. Average NPV (€) for each investment option by type of vessel, engine power and autonomy (base scenario. 2013 prices)

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

CONTAINER SHIP

		1st STAGE			2nd STAGE	
AUTONOMY (ROUTE DISTANCE RANGE IN nm)	ENGINE POWER (kW)	SCRUBBER + HFO vs MGO	RETROFITTING LNG DUAL FUEL vs HFO & Scrubbers	RETROFITTING LNG DUAL FUEL vs MGO	NEWBUILDING LNG vs HFO & Scrubbers	NEWBUILDING LNG vs MGO
< 500 nm	< 8,000 kW	-1,428,593	-633,628	-2,062,220	2,002,823	1,046,661
	8,000 - 16,000 kW	-1,523,159	-2,439,903	-3,963,061	1,094,197	8,907
	16,000 - 26,000 kW	-5,030	-1,516,731	-1,521,762	668,152	912,144
500 - 2,000 nm	< 8,000 kW	966,535	-476,959	489,576	3,623,578	5,603,676
	8,000 - 16,000 kW	-443,237	-526,739	-1,122,396	2,855,496	3,385,252
	16,000 - 26,000 kW	4,676,147	2,808,855	7,485,002	7,139,968	13,741,092
	> 26,000 kW	8,552,860	4,190,243	12,743,102	8,246,595	18,028,620
2,000 - 4,000 nm	< 8,000 kW	2,273,695	-5,465	2,268,231	4,436,666	7,892,732
	8,000 - 16,000 kW	3,247,242	2,800,538	5,807,190	6,942,784	12,026,302
	16,000 - 26,000 kW	3,409,732	1,206,909	4,616,641	7,729,277	15,193,840
	> 26,000 kW	27,239,220	10,718,111	37,957,331	20,902,863	55,725,818
4,000 - 10,000 nm	< 8,000 kW	988,652	1,291,977	2,280,630	7,658,344	12,798,352
	8,000 - 16,000 kW	4,514,377	2,457,387	6,971,764	8,062,008	15,078,255
	16,000 - 26,000 kW	12,663,180	9,153,590	21,816,770	15,354,771	31,873,525
	> 26,000 kW	26,460,121	13,425,234	39,885,355	21,048,057	52,099,876

NPV

Table 20. Average NPV (€) for each investment option by type of vessel, engine power and autonomy (base scenario. 2013 prices)

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

GENERAL CARGO

				1st STAGE	2nd STAGE	
AUTONOMY (ROUTE DISTANCE RANGE IN nm)	ENGINE POWER (kW)	SCRUBBER + HFO vs MGO	RETROFITTING LNG DUAL FUEL vs HFO & Scrubbers	RETROFITTING LNG DUAL FUEL vs MGO	NEWBUILDING LNG vs HFO & Scrubbers	NEWBUILDING LNG vs MGO
500 - 2,000 nm	< 8,000 kW	224,281	-1,305,551	-1,081,270	1,791,172	2,409,464
2,000 - 4,000 nm	< 8,000 kW	823,094	-1,402,568	-579,474	1,239,276	1,982,260

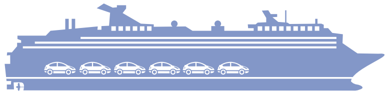
PAX

				1st STAGE	2nd STAGE	
AUTONOMY (ROUTE DISTANCE RANGE IN nm)	ENGINE POWER (kW)	SCRUBBER + HFO vs MGO	RETROFITTING LNG DUAL FUEL vs HFO & Scrubbers	RETROFITTING LNG DUAL FUEL vs MGO	NEWBUILDING LNG vs HFO & Scrubbers	NEWBUILDING LNG vs MGO
< 500 nm	< 8,000 kW	-3,972,367	3,456,935	-834,533	6,067,104	1,299,067
	8,000 - 16,000 kW	-3,794,307	NA	-5,201,034	8,930,133	4,132,024

Table 20. Average NPV (€) for each investment option by type of vessel, engine power and autonomy (base scenario. 2013 prices)

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

RO-PAX



AUTONOMY (ROUTE DISTANCE RANGE IN nm)	ENGINE POWER (kW)	HFO + SCRUBBER vs MGO	RETROFITTING LNG DUAL FUEL vs HFO & Scrubbers	1st STAGE RETROFITTING LNG DUAL FUEL vs MGO	2nd STAGE NEWBUILDING LNG vs HFO & Scrubbers	NEWBUILDING LNG vs MGO
< 500 nm	< 8,000 kW	-1,590,844	-1,203,564	-3,071,438	2,312,299	1,953,373
	8,000 - 16,000 kW	-544,103	-2,398,538	-2,942,641	4,622,906	7,272,289
	16,000 - 26,000 kW	8,902,667	3,883,564	12,101,575	11,377,186	21,772,448
	> 26,000 kW	4,372,043	5,736,235	10,108,278	22,542,026	29,447,889
500 - 2,000 nm	< 8,000 kW	NA	NA	NA	20,065,741	38,987,143
	8,000 - 16,000 kW	2,939,549	-1,129,549	856,707	8,642,471	17,353,856
	16,000 - 26,000 kW	10,266,121	4,658,758	14,924,878	17,751,504	34,101,315
	> 26,000 kW	31,669,570	21,422,413	53,091,983	37,916,535	73,606,145

Table 20. Average NPV (€) for each investment option by type of vessel, engine power and autonomy (base scenario. 2013 prices)

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

RO-RO

				1st STAGE	2nd STAGE	
AUTONOMY (ROUTE DISTANCE RANGE IN nm)	**ENGINE POWER (kW)**	SCRUBBER + HFO **vs MGO**	RETROFITTING LNG DUAL FUEL **vs HFO & Scrubbers**	RETROFITTING LNG DUAL FUEL **vs MGO**	NEWBUILDING LNG **vs HFO & Scrubbers**	NEWBUILDING LNG **vs MGO**
< 500 nm	< 8,000 kW	NA	NA	NA	2,816,178	2,549,629
	8,000 - 16,000 kW	1,780,075	-1,939,933	-159,858	886,525	953,485
500 - 2,000 nm	< 8,000 kW	831,370	-1,126,152	-294,782	3,564,408	6,044,812
	8,000 - 16,000 kW	2,588,034	-613,098	1,974,936	6,610,275	13,147,473
	16,000 - 26,000 kW	17,139,466	8,793,419	25,932,884	16,064,937	34,902,584
	> 26,000 kW	13,636,718	-12,562,805	1,073,913	892,094	15,420,875
2,000 - 4,000 nm	< 8,000 kW	-422,085	-1,086,385	-1,508,470	1,421,831	1,395,095
	8,000 - 16,000 kW	3,375,438	679,415	4,054,853	5,560,932	10,964,458
	16,000 - 26,000 kW	15,067,501	7,762,971	22,830,472	14,048,620	29,996,689
4,000 - 10,000 nm	< 8,000 kW	-721,115	-3,269,694	-3,990,810	1,467,628	2,266,473
	8,000 - 16,000 kW	8,256,952	2,696,560	10,953,512	15,482,532	31,754,615

Table 20. Average NPV (€) for each investment option by type of vessel, engine power and autonomy (base scenario. 2013 prices)

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

The following table shows the average NPV results obtained when comparing five sets of alternative options for different types of ships deployed in the Mediterranean SSS fleet in the base scenario and taking as a base 2013 prices.

			1st STAGE	2nd STAGE	
	SCRUBBER + HFO vs MGO	RETROFITTING LNG DUAL FUEL vs HFO & Scrubbers	RETROFITTING LNG DUAL FUEL vs MGO	NEWBUILDING LNG vs HFO & Scrubbers	NEWBUILDING LNG vs MGO
CC 1	NA	NA	NA	3,527,097	4,757,832
CC 2	4,919,584	2,226,252	7,145,835	5,183,197	11,483,929
CC 3	10,208,905	5,952,327	16,161,232	13,254,458	28,600,524
CONT-SHIP 1	294,839	-519,578	-224,739	3,441,270	4,968,197
CONT-SHIP 2	3,347,572	-626,343	2,506,954	4,473,621	8,874,708
CONT-SHIP 3	1,100,184	2,217,855	3,258,915	5,803,518	8,678,454
CONT-SHIP 4	4,478,771	2,336,917	6,815,688	7,824,058	15,547,145
CONT-SHIP 5	14,482,229	8,587,618	23,069,846	15,248,715	33,296,048
CONT-SHIP 6	20,857,994	5,772,763	26,630,756	15,316,013	43,303,771
CONT-SHIP 7	54,566,825	28,304,512	82,871,337	37,944,076	99,480,680
GC 1	463,806	-1,344,358	-880,552	1,554,646	2,226,377
PAX	-3,685,866	2,694,786	-1,139,680	5,388,840	732,979

Table 21. Average NPV (€) for different types of vessels (base scenario, 2013 prices)

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

	SCRUBBER + HFO vs MGO	RETROFITTING LNG DUAL FUEL vs HFO & Scrubbers	1st STAGE: RETROFITTING LNG DUAL FUEL vs MGO	2nd STAGE: NEWBUILDING LNG vs HFO & Scrubbers	NEWBUILDING LNG vs MGO
HSC	-5,056,641	2,828,877	-2,227,763	16,043,860	11,774,420
RO-PAX 1A	-604,500	-1,558,167	-2,355,479	3,104,368	4,560,124
RO-PAX 1B	1,261,649	-4,178,932	-3,434,949	4,505,451	8,722,086
RO-PAX 2	8,487,985	2,009,151	10,139,897	11,873,031	23,536,451
RO-PAX 3	12,625,451	14,425,671	27,051,122	25,034,532	39,484,392
RO-PAX 4A	6,564,568	2,711,732	9,276,300	18,808,801	30,745,944
RO-PAX 4B	30,074,637	17,253,692	47,328,329	37,391,367	74,578,573
RO-RO 1	380,326	-1,355,486	-975,160	2,781,148	4,125,136
RO-RO 2	2,880,741	-132,696	2,748,045	5,133,054	10,040,657
RO-RO 3	15,874,557	7,572,856	23,447,414	14,018,600	30,425,229

Table 21. Average NPV (€) for different types of vessels (base scenario, 2013 prices)

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

7 SCENARIOS

7.1 INTRODUCTION

Uncertainty is undoubtedly the most appropriate word to describe the first 15 years of the 21st century. A major financial crisis unchained in 2008, the collapse of the construction sector in many countries, which was the engine driving the growth of their economies, political upheavals in the Southern shore of the Mediterranean since 2011 and giant forces in the energy market at play, which are at the doorstep of the EU; all of these events shape the world we live in and are particularly difficult to predict in advance.

Given the limited ability of the shipping industry to control such events, taking into account that uncertainty in the expected evolution of trade flows affects demand for maritime transport, and the fact that uncertainty in the energy market influences their operational costs; trying to understand the effect of key determinant factors in the results that different strategies would have in various scenarios becomes crucial.

Following a scenario qualitative methodology, three different scenarios have been designed. The scenarios defined are not projections but alternative plausible futures for the SSS sector in Southern Europe. This methodology has been used as a technique to understand the impact of risk and uncertainty as it constitutes a method to reflect about a complex and changing environment. The three scenarios depicted in this section pose a challenge for conventional modes of thinking and we hope that this will provide useful information for the decision-making processes of ship owners and policy-makers.

The methodology that has been followed is illustrated in the next figure. The first step has been the analysis of the current situation in the SSS market in the Mediterranean, Black Sea and Portugal. Next, critical factors influencing this market and more specifically having an impact on the investment required by the different technological options for ship owners to comply with environmental regulation and on the operational costs that these options imply have been identified and analysed. Plausible future evolutions for each driving factor have been projected in step three and the combination of these potential future situations for the different determinant factors have configured three scenarios named **rough black seas, greener MoS and blue oceans.**

For each of these scenarios, the financial feasibility results for each technological option to comply with environmental regulation and the cost-benefit analysis for each vessel in the SSS fleet in the Mediterranean, Black Sea and Portugal have been calculated. These results have been validated with key informants from leading companies in this sector: MAN Diesel & Turbo, Wärtsilä, Caterpillar, Ros Roca Indox Cryo Energy, S.L., Boluda Corporación Marítima, RINA and Bureau Veritas. Feedback received from experts in these prominent firms has been taken into account to re-define the three scenarios which results are presented here below.

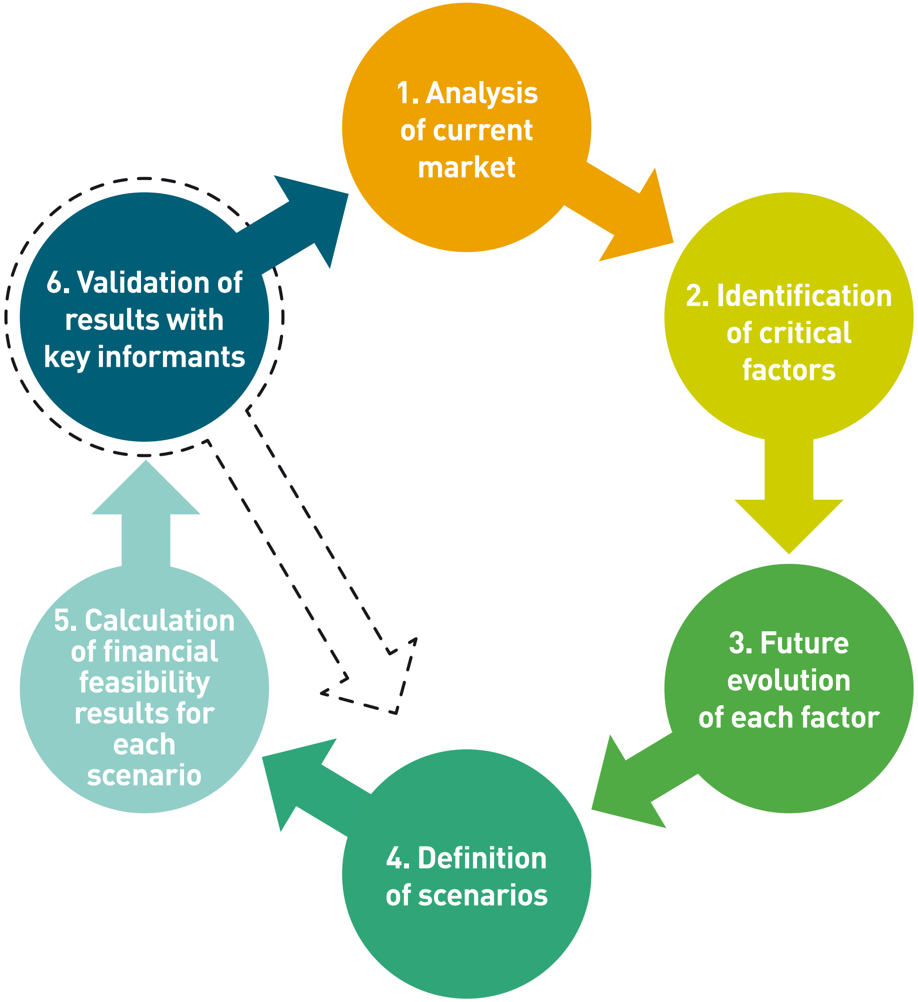


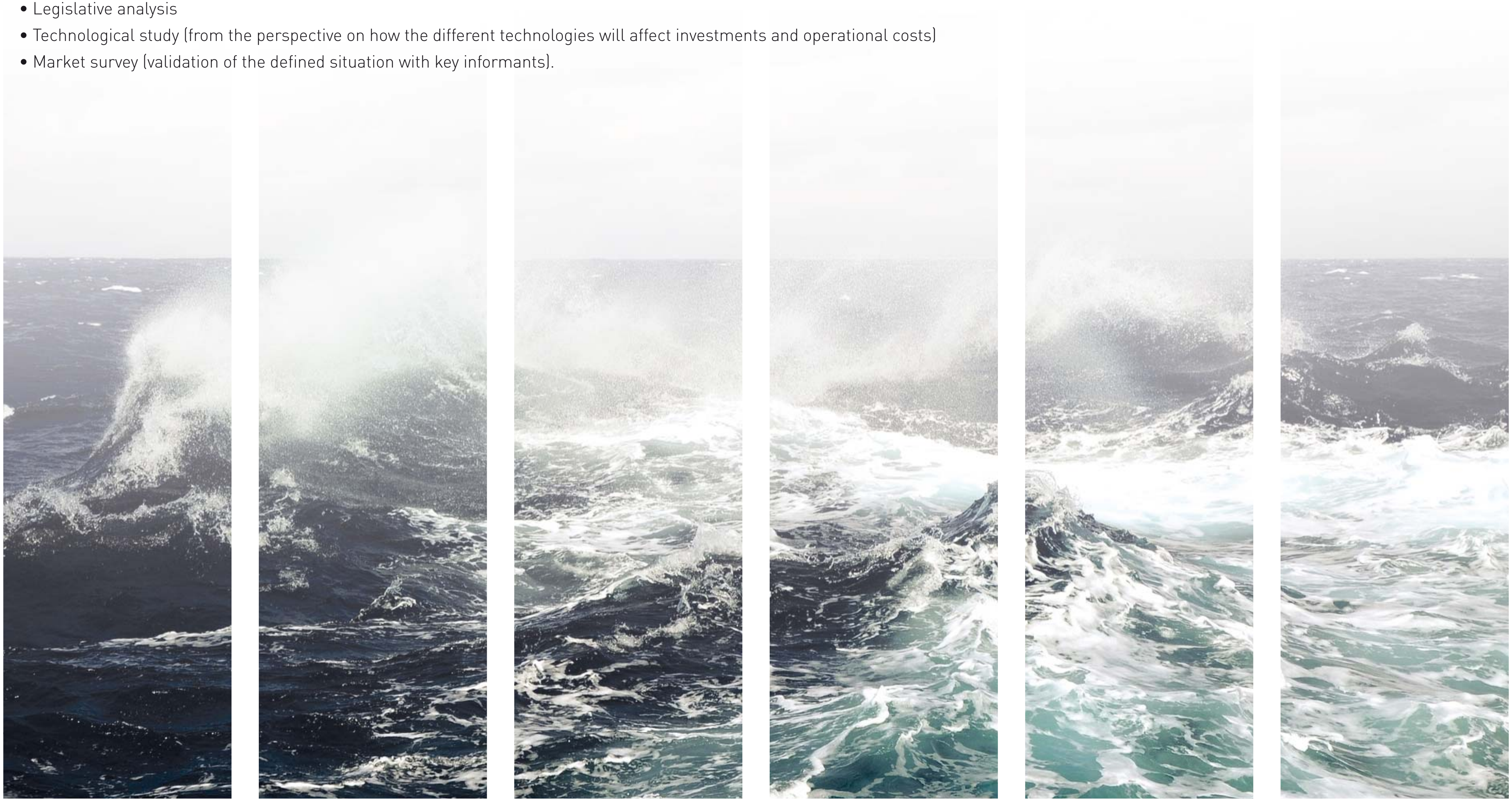
Figure 53. Methodological scheme

Source: Fundación Valenciaport, 2014

7.2 ANALYSIS OF CURRENT MARKET

The analysis conducted in the previous sections (SSS supply, fleet and consumptions) has been completed in this part of the study in order to analyse the current market situation that would permit the definition of the three scenarios. More specifically, the following studies have been conducted:

- Macroeconomics analysis (evolution of main economic variables and trade forecasts)
- Industry review (evolution of main variables related to the maritime sector)
- Legislative analysis
- Technological study (from the perspective on how the different technologies will affect investments and operational costs)
- Market survey (validation of the defined situation with key informants).



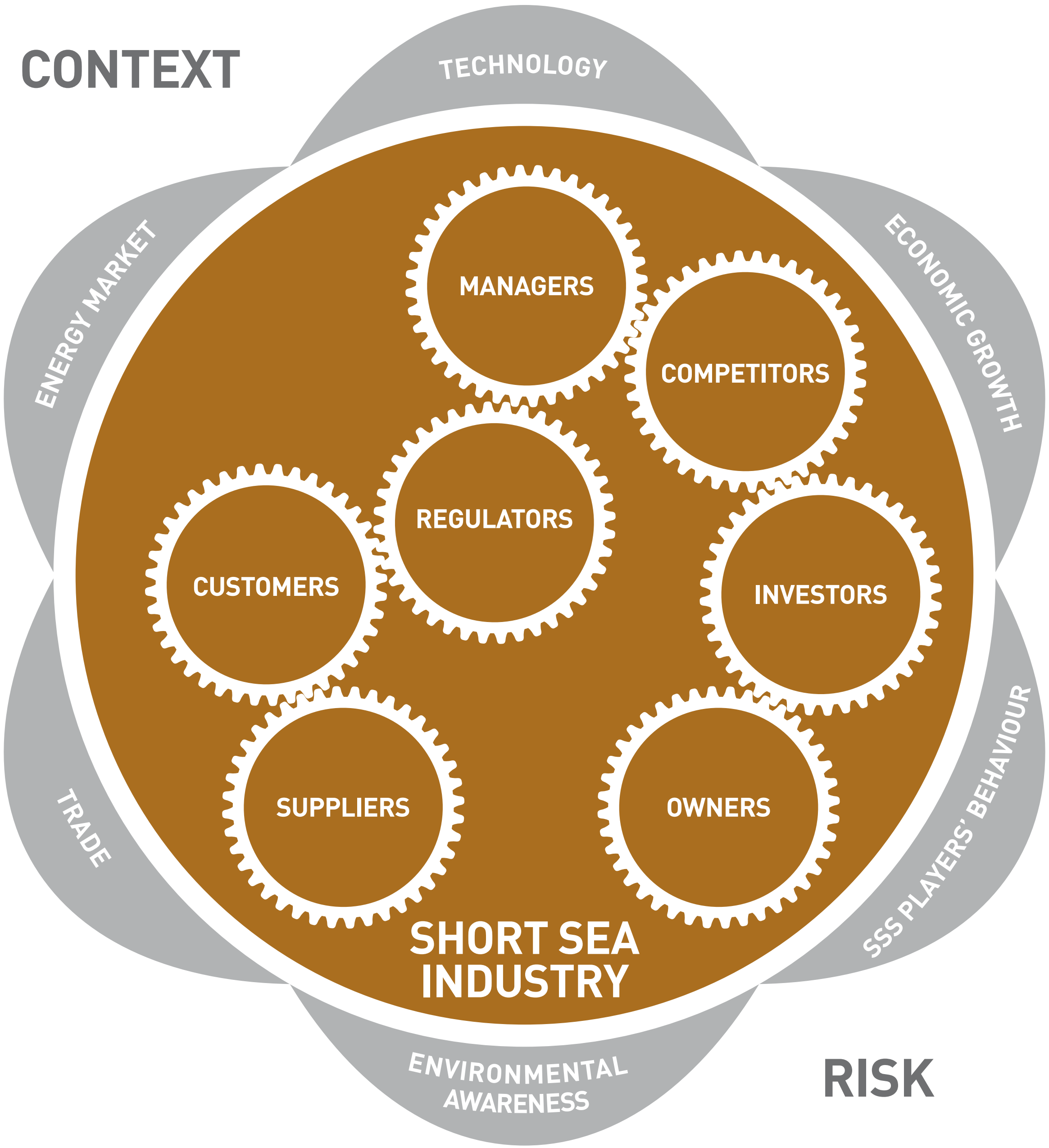


Figure 54. Identification of critical factors

Source: Fundación Valenciaport, 2014

7.4 FUTURE EVOLUTION OF EACH FACTOR

Rough Black Seas

Greener MoS

Blue Oceans

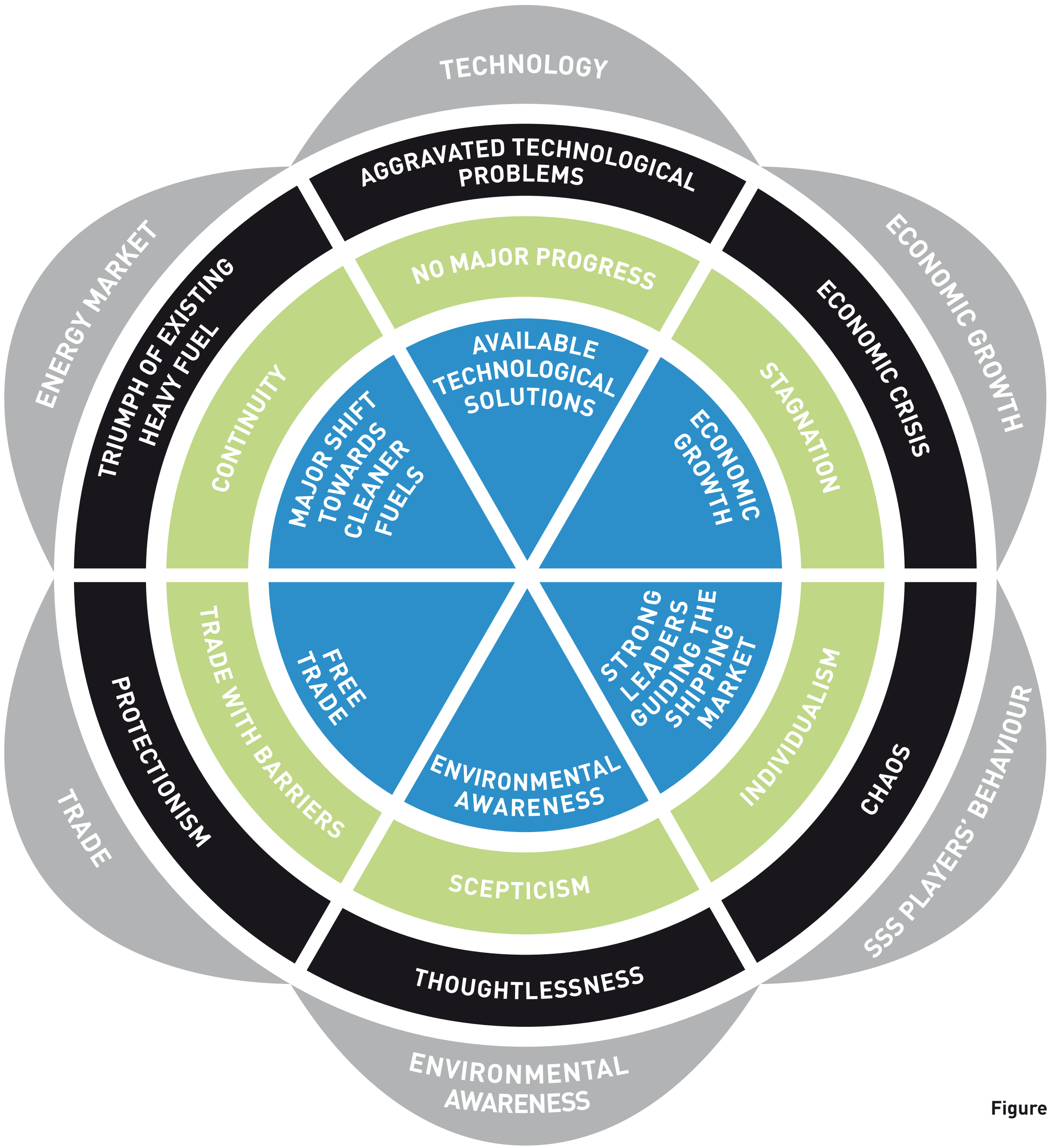


Figure 55. Future evolution of each factor

Source: Fundación Valenciaport, 2014

7.5
DEFINITION OF SCENARIOS

Figure 56. Definition of scenarios

Source: Fundación Valenciaport, 2014

SCENARIO	DESCRIPTION	HFO Price (US$/ tonne) in 2020	MGO Price (US$/ tonne) in 2020	LNG Price (US$/ tonne) in 2020	Forecast of yearly change in gap LNG-MGO (%)	Forecast of yearly changed in gap LNG-HFO (%)	Forecast of yearly change in gap MGO-HFO (%)	Change in retrofitting investments 2020 vs 2013 prices(%)	Change in LNG newbuilding investments 2020 vs 2013 (%)	Forecast of trade growth rate (%)	No. vessels in SSS fleet in 2020 as a result of demand forecast	No. vessels in SSS fleet in 2030 as a result of demand forecast	Discount rate (%)	Inflation rate (%)
Rough Black Seas	• Protectionist trends rule the markets, trade volumes decrease and consequently demand for shipping is reduced • Continued economic stagnation in the EU • Skepticism about climate change • Lack of leadership in the shipping market • No solutions to technological challenges in the LNG bunkering business	350	550	950	-0.05%	-0.05%	0.00%	+25%	+25%	-1.00%	610	635	10.00%	1.00%
Greener MoS	• EU on the road to stable economic recovery and steady growth • Climate change awareness and short sea shipping increasing market share • Environmentally aware strong leaders in the shipping market pulling players towards the most sustainable solutions • Technological solutions to LNG bunkering progressively entering the market	800	1,250	500	0.05%	0.05%	0.05%	0.00%	0.00%	1.50%	690	750	12.00%	2.00%
Blue Oceans	• Steady economic growth in the EU by 2020 and no signs of imbalance nor economic over-heating • Deepening EU integration leading to stronger trade relationships • Environmental sustainability as the top priority • Strong leaders in the shipping market and well designed incentives convince most players to adopt the most environmentally friendly solutions • Technological solutions for LNG bunkering well established in the market	1,150	1,750	500	0.10%	0.10%	0.10%	-25%	-25%	5.00%	775	1,035	15.00%	3.00%

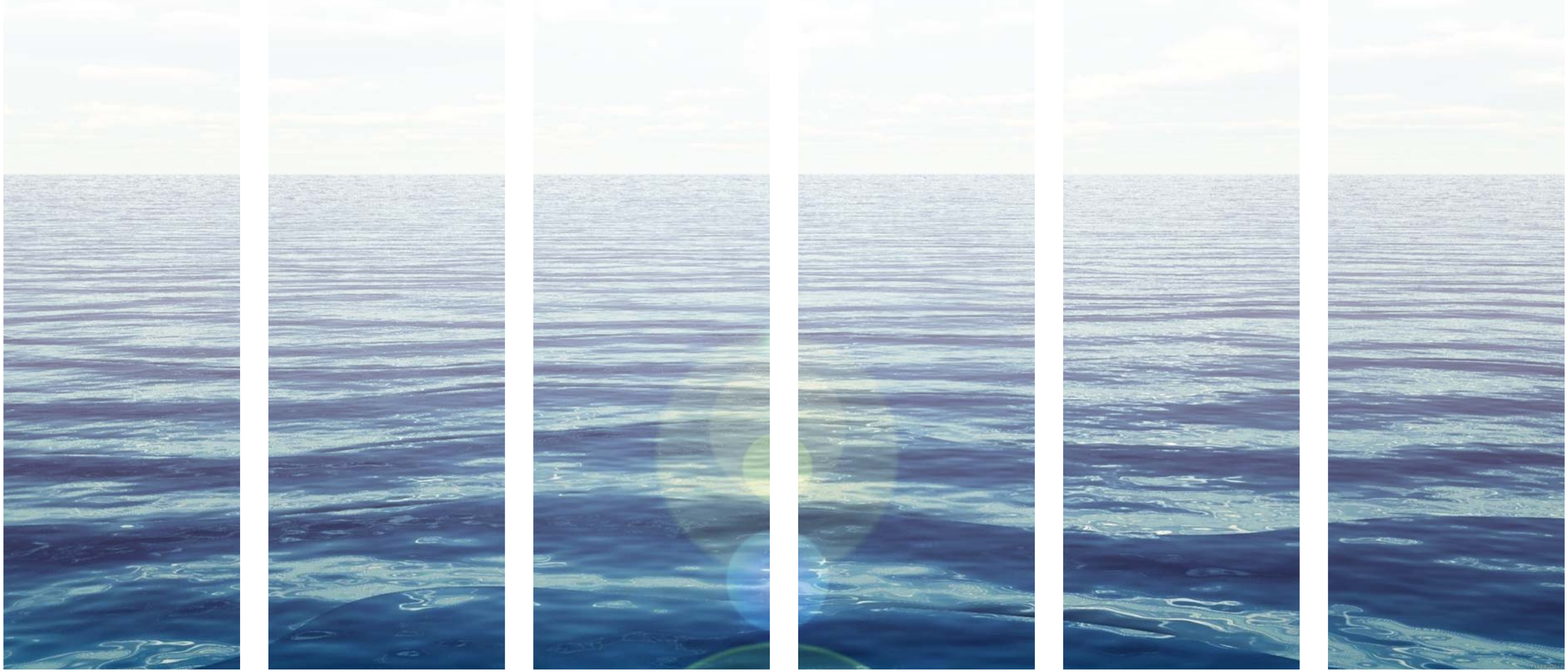
Table 22. Selected input data of each scenario

Source: Fundación Valenciaport, 2014

7.6 CALCULATION OF FINANCIAL FEASIBILITY RESULTS FOR EACH SCENARIO

This section includes the main results of the financial feasibility study conducted for the three constructed scenarios, following the same methodology employed in the base scenario. The next results are shown for the three cases:

- The average investment (€) for installing scrubbers, retrofitting or newbuilding engines considering the most representative sub-category of vessel
- Total investments in scrubbers, retrofitting and newbuilding engines if all vessels opted for the same strategy classified by:
  - Type of vessel (car carrier, container ship, general cargo, pax, ro-pax and ro-ro)
  - Geographical area (Atlantic area, Western Mediterranean, Eastern Mediterranean & Black Sea and Mixed Area)
- The best option to comply with international environmental legislation for each of the vessels deployed in the Med SSS fleet
  - First stage (assuming that vessels will be operational until the end of their economic lives)
  - Second stage (including newbuilding options)



Rough Black Seas

	SCRUBBER + HFO	RETROFITTING LNG DUAL FUEL	SCRUBBER + NEWBUILDING HFO	NEWBUILDING MGO	NEWBUILDING LNG
CC 2	2,657,236	10,249,343	6,396,411	3,739,175	12,076,335
CONT-SHIP 3	3,683,008	8,562,436	7,295,007	3,611,999	10,130,778
GC 1	1,888,722	6,544,382	3,611,977	1,723,256	5,841,335
PAX	3,968,886	1,885,235	5,231,783	1,262,897	1,952,000
RO-PAX 2	3,777,444	18,648,476	12,918,828	9,141,385	18,772,013
RO-RO 3	3,683,008	19,009,108	10,879,778	7,196,771	18,658,256

Table 23: Average investment (€) for installing scrubbers, retrofitting or newbuilding engines considering the most representative vessels (rough black seas scenario, 2013 prices)

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

	SCRUBBER + HFO	RETROFITTING LNG DUAL FUEL	SCRUBBER + NEWBUILDING HFO	NEWBUILDING MGO	NEWBUILDING LNG
CAR CARRIER	119.61	426.51	272.70	153.09	495.95
CONTAINER SHIP	928.21	3,378.75	2,420.92	1,492.71	3,925.13
GENERAL CARGO	12.76	44.21	24.40	11.64	39.46
PAX	218.28	131.76	307.04	88.76	136.70
RO-PAX	855.35	3,417.00	2,731.87	1,876.52	3,584.39
RO-RO	224.60	1,022.91	590.02	365.42	992.79
TOTAL SSS FLEET	**€2,358.82M**	**€8,421.14M**	**€6,346.95M**	**€3,988.13M**	**€9,174.43M**

Table 24: Sum of investments (million €) in scrubbers, retrofitting and newbuilding engines if all vessels of a specific type opted for the same strategy (rough black seas scenario, 2013 prices)

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

Rough Black Seas

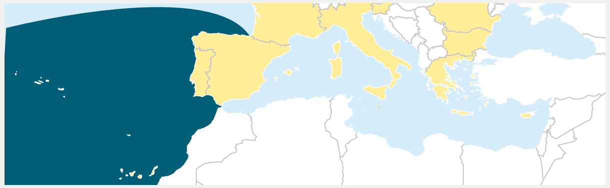
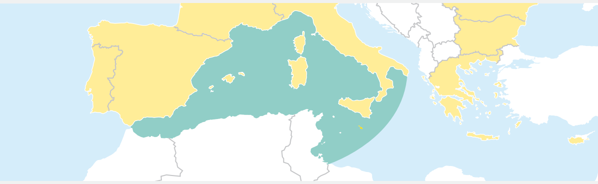
	SCRUBBER + HFO	RETROFITTING LNG DUAL FUEL	SCRUBBER + NEWBUILDING HFO	NEWBUILDING MGO	NEWBUILDING LNG
ATLANTIC AREA 	203.44	844.21	581.36	377.92	814.40
WESTERN MEDITERRANEAN SEA 	793.35	2,641.50	2,113.96	1,320.61	2,743.99
EASTERN MEDITERRANEAN & BLACK SEA 	685.28	2,281.39	1,806.18	1,120.90	2,422.32
ATLANTIC - WESTERN MED - EASTERN MED 	676.75	2,654.03	1,845.45	1,168.70	3,193.73
TOTAL SSS FLEET	**€2,358.82M**	**€8,421.14M**	**€6,346.95M**	**€3,988.13M**	**€9,174.43M**

Table 25: Sum of investments (million €) if all vessels opted for the same strategy by geographical zone (rough black seas scenario, 2013 prices)

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

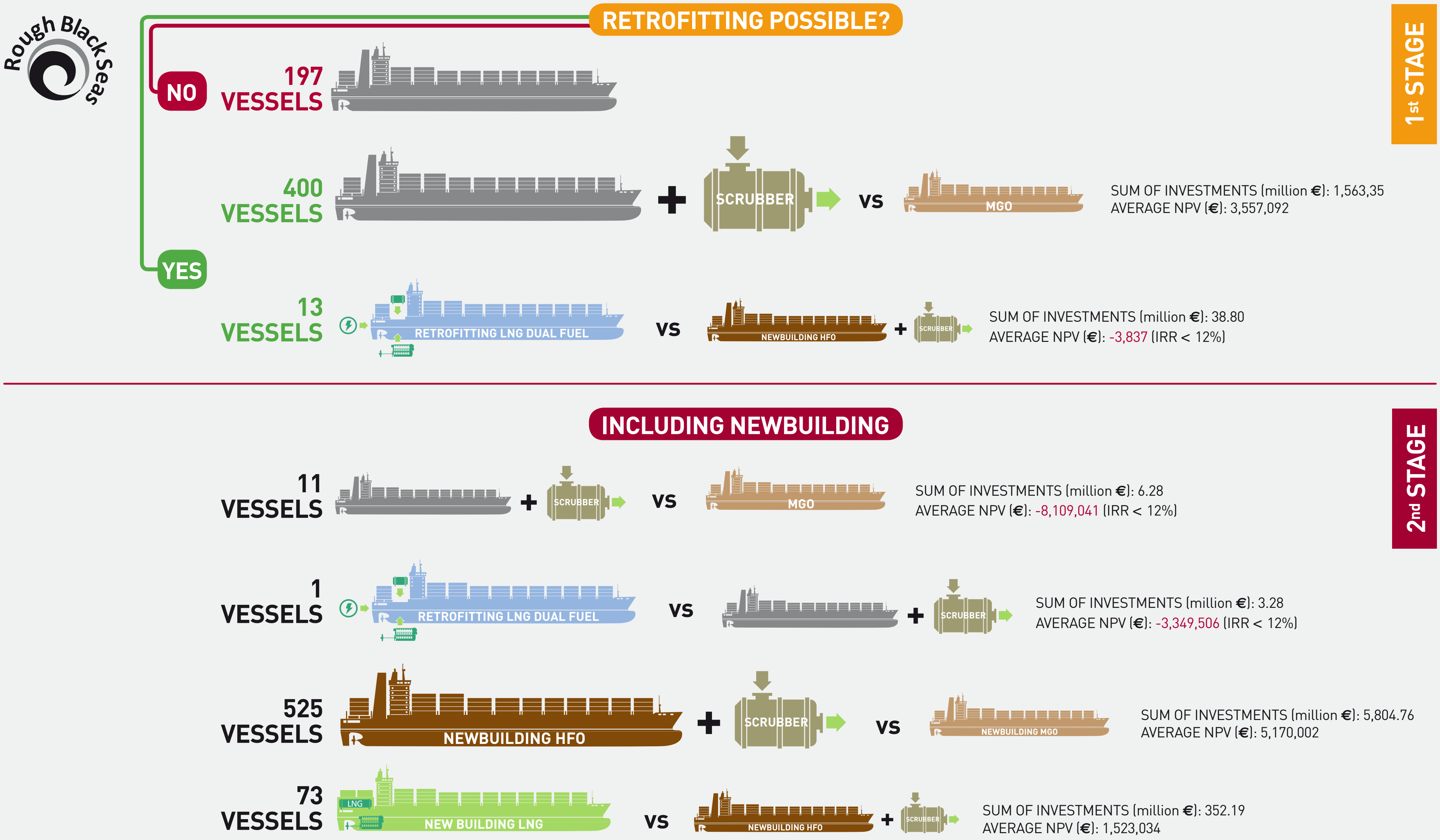


Figure 57. The best option to comply with international environmental legislation for each of the vessels deployed in the Med SSS fleet – First stage (assuming that vessels will be operational until the end of their economic lives) and second stage (including newbuilding options), (rough black seas scenario, 2013 prices)

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

Greener MoS

	SCRUBBER + HFO	RETROFITTING LNG DUAL FUEL	SCRUBBER + NEWBUILDING HFO	NEWBUILDING MGO	NEWBUILDING LNG
CC 2	2,657,236	8,199,475	5,648,576	2,991,340	9,661,068
CONT-SHIP 3	3,683,008	6,849,949	6,572,607	2,889,599	8,104,622
GC 1	1,888,722	5,235,506	3,267,326	1,378,605	4,673,068
PAX	3,968,886	1,508,188	4,979,204	1,010,318	1,561,600
RO-PAX 2	3,777,444	14,918,781	11,090,551	7,313,108	15,017,611
RO-RO 3	3,683,008	15,207,286	9,440,424	5,757,416	14,926,604

Table 26: Average investment (€) for installing scrubbers, retrofitting or newbuilding engines considering the most representative vessels (Greener MoS scenario, 2013 prices)

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

	SCRUBBER + HFO	RETROFITTING LNG DUAL FUEL	SCRUBBER + NEWBUILDING HFO	NEWBUILDING MGO	NEWBUILDING LNG
CAR CARRIER	129.98	370.76	263.05	133.08	431.13
CONTAINER SHIP	1,008.61	2,937.12	2,306.21	1,297.60	3,412.08
GENERAL CARGO	13.86	38.43	23.98	10.12	34.30
PAX	237.19	114.54	314.35	77.16	118.83
RO-PAX	929.43	2,970.37	2,560.67	1,631.24	3,115.88
RO-RO	244.06	889.21	561.71	317.66	863.02
TOTAL SSS FLEET	**€2,563.13M**	**€7,320.42M**	**€6,029.97M**	**€3,466.85M**	**€7,975.25M**

Table 27: Sum of investments (million €) in scrubbers, retrofitting and newbuilding engines if all vessels of a specific type opted for the same strategy (Greener MoS, 2013 prices)

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

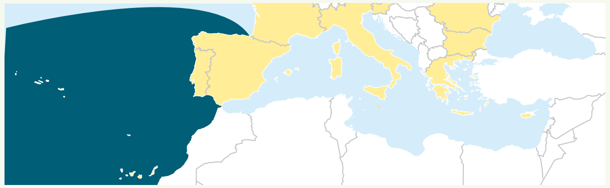
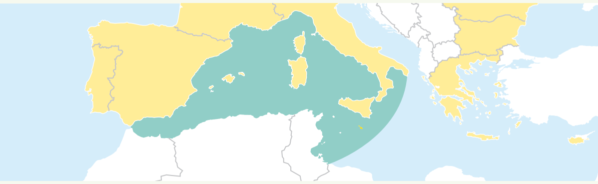
	Scrubber + HFO	RETROFITTING LNG DUAL FUEL	Scrubber + NEWBUILDING HFO	NEWBUILDING MGO	NEWBUILDING LNG
ATLANTIC AREA 	221.06	733.86	549.59	328.52	707.95
WESTERN MEDITERRANEAN SEA 	862.07	2,296.23	2,010.06	1,147.99	2,385.32
EASTERN MEDITERRANEAN & BLACK SEA 	744.63	1,983.20	1,719.02	974.39	2,105.70
ATLANTIC - WESTERN MED - EASTERN MED 	735.36	2,307.13	1,751.30	1,015.94	2,776.28
TOTAL SSS FLEET	**€2,563.13M**	**€7,320.42M**	**€6,029.97M**	**€3,466.85M**	**€7,975.25M**

Table 28: Sum of investments (million €) if all vessels opted for the same strategy by geographical zone (Greener MoS, 2013 prices)

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

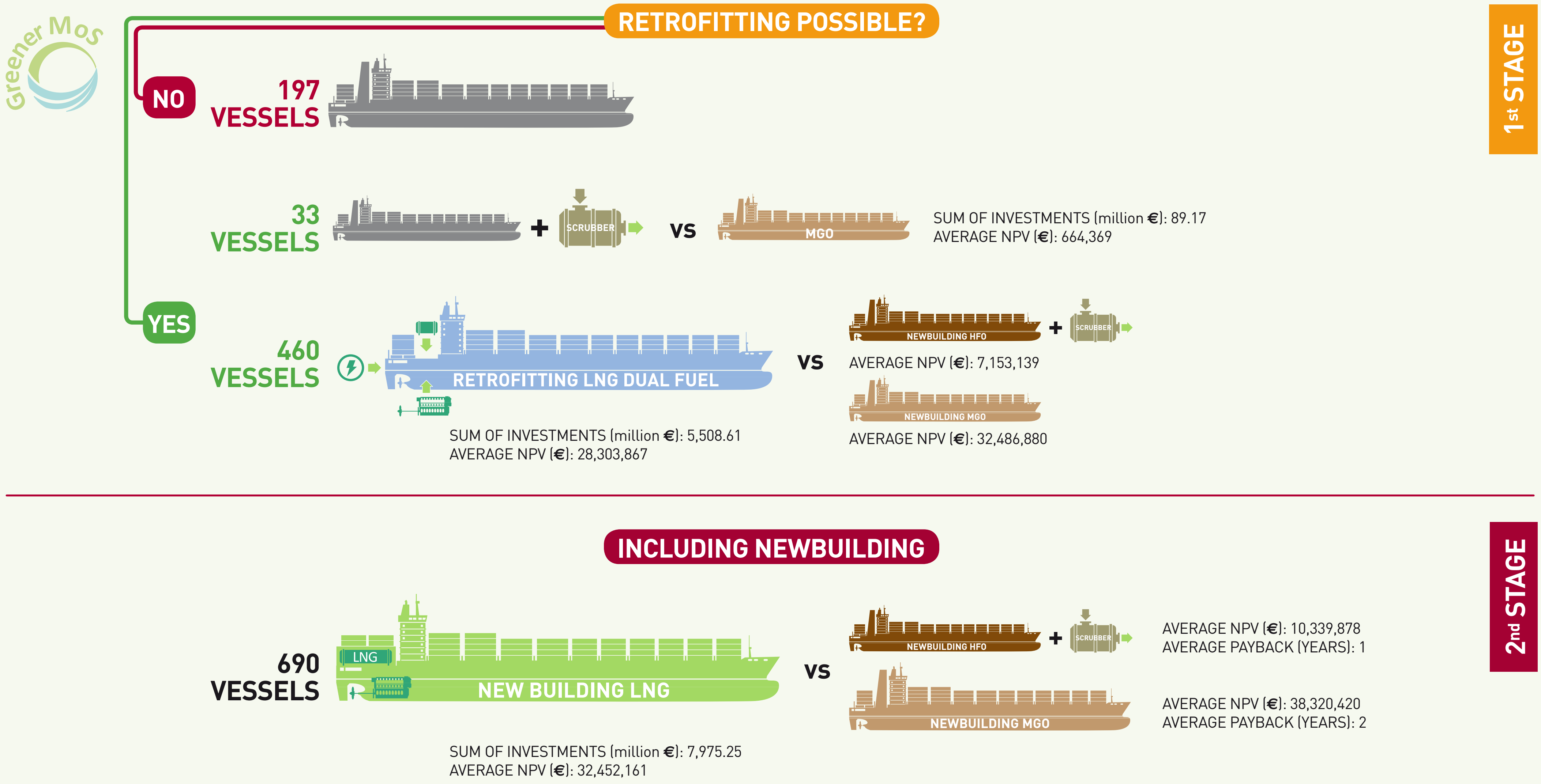


Figure 58. The best option to comply with international environmental legislation for each of the vessels deployed in the Med SSS fleet – First stage (assuming that vessels will be operational until the end of their economic lives) and second stage (including newbuilding options), (Greener MoS scenario, 2013 prices)

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

Blue Oceans

	SCRUBBER + HFO	RETROFITTING LNG DUAL FUEL	SCRUBBER + NEWBUILDING HFO	NEWBUILDING MGO	NEWBUILDING LNG
CC 2	2,657,236	6,149,606	4,900,741	2,243,505	7,245,801
CONT-SHIP 3	3,683,008	5,137,462	5,850,207	2,167,199	6,078,467
GC 1	1,888,722	3,926,629	2,922,675	1,033,953	3,504,801
PAX	3,968,886	1,131,141	4,726,624	757,738	1,171,200
RO-PAX 2	3,777,444	11,189,086	9,262,274	5,484,831	11,263,208
RO-RO 3	3,683,008	11,405,465	8,001,070	4,318,062	11,194,953

Table 29: Average investment (€) for installing scrubbers, retrofitting or newbuilding engines considering the most representative vessels (Blue Oceans scenario, 2013 prices)

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

	SCRUBBER + HFO	RETROFITTING LNG DUAL FUEL	SCRUBBER + NEWBUILDING HFO	NEWBUILDING MGO	NEWBUILDING LNG
CAR CARRIER	145.99	312.32	258.09	112.10	363.18
CONTAINER SHIP	1,132.86	2,474.20	2,225.94	1,093.09	2,874.31
GENERAL CARGO	15.57	32.37	24.10	8.52	28.90
PAX	266.41	96.49	331.40	65.00	100.10
RO-PAX	1,043.93	2,502.21	2,418.07	1,374.14	2,624.79
RO-RO	274.12	749.06	541.71	267.59	727.00
TOTAL SSS FLEET	**€2,878.87M**	**€6,166.66M**	**€5,799.32M**	**€2,920.44M**	**€6,718.28M**

Table 30: Sum of investments (million €) in scrubbers, retrofitting and newbuilding engines if all vessels of a specific type opted for the same strategy (Blue Oceans scenario, 2013 prices)

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

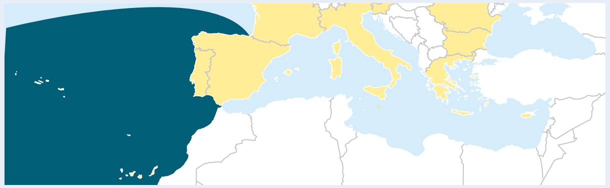
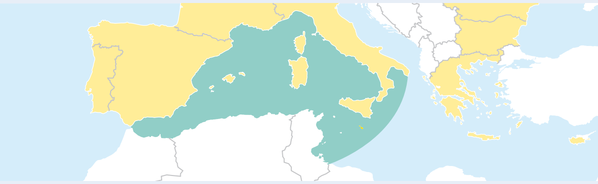
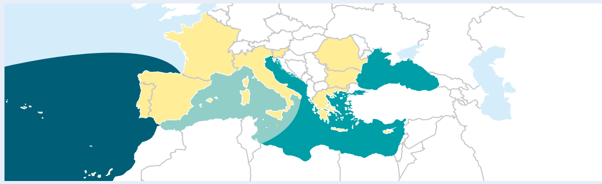
	HFO + SCRUBBER	RETROFITTING LNG DUAL FUEL	NEWBUILDING HFO + SCRUBBER	NEWBUILDING MGO	NEWBUILDING LNG
ATLANTIC AREA 	248.29	618.20	525.04	276.74	596.37
WESTERN MEDITERRANEAN SEA 	968.27	1,934.33	1,935.33	967.06	2,009.38
EASTERN MEDITERRANEAN & BLACK SEA 	836.36	1,670.63	1,657.18	820.82	1,773.82
ATLANTIC - WESTERN MED - EASTERN MED 	825.95	1,943.50	1,681.77	855.82	2,338.71
TOTAL SSS FLEET	**€2,878.87M**	**€6,166.66M**	**€5,799.32M**	**€2,920.44M**	**€6,718.28M**

Table 31: Sum of investments (million €) if all vessels opted for the same strategy by geographical zone (Blue Oceans scenario, 2013 prices)

Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

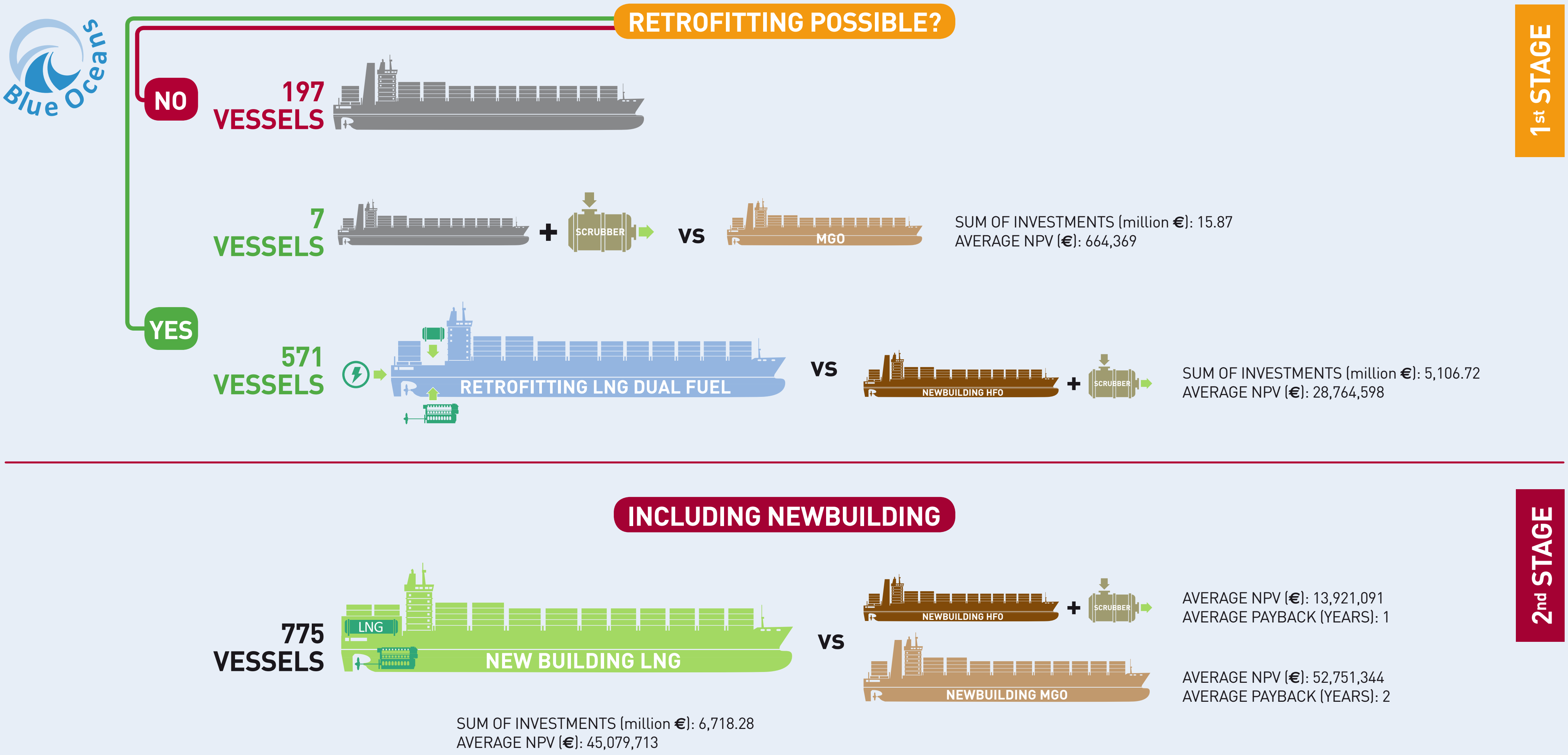


Figure 59. The best option to comply with international environmental legislation for each of the vessels deployed in the Med SSS fleet – First stage (assuming that vessels will be operational until the end of their economic lives) and second stage (including newbuilding options), (Blue Oceans scenario, 2013 prices)

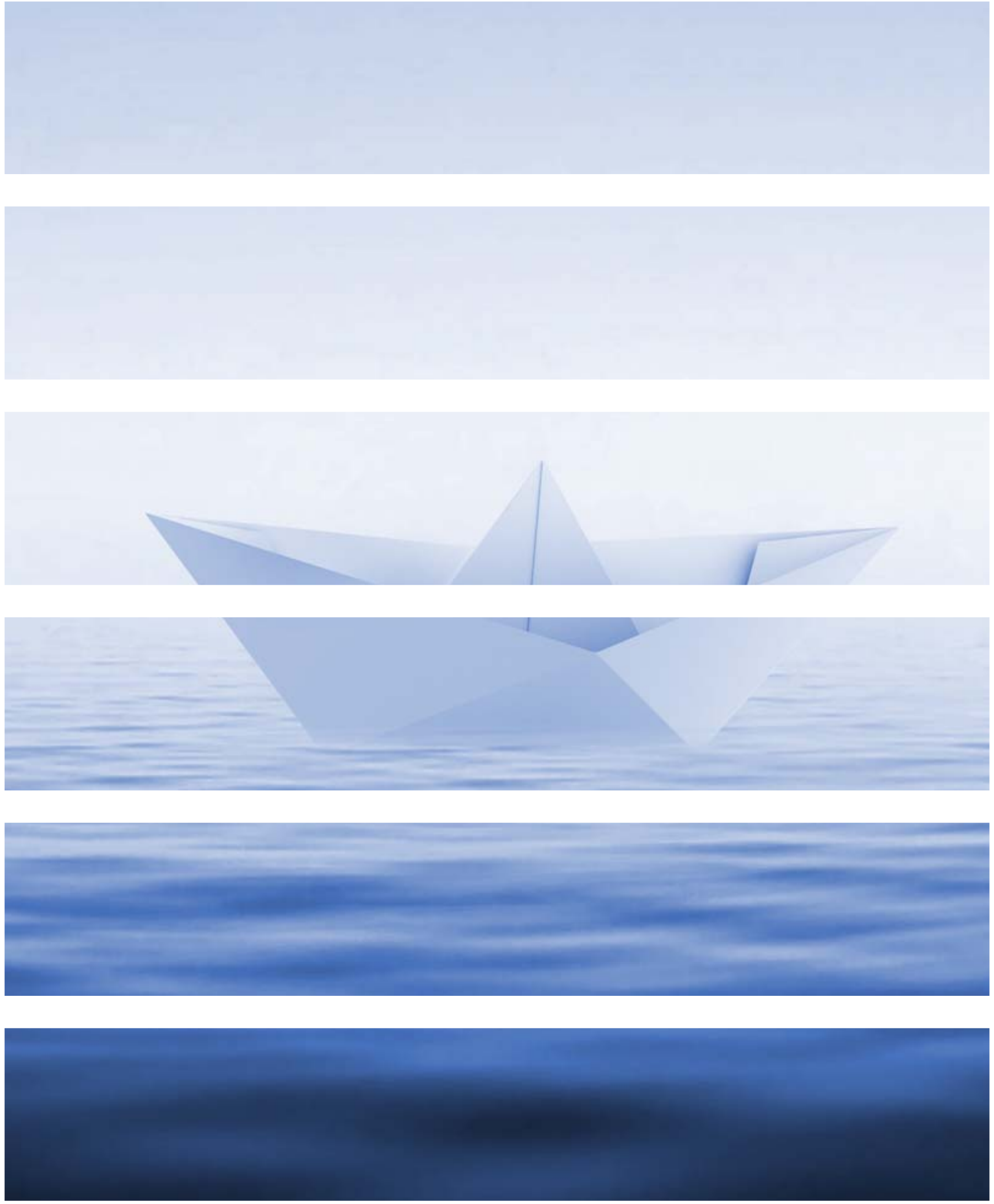
Source: Fundación Valenciaport (2014) based on the MED Short-Sea Lines database

8 CASE STUDIES

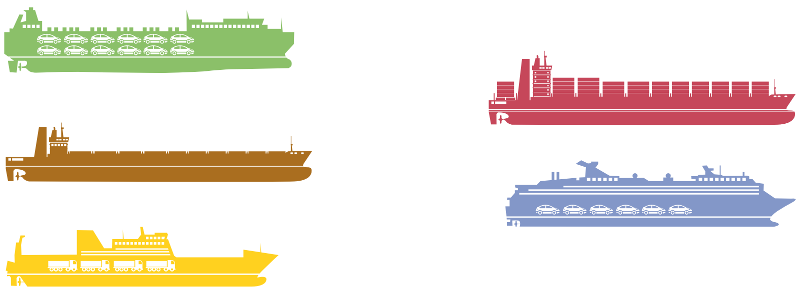
8.1 BUSINESS CASES

The results of the financial feasibility analyses of the different options available for shipowners to comply with international environmental regulations vary considerably depending on factors such as the future prices of various marine fuels and the investment required by the different alternatives to comply with regulation. Uncertainty in the values that these factors will take in the future is the main motivation for the study of the three scenarios in the previous section and for the analysis of six case studies that follows. After identifying the five types of vessels defined in this publication, a specific vessel segment has been selected. For each type of vessel, the vessel segment with the largest number of vessels has been chosen. For instance, in the case of car carriers, the vessel segment where most car carriers are classified is CC2, whilst the most frequent type of vessel segment for containerships is number 3. Once the vessel segment choice has been made, the area where most of the vessels of that type and segment are deployed has been identified. Next, the average ship characteristics (within the selected vessel segment) operating in the specific chosen area has been defined and a sensitivity analysis of the financial feasibility analysis results of the most convenient option for that average ship to comply with international environmental regulation has been conducted. Whenever the age of the average ship allowed for the payback of the retrofitting or installing scrubbers options plus its age to be below the assumed economic life of the vessel, the results presented will be of the option that would enable the shipowner to continue deploying the vessel (these being retrofitting to LNG dual fuel or installing scrubbers).

For clarity sake, an example of how the graphs could be interpreted is provided. Given the average age of the ships in the car carrier CC2 segment deployed in lines connecting the Atlantic with the Western and Eastern Mediterranean (15 years old in 2020) and the payback of the option studied in the base scenario (5 years), only the options that would allow the vessels to continue operating have been considered. For this type of vessel segment and area, the most convenient option from a financial profitability point of view would be retrofitting the vessel. The net present value (NPV) of retrofitting to LNG dual fuel in comparison to using MGO as marine fuel for this average ship would be €15 million if the gap between the prices of MGO and LNG is 500 €/tonne and the differential investment required for the LNG engines in comparison to MGO engines is €8,860,640. If the level of investment remains at €8,860,640 but with a fuel price difference of only €75, the NPV would be negative (€-210,335), and thus retrofitting would be no longer profitable. Logically, if larger investments were required for the retrofitting of the ship, the NPV would turn negative even with higher fuel price differences. Should the differential investment required reach €10,744,000, the NPV would be negative if the price gap of the two marine fuels is below €100.



Case study methodological steps



01

Type of vessels identification

02

Vessel segment selection

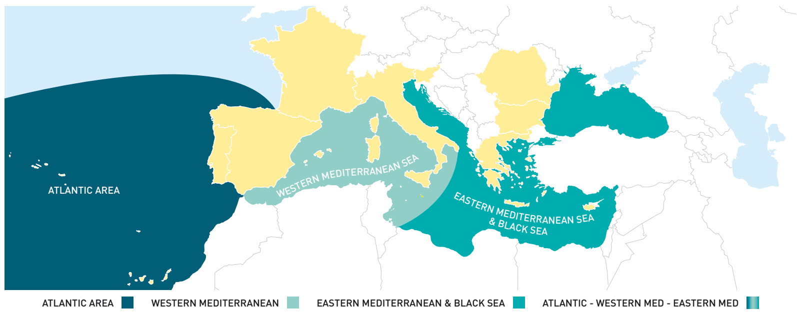
CC 2

GC 1

RO-RO 3

CONT-SHIP 3

RO-PAX 2



03

Area identification

Sensitivity analysis depending on investments and fuel price differential

04

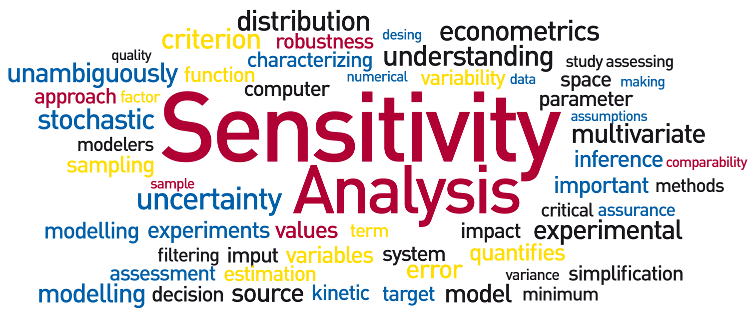


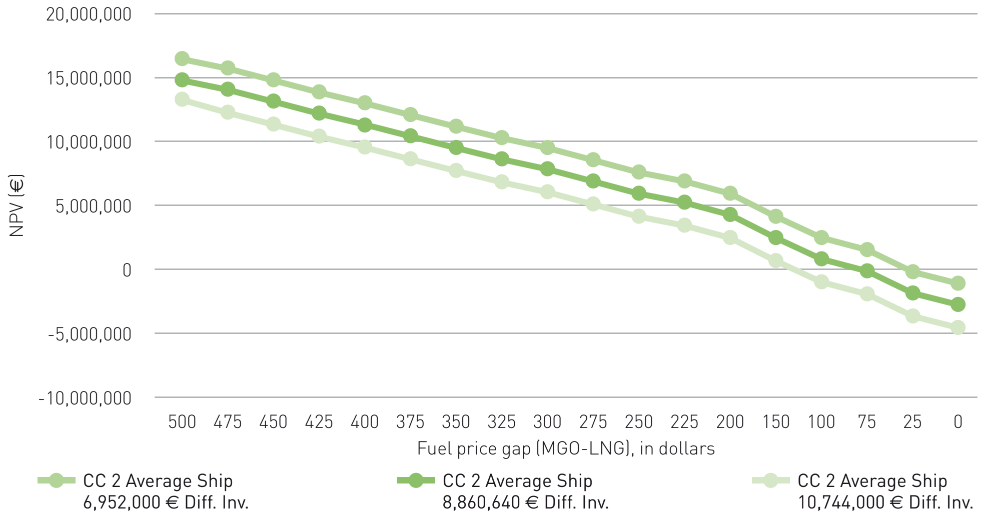
Figure 60: Case study methodological steps

Source: Fundación Valenciaport, 2014

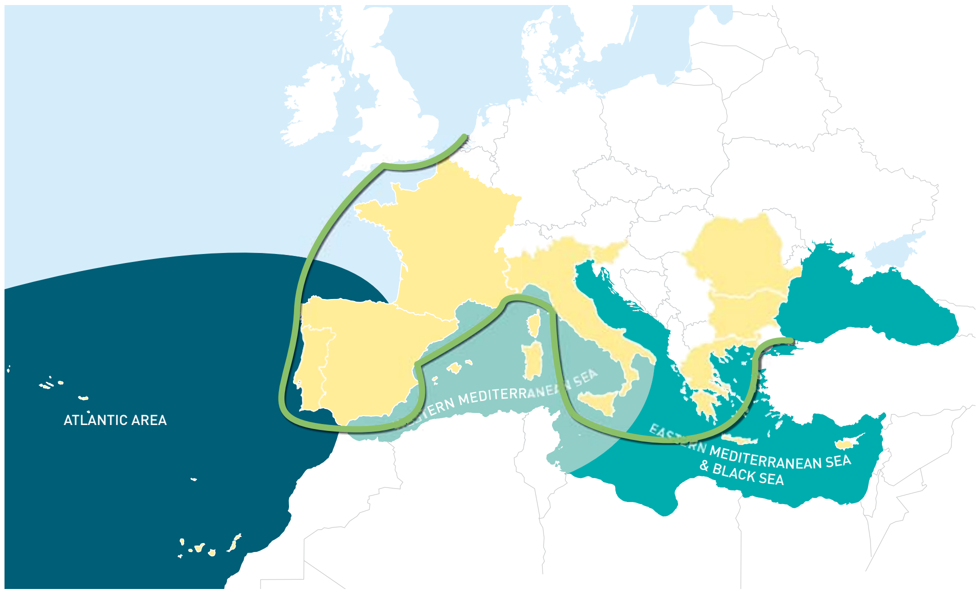
CASE STUDY 1: CC2 AVERAGE SHIP OPERATING IN THE ATLANTIC – WESTERN MED- EASTERN MED AREA

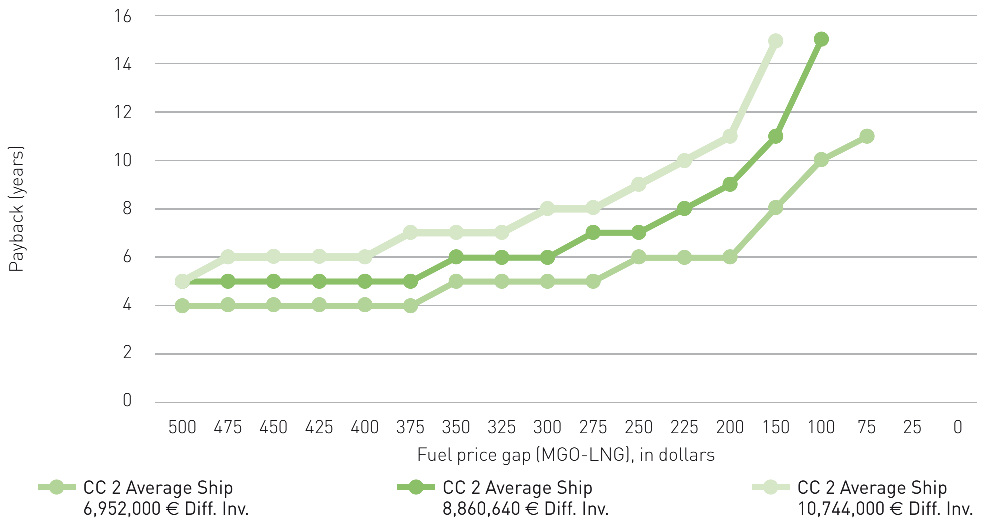
Average distance – Roundtrip (nm)	7,997
GT	39,136
DWT	12,337
Capacity (No. Cars)	4,483
Service Speed (knots)	17
Engine power (kW)	11,457
No. Strokes	2
Average vessel age in 2013 (years)	8
Average HFO consumption per voyage in tonnes (2013)	834
Average LNG consumption per voyage in tonnes (2013)	689
Average MGO consumption per voyage in tonnes (2013)	791

Table 32: Main features of the CC2 average ship
Source: Fundación Valenciaport (2014) based on the MED Short-sea Lines database



Graph 43: Best option to comply with international environmental regulations: NPV Retroffiting LNG vs MGO
Source: Fundación Valenciaport (2014) based on the MED Short-sea Lines database



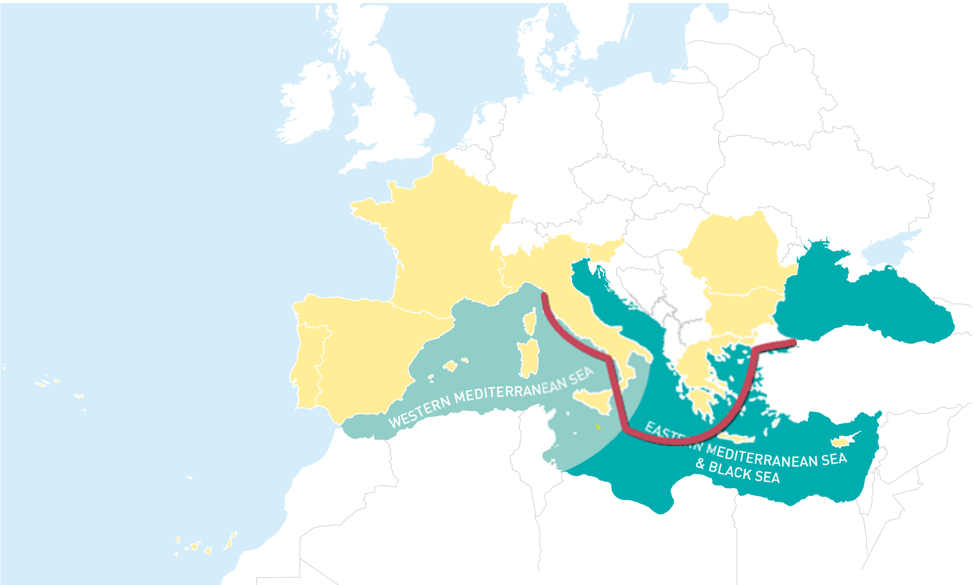


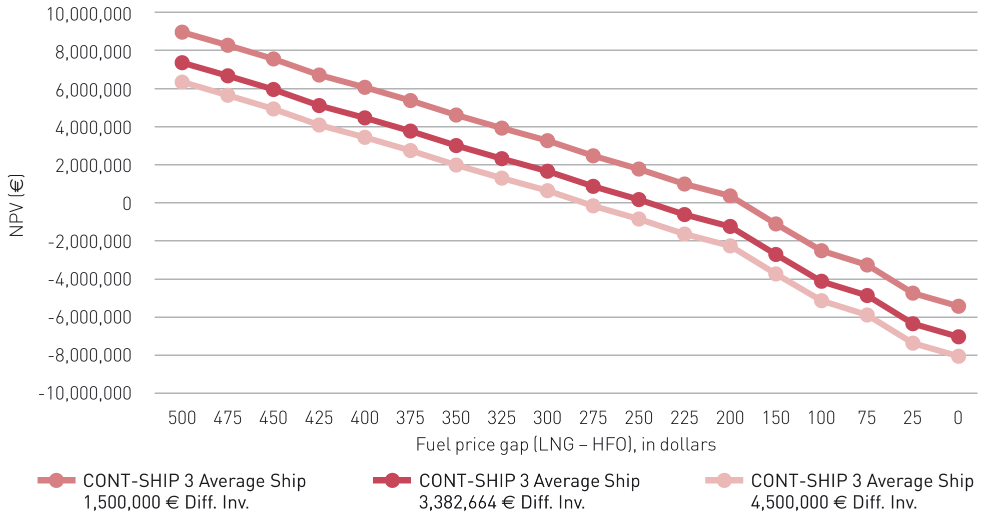
Graph 44: Best option to comply with international environmental regulations: Payback Retroffiting LNG vs MGO
Source: Fundación Valenciaport (2014) based on the MED Short-sea Lines database

CASE STUDY 2: CONT-SHIP 3 AVERAGE SHIP OPERATING IN THE WESTERN MED- EASTERN MED AREA

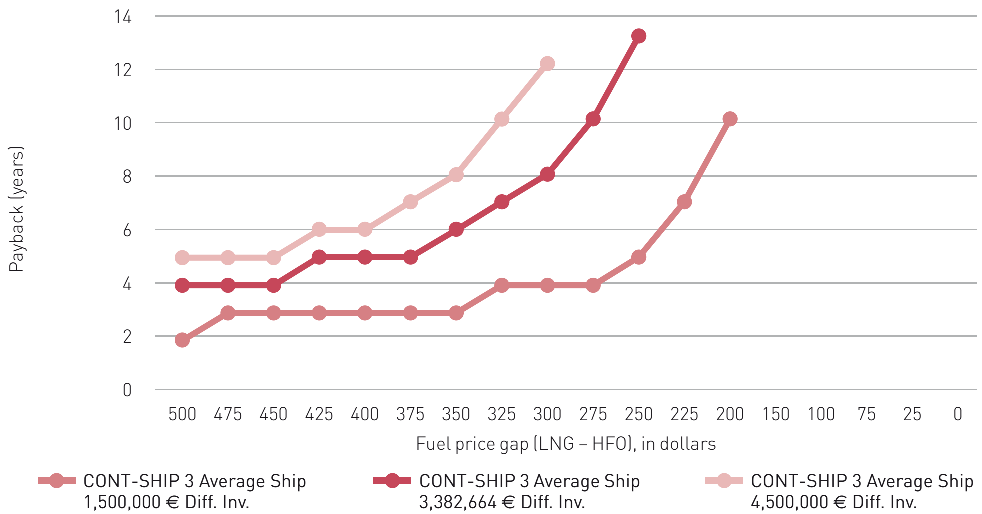
Average distance – Roundtrip (nm)	2,400
GT	14,649
DWT	19,136
Capacity (TEUs)	1,352
Service Speed (knots)	16
Engine power (kW)	10,701
No. Strokes	2
Average vessel age in 2013 (years)	14
Average HFO consumption per voyage in tonnes (2013)	254
Average LNG consumption per voyage in tonnes (2013)	209
Average MGO consumption per voyage in tonnes (2013)	241

Table 33: Main features of the CONT-SHIP 3 average ship
Source: Fundación Valenciaport (2014) based on the MED Short-sea Lines database





Graph 45: Best option to comply with international environmental regulations: NPV Retrofitting LNG vs Scrubbers & HFO
Source: Fundación Valenciaport (2014) based on the MED Short-sea Lines database

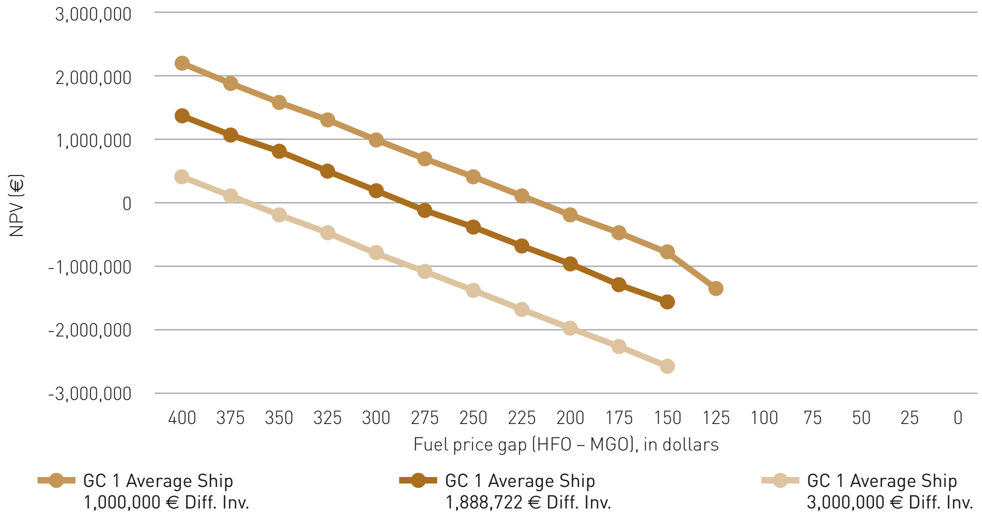


Graph 46: Best option to comply with international environmental regulations: Payback Retrofitting LNG vs Scrubbers & HFO
Source: Fundación Valenciaport (2014) based on the MED Short-sea Lines database

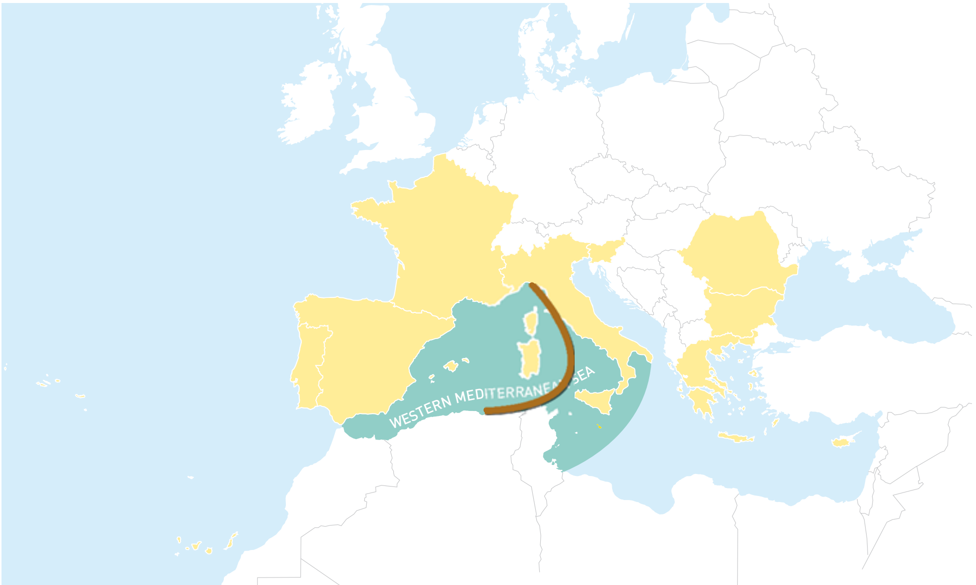
CASE STUDY 3: GC1 AVERAGE SHIP OPERATING IN THE WESTERN MEDITERRANEAN AREA

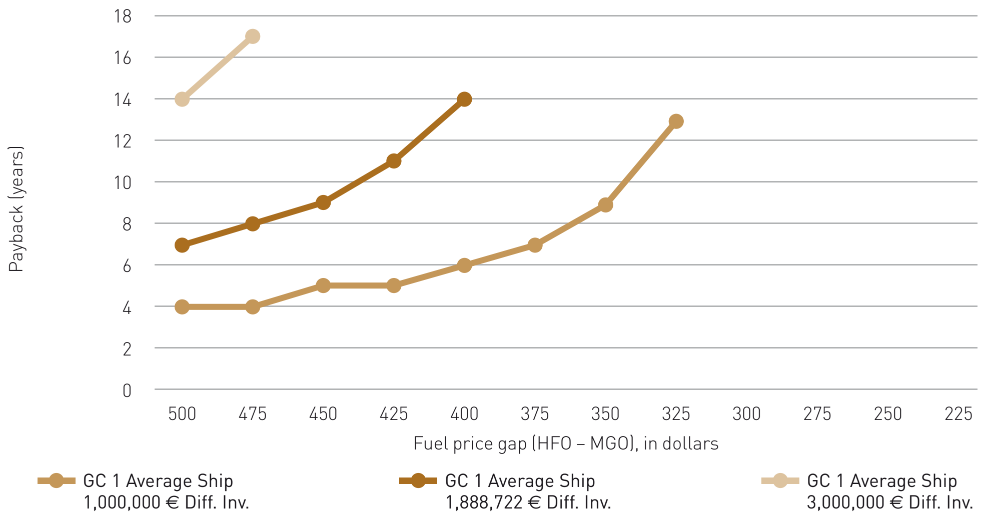
Average distance – Roundtrip (nm)	1,131
GT	5,164
DWT	7,501
Capacity (TEUs)	540
Service Speed (knots)	12
Engine power (kW)	4,840
No. Strokes	4
Average vessel age in 2013 (years)	13
Average HFO consumption per voyage in tonnes (2013)	82
Average LNG consumption per voyage in tonnes (2013)	68
Average MGO consumption per voyage in tonnes (2013)	78

Table 34: Main features of the GC 1 average ship
Source: Fundación Valenciaport (2014) based on the MED Short-sea Lines database



Graph 47: Best option to comply with international environmental regulations: NPV Scrubbers & HFO vs MGO
Source: Fundación Valenciaport (2014) based on the MED Short-sea Lines database



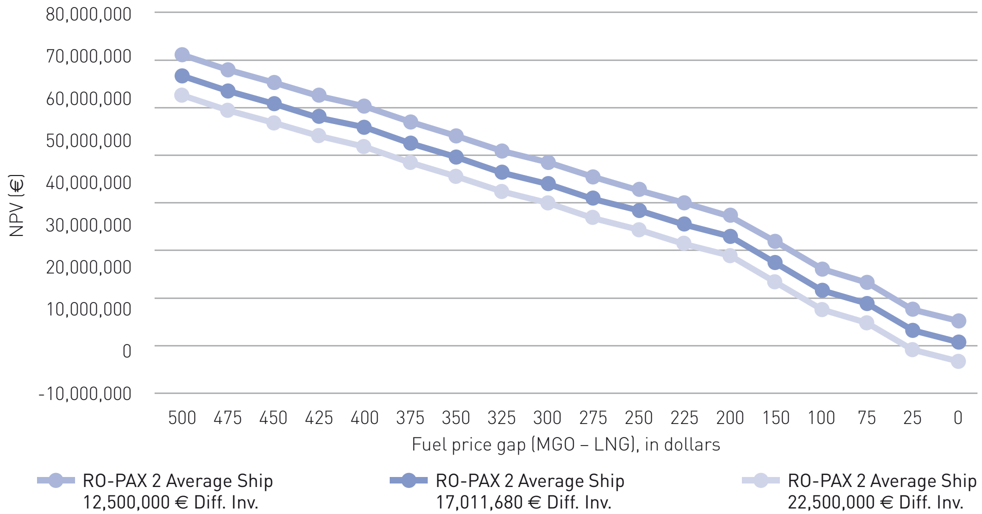


Graph 48: Best option to comply with international environmental regulations: Payback Scrubbers & HFO vs MGO
Source: Fundación Valenciaport (2014) based on the MED Short-sea Lines database

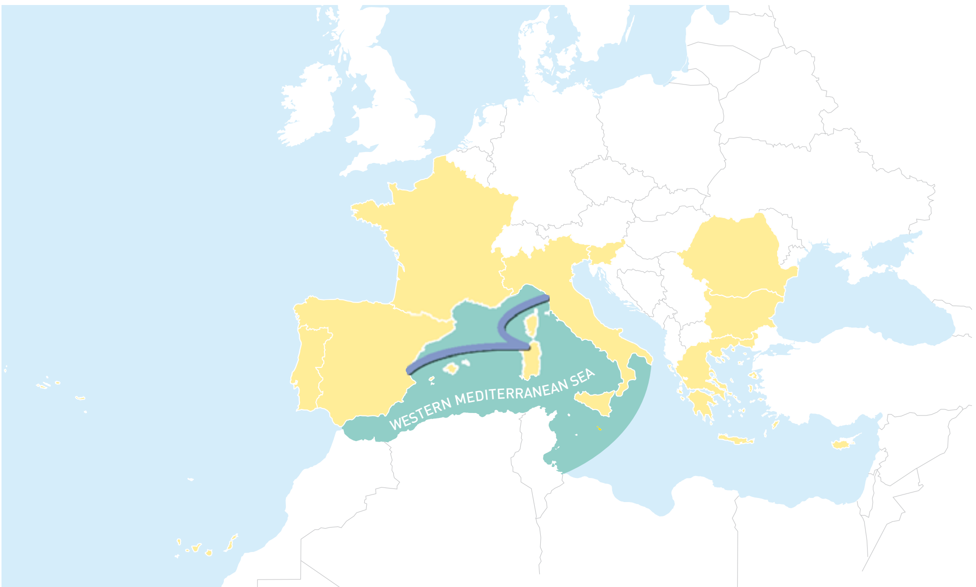
CASE STUDY 5: RO-PAX 2 AVERAGE SHIP OPERATING IN THE WESTERN MEDITERRANEAN AREA

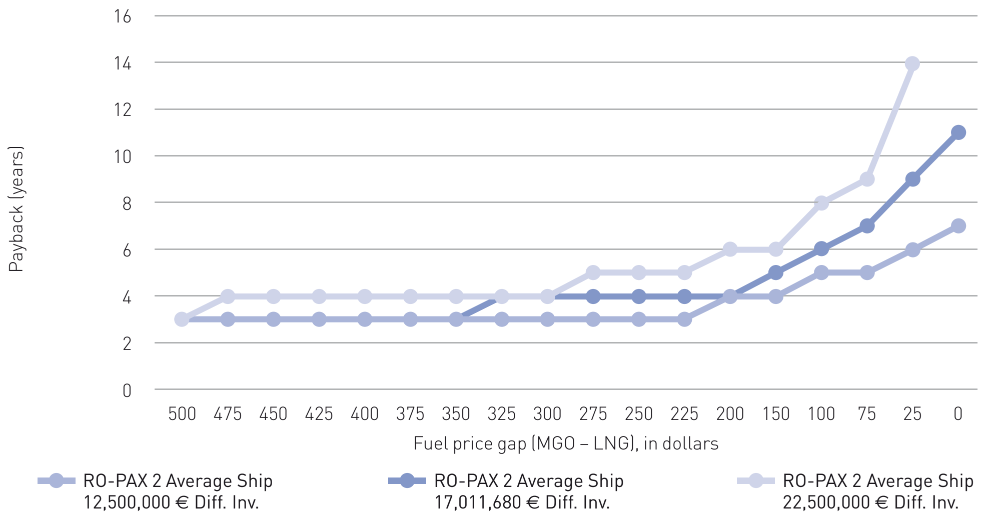
Average distance – Roundtrip (nm)	485
GT	24,223
DWT	5,443
Capacity (Lane metres)	1,699
Service Speed (knots)	18
Engine power (kW)	19,498
No. Strokes	4
Average vessel age in 2013 (years)	17
Average HFO consumption per voyage in tonnes (2013)	90
Average LNG consumption per voyage in tonnes (2013)	74
Average MGO consumption per voyage in tonnes (2013)	85

Table 35: Main features of the RO-PAX 2 average ship
Source: Fundación Valenciaport (2014) based on the MED Short-sea Lines database



Graph 49: Best option to comply with international environmental regulations: NPV Retrofitting LNG vs MGO
Source: Fundación Valenciaport (2014) based on the MED Short-sea Lines database



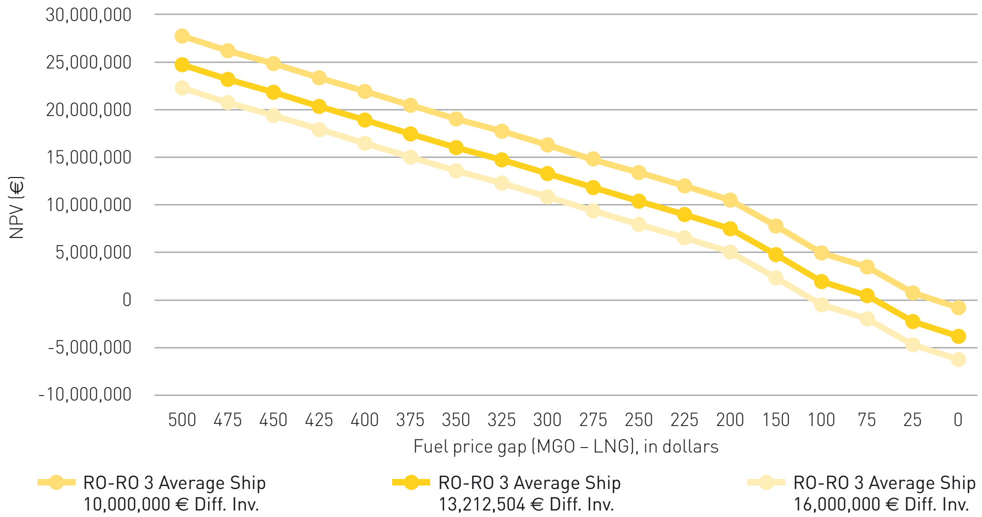


Graph 50: Best option to comply with international environmental regulations: Payback Retrofitting LNG vs MGO
Source: Fundación Valenciaport (2014) based on the MED Short-sea Lines database

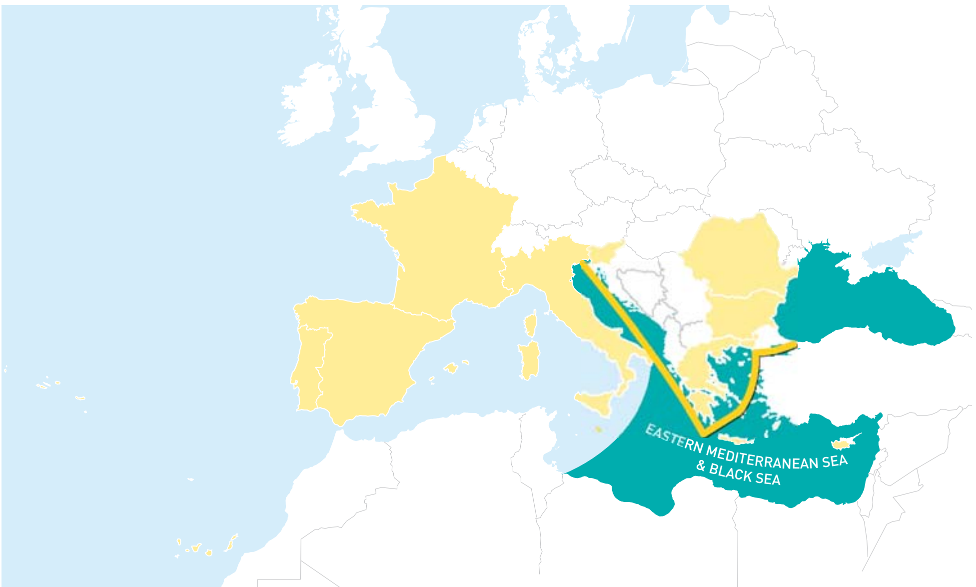
CASE STUDY 6: RO-RO 3 AVERAGE SHIP OPERATING IN THE EASTERN MEDITERRANEAN & BLACK SEA AREA

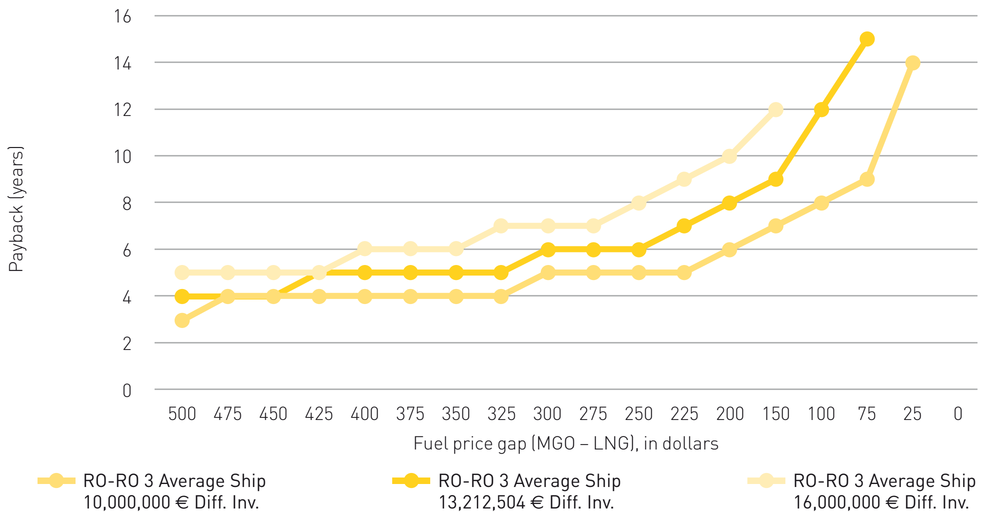
Average distance – Roundtrip (nm)	2,077
GT	27,627
DWT	11,786
Capacity (Lane metres)	3,479
Service Speed (knots)	18
Engine power (kW)	17,188
No. Strokes	4
Average vessel age in 2013 (years)	7
Average HFO consumption per voyage in tonnes (2013)	312
Average LNG consumption per voyage in tonnes (2013)	258
Average MGO consumption per voyage in tonnes (2013)	296

Table 36: Main features of the RO-RO 3 average ship
Source: Fundación Valenciaport (2014) based on the MED Short-sea Lines database



Graph 51: Best option to comply with international environmental regulations: NPV Retroffiting LNG vs MGO
Source: Fundación Valenciaport (2014) based on the MED Short-sea Lines database



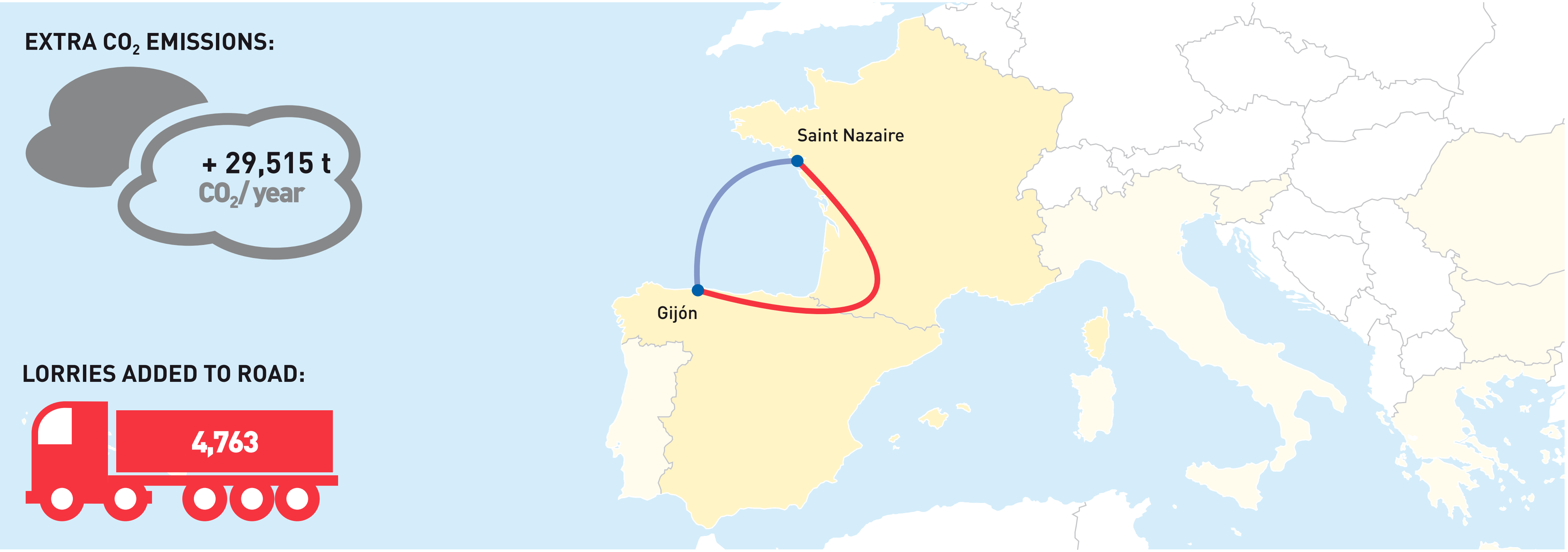


Graph 52: Best option to comply with international environmental regulations: Payback Retroffiting LNG vs MGO
Source: Fundación Valenciaport (2014) based on the MED Short-sea Lines database

8.2 MODAL BACKSHIFT

The previous sections show the profitability of using LNG as a fuel for vessels and also importantly highlights the level of uncertainty that exists in the market. This level of uncertainty could potentially discourage the market from adopting this technology. In this case, shipowners would be obliged to choose conventional fuels to meet sulphur requirements and this decision will affect considerably the competitiveness of short sea shipping.

This section estimates the modal backshift that could be generated from the increase in freight rates derived from the use of MGO instead of LNG. This estimation is calculated based on the price elasticity of maritime transport compared to road transport applied to each particular route where a modal shift is viable (that is, excluding insular traffics). For every MoS service, the increase in the freight rate per transport unit due to the use of MGO has been calculated and the elasticity has been applied. Next, the number of trucks that would be transferred to roads has been obtained, along with the additional CO_2 emissions that this would inherit. Although this kind of study required a particular analysis of the trade flows existing in each route, applying a general approach has been considered interesting. In fact, using a very conservative scenario, the results show that the lack of a complete and coherent fuel strategy could result in serious problems for the European Transport Network, therefore increasing the imbalance that already exists among transport modes.



MoS	Distance Maritime transport (nm) one voyage	% from SSS back to Road	Distance Road transport (km) one trip	Hinterland Loss (km)
GIJÓN - SAINT NAZAIRE	534	11.96%	1,016	108

RO-PAX ROAD ROUTE

Figure 61: Western European MoS Corridor. Modal backshift scenario
Source: Fundación Valenciaport (2014) based on the Med Short-Sea Lines database

MoS	Distance Maritime transport (nm) one voyage	% from SSS back to Road	Distance Road transport (km) one trip	Hinterland Loss (km)
BARCELONA - CIVITAVECCHIA	886	13.56%	1,273	144
VALENCIA - BARCELONA - LIVORNO - SAVONA	1,127	13.56%	1,392	168
VALENCIA - CAGLIARI - SALERNO	1,436	13.56%	1,940	179

RO-PAX RO-RO ROAD ROUTE

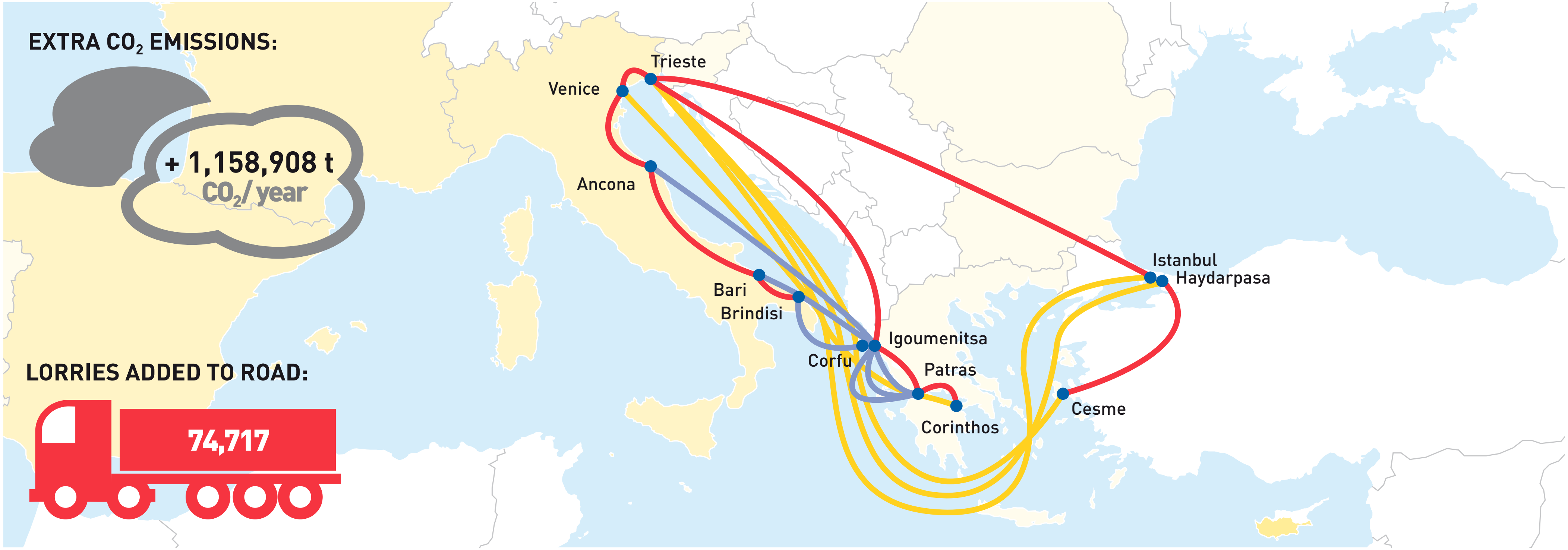
Figure 62: South-Western European MoS Corridor (Spain – Italy). Modal backshift scenario
Source: Fundación Valenciaport (2014) based on the Med Short-Sea Lines database

MoS	Distance Maritime transport (nm) one voyage	% from SSS back to Road	Distance Road transport (km) one trip	Hinterland Loss (km)
GENOA - CATANIA - VALLETTA - NAPLES	1,296	16.77%	1,312	191
LIVORNO - CATANIA - VALLETTA	1,080	16.77%	1,123	191
SALERNO - CATANIA - VALLETTA - CIVITAVECCHIA	884	16.77%	874	191

RO-PAX RO-RO ROAD ROUTE

Figure 63: South-Western European MoS Corridor (Italy). Modal backshift scenario

Source: Fundación Valenciaport (2014) based on the Med Short-Sea Lines database



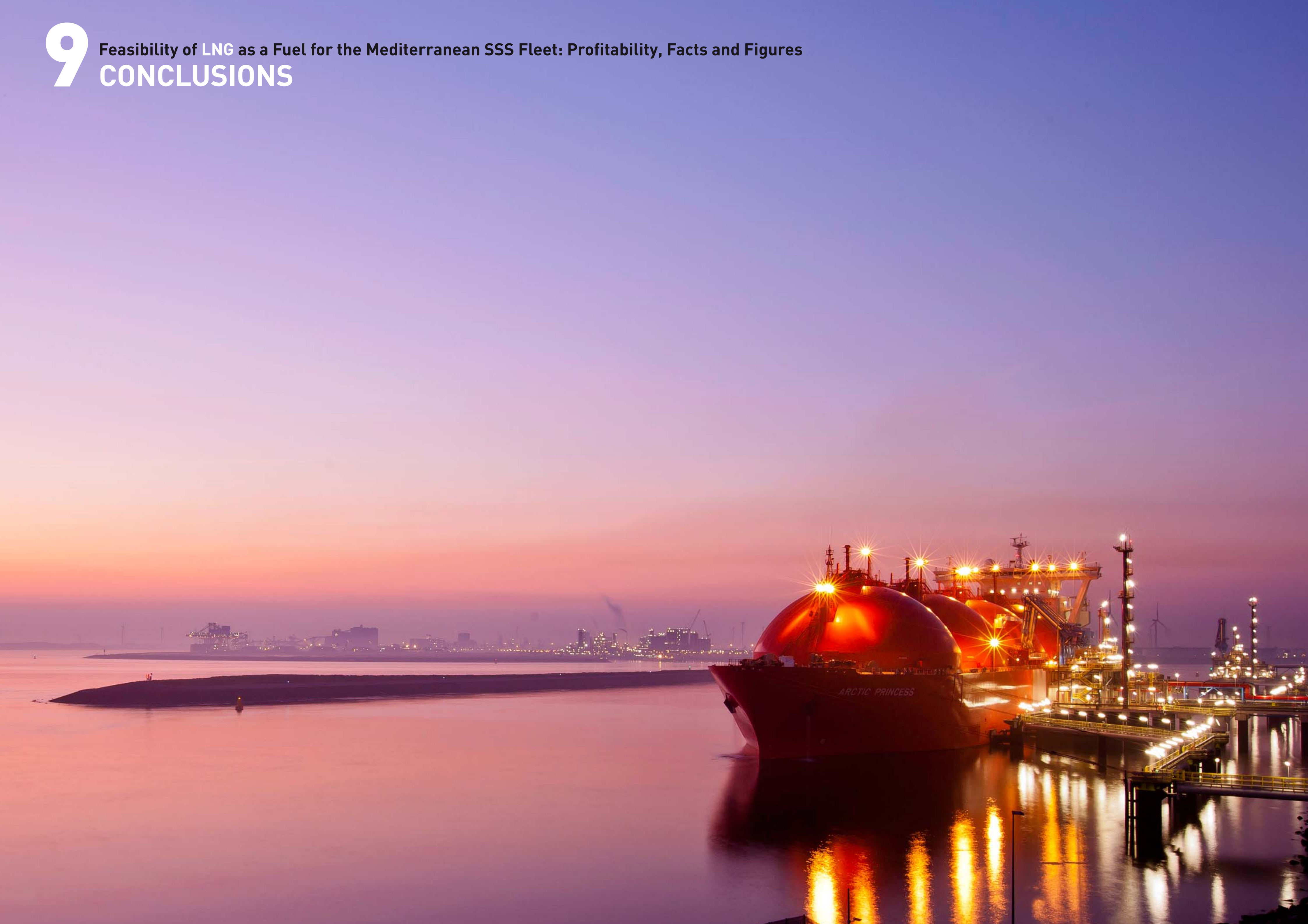
MoS	Distance Maritime transport (nm) one voyage	% from SSS back to Road	Distance Road transport (km) one trip	Hinterland Loss (km)
ANCONA - IGOUMENITSA - PATRAS - IGOUMENITSA	1,020	13.56%	2,043	199
BRINDISI - CORFU - IGOUMENITSA - PATRAS	500	13.56%	2,618	103
PATRAS - IGOUMENITSA - BARI	608	13.56%	2,496	103
TRIESTE - CESME	1,670	13.56%	2,241	335
TRIESTE - HAYDARPASA	2,074	13.56%	1,590	335
TRIESTE - ISTANBUL	2,074	13.56%	1,619	335
VENICE - CORINTHOS	1,350	13.56%	1,734	215

RO-PAX RO-RO ROAD ROUTE

Figure 64: South-East European MoS Corridor. Modal backshift scenario

Source: Fundación Valenciaport (2014) based on the Med Short-Sea Lines database

CONCLUSIONS



CONCLUSIONS

This document summarises the most salient results of the analysis carried out by Fundación Valenciaport's team during the past two years in the field of the feasibility of LNG as an alternative fuel for vessels. The study performed could be qualified as extensive enough to define the current situation of the Short Sea Shipping market in the Mediterranean, Black Sea and Portugal, building an *ad-hoc* database for this purpose covering 395 shipping lines, 658 vessels, 139 sea carriers and 62 ports. Each single vessel has been studied as a particular business case, analysing the feasibility of each of the alternative solutions to comply with environmental regulations in different scenarios. In accordance with the initial objective of the work, the evaluation of both specific and aggregated results highlights some interesting statements to be considered by stakeholders when they define their business or policy strategies.

The results of the feasibility analysis show that, generally for the case of the SSS fleet in the Mediterranean, Black Sea and Portugal, it is more convenient to invest in more expensive LNG technological solutions. From a financial point of view, projects involving the use of LNG as marine fuel are more profitable in the long term even though a major investment is initially required. In fact, only in the Black Rough Sea scenario (characterised by permanent economic stagnation and no development of alternative technologies) the best solution for the majority of vessels would be installing scrubbers to meet the sulphur requirements. For the other cases, the use of LNG results in the most profitable solution for the majority of the fleet, both in a first stage where newbuildings are not contemplated and in a second stage where newbuildings are included.

These conclusions include an important uncertainty component. Indeed, the sensitivity analysis carried out highlights the price gap between conventional fuels and LNG as the main risk factor that could affect the final result of the investment. Pressures in supply and demand markets, fiscal issues or infrastructure capacity of ports to bunker LNG are some of the aspects that concern ship owners and explain the hesitant attitude of the market regarding this topic. In this sense, the results obtained from this study show that the use of LNG could represent a global gain for the SSS market. This would be transferred to final users in terms of savings or an increase in efficiency of transport services. However, due to the high degree of uncertainty in this market, policy measures aimed at providing incentives to guide the decision-making processes of ship owners in the direction that will foster the most the competitiveness of the SSS sector would be necessary.

LNG has been proven to be a cheaper and cleaner fuel than existing conventional fuels that not only could increase the efficiency of the existing SSS services but also the use of maritime transport, as it could mean an important modal shift from road transport for certain types of commodities. Furthermore, this has been demonstrated for the most likely scenarios. The adoption of this technology represents an important commitment for ship owners who may still feel reluctant to convert due to existing uncertainty. In this point, the public sector is the main actor and should define policy measures that foster the use of LNG in the maritime sector and support private initiatives. Developing infrastructures, defining an incentive policy, establishing mechanisms to implement the "polluter pays" principle and acting against the speculative movements in the fuels markets are actions that should be addressed strongly by the public sector and permit the companies to design their investments in the most efficient way; bearing in mind that for meeting the 2020 objectives and their deadlines, decisive steps should be taken as soon as possible.

EPILOGUE

Mario Dogliani
COORDINATOR COSTA ACTION
AUTHORISED REPRESENTATIVE OF THE ITALIAN MINISTRY OF TRANSPORT
GAINN INITIATIVE
RINA SERVICES SPA

This is the last page of this technical report but it is not the epilogue of the story. In fact, it is quite the contrary; it is the first step of an important saga. The COSTA Action, of which this document is an important part of, highlighted that too many factors are still unknown, which is preventing an immediate deployment of alternative fuels for shipping in the Mediterranean and Atlantic areas. Among these factors, these are considered the most important:

- There is a lack of established ports at present which offer either LNG refuelling infrastructures or scrubber residue reception facilities (or even better: both). Consequently, no shipowner has sufficient confidence to decide whether to invest in either converting to LNG or installing scrubbers. This results in a lack of future demand for LNG in 2020, leading to almost no port/fuels provider being ready to invest in alternative fuel infrastructures.
- There is a lack of procedures describing who and on which basis permission should be given to e.g. operating LNG refuelling infrastructures in port areas and/or allow a ship to refuel LNG while at the jetty in port and maybe with persons (passengers, crew or both) on board. The lack of clear procedures, regulations and criteria makes it impossible for those who would be ready to invest to see if they will be allowed to operate.
- It is noted that Directive 2014/94/EU requires each Member State to decide and communicate to the Commission, within November 2016:
    - Which, where and by when alternative fuel infrastructures will be located in its country
    - Who and how (e.g. national law and/or guidelines) will be in charge of giving authorisation to operate alternative fuel infrastructures.

Due to the level of the economic investment required as well as the complexity of the related logistics and governance, it is not reasonable to wait until January 2017 (when the above information will be available) to start planning, developing, testing and deploying the necessary network of solutions.

However, this is where the second part of the saga starts: the COSTA's follows up or, as we called it, the GAINN initiative. Its objectives are to conceive, define, prototype, test, validate and to deploy the Mediterranean and Atlantic Network of Infrastructures of Alternative Fuels for surface transport in the period 2017-2030. In doing so, it will contribute to the cross border continuity of alternative fuels supply.

GAINN already includes the countries of Italy, Spain, Portugal, France, Slovenia and Croatia and is expected to grow to cover all the basins in Europe. Its approach is simple, it is based on the fact that at least as far as Italy is concerned, in terms of LNG, each Italian port that is an element of the GAINN-IT Network will include, in 2030 at the latest, the following four components:

1. An LNG receiving system and related ancillaries. For example, the system could be an LNG bunkering ship, which loads LNG in another port (anywhere in Europe) and transports it to the destination port.

2. An LNG storage local distribution system and related ancillaries. For example, the simplest system would consist of trucks equipped with ISO containers being filled with LNG by a bunkering ship/barge and transporting the LNG to the users (ships and/or road vehicles). The most complex solution would be a system consisting of multiple dedicated and interconnected LNG storage tanks from which LNG is distributed to different locations by means of cryogenic pipes, trucks equipped with ISO containers and small LNG barges;

3. An LNG ship bunkering system and related ancillaries;

4. LNG vehicles (not ships) bunkering system and related ancillaries.

In the next few years, we will develop prototypes and standards that are necessary in order for the Italian LNG network to be self-sustainable from both the economic and environmental point of view as well as to be interoperable with similar networks to the other Member States. More specifically, within 2018 for each Italian port included in the network one or more prototype components out of the four basic components mentioned above will be defined, piloted and tested. This aims at identifying the best local solutions as well as at establishing the necessary governance within the LNG grid and between them to achieve the desired structure for the GAINN-IT network.

The GAINN initiative will be developed, taking advantage of any possible relevant financial schemes, among which the CEF programme is expected to be the most important. Having had the honour of coordinating the COSTA Action and having enjoyed the enthusiasm and technical skills of the team, I have no doubt that this is only the first out of a series of technical reports through which the European team participating in these projects will contribute to paving the way to sustainable shipping.

I look forward to the pleasure of being again part of this.

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