CORE LNGas hive

Co-financed by the European Union
Trans-European Transport Network (TEN-T)

LNG LOGISTIC SUPPLY STUDY

WP2 FEASIBLE SUPPLY CHAINS
WP3 OPTIMAL SUPPLY CHAINS

Activity 2 – WP2.1 – ET1,2,3 – WP2 WP3

Core Network Corridors and Liquefied Natural Gas

2014-EU-TM-0732-S

Date: 04/06/2018

Project	Study on LNG Supply Logistic Chain
Report title	WP 2 FEASIBLE SUPPLY CHAINS WP3 OPTIMAL SUPPLY CHAINS
Customer	Proyecto Core LNGas Hive

Project led by:

Shipping Business Consultants

Basauri 17, 28023 Madrid, Spain

Tel. +34 91 372 96 77

www.sbc-spain.com

Contact: Jesús Nieto García

jesus.nieto@sbc-spain.com

Collaborators: Cringás LNG, I.C.C. Ingenieros, S.A.

Rev.No	Date	Reason for Issue	Prepared by	Verified by	Approved by
1	05-07-2018	First revision	SBC	-	-
2	19/07/2018	Second revision	SBC	-	-
3	24/10/2018	EN Translation	SBC	REN	

List of Figures

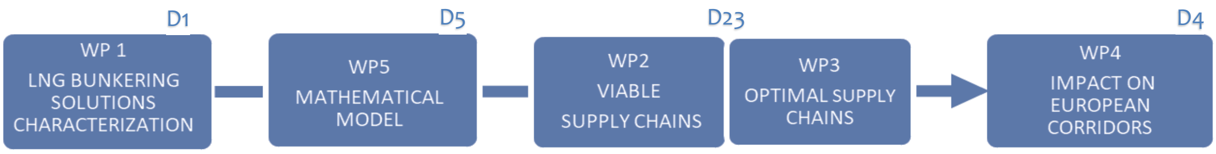
List of Tables

1 Introduction

This document studies the different logistic chains available for the distribution of LNG as a maritime fuel in Spain and Portugal in the 2020-2050-time frame. As a part of the CORE LNGas HIVE Project, logistic supply chains originate in the LNG import plants of Spain's and Portugal's gas network and ends in the final consumer vessel's tanks. This study is part of activities ET2, ET3 and ET4 of the CORE LNGas HIVE Project, financed with CEF funding.

This report is part of deliverables D2 and D3 and linked to work packages WP2 Analysis of viable supply chains and WP3 Optimal supply chains for LNG supply in the frame of a demand situation determined in a previous study by DNV-GL, respectively. Work package WP1, where the different means of transportation, storage and LNG bunkering where analyzed based on technical, economic and financial criteria, was previously completed. Finally, conclusions extracted from this study will be contrasted in WP4 with the different initiatives and procedures of those countries sharing logistic routes within the Iberian Peninsula.

The following diagram shows the workflow of the different work packages:



Our intention was to make a comprehensive document which doesn't require previous knowledge of deliverables D1 and D5 corresponding to previous activities in WP1 and WP5.

In **Chapter 1**, our subjective vision of bunkering will be explained, as a possible alternative for maritime fuel as well as long with those factors that may influence it.

Chapter 2 includes a few concepts necessary for the proper understanding of the methodology and evaluation of supply chains. These concepts arise from the mathematic model designed in work package WP5. Besides that, most relevant date from WP1 are summarized in this chapter.

Before starting to analyze new supply chain models, we deemed convenient to describe the background in which this economic activity will be developed, describing port traffic in both Spain and Portugal and focusing on the conventional bunkering operations being carried out in our national ports. This background review would be developed along **Chapter 3** and consists of 4 different pieces. First, a generic analysis on Spanish and Portuguese ports (3.1) follow by a brief description of the current market of conventional fuels in these ports, consumption, operators and mechanisms used (3.2). LNG demand from a previous study within the HIVE project has also been reviewed (3.4). Finally, to complete this background review, LNG infrastructure and current use degree in the import plants is described as well.

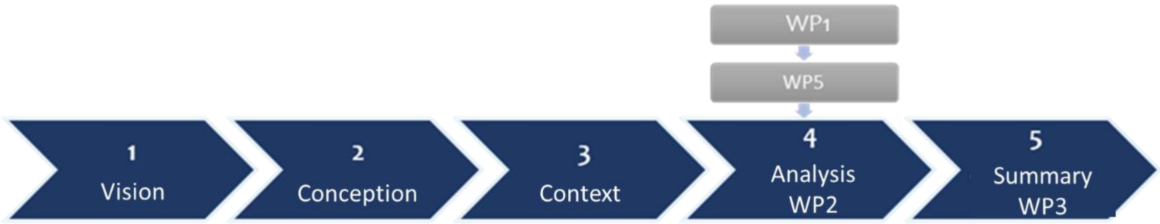
Chapter 4 details viable logistic chains. Viable chains are those that, besides being technically feasible are economically sound as well.

This analysis is organized in clusters, defined as a group of ports which are being supplied by the same import plant. A detail analysis is carried out for each individual cluster, following the same workflow explained in Chapter 3. Detailed analysis of each of the potential supply chains, it's done individually, according to each cluster's specific characteristics.

The analysis has been developed based on the mathematical model supported by the tool whose design is described in WP5. A heuristic approach has been followed -using the consultant's experience to find the optimal solution for each problem- combined with optimization methods carried out automatically by the tool.

Finally, chapter 5 includes conclusions and results. This includes optimal supply chain for each port, unitary costs, necessary investments associated with them and an overall vision of Spanish and Portuguese supply chain competitiveness but, not includes investment needed in import terminal infrastructure.

Workflow followed in this study can be summarized in the following diagram:



Annex 4 includes references to different Excel files containing analysis completed in Chapter 4 as well as results included in Chapter 5. This will allow to examine the different chains with more detail, using the design tool. Annex 3 describes the methodology and references used in the calculation of the chain's carbon footprint.

1.1 *Vision on bunkering.*

Throughout the XIX century, steam boiler supply chain was introduced to sea shipping, replacing tractional sailing. By 1880 steam boiler reached 50% of the market and coal became the prevalent fuel in sea shipping after 1920. The term bunker originates from the containers used to transport and store coal. A new supply chain was developed to supply coal from the coal mines to the ports and this is the reason why this process was known as bunkering. With the expansion of the internal combustion engine in the dawn of the XX century, diesel fuel boomed, matching coal in market share by 1950 and becoming the predominant source of fuel in the present days. Despite the development of a new supply chain for liquid fuels, the process to supply fuel to vessels is still known as bunkering. LNG as a maritime source of fuel, is starting to breakthrough in the present, but despite of the specific characteristic of this new supply chain, we will keep using the term "bunkering" when supplying LNG to a vessel as fuel.

We understand that a new supply chain for a new type of fuel shouldn't interfere in the current sea shipping market and operations and thus, it wouldn't affect the geographical situation of conventional bunkering market. We believe a change in the type of fuel used, wouldn't imply a change in the criteria used by shipping companies to choose supply ports for their fleets. Major changes in the geographical location of the demand market won't be expected, if current bunkering hubs decision makers keep answering the same criteria.

1.2 Bunkering ports.

To determine the relative importance of a bunkering port, a indicator was defined as the ratio between his actual bunkering (actual volume of fuel supplied in a port) and the fair share (theorical demand if vessels divide its consumption homogeneously between all the ports where they call). We will refer as "bunkering port" to those where this indicator is bigger than 1 (e.g: actual_bunkering > fair_share).

According to this definition, Spain and Portugal together appear in the rankings with a 1.6 ratio, thanks to the high competitiveness of just 6 ports. Algeciras (3.8), Las Palmas (5.9), Ceuta (7.8), Tenerife (2.9), Lisbon (1.7) and Barcelona (1.1). Although geographic location of import plants plays an important role in the competitiveness of this new market, current market's situation is not expected to change drastically.

In this regard, there are several examples in which the proximity of the port to the supply chain source, doesn't determine the volume commercialized. In this way and proportionally with their respective traffic volumes, Barcelona bunkers more fuel than Tarragona (which has a refinery in place). Same situation has been happening historically in Las Palmas, compared to Santa Cruz de Tenerife, the latter also had a refinery in the port. Evidently, the aggregate of geographical location, captive traffic, quality of service and operator's commercial activities are a driving factors in the regional and global supply landscape.

It's possible that the geographical proximity of some ports to LNG import plants, could boost some of them to the bunkering port category, but as far as we understand, current market leaders will make the necessary efforts to keep their leadership in the LNG space alongside current and new market operators.

1.3 Price range and level of service.

To satisfy this assumption, price and level of service in top bunkering ports should remain as competitive as before. On the other hand, not bunkering ports wouldn't be required to maintain the same service requirements as market leaders, but they will need to remain competitive costs with gasoil or ultra-low sulphur as of 2020.

As of today, LNG market doesn't have a clear reference of logistic costs associated with its supply chain yet. It still exists a lack of transparency associated to the emerging and experimental nature of current LNG operations in Europe.

The most recent market research carried out in this matter was performed by the Danish Maritime Authority[1]. Associated costs for the top efficiency LNG supply chains ranged from 6 to 8 €/MWh served on the ship.

[1] North European LNG Infrastructure Project A feasibility study for an LNG filling station infrastructure and test of recommendations (A feasibility study for an LNG filling station infrastructure and test of recommendations)

Based on the estimation of conventional fuel prices hiking up to 40 €/MWh, - including logistic costs -1 to 1.5 €/MWh –, LNG prices at the import hub at 20 €/MWh and if an efficient LNG logistic operation would increase the margin in a 10-25% percent, LNG bunkering costs would be in the 2 to 5 €/MWh range.

A shipping company investing in LNG for a vessel consuming 10,000 t a year -based on a reduction of 65% on their fuel bills – would reduce its operating expenses in 2.2 M€. We believe an efficient LNG bunkering logistic operation shouldn't be over 5 €/MWh for top ranked ports and 8€/MWh for other ports.

1.4 *Transport, storage and Bunkering.*

There are three main activities associated to this supply chain: storage, transport and distribution.

LNG tank trucks, hereinafter referred as tanker, covers two of the three main activities necessary in the supply chain: transport and distribution. We believe bunkering via tanker would be relevant in the early stages of this market in the Iberian Peninsula and specially in non-bunkering ports, thanks to its high flexibility, low cost and small investment needed.

LNG transport and distribution in the European domestic market, hit 49,000 movements in 2016, with Iberia representing 86% of the total movements.

The vast presence of tank trucks operators in the domestic market, allows us to affirm that every single port in the peninsula, both the basic and Trans-European Transport network, are in position to offer LNG bunkering services with costs below 5€/MWh. Estimates shows bunkering business adding around 3,500 extra services to the LNG distribution market in Iberia by 2030.

The main advantage of the tanker-based supply system relays on its short operation time when the supplied volume goes below the 200 m^3 threshold. Although the MTTS technique (Multi Truck-To-Ship) could increase the effectivity of the tanker based- supply operation but it wouldn't be compatible in certain cases with layover times and loading operations in the vessel or the port terminal.

High volume bunkering operations should be performed via STS technique (Ship-To-Ship) as it happens in current traditional bunkering. As we can extract from the new designs and tankers already in operation, these vessels will have the ability to navigate open waters, allowing them to cover the three basic logistic activities needed for LNG bunkering: transport, supply and storage. These vessels would be capable to offer their services in nearby ports and move to closest import plant to reload.

Regarding storage, the extensive investment on import plants carried out in Spain along with the plant in Portugal and the new plant in Canarias, are a determinant factor for the competitiveness of Iberia in the LNG market. The location of these import plants, close to high demand ports, will reduce the amount of investment needed in ancillary storage in the region.

Adaptation projects being carried out in import plants to target the small-scale business, will improve the availability of the storage capacity for LNG bunkering, a situation that will benefit the natural gas sector.

New policy on access tolls for third party users to LNG import facilities, which is expected to create a specific toll structure for the LNG distribution from import plants to vessels, would constitute a key factor for the overall competitiveness of logistic supply chains of LNG bunkering. We believe that the proper design of a service-specific pricing policy could benefit the exploitation of the system's infrastructure as well as an improvement of the overall LNG bunkering competitive growth.

1.5 *Complementary demand.*

This study was based in considering only the demand from the maritime and port sectors. It's possible that a joint operation of bunkering supply chains plus additional mainland demand, could reduce the supply cost, especially in island and other territories isolated from the gas network.

2 Conceptual model and workflow for the analysis of supply chains.

The main goal of this chapter is to introduce and explain a set of operational rules, procedures and assumptions used for the calculation and design of LNG supply chains as a source of fuel for maritime transport.

The workflow followed to carry out a conceptual model that allows the calculation and optimization of supply chains, consists of the following steps.

1. *Section* 2.1 ***Cluster***: Geographical grouping of ports, sharing the same import terminal for LNG supply.
2. *Section* 2.2 ***Logistic models:*** Determination of the logistic models and operational rules associated with the transport and bunkering of LNG in each port.
3. *Section* 2.3 ***General inputs:*** Set up input data delimiting geographic location (distances between ports…), demand in different ports, periods and scenarios and costs associated to operations and supply activity.
4. *Section* 2.4 ***Calculation process:*** Design and execution of a calculation tool that allows us to determine the operational viability and provides all necessary results for the analysis and design of the different possible solutions available for each situation.
5. Section 2.5 ***Key indicators*** Determine a group of key indicators aimed at making decisions on optimization.

2.1 *Cluster*

2.1.1 Concept

The concept of cluster in this project refers to a group of geographically close ports who share an import terminal, being able - or not- to generate operational synergies and cost reduction.

Three different types of port exist within a cluster:

- **Port with import terminal (IT):** Ports with import terminal in place.
- **Base port:** Port where supply vessel is stationed.
- **Client port:** Port without supply vessel station or import terminal.

While ports within the IT port category are already stablished (the location of the import plants/ future import plants is known), the location of the base ports will be subject to the result of the analysis.

Proposal for ports assignation the clustering of ports implemented in this report, follows a criterion based on maritime proximity, subsequently adjusted to real life scenarios (section 3.4).

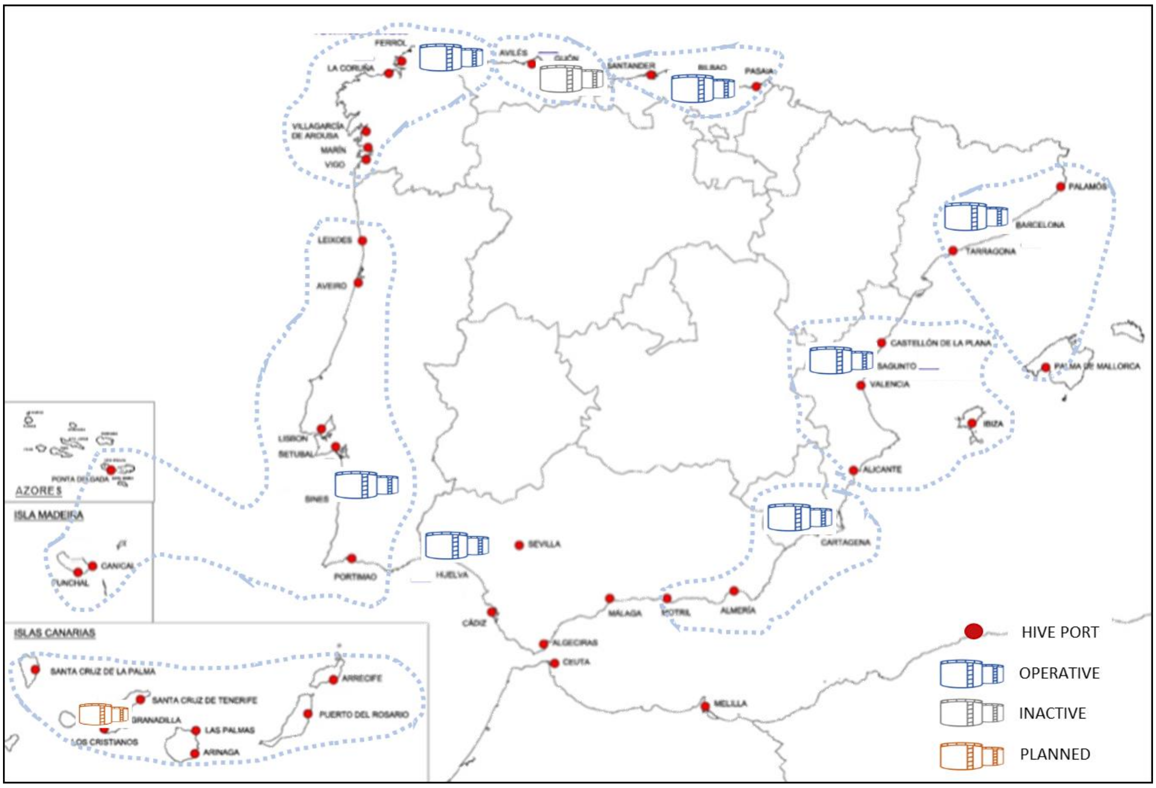


Figure 2.1 Geographic location and port aggregation.

2.1.2 Adjustments made to port assignations

Adjustments made to the default cluster criteria:

- **Assignation of Leixoes port to Sines cluster:** Even though this port, due to its proximity, should be included in the Ferrol cluster, it was assigned to the Sines cluster, since is managed by Portuguese companies based in the port of Sines.
- **Assignation of Malaga port to Huelva cluster:** Port of Malaga currently receives STS supplies of conventional fuel from Algeciras, which despite of not being an IT port, it's expected to receive a great amount of resources that will make the Port of Malaga benefit from Huelva's cluster proximity.
- **Assignation of Alicante port to Valencia cluster:** Due to the lack of demand expected in the Cartagena terminal, not many resources for maritime supply will be in place. Thus, assigning Alicante in Valencia's port will ensure maritime fuel supply to this port.

2.2 *Logistic models*

Simulation of the different LNG supply chains, as a source of fuel for maritime transport, previously requires the identification of the different logistic models available and technically suitable. These models contain interactions between the different supply patterns, storage and distribution, allowing to run the calculations necessary to evaluate the viability of each solution, next to its associated costs.

This study contains six predefined calculation models that cover most of the potential alternatives. Only two main logistic models exist, but the necessity of adding small adjustments requires adding four extra models to the study.

For calculation proposes, customer's vessels will only be supplied in their terminals of operation or in authorized anchoring areas, not considering second port maneuvers for fuel supply. Based on this, PTS supply operation hasn't been considered in the calculation model and no economic estimations have been made either, despite of PTS operations being available in both import terminals and auxiliary storage facilities. An additional detailed and individualized report including terminal characteristics, demand and vessels in operations would be needed to determine when PTS is a potential alternative.

2.2.1 Logistic model 1

Supply vessel = Transport Vessel

Supply vessel serves as storage for STS supply and reloads in port with import terminal

In this model, the same vessel is used to transport fuel from the import terminal to the base port without using an intermediate supply terminal. This model allows a significant reduction of both initial investment and supply costs, facilitating the evolution of the service during the initial stage.

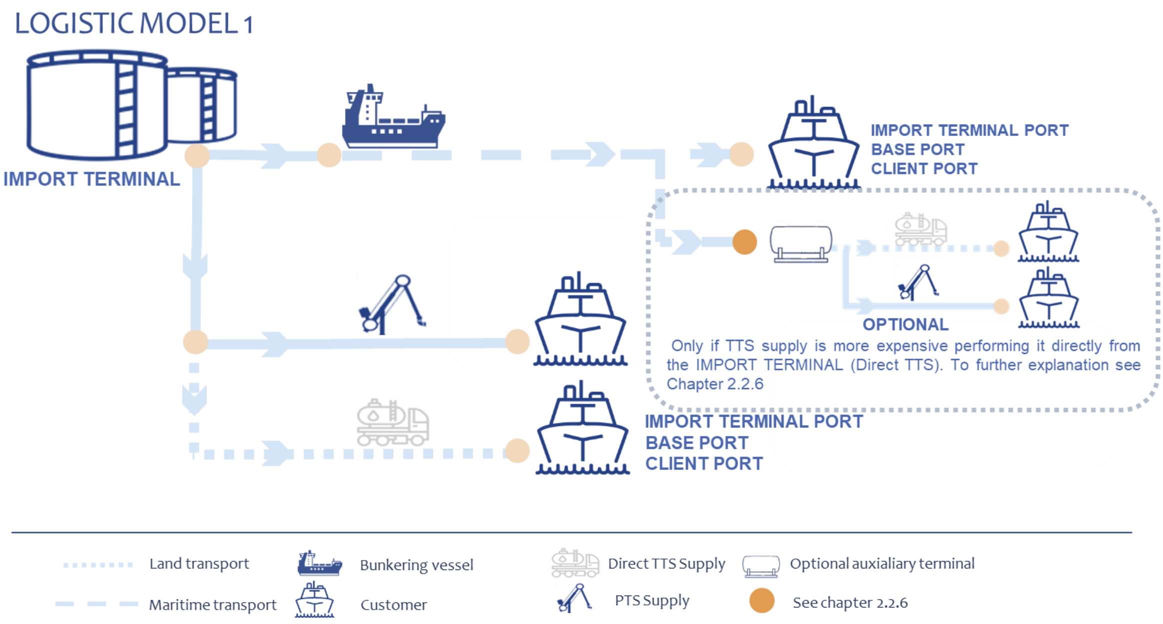


Figure 2.2 Logistic Model 1 diagram

Due to its simplicity and low resource requirement, this model is considered as the basic or main model, being also the first option considered by the calculation tool when designing the supply chain. The main disadvantage of this model is the lack of service in the Base Port, when the supply vessel is reloading. This issue won't be important in the early stages of the service and it could be sorted out using different supply routines, diminishing or canceling this negative effect.

Basic features:

- All STS supply operations are performed in the Base Port
- Resources necessary for TTS supply operations will be provided from the Import Terminal or ports with auxiliary storage terminals.
- Supply vessel reloads its tanks in the import terminal associated to its cluster.

2.2.2 Logistic Model 2

Supply vessel + Feedering vessel + Auxiliary storage terminal

Supply to supply vessel is performed from an auxiliary terminal in the Base Port

Logistic Model 2 is defined as the supply chain that uses auxiliary storage terminals, supplied by feedering vessels – not dependent of STS supplies – based at auxiliary terminals.

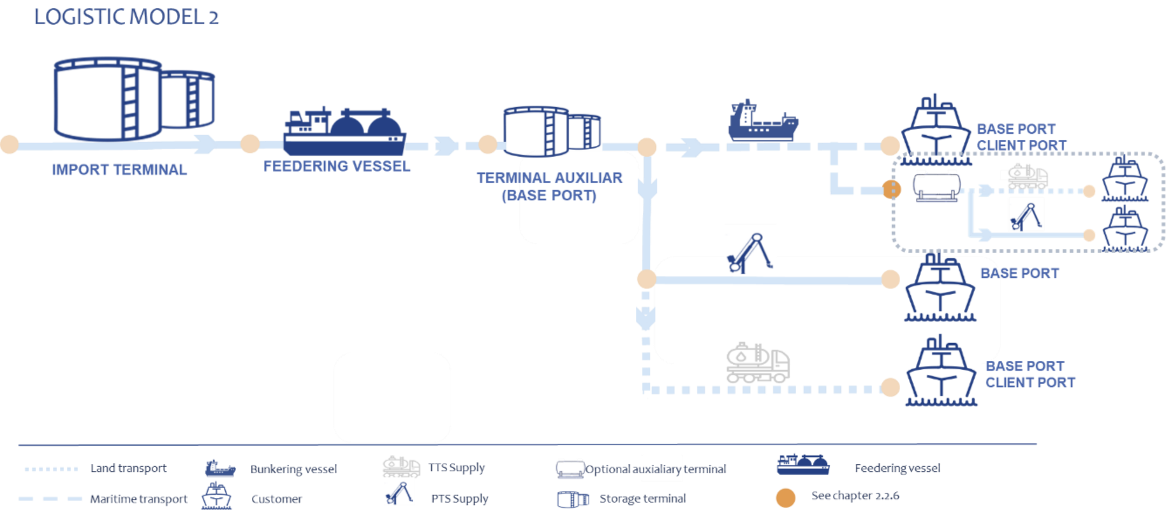


Figure 2.3 Logistic model 2 diagram

Supplying auxiliary terminals will require transport vessels – exclusive or not – to transport LNG from the import terminals.

The main disadvantages of this model are the higher cost compared to the previous model and the possible lack of transport ship in the initial stages of the service. To mitigate the negative effects mentioned before, the calculation tool considers alternative reload operations using tank trucks or intermodal railway transportation for low capacity auxiliary platforms.

Basic features:

- Requires an auxiliary storage terminal.
- Requires a feedering vessel or tank truck for provisioning operations.
- All STS supply operations are performed from the Base Port.
- Direct TTS supply operations are performed from Base Port.
- Supply vessel reloads its tanks in the Base Port.

Feedering service for Logistic Model 2 (LNG transport from import platform to auxiliary platform).

Auxiliary terminals require a provisioning system, which can be done as follows:

- **Using feedering vessels**: Used for medium/high demands and executed by specialized bulk liquid vessels.
- **Using tankers/ISO container**: Used for lower demands and transported via:
  - Ground transportation: Using a tractor head to pull the tank.
  - Marine transportation: Boarding the tanker into RoRo type vessels or ISO containers in a container ship.
  - Train transportation: Using ISOcontainers, suitable for intermediate demands and long distances.

Estimations of the size and features required in the auxiliary terminal, along with the features needed for the different alternatives, requires a comprehensive and interconnected design and study. In a standard situation, for analogous levels of demand, smaller terminals will require a small but constant volume service, while bigger storage terminals will require larger and less frequent volumes.

Basic features (Transport vessel + Auxiliary terminal)

- Supplies needed for storage terminals will always represent 80% of its total capacity (Always complying with logistic flexibility and safety levels).
- Feedering vessels can perform partial unloads.
- Transport cost is calculated simulating a round trip between the import terminal and the auxiliary terminal.
- For calculation purposes, transport vessels have an activity level of 70%

Basic features (Tank truck/Intermodal +Auxiliary terminal)

- Terminal's LNG capacity would be at least the same as the bunkering ship supplied.
- Considered flow for unloading a tank truck or ISO container is 60 m^3/h.
- Potential synergies and benefits arising in the regional supply chain such as the filling of trucks and/or ISO containers directly at the auxiliary terminal instead of the LNG Terminal are not evaluated and should be verified on a case-by-case basis in accordance with each cluster and interested stakeholders

2.2.3 Logistic model 3

Supply vessel + Feedering vessel

LNG provisioning is performed ship to ship from the feedering to the supply vessel

Logistic model 3 foregoes the auxiliary storage terminal used in Model 2. In this model, the feedering ship is expected to provide the supply vessel directly. This model is recommendable for ports away from import terminals and with a medium demand. A longer distance to an import terminal, makes Model 1 too expensive and keeps a low demand level in Model 2.

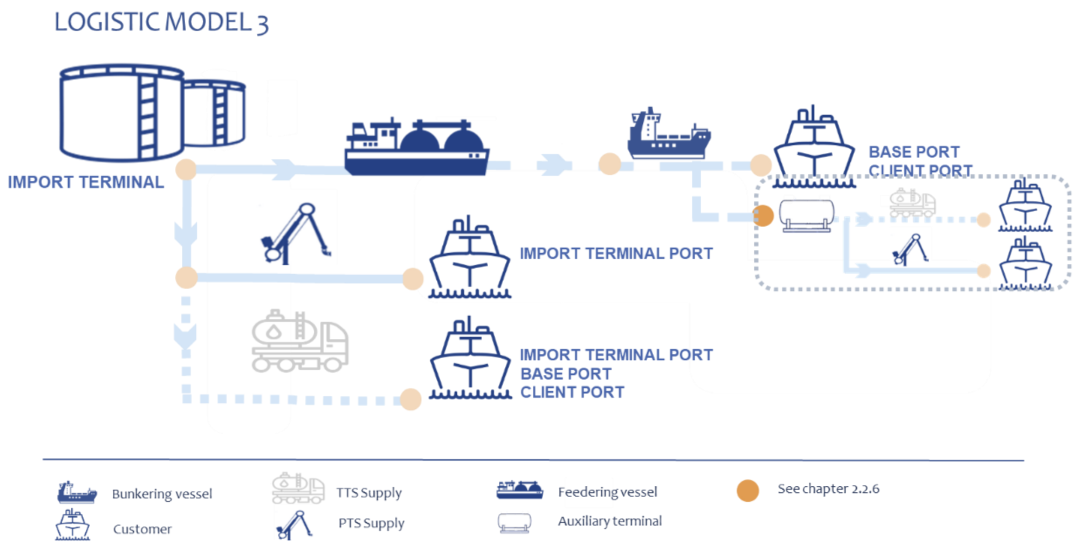


Figure 2.4 Logistic model 4 diagram

Basic features:

- Requires provisioning via feedering ship
- All STS supply operations are performed from the Base Port.

Feedering service in Logistic model 3.

Shows the following features.

- Feedering ship must serve the supply ship its whole assigned capacity.
- Supply ship reloads its tanks in Base Port.
- Feedering ships can perform partial unloads.
- Transportation cost are calculated simulating a round trip between the import terminal to the auxiliary terminal.
- For calculation purposes, transport vessels have an activity level of 70%

2.2.4 Logistic model 4

Logistic Model 4 serves as a tool that allows the computation model to divide a cluster into two different groupings, with Model 1 configuration where:

Supply vessel = Transport vessel

This model will be useful in a scenario where two or more ports within the same cluster, require independent supply ships but without its own auxiliary terminal.

2.2.5 Logistic Model 5 (TTS only)

Supply using tank trucks only

Low demand during the early years of the service in the ports studied, would require low investment solutions that contribute to a quick implementation of the service. LNG supply from tank trucks, ensures its availability in any port, providing a – sometimes limited - solution for most of the shipping companies and allowing a quick development of the service during the first years, in low bunkering demand ports.

Even though TTS supply is normally recommended for lower volumes, it's a sound option for ports with short distanced local and regional traffic with a high number of port calls per ship. For storage and transportation purposes ISOcontainers such as tanks or cryo-tanks can be used, being tanks more convenient for intermodal transport.

Basic features:

- Supply operations will be performed from a port with import terminal linked to the cluster.

2.2.6 TTS supply optimization

Within logistic models 1, 2, 3 and 4, an extra algorithm is added to determine if TTS supply cost is lower when:

- TTS supply operations are carried out loading the tank in the closest import terminal **(Direct TTS)**
- Tank trucks in TTS operations are loaded from auxiliary platforms, which at the same time are supplied by bunkering ships, operating from the Base Port (Proprietary TTS) (Scenario shown in Chart 2.5)

This algorithm is applied to every selected logistic model in every port, except for those that already have an import terminal in place or those with Logistic Model 2 storage system.

See supply workflow below for ports where Proprietary TSS is found as the best solution from an economic stand point:

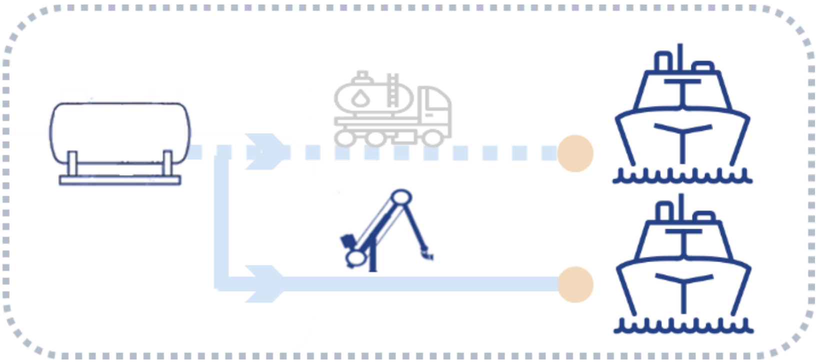


Figure 2.5 "Own TTS" supply chain model diagram

For calculation purposes, supply for storage terminal included in the Proprietary TTS model will be subject to each port's bunkering ships operations, assuming that:

- Minimum supply amounts to the auxiliary terminal facility will be 200 m^3, since this is the minimum supply amount that a bunkering ship would consider.
- Maximum reload frequency will be weekly. (Avoids bunkering ship overuse).

2.3 *Input Data*

Aimed to delimit calculations and know all costs associated with this operation, the following input data items are detailed below.

2.3.1 Marine and terrestrial transportation distances

To determine shipping/driving distances for transport, supply or bunkering operations, two reference tables were created.

- **Table of marine distances:** Based on the reference table created by *Instituto hidrografico de la Marina* and complemented with data found in **www.searoutes.com.** This reference table is presented in Annex 1.
- **Table of ground distances:** Prepared using routes and distances provided by *Google Maps™.* This second reference table is presented in Annex 2.

2.3.2 Features of the demand supplied.

As presented in section 3.4, to design a supply chain, demand features must be grouped by time frame, port and unitary bunkering volume.

All data related to the expected unitary volumes in bunkering services are reflected in the file "demand editor", part of WP5. The following table serves as an example of a high demand scenario for Sagunto Cluster in 2050.

Table 2.1 Example of table used to describe demand in a cluster.

Unit volume	Valencia	Sagunto	Castellón de la Plana	Ibiza	Alicante
TTS (44 m³)	174	229	28	161	7
250 m³	238	121	13	21	9
400 m³	497	38	19	0	7
600 m³	453	84	10	0	2
1.600 m³	383	41	1	0	1
Total bunkering services	**1.745**	**513**	**71**	**182**	**26**
Demand supplied	**1.150.727 m³**	**170.920 m³**	**19.635 m³**	**12.444 m³**	**7.774 m³**

2.3.3 Supply resources and associated costs (WP1 summary)

Both operational aspects and costs incurred during the activity of the service, have a remarkable impact in the optimization of the supply chain and they need to be considered beforehand.

Even though all the cost estimations for supply resources were accomplished in WP1, when dealing with import and ships terminals it's necessary to organize all the information available and stablish a time and cost structure as a starting point for further calculations.

The following table reflects input data for the different types of bunkering and/or feedering vessels.

Table 2.2 LNG supply and transport ships considered in the study.

Capacity (m³)	600	1.200	3.000	5.000	7.500	10.000	20.000	30.000
Fuel used	MDO	MDO	DF	DF	DF	DF	DF	DF
Gross Tonnage	1.590	2.743	3.500	7.403	6.850	7.000	17.000	25.000
Daily cost (timecharter)	3.700 €	5.200 €	8.300 €	12.000 €	16.300 €	25.000 €	28.000 €	35.000 €
Speed	7 kn	10 kn	10 kn	12 kn	12 kn	14 kn	16 kn	18 kn
Pump rate m³/h	250	300	500	750	1.000	2.000	3.000	4.400
Loading rate m³/h	250	300	500	1.000	1.500	2.000	3.000	4.400
Navigation consumption t/day	9	9	10	12	13	21	26	35
Operation consumption t/day	4	4	4	4	5	7	10	15
Consumption at port t/day	3	3	3	3	3	4	5	7
Mooring	0,50 h	0,50 h	0,50 h	0,50 h	0,75 h	0,75 h	0,75 h	0,75 h
Ship siding	0,35 h	0,35 h	0,35 h	0,35 h	0,45 h	0,45 h	0,45 h	0,45 h
Ramp-up	0,50 h	0,50 h	0,50 h	0,50 h	1,00 h	1,00 h	1,00 h	1,00 h
Ramp-down	0,50 h	0,50 h	0,50 h	0,50 h	0,50 h	0,50 h	0,50 h	0,50 h
Unmooring	0,50 h	0,50 h	0,50 h	0,50 h	0,75 h	0,75 h	0,75 h	0,75 h

The following table represents storage facilities input data extracted from WP1:

Table 2.3 Storage and auxiliary terminals considered in the study.

Capacity (m³)	320	1.000	2.000	3.000	5 x 1.000	10 x 1.000	5.000	10.000	30.000
Tank type	PT	PT	PT	PT	PT	PT	FB	FB	FB
Plant cost	1,00 M€	1,25 M€	1,50 M€	1,75 M€	2,84 M€	4,84 M€	1,94 M€	2,50 M€	4,16 M€
Terminal cost	0,34 M€	0,34 M€	0,34 M€	0,34 M€	0,34 M€	0,34 M€	0,34 M€	0,34 M€	0,34 M€
Pumping energy cost	0,015 M€	0,021 M€	0,021 M€	0,021 M€	0,031M€	0,047 M€	0,031M€	0,031M€	0,1 €
Total annual cost	**1,35 M€**	**1,61 M€**	**1,86 M€**	**2,11M€**	**3,21 M€**	**5,23 M€**	**2,31 M€**	**2,87 M€**	**4,51 M€**
Investment[2]	**6,4 M€**	**9,1 M€**	**13,7 M€**	**18,2 M€**	**24,1 M€**	**42,8 M€**	**14,5 M€**	**19,7 M€**	**34,9 M€**

[2] Does not include jetty.

2.3.4 Costs associated to sea transport and port activity

As shown in work package WP1, the following table reflects the costs for supply ships, terminal construction in port facilities and LNG supply within the gas sector.

Costs associated to port operations are as follow:

Table 2.4 Values used for the estimation of port fees considered in the study

Parameter	Unit	Value
General T-1	€/ day/100GT	**5,604**
T-1	€/hour/100GT	**0,72**
T-1 reductions	%	**1**
T-1 bonifications	%	**-**
Land cost	€/m2	**11,44**
T-3	€/t	**0,25**
T-A	Business share on port	**0,02**
T-M <2,500 GT	€	**120**
T-M <25,000 GT	€/GT	**0,048**
Mooring	€/call	**121**
Pilotage	€/call	**273**
Stevedoring container	Service	**107**
Stevedoring truck	Service	**78**

Regarding service to ships, tolls currently in place for third party access to Spanish gas system are remarkably high for "small-scale" services. In its current state, these costs have a huge effect in today's bunkering logistic chain price, as it's explained in this report. After the publication of RD 335/2018 on May 25th, the toll structure has been modified but, not the prices yet. Despite not haven't been published it, segmented pricing is expected to experiment a significant reduction. For this reason, this report uses a remarkable lower access to system toll structure, for the fixed component of this cost.

In respect of tank loading operation, costs reflected in WP1 remain the same for calculation purposes.

Table 2.5 Regulated Access fees to the Spanish port network considered in this study

Reloading fees	Fixed term	Variable term
Up to 5.000 m³	5.000 €	0,70 €/MWh
From 5.001 m³ to 15.000 m³	20.000 €	0,70 €/MWh
Above 15.001 m³	90.000 €	0,70 €/MWh
Tank reload fee		1,13 €/MWh

For information purposes, current access tolls are reflected below:

Reloading fees	Fixed term	Variable term
Up to 9.000 m³	87.978 €	0,52 €/MWh
Above 9.001 m³	176.841 €	1,56 €/MWh

In the event of establishing overseas supply chains for tank trucks or ISOcontainers, an additional table is needed to reflect the costs associated to the added routes.

Table 2.6 LNG Routes for shipping of LNG tanks or ISOcontainers

Destination	Palma/ Ibiza	Ceuta	LasPalmas Tenerife	Funchal	Canical	Melilla	Pto. Rosario	Pta. delgada
Transport equipment	Tank	Tank	Container	Container	Container	Tank	Container	Container
Stevedoring	312 €	312 €	428 €	428 €	428 €	312 €	428 €	428 €
Maritime transport	2.080 €	1.400 €	1.250 €	1.500 €	1.500 €	2.800 €	1.250 €	2.000 €
Road transport	-€	583 €	168 €	552 €	432 €	583 €	168 €	432 €
Immobilization (days)	1	1	1	7	7	1	2	7
Immobilization (cost)	1.200 €	1.200 €	127 €	889 €	889 €	1.200 €	254 €	889 €
1 trip cost	3.592 €	3.495 €	1.973 €	3.369 €	3.249 €	4.895 €	2.100 €	3.749 €
Unit cost	82 €/m³	79 €/ m³	49 €/ m³	84 €/ m³	81 €/ m³	111 €/ m³	53 €/ m³	94 €/ m³

2.3.5 Constants, conversion values and other costs associated to the supply chain.

Table 2.7 Constants and additional values considered in the study.

Energy and fuel costs	Units	Value
Electricity	€/MWh	90
LNG	€/MWh	22,00
MDO	€/t	570,00
LNG conversion factors		
From volumen to energy	MWh/m3	6,788
From mass to energy	MWh/t	15,747
Other		
Operating days	days	360
Tank capacity	m3	44
ISOcontainer capacity	m3	40
Inner ort speed	knots	6
Tank reload time	h	1,20
Tank pumping speed	m3/h	60
Operational margin	%	15%

Loading time for tankers includes all the operations to be performed in the import terminal, such us approach operations, present permissions and entrance and exit maneuver.

2.4 Calculation process and key indicator for the analysis.

Due to the variability in demand features, expected demand levels and different resource allocation alternatives taken in to account for the design and optimization of LNG bunkering supply chains reflected in this study, the design of an automated calculation tool was required for both resource selection and economic analysis of every supply chain considered for study.

The workflow followed for design and evaluation of the different logistic chains is as follows:

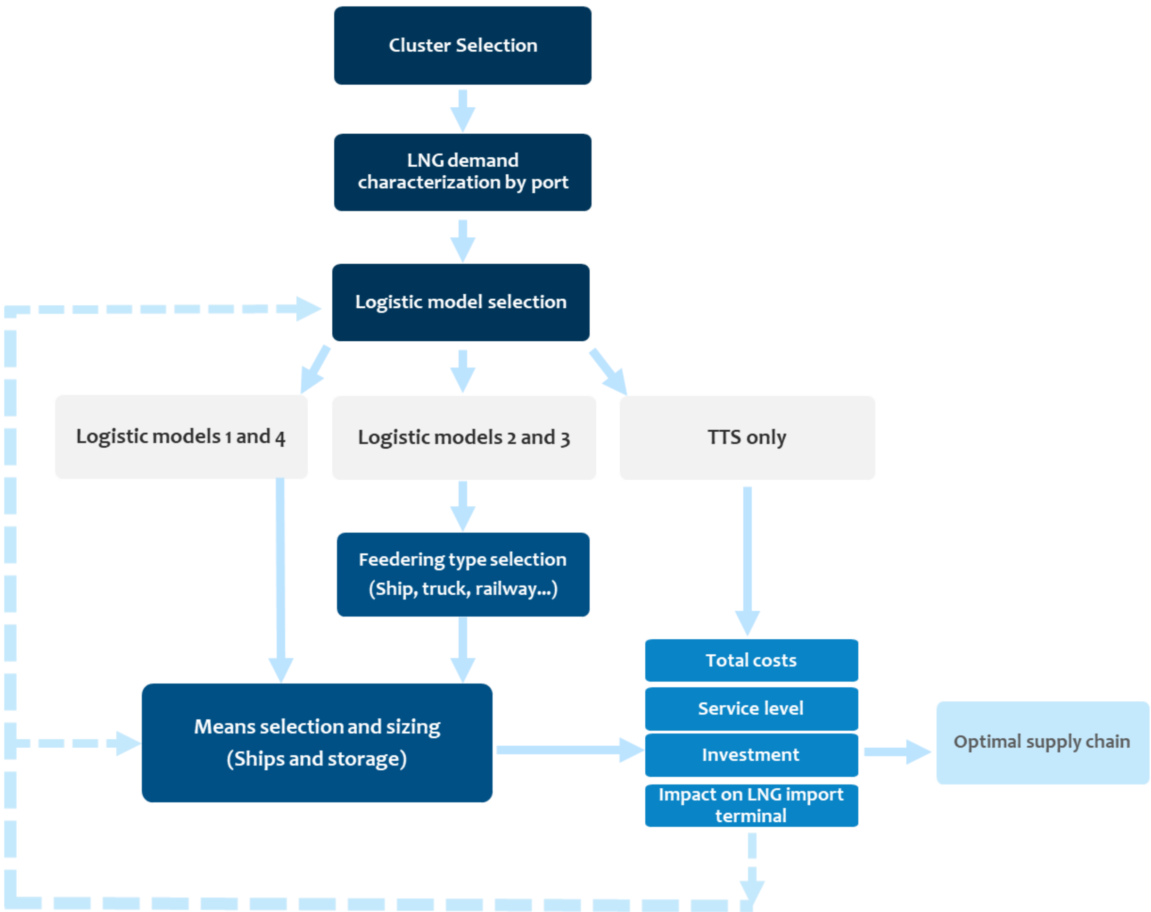


Figure 2.6 Viable logistic supply chain design diagram.

Once the model is run, the next step is to evaluate if the solution meets the expected service availability, supply frequency, and supply means required for every port as well as to assess if the costs are competitive. Otherwise, design conditions would be changed and the solution would be evaluated again.

This workflow will provide:

1. Solution proposal: Chain design, resources and scale of those resources.
2. Required investment for each solution.
3. Costs per m^3 and MWh supplied for each solution.
4. Impacts in import terminals.
5. Level of services provided.

Each one of this analysis results constitute calibration parameters in the search of an optimal solution for each cluster and each port.

All ports must have LNG supply service available. Since every port receives different kind of traffic and with different supply necessities, proposed solutions must be different as well, based on supply resources and availability.

Thus, a standard solution is not an option, each individual solution should be adjusted for each port, being this the reason why the model can use its own results as feedback in the process to find the optimal solution.

2.4.1 Results presentation

Results presented for each one of the clusters analyzed, include the following categories:

1. Resources to implement.

Number, capacity and location of all the supply resources implemented. For feedering operations, = knowing loading frequency is also necessary.

2. Yearly costs for bunkering supply in each cluster.

The result of adding up the following items:

- **Service cost:** terrestrial and marine costs incurred during bunkering supply operations.
- **Procurement cost:** All costs in which both ground and marine resources incur during LNG supply operations, including access tolls to gas system.
- **Feedering:** Costs in which feedering ships in chain Models 2 and 3 incur to supply to auxiliary storage terminals, including proportional access toll costs to gas system, based on the amount of product supplied.
- **Storage terminal:** Fixed costs associated to the installation of new terminals.
- **Inactivity costs:** Yearly fixed costs associated to inactivity time of bunkering – not feedering- ships.

To compare all the different options outlined, the total yearly cost, expressed in €/MWh of LNG supplied will be used as a reference.

3. Service level

Is defined as the total time in which supply vessels are available for service in the base port. This percentage could be higher than 100% if more than one mean of supply is deployed.

A 70% minimum acceptable service level has been set, making sure that the vessel assigned doesn't spent more than 30% of the time in loading operations or servicing outside the base port premises. If top ports – Algeciras, Las Palmas and Barcelona – wants to continue being sector leaders, they would need to make sure they can offer a level of service enough to compensate the concurrence of client ships. Thus, once the demand grows (+100,000 m^3) these ports would need at least one vessel available for service (at least 100% of service level).

$$Level\ of\ Service\ PB^{3} = \frac{Nº\ ships\ *(activity\ time\ PB + total\ inactive\ time - loading\ time)}{365}$$

4. Total investment amount for the selected resource allocation.

Addition of all investment amounts required by all resources to implement in every cluster, as reflected in section WP1 of this study and summarized in section 2.1.3.

Regarding auxiliary terminals, the adjustment of preexisting infrastructure was considered as rule of thumb, rejecting new facilities as a possible option.

5. LNG import terminal impact in the supply chain.

Combining and representing time spent vs costs generated by the different resources in the import terminal, is useful to know the following facts:

- Effect of regulated costs in the supply chain.
  - **Total regulated cost:** Includes total costs of all the loads carried out in the import terminal, weather through tanker truck or ship.
- If current infrastructures would withstand the level of activity required for the new operation.

  In this regard, we will analyze:
  - **Truck/Vessel slots:** Number of total loading operations, distinguishing between tank trucks or tank ships loads.
  - **Truck/Vessel terminal usage:** Estimation of total number of days necessary to perform load operations, distinguishing between tank trucks or tank ship loads.

3

3 CURRENT CONTEXT STUDY. Traffic analysis, traditional fuel markets, LNG import infrastructures and expected LNG demand for the port network.

Spain and Portugal's coast, with more than 5,000 km, house more than 50 ports, making these two European countries leaders in transport of goods, surpassed only by The Netherlands and United Kingdom. Within the Iberian port network, 4 ports stand out: Port of Algeciras, Port of Valencia, Port of Barcelona and Port of Sines, all of them ranking among the top 20 European ports.

- **Algeciras** (CORE)
- Alicante (Comprehensive)
- Almería (Comprehensive)
- Arinaga (Comprehensive)
- Arrecife (Comprehensive)
- Aveiro (Comprehensive)
- Avilés (Comprehensive)
- **Barcelona** (CORE)
- **Bilbao** (CORE)
- Cádiz (Comprehensive)
- Canical (Comprehensive)
- Cartagena (CORE)
- Castellón (Comprehensive)
- Ceuta (Comprehensive)
- Ferrol (Comprehensive)
- Funchal (Comprehensive)
- **Gijón** (CORE)
- Granadilla
- **Huelva** (CORE)
- Ibiza (Comprehensive)
- **La Coruña** (CORE)
- Las Palmas (CORE)
- **Leixoes** (CORE)
- **Lisbon** (CORE)
- Los Cristianos
- Málaga (Comprehensive)
- Marín
- Melilla (Comprehensive)
- Motril (Comprehensive)
- Palamós
- **Palma Mallorca** (CORE)
- Pasaia (Comprehensive)
- Ponta delgada
- Portimao (Comprehensive)
- Puerto Rosario
- Sagunto (Comprehensive)
- Santa Cruz de la Palma (Comprehensive)
- **Santa Cruz de Tenerife**
- (CORE)
- Santander (Comprehensive)
- Setúbal (Comprehensive)
- **Sevilla** (CORE)
- **Sines** (CORE)
- **Tarragona** (CORE)
- **Valencia** (CORE)
- Vigo (Comprehensive)
- Villagarcia de Arousa

3.1 Description of movement of goods, ships and passengers.

The Spanish port network is comprised of a total of 28 peninsular ports, 16 insular ports and 2 ports in the cost of Africa, of which 37 of them has been considered for this study. The Portuguese port network is comprised of 10 ports, of which 9 has been selected for the study, totaling 46 ports considered for this study.

Throughout 2017, transport of goods in Spanish ports added up to 545 million tons, while Portuguese ports added up a total of 96 million tons, which represents an increase of 6.9% in Spanish port traffic and a 2.2% increase in Portuguese ports.

Passenger traffic is also an important element in Spanish marine traffic due to the inter-island, peninsula-island and peninsula – north of Africa traffic, in addition to multiple cruise port calls.

The following charts shows the movement of goods and passengers in the selected ports, grouped by port authority.

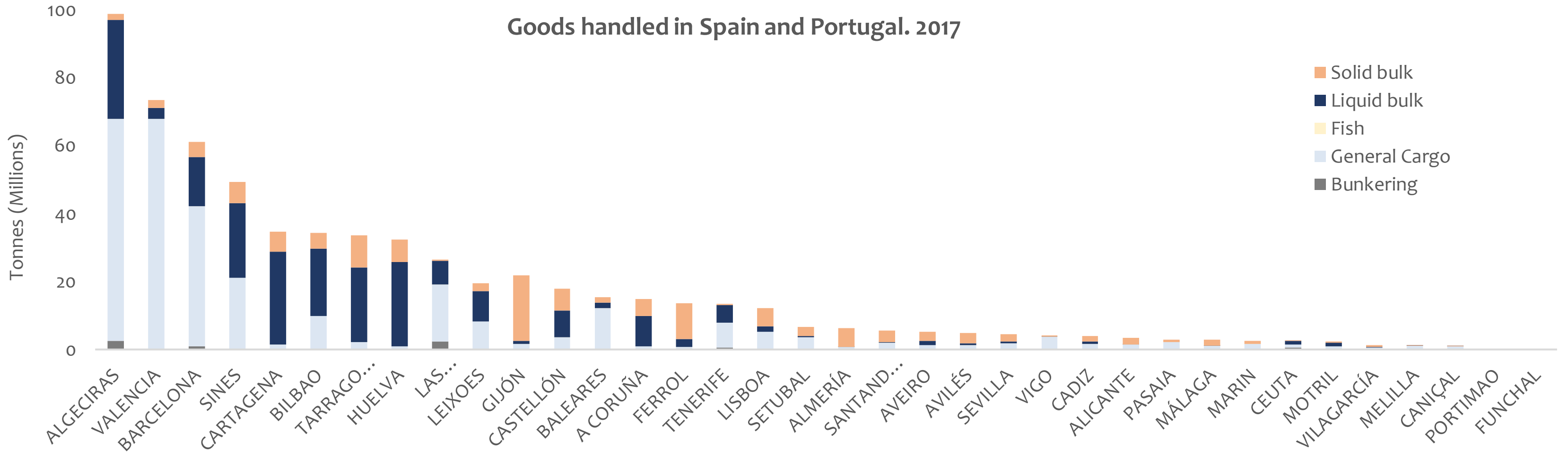


Figure 3.1 Goods handled in Spain and Portugal. 2017

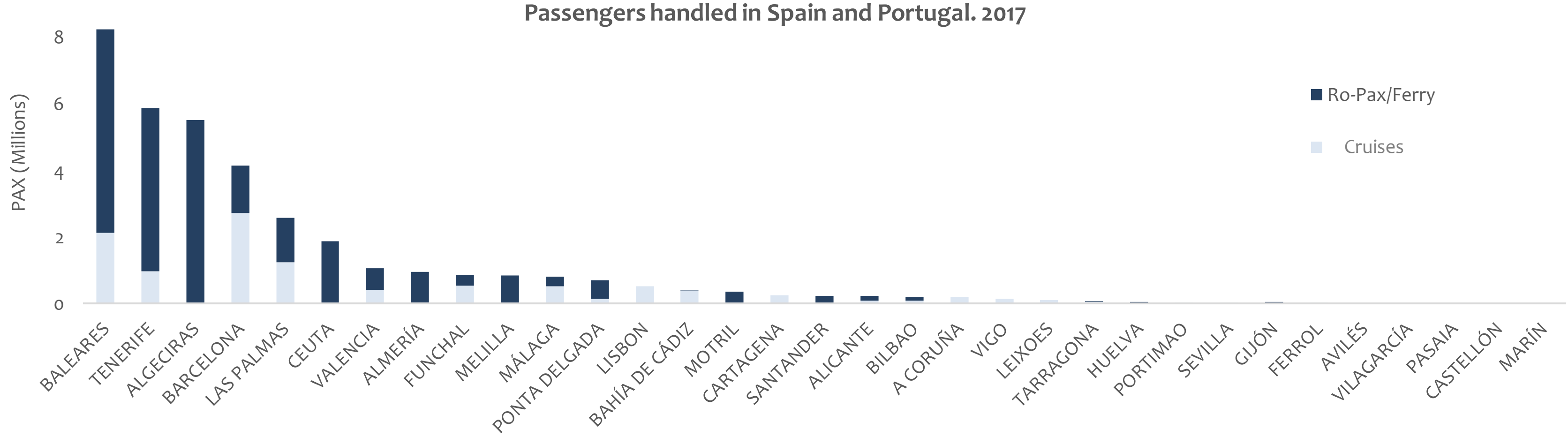


Figure 3.2 Passengers handled in Spain and Portugal. 2017

3.2 *Current conventional fuel market analysis.*

Attending to the different sources of fuel supplied, world's bunkering market is dominated by fuel oil with a market share of 84%, representing a total of 195.000.000 t, which in addition to 31,000,000 t of gasoil supplied make a total of 226.000.000 t supplied.

Out of the total fuel supplied, three ports account for approximately 30% of the total. These ports are:

- **Singapore:** Main bunkering port in the world with a market share of approximately 50.000.000 t (22% market share).
- **Fujairah:** Located in UAB, it supplies approximately around 24.000.000 t a year.
- **Rotterdam:** Main European bunkering port, in 2017 reported sales of 9.800.000 t.

Total market share for the European market accounts for approximately 46.000.000 t, with two predominant bunkering areas:

- **ARA area**: Including Rotterdam, Antwerp and Amsterdam, accounting for 60% of the market with 20.000.000t
- **Gibraltar Strait:** Located in the Iberian Peninsula, accounts for 8.000.000 t including ports of Algeciras, Gibraltar and Ceuta.

Within our range of study, Gibraltar Strait is the most important bunkering area because in located in one of the most important maritime corridors in the world, transit point for a great number of vessels which recognizes Algeciras bay anchorage spots and competitive fuel prices as a perfect location to refuel.
Total bunkering volume supplied in Spain and Portugal in 2017 was estimated in 8.900.000 t, accounting for a 4% of the world's supply and 20% of Europe's total supply volume. Figure 3.3 shows total volume supplied by each of the top 20 ports of the network. On top of that, this graphic shows the supply level that would correspond to each port, in reference to its traffic, if supply to ships were to be based on the activity level of each port.

Within the same corridor or maritime route, the failure or success of a supplier port, lays on several factors, being the most relevant:

- Economic factors: Fuel price competitiveness and cost of service.
- Quality factors: Service guarantee and with non or minimum effect in ship's travel time.

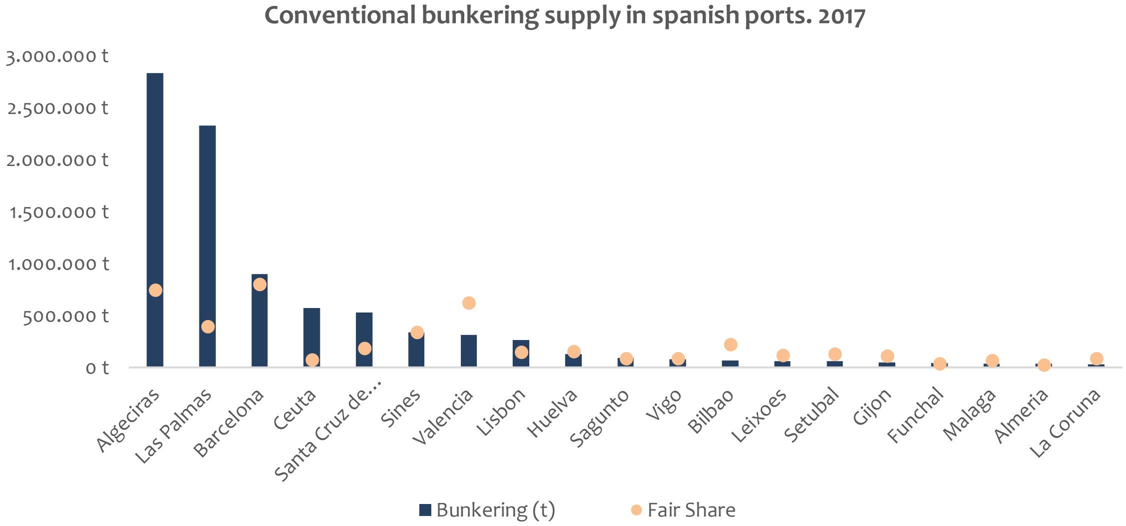


Figure 3.3 Leading ports in traditional bunkering supply operations

Top 5 Spanish bunkering ports stand out thanks to its competitive price – See Figure 3.4 – as well as for its broad product offer and means of supply and thanks to being in important anchoring spots near Gibraltar Strait and Canary Islands, two of the most important maritime corridors on earth.

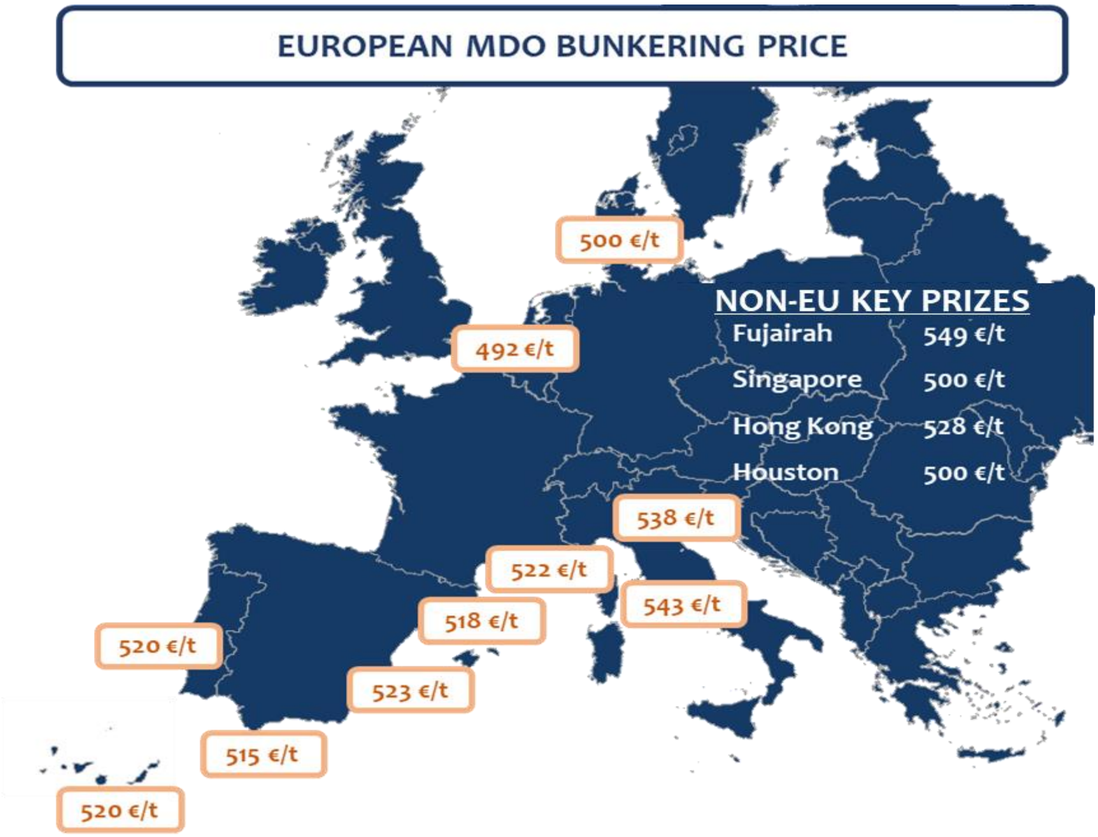


Figure 3.4. Average MDO price in Europe's leading ports. Provided by Mabux.com April 2018

As reflected in the map, Spanish ports shows lower prices than its direct competitors. On the contrary, Atlantic ports competing with ports in the ARA zone, show higher prices. This is the main reason why Atlantic ports supply smaller bunkering volumes than Mediterranean or Canary ports since most of the traffic refuels either on this area or in the north of Europe, where prices are cheaper.

3.2.1 Means of supply.

Thanks to the flexibility, speed and possibility of performing simultaneous operation, marine supply means are the customer's favorite. In addition to this, using tanker trucks for high volumes is not viable.

To ensure the profitability of a supply vessel, the port requires to meet a level of demand not available to every port in the network, thus, only those ports with higher demands will be suitable to host a supply ship. Smaller ports normally use tankers or special docks with "ex-pipe" fueling system. There are currently 29 supply ships in the Iberian Peninsula, including Gibraltar and Canary Island. Figure 3.5 reflects the location of these supply vessels and a detailed analysis of supply service for each port in every cluster is also included in this analysis.

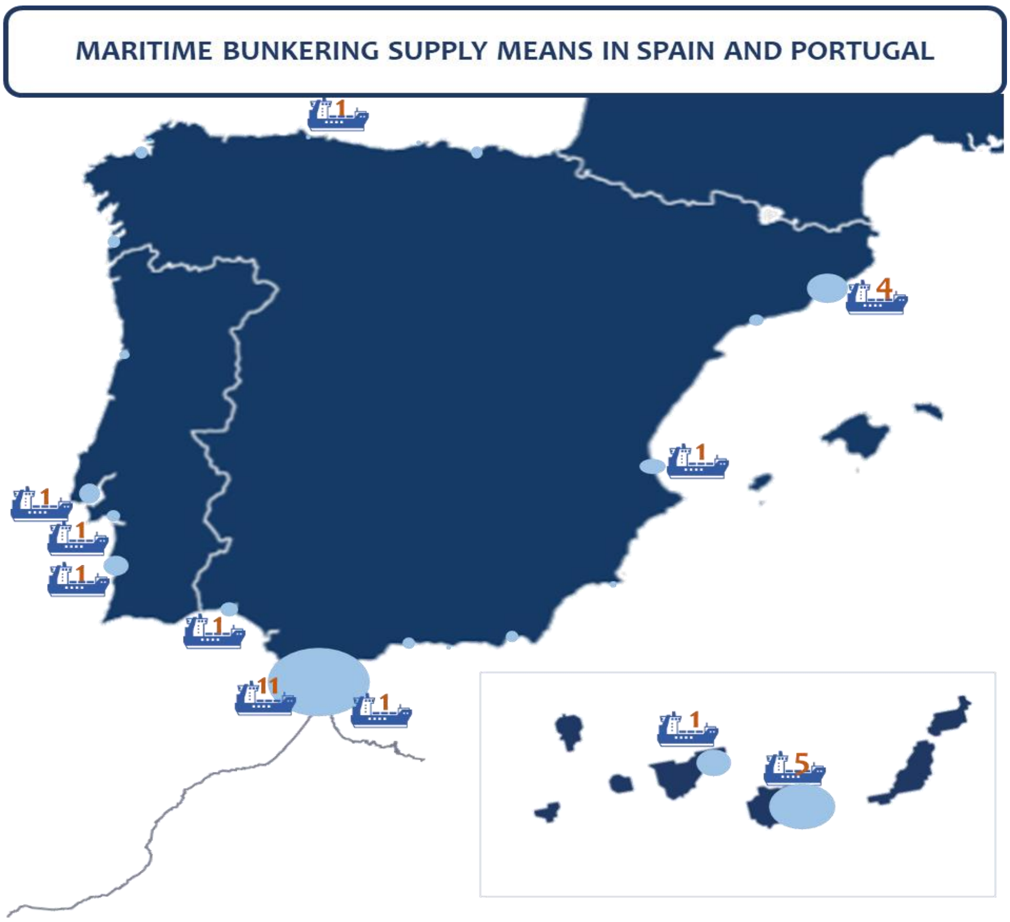


Figure 3.5 Geographic situation of demand and resources for traditional supply.

It's worth noticing, that despite the fact Spain and Portugal hosts more than 50 ports on its shores, only 9 of them count with a supply ship and only three of them has more than 4 units. It's possible to request STS service in a neighboring port with the necessary means available. For example, barge Patagonia 100 serves STS operations in the Port of Tarragona from the Port of Barcelona and barge Hercules 100 does the same in Port of Malaga despite being based on the Port of Algeciras. Average loading capacity of a barge is around 4.300 t (4.000 m^3 approx.).

Pipe bunkering service (PTS) is also very common in those ports with refining or storage facilities. Despite this is a rigid system that only allows fueling service in specific locations, the very nature of liquid fuels allows to set up several fueling stations along the dock. Although flexibility is very low, low prices and high flows makes PTS a perfect system for refueling in prepared docks.

3.3 LNG import terminals

All LNG import terminals considered in this study are within the Iberian Peninsula, except Granadilla terminal which is currently pending on approval. Spain has 6 active terminals, 1 inactive terminal and one pending approval, while Portugal only has one active terminal (See Figure 2.1).

The aggregation of these 7 terminals, gives the system its following capabilities:

- 3.706.500 m^3 LNG storage.
- 9 docks for methane tankers (4 of them adapted for small-scale)
- 19 tank loaders with capacity to serve 101 GWh

Total LNG traffic in Spanish ports added up to 183,943 GWh, which represents a total of 11.600.000 t (2% of total port network's goods) and the arrival of 216 methane tanker ships, distributed as follows:

Table 3.1 LNG imports (t) and LNG ships arriving at Spanish import terminals.

	LNG Imports	Number of vessels						Δ YEAR[4]
Port	**GWh**	**Qmax**	**Qflex**	**G**	**M**	**P**	**Total**	**2016/2017**
Barcelona	61.421	3	8	37	24	2	74	+71%
Huelva	50.188	-	3	45	9	-	57	+30%
Cartagena	9.379	-	-	9	4	-	13	-21%
Bilbao	30.284	-	-	33	-	-	33	+68%
Sagunto	21.167	-	1	18	8	-	27	-40%
Mugardos	11.504	-	1	10	1	-	11	-16%
Total Spain	**183.943**	**3**	**13**	**152**	**46**	**2**	**216**	**+20%**
Total Portugal	**40.300**						**42**	**+83%**

[4] Variation from last year imports.

On the other hand, on 2016, Portugal imported 21.974 GWh via maritime transport, 1.400.000 t approximately (1.5% of total goods) but during 2017 this amount grew 83%, reaching 40.300 GWh.

Figure 3.6 shows the distribution of imported LNG per country.

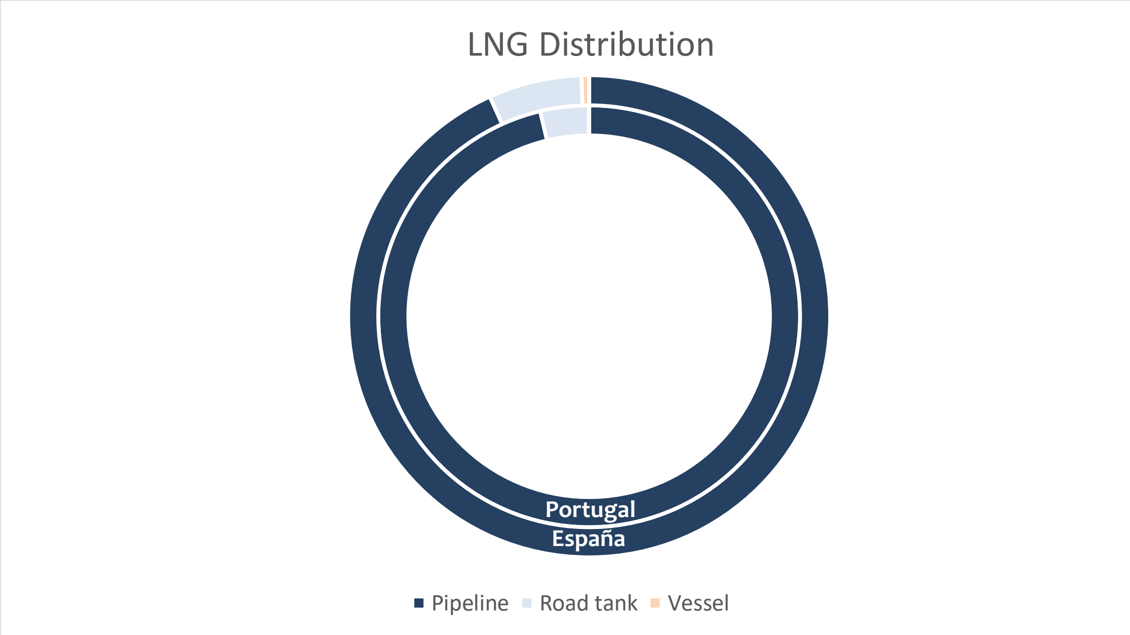


Figure 3.6 LNG distribution in Spain and Portugal

Data shows Spain as the leader of LNG imports in the European union, with 25% of the market share, also standing out in the market of tankers transportation, with 38.821 tankers transported. Portugal allocated 1.529 GWh via tanker trucks, which accounted for 6.100 movements, out if which 389 GWh of LNG were assigned to supply the island of Madeira, using 40 ft ISOcontainers.

Regarding the use of terminals, 2017 registered:

- Average stocks in tanks corresponding to 43% of nominal capacity for Spain and 53% for Portugal.
- 53% contracting of tankers and 44% usage rate.

To obtain an in-depth knowledge of the average level of utilization and availability of services of each plant in the network, Figure 3.7 shows the average level registered in LNG import tanks considered in this study and Figure 3.8 reflects the contracted capacity and the production registered in LNG tank trucks loaders.

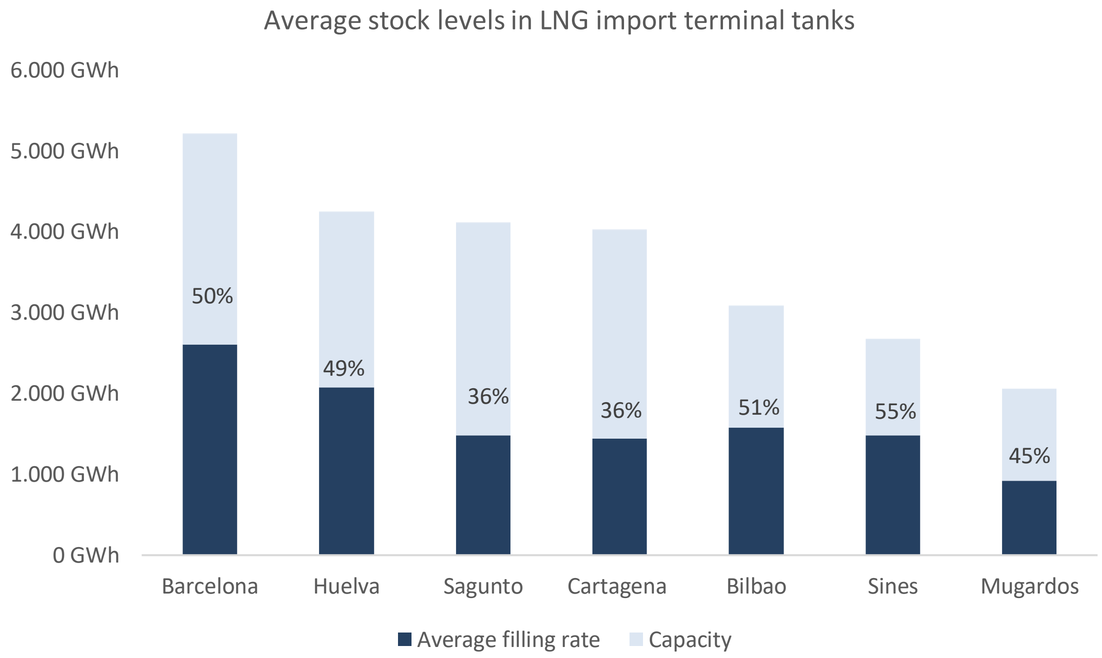


Figure 3.7 2017 average LNG reserves in LNG import terminal tanks as of 2017

On 2018, Sagunto terminal maintains the lower production rate registered during 2017, lowering the average stock level in the first for months of 2018 to an average value of 13%. Cartagena has also lowered this level down to 25%.

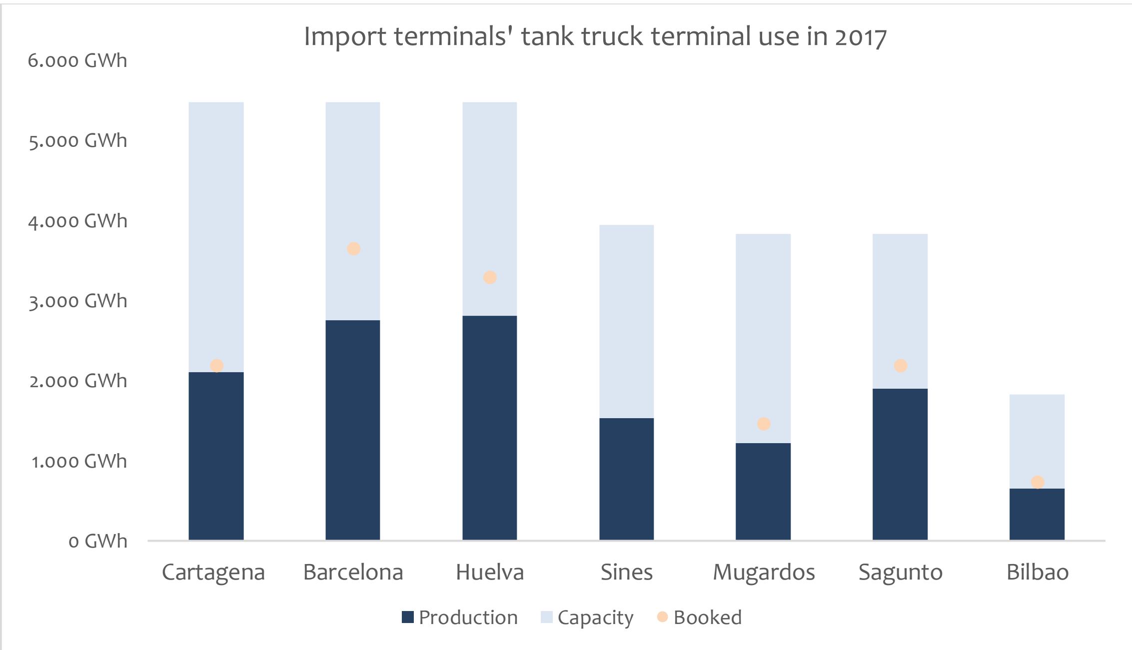


Figure 3.8 [5] Contracting and use of LNG tanks loading stations in the studied terminals during as of 2017.

[5] No data was available from truck tanks reloads at Sines

With a total of 12.970 GWh served per tank, the total average use of the infrastructure is 43%, being Barcelona the terminal with the highest usage percentage at 50% and an average contracting of 67%.

All companies operating import terminals are heavily involved in the development of LNG as a source of fuel for marine transport being this the reason why Spain and Portugal are currently developing studies and actions aimed to provide both countries network system with the infrastructure and resources needed to supply LNG by adapting or building new docks, developing new commercial services and adjusting technical resources for the operation of small-scale LNG ships. During 2017 and 2018, the first operations with all the available resources in the market has taken place, distributed as seen below.

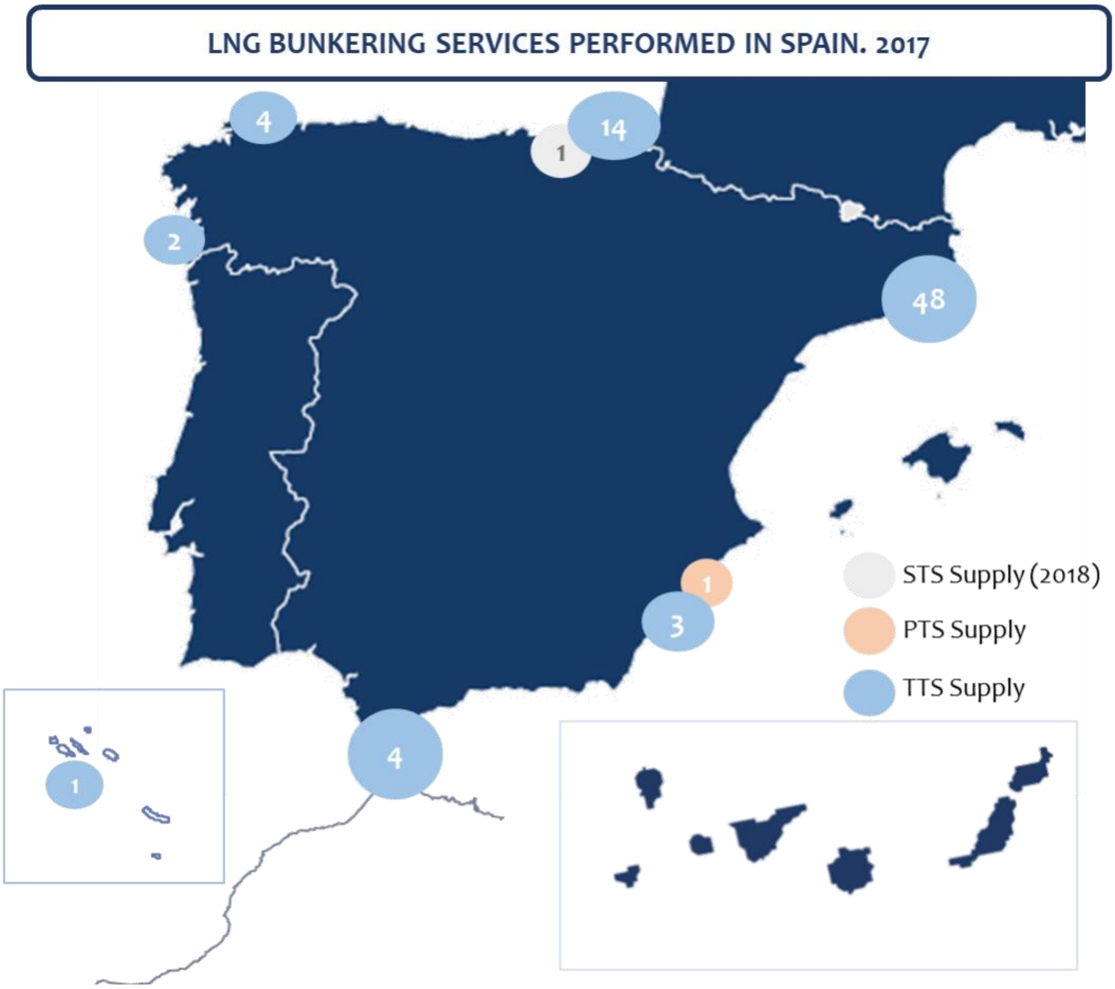


Figure 3.9 LNG bunkering supplied operations performed in the Iberian Peninsula in 2017

3.4 Expected demand for LNG supply as a source of marine fuel

The study of LNG expected demand as a marine fuel, was carried out by the consulting firm DNV-GL in previous study. A summarized version of this study is available in the document "Consolidation Top down and Bottom up Analysis", from December 2016.

This study consolidated previous studies with two different approaches, a "top down" study based on a detailed port traffic study using data from AIS collected between the second semester of 2014 and first of 2016, from all Portuguese and Spanish ports. This data was also contrasted in a "bottom up" study after interviewing the main stakeholders: Port Authority offices, shipping companies, LNG storage plants, marketers, and conventional bunkering suppliers. It also included additional details about the fleet, fishing sector demand and port service demand.

The aim of this study was to quantify the expected demand, but before using the results of this study to scale the offer, a few modifications were needed to be done, aiming to refine the demand on a port level since the study was based on a more regional scale: Mediterranean, Atlantic and Gibraltar and Islands. This configuration diluted some of the values of the region.

The following diagram shows the process follow to transform the demand calculated by DNV-GL in to the so-called HIVE demand, in which the logistic chains will be based on.

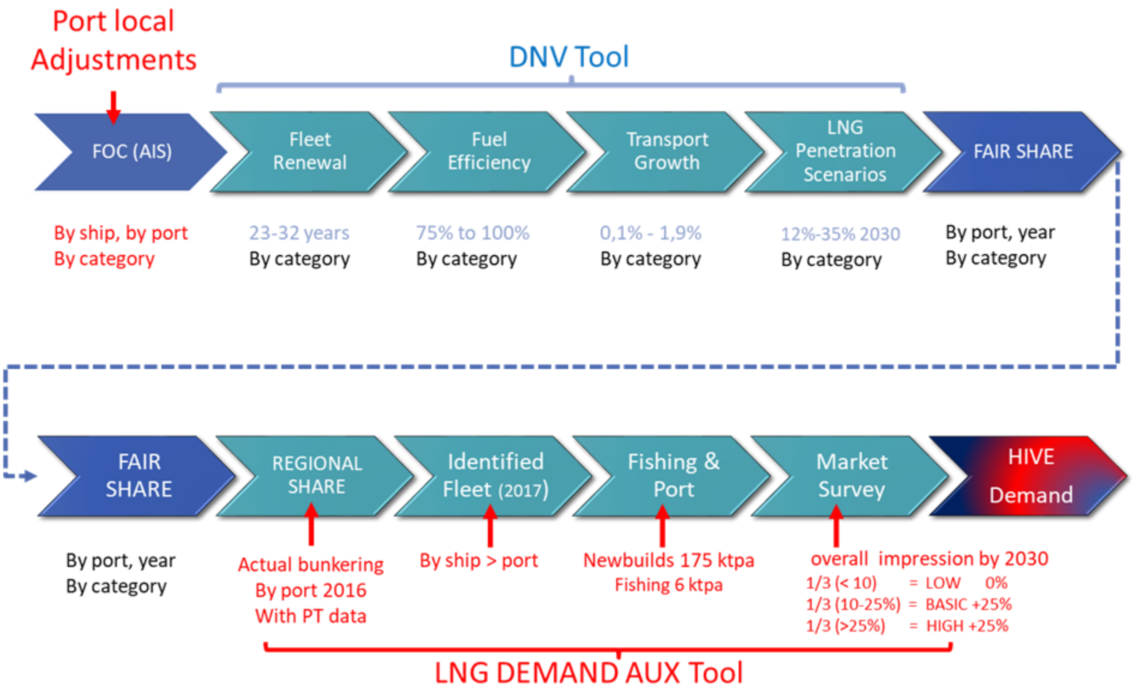


Figure 3.10 Expected demand analysis workflow

The diagram describes the methodology followed by DNV-GL, emphasizing in red the transformations applied by SBC aiming to refine the demand at the port level.

- **Adjustment per port:** The demand generated from traffic between peninsula and Baleares and Madeira and Ceuta y Melilla is assigned to the associated peninsular ports. For example, the demand of the ships connecting Barcelona and Valencia with Baleares is assigned to peninsular ports since it makes more sense for these ships to refuel in ports which are closer to the LNG import plants.

- **Current bunkering:** The ratio used to calculate the increase or reduction of bunkering service in proportion to current values, is calculated individually, per port, instead of applying the averaged factor per region. Current bunkering values have been updated and data for actual bunkering in Portuguese ports has also been included.
- **Known fleet with LNG motorization or dual LNG motorization.** Updated using know fleet data as of December 2017. For additional information, Annex 5 shows the estimated demand for shipping fleet, port machinery and new infrastructures.
- **Market evolution expectations:** This subjective factor showed an increase in demand of 50% for BASIC and HIGH scenarios. This factor was reduced to 25% to adjust the total demand after the transformations performed before, considered by DNV-GL's study.

This result matches with previous results for each corridor. Since the demand can experiment some alterations at a port level, to know the results in further detail, the file "demand editor", part of WPS is attached. This file shows a master table with all the possible demand values and unitary volumes for the bunkering services expected in each port.

3.4.1 Unitary volumes estimated

As a previous step before simulating the different logistic chains, is necessary to propose bunkering unitary volumes expected in every considered port. Since the market doesn't exist yet, is not possible to estimate in an accurate way the unitary volume served as today.

A good reference for the study could be made by looking at the average services performed for conventional fuels in the selected ports as today. The following table shows the main features of the unitary services in one of the top three bunkering ports.

Table 3.2 Spanish bunkering supply characterization by type of ship and size of port.

Vessel type	Units	<10.000 GT	10.000-30.000 GT	30.000-50.000 GT	>50,000 GT
Cruise ship	m^3 of LNG each service	62	533	638	1018
General Cargo	m^3 of LNG each service	355	503	735	611
Bulk carrier	m^3 of LNG each service	309	561	707	817
Containerships	m^3 of LNG each service	181	402	231	537
Ro-Pax	m^3 of LNG each service	70	548	810	
Ro-Ro	m^3 of LNG each service	264	525		
Tankers	m^3 of LNG each service	303	647	912	1.701
Total general	m^3 of LNG each service	182	541	689	1.253

Another good reference to take in to account is the average capacity per vessel type of the different LNG fuel tanks installed. The following graph shows the capacity of the tanks installed in 70% of the vessels propelled by LNG as today.

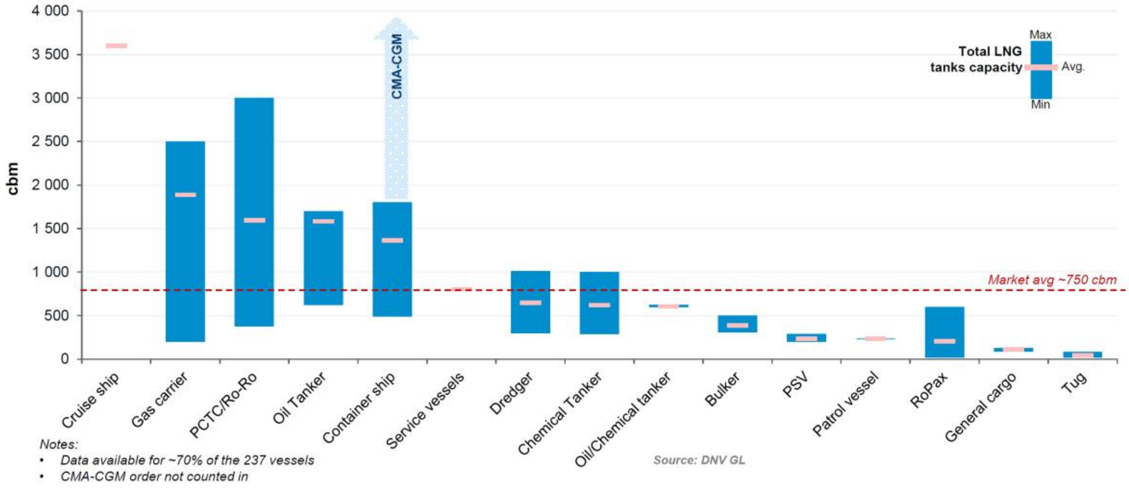


Figure 3.11. Installed LNG tank capacity in ships powered by LNG. Source: GTT Investor. January 2017

Using these two references, the unitary volumes used in this study would be as follow:

Table 3.3 Unitary volumes considered in this study

Unit volume
TTS (44 m^3)
250 m^3
400 m^3
600 m^3
1.600 m^3

This configuration has been chosen to perform the analysis needed in this report but, the design tool provided allows to modify these values to adapt the solution to the demand characterization desired. An example of this can be seen in chapter 4.4.3, where this unitary volumes are modified, using the values on Table 4.12 to perform different calculations.

Aimed to know the distribution of the expected unitary volumes in each port, both tables are combined as is reflected below:

- One table per each port, detailing the percentage of port calls by vessel type and GT section (For additional detail, check DNV report for CORE LNGas HIVE "Top Down" report)
- One table including a characterization of the expected average unitary volume by vessel type and GT section. (See Table 3.4)

Table 3.4 Average unitary volume expected by type of ship and size.

	<1000 GT	1000-5000 GT	5000-10000 GT	10000-25000 GT	25000-50000 GT	>50000 GT
Bulk carriers	TTS	TTS	250 m³	400 m³	600 m³	1.600 m³
Car carriers	TTS	TTS	250 m³	400 m³	600 m³	600 m³
Container ships	TTS	TTS	250 m³	400 m³	600 m³	1.600 m³
General cargo	TTS	TTS	250 m³	400 m³	400 m³	600 m³
Other	TTS	TTS	250 m³	400 m³	400 m³	600 m³
Passenger ship	TTS	TTS	250 m³	400 m³	400 m³	1.600 m³
Ro-Pax	TTS	250 m³	250 m³	400 m³	1.600 m³	1.600 m³
Ro-Ro	TTS	TTS	250 m³	250 m³	400 m³	600 m³

Results reflecting the total percentage of demand served for each expected unitary volume per port and vessel type, are included in Annex 5.

3.4.2 LNG demand for the Iberian port network

This section summarizes the expected demand for the whole network by year and scenario. Chapter 4 would explain in a more detailed way, the expected demand per cluster, time frame and vessel type.

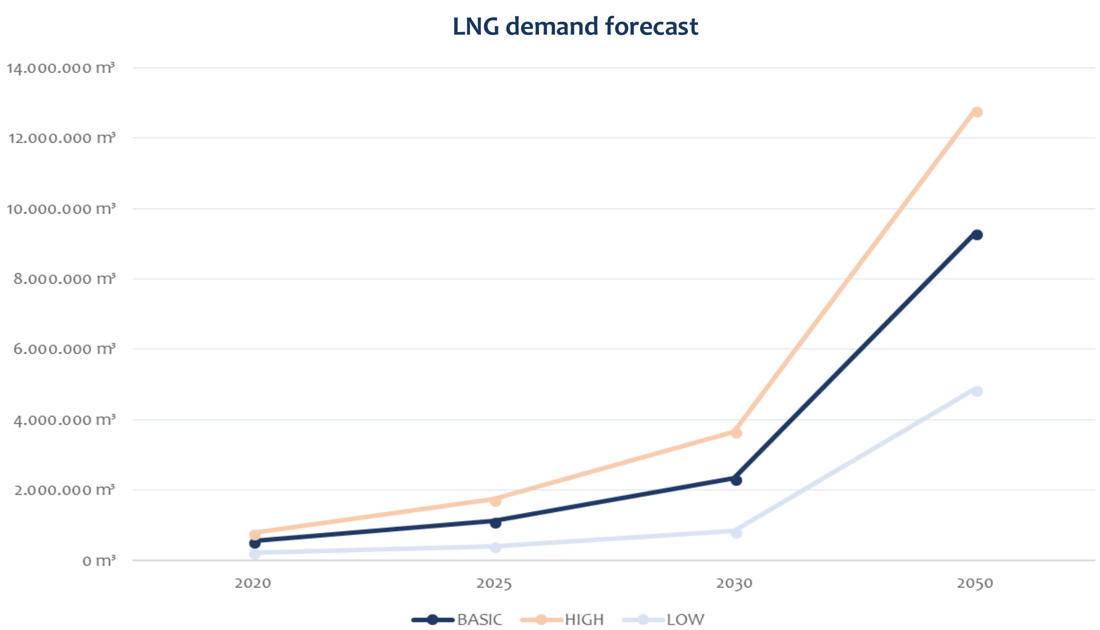


Figure 3.12 Estimated total demand considered in this study

4 ANALYSIS AND SOLUTIONS PROPOSED PER CLUSTER

Once established the initial hypothesis and the set of input data to be used, the aim of this chapter is to develop and present the analysis performed for the design of the possible LNG supply chains, in the Spanish and Portuguese port network.

Adapting the deployment of necessary resources for each cluster, requires a previous analysis of the current situation. Thus, each chapter of this section contains a subsection explaining the current situation of each cluster regarding this matter.

- Port traffic (Extracted from the DNV report for Core LNGas Hive project from 2015)
- Conventional bunkering market
- LNG bunkering development millstones.

The second subchapter includes decisive factors needed to take in to account when selecting the different supply chains to be developed, as well as an analysis of all potential viable solutions at a cluster level.

Knowing further information about any of the solutions referred in this chapter, is possible by using the calculation tool included in work package WP5 and .xls files included in work packages WP2/3.

4.1 *Barcelona cluster*

4.1.1 Introduction and current market characterization.

Barcelona cluster consists of 4 ports:

- Barcelona (LNG Terminal) (Base Port)
- Palamós
- Palma de Mallorca
- Tarragona

4.1.1.1 Port traffic analysis

Located in the east coast of Spain, these four Mediterranean ports show an uneven level of activity. Regarding number of port calls, Barcelona stands out, closely followed by Palma de Mallorca and Barcelona and far from Palamos.

Figure 4.1 shows port calls within this cluster.

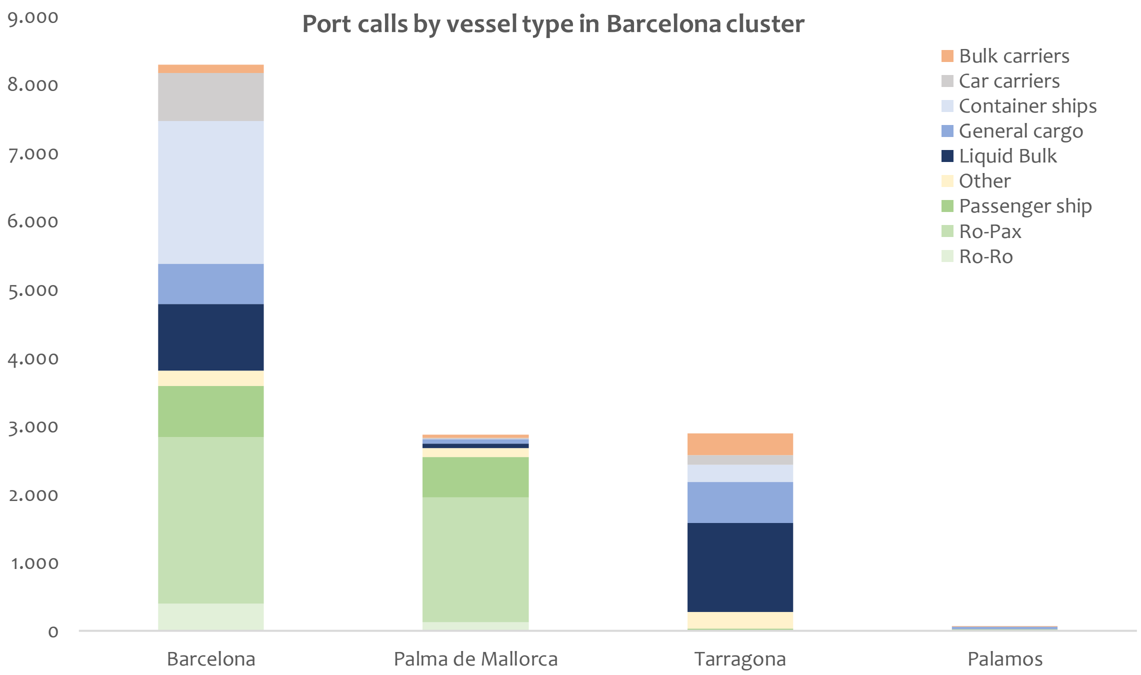


Figure 4.1 Port calls by vessel type in Barcelona cluster

Port of Barcelona, one of the main ports in the Mediterranean Sea, ranks number three by goods transported and shows a balanced traffic structure, standing out for being the number one cruise port in Europe and also number one port for the import/export of new vehicles. It's worth noting that traffic in 2017 increased 50% driven by a 300% growth in the number of containers in transit, which now constitutes 42% of the total container load.

Port of Tarragona is an important industrial port that hosts an oil refinery and is one of the most important petrochemical industry hubs in the peninsula. Thus, traffic of liquid fuels stands out in this port.

Palma de Mallorca and Ibiza ports mainly host goods transported by trucks coming from the peninsula via regular lines established between Barcelona and Valencia ports. Besides that, and thanks to the inter-insular traffic and the island's attractive for cruises, Palma de Mallorca is the port hosting most passengers in the whole system.

4.1.1.2 Traditional marine fuel bunkering

The great increase on marine traffic and the presence of fuel supply barges in the last decade, has contribute the development of bunkering in the Port of Barcelona, now ranking as the third supply port with 920.000 t served in 2017.

Figure 4.2 Conventional bunkering supplied in the cluster of Barcelona

Despite not showing a clear pattern, the most common client ships in the port of Barcelona are, in first place, big cruises, for which Barcelona constitutes its base port in the Mediterranean Sea, followed by large container ships and finally RORO ships connecting Balearic Islands with different Mediterranean ports. Port of Barcelona offers a competitive and high-quality service compared to other ports in the area, counting with a high storage capacity for oil-based products – CLH terminal, Decal Terminal – several operators and broad range of means for fuel supply.

Despite not having its own supply barge, Port of Tarragona offers TST service from Barcelona operated by the company Peninsula Petroleum and offers pipe service from the REPSOL terminal based on the port in addition to tanker truck supply service. It ranks number 11 among the Spanish fuel supply ports.

Table 4.1 Bunkering means in the cluster of Barcelona

Port	Marine suppliers		Ex-Pipe suppliers	
Barcelona	✓	CEPSA, REPSOL, Peninsula Petroleum	✓	decal, CLH
Tarragona	✓	Peninsula Petroleum	✓	REPSOL
Palma de Mallorca				
Palamos				

All ports count with small operator to service with tanks. Table 4.3 shows the 5 current conventional bunkering barges servicing this cluster.

Table 4.2 Marine bunkering means available

Barge	Base Port	Capacity	Supplier	Delivery Year	Other
Spabunker 30	Barcelona	4.215 t	CEPSA	2006	
Spabunker 41	Barcelona	3.770 t	CEPSA	2008	
Green Oil	Barcelona	4.300 t	REPSOL	2008	
Patagonia 100	Barcelona	4.000 t	Peninsula Petroleum	2006	*Operates also in Tarragona
Florence B	Barcelona	3.530 t	CEPSA	2008	

4.1.1.3 LNG bunkering development milestones.

Barcelona Port Authority, along with ENAGAS has promoted the development of several initiatives aimed to the implementation of different services directed to the small-scale LNG market and to improve the environmental conditions in the port area, being this terminal one of the most advanced on this matter. The most relevant milestones regarding the use of LNG as a marine fuel in Barcelona are:

- Frequent TTS supply service to ship Abel Matutes, propelled by an auxiliary LNG engine.
- Construction of a second jetty assigned to the reload of small-scale LNG ships and PTS bunkering for medium and large volume.
- Supply LNG to AIDA auxiliary engines using cryogenic tankers.
- Pilot study for OPS container system with natural gas generation.
- Project for retrofitting a conventional fuel supply barge into an LNG supply barge.
- Project for ship supply (LNG Natural Gas)

4.1.2 Potential supply chain analysis

General input data applied to every cluster was shown in section 2.3. This chapter focuses on the specific data for the estimated demand.

Figure 4.3 shows demand estimations for Barcelona cluster by period and vessel type.

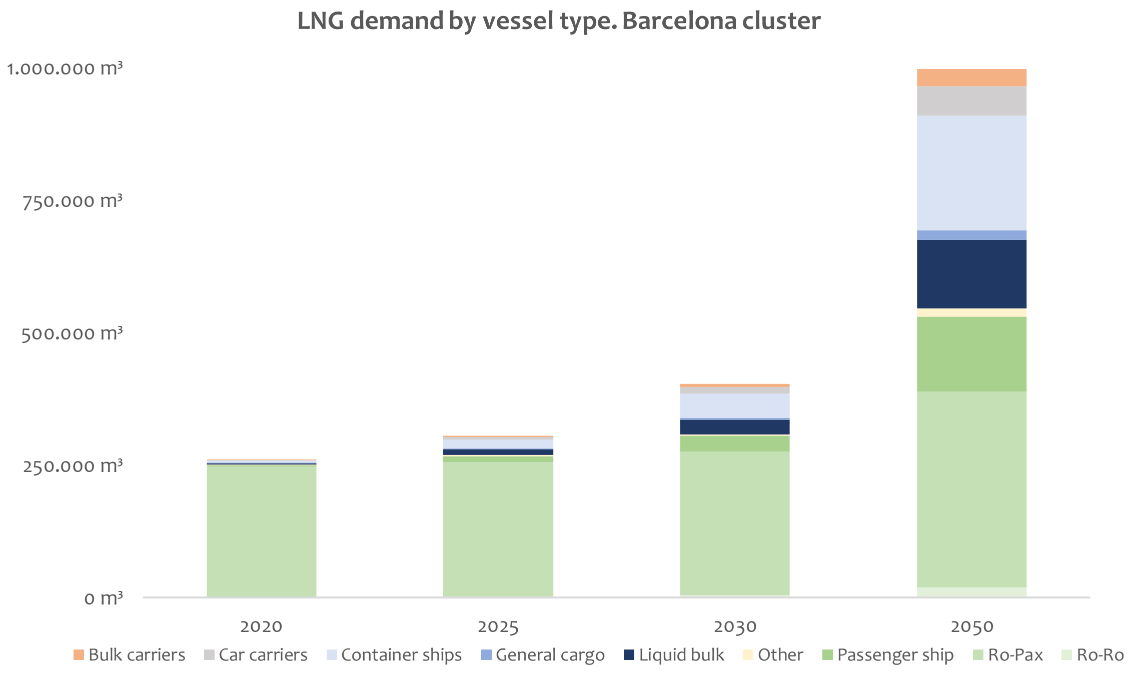


Figure 4.3 LNG demand by vessel type. Barcelona Cluster

Table 4.3 LNG demand by port in Barcelona cluster and Base scenario

Base Escenario	2020	2025	2030	2050
Barcelona	258.620 m³	301.092 m³	392.488 m³	944.826 m³
Tarragona	850 m³	3.760 m³	10.146 m³	47.997 m³
Palma Mallorca	81 m³	314 m³	795 m³	3.634 m³
Palamos	32 m³	142 m³	382 m³	1.808 m³
Total	**259.583 m³**	**305.308 m³**	**403.810 m³**	**998.265 m³**

It's important to know the distribution of the expected unitary bunkering services, since this will affect the size and evolution of the means to be implemented in a considerable way. The file "demand editor", attached to this report, includes different unitary volumes considered and the percentage of the total demand supply by each of them. This table is also reflected in Annex 5.

4.1.2.1 Logistic models to be implemented

Geographic and demand conditions defining each cluster, would be important when determining the viability of the different logistic models to be implemented. Thus, is important to narrow down these conditions, which will allow us to reduce the total numbers of solutions to analyze for each cluster.

For Barcelona cluster, is worth noting:

- Port of Barcelona would gather between 95% and 99% of the cluster's total LNG demand for the time frame considered.
- LNG import terminal is in the port with most demand.

The fact of having an LNG plant already in place for the service to small-scale vessels and the quick development of LNG tanks in cruises and Ro-Pax ships, makes Barcelona a perfect port to deploy LNG supply ships. Besides this, its high storage capacity – avoiding extra trips for refueling or construction of new auxiliary terminals – reduces supply costs considerably, especially during the early stages of the project.

The best logistic model to implement would be Model 1. This model doesn't consider the construction of auxiliary terminals or deployment of marine means outside the Base Port. Additional studies were performed to assess the viability of installing auxiliary terminals in Tarragona or Palma ports but due to its low demand, these solutions, even in the fairest scenarios, would increase final costs significantly.

To understand the evolution of logistic prices along the time frame studied, a total of 15 analysis were performed.

As it was pointed out in previous sections, Port of Barcelona is the third best bunkering port in Spain and number one in the Mediterranean area. Keeping this leadership in LNG supply would require a high availability and quality of service. This study is aimed to find an optimal cost solution but at the same time, a solution that allows a service availability right above the minimum required, so several supply operations could be carried out at the same time. Thus, two different solutions are presented.

First, a basic solution – blue line – that meets the minimum requirements, both economic and operational and a second one – orange line – that includes the installation of auxiliary terminals or additional maritime means to increase the quality of service offered.

In this case, - Barcelona port has an import terminal – auxiliary terminals weren't included, but additional ships or extended capacity was considered to increase the level of service provided.

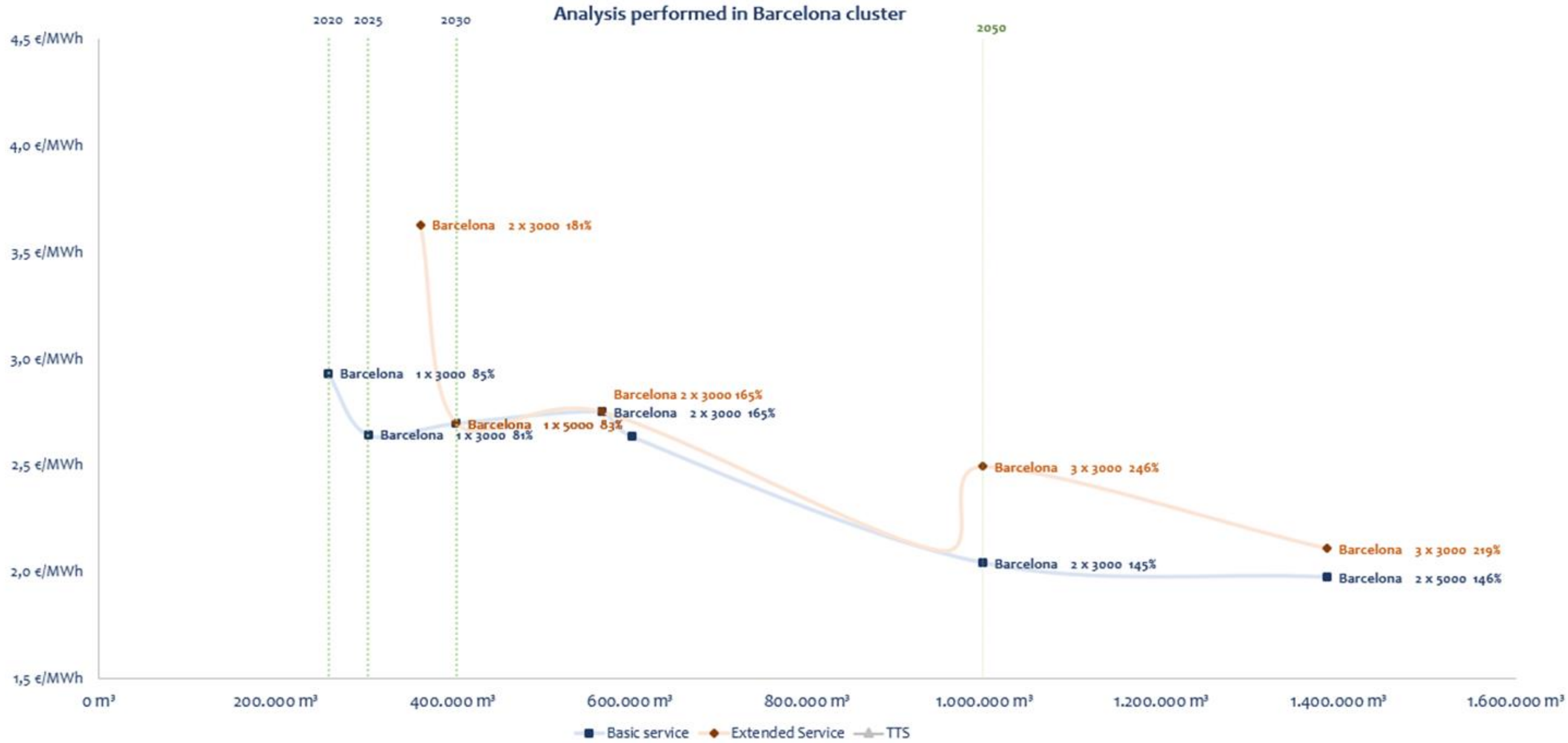
To know further details about the logistic solution presented, Figure 4.5 and 4.6 reflects the following: summarized investment costs, annual costs and implemented means for each of the solutions proposed. Data shown in these charts represent the cluster as a whole; estimated service costs for each port can be found using the optimization and design tool included in WP5 and in the next chapter, where more detailed data will be shown, but only for the optimal solution proposed for that cluster.

Looking at the price vs demand curves shown in Figure 4.4, this cluster doesn't show a high supply cost variability thanks to the high expected demand in the first years and to the lineal increments of demand along the time frame studied. **The final cost for these solutions ranges between 4 €/MWh y 2€/MWh.**

Barcelona's strong commitment for the development and supply of LNG bunkering plus its large potential as an LNG consumer and supplier makes service availability a crucial factor, recommending implementing at least two vessels with capacity over 500.000 m^3 and 3 over 1.000.000 m^3.

The chosen solution – which will be further detailed in the next chapter – for Barcelona cluster is:

- **Year 2020:** 3.000 m^3 vessel with Base Port in Barcelona **(Solution 1A)**
- **Year 2025:** 3.000 m^3 vessel with Base Port in Barcelona **(Solution 2A)**
- **Year 2030:** 2 3.000 m^3 vessels with Base Port in Barcelona **(Solution 2B)**
- **Year 2050:** 2 3.000 m^3 vessel with Base Port in Barcelona **(Solution 3B)**



Label explanation **Base Port; Number of vessel x Vol. Capacity; Service level**

Figure 4.4 Supply chains analyzed in the cluster of Barcelona

Figure 4.5 Cost summary for analysis performed in the cluster of Barcelona

	Solución 1A	Solución 2A	Solución 3A	Solución 4A	Solución 5A	Solución 6A	Solución 7A
Cluster	BARCELONA	BARCELONA	BARCELONA	BARCELONA	BARCELONA	BARCELONA	BARCELONA
Method	HIVE	HIVE	HIVE	HIVE	HIVE	HIVE	HIVE
Scenario	BASIC	BASIC	BASIC	LOW	HIGH	BASIC	HIGH
Year	2020	2025	2030	2050	2030	2050	2050
ID analysis	BCN2020	BCN2025	BCN2030	BCN2050L	BCN2030H	BCN2050	BCN2050H
Demand	259.470 m³	304.853 m³	403.810 m³	568.340 m³	602.574 m³	998.265 m³	1.387.054 m³
Services STS	25	49	101	259	171	477	690
Services TTS	269	333	465	718	705	1.271	1.808
Unit cost	2,93 €/MWh	2,64 €/MWh	2,70 €/MWh	2,75 €/MWh	2,63 €/MWh	2,04 €/MWh	1,98 €/MWh
SERVICE COST	€814.348	€927.114	€1.480.835	€1.941.067	€1.827.261	€2.956.887	€4.830.725
RELOAD COST	€2.092.504	€2.456.994	€2.839.245	€4.417.691	€4.686.947	€7.752.132	€9.393.285
FEEDERING	€0	€0	€0	€0	€0	€0	€0
AUX. TERMINAL	€0	€0	€0	€0	€0	€0	€0
INACTIVITY COST	€2.255.208	€2.084.169	€3.069.671	€4.257.225	€4.258.345	€3.136.148	€4.389.525
Total cost	5.162.059	5.468.276	7.389.750	10.615.983	10.772.554	13.845.167	18.613.536
Total investment	20.000.000	20.000.000	32.000.000	40.000.000	40.000.000	40.000.000	64.000.000
Income fee for IT	€1.670.425	€1.961.272	€2.332.365	€3.662.730	€3.885.030	€6.425.902	€8.019.205
Cost impact	0,95 €/MWh	0,95 €/MWh	0,85 €/MWh	0,95 €/MWh	0,95 €/MWh	0,95 €/MWh	0,85 €/MWh
Cost impact %	32%	36%	32%	35%	36%	46%	43%
Vessel slots	86	101	80	186	199	326	271
Truck slots	43	49	94	241	158	441	669
Vessel Terminal usage days	29	34	23	108	116	190	135
Truck Terminal usage days	2	2	5	12	8	22	33
Vessels							
Port, no., size, service BP1	Barcelona 1 x 3000 85%	Barcelona 1 x 3000 81%	Barcelona 1 x 5000 83%	Barcelona 2 x 3000 165%	Barcelona 2 x 3000 166%	Barcelona 2 x 3000 145%	Barcelona 2 x 5000 146%
BP2							
BP3							
BP4							
Terminals							
Port, size							
Feeders							

Header colors makes reference to those used in Figure 4.4

Figure 4.6 Cost summary for analysis performed in the cluster of Barcelona

		Solución 1B	Solución 2B	Solución 3B	Solución 4B	Solución 1T	Solución 2T
Cluster		BARCELONA	BARCELONA	BARCELONA	BARCELONA	BARCELONA	BARCELONA
Method		HIVE	HIVE	HIVE	HIVE	HIVE	HIVE
Scenario		HIGH	BASIC	BASIC	HIGH	LOW	HIGH
Year		2020	2030	2050	2050	2020	2050
ID analysis		BCN2020H*	BCN2030**	BCN2050*	BCN2050H+	BCN2020TTSL	BCNTTS2050
Demand		363.161 m^3	403.810 m^3	998.265 m^3	1.387.054 m^3	160.228 m^3	998.265 m^3
Services STS		52	101	477	690	3	477
Services TTS		382	465	1.276	1.820	0	0
Unit cost		3,63 €/MWh	3,40 €/MWh	2,49 €/MWh	2,11 €/MWh	2,02 €/MWh	2,10 €/MWh
SERVICE COST		€1.075.508	€1.341.085	€3.009.034	€4.232.096	€969.249	€6.597.465
RELOAD COST		€2.828.864	€3.133.972	€7.696.055	€10.702.115	€1.229.019	€7.657.132
FEEDERING		€0	€0	€0	€0	€0	€0
AUX. TERMINAL		€0	€0	€0	€0	€0	€0
INACTIVITY COST		€5.033.833	€4.836.123	€6.186.042	€4.928.042	€0	€0
Total cost		8.938.205	9.311.180	16.891.130	19.862.254	2.198.268	14.254.597
Total investment		40.000.000	40.000.000	60.000.000	60.000.000	0	0
Income fee for IT		€2.347.718	€2.592.613	€6.438.389	€8.955.636	€1.228.835	€7.496.873
Cost impact		0,95 €/MWh	0,95 €/MWh	0,95 €/MWh	0,95 €/MWh	1,13 €/MWh	1,11 €/MWh
Cost impact %		26%	28%	38%	45%	56%	53%
Vessel slots		121	133	326	453	0	0
Truck slots		53	94	478	691	3641	22213
Vessel Terminal usage	**days**	70	78	271	377	0	0
Truck Terminal usage	**days**	3	5	24	35	182	1.111
Vessels							
Port, no., size, service	BP1	Barcelona 2 x 3000 181%	Barcelona 2 x 3000 177%	Barcelona 3 x 3000 246%	Barcelona 3 x 3000 219%		
	BP2						
	BP3						
	BP4						
Terminals							
Port, size							
Feeders							
Notes							

Solución xT = TTS only logistic solution

4.2 *Sagunto Cluster*

Sagunto cluster consists of 4 ports:

- Alicante
- Castellón
- Ibiza
- Sagunto (Import terminal)
- Valencia (Base Port)

4.2.1 Introduction and current market characterization.

4.2.1.1 Port traffic analysis

As in Barcelona cluster, these four ports present an uneven activity level. Valencia stands out with an important number of container ships and with and important number of passenger ships and a smaller, but also relevant number of Car Carriers. Valencia is followed by Ibiza in number of port calls, mostly due to its insularity condition, with an important number of small passenger ships. Sagunto and Castellon, with similar port call numbers but with different type of traffic and finally, Port of Alicante is last in port calls. Figure 4.5 shows this distribution:

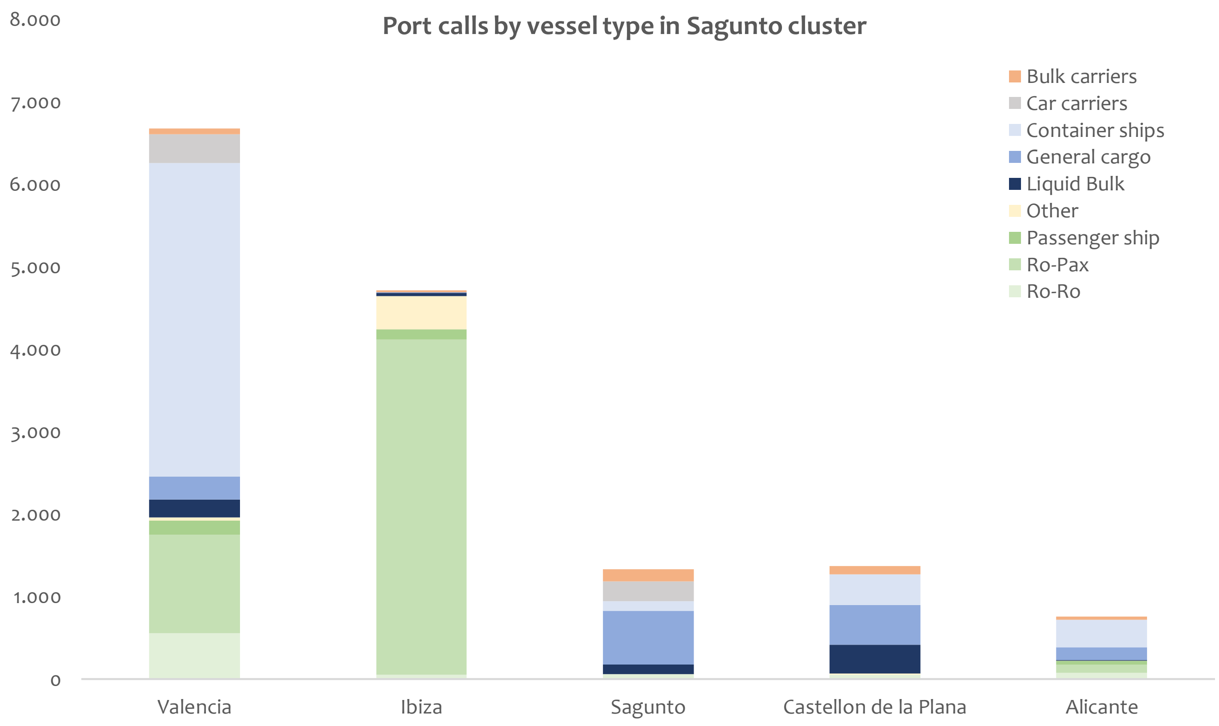


Figure 4.7 Port calls in the cluster of Sagunto

As was mentioned before, port of Valencia stands out by its high number of container ships, with an important growth in the last decade, making it the second biggest Spanish port in container traffic and one of the European leaders. In addition to this, Valencia hosts several regular passenger and cargo lines throughout the year.

On the other hand, Castellon is an industrial port whose goods are divided between bulk and liquid products, due to the refinery located in this town and solid bulk, thanks to the important ceramic and construction business present in this region.

Port of Sagunto, close to Valencia (15 miles), hosts general traffic and car-carriers operating transatlantic lines.

Por of Ibiza hosts passengers and cargo using Ro-pax ships from the Peninsula through regular lines to Port of Valencia or Port of Barcelona.

Alicante is the smallest port attending to port calls received and hosts small container ships and Ro-Pax vessels.

4.2.1.2 Conventional marine fuel bunkering

In contrast to Port of Barcelona situation, the increase in foreign container ship traffic didn't transform in to an excessive bunkering market increase in the Port of Valencia, ranking 7th with 309,381 t despite being 2nd in overall goods transport.

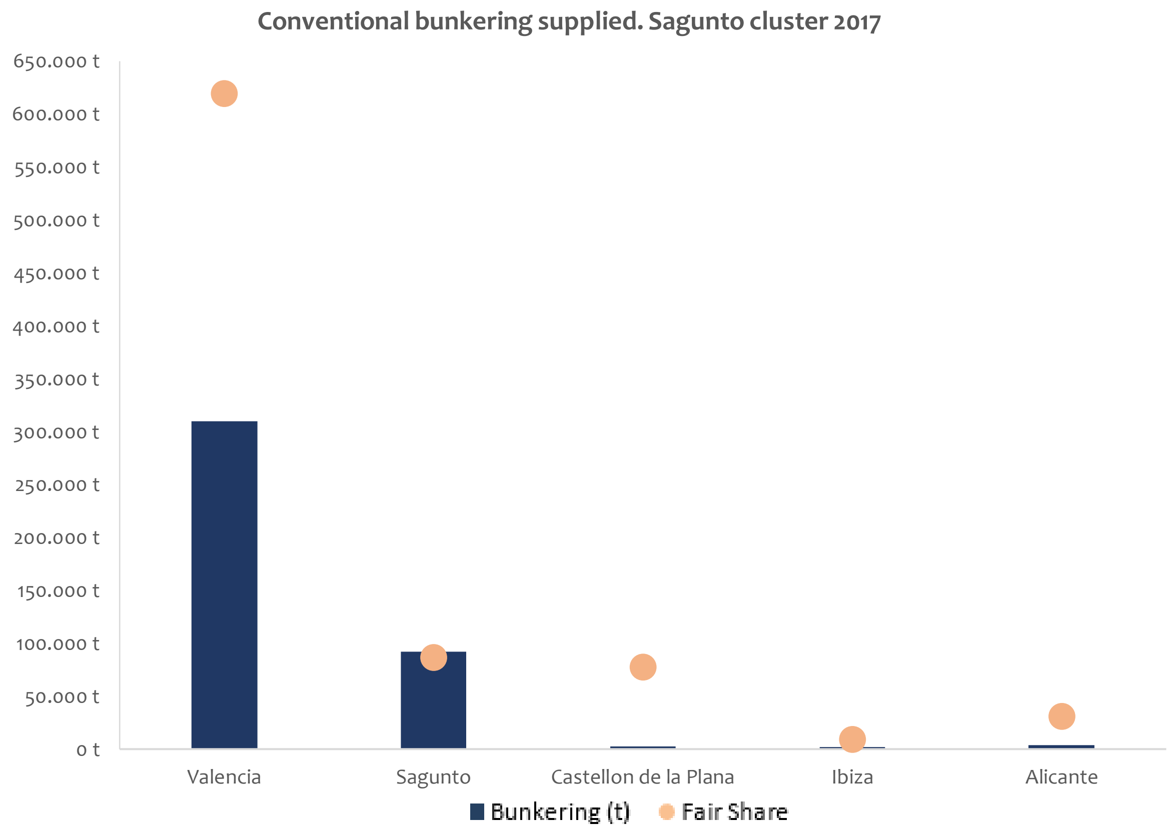


Figure 4.8 Conventional bunkering supplied in the cluster of Sagunto

As can be seen in the graph above, the orange dot represents its traffic baseline, Port of Valencia should at least double the amount of fuel served annually but this doesn't happen due to two main factors: Lack of competitive fuel prices and the reduced service capacity, having only one supply barge available in the port.

As Table 4.3 reflects, ports of Sagunto and Valencia are supplied mainly by Repsol, who owns a supply barge to serve both ports, even though none of these ports owns a pipe supply fuel system.

Table 4.4 Bunkering means in the cluster of Sagunto

Puerto	Marine suppliers		Ex-Pipe suppliers
Valencia	✓	REPSOL	
Sagunto	✓	REPSOL	
Castellón			
Ibiza			

Table 4.5 Available marine bunkering means

Barge	Base Port	Capacity	Supplier	Delivery year	Comments
Erregaia	Valencia	1.310 t	REPSOL	1996	

4.2.1.3 LNG bunkering development milestones.

Non-small-scale projects are being executed currently but the following projects are being carried on:

- Project to adjust the existent jetty for the reload of small-scale LNG ships and medium and large PTS bunkering ships at Sagunto's import terminal.

4.2.2 Potential supply chain analysis.

Sagunto Cluster has 5 ports but most of the expected demand is focused in a single port, Valencia. In contrast to Port of Barcelona, the projected demand generation is expected to be slow, speeding up gradually in the latest phase of the period studied. This is mostly

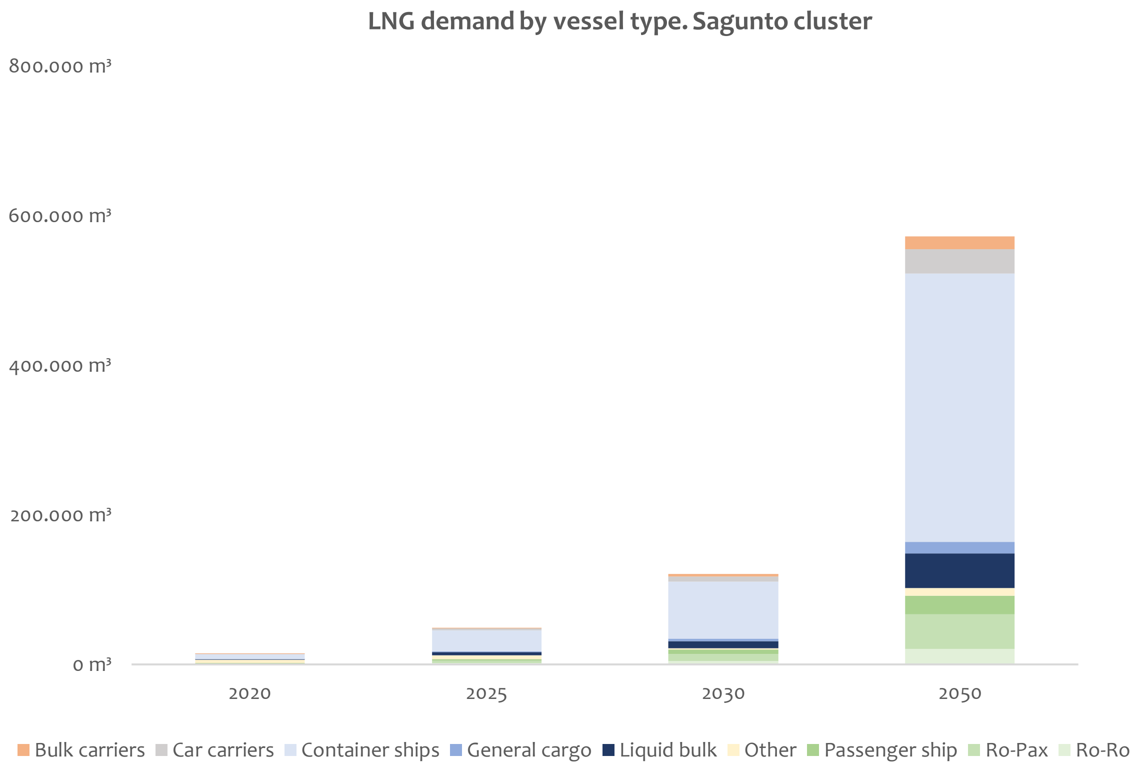


Figure 4.9 LNG demand by vessel type. Sagunto cluster

Table 4.6 LNG demand by port in Sagunto cluster and Base scenario

Base scenairo	2020	2025	2030	2050
Valencia	12.802 m³	41.428 m³	99.782 m³	472.057 m³
Sagunto	1.241 m³	5.491 m³	14.816 m³	70.091 m³
Castellon de la Plana	262 m³	1.161 m³	3.133 m³	14.820 m³
Ibiza	212 m³	823 m³	2.084 m³	9.527 m³
Alicante	104 m³	460 m³	1.240 m³	5.868 m³
Total	**14.622 m³**	**49.363 m³**	**121.055 m³**	**572.363 m³**

4.2.2.1 *Logistic models to be implemented*

Sagunto Cluster is pretty similar to Barcelona Cluster for the following reasons:

- Una concentración de demanda aproximada del 85% en el puerto de Valencia
- Around 85% of its total demand comes from Port of Valencia.
- LNG Import terminal situada a menos de 15 nm del puerto de mayor demanda
- LNG import terminal located within less than 15 nm from the port with highest demand.

Logistic Model 1 is considered the most suitable model for this cluster.

Figure 4.8 shows the resources assigned to the optimal solution considered in the simulation for Sagunto Cluster.

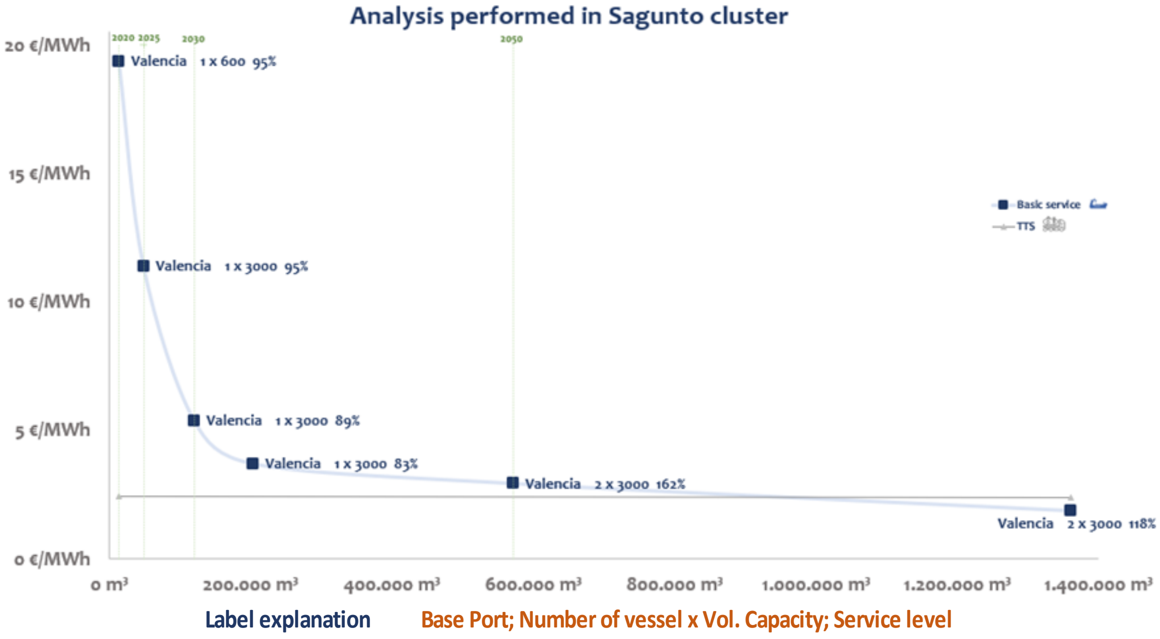


Figure 4.10 Supply chains analyzed in the cluster of Sagunto

Attending to the price vs demand curve in the figure above, we can see how this cluster shows a high cost variability during the first 10 years of operation, due to the low demand expected during these first years and due to the remarkable triggered by the effect of economies of scale as demand grows. The minimum expected demand threshold required to make LNG supply competitive, compared to TTS supply and other fuel sources, is estimated to be around 150,000 m³. Volumes above this threshold, reduce costs considerably ranging between **5 €/MWh y 2,5€/MWh.**

The chosen solution - which will be detailed in the next chapter- for Sagunto Cluster is:

- **Year 2020:** TTS Supply (Solution 1)
- **Year 2025:** 3,000 m³ ship based in Port of Valencia (Solution 2A)
- **Year 2030:** 3,000 ship based in Port of Valencia (Solution 3A)
- **Year 2050:** 2 3,000 m³ based in Port of Valencia (Solution 6A)

Detailed features for all solutions shown in this graph are summarized in Figure 4.11

Is important to notice again, as it was already noted in figure 4.6, the difference between the demand corresponding to Port of Valencia, based on actual supplies, could be much higher – almost double – to its current demand, if supply demand were to be proportional to the port traffic.

Based on the high port call activity and freight transport at Port of Valencia and to the proximity to Sagunto's import plant, boosting the development of LNG supply by increasing service availability levels, making sure that service is available in case of overlapping demand requests from more than one ship. In such case, a new scenario should be simulated, including extra service availability, increasing cost per MWh during the first years and waiting for unitary costs to come down, once Valencia is considered as a reference in the peninsular LNG bunkering market.

Figure 4.11 Cost summary for analysis performed in the cluster of Sagunto

	Solución 1A	Solución 2A	Solución 3A	Solución 4A	Solución 6A	Solución 7A	Solución 1T	Solución 2T
Cluster	SAGUNTO	SAGUNTO	SAGUNTO	SAGUNTO	SAGUNTO	SAGUNTO	SAGUNTO	SAGUNTO
Method	HIVE	HIVE	HIVE	HIVE	HIVE	HIVE	HIVE	HIVE
Scenario	BASIC	BASIC	BASIC	HIGH	BASIC	HIGH	BASIC	HIGH
Year	2020	2025	2030	2030	2050	2050	2020	2050
ID analysis	SAG2020	VLC2025	VLC2030	VLC2030H	VLC2050-1	VLC2050H	VLC2020TTS	VLC2050TTS
Demand	14.622 m³	49.363 m³	121.055 m³	204.469 m³	572.363 m³	1.361.500 m³	14.622 m³	1.361.500 m³
Services STS	8	28	68	113	315	599	8	599
Services TTS	31	77	168	283	793	1.897	0	0
Unit cost	19,37 €/MWh	11,40 €/MWh	5,38 €/MWh	3,71 €/MWh	2,93 €/MWh	1,87 €/MWh	2,45 €/MWh	2,37 €/MWh
SERVICE COST	€656.194	€576.964	€839.998	€1.140.711	€2.609.269	€4.542.314	€130.969	€11.483.127
RELOAD COST	€269.665	€425.862	€1.021.151	€1.727.250	€4.547.102	€10.822.023	€112.159	€10.443.305
FEEDERING	€0	€0	€0	€0	€0	€0	€0	€0
AUX. TERMINAL	€0	€0	€0	€0	€0	€0	€0	€0
INACTIVITY COST	€996.742	€2.816.495	€2.563.073	€2.274.477	€4.242.775	€1.948.679	€0	€0
Total cost	1.922.600	3.819.321	4.424.222	5.142.439	11.399.147	17.313.016	243.127	21.926.433
Total investment	9.522.000	20.000.000	20.000.000	20.000.000	40.000.000	40.000.000	0	0
Income fee for IT	€194.498	€328.664	€780.975	€1.320.429	€3.661.328	€8.735.379	€110.362	€10.242.093
Cost impact	1,96 €/MWh	0,98 €/MWh	0,95 €/MWh	0,95 €/MWh	0,94 €/MWh	0,95 €/MWh	1,11 €/MWh	1,11 €/MWh
Cost impact %	10%	9%	18%	26%	32%	50%	45%	47%
Vessel slots	24	16	39	66	183	441	0	0
Truck slots	18	61	89	147	408	723	327	30347
Vessel Terminal usage days	4	5	13	22	107	257	0	0
Truck Terminal usage days	1	3	4	7	20	36	16	1.517
Vessels								
Port, no., size, service BP1	Valencia 1 x 600 95%	Valencia 1 x 3000 95%	Valencia 1 x 3000 89%	Valencia 1 x 3000 83%	Valencia 2 x 3000 162%	Valencia 2 x 3000 118%		
BP2								
BP3								
BP4								
Terminals								
Port, size								
Feeders								

4.3 *Cartagena Cluster*

Cartagena cluster consists of 3 ports:

- Almería
- Cartagena (LNG import terminal) (Base Port)
- Motril

4.3.1 Introduction and current market characterization.

4.3.1.1 Port traffic analysis

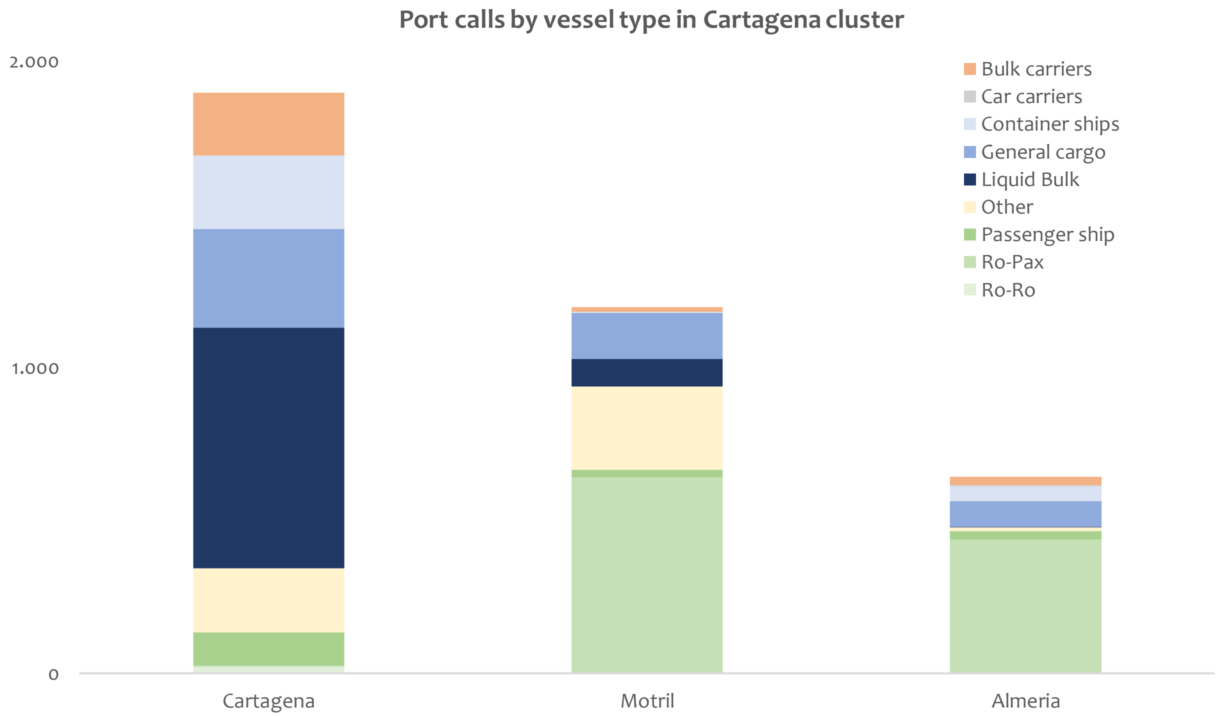


Figure 4.12 Port calls in the cluster of Cartagena

Port of Cartagena ranks number 4 in freight transportation and is considered an industrial port due to its high volume of bulk liquid freight. It hosts one of the biggest refineries in the Iberian Peninsula and serves as a maritime terminal for delivery and reception of raw materials and finished products for Puertollano's refinery.

Motril and Almeria mainly hosts Ro-Pax traffic from routes coming from north African ports.

4.3.1.2 Traditional marine fuel bunkering

Non-of the ports included in this cluster are considered as conventional supply ports, having only tanker supply based systems used in Motril and Almeria ports, to attend the needs of regular service Ro-pax ships.

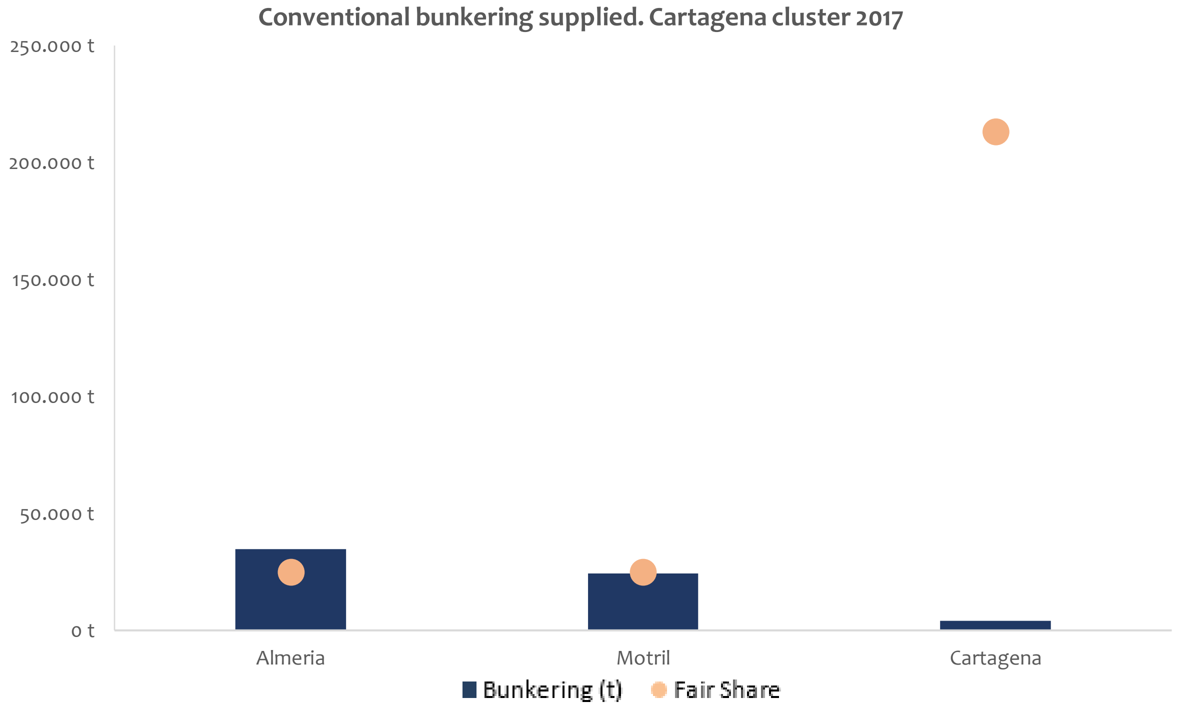


Figure 4.13 Conventional bunkering supplied in the cluster of Cartagena

A total of 63,000 t will be supplied in this cluster using tanker trucks.

Table 4.7 Bunkering means in the cluster of Cartagena

Puerto	Marine suppliers	Ex-Pipe suppliers
Almería		
Cartagena		
Motril		

4.3.1.3 LNG bunkering development milestones.

Until now, the most important milestones in terms of LNG bunkering have been carried out at Port of Cartagena, where the followings operations are currently in place.

- Adjustments to the existing dock belonging to the regasification plant of Escombreras for PTS supply.
- 1st PTS supply in a European import terminal.
- Largest TTS supply made in Spain and Portugal

4.3.2 Potential supply chain analysis

Consisting on three ports, this cluster expects the lowest demand of the whole network, since its traffic, mostly comprised of liquid and solid bulk ships, has a lower LNG conversion traffic and with progression and as of today, minimum bunkering market share.

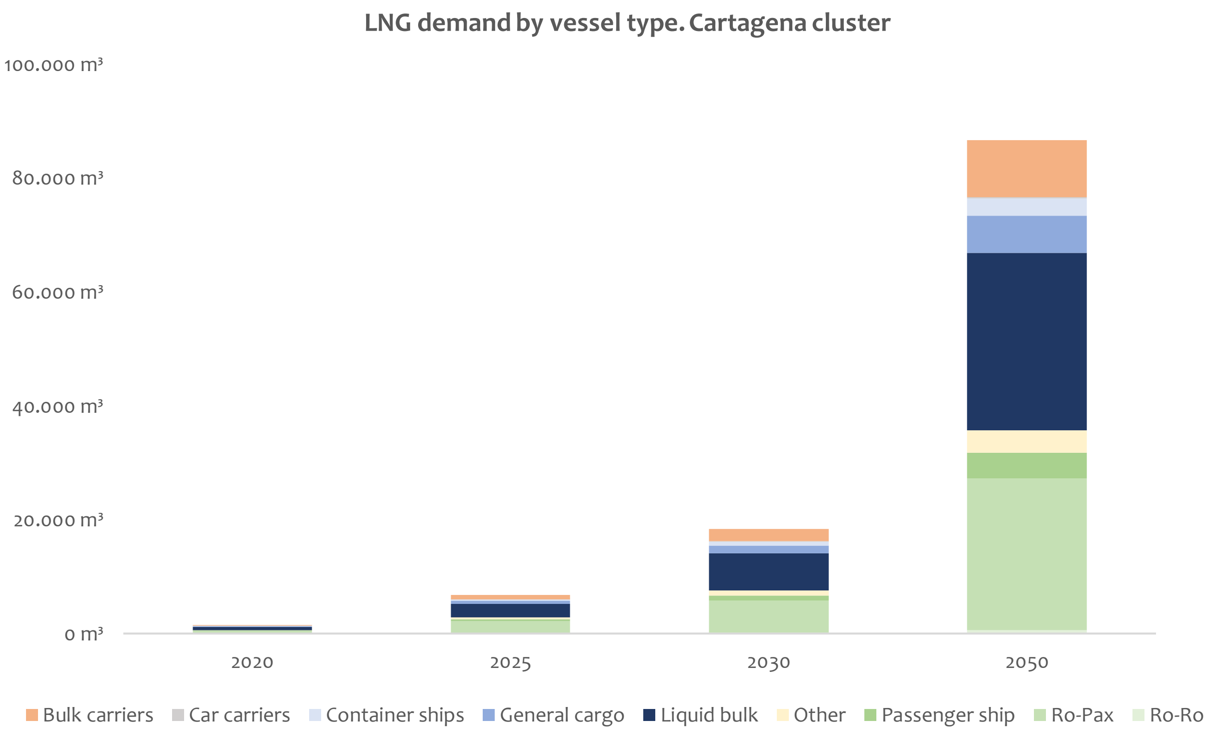


Figure 4.14 LNG demand by vessel type. Cartagena cluster

Table 4.8 LNG demand by port in Cartagena cluster and Base scenario

Base scenario	2020	2025	2030	2050
Cartagena	718 m³	3.179 m³	8.577 m³	40.574 m³
Almeria	534 m³	2.364 m³	6.379 m³	30.178 m³
Motril	282 m³	1.249 m³	3.371 m³	15.947 m³
Palamos	32 m³	142 m³	382 m³	1.808 m³
Total	1.535 m³	6.793 m³	18.326 m³	86.700 m³

As the graph reflects, the low demand expected will be divided proportionally between bulk ships with calls in Cartagena and passenger and road freight ships in ports of Almeria and Motril.

4.3.2.1 *Logistic models to be implemented*

Analysis of lower volume clusters such as Cartagena, requires a different approach, with special focus on knowing if the demand would be enough to justify the existence of marine fuel supply services.

For Cartagena cluster, is worth noting:

- Demand will be evenly, with 50% for Cartagena and 50% for the rest.
- Almeria and Motril ports are noticeably apart from the Base Port.

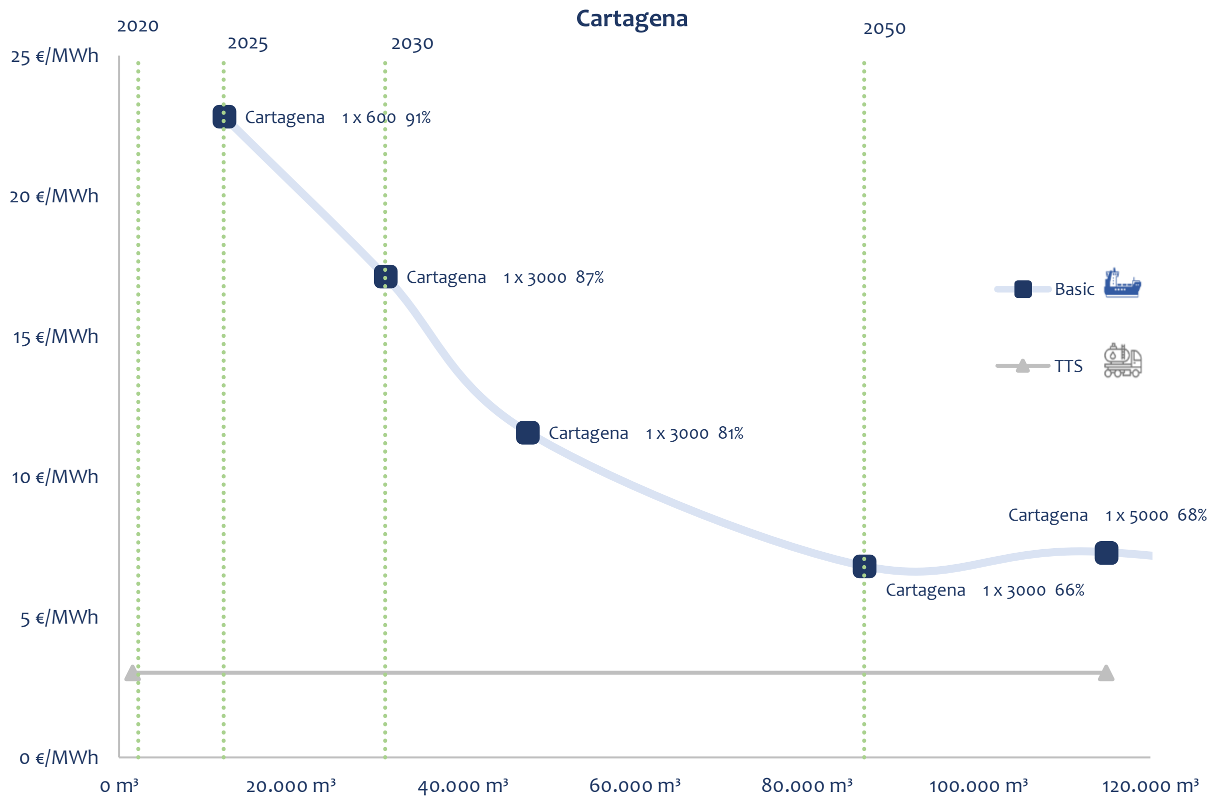


Figure 4.15 Supply chains analyzed in the cluster of Cartagena

Low demand and remoteness of Almeria and Motril ports, increases cost services remarkably, making supply with multi-product ships less feasible and reducing service levels at Base Port, which will require higher capacity vessels. **Above the 100,000 m³ demand threshold, supply costs steady around 7 €/MWh, far from the 3 €/MWh for TTS supply.** Construction of new auxiliary storage facility or supply ships in Almeria or Motril, would increase costs above 10 €/MWh, thus this option hasn't been considered.

The chosen solution for this cluster is the following.

- **Year 2020:** TTS Supply **(Solution 1T)**
- **Year 2025:** TTS Supply **(Solution 1T)**
- **Year 2030:** TTS Supply **(Solution 1T)**

- **Year 2050:** de 3.000 m^3 ship with Base Port in Cartagena. **(Solution 4A)**

Figure 4.16 Cost summary for analysis performed in the cluster of Cartagena

	Solución 1A	Solución 2A	Solución 3A	Solución 4A	Solución 5A	Solución 1T	Solución 2T
Cluster	CARTAGENA	CARTAGENA	CARTAGENA	CARTAGENA	CARTAGENA	CARTAGENA	CARTAGENA
Method	HIVE	HIVE	HIVE	HIVE	HIVE	HIVE	HIVE
Scenario	HIGH	HIGH	LOW	BASIC	HIGH	BASIC	HIGH
Year	2025	2030	2050	2050	2050	2020	2050
ID analysis	CAR2025H	CAR2030H	CAR2050L	CAR2050	CAR2050H	CAR2020TTS	CAR2050HTTS
Demand	12.173 m^3	30.964 m^3	47.488 m^3	86.700 m^3	114.864 m^3	1.535 m^3	114.864 m^3
Services STS	12	30	47	85	113	2	113
Services TTS	20	50	77	141	187	0	0
Unit cost	22,83 €/MWh	17,14 €/MWh	11,59 €/MWh	6,82 €/MWh	7,31 €/MWh	3,02 €/MWh	3,02 €/MWh
SERVICE COST	€720.786	€744.664	€930.768	€1.366.184	€2.009.778	€19.648	€1.470.229
RELOAD COST	€203.731	€251.644	€400.392	€704.604	€808.766	€11.775	€881.057
FEEDERING	€0	€0	€0	€0	€0	€0	€0
AUX. TERMINAL	€0	€0	€0	€0	€0	€0	€0
INACTIVITY COST	€962.249	€2.607.171	€2.406.426	€1.940.817	€2.883.662	€0	€0
Total cost	1.886.766	3.603.479	3.737.585	4.011.605	5.702.205	31.423	2.351.286
Total investment	9.522.000	20.000.000	20.000.000	20.000.000	32.000.000	0	0
Income fee for IT	€161.069	€203.010	€323.939	€568.159	€670.813	€11.475	€843.411
Cost impact	1,95 €/MWh	0,97 €/MWh	1,00 €/MWh	0,97 €/MWh	0,86 €/MWh	1,10 €/MWh	1,08 €/MWh
Cost impact %	9%	6%	9%	14%	12%	37%	36%
Vessel slots	20	10	16	28	22	0	0
Truck slots	12	31	47	86	113	34	2499
Vessel Terminal usage days	4	3	5	9	6	0	0
Truck Terminal usage days	1	2	2	4	6	2	125
Vessels							
Port, no., size, service BP1	Cartagena 1 x 600 91%	Cartagena 1 x 3000 87%	Cartagena 1 x 3000 81%	Cartagena 1 x 3000 66%	Cartagena 1 x 5000 68%		
BP2							
BP3							
BP4							
Terminals							
Port, size							
Feeders							

4.4 *Huelva Cluster*

4.4.1 Introduction and current market characterization.

Huelva cluster consists of 4 ports:

- Algeciras (Base Port)
- Ceuta
- Cádiz
- Málaga
- Huelva (LNG Import terminal)
- Sevilla
- Melilla

4.4.1.1 Port traffic analysis.

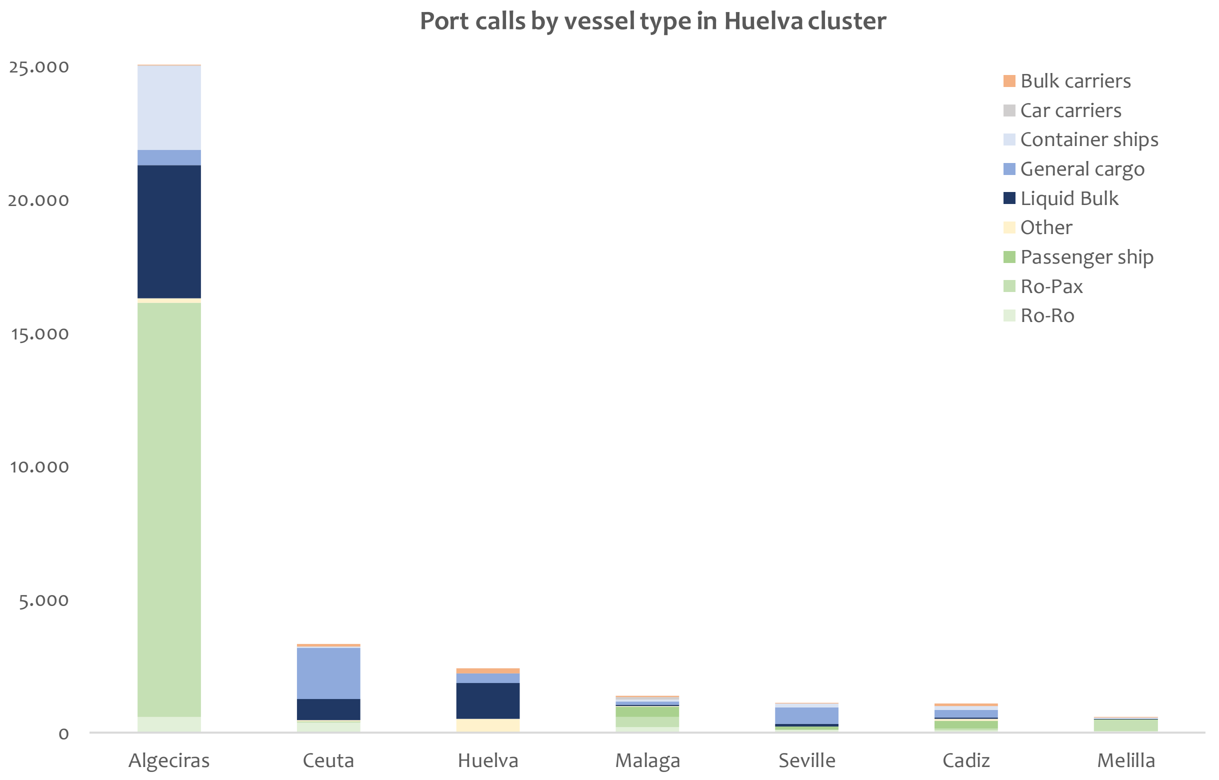


Figure 4.17 Port calls in the cluster of Huelva

This cluster has the highest activity of the whole network, featuring a wide range of traffic sizes and ship types. Within this cluster, Port of Algeciras stands out as the number ranked national port. It hosts the biggest refinery in the peninsula and counts with a big anchoring area with perfect conditions for ships carrying transit cargo (transit cargo is unloaded in a Spanish port but is not introduced to the domestic market, is picked up by a third ship with a different destination). All this make Algeciras a reference port for bunkering at a global scale.

Port of Algeciras is known for hosting these types of traffic.

- **Container ships:** Thanks to its proximity to Gibraltar Strait, a perfect location for transit container cargo activity. This port hosts big container ships regularly.
- **Oil tanker and oil products ships:** This port has large storage facilities for the liquid bulk market.
    - **Cepsa refinery.** High refining capacity and multiple petrochemical companies present.
    - **CLH terminal:** 190.000 m^3 storage capacity and connected to the national oil pipeline network.
    - **Vopak terminal:** 400.000 m^3 storage capacity terminal. Not connected to the pipeline network.
- **Road and passenger cargo:** Its proximity to the Moroccan coast and to the port of Ceuta in particular, makes the transport of cargo between both continents possible in a short period of time, having a high level of Ro-Ro and Ro-Pax service with a strong seasonal peak, since this is the preferred way to return from Europe to their countries of origin in the African continent.

Despite ranking number 25 in freight transit, Port of Ceuta is the destination of the majority of passengers departing from Algeciras, counting with multiple road and passengers port calls. This port also stands out in bunkering supply, ranking 4th in total tons of fuel supplied in Spain.

Port of Huelva is mainly industrial and ranks high among liquid bulk traffic ports. This port hosts a large Cepsa refinery, two large oil products storage facilities (CLH and DECAL) and import plant and an LNG regasification plant (ENAGAS) in addition to an important number of chemical companies present. Regarding passenger and road cargo, it has frequent calls with regular lines coming from the Canary Islands.

The rest of the ports included in this cluster mostly hosts road and passenger cargo heading to north of Africa and Canary Islands and is trying capture cruise traffic, specially to Malaga and Cadiz.

4.4.1.2 Traditional marine fuel bunkering

First on tonnes handled ranking, Algeciras port is also the main bunkering port in Spain serving 2.800.000 t last year. Within this cluster also Ceuta with 570.000 t and Huelva with 126.000 t are key bunkering ports. Adding Gibraltar market -placed next to Algeciras port- this area is the second biggest market for conventional bunkering.

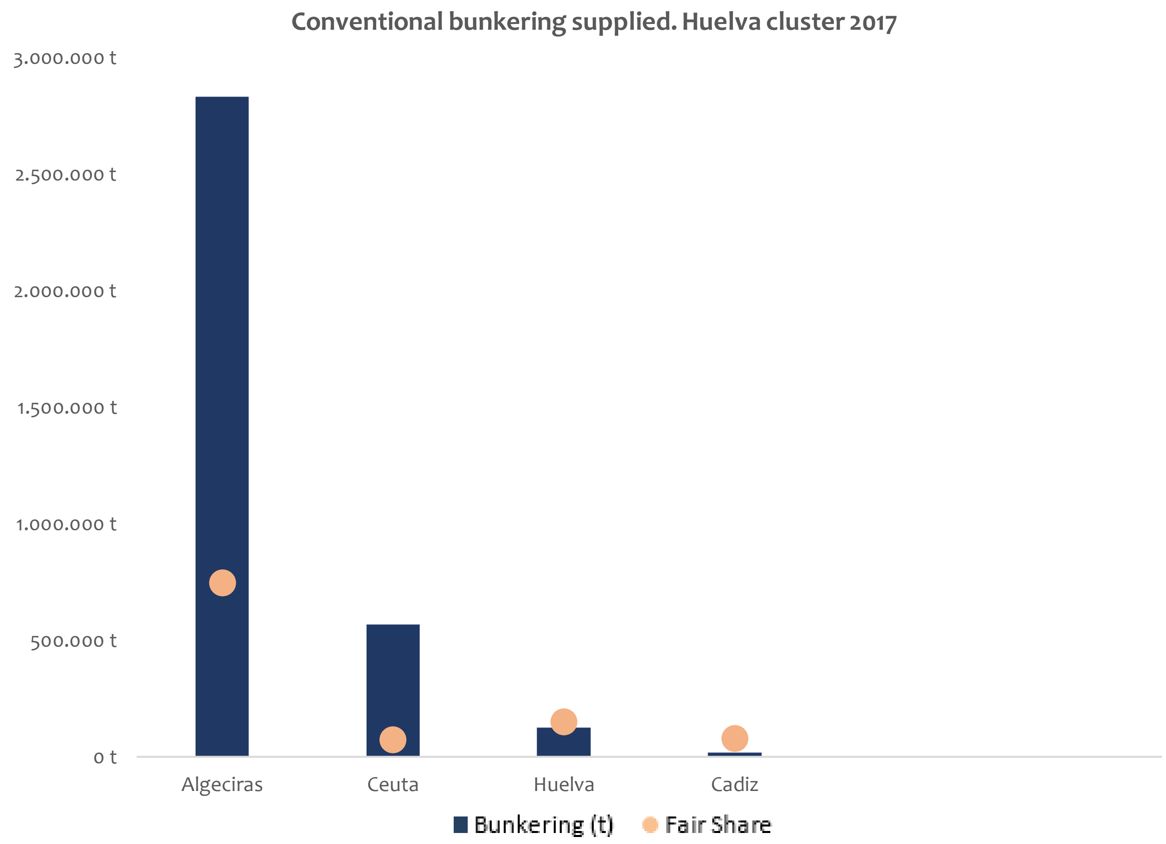


Figure 4.18 Conventional bunkering supplied in the cluster of Huelva

The large anchoring area in addition to the intense marine traffic in the Gibraltar Strait has facilitated the development of a completive fuel supply market. As can be seen in the previous graphic, the volume supplied is considerably higher than expected based on the number of calls in those ports. A good example of this is the port of Ceuta which despite registering a smaller traffic, hosts many smaller ships for provisioning services. This orientation to smaller ship traffic is due to the best adaptation of the port's infrastructure and services to smaller vessels.

Client ships in the port of Algeciras are:

- **Large regular line container ships** performing load and unload operations in the port.
- **Bulk ships and tankers** operating in the spot market and anchored in Algeciras bay for provisioning, reparations or just waiting for a new destination.

The next table shows the different companies and supply types available for each port within this cluster.

Table 4.9 Bunkering means in the cluster of Huelva

Puerto		Marine suppliers		Ex-Pipe suppliers
Algeciras	✓	CEPSA, AEGEAN, ORYX ENERGIES, Peninsula Petroleum, REPSOL, VEMAOIL	✓	Vopak, CLH
Cádiz	✓	Peninsula Petroleum		
Ceuta	✓	Peninsula Petroleum, vilma oil	✓	vilma oil
Huelva	✓	CEPSA	✓	decal, CEPSA
Málaga	✓	Peninsula Petroleum		
Melilla				

Supply operations in ports of Cadiz and Malaga are carried out on-demand, by ships based in the port of Algeciras.

Table 4.10 Available marine bunkering means

Barge	Base Port	Capacity	Supplier	Delivery year	Comments
Bahía Uno	Algeciras/Gibraltar	3.700 t	REPSOL	2004	
Green Cádiz	Algeciras/Gibraltar	3.010 t	CEPSA	2017	
-Monte Anaga	Algeciras/Gibraltar	4.330 t	CEPSA	2010	
Spabunker 50	Algeciras/Gibraltar	5.200 t	CEPSA	2007	
Spabunker 51	Algeciras/Gibraltar	5.200 t	CEPSA	2008	
Hércules 100	Algeciras/Gibraltar	3.560t	Peninsula Petroleum	2008	Under request bunkering in Malaga Port
Gibunker 100	Algeciras/Gibraltar	7.510 t	Peninsula Petroleum	2007	
Spabunker 60	Algeciras/Gibraltar	2.540 t	CEPSA	2008	
Vemaoil XXV	Algeciras/Gibraltar	5.200 t	VEMAOIL	1993	
Nysiros	Algeciras/Gibraltar	6.300 t	AEGEAN	2010	
Paxoi	Algeciras/Gibraltar	6.310 t	AEGEAN	2009	
Petromar	Ceuta	3.200 t	vilma oil	2015	
Oizmendi	Huelva	3.100t + 650m3 LNG	CEPSA		LNG Bunkering

4.4.1.3 LNG bunkering development milestones.

Since the LNG import terminal for this cluster is in the port of Huelva, it has hosted most of the initiatives:

- Oizmendi's multi-product barge in service.
- Project for the construction of a new dock, aimed to the small-scale service in Huelva's terminal
- 4 TTS supply in the port of Algeciras.

4.4.2 Potential supply chain analysis

This area is expected to keep being a reference on the supply market even if the product swifts to LNG, if the service keeps its same level of quality and competitiveness. Demand is expected to grow progressively without any abrupt increments and being affected by the inclusion of further LNG motorization in larger container ships, which constitutes most of the traffic registered in the port of Algeciras.

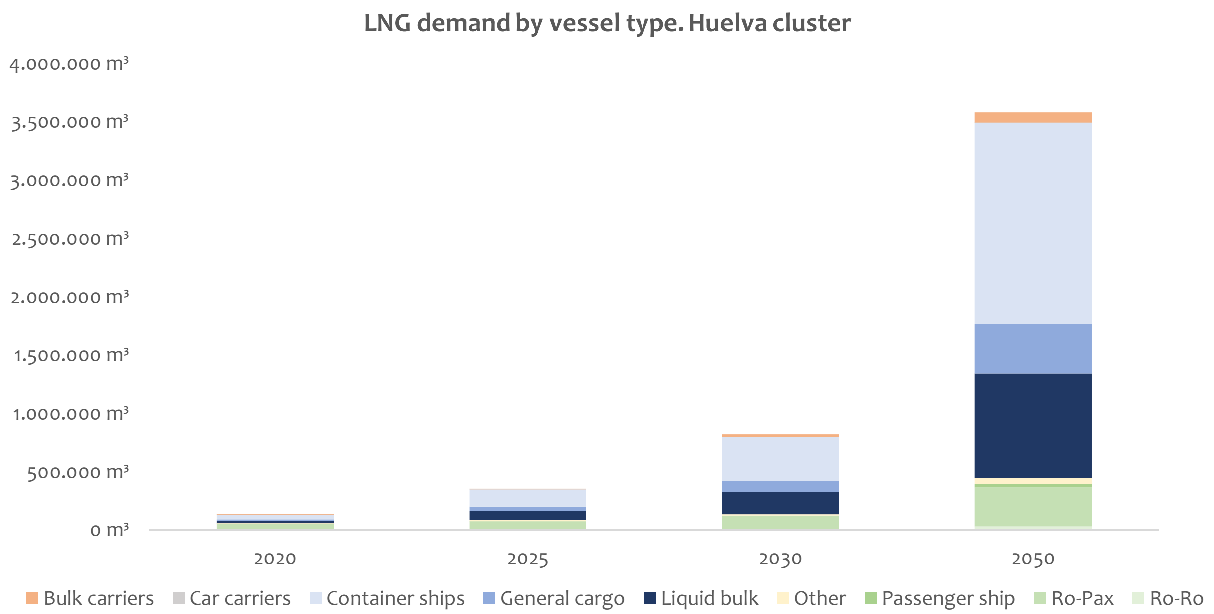


Figure 4.19 LNG demand by vessel type. Huelva cluster

Table 4.11 LNG demand by port in Huelva cluster and Base scenario

	2020	2025	2030	2050
Algeciras	65.466 m³	240.804 m³	598.350 m³	2.735.890 m³
Ceuta	14.313 m³	55.440 m³	140.349 m³	641.729 m³
Huelva	46.122 m³	51.870 m³	64.479 m³	139.225 m³
Malaga	520 m³	2.301 m³	6.208 m³	29.369 m³
Seville	307 m³	1.356 m³	3.659 m³	17.311 m³
Cadiz	268 m³	1.184 m³	3.196 m³	15.118 m³
Melilla	3 m³	14 m³	34 m³	157 m³
Total	307 m³	1.356 m³	3.659 m³	17.311 m³

4.4.2.1 *Logistic models to be implemented*

Huelva Cluster is comprised by 7 ports with different demand levels and scenarios:

- High demand consolidation in two ports: 2 ports close to each other but not connected by road – Algeciras and Ceuta – gather more than 90% of the demand, with Algeciras hosting between 70% and 80% of the total demand.
- Import terminal located 120 nm away.
- Higher service availability level required in ports with higher demand
- Geographical spread of ports with smaller demand.

La dispersión geográfica de los puertos, y la lejanía de la terminal de importación con los grandes puntos de demanda, son factores clave a la hora de plantearse la asignación de medios marítimos, ya que mantener la posición de liderazgo en el mercado de bunkering requerirá asegurar unos altos niveles de servicio.

Geographic spread and remoteness of import terminals to demand areas, are key factors to determine the correct marine resources allocation. Keeping a leadership position in the bunkering market will requires higher levels of service.

The following logistic models were developed:

- **Solution without dedicated storage (Logistic Model 1)**: Offering a high level of service with shared supply resources and a supply terminal farther than 100 nm can be difficult. If the number of units assigned to the port of Algeciras is increased, this will facilitate procurement and supply to other ports within the cluster without neglecting service in the port of Algeciras, at a competitive cost. This solution could be feasible during the first years of operations, recommending a change to Logistic Model 2 if required by higher demand levels.
- **Solution with dedicated storage in Algeciras (Logistic Model 2):** If an auxiliary storage plant is built in the port Algeciras, supply vessels would have a procurement source next to their area of activity. The construction of such a plant will require a transportation ship (feeder) from the import plant to the auxiliary plant, whit the consequent increase in costs.

Solutions without storage terminals are, in general, cheaper for the same level of service but they present other challenges associate with procurement outside the Base Port such as, difficult navigability due to inclement weather conditions or overcrowding in accesses or docks. A solution with a dedicated storage terminal has the main disadvantage of the low availability of transport vessels due to the incipient small-scale LNG market in the Iberian Peninsula.

All 15-analysis showed in Figure 4.20 and Figures 4.21 and 4.22 shows different cost estimations for the different solutions proposed, noting the following.

- Unitary cost stability around **2,20 €/MWh** above 800,000 m^3 for Logistic Model 1 and a level of service of 130%
- Total unitary cost for Logistic Model 2 between **4 €/MWh and 3 €/MWh** for a demand range between 1,000,000 m^3 and a level of service of 200%
- TTS supply cost is high compared to other clusters – between 5€/MWh and 4 €/MWh, due to the high demand of small services expected in Ceuta, where LNG tanks need to arrive by sea since they are in the African continent.

According to the same train of thought follow in the Barcelona cluster, a port pretending to keep its leadership in the bunkering market needs to be able to keep a full-service availability. The solutions chosen for this cluster seek to achieve a level of service above 100% in the port of Algeciras at the lowest possible cost. Despite not being the cheapest solution, a dedicated storage terminal is planned for 2050 mostly fostered by the operative impact in Huelva's import terminal and not by a cost reason. With high demand and logistic model 1, the number of calls in the terminal could cause blockage in these facilities.

The chosen solution for this cluster is the following:

- **Year 2020:** 3000 m^3 ship based on port of Algeciras **(Solution 1A)**
- **Year 2025:** 2 3,000 m^3 ship based on Puerto de Algeciras **(Solution 3A)**
- **Year 2030:** 2 3,000 m^3 ships based on Port of Algeciras. **(Solution 5A)**
- **Year 2050:** 1 30,000 m^3 storage terminal and 3 5,000 m^3 ships based on Port of Algeciras **(Solution 8B)**

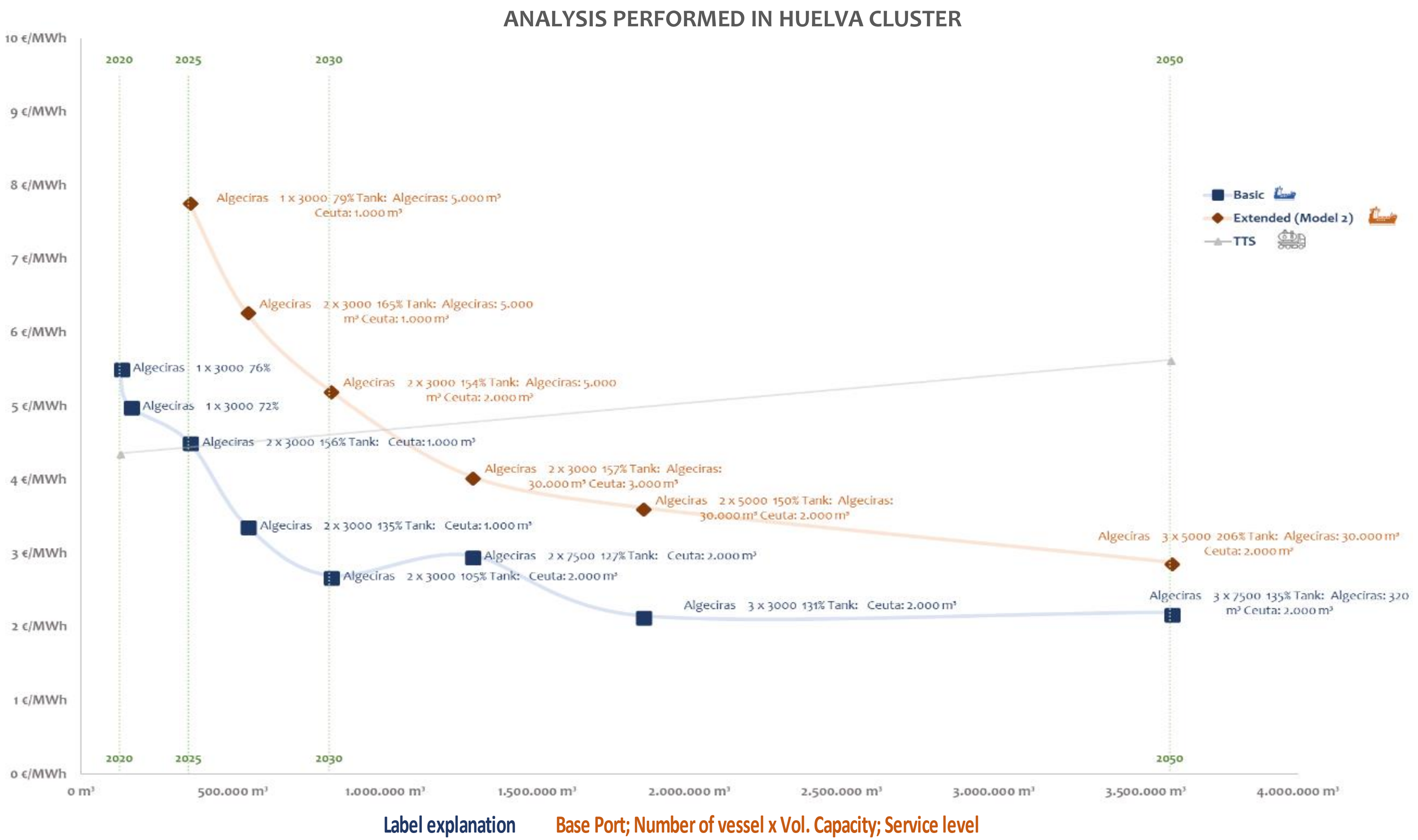


Figure 4.20 Supply chains analyzed in the cluster of Huelva

Figure 4.21 Cost summary for analysis performed in the cluster of Huelva

	Solución 1A	Solución 2A	Solución 3A	Solución 4A	Solución 5A	Solución 6A	Solución 7A	Solución 8A
Cluster	HUELVA	HUELVA	HUELVA	HUELVA	HUELVA	HUELVA	HUELVA	HUELVA
Method	HIVE	HIVE	HIVE	HIVE	HIVE	HIVE	HIVE	HIVE
Scenario	BASIC	HIGH	BASIC	HIGH	BASIC	HIGH	LOW	BASIC
Year	2020	2020	2025	2025	2030	2030	2050	2050
ID analysis	HUE2020	HUE2020H	HUE2025	HUE2025H	HUE2030	HUE2030H	HUE2050L	HUE2050
Demand	126.995 m³	159.015 m³	352.956 m³	541.680 m³	816.240 m³	1.281.018 m³	1.842.161 m³	3.578.642 m³
Services STS	173	337	639	1.118	1.592	2.643	3.800	7.291
Services TTS	167	278	535	882	1.284	2.084	2.994	5.776
Unit cost	5,53 €/MWh	5,01 €/MWh	4,52 €/MWh	3,38 €/MWh	2,70 €/MWh	2,97 €/MWh	2,15 €/MWh	2,19 €/MWh
SERVICE COST	€1.141.072	€1.666.356	€1.515.706	€2.226.126	€2.942.076	€6.695.913	€6.300.233	€16.350.614
RELOAD COST	€1.433.241	€1.769.501	€3.413.919	€5.228.510	€7.893.520	€12.399.079	€16.869.675	€33.352.643
FEEDERING	€0	€0	€0	€0	€0	€0	€0	€0
AUX. TERMINAL	€0	€0	€1.537.458	€1.537.458	€1.810.208	€1.810.208	€1.810.208	€3.103.683
INACTIVITY COST	€2.188.517	€1.966.843	€4.358.753	€3.452.066	€2.294.967	€4.920.107	€1.891.195	€496.765
Total cost	4.762.830	5.402.701	10.825.836	12.444.160	14.940.772	25.825.307	26.871.311	53.303.705
Total investment	20.000.000	20.000.000	52.120.777	52.120.777	56.681.166	106.681.166	76.681.166	173.081.156
Income fee for IT	€835.329	€1.051.130	€2.283.472	€3.501.197	€5.283.724	€9.546.967	€11.902.693	€26.561.190
Cost impact	0,97 €/MWh	0,97 €/MWh	0,95 €/MWh	0,95 €/MWh	0,95 €/MWh	1,10 €/MWh	0,95 €/MWh	1,09 €/MWh
Cost impact %	18%	19%	21%	28%	35%	37%	44%	50%
Vessel slots	40	48	114	174	263	165	590	469
Truck slots	193	376	262	447	651	1087	1607	1385
Vessel Terminal usage days	13	16	66	101	153	89	491	351
Truck Terminal usage days	10	19	13	22	33	54	80	69
Vessels								
Port, no., size, service BP1	Algeciras 1 x 3000 76%	Algeciras 1 x 3000 72%	Algeciras 2 x 3000 156%	Algeciras 2 x 3000 135%	Algeciras 2 x 3000 105%	Algeciras 2 x 7500 127%	Algeciras 3 x 3000 131%	Algeciras 3 x 7500 135%
BP2								
BP3								
BP4								
Terminals								
Port, size			Ceuta: 1.000 m³	Ceuta: 1.000 m³	Ceuta: 2.000 m³	Ceuta: 2.000 m³	Ceuta: 2.000 m³	Algeciras: 320 m³ Ceuta: 2.000 m³
Feeders								

Figure 4.22 Cost summary for analysis performed in the cluster of Huelva

	Solución 1B	Solución 2B	Solución 3B	Solución 4B	Solución 5B	Solución 6B	Solución 7B	Solución 8B	Solución 1T	Solución 2T
Cluster	HUELVA	HUELVA	HUELVA	HUELVA	HUELVA	HUELVA	HUELVA	HUELVA	HUELVA	HUELVA
Method	HIVE	HIVE	HIVE	HIVE	HIVE	HIVE	HIVE	HIVE	HIVE	HIVE
Scenario	BASIC	HIGH	BASIC	HIGH	BASIC	HIGH	LOW	BASIC	BASIC	BASIC
Year	2020	2020	2025	2025	2030	2030	2050	2050	2020	2050
ID analysis	HUE2020*	HUE2020H*	HUE2025M2	HUE2025HM2	HUE2030M2	HUE2030HM2	HUE2050LM2	HUE2050M2	HUE2020TTS	HUE2050TTS
Demand	**126.995 m^3**	**159.015 m^3**	**352.956 m^3**	**541.680 m^3**	**816.240 m^3**	**1.281.018 m^3**	**1.842.161 m^3**	**3.578.642 m^3**	**126.995 m^3**	**3.578.642 m^3**
Services STS	173	337	639	1.118	1.592	2.643	3.800	7.291	173	7.291
Services TTS	167	278	535	882	1.284	2.084	2.994	5.819	0	0
Unit cost	**9,17 €/MWh**	**7,93 €/MWh**	**7,78 €/MWh**	**6,29 €/MWh**	**5,22 €/MWh**	**4,05 €/MWh**	**3,62 €/MWh**	**2,76 €/MWh**	**4,35 €/MWh**	**5,63 €/MWh**
SERVICE COST	€1.473.088	€2.125.735	€1.730.657	€2.606.014	€3.046.418	€4.640.017	€6.795.973	€12.051.586	€2.777.752	€109.281.232
RELOAD COST	€1.372.312	€1.680.741	€851.857	€856.287	€1.454.118	€1.016.766	€1.443.270	€2.678.821	€974.110	€27.449.756
FEEDERING	€0	€0	€4.084.098	€7.164.658	€10.183.883	€13.547.326	€19.422.563	€37.675.050	€0	€0
AUX. TERMINAL	€0	€0	€7.100.667	€7.100.667	€7.646.168	€11.311.154	€10.758.789	€8.034.175	€0	€0
INACTIVITY COST	€5.061.758	€4.755.490	€4.879.727	€5.399.318	€6.584.294	€4.679.919	€6.853.362	€6.699.629	€0	€0
Total cost	7.907.158	8.561.966	18.647.007	23.126.945	28.914.881	35.195.181	45.273.957	67.139.261	3.751.862	136.730.988
Total investment	45.000.000	45.000.000	93.632.460	103.154.460	118.192.849	139.137.401	162.577.013	170.577.013	0	0
Income fee for IT	**€955.329**	**€1.184.003**	**€2.224.602**	**€3.460.798**	**€5.113.512**	**€10.115.908**	**€14.432.229**	**€27.977.708**	**€916.648**	**€24.990.140**
Cost impact	1,11 €/MWh	1,10 €/MWh	0,93 €/MWh	0,94 €/MWh	0,92 €/MWh	1,16 €/MWh	1,15 €/MWh	1,15 €/MWh	1,06 €/MWh	1,03 €/MWh
Cost impact %	12%	14%	12%	15%	18%	29%	32%	40%	24%	18%
Vessel slots	16	19	18	21	22	27	17	45	0	0
Truck slots	193	376	110	197	295	496	759	735	2716	74045
Vessel Terminal usage days	5	6	6	4	7	7	5	15	0	0
Truck Terminal usage days	10	19	6	10	15	25	38	37	136	3.702
Vessels										
Port, no., size, service BP1	Algeciras 1 x 7500 88%	Algeciras 1 x 7500 86%	Huelva 1 x 3000 96%	Huelva 1 x 600 97%	Huelva 1 x 3000 95%	Huelva 1 x 1200 95%	Huelva 1 x 3000 96%	Huelva 1 x 3000 92%		
BP2			Algeciras 1 x 3000 79%	Algeciras 2 x 3000 165%	Algeciras 2 x 3000 154%	Algeciras 2 x 3000 157%	Algeciras 2 x 5000 150%	Algeciras 3 x 5000 206%		
BP3										
BP4										
Terminals										
Port, size			Algeciras: 5.000 m^3 Ceuta: 1.000 m^3	Algeciras: 5.000 m^3 Ceuta: 1.000 m^3	Algeciras: 5.000 m^3 Ceuta: 2.000 m^3	Algeciras: 30.000 m^3 Ceuta: 3.000 m^3	Algeciras: 30.000 m^3 Ceuta: 2.000 m^3	Algeciras: 30.000 m^3 Ceuta: 2.000 m^3		
Feeders										
			Vessel 5000 m^3 freq. 5 d.	Vessel 5000 m^3 freq. 3 d.	Vessel 5000 m^3 freq. 2 d.	Vessel 30000 m^3 freq. 7 d.	Vessel 30000 m^3 freq. 5 d.	Vessel 30000 m^3 freq. 3 d.		

4.4.3 Analysis of potential supply chains considering Algeciras Bay area of influence (Port of Gibraltar and Tanger-Med)

Attending to current fuel supply market situation, marine supply resources located in the Bay of Algeciras are not only operating in this area. Are also supply Tanger-Med and Ceuta ports. Along with this, the proximity to port of Gibraltar, the fuel storage facilities in Algeciras are used by operators from the port of Gibraltar.

Aiming to provide a more thoughtful analysis on the feasible supply chains, closer to an operational reality for the Huelva cluster and quantifying the potential effects of this additional LNG demand – Tanger-Med and Gibraltar – an additional analysis was carried out including the following:

- **Calculation and characterization of LNG demand in port of Gibraltar and por of Tanger-Med:** Gibraltar's traffic is mostly focus on fuel supply and most of the calls are in the anchoring zones assigned to Gibraltar. These operations are normally carried out by tankers, bulk carriers and medium/large non-containerized general cargo ships. On the other hand, Tanger-Med stands out for its abundant container traffic (Approximately 65% of Algeciras's traffic) and is estimated that marine fuels demand will follow container traffic demand. Estimation of demand for these ports is summarized in the demand report consolidated for project HIVE carried out by DNV-GL consulting company.

kton LNG	2020	2025	2030	2050
Gibraltar	17	70	190	880
Tanger	10	40	105	495

- **LNG supply for a new 5,000 m^3 storage terminal in the port of Gibraltar, associated to a new electric power plant.** Assuming a permanent operation of 37,5% of the total power installed (80MW) the estimated consumption will be 37,000 m^3.
- **Variation to the unitary volumes considered for the cluster:** Supply to the new storage terminal in Gibraltar plus the expected arrival of big container ships by 2025 will affect the characterization of unitary values, thus, the characterization showed in Table 3.3 has been modified as well as the total served demand ratios by type in the different ports of the cluster, resulting in the unitary volumes shown below:

Table 4.12 Modified unit bunkering volume characterization for Huelva cluster

Unit volume
TTS (44 m^3)
250 m^3
500 m^3
1.500 m^3
5.000 m^3

- **Update of expected demand for container ships in the port of Algeciras:** Throughout 2018, has become clear that big shipping companies specialized in container ships are interested in LNG propulsion. The construction of new large LNG powered ships will be carried out in series. If these new ships are assigned to routes operating in the Gibraltar Strait, a higher demand will be generated in the 2025 – 2030 period than the demand previously estimated in this study. These new assumptions won't modify the estimations for the 2020 or 2050 period.

The analysis of a qualified demand entirely focused in the large container ship market during 2018 will provide a better understanding about how this type of demand will develop.

To know how previous demand scenarios have been modified, these two tables have been created:

Table 4.13 Estimated HIVE LNG bunkering demand for containerships

Demand (m^3)	2020	2025	2030	2050
Algeciras	38.176	147.869	374.333	1.711.597
Ceuta	152	589	1.490	6.815
Málaga	33	146	395	1.869
Cádiz	18	81	217	1.028
Motril	2	8	21	99
Huelva	0	1	2	8
Total general	**38.416**	**148.847**	**376.874**	**1.723.380**

Table 4.14 Estimated NEW LNG bunkering demand for containerships

Demand (m^3)	2020	2025	2030	2050
Algeciras	38.176	**403.703**	**626.669**	1.711.597
Tanger-Med	**22.222**	**242.664**	**390.618**	**1.099.989**
Ceuta	152	589	1.490	6.815
Málaga	33	146	395	1.869
Cádiz	18	81	217	1.028
Motril	2	8	21	99
Huelva	0	1	2	8
Total general	**60.601**	**647.183**	**1.019.392**	**2.821.305**

With this new scenario considering container ship demand and including Gibraltar's traffic, 3 new scenarios appear:

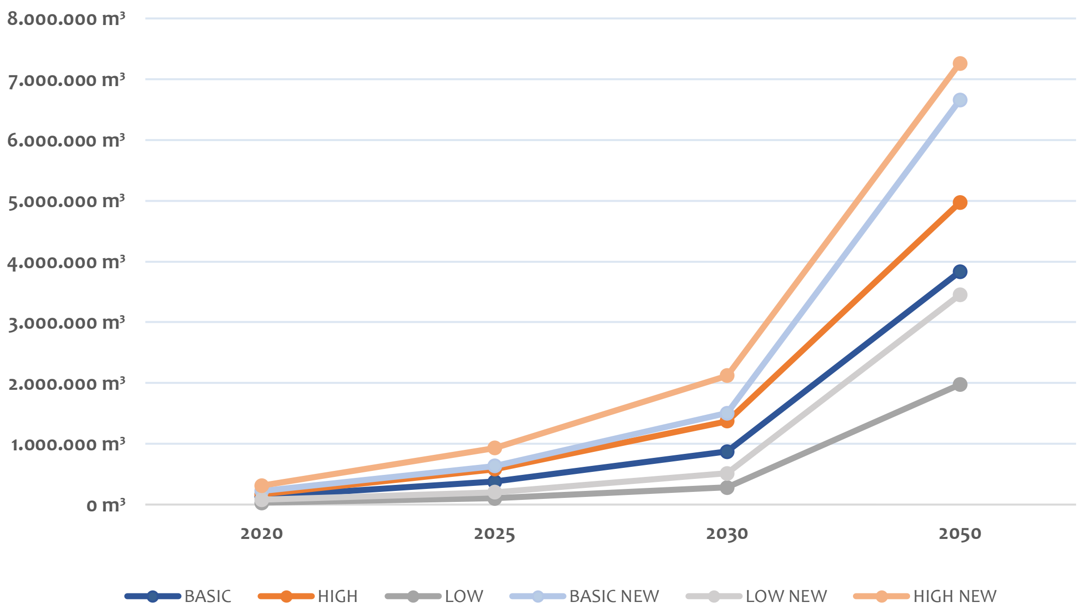


Figure 4.23 NEW LNG demand for modified Huelva cluster

To know further details about the characterization of the demand considered, the attached report "HIVE LNG SC DEMAND EDITOR -Revision 2 (GIB+TAN)" can be reviewed.

4.4.3.1 *Logistic models to be implemented*

Same models applied in chapter 4.4.2 has been applied but only focusing in the 2025 and 2030 period since the biggest deviations respect the previous scenario are observed in this time frame.

The two extra ports included (Tanger-Med and Gibraltar) are included in the Huelva cluster as two client ports, keeping Algeciras a Base Port and placing here an auxiliary storage terminal and logistic model 2.

Due to the higher unitary volumes considered, calculations for logistic model 1 were run with two different ship capacities. 7.500 m^3 (economic optimal) and 10.000 m^3 (Operational upgrade allowing two 5,000 m^3 supply without reloading).

Figure 4.24 Summary of costs for analysis performed considering Algeciras Bay

	Solución 1 A	Solución 2A	Solución 3A	Solución 4A	Solución 1 B	Solución 2B	Solución 3B	Solución 4B
Cluster	HUELVA	HUELVA	HUELVA	HUELVA	HUELVA	HUELVA	HUELVA	HUELVA
Method	HIVE	HIVE	HIVE	HIVE	HIVE	HIVE	HIVE	HIVE
Scenario	BASIC	BASIC	HIGH	HIGH	BASIC	BASIC	HIGH	HIGH
Year	2025	2030	2025	2030	2025	2030	2025	2030
ID analysis	2025/TodosM1	2030/Todos-M1	2025H/TodosM1	2030H/Todos-M1	2025/Todos-M2	2030/Todos-M2	2025H/Todos-M2	2030/Todos-M2/
Demand	1.042.735 m³	1.914.837 m³	2.170.577 m³	3.557.995 m³	1.042.735 m³	1.914.837 m³	2.170.577 m³	3.557.995 m³
Services STS	941	2.411	1.657	4.002	941	2.411	1.657	4.002
Services TTS	871	1.852	1.662	3.232	871	1.852	1.662	3.232
Unit cost	3,72 €/MWh	3,13 €/MWh	2,86 €/MWh	2,29 €/MWh	4,81 €/MWh	3,99 €/MWh	3,67 €/MWh	2,97 €/MWh
SERVICE COST	€4.338.223	€8.059.801	€7.626.429	€13.035.350	€4.002.978	€6.730.133	€6.663.037	€10.955.313
RELOAD COST	€10.061.154	€17.752.978	€20.156.604	€33.017.380	€1.286.224	€1.809.046	€1.766.756	€2.909.755
FEEDERING	€0	€0	€0	€0	€10.928.408	€20.387.846	€23.310.224	€38.467.299
AUX. TERMINAL	€1.582.956	€1.908.539	€1.609.706	€1.940.537	€7.488.674	€8.034.175	€7.488.674	€8.586.540
INACTIVITY COST	€10.346.636	€13.022.020	€12.743.768	€7.305.702	€10.315.432	€14.943.928	€14.840.221	€10.759.918
Total cost	26.328.969	40.743.337	42.136.506	55.298.969	34.021.715	51.905.128	54.068.912	71.678.824
Total investment	122.120.778	171.681.167	167.120.778	171.681.167	156.016.625	209.577.014	205.016.625	214.137.402
Income fee for IT	€7.741.059	€14.197.450	€16.078.019	€26.384.772	€8.289.220	€15.031.200	€17.033.516	€27.986.444
Cost impact	1,09 €/MWh	1,09 €/MWh	1,09 €/MWh	1,09 €/MWh	1,17 €/MWh	1,16 €/MWh	1,16 €/MWh	1,16 €/MWh
Cost impact %	29%	35%	38%	48%	24%	29%	32%	39%
Vessel slots	148	264	297	482	46	25	21	28
Feedering slot	0	0	0	0	41	77	88	145
Truck slots	479	1241	834	2061	14	38	25	57
Vessel Te days	76	187	214	348	11	8	7	9
Feederin days	0	0	0	0	57	35	41	67
Truck Ter days	24	62	42	103	1	2	1	3
Vessels								
Port, no., siz BP1	Algeciras 2 x 7500 140%	Algeciras 3 x 7500 200%	Algeciras 3 x 7500 196%	Algeciras 3 x 7500 129%	Huelva 1 x 1200 91%	Huelva 1 x 3000 90%	Huelva 1 x 3000 92%	Huelva 1 x 3000 93%
BP2					Algeciras 2 x 7500 165%	Algeciras 3 x 7500 232%	Algeciras 3 x 7500 233%	Algeciras 3 x 7500 184%
BP3								
BP4	Huelva 1 x 3000 96%	Huelva 1 x 3000 90%	Huelva 1 x 3000 95%	Huelva 1 x 3000 85%				
Terminals								
Port, size					Algeciras: 30.000 m³	Algeciras: 30.000 m³	Algeciras: 30.000 m³	Algeciras: 30.000 m³
Feeders								
					Vessel 30000 m³ freq. 9 d.	Vessel 30000 m³ freq. 5 d.	Vessel 30000 m³ freq. 4 d.	Vessel 30000 m³ freq. 3 d.

Cluster	HUELVA	HUELVA	HUELVA	HUELVA
Method	HIVE	HIVE	HIVE	HIVE
Scenario	BASIC	BASIC	HIGH	HIGH
Year	2025	2030	2025	2030
ID analysis	2025/TodosM1/Buque10000	2030/Todos-M1/Buques 10000	2025H/TodosM1/Buque 10000	2030H/Todos-M1/Buque 10000
Demand	**1.042.735 m³**	**1.914.837 m³**	**2.170.577 m³**	**3.557.995 m³**
Services STS	941	2.411	1.657	4.002
Services TTS	871	1.852	1.662	3.233
Unit cost	**4,53 €/MWh**	**3,77 €/MWh**	**3,41 €/MWh**	**2,59 €/MWh**
Total cost	32.059.078	49.057.573	50.238.855	62.532.902
Total investment	136.120.777	192.681.166	188.120.777	192.681.166
Income fee for IT	**€7.124.817**	**€13.053.087**	**€14.709.898**	**€24.180.409**
Cost impact	1,01 €/MWh	1,00 €/MWh	1,00 €/MWh	1,00 €/MWh
Cost impact %	22%	27%	29%	39%
Vessel slots	116	205	228	370
Feedering slot	0	0	0	0
Truck slots	479	1241	834	2061
Vessel Terminal usage days	59	143	162	264
Feedering terminal us days	0	0	0	0
Truck Terminal usage days	24	62	42	103
Vessels				
Port, no., size, service BP1	Algeciras 2 x 10000 154%	Algeciras 3 x 10000 221%	Algeciras 3 x 10000 220%	Algeciras 3 x 10000 168%
BP2				
BP3				
BP4	Huelva 1 x 3000 96%	Huelva 1 x 3000 90%	Huelva 1 x 3000 95%	Huelva 1 x 3000 85%
Terminals				
Port, size				
Feeders				

To compare results from logistic models and results obtained from the previous analysis, Figure 4.25 shows the evolution of average unitary costs respect to the total demand to be served in the cluster.

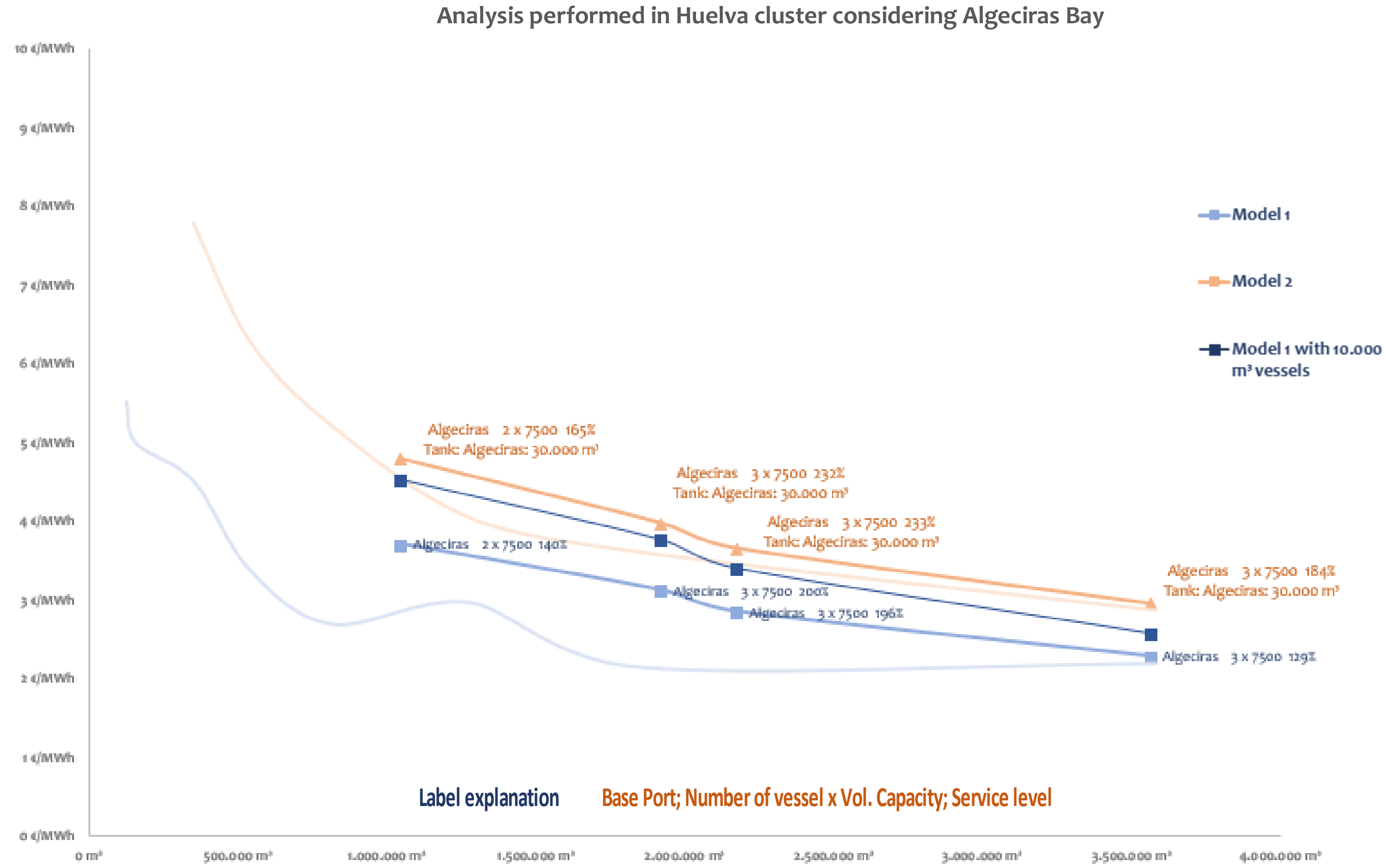
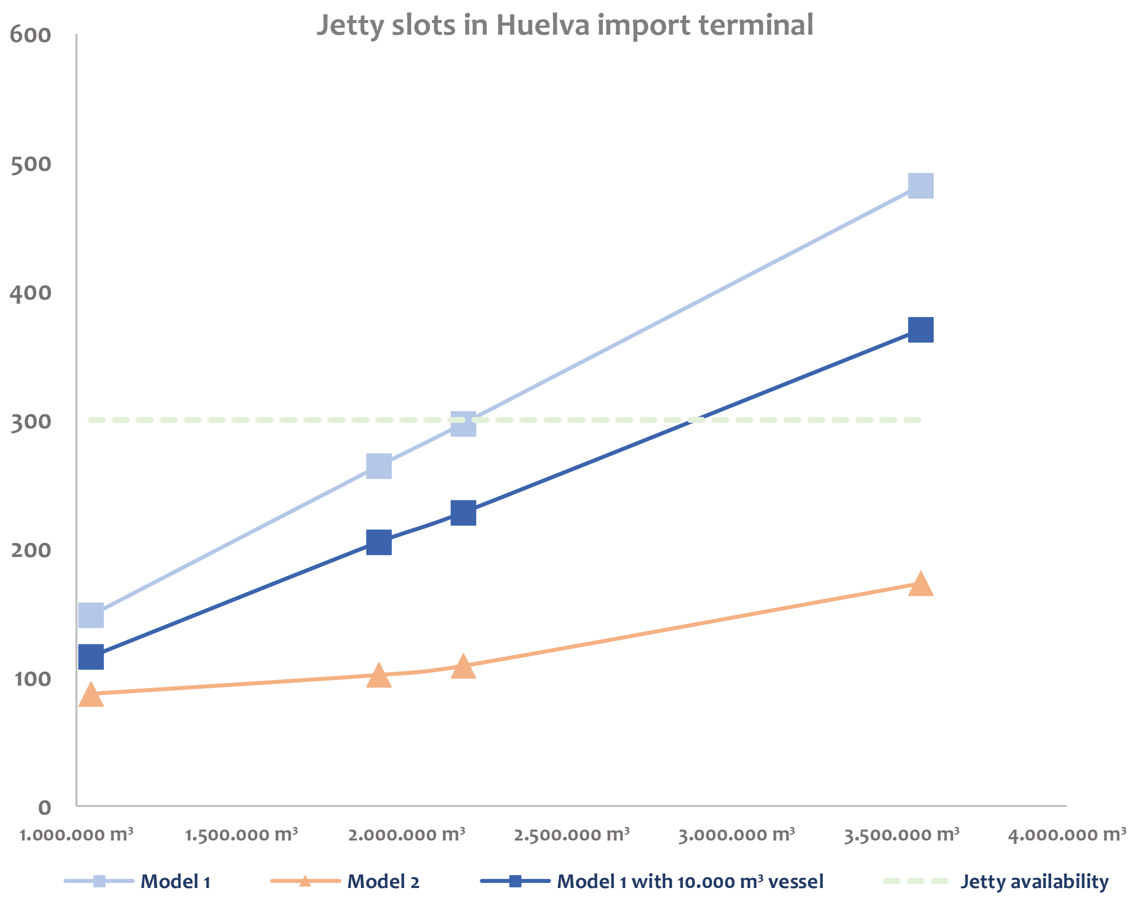


Figure 4.25 Supply chains analyzed in Huelva cluster considering Algeciras Bay

After analyzing the results shown above, including port of Gibraltar (Electric demand + bunkering), port of Tanger-Med and a qualified demand for the addition of large container ships (+15,000 TEU) in the Gibraltar Strait, a few modifications can be observed:

- The addition of higher unitary volumes increases the total cost of service because is necessary to ensure a higher unitary volume, increasing the supply ships capacity. Thus, we see supply chains with 7,500 m³/10,000 m³ ships while previous analysis showed ships in the 3,000 m³/5.000 m³ range. For volumes above 3,000,000 m³ this difference is mitigated thanks to economies of scale.
- The use of 10,000 m³ ships will allow a higher logistic flexibility and will cause a smaller impact in Huelva's import terminal but will also increase supply costs matching costs seen in the storage terminal model.
- Cost difference between model 1 and model 2 is reduced, making the construction of an auxiliary facility in port of Algeciras more attractive, serving every port in the Gibraltar Strait are of influence.
- Not building an auxiliary storage terminal in Algeciras would require the construction of new cargo terminal in the Huelva's import terminal because the number of reloads require in the plant is too high if logistic model 2 solution is not implemented.



4.5 *Sines Cluster*

This cluster is formed by 9 ports:

- Aveiro
- Canical
- Funchal
- Leixoes
- Lisbon
- Ponta delgada
- Portimao
- Setubal
- Sines (Terminal de importación) (Base Port)

4.5.1 Introduction and current market characterization.

4.5.1.1 Port traffic analysis

All these ports belong to Portugal are located in the Atlantic coast. Figure 4.26 represents the number of por calls by type of ship.

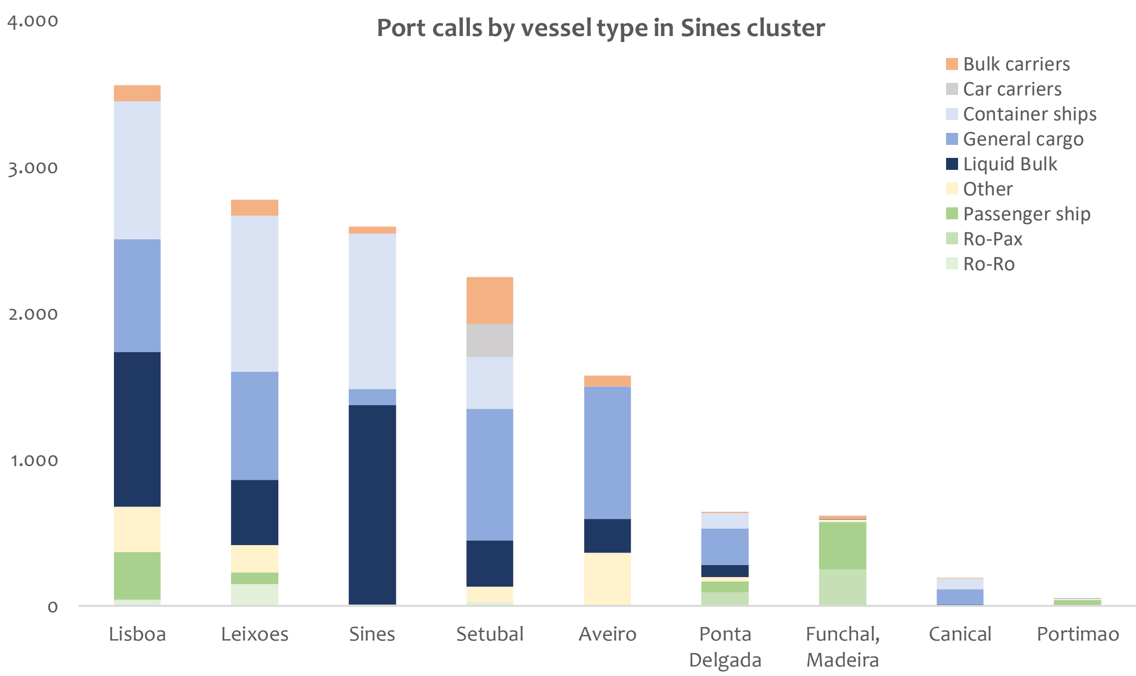


Figure 4.26 Port calls in the cluster of Sines

Since these ports are spread-out all-over Portugal, its traffic is very diverse and in contrast to what happens in Spain, mixed road-passenger cargo traffic is not developed at all, not having any insular connections from the peninsula or any intercontinental ports. Container ship traffic is divided among the three main ports of the network, Lisbon, Leixoes and Sines with Sines standing out as the main port for large container ships, moving more than 1.4 million TEU in 2017 in contrast to the 1.1 mill moved by Setubal and Leixoes together. Sines is also leader in liquid and solid bulk transportation who hosts one of the biggest refineries in the peninsula, additional storage and distribution hub for oil products to the rest of the country, showing a high activity of product ships. Finally, Leixoes, Setubal and Aveiro ports are mostly industrial and present non-containerized and bulk cargo, with Leixoes standing out as leader in general cargo traffic. In addition to this, port of Lisbon hosted 786,000 cruise passengers in 2016.

4.5.1.2 Traditional marine fuel bunkering

Mainly oriented to serve local traffic, none of these ports stands out for its international fuel supply service in contrast to what happens in ports such as Algeciras or Las Palmas, serving Portugal a total of 80,000 t, around 10% of the total volume served in Spain.

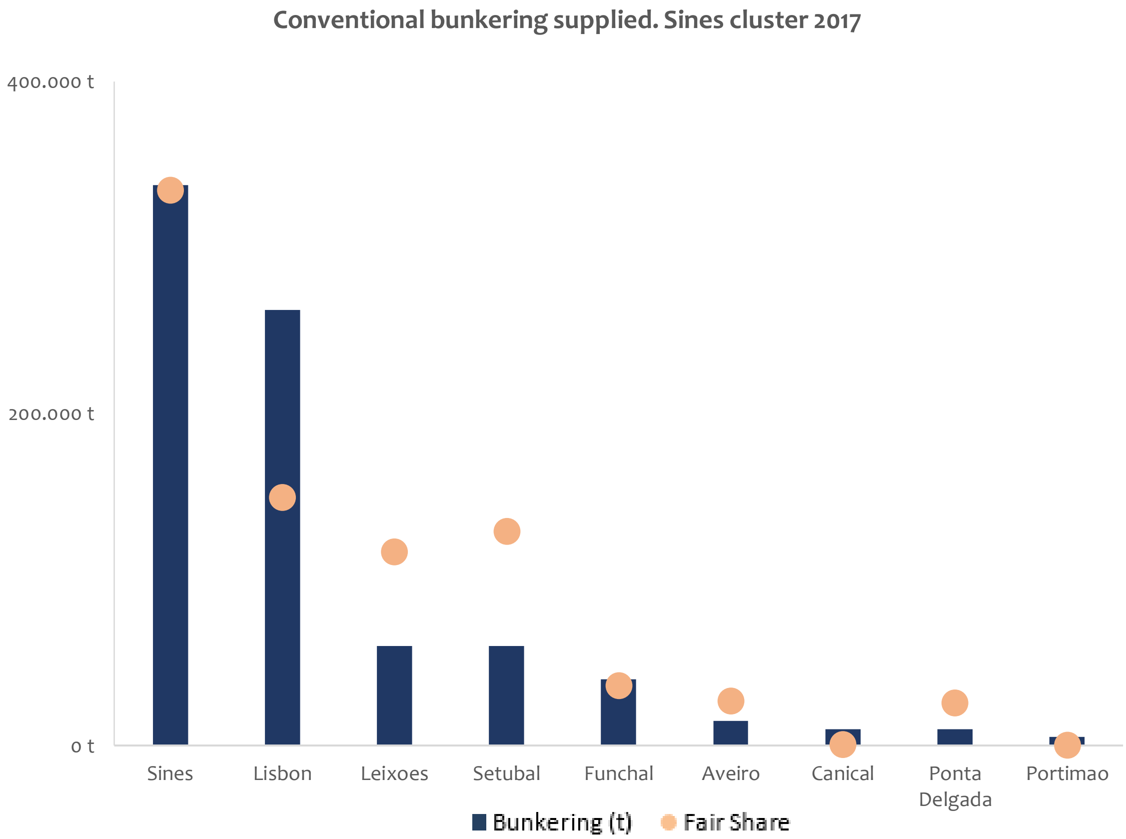


Figure 4.27 Conventional bunkering supplied in the cluster of Sines

Most of the supply resources for this cluster are in the ports of Sines and Lisbon, both having available marine and terrestrial resources. Sines stands out for supplying to most of the large container ships in and Lisbon is more focused on smaller capacity ships operating in the domestic coasting market, cruises and serving a captive market comprised of all ships operating in the Tajo river.

Table 4.15 Bunkering means in the cluster of Sines

Puerto	Marine suppliers		Ex-Pipe suppliers	
Aveiro				
Canical				
Funchal				
Leixoes				
Lisbon	✓	galp	✓	galp
Ponta Delgada				
Sines	✓	galp	✓	galp
Portimao				
Setubal	✓	galp		

Sines cluster has 3 barges operated by the company Galp, presenting some geographical flexibility with two barges permanently based in Lisbon and Sines and a third one between Setubal and Sines.

Table 4.16 Available marine bunkering means

Barge	Base Port	Capacity	Supplier	Delivery year	Comments
Bahía 3	Sines	7.480 t	galp	2007	
Guanarteme	Lisbon/Setubal	4.250 t	galp	2004	
Sacor II	Lisbon	2.500 t	galp	2011	

4.5.1.3 LNG bunkering development milestones.

Within Sines Cluster, is relevant to note an intermodal LNG supply chain with ISOcontainers in the Island of Madeira, which has a 600 m³ satellite LNG storage facility. Takin advantage of this preexisting logistic, in 2017 a TTS bunkering operation was performed to supply ship AIDAperla in the port of Funchal, only operation carried out in Portugal so far.

4.5.1 Potential supply chain analysis

Sines cluster contains every port in the Portuguese port network, including the archipelago of Madeira, located 600 nm away from the Iberian Peninsula and without an LNG import platform, thus, LNG should be supplied from the Sines terminal. This exceptional situation has been analyzed as a particular case and would be detailed in section 4.5.3.

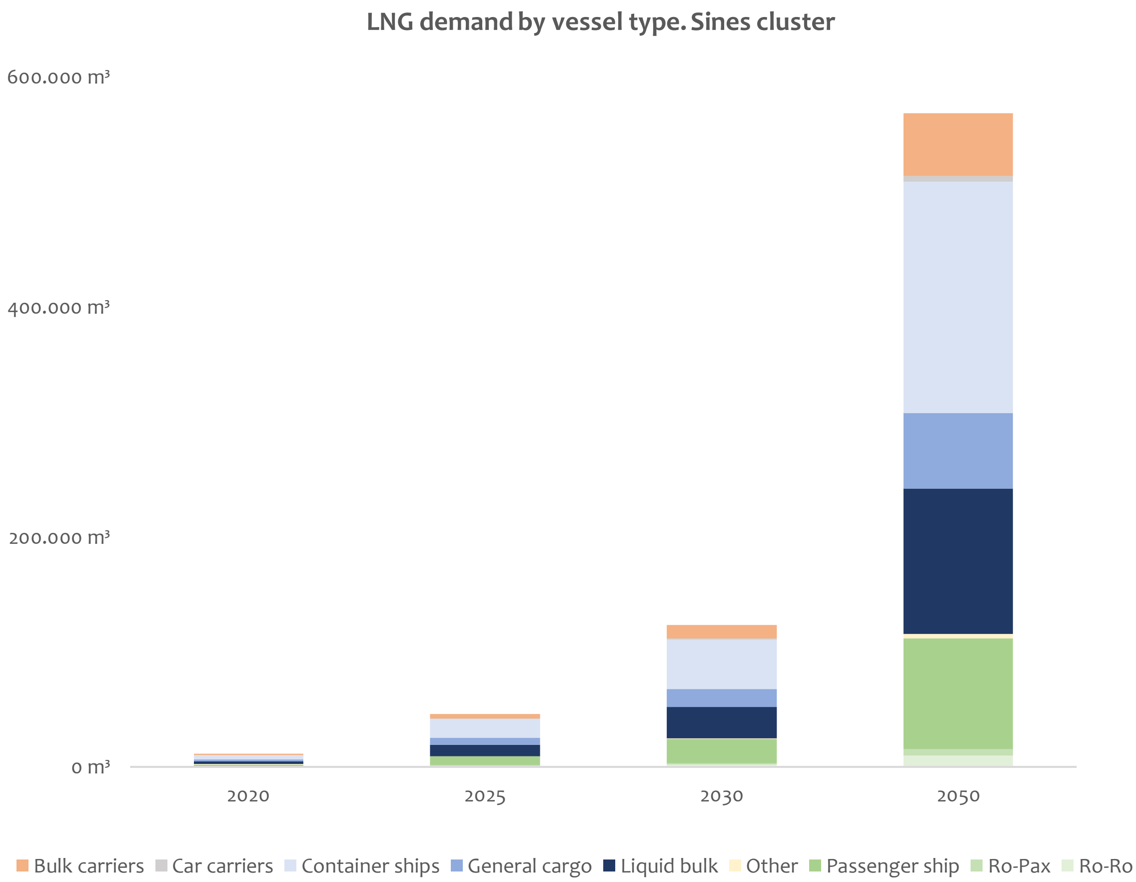


Figure 4.28 LNG demand by vessel type. Sines cluster

Table 4.17 LNG demand by port in Sines cluster and Base scenario

Base scenario	2020	2025	2030	2050
Sines	4.250 m³	17.906 m³	48.855 m³	225.806 m³
Lisbon	3.266 m³	13.951 m³	38.159 m³	176.975 m³
Leixoes	725 m³	3.115 m³	8.556 m³	39.709 m³
Setubal	725 m³	3.115 m³	8.556 m³	39.709 m³
Funchal	860 m³	3.333 m³	8.436 m³	38.574 m³
Ponta Delgada	831 m³	2.861 m³	6.920 m³	30.482 m³
Aveiro	181 m³	779 m³	2.139 m³	9.927 m³
Canical	466 m³	1.071 m³	2.058 m³	7.076 m³
Portimao	0 m³	2 m³	6 m³	26 m³
Total	**11.306 m³**	**46.132 m³**	**123.685 m³**	**568.285 m³**

In contrast to previous scenarios analyzed where demand is not evenly distributed, Sines cluster demand is balanced between its two main ports – Sines and Lisbon – with 80% of the total expected demand and Setubal and Leixoes with 10% each. This will facilitate the allocation of resources and the potential installation of auxiliary terminals.

4.5.1.1 Logistic models to be implemented

Since the demand in this cluster is scattered with 4 different ports to be supplied with one of them located 200 nm away of the import terminal, is interesting to determine in which ports is more economic to stablish a supply fleet and if navigation distances justify the installation of storage terminals.

Despite non-of these ports being a referent in the European bunkering market, the solutions chosen in this study aim to provide a high level of service in addition to supply Setubal and Leixoes ports. On the other side, if LNG demand would develop in a positive way, the long distance between Lisbon and Leixoes would reduce service availability in Lisbon and Leixoes, for this reason the installation of a storage terminal has been studied as well in the port of Leixoes.

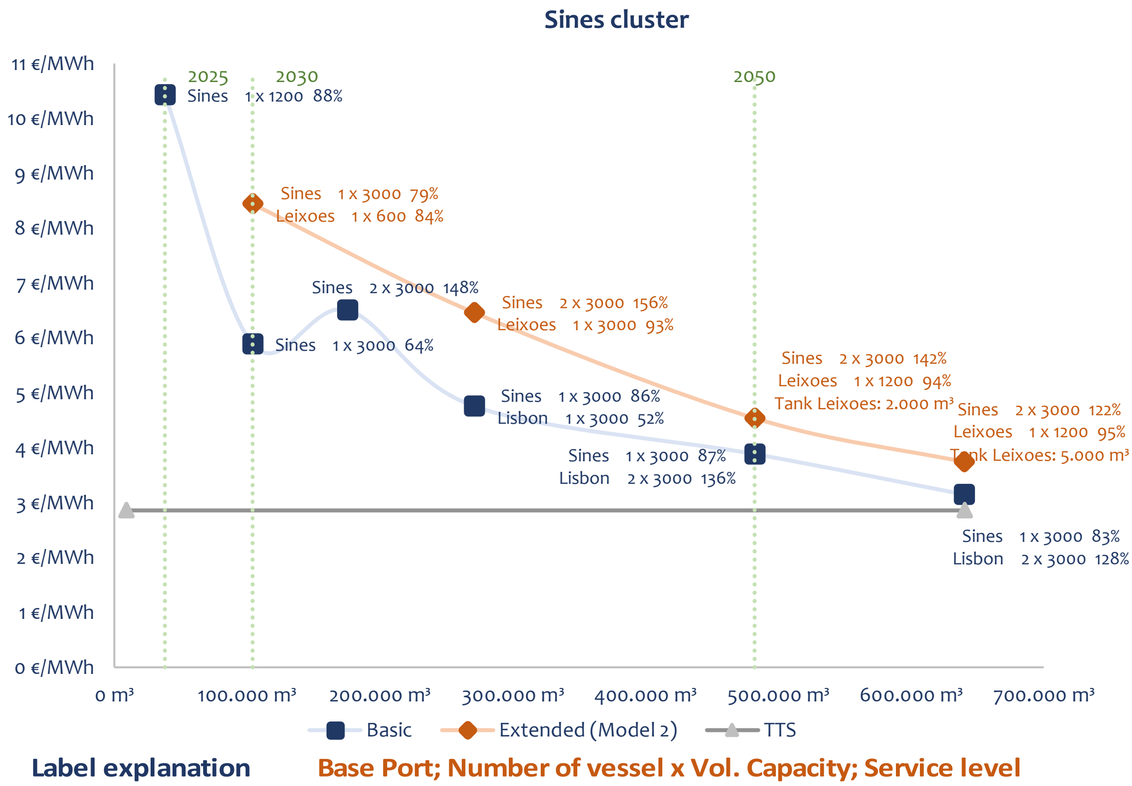


Figure 4.29 Supply chains analyzed in the cluster of Sines[6]

After analyzing 12 different logistic solutions represented in the graph above, is evident that the cheaper solution – blue line – is very similar to the one observed in the traditional fuel market. Based on this, the deployment of marine resources for fuel supply will be feasible above 100,000 m³ with a price starting at **6 €/MWh** higher than the cost estimated for other cluster with less scattered distributions. If total demand would increase above 500,00 m³, costs would go down close to **3 €/MWh.**

With the idea of relieving the fleet from supplying port of Leixoes, the scenario of building an auxiliary terminal in this port was considered. This solution allows to reduce the capacity of the fleet in the other ports and base it only in the port of Sines, which means an increase of 1 €/MWh, increasing the total logistic cost to 4 €/MWh and reducing level of service at port of Lisbon. Since port of Leixoes is not a reference in LNG bunkering market and Lisbon is only 45 nm away from Sines, a basic solution is the most suitable for this cluster.

- **Year 2020:** TTS supply **(Solution 1T)**
- **Year 2025:** 3.000 m³ ship based on port of Sines **(Solution 1A)**
- **Year 2030:** 3.000 m³ ship based on port of Sines **(Solution 2A)**
- **Year 2050: 2** 3.000 m³ based on port of Lisbon and **1** 3.000 m³ ship based on port of Sines **(Solution 5A)**

[6] Does not include Madeira islands

Figure 4.30 Cost summary for analysis performed in the cluster of Sines

		Solución 1A	Solución 2A	Solución 3A	Solución 4A	Solución 5A	Solución 6A
Cluster		**SINES**	**SINES**	**SINES**	**SINES**	**SINES**	**SINES**
Method		**HIVE**	**HIVE**	**HIVE**	**HIVE**	**HIVE**	**HIVE**
Scenario		**BASIC**	**BASIC**	**HIGH**	**LOW**	**BASIC**	**HIGH**
Year		**2025**	**2030**	**2030**	**2050**	**2050**	**2050**
ID analysis		SIN2025	SIN2030	SIN2030H	SIN2050L	SIN2050	SIN2050H
Demand		**38.087 m³**	**104.125 m³**	**175.661 m³**	**270.984 m³**	**482.200 m³**	**640.233 m³**
Services STS		53	166	280	431	768	1.017
Services TTS		41	109	181	278	496	637
Unit cost		**10,43 €/MWh**	**5,89 €/MWh**	**6,51 €/MWh**	**4,76 €/MWh**	**3,89 €/MWh**	**3,15 €/MWh**
SERVICE COST		€974.178	€1.435.250	€2.033.833	€2.483.212	€3.240.194	€3.635.294
RELOAD COST		€422.139	€856.239	€1.362.844	€2.418.105	€3.320.056	€4.421.792
FEEDERING		€0	€0	€0	€0	€0	€0
AUX. TERMINAL		€0	€0	€0	€0	€0	€0
INACTIVITY COST		€1.300.387	€1.872.108	€4.363.492	€3.848.526	€6.156.866	€5.625.711
Total cost		2.696.704	4.163.597	7.760.169	8.749.842	12.717.116	13.682.797
Total investment		16.000.000	20.000.000	40.000.000	40.000.000	60.000.000	60.000.000
Income fee for IT		**€334.079**	**€691.451**	**€1.139.694**	**€1.769.330**	**€2.362.784**	**€3.141.717**
Cost impact		1,29 €/MWh	0,98 €/MWh	0,96 €/MWh	0,96 €/MWh	0,72 €/MWh	0,72 €/MWh
Cost impact %		12%	17%	15%	20%	19%	23%
Vessel slots		28	34	56	87	114	152
Truck slots		102	109	182	279	497	637
Vessel Terminal usage	**days**	7	11	33	29	48	64
Truck Terminal usage	**days**	5	5	9	14	25	32
Vessels							
Port, no., size, service	BP1	Sines 1 x 1200 88%	Sines 1 x 3000 64%	Sines 2 x 3000 148%	Sines 1 x 3000 86%	Sines 1 x 3000 87%	Sines 1 x 3000 83%
	BP2						
	BP3						
	BP4				Lisbon 1 x 3000 52%	Lisbon 2 x 3000 136%	Lisbon 2 x 3000 128%
Terminals							
Port, size							
Feeders							

Figure 4.31 Cost summary for analysis performed in the cluster of Sines

	Solución 1B	Solución 2B	Solución 3B	Solución 4B	Solución 1T	Solución 2T
Cluster	SINES	SINES	SINES	SINES	SINES	SINES
Method	HIVE	HIVE	HIVE	HIVE	HIVE	HIVE
Scenario	HIGH	LOW	BASIC	BASIC	BASIC	BASIC
Year	2030	2050	2050	2050	2020	2050
ID analysis	SIN2030*	SIN2050L*	SIN2050*	SIN2050H*	SINES2020TTS	sines2050tts
Demand	**104.125 m³**	**270.984 m³**	**482.200 m³**	**640.233 m³**	**8.967 m³**	**482.200 m³**
Services STS	166	431	768	1.017	0	0
Services TTS	109	278	496	637	10	496
Unit cost	**8,44 €/MWh**	**6,46 €/MWh**	**4,54 €/MWh**	**3,74 €/MWh**	**2,86 €/MWh**	**2,87 €/MWh**
SERVICE COST	€1.407.981	€2.311.688	€3.050.756	€3.777.641	€105.169	€5.689.392
RELOAD COST	€1.185.962	€2.265.503	€3.529.720	€4.626.472	€68.780	€3.698.685
FEEDERING	€0	€0	€1.094.095	€979.253	€0	€0
AUX. TERMINAL	€152.397	€0	€1.810.208	€2.202.236	€0	€0
INACTIVITY COST	€3.219.428	€7.307.478	€5.370.308	€4.669.438	€0	€0
Total cost	5.965.769	11.884.670	14.855.088	16.255.040	173.949	9.388.077
Total investment	29.522.000	60.000.000	72.681.166	73.511.683	0	0
Income fee for IT	**€743.600**	**€1.769.330**	**€3.140.563**	**€4.136.436**	**€65.812**	**€3.532.268**
Cost impact	1,05 €/MWh	0,96 €/MWh	0,96 €/MWh	0,95 €/MWh	1,08 €/MWh	1,08 €/MWh
Cost impact %	12%	15%	21%	25%	38%	38%
Vessel slots	45	87	142	188	0	0
Truck slots	109	279	434	554	195	10466
Vessel Terminal usage days	13	49	82	109	0	0
Truck Terminal usage days	5	14	22	28	10	523
Vessels						
Port, no., size, service BP1	Sines 1 x 3000 79%	Sines 2 x 3000 156%	Sines 2 x 3000 142%	Sines 2 x 3000 122%		
BP2			Leixoes 1 x 1200 94%	Leixoes 1 x 1200 95%		
BP3						
BP4	Leixoes 1 x 600 84%	Leixoes 1 x 3000 93%				
Terminals						
Port, size			Leixoes: 2.000 m³	Leixoes: 5.000 m³		
Feeders						
			Vessel 5000 m³ freq. 15 d.	Vessel 5000 m³ freq. 28 d.		

4.5.2 Archipelago of Madeira

The great distance between this archipelago and the mainland and the lack of an LNG import terminal makes supply from the Sines terminal excessively expensive. Nevertheless, an intermodal supply chain exists serving LNG to a satellite plant which feeds the electric generation plant in Funchal.

Aiming to properly simulate the real conditions in place for the deployment of supply resources in the archipelago, electric generation's expected demand analysis was included.

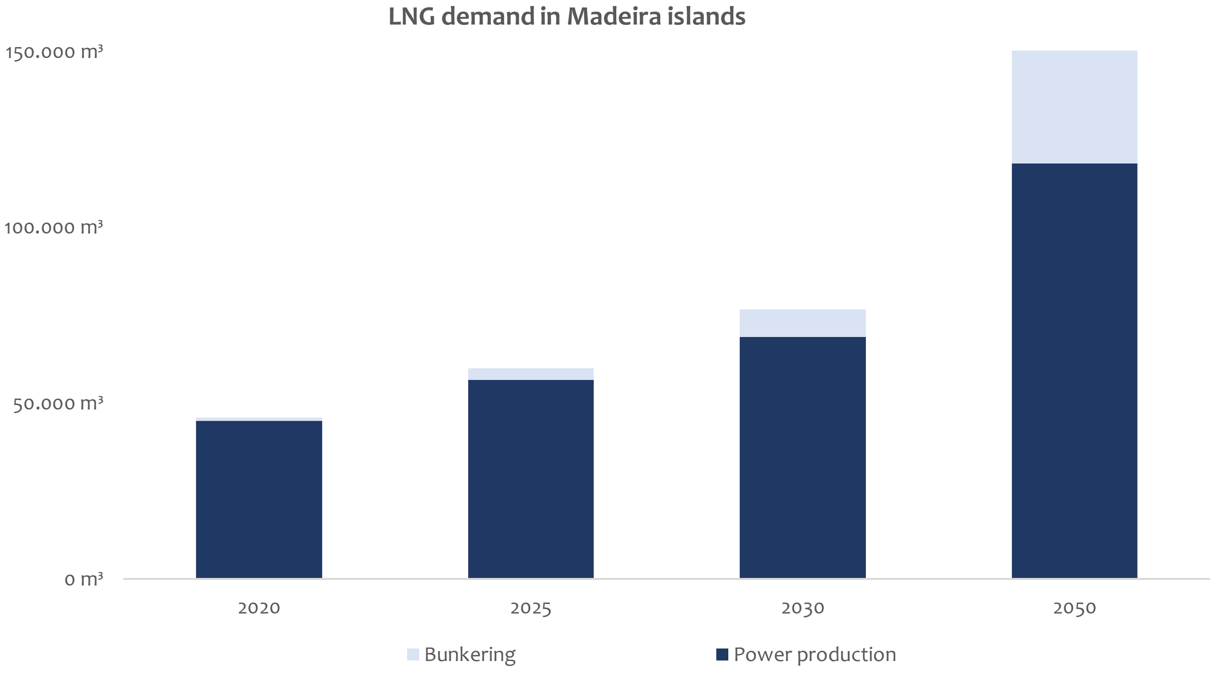


Figure 4.32 Estimated LNG demand in Madeira islands

Due to the low demand expected for bunkering, the solution for the island would entail an auxiliary storage terminal, fed by a feeder vessel based on the peninsula and TTS supply for the rest of the demand.

Table 4.18 Summary of analysis performed for Madeira islands

Year	Demand	Unit cost	Means
2020	45.000 m³	12,53 €/MWh	5.000 m³ Storage terminal + TTS bunkering
2025	60.000 m³	10,83 €/MWh	5.000 m³ Storage terminal + TTS bunkering
2030	77.160 m³	9,51 €/MWh	5.000 m³ Storage terminal + TTS bunkering
2050	156.760 m³	8,80 €/MWh	10.000 m³ Storage terminal + 1.200 m³ multiproduct barge

4.6 *Ferrol Cluster*

This cluster consists of 5 ports:

- A Coruña (Base Port)
- Ferrol (LNG Import terminal)
- Marín y Ría de Pontevedra
- Vigo
- Villagarcía de Arousa

4.6.1 Introduction and current market characterization.

4.6.1.1 Port traffic analysis

Figure 4.33 Shows port call distributions in these 5 Atlantic ports:

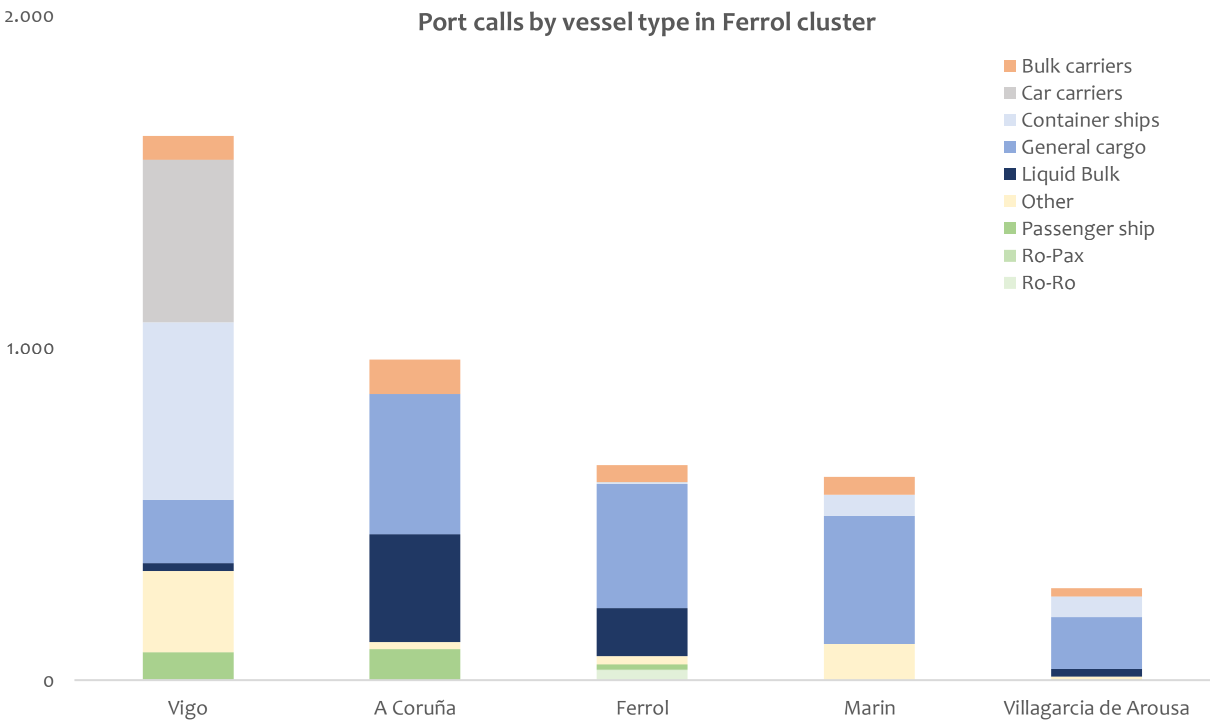


Figure 4.33 Port calls in the cluster of Ferrol

Like the rest of Atlantic ports, Ferrol cluster ports are mostly industrial and focused on solid bulk cargo – charcoal and minerals – and non-containerized cargo except port of Vigo, with a special orientation in container traffic and CarCarrier ships – 4th port in new vehicle traffic – and fishing ships.

Port of A Coruna hosts a refinery, being frequent to see large oil tankers but not as many traffic of oil products as can be registered in other ports hosting refineries such us Huelva, Algeciras or Tarragona.

Galician ports host most of the network's fishing fleet, serving as base ports for both coastal and offshore ships. Vigo and A Coruna ports together register 140,225 t, more than 50% of the Spanish total network.

4.6.1.2 Traditional marine fuel bunkering

Galician ports don't stand out as bunkering ports, since traffic in this area tends to reload in ports located in the north of Europe, supplying only 126,039 t in this cluster.

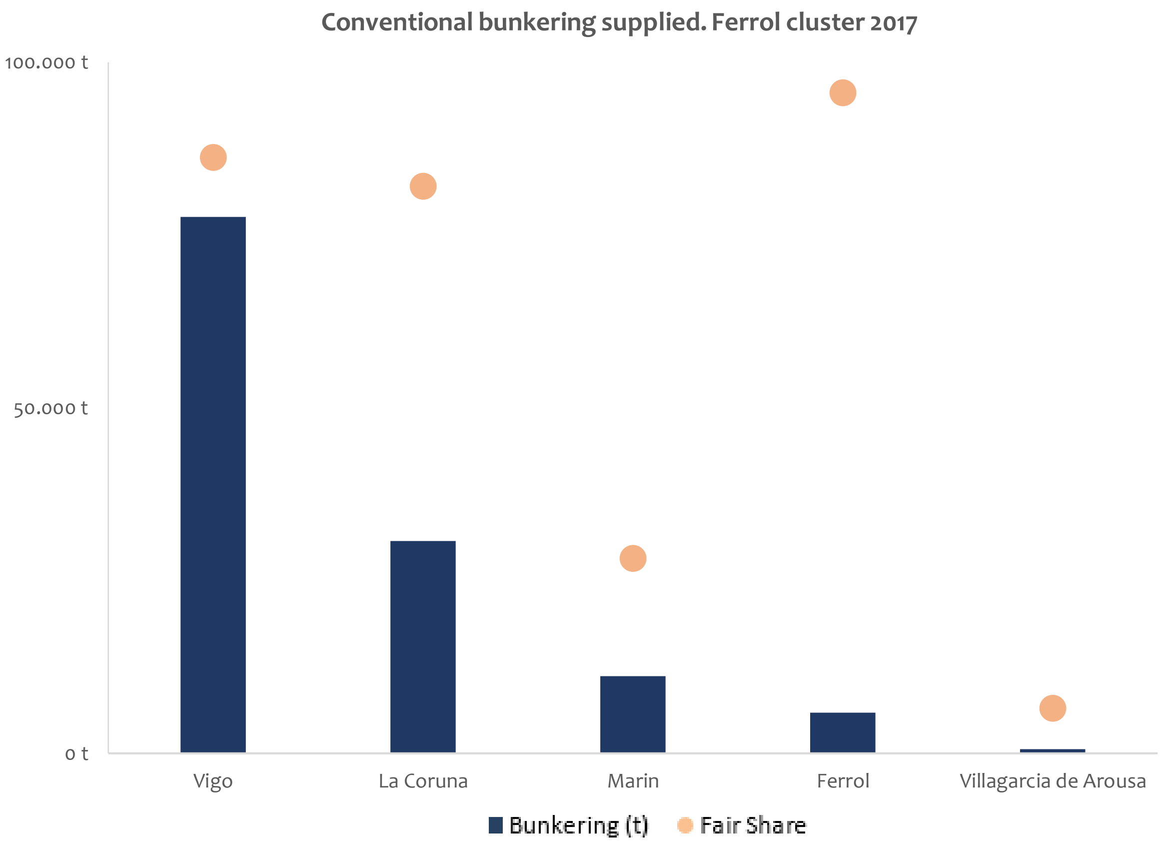


Figure 4.34 Conventional bunkering supplied in the cluster of Ferrol

Among all the ports included in this cluster, and despite not having any additional supply resources besides tank trucks, Vigo is the only port whose supplied amount is close to the amount proportional to its traffic, since this system is demanded by the large fishing fleet present in this port.

Table 4.19 Bunkering means in the cluster of Ferrol

Puerto	Marine suppliers	Ex-Pipe suppliers
Ferrol		
A Coruña	✓	REPSOL
Vigo		
Marín		
Villagarcia de Arousa		

4.6.1.3 LNG bunkering development milestones.

As seen in other LNG plants operators, the company managing Ferrol's LNG terminal in port of Ferrol – Reganosa- supports most of the efforts aimed to develop LNG as a marine fuel, promoting the construction of new infrastructures and supply service:

- Two TTS supplies in the port of Vigo
- Project for the deployment of a non-propelled supply barge in the port of Vigo (Project SAMUELNG)
- Adaptation of the large dock at Ferrol's degasification plant, for ship supply (PTS supply).
- Design of a new dock at Ferrol's degasification plant for ship refueling (2nd dock).
- Pilot test for a containerized OPS system with natural gas generation at port of Ferrol.

4.6.2 Potential supply chain analysis

Attending to the expected demand, this cluster is like Cartagena o Bilbao but with a more diverse traffic, featuring liquid and solid cargo ships.

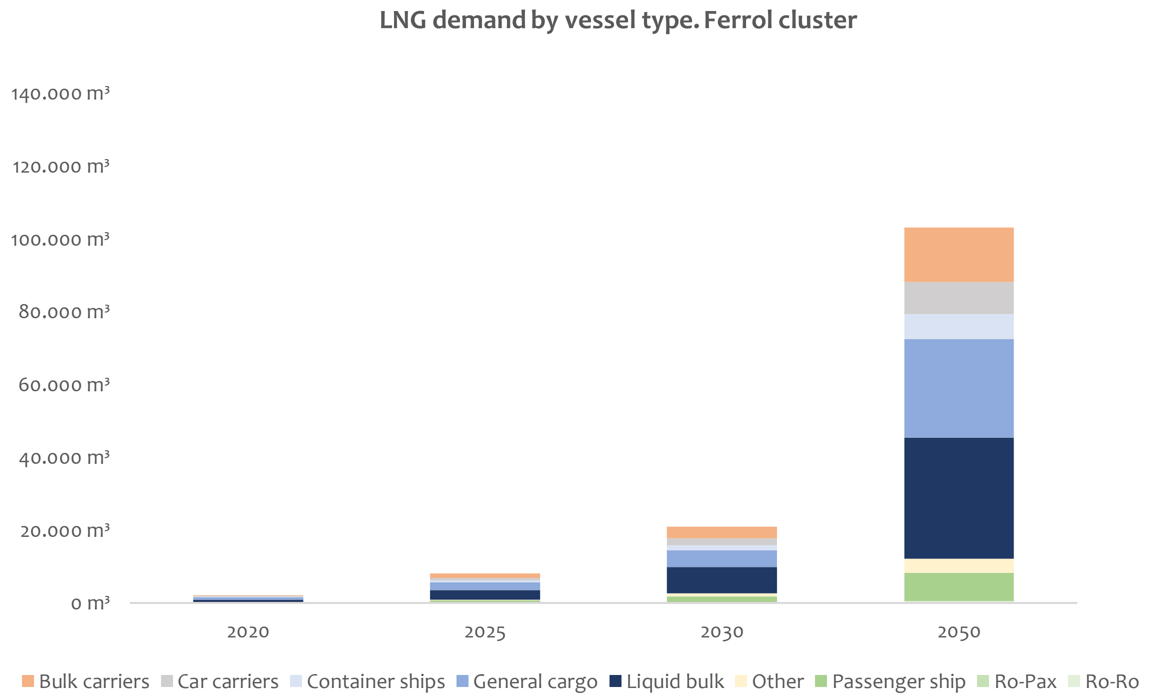


Figure 4.35 LNG demand by vessel type. Ferrol cluster

Table 4.20 LNG demand by port in Ferrol cluster and Base scenario

Base scenario	2020	2025	2030	2050
La Coruna	1.057 m³	3.252 m³	7.712 m³	32.330 m³
Ferrol	578 m³	2.482 m³	6.818 m³	31.644 m³
Vigo	423 m³	1.816 m³	4.988 m³	32.313 m³
Marin	105 m³	450 m³	1.235 m³	5.731 m³
Villagarcia	20 m³	85 m³	233 m³	1.083 m³
Total	**2.182 m³**	**8.085 m³**	**20.986 m³**	**103.101 m³**

Demand is divided evenly between the three biggest ports – La Coruna, Vigo and Ferrol- consolidating more than 95% of the total expected demand.

4.6.2.1 *Logistic models to be implemented*

The lower consolidation of demand in this cluster, is an important factor to assess the viability of the different supply chains. As it was shown in Cartagena cluster, supplying ports far from import plants require extra availability of the assigned resources, reducing the level of service in the Base Port.

Ferrol cluster stands out for:

- Demand will be consolidated around La Coruna and Ferrol ports, separated 11 nm from each other.
- Port of Ferrol hosts an LNG import terminal
- Ports of Vigo, Marin and Villagarcia de Arousa are 120 nm away from each other.

5 marine supply solutions over the 21,000 m³ threshold were considered and are shown in the following graph.

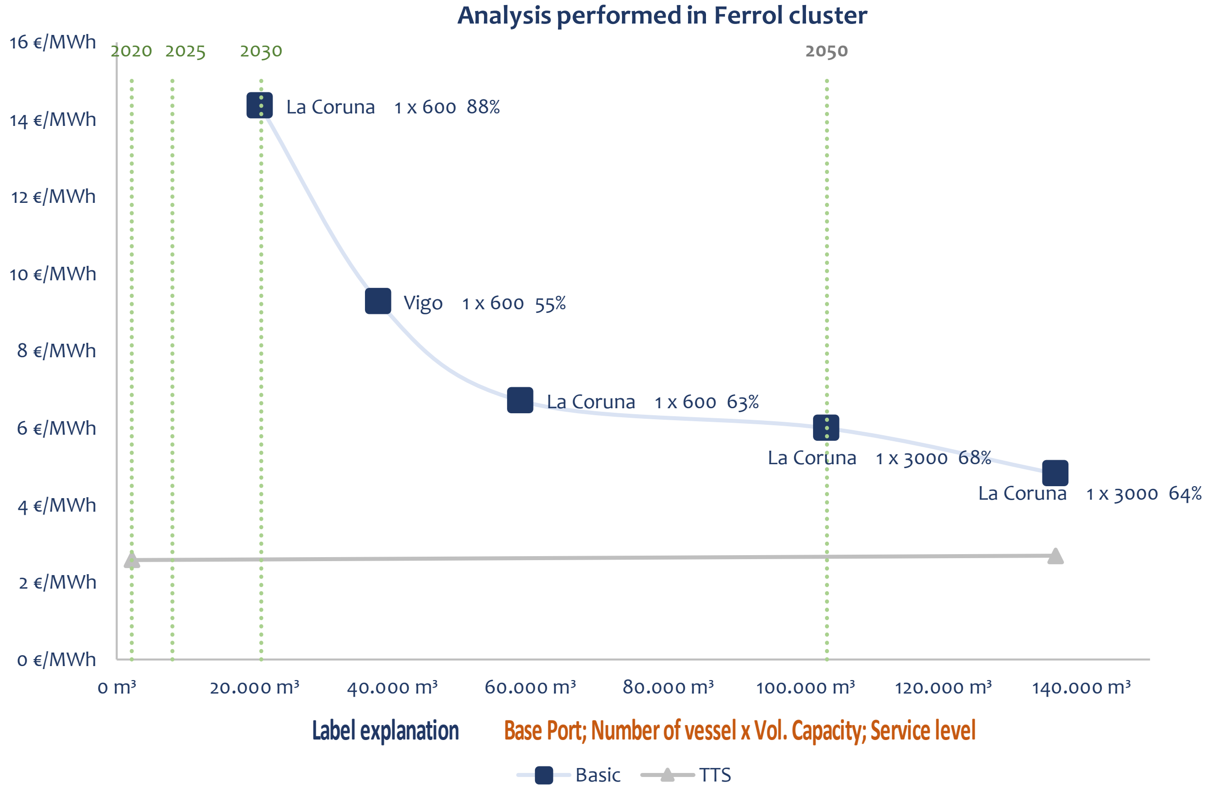


Figure 4.36 Supply chains analyzed in the cluster of Ferrol

Low demand and far distance between ports increases service costs, reducing the efficiency of multiproduct options and reducing level of service at Base Port, being needed higher capacity ships above 100,000 m^3.

The allocation of higher capacity and speed ships will mitigate the lack of demand consolidation but will increase the final cost of supply compared to other cluster with a similar demand such as Bilbao or Cartagena. Additional calculations were made adding an auxiliary terminal in the port of Vigo but because of the low demand this solution will increase costs to a point higher than the costs shown in the previous figure.

In the 100,000 m^3 demand threshold, supply costs would be around 6 €/MWh and 5€/MWh, far from the 3€/MWh calculated for TTS supply operations.

TTS supply is the solution recommended until demand reaches the 100,000 m^3 threshold to have a dedicated supply ship. Solutions -2A and 3B – with 600 m^3 multi-purpose barge won't be competitive compared to a TTS solution.

Chosen solution for this cluster is the following:

- **Year 2020:** TTS supply (Solución 1T)
- **Year 2020:** TTS supply (Solution 1T)
- **Year 2025:** TTS supply (Solution 1T)
- **Year 2025:** TTS supply (Solution 1T)
- **Year 2030:** TTS supply (Solution 1T)
- **Year 2030:** TTS supply (Solution 1T)
- **Year 2050:** 3.000 m^3 ship (Solution 4A)
- **Year 2050:** 3.000 m3 ship (Solution 4A)

Figure 4.37 Cost summary for analysis performed in the cluster of Ferrol

	Solución 1A	Solución 2A	Solución 3A	Solución 4A	Solución 5A	Solución 1T	Solución 2T
Cluster	FERROL	FERROL	FERROL	FERROL	FERROL	FERROL	FERROL
Method	HIVE	HIVE	HIVE	HIVE	HIVE	HIVE	HIVE
Scenario	BASIC	HIGH	LOW	BASIC	HIGH	BASIC	HIGH
Year	2030	2030	2050	2050	2050	2020	2050
ID analysis	20B-	38B-	58B-	92B-	136B-	2T	136T
Demand	**20.825 m³**	**37.985 m³**	**58.617 m³**	**103.101 m³**	**136.281 m³**	**2.182 m³**	**136.281 m³**
Services STS	32	61	94	165	217	0	0
Services TTS	53	90	137	237	310	8	310
Unit cost	**14,35 €/MWh**	**9,28 €/MWh**	**6,70 €/MWh**	**5,99 €/MWh**	**4,82 €/MWh**	**2,58 €/MWh**	**2,69 €/MWh**
SERVICE COST	€739.552	€666.073	€1.028.882	€1.327.204	€1.461.485	€21.440	€1.443.611
RELOAD COST	€359.583	€1.157.132	€987.219	€851.004	€1.124.200	€16.738	€1.045.338
FEEDERING	€0	€0	€0	€0	€0	€0	€0
AUX. TERMINAL	€0	€0	€0	€0	€0	€0	€0
INACTIVITY COST	€929.162	€569.495	€651.557	€2.015.799	€1.872.438	€0	€0
Total cost	2.028.297	2.392.700	2.667.659	4.194.006	4.458.123	38.177	2.488.950
Total investment	9.522.000	9.522.000	9.522.000	20.000.000	20.000.000	0	0
Income fee for IT	**€269.118**	**€486.068**	**€737.122**	**€677.224**	**€894.072**	**€14.850**	**€941.961**
Cost impact	1,90 €/MWh	1,89 €/MWh	1,85 €/MWh	0,97 €/MWh	0,97 €/MWh	1,00 €/MWh	1,02 €/MWh
Cost impact %	13%	20%	28%	16%	20%	39%	38%
Vessel slots	32	58	88	31	41	0	0
Truck slots	53	91	137	238	310	44	2791
Vessel Terminal usage days	6	11	16	10	14	0	0
Truck Terminal usage days	3	5	7	12	16	2	140
Vessels							
Port, no., size, service BP1	La Coruna 1 x 600 88%	Vigo 1 x 600 55%	La Coruna 1 x 600 63%	La Coruna 1 x 3000 68%	La Coruna 1 x 3000 64%		
BP2							
BP3							
BP4							
Terminals							
Port, size							
Feeders							

4.7 *Gijon Cluster*

Gijon cluster consists of 2 ports:

- Avilés
- Gijón (LNG Import terminal in hibernation) (Base Port)

4.7.1 Introduction and current market characterization.

4.7.1.1 Port traffic analysis

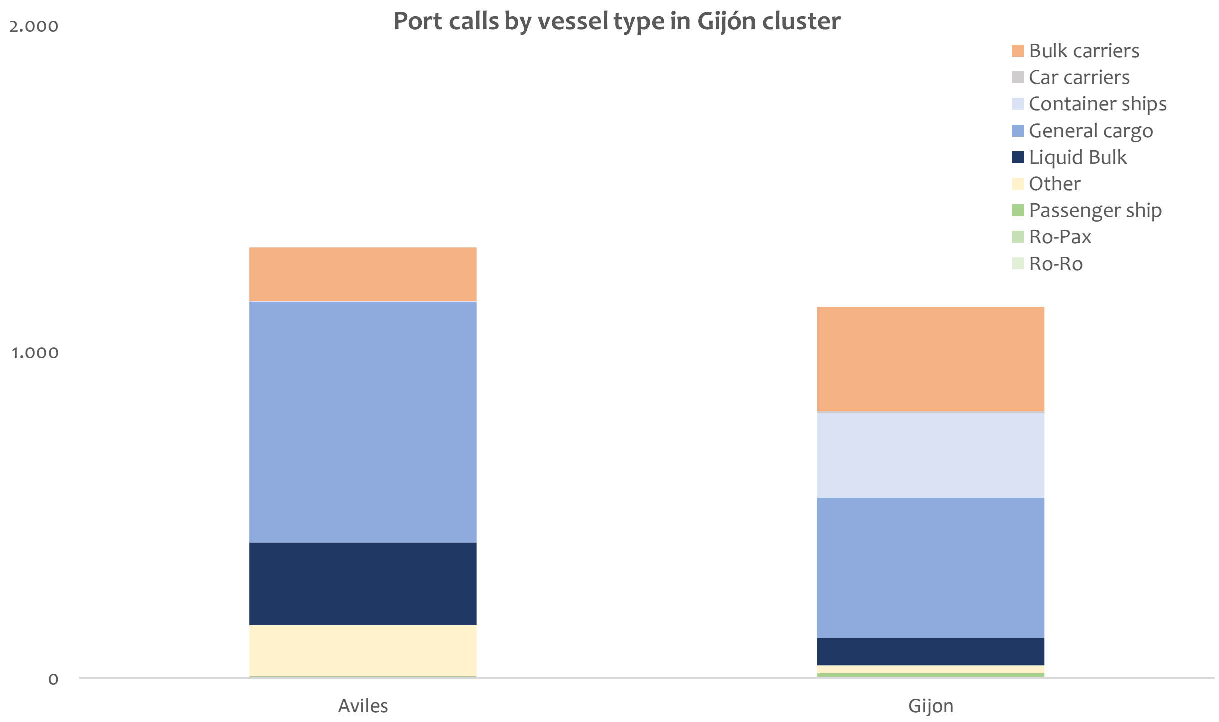


Figure 4.38 Port calls in the cluster of Gijón

Gijon and Aviles ports are in the Cantabric sea with a traffic focused on solid bulk materials – Gijon is the number one port in solid bulk cargo traffic – and general cargo, supporting also an important fishing fleet.

4.7.1.2 Traditional marine fuel bunkering

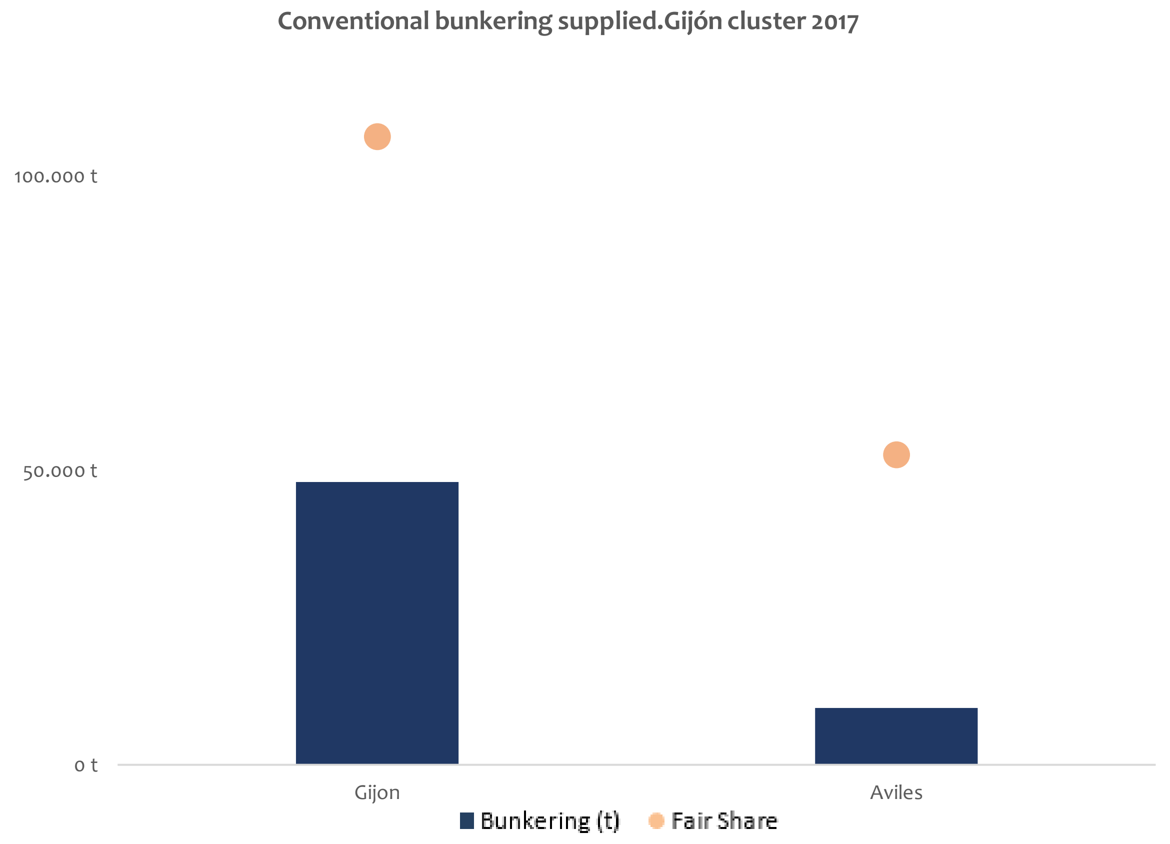


Figure 4.39 Conventional bunkering supplied in the cluster of Gijón

As happened in the previous cluster, ships operating in the Cantabric sea tend to choose other areas for fuel provisioning. Port of Gijon has a supply barge as well as supply pipe service, supplying 48,067 t.

Table 4.21 Bunkering means in the cluster of Gijón

Puerto	Marine suppliers		Ex-Pipe suppliers	
Avilés				
Gijón	✓	REPSOL	✓	CLH

Table 4.22 Available marine bunkering means

Barge	Base Port	Capacity	Supplier	Delivery year	Comments
Sobia	Gijón	1.130 t	REPSOL	1996	Inactive now

4.7.1.3 LNG bunkering development milestones.

Despite having an inactive import terminal in, por of Gijon has hosted:

- 4 TTS supply operations.
- Project for the installation of a MTTS supply system.

4.7.2 Potential supply chain analysis

This is the cluster with the lower expected demand and only consists of 4 ports, closed to each other.

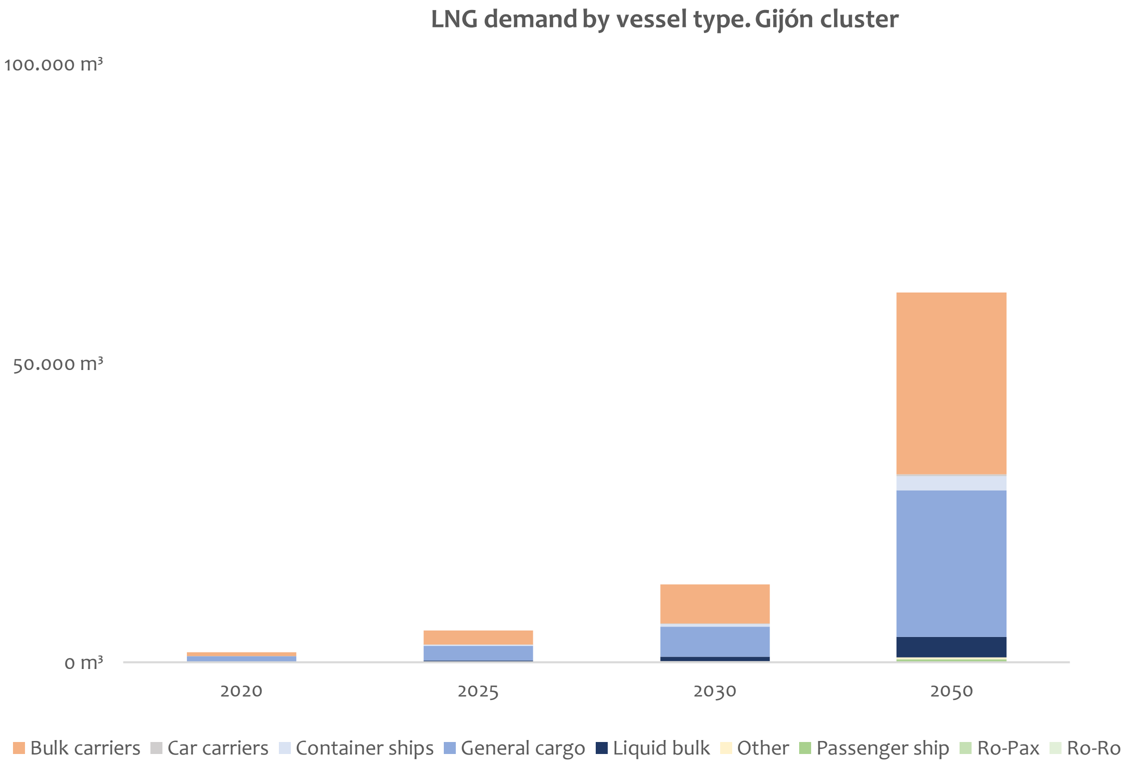


Figure 4.40 LNG demand by vessel type. Gijón cluster

Table 4.23 LNG demand by port in Gijon cluster and Base scenario

Base scenario	2020	2025	2030	2050
Gijon	1.058 m³	3.701 m³	9.368 m³	47.110 m³
Aviles	581 m³	1.634 m³	3.675 m³	14.738 m³
Total general	**1.639 m³**	**5.335 m³**	**13.043 m³**	**61.848 m³**

Demand is unbalanced with 80% of the total for port of Gijon and 20% for port of Aviles.

4.7.2.1 *Logistic models to be implemented*

4 different supply chain analysis has been performed for a threshold volume above 20.840 m³.

This cluster's features are like Bilbao's but with lower demand expectations making a lower capacity multi-product barge a feasible option. For demand thresholds below 70.000 m³ the allocation of marine resources would be an affordable option with a supply cost close to 5 **€/MWh.**

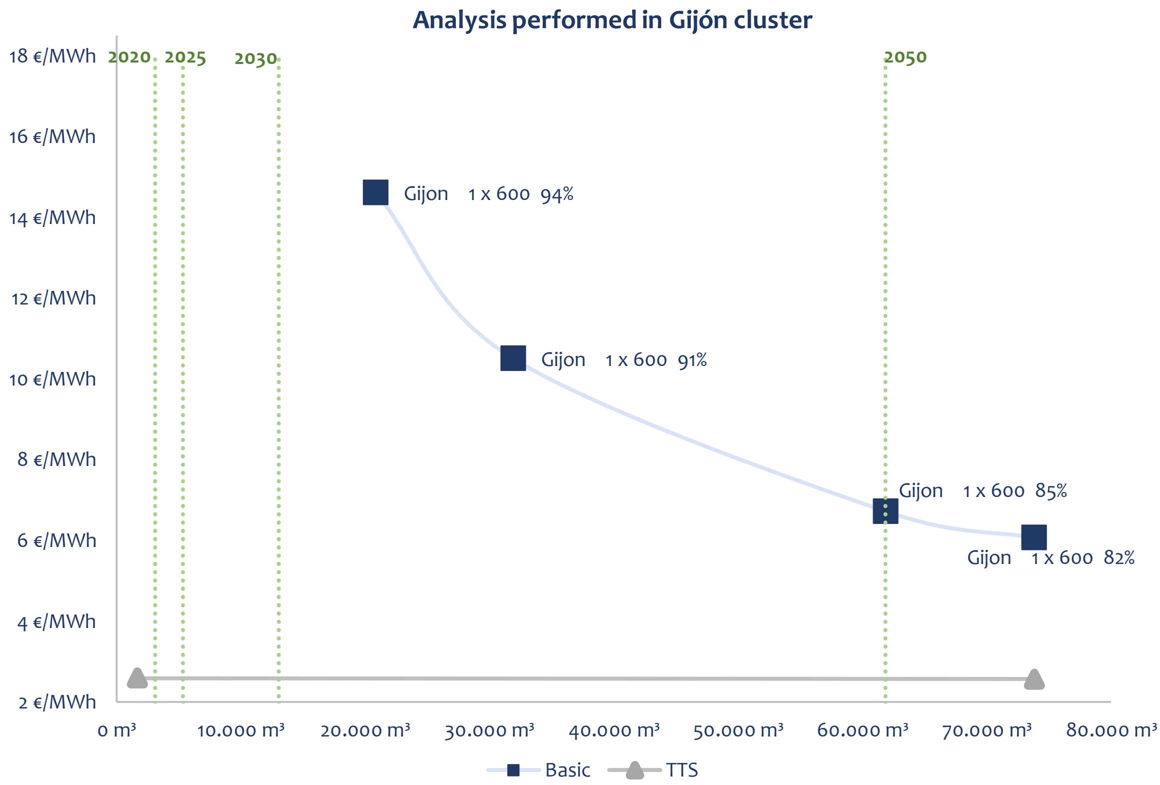


Figure 4.41 Supply chains analyzed in the cluster of Gijón

The solution chosen for this cluster is the following:

- **Year 2020:** TTS Supply (Solution 1T)
- **Year 2025:** TTS Supply (Solution 1T)
- **Year 2030:** TTS Supply (Solution 1T)
- **Year 2050:** 3.000 m³ ship (Solution 3A)

Figure 4.42 Cost summary for analysis performed in the cluster of Gijón

		Solución 1A	Solución 2A	Solución 3A	Solución 4A	Solución 1T	Solución 2T
Cluster		GIJON	GIJON	GIJON	GIJON	GIJON	GIJON
Method		HIVE	HIVE	HIVE	HIVE	HIVE	HIVE
Scenario		HIGH	LOW	BASIC	HIGH	BASIC	BASIC
Year		2030	2050	2050	2050	2020	2050
ID analysis		gij2030h	31B	61B	73B	2	61
Demand		20.840 m³	31.880 m³	61.848 m³	73.807 m³	1.639 m³	61.848 m³
Services STS		45	60	121	138	0	0
Services TTS		40	67	147	150	5	147
Unit cost		14,12 €/MWh	10,01 €/MWh	6,22 €/MWh	5,57 €/MWh	2,09 €/MWh	2,06 €/MWh
SERVICE COST		€679.257	€703.674	€768.556	€794.768	€10.639	€391.895
RELOAD COST		€334.775	€512.277	€979.111	€1.170.524	€12.575	€474.402
FEEDERING		€0	€0	€0	€0	€0	€0
AUX. TERMINAL		€0	€0	€0	€0	€0	€0
INACTIVITY COST		€982.999	€949.576	€864.061	€824.280	€0	€0
Total cost		1.997.031	2.165.527	2.611.728	2.789.572	23.215	866.298
Total investment		9.522.000	9.522.000	9.522.000	9.522.000	0	0
Income fee for IT		€266.418	€407.647	€779.752	€930.270	€11.137	€425.249
Cost impact		1,88 €/MWh	1,88 €/MWh	1,86 €/MWh	1,86 €/MWh	1,00 €/MWh	1,01 €/MWh
Cost impact %		13%	19%	30%	33%	48%	49%
Vessel slots		32	49	93	112	0	0
Truck slots		45	68	147	151	33	1260
Vessel Terminal usage	days	6	9	17	21	0	0
Truck Terminal usage	days	2	3	7	8	2	63
Vessels							
Port, no., size, service	BP1	Gijon 1 x 600 94%	Gijon 1 x 600 91%	Gijon 1 x 600 85%	Gijon 1 x 600 82%		
	BP2						
	BP3						
	BP4						
Terminals							
Port, size							

4.8 *Bilbao Cluster*

Bilbao cluster consists of 3 ports:

- Bilbao (LNG Import terminal) (Base Port)
- Pasaia
- Santander

4.8.1 Introduction and current market characterization.

4.8.1.1 Port traffic analysis

These three ports show the following por scales distribution shown in figure 4.43.

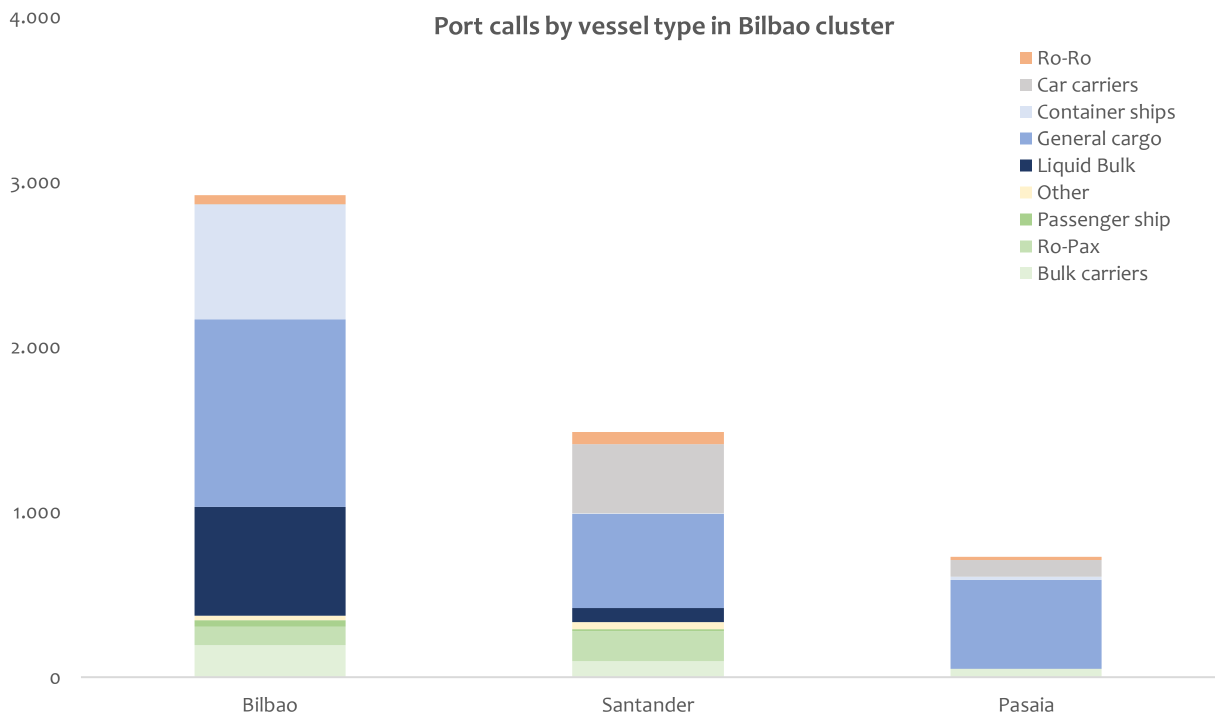


Figure 4.43 Port calls in the cluster of Bilbao

Ports within this cluster are mostly industrial, hosting non-containerized cargo, new vehicles and oil tankers and products in the port of Bilbao which hosts a refinery. New vehicle traffic is located in ports of Santander and Pasaia ranking 3rd and 5th respectively with 494,000 and 234,100 new cars handled.

4.8.1.2 Traditional marine fuel bunkering

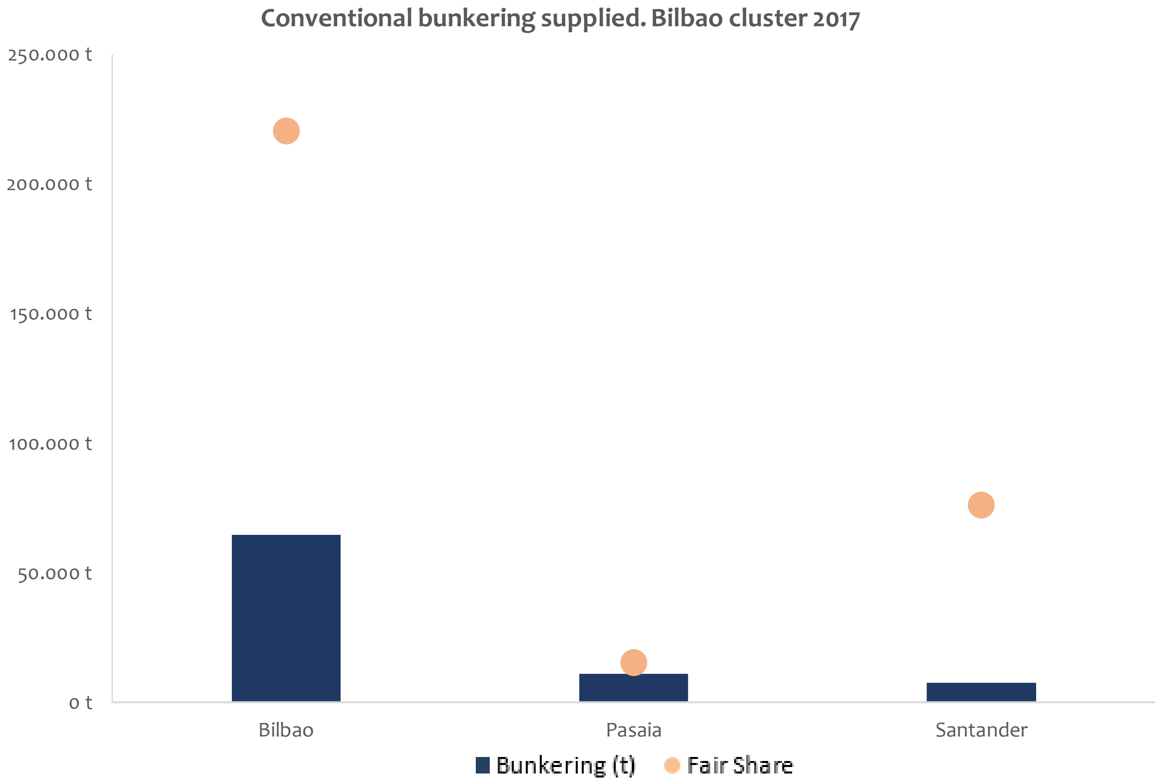


Figure 4.44 Conventional bunkering supplied in the cluster of Bilbao

None of these three ports stands out as a reference in the fuel supply market, being Santander and Bilbao way below the level of supply expected according to its traffic. This is caused by the lack of price competitiveness and service compared to other ports in the north Europe hosting similar traffic.

Port of Bilbao offers conventional fuel tank service supply and pipe service for heavy fuels.

Table 4.24 Bunkering means in the cluster of Bilbao

Puerto	Marine suppliers	Ex-Pipe suppliers
Bilbao		✓ CLH REPSOL IFO 380
Santander		
Pasaia		

4.8.1.3 LNG bunkering development milestones.

The commitment of the import terminal owner company -BBG- in developing LNG bunkering in Bilbao, has made possible to host the following projects:

- First STS supply service in Spain and Portugal performed from a multiproduct barge.
- 10 TTS supply operations from the port of Bilbao
- 1 TTS supply operation from port of Santander
- Adaptation of the LNG terminal dock to host small-scale LNG ships.

4.8.2 Potential supply chain analysis

Traffic and bunkering operations in this cluster are pretty similar to those observed at port of Cartagena but LNG expected demand for these three ports is smaller compared with the rest of the network and will be strongly correlated to the level of implementation of LNG as a source of fuel for general cargo and bulk cargo ships.

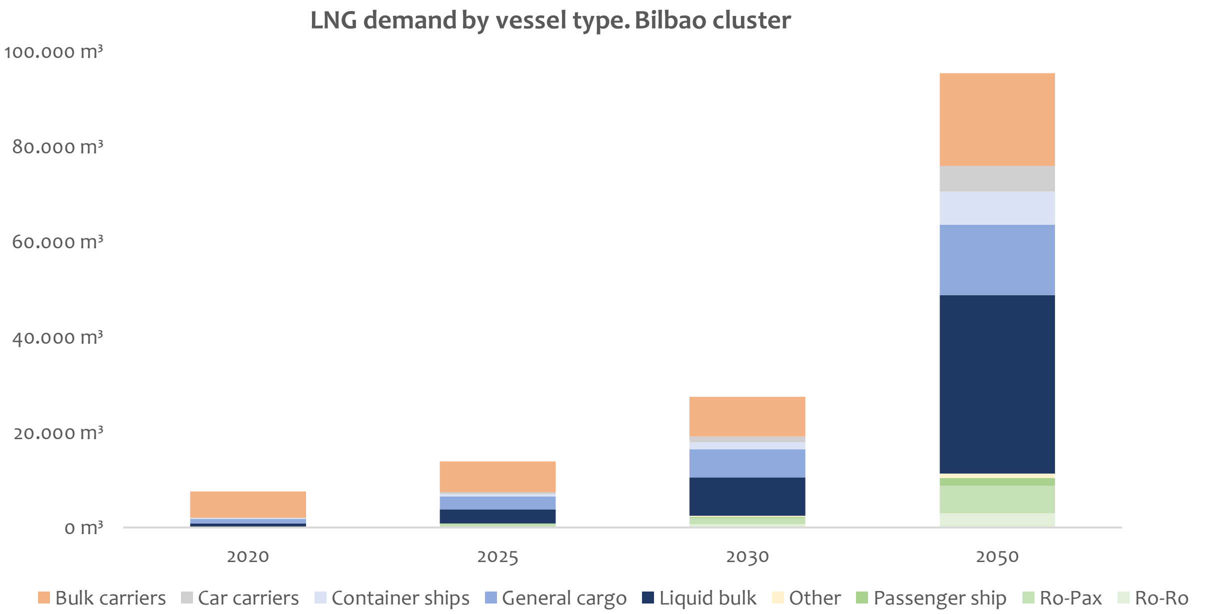


Figure 4.45 LNG demand by vessel type. Bilbao cluster

Table 4.25 LNG demand by port in Bilbao cluster and Base scenario

Base scenario	2020	2025	2030	2050
Bilbao	6.665 m³	11.056 m³	21.050 m³	78.280 m³
Santander	872 m³	2.435 m³	5.447 m³	12.593 m³
Pasaia	84 m³	361 m³	992 m³	4.606 m³
Palamos	32 m³	142 m³	382 m³	1.808 m³
Total	1.535 m³	6.793 m³	18.326 m³	86.700 m³

Port of Bilbao hosts 80% of the total demand of this cluster and the other 20% is divided among the other ports, showing a highly consolidated demand.

4.8.2.1 Logistic models to be implemented.

6 supply chains were analyzed following an approach like Cartagena cluster and is reflected in Figure 4.47.

For this cluster, is worth noting:

- Demand will be mostly consolidated around port of Bilbao
- Port of Bilbao hosts an LNG import terminal
- Santander and Pasaia ports are close to Bilbao, 36 nm and 58 nm respectively.

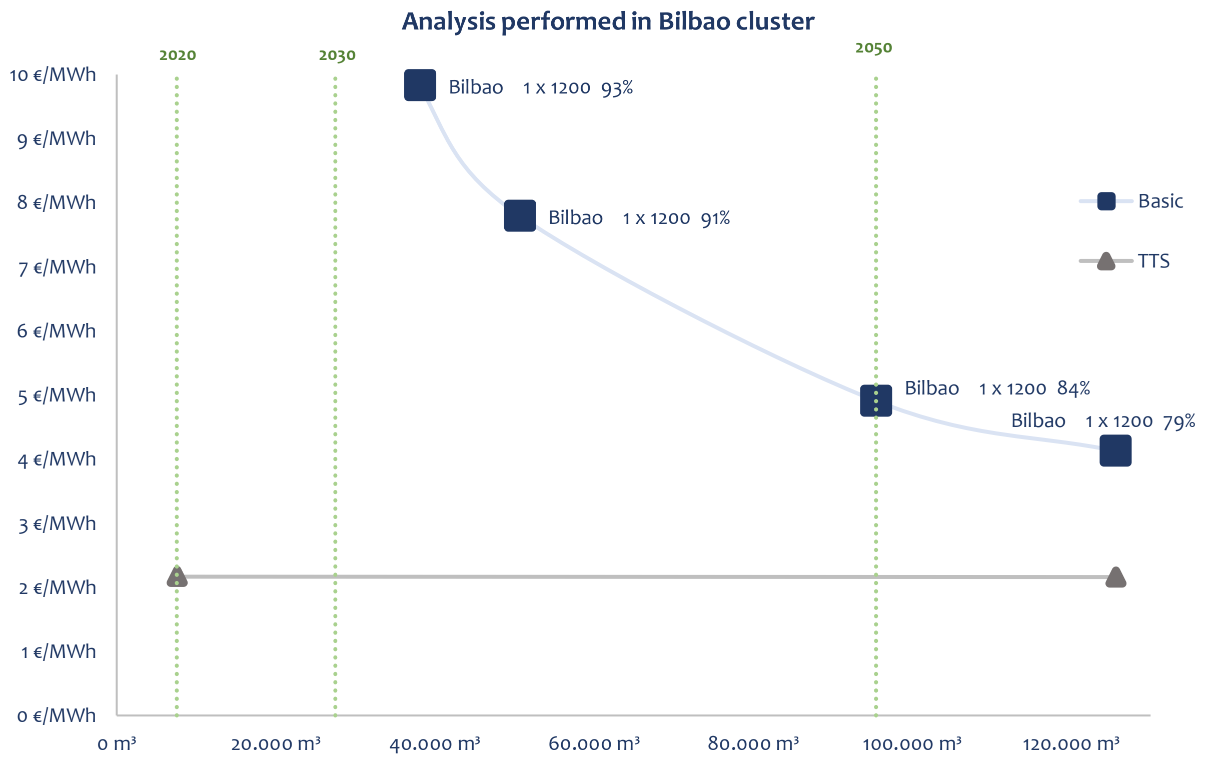


Figure 4.46 Supply chains analyzed in the cluster of Bilbao

As the graphic shows, for a volume threshold like Cartagena's - 100.000 m³ – supply costs for this cluster has been decreased from 7 €/MWh to **4 €/MWh** for marine supply. This is mostly because Bilbao uses a multiproduct barge instead of a dedicated 3,000 m³ ship, which is ideal for low demand scenarios where performing supply operations outside the base port is not necessary. This **4 €/MWh** in addition to the also low TTS supply price **2.17 €/MWh** could be advantageous for local/captive fleets and promoting this way the consumption of LNG as opposed to diesel. During the first years of operation and until the 100.000 m³ volume threshold was reached, tanker truck supply would be the most suitable solution.

Solution chosen for this cluster is the following:

- **Year 2020:** TTS Supply (Solution 1T)
- **Year 2025:** TTS Supply (Solution 1T)
- **Year 2030:** TTS Supply (Solution 1T)
- **Year 2050:** 1 3.000 m³ ship (Solution 4A)

Figure 4.47 Cost summary for analysis performed in the cluster of Bilbao

	Solución 1A	Solución 2A	Solución 3A	Solución 4A	Solución 5A	Solución 1T	Solución 2T
Cluster	BILBAO	BILBAO	BILBAO	BILBAO	BILBAO	BILBAO	BILBAO
Method	HIVE	HIVE	HIVE	HIVE	HIVE	HIVE	HIVE
Scenario	BASIC	HIGH	LOW	BASIC	HIGH	BASIC	HIGH
Year	2030	2030	2050	2050	2050	2020	2050
ID analysis	27B	38B	51B	95B	126B	8	126
Demand	27.489 m³	38.157 m³	50.712 m³	95.479 m³	125.618 m³	7.622 m³	125.618 m³
Services STS	46	41	63	172	226	7	150
Services TTS	51	69	91	113	150	0	0
Unit cost	13,09 €/MWh	9,82 €/MWh	7,79 €/MWh	4,91 €/MWh	4,13 €/MWh	2,11 €/MWh	2,16 €/MWh
SERVICE COST	€741.753	€747.958	€795.856	€920.078	€1.010.453	€50.678	€877.689
RELOAD COST	€318.335	€440.843	€573.188	€1.086.009	€1.429.572	€58.462	€963.549
FEEDERING	€0	€0	€0	€0	€0	€0	€0
AUX. TERMINAL	€0	€0	€0	€0	€0	€0	€0
INACTIVITY COST	€1.382.216	€1.354.910	€1.312.836	€1.174.013	€1.078.598	€0	€0
Total cost	2.442.305	2.543.712	2.681.880	3.180.099	3.518.623	109.140	1.841.238
Total investment	16.000.000	16.000.000	16.000.000	16.000.000	16.000.000	0	0
Income fee for IT	€251.305	€345.934	€449.677	€851.483	€1.121.154	€56.700	€912.936
Cost impact	1,35 €/MWh	1,34 €/MWh	1,31 €/MWh	1,31 €/MWh	1,31 €/MWh	1,10 €/MWh	1,07 €/MWh
Cost impact %	10%	14%	17%	27%	32%	52%	50%
Vessel slots	22	31	40	76	100	0	0
Truck slots	47	42	64	113	151	168	2705
Vessel Terminal usage days	5	8	10	19	25	0	0
Truck Terminal usage days	2	2	3	6	8	8	135
Vessels							
Port, no., size, service BP1	Bilbao 1 x 1200 94%	Bilbao 1 x 1200 93%	Bilbao 1 x 1200 91%	Bilbao 1 x 1200 84%	Bilbao 1 x 1200 79%		
BP2							
BP3							
BP4							
Terminals							
Port, size							
Feeders							

4.9 *Granadilla Cluster*

This cluster is formed by 7 extra peninsular ports:

- Arrecife
- Granadilla (LNG Import terminal projected)
- La Luz y de Las Palmas (Base Port)
- Los Cristianos
- Puerto Rosario
- Santa Cruz de La Palma
- Santa Cruz de Tenerife

4.9.1 Introduction and current market characterization.

4.9.1.1 Port traffic analysis

Port call distribution for these 7 ports is as reflected in Figure 4.48:

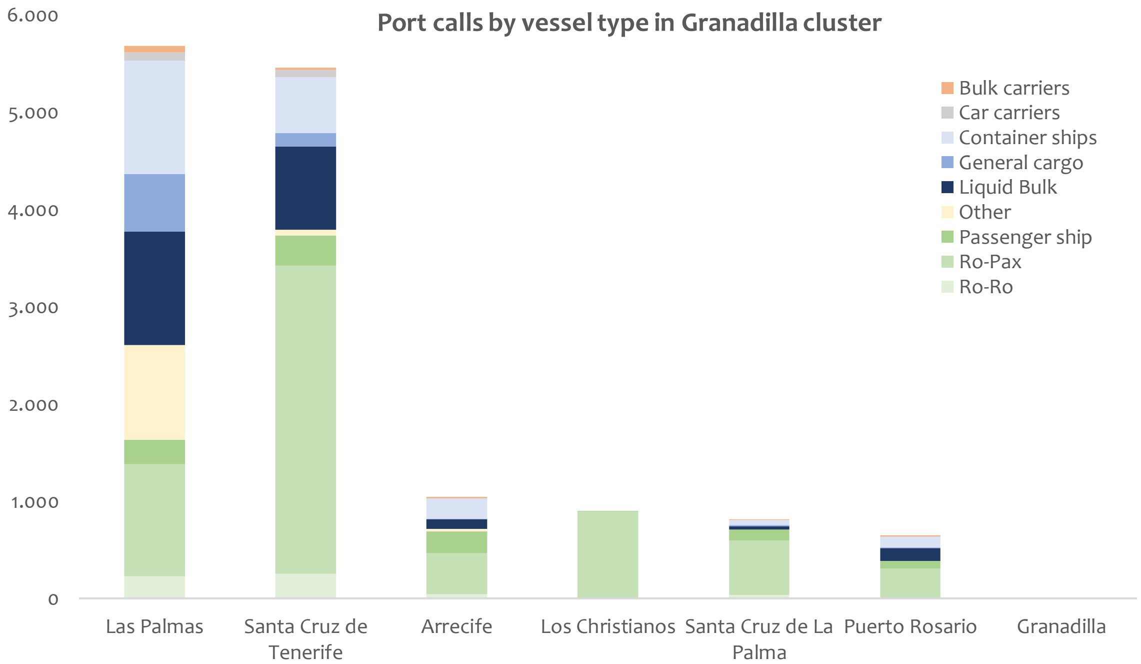


Figure 4.48 Port calls in the cluster of Granadilla

The principal traffic source in this port is the inter-insular road and passenger cargo, hosting Ro-Pax and Ro-Ro ships in addition to the non-containerized cargo and solid and liquid bulk cargo generated from and to the peninsula.

The major ports within this cluster are: port of Las Palmas – in the Island of Gran Canaria – and port of Santa Cruz de Tenerife – in Island of Tenerife – two biggest islands of the archipelago and two of the most important ports in Spain, with important traffic of the following cargo:

- **Peninsular and inter-insular cargo and passenger traffic:** Both Santa Cruz de Tenerife and Las Palmas hosts most of the lines between islands and are base ports for lines connecting with the Iberian Peninsula.
- **Cruise ships:** Port of La Luz and Port of las Palmas received 1,230,000 cruise passengers, ranking third in the entire network, followed by port of Santa Cruz de Tenerife with 964,37 passengers. In addition to this, both ports are base ports for cruising working in the Atlantic area, including other Canary Islands and Madeira.
- **Transit containers and inter-insular distribution:** Las Palmas port geographic location in the Atlantic corridor, makes it an ideal transit port, ranking 4th in the import/export transit market.
- **Liquid bulk cargo:** The entire demand of fossil fuel demand in the island, previously supplied by Tenerife's refinery is currently being totally imported through Tenerife and Las Palmas ports, where large storage terminals are available and from where are later distributed to other islands. Ships operating these routes are normally medium/small size oil/chemical products carrier ships.
- **Fuel supply, ship maintenance and fleeting platforms:** Thanks to wide anchoring areas, its geographic situation and the important development of services focused on ship provisioning and maintenance through the years, Las Palmas is the second most important port in the network serving 2,3000,000 t and Tenerife ranks 5th with 520,000 t served. In addition to this, both ports stand out for providing a good service of maintenance and reparation of both ships and fleeting platforms for oil extraction, surveying or production.

4.9.1.2 Traditional marine fuel bunkering

The ideal location of two of the largest ports in the Atlantic Ocean has developed a highly competitive market for fuel supply, mostly in Las Palmas, with a volume like Algeciras's.

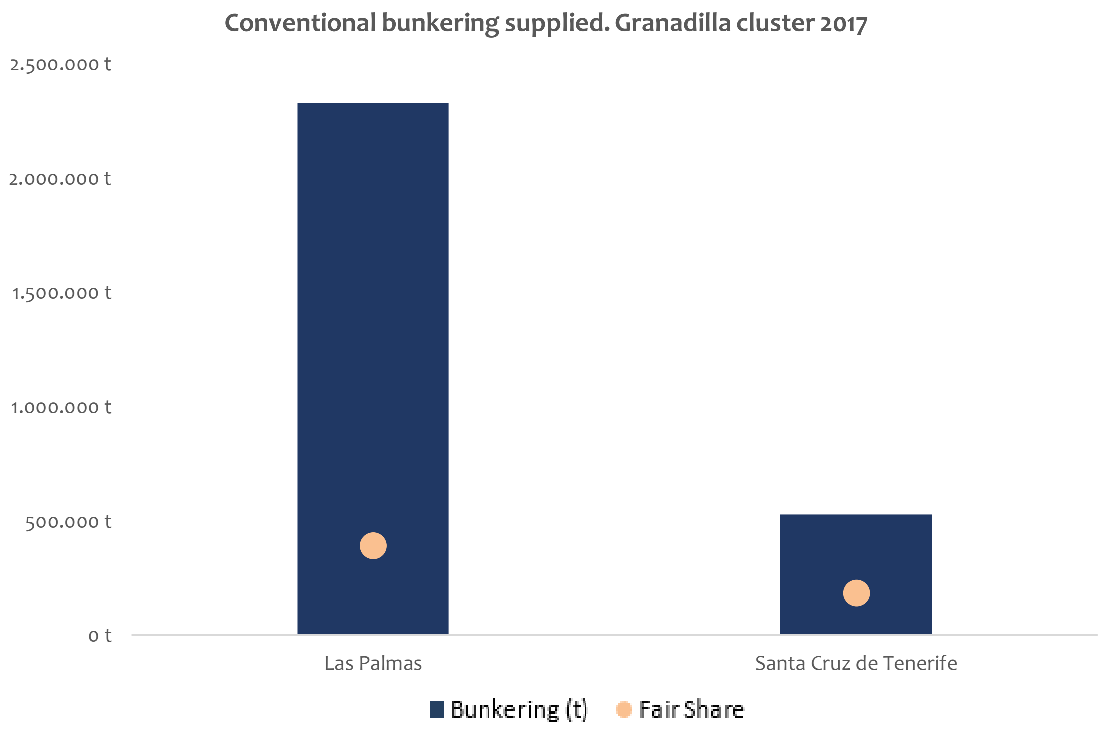


Figure 4.49 Conventional bunkering supplied in the cluster of Granadilla

The bulk of Las Palmas traffic is as follows:

- **Large oil tankers and solid bulk cargo ships**: Located in the center of large African oil export routes and agricultural commodities routes from South America, Las Palmas is the ideal port for reparations or refueling thanks to its wide anchoring area (+60% of total).
- **General cargo ships and miscellaneous ships:** Wide range of general cargo vessels, non-containerized cargo ships, fleeting platforms, service and life guard ships provisioning in the port make for almost 20% of the total traffic.

On the other hand, Tenerife stands out for supplying fuel to cruise ships, road cargo ships and high-speed ferries.

Both Las Palmas and Tenerife ports have a large storage capacity, especially in Las Palmas, hosting three independent terminals, storing and delivering oil products for fuel supply. The high number of companies and operators present in the port of Las Palmas, guarantees a competitive market with a higher availability, flexibility and quality service than other ports.

Table 4.26 Bunkering means in the cluster of Granadilla

Puerto	Marine suppliers		Ex-Pipe suppliers	
Arinaga				
Arrecife				
Granadilla				
Las Palmas	✓	AEGEAN, CEPSA, ORYX ENERGIES	✓	TERMINALES CANARIOS, S. L.: bp, REPSOL, CEPSA, AEGEAN
Los Christianos				
Puerto Rosario				
Santa Cruz de La Palma				
Santa Cruz de Tenerife	✓	CEPSA	✓	TERMINALES CANARIOS, S. L.: bp, REPSOL, CEPSA

Distribution of the fleet based in Canarias is reflected in Table 4.19 but is subject to on demand to serve other islands:

Table 4.27 Available marine bunkering means

Barge	Base Port	Capacity	Supplier	Delivery year	Otros/Com
Spabunker 22	Las Palmas	4.280 t	CEPSA	2003	
Anafi	Las Palmas	4.200 t	AEGEAN	2001	
Petroport	Las Palmas	7.250 t	ORYX ENERGIES	2002	
Santorini	Las Palmas	3.850 t	AEGEAN	2008	
Zakynthos	Las Palmas	6.400 t	AEGEAN	2010	
Petrobay	Tenerife	2.570 t	CEPSA	2004	

4.9.1.3 LNG bunkering development milestones.

The lack of an LNG terminal in this cluster has slowed down this market in the archipelago. No services or active project are currently being performed yet, but a new large capacity LNG import platform is planned in the port of Granadilla in the next few years.

4.9.1 Potential supply chain analysis

These seven ports located in the Canarian archipelago along with ports within Huelva Cluster are expected to lead LNG demand as a marine fuel. Unlike Huelva, demand aggregation in these two ports is higher, accounting for more than 99% of the total demand in ports of La Luz, Las Palmas and Santa Cruz de Tenerife.

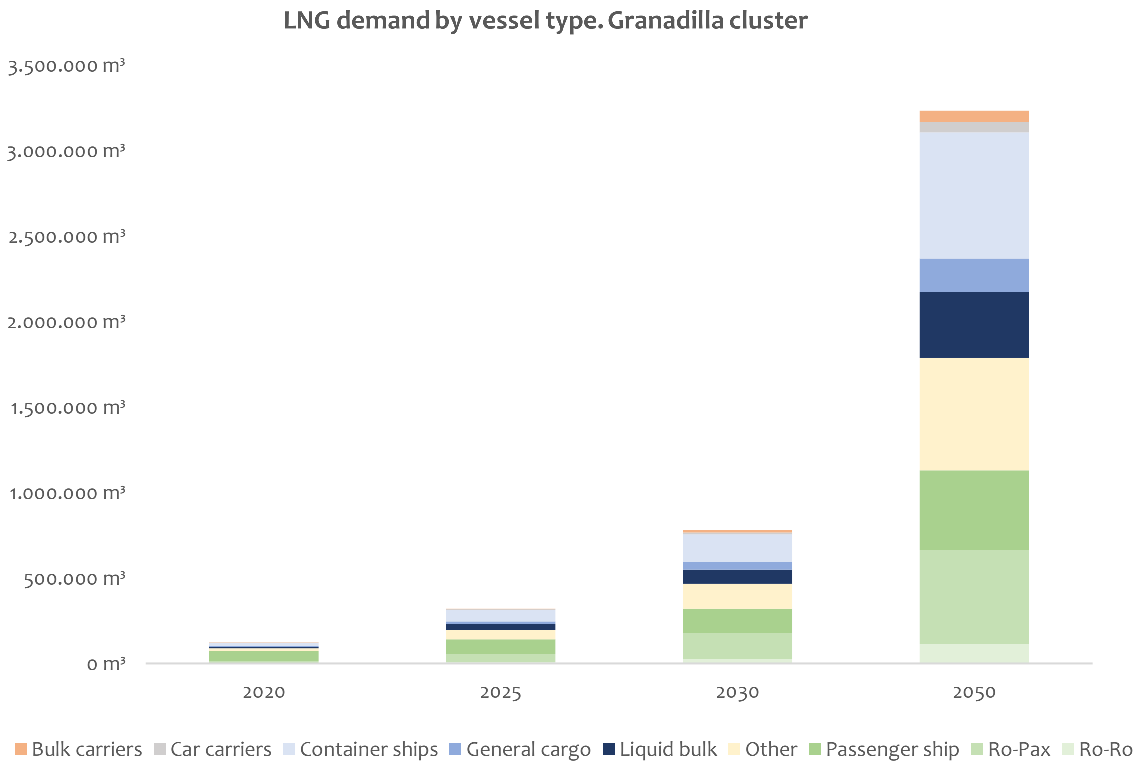


Figure 4.50 LNG demand by vessel type. Granadilla cluster

Table 4.28 LNG demand by port in Granadilla cluster and Base scenario

Base scenario	2020	2025	2030	2050
Las Palmas	87.315 m³	249.670 m³	629.150 m³	2.607.060 m³
Santa Cruz de Tenerife	33.500 m³	71.015 m³	148.465 m³	605.806 m³
Los Christianos	406 m³	1.574 m³	3.985 m³	18.220 m³
Puerto Rosario	19 m³	74 m³	189 m³	862 m³
Arrecife	19 m³	73 m³	186 m³	849 m³
Arinaga	12 m³	47 m³	120 m³	549 m³
Santa Cruz de la Palma	8 m³	32 m³	80 m³	368 m³
Granadilla	0 m³	0 m³	0 m³	0 m³
Total	**121.280 m³**	**322.486 m³**	**782.175 m³**	**3.233.714 m³**

As reflected in the graph above, during the first 10 years considered, market will increase thanks to the road cargo and passenger sector, followed by the container ship sector as of 2030. Finally, the biggest jump in the market will come during the last years of the time frame considered thanks to the incorporation of large oil tankers, bulk cargo ships and non-containerized ships which constitute more than 80% of the total fuel supplied in Las Palmas.

4.9.1.1 Logistic models to be implemented

Similar to Huelva's features, these are the main feature for Granadilla cluster:

- High demand consolidation around two ports, closed to each other but not connected by road – Las Palmas and Tenerife – with Las Palmas gathering 70% of the total expected demand.
- Import terminal located in the Island of Tenerife, 70 nm from Las Palmas
- Except ports of Tenerife and Los Cristianos, TTS bunkering would require sea transport of tankers.
- Additional availability service requirements in the port of Las Palmas.
- Minimum demand in smaller ports.

This analysis follows the same logic used in the port of Huelva, where not only price was considered but also a high service availability in the main port of the cluster – Las Palmas – although, the proximity to the import terminal and the longer distance between the two main supply ports, requires the implementation of different logistic models in contrast to Algeciras's and Ceuta's models which shared the same resources.

15 different options were analyzed, focusing in two main types of solutions:

- **Solutions without dedicated storage (Logistic Model 1 or 4):** Since Tenerife and Las Palmas are farther from each other than Ceuta and Algeciras and the expected demand proportion is more balanced, the fleet wouldn't need to be based in Las Palmas exclusively. The solution proposed is having supply ships working independently in both ports but always provisioning from the future LNG import terminal of Granadilla.
- **Solutions with dedicated storage in Las Palmas (Logistic Model 2):** The effect of insularity and the additional demand expected in las Palmas, could facilitate this solution even though supply costs for this chain will be higher. Cost difference for this solution is not as relevant as in Algeciras Cluster.

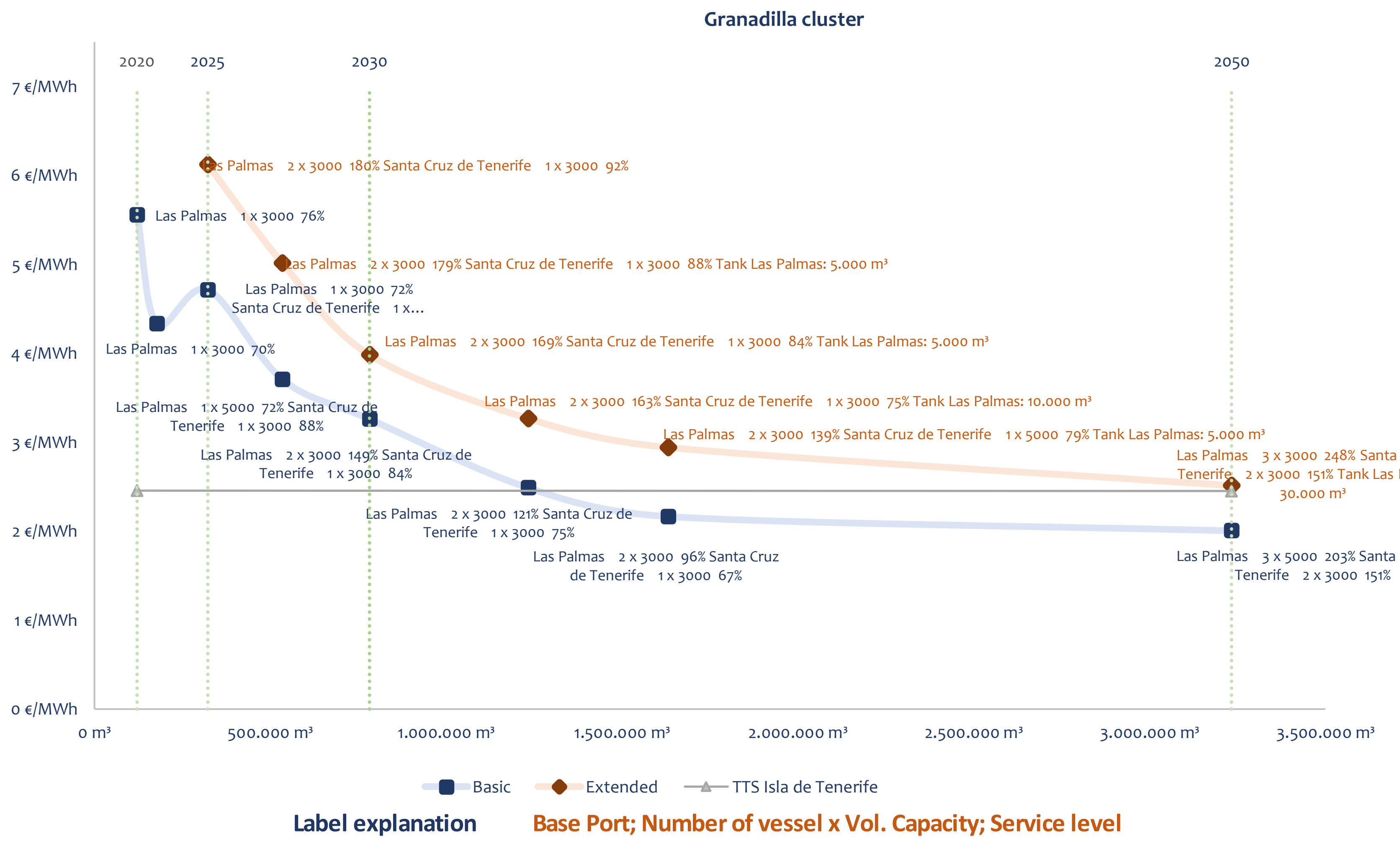


Figure 4.51 Supply chains analyzed in the cluster of Granadilla

All15 analysis reflected in the previous figure and detailed in Figures 4.52 and 4.53, shows an estimation of unitary costs for the different proposed solutions.

- Steady total unitary cost around 2 €/MWh above the 1,200,000 m^3 threshold for Logistic Model 1 and between 4 €/MWh and 2.5 €/MWh for a demand between 300,000 m^3 and 1,200,000 m^3
- Total unitary cost for Logistic Model 2 between 4 €/MWh and for a demand between 1,000,000 m^3 and 3,500,000 m^3
- High TTS supply cost for ports outside the island of Tenerife – around 9 €/MWh –.
- Construction of an auxiliary terminal for TTS supply service in Las Palmas (because of high freight costs for hazardous cargo transport)

Since Las Palmas is a reference port in conventional fuel supply, a higher level of service will be required, which, at the same time, will require more supply ships which will eventually obstruct the port. Thus, a solution without dedicated terminals has been selected for the first three periods, selecting for the last period the same solution used in Huelva: building a storage terminal which allows ships to refuel directly in the Port of las Palmas, mitigating the impact and use of the import terminal and increasing the level of service while increasing supply costs slightly.

The selected solution is as follows:

- **Year 2020:** 3,000 m^3 ship based on Las Palmas (Solution 1A)
- **Year 2025:** 1 3,000 m^3 ship based in Las Palmas and 1 3,000 m^3 based in Tenerife.
- **Year 2030:** 2 3,000 m^3 ships based on Las Palmas and 1 3,000 m^3 ship based on Tenerife and 1 1,000 m^3 auxiliary plant based in the port of Las Palmas **(Solution 5A)**
- **Year 2050:** 1 30,000 m^3 storage terminal and 3 3,000 m^3 ships based in Las Palmas and 2 3,000 m^3 based in the port of Tenerife **(Solution 6B)**

Figure 4.52Cost summary for analysis performed in the cluster of Granadilla

	Solución 1A	Solución 2A	Solución 3A	Solución 4A	Solución 5A	Solución 6A	Solución 7A	Solución 8A
Cluster	**GRANADILLA**	**GRANADILLA**	**GRANADILLA**	**GRANADILLA**	**GRANADILLA**	**GRANADILLA**	**GRANADILLA**	**GRANADILLA**
Method	**HIVE**	**HIVE**	**HIVE**	**HIVE**	**HIVE**	**HIVE**	**HIVE**	**HIVE**
Scenario	**BASIC**	**HIGH**	**BASIC**	**HIGH**	**BASIC**	**HIGH**	**LOW**	**BASIC**
Year	**2020**	**2020**	**2025**	**2025**	**2030**	**2030**	**2050**	**2050**
ID analysis	GRA2020	GRA2020H	GRA2025	GRA2025H	GRA2030	GRA2030H	GRA2050L	GRA2050
Demand	**121.268 m³**	**177.407 m³**	**322.438 m³**	**534.150 m³**	**782.055 m³**	**1.233.747 m³**	**1.631.875 m³**	**3.233.165 m³**
Services STS	151	269	575	1.021	1.449	2.401	3.438	6.613
Services TTS	213	339	663	1.145	1.688	2.706	3.679	7.214
Unit cost	**5,56 €/MWh**	**4,33 €/MWh**	**4,71 €/MWh**	**3,71 €/MWh**	**3,26 €/MWh**	**2,49 €/MWh**	**2,16 €/MWh**	**2,00 €/MWh**
SERVICE COST	€1.197.322	€1.585.789	€2.761.798	€2.690.131	€3.229.164	€4.706.619	€6.128.868	€13.084.214
RELOAD COST	€1.223.697	€1.748.966	€3.131.318	€4.661.385	€6.980.303	€11.009.742	€14.535.772	€22.747.890
FEEDERING	€0	€0	€0	€0	€0	€0	€0	€0
AUX. TERMINAL	€0	€0	€0	€1.537.458	€1.537.458	€1.537.458	€1.537.458	€2.086.391
INACTIVITY COST	€2.154.195	€1.882.888	€4.424.364	€4.557.558	€5.559.747	€3.575.562	€1.777.967	€6.076.968
Total cost	4.575.214	5.217.643	10.317.480	13.446.532	17.306.672	20.829.382	23.980.064	43.995.463
Total investment	20.000.000	20.000.000	40.000.000	64.120.777	72.120.777	72.120.777	72.120.777	157.241.554
Income fee for IT	**€804.937**	**€1.155.201**	**€2.130.342**	**€3.176.770**	**€5.034.260**	**€7.940.705**	**€10.482.997**	**€17.102.565**
Cost impact	0,98 €/MWh	0,96 €/MWh	0,97 €/MWh	0,88 €/MWh	0,95 €/MWh	0,95 €/MWh	0,95 €/MWh	0,78 €/MWh
Cost impact %	18%	22%	21%	24%	29%	38%	44%	39%
Vessel slots	39	55	100	122	260	410	541	624
Truck slots	160	285	607	59	83	137	196	376
Vessel Terminal usage days	13	18	33	37	139	219	290	429
Truck Terminal usage days	8	14	30	3	4	7	10	19
Vessels								
Port, no., size, service BP1	Las Palmas 1 x 3000 76%	Las Palmas 1 x 3000 70%	Las Palmas 1 x 3000 72%	Las Palmas 1 x 5000 72%	Las Palmas 2 x 3000 149%	Las Palmas 2 x 3000 121%	Las Palmas 2 x 3000 96%	Las Palmas 3 x 5000 203%
BP2								
BP3								
BP4			Santa Cruz de Tenerife 1 x 3000 93%	Santa Cruz de Tenerife 1 x 3000 88%	Santa Cruz de Tenerife 1 x 3000 84%	Santa Cruz de Tenerife 1 x 3000 75%	Santa Cruz de Tenerife 1 x 3000 67%	Santa Cruz de Tenerife 2 x 3000 151%
Terminals								
Port, size				Las Palmas: 1.000 m³	Las Palmas: 1.000 m³	Las Palmas: 1.000 m³	Las Palmas: 1.000 m³	Las Palmas: 3.000 m³
Feeders								

Figure 4.53Cost summary for analysis performed in the cluster of Granadilla

	Solución 1B	Solución 2B	Solución 3B	Solución 4B	Solución 5B	Solución 6B	Solución 1T	Solución 2T	Solución 3T	Solución 4T
Cluster	GRANADILLA	GRANADILLA	GRANADILLA	GRANADILLA	GRANADILLA	GRANADILLA	GRANADILLA	GRANADILLA	GRANADILLA	GRANADILLA
Method	HIVE	HIVE	HIVE	HIVE	HIVE	HIVE	HIVE	HIVE	HIVE	HIVE
Scenario	BASIC	HIGH	BASIC	HIGH	LOW	BASIC	BASIC	BASIC	BASIC	BASIC
Year	2025	2025	2030	2030	2050	2050	2020	2050	2020	2050
ID analysis	GRA2025*	GRA2025H*12	GRA2030*	GRA2030H*	GRA2050L*	GRA2050*	TTSTENERIFE2020	TTSTENERIFE2050	TTSISLAS2020	TTSISLAS2050
Demand	**322.438 m^3**	**534.150 m^3**	**782.055 m^3**	**1.233.747 m^3**	**1.631.875 m^3**	**3.233.165 m^3**	**33.907 m^3**	**624.026 m^3**	**87.361 m^3**	**2.609.139 m^3**
Services STS	575	1.021	1.449	2.401	3.438	6.613	9	376	142	6.237
Services TTS	668	1.145	1.688	2.706	3.679	7.214	0	0	0	0
Unit cost	**6,12 €/MWh**	**5,02 €/MWh**	**3,98 €/MWh**	**3,27 €/MWh**	**2,94 €/MWh**	**2,51 €/MWh**	**2,46 €/MWh**	**2,45 €/MWh**	**9,49 €/MWh**	**9,49 €/MWh**
SERVICE COST	€2.876.569	€2.376.191	€3.107.140	€4.527.796	€6.216.669	€11.119.750	€305.265	€5.600.615	€4.954.996	€147.988.124
RELOAD COST	€2.865.674	€1.475.833	€2.064.943	€2.928.438	€3.891.976	€5.995.778	€260.078	€4.786.558	€670.099	€20.013.244
FEEDERING	€0	€5.020.030	€7.510.652	€12.157.857	€15.721.149	€27.370.910	€0	€0	€0	€0
AUX. TERMINAL	€0	€2.202.236	€2.202.236	€2.734.192	€2.202.236	€4.413.758	€0	€0	€0	€0
INACTIVITY COST	€7.654.531	€7.109.411	€6.262.624	€5.007.409	€4.553.462	€6.255.126	€0	€0	€0	€0
Total cost	13.396.774	18.183.700	21.147.594	27.355.692	32.585.492	55.155.322	565.344	10.387.172	5.625.096	168.001.367
Total investment	60.000.000	77.511.683	77.511.683	82.691.550	89.511.683	137.895.847	0	0	0	0
Income fee for IT	**€2.118.192**	**€3.344.533**	**€4.898.950**	**€9.476.791**	**€10.029.708**	**€24.589.416**	**€257.512**	**€4.660.191**	**€622.349**	**€17.908.391**
Cost impact	0,97 €/MWh	0,92 €/MWh	0,92 €/MWh	1,13 €/MWh	0,91 €/MWh	1,12 €/MWh	1,12 €/MWh	1,10 €/MWh	1,05 €/MWh	1,01 €/MWh
Cost impact %	16%	18%	23%	35%	31%	45%	46%	45%	11%	11%
Vessel slots	100	37	50	78	62	203	0	0	0	0
Truck slots	571	59	83	137	196	376	763	13808	1844	53062
Vessel Terminal usage days	52	12	17	26	18	118	0	0	0	0
Truck Terminal usage days	29	3	4	7	10	19	38	690	92	2.653
Vessels										
Port, no., size, service BP1	Las Palmas 2 x 3000 180%	Santa Cruz de Tenerife 1 x 3000 88%	Santa Cruz de Tenerife 1 x 3000 84%	Santa Cruz de Tenerife 1 x 3000 75%	Santa Cruz de Tenerife 1 x 5000 79%	Santa Cruz de Tenerife 2 x 3000 151%				
BP2		Las Palmas 2 x 3000 179%	Las Palmas 2 x 3000 169%	Las Palmas 2 x 3000 163%	Las Palmas 2 x 3000 139%	Las Palmas 3 x 3000 248%				
BP3										
BP4	Santa Cruz de Tenerife 1 x 3000 92%									
Terminals										
Port, size		Las Palmas: 5.000 m^3	Las Palmas: 5.000 m^3	Las Palmas: 10.000 m^3	Las Palmas: 5.000 m^3	Las Palmas: 30.000 m^3				
Feeders										
		Vessel 5000 m^3 freq. 3 d.	Vessel 5000 m^3 freq. 2 d.	Vessel 30000 m^3 freq. 3 d.	Vessel 5000 m^3 freq. 1 d.	Vessel 30000 m^3 freq. 3 d.				

5 OPTIMAL SUPPLY CHAINS ANALYSIS

The aim of this last chapter is to put together all the results obtained for each of the optimal supply chains studied. The following content is divided in to two parts:

- **Detailed analysis of the chosen solution:** focusing on key indicators shown in section 2.4 along with an environmental assessment expressed in $kgCO_{2eq}$/MWh, for each individual port in the system.
- **Analysis of the global results** for the entire Portuguese and Spanish port network, focusing once again on the key indicators detailed in section 2.4.

The election of the optimal supply chains is a result of the analysis performed in chapter 4, where the solutions and key indicators are weighted based on professional and experienced criteria and chosen for adapting better than others to the evolution of demand and other specific conditions for each cluster. As a rule, the optimal solution will be such that generates the lowest cost with a minimum level of service (+70%), except the top three highest volume ports, which will satisfy a higher level of service, according to the explanations given in section 2.2.

5.1 *Port-level results*

This chapter summarizes key results for each port – grouped by cluster – as were detailed in chapter 2.4

- **Summary of resources and cost allocation:** all necessary resources/terminals needed for each supply chain were summarized in a table and all the unitary STS and TTS are summarized in a line chart. All those ports were TTS supply service is available, will be represented with a truck icon while all those with STS supply service – only for Base Port – will be represented with the correspondent symbol.
- **Level of service:** Percentage of the total inactive time of a ship, both during operation and while docked in the Base Port. This percentage could be higher than 100% if more than one resource is deployed.
- **Total annual bunkering supply cost,** by type of cost and by port.
- **Investment amount for deployment of expected resources,** expressed as a delta, assuming the continuity of resources throughout time.
- **Impact in the cluster's LNG import terminal,** showing potential earnings for the gas network and total expected use of the infrastructure.

5.1.1 Barcelona Cluster

The aggregation of demand and an LNG import terminal already in place, reduces the total number and capacity of resources needed, obtaining the lowest unitary costs of the whole network.

5.1.1.1 Resource allocation and unitary cost by port.

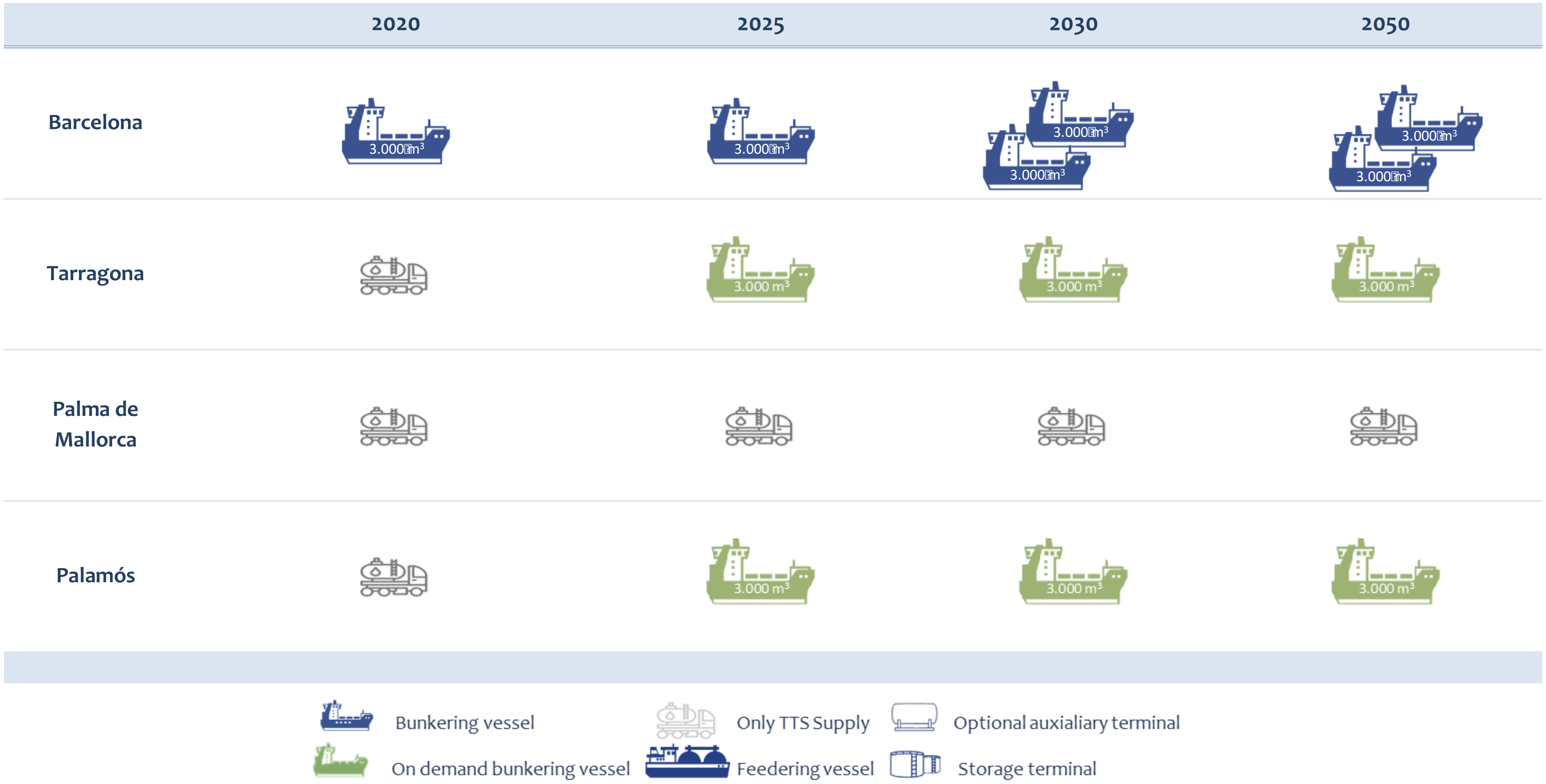
Selected solutions, total demand served and unitary costs for Barcelona cluster, detailed in section 4.1.2 are:

Table 5.1 Selected solutions for Barcelona cluster

Year 2020	Year 2025	Year 2030	Year 2050
1A	2A	2B	3B
259.470 m³	304.853 m³	403.759 m³	998.032 m³
2,93 €/MWh	2,64 €/MWh	3,45 €/MWh	2,49 €/MWh

Final allocation of supply resources and auxiliary terminals for Barcelona Cluster are summarized in Table 5.2, while unitary costs per port and type of supply are reflected in Figure 5.1.

Table 5.2 Resources allocation in Barcelona cluster



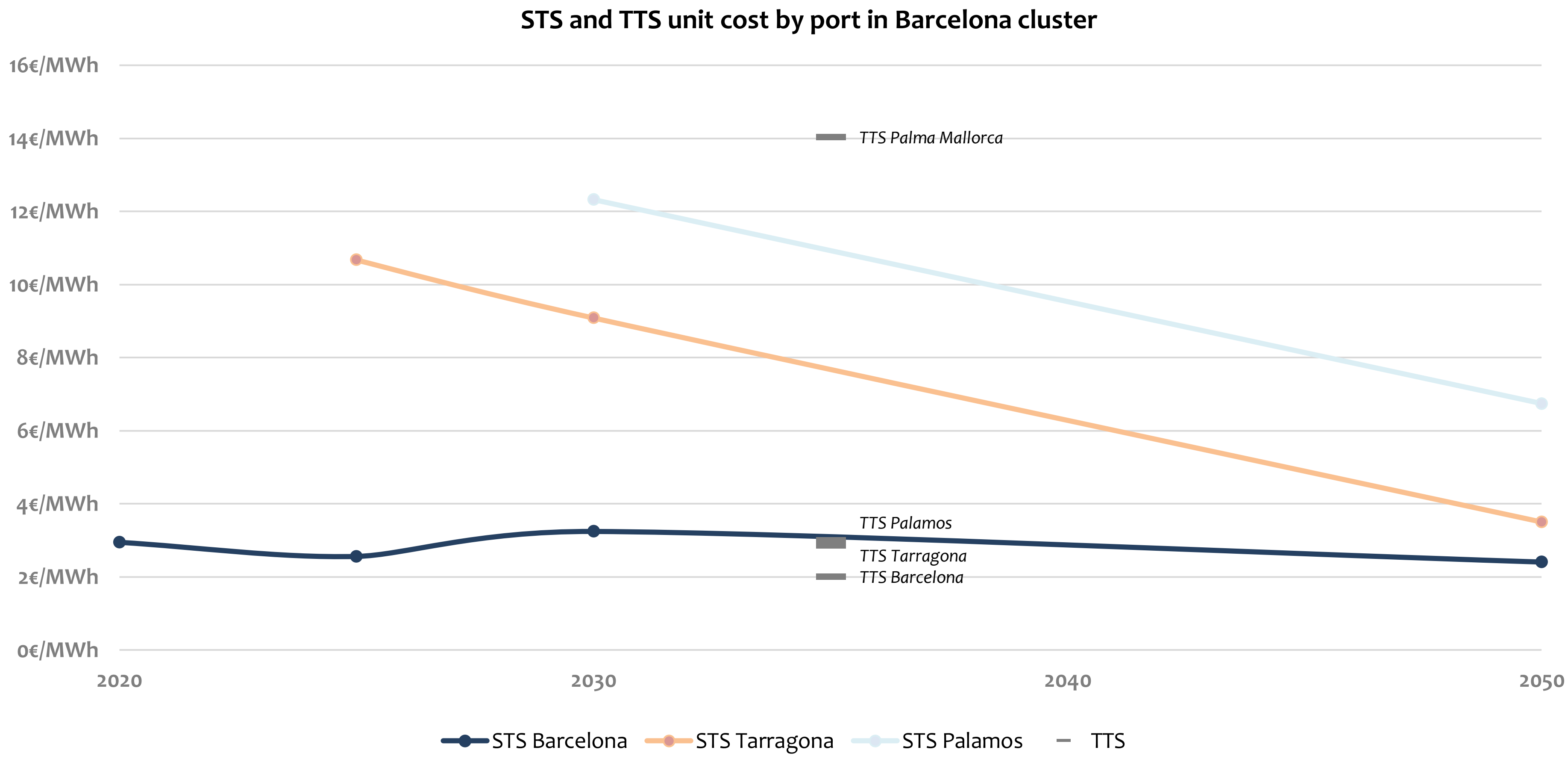


Figure 5.1 STS and TTS supply unit cost by port in Barcelona

TTS cost supply in the graphic above – represented by a grey bar – is not a variable depending on demand, thus is represented as a constant

5.1.1.2 Bunkering supply annual costs

The following figure shows the total annual cost for bunkering supply separated by the 5 different activities included in a supply chain, at a cluster level.

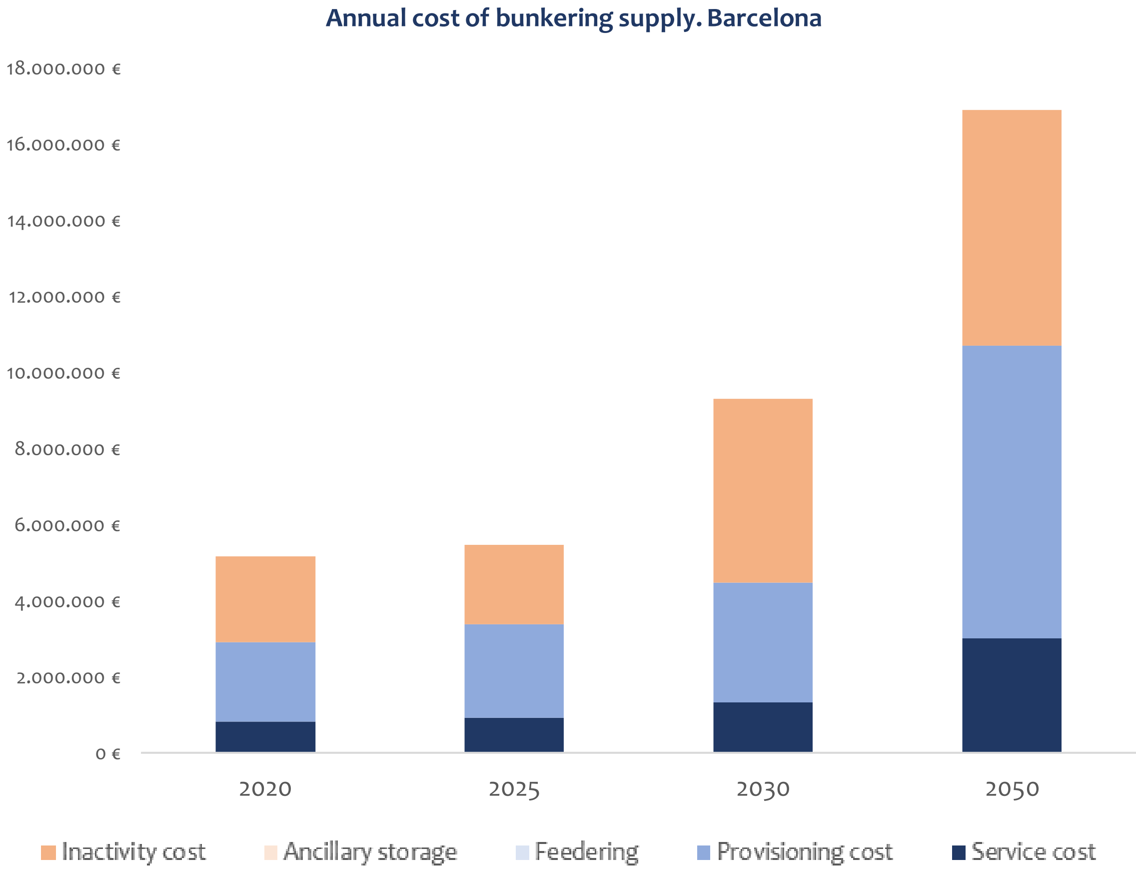


Figure 5.2 Annual cost of bunkering supply in Barcelona cluster

Hosting an LNG import plan in Barcelona reduces the amount of provisioning costs compared to other clusters, however this will be the most relevant cost during the first stages. The position of Barcelona as a reference port in the bunkering market, will require a higher level of availability as of 2030, remarkably increasing inactivity costs.

5.1.1.3 2020-2050 Investment requirements

Expressed as a differential value, investment requirements for this cluster are shown in Figure 5.3

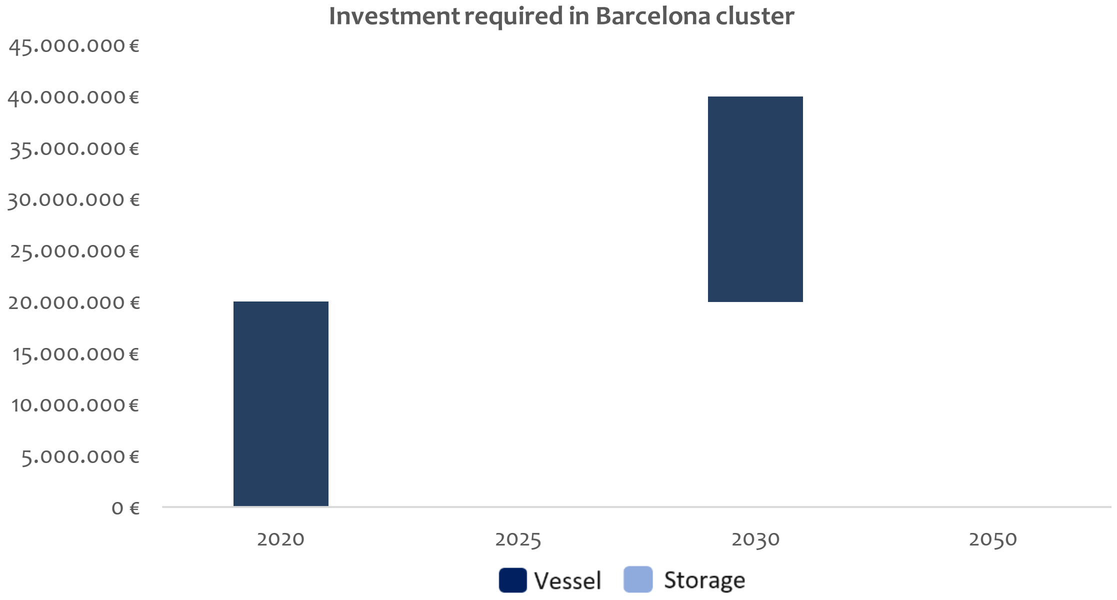


Figure 5.3 Investment required in Barcelona cluster

5.1.1.4 Environmental Impact.

An estimated environmental impact assessment of bunkering activity expressed in CO_{2eq} generated for each cluster has been generated using emission factors detailed in Annex 3 and results obtained from the design of supply chains. Total and unitary values are reflected in the next figure.

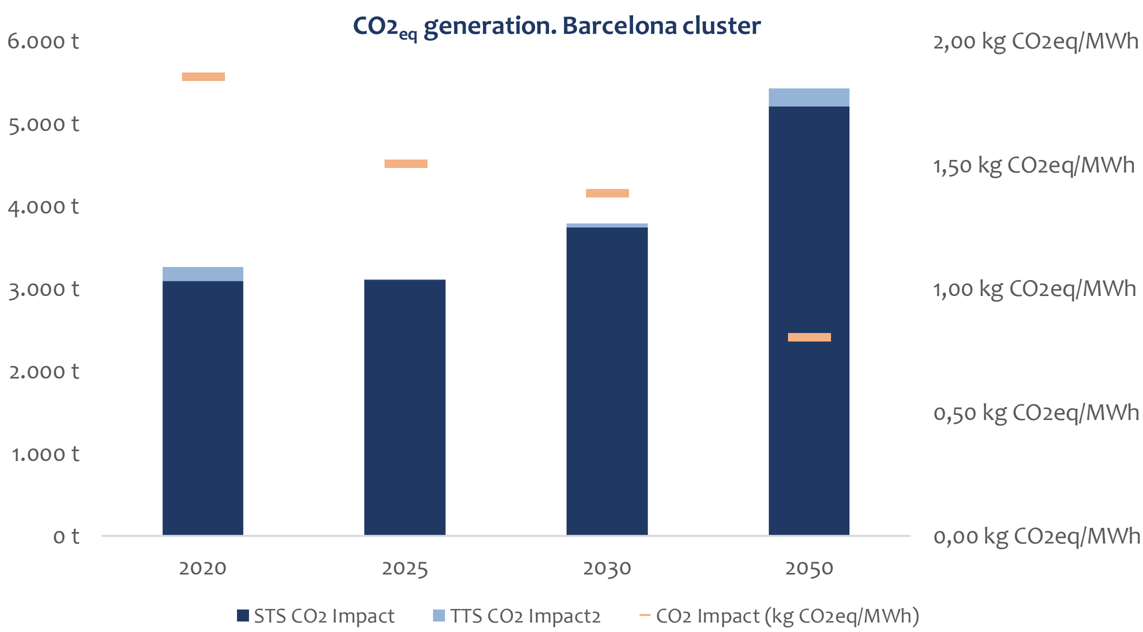


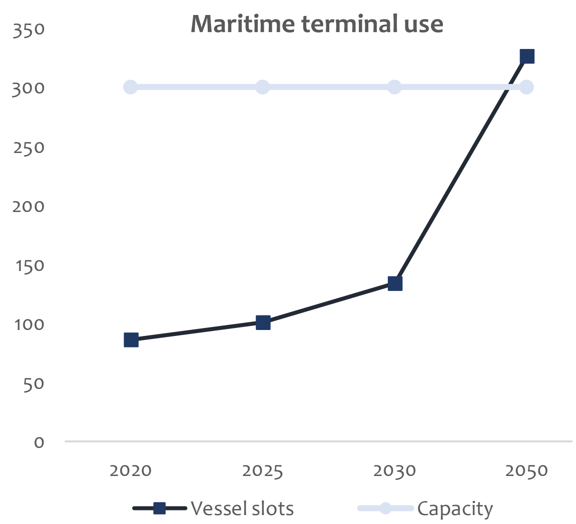
Figure 5.4 CO2eq generation. Cluster Barcelona

5.1.1.5 Impact in Barcelona's port LNG import terminal

Using gas network's LNG loading and unloading facilities involves paying several tolls – Table 2.5-. This total cost is included within the provisioning activity and is reflected in Figure 5.5.

In addition to this, to predict if additional investments would be needed in the import terminals, current import terminal capacity will be contrasted with the extra activity generated by bunkering for both STS – Figure 5.6 – and STS – Figure 5.7-.

Figure 5.5 Total fees cost. Barcelona



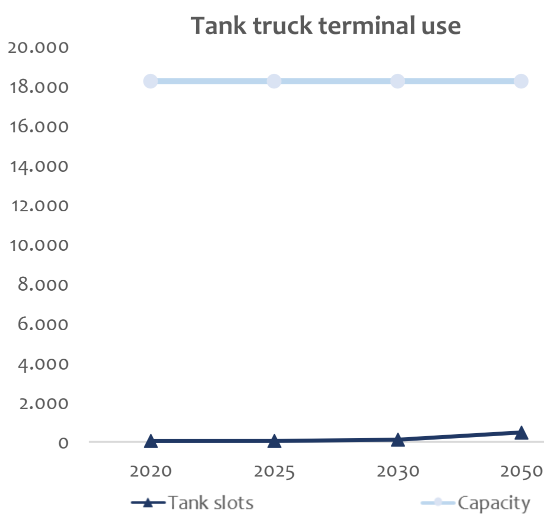


Figure 5.6 Maritime terminal use. Barcelona cluster

Figure 5.7 Tank truck terminal use. (IT) Barcelona

As can be observed in the graphs above, TTS supply impact in the terminal is not important. Only for 2050 expected demand levels – 998,032 m^3 – more than 300 reloads will be made, exceeding the terminal's capacity. This won't require an additional investment in Barcelona since it has two cargo terminals, one of them dedicated to small-scale.

5.1.2 Sagunto Cluster.

Resource allocation in this cluster is very similar to Barcelona's but variations in the expected demand evolution would require lower scale solutions during the first years.

5.1.2.1 Resource allocation and unitary cost by port.

Selected solutions, total demand served and unitary costs for Barcelona cluster, detailed in section 4.2.2 are:

Table 5.3 Selected solutions for Sagunto

Year 2020	Year 2025	Year 2030	Year 2050
1T	2A	3A	6A
14.622 m³	49.363 m³	121.055 m³	572.363 m³
2,45 €/MWh	11,40 €/MWh	5,38 €/MWh	2,93 €/MWh

Final allocation of supply resources and auxiliary terminals for Sagunto Cluster are summarized in Table 5.4, while unitary costs per port and type of supply are reflected in Figure 5.8.

Table 5.4 Resources allocation in Sagunto

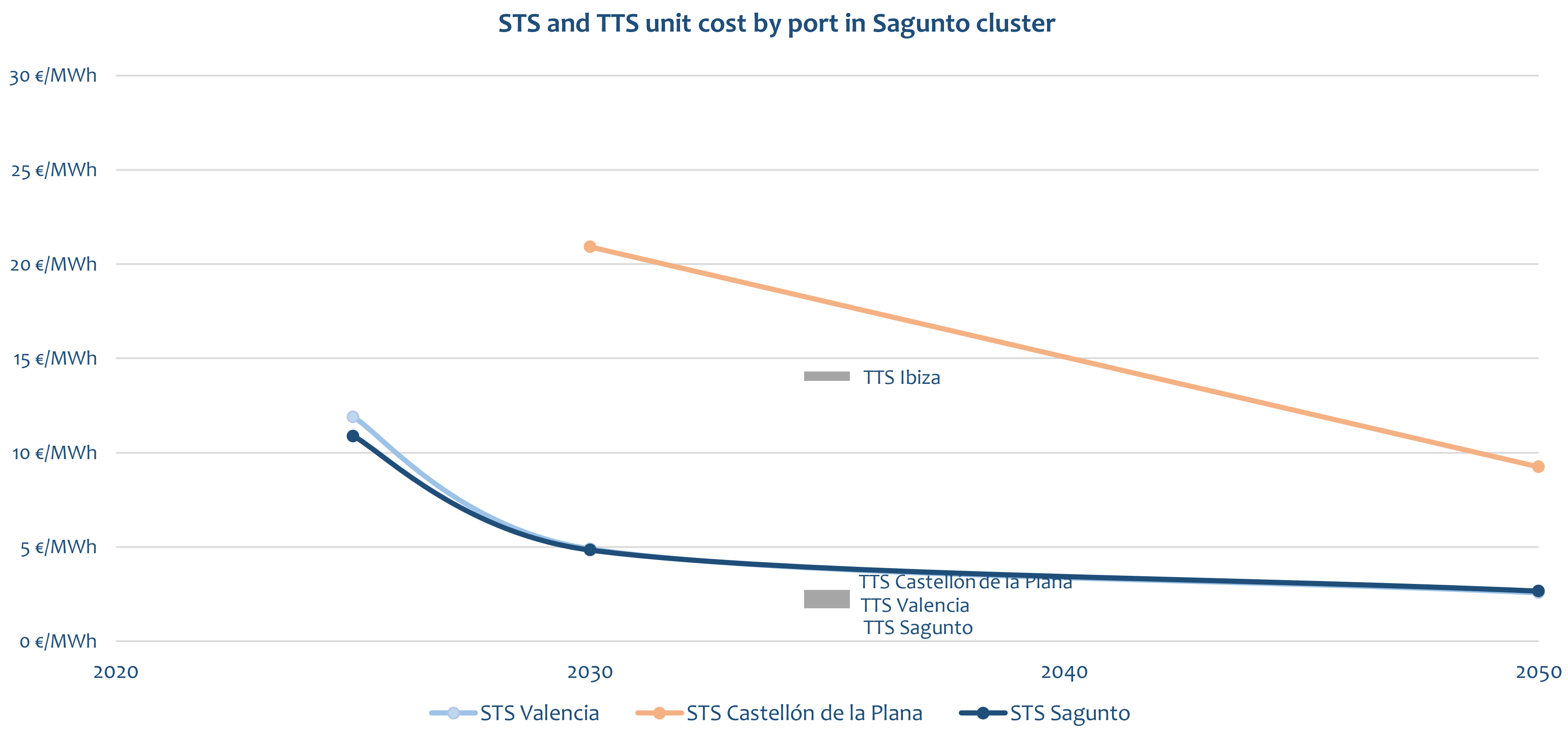


Figure 5.8 STS and TTS supply unit cost by port in Sagunto cluster

STS demand for Ibiza and Alicante is expected to be very low and hasn't been considered as a supply chain for these ports. TTS cost will remain constant regardless of demand evolution.

5.1.2.2 Bunkering supply annual costs

The following figure shows the total annual cost for bunkering supply separated by the 5 different activities included in a supply chain, at a cluster level.

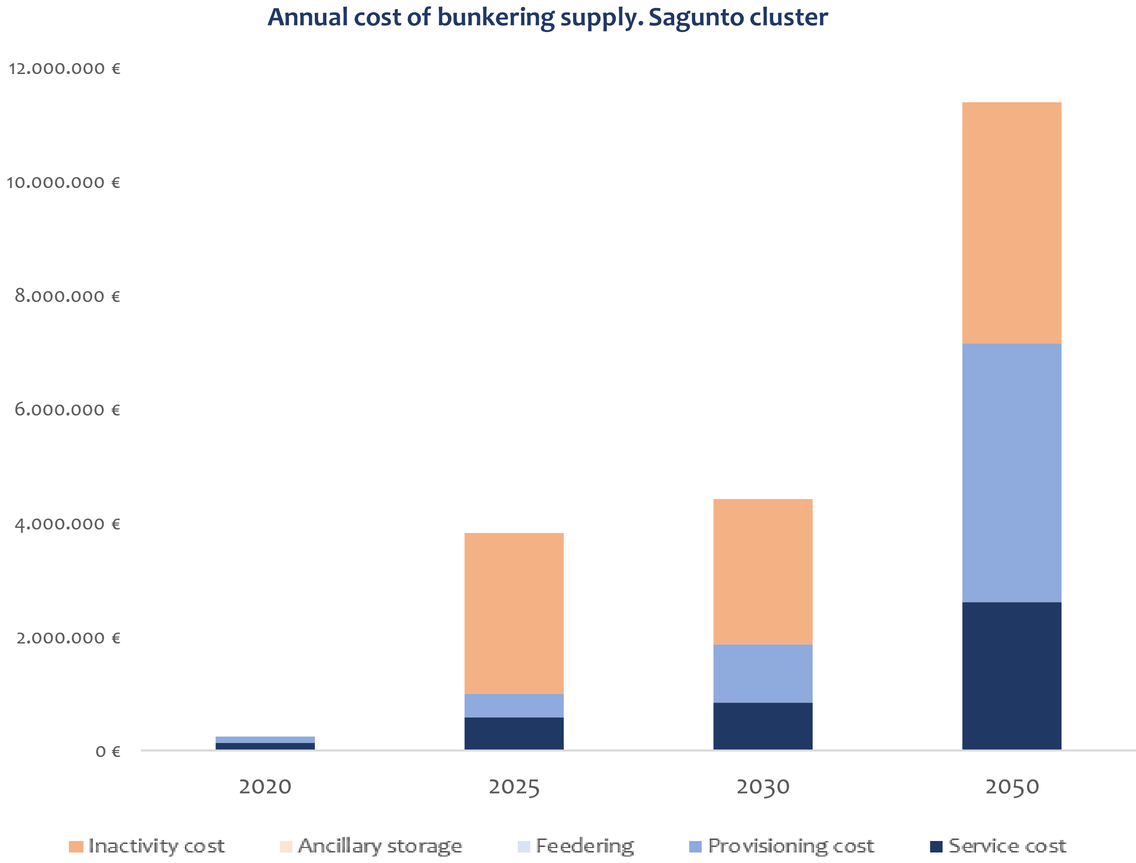


Figure 5.9 Annual cost of bunkering supply in Sagunto cluster

Sagunto cluster has a similar structure to Barcelona's but with a higher inactivity cost due to the lower expected demand.

5.1.2.3 2020-2050 investment requirements

Expressed as a differential value, investment requirements for this cluster are shown in Figure 5.10.

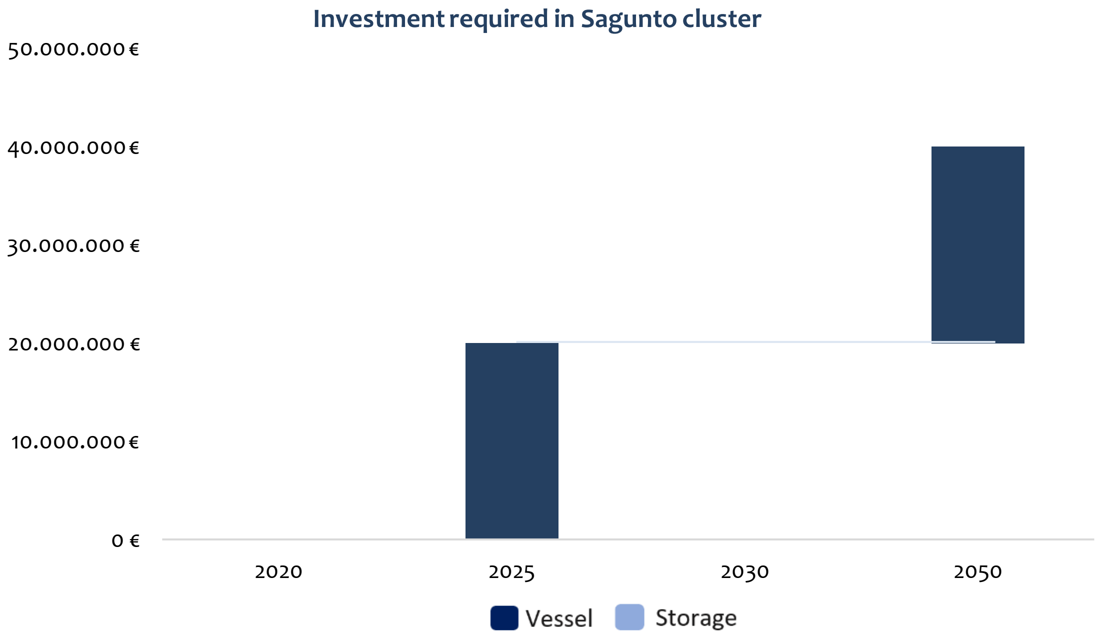


Figure 5.10 Investment required in Sagunto cluster

5.1.2.4 Environmental impact

An estimated environmental impact assessment of bunkering activity expressed in CO_{2eq} generated for each cluster has been generated using emission factors detailed in Annex 3 and results obtained from the design of supply chains. Total and unitary values are reflected in the next figure.

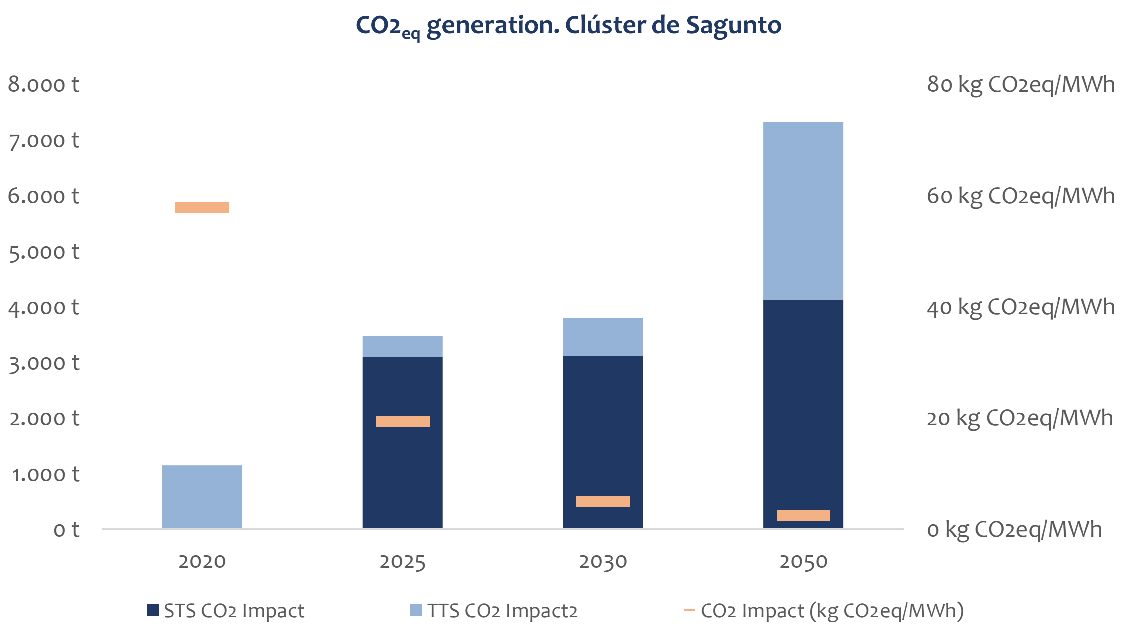


Figure 5.11 CO2eq generation. Cluster Sagunto

5.1.2.5 Impact in Sagunto's port LNG import terminal

Using gas network's LNG loading and unloading facilities involves paying several tolls – Table 2.5-. This total cost is included within the provisioning activity and is reflected in Figure 5.12.

In addition to this, to predict if additional investments would be needed in the import terminals, current import terminal capacity will be contrasted with the extra activity generated by bunkering for both STS – Figure 5.13 – and STS – Figure 5.14-.

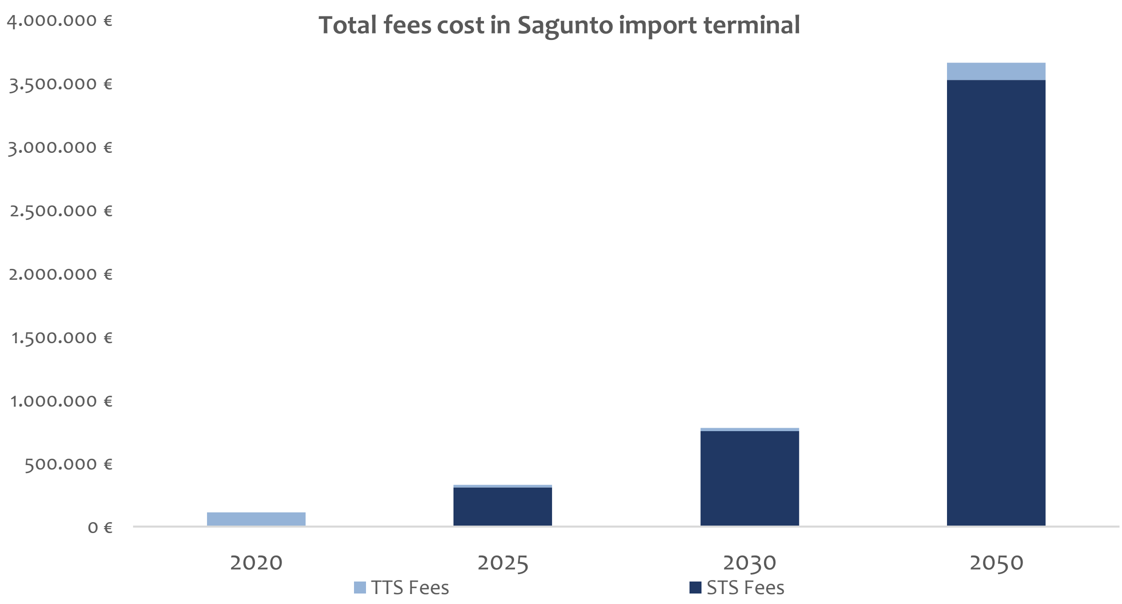
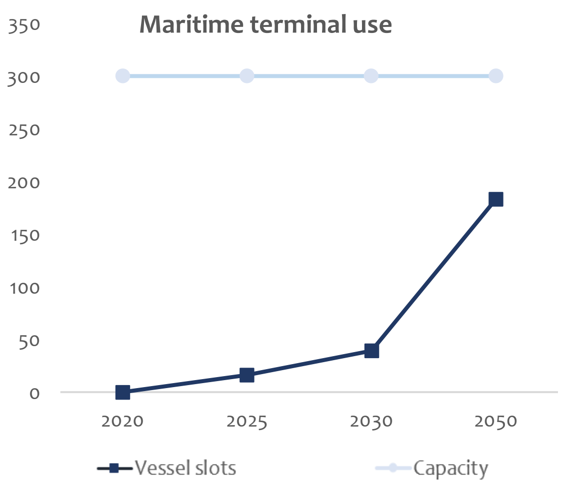


Figure 5.12 Total fees cost. Sagunto



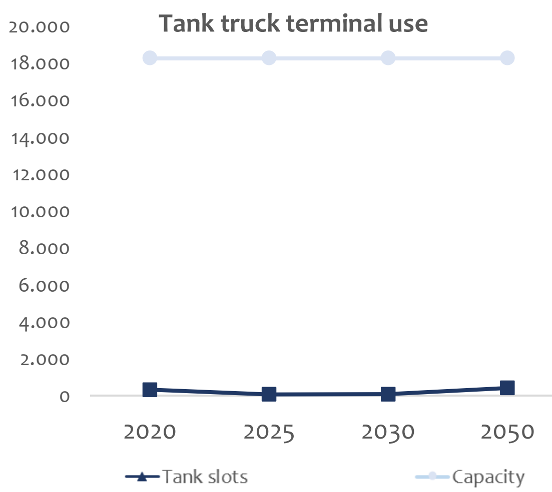


Figure 5.13 Maritime terminal use. (IT) Sagunto

Figure 5.14 Tank truck terminal use. (IT) Sagunto

In this case only 183 reloads are registered, thus according to the terminal's current activity, existing infrastructure will be enough.

5.1.3 Cartagena Cluster

Low demand expected in this cluster calls for a TTS supply operation until 2050, when demand levels will be above the 100,000 m^3 level, high enough to include a supply ship.

5.1.3.1 Resource allocation and unitary cost by port.

Selected solutions, total demand served and unitary costs for Barcelona cluster, detailed in section 4.3.2 are:

Table 5.5 Selected solutions for Cartagena

Year 2020	Year 2025	Year 2030	Year 2050
1T	1T	1T	4A
1.535 m^3	6.793 m^3	18.326 m^3	86.700 m^3
3,02 €/MWh	3,02 €/MWh	3,02 €/MWh	6,82 €/MWh

Final allocation of supply resources and auxiliary terminals for Barcelona Cluster are summarized in Table 5.6, while unitary costs per port and type of supply are reflected in Figure 5.15.

Table 5.6 Resources allocation in Cartagena

	2020	2025	2030	2050
Cartagena				3.000 m^3
Motril				3.000 m^3
Almería				3.000 m^3

Bunkering vessel — Only TTS Supply — Optional auxialiary terminal

On demand bunkering vessel — Feedering vessel — Storage terminal

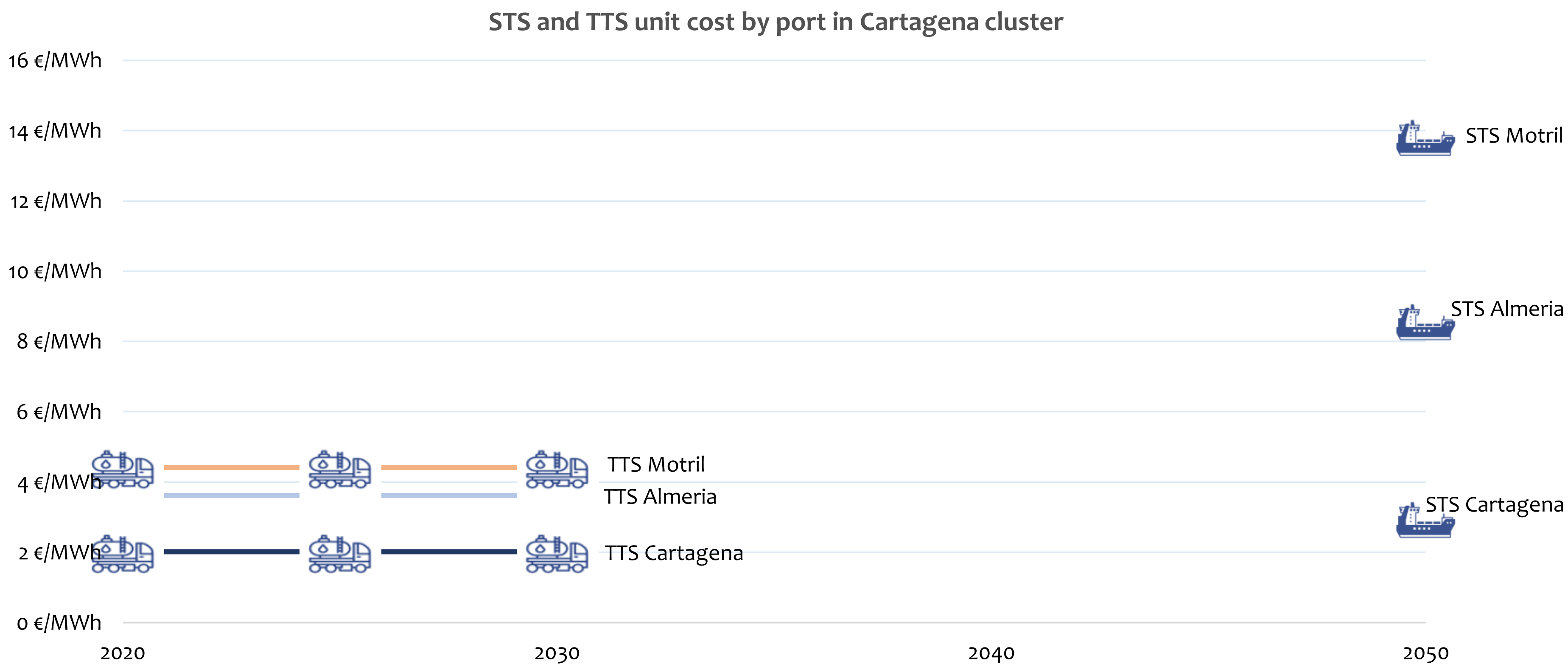


Figure 5.15 STS and TTS supply unit cost by port in Cartagena cluster

Unlike previous graphs representing unitary costs, TTS supply cost evolution is shown here as a continuous line. For levels of demand expected in this cluster, STS supply will only be available as of 2050.

5.1.3.2 Bunkering supply annual costs.

The following figure shows the total annual cost for bunkering supply separated by the 5 different activities included in a supply chain, at a cluster level.

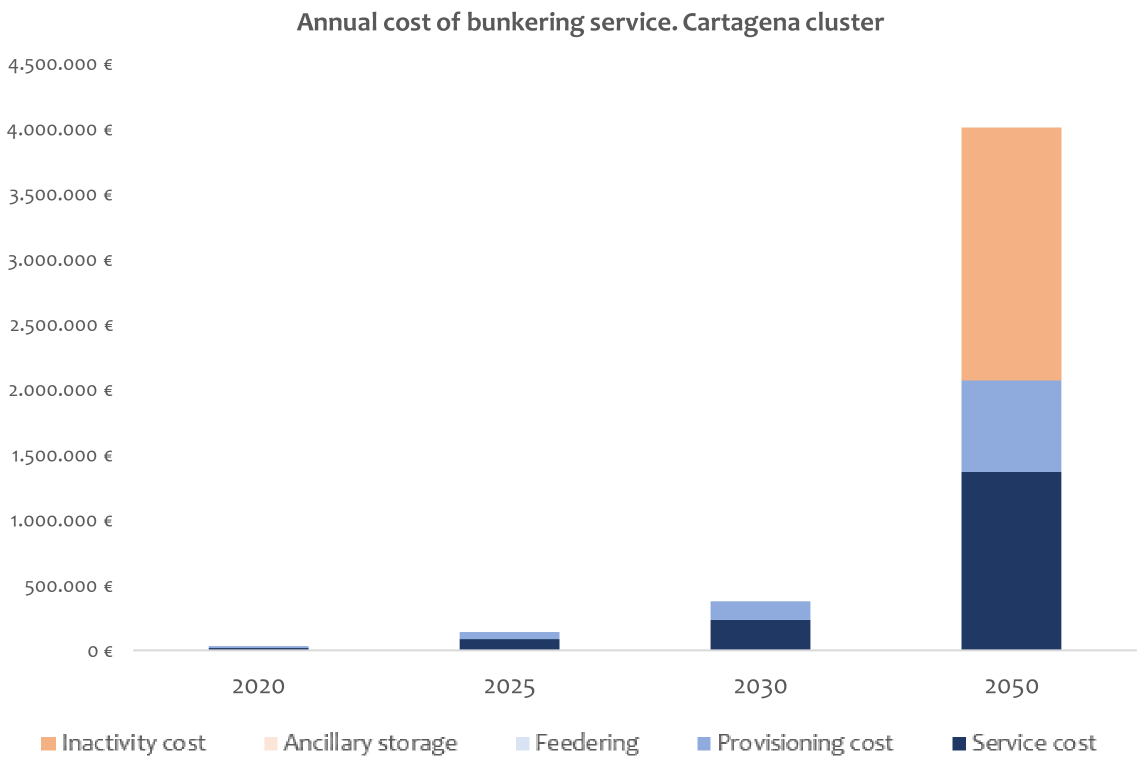


Figure 5.16 Annual cost of bunkering supply in Cartagena cluster

If we look at year 2050 – only with STS supply – we see how a low demand increases inactivity costs in a more relevant way than we've seen in other clusters.

5.1.3.3 2020-2050 investment requirements

Expressed as a differential value, investment requirements for this cluster are shown in Figure 5.17.

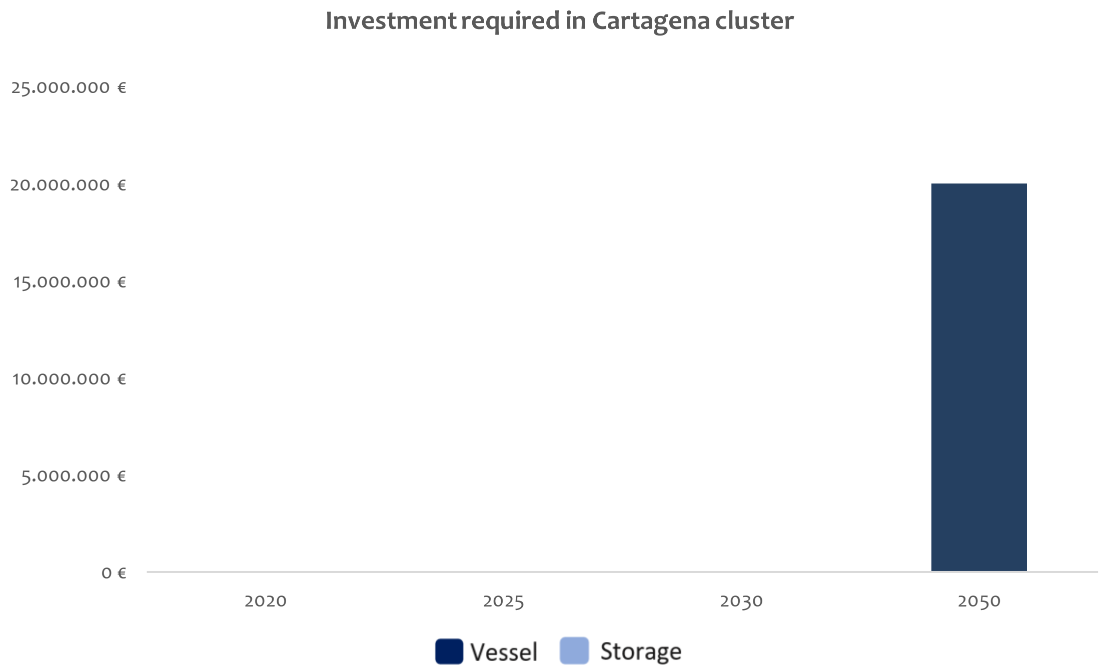


Figure 5.17 Investment required in Cartagena cluster

5.1.3.4 Environmental impact

An estimated environmental impact assessment of bunkering activity expressed in CO_{2eq} generated for each cluster has been generated using emission factors detailed in Annex 3 and results obtained from the design of supply chains. Total and unitary values are reflected in the next figure.

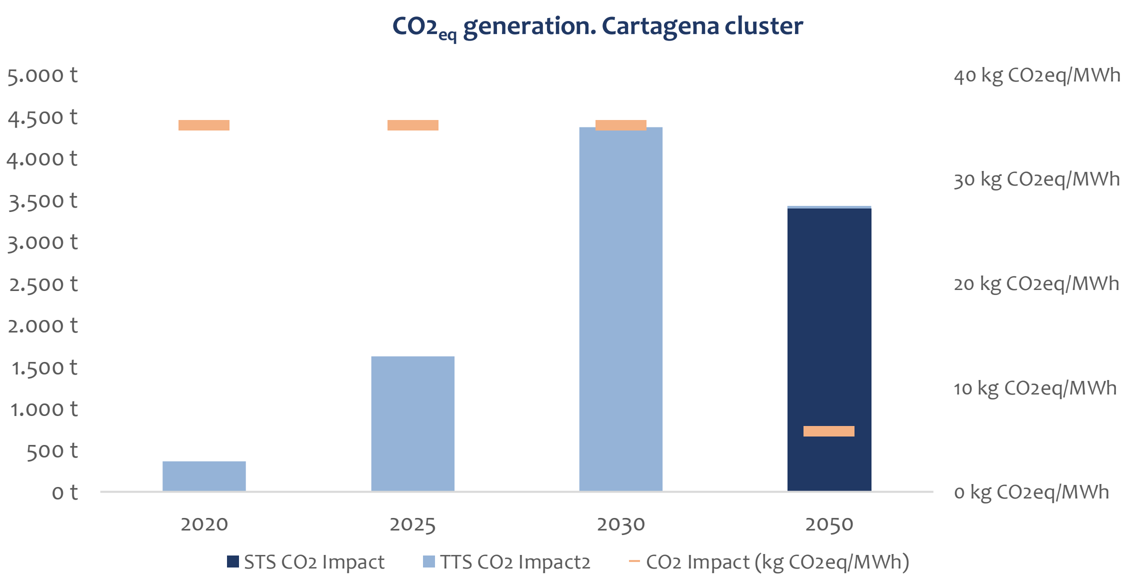


Figure 5.18 CO2eq generation. Cluster Cartagena

5.1.3.5 Impact in Cartagena's port LNG import terminal

Using gas network's LNG loading and unloading facilities involves paying several tolls – Table 2.5-. This total cost is included within the provisioning activity and is reflected in Figure 5.19.

In addition to this, to predict if additional investments would be needed in the import terminals, current import terminal capacity will be contrasted with the extra activity generated by bunkering for both STS – Figure 5.20 – and STS – Figure 5.21-.

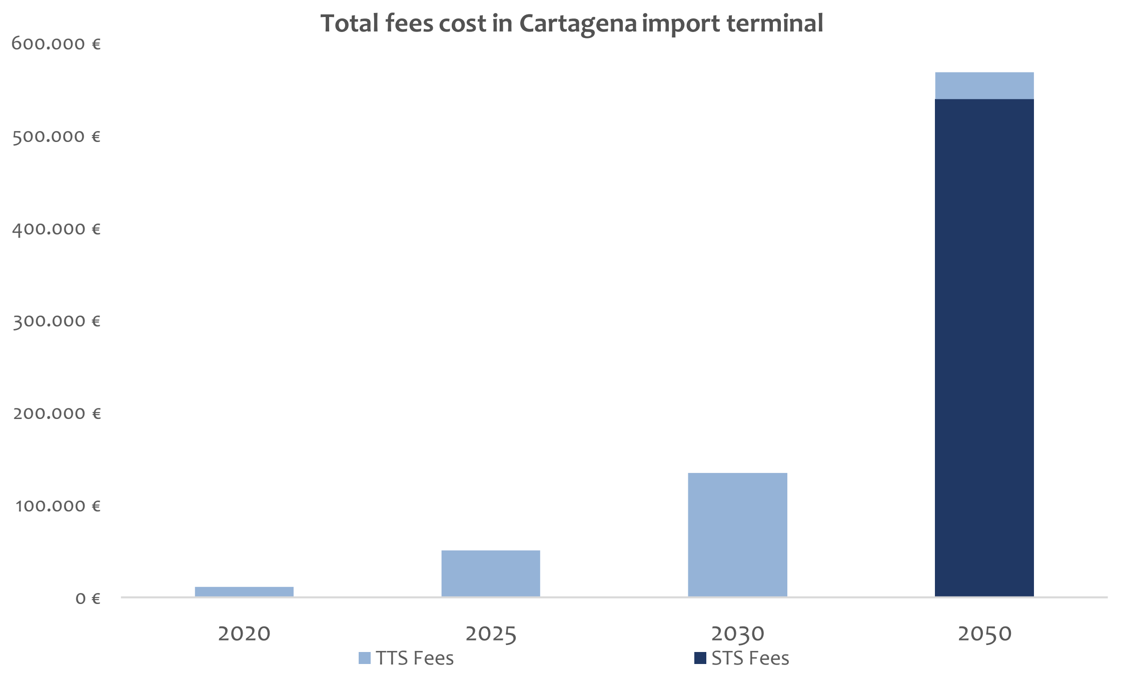


Figure 5.19 Total fees cost. Cartagena

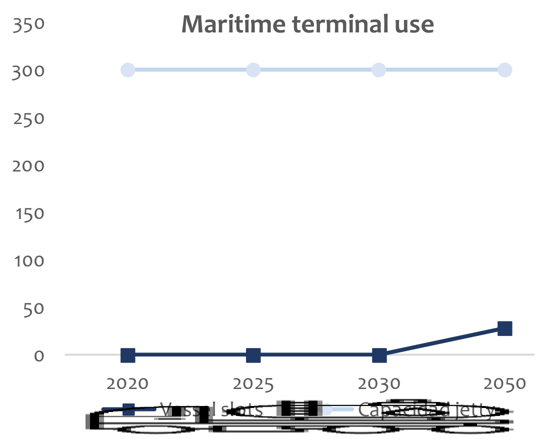


Figure 5.20 Maritime terminal use. (IT) Cartagena

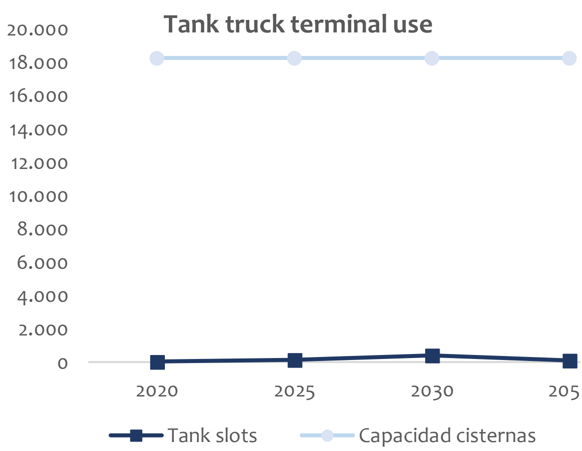


Figure 5.21 Tank truck terminal use. (IT) Cartagena

Expected demand in this cluster is low and won't have a great impact in the LNG terminal, thus, no additional investment would be necessary.

5.1.4 Huelva Cluster

High volume expected in the port of Algeciras and its distance to the closest LNG import terminal, -120 nm – make this the most relevant port in number of supply resources and is considered for the construction of additional auxiliary storage facilities.

5.1.4.1 Resource allocation and unitary cost by port

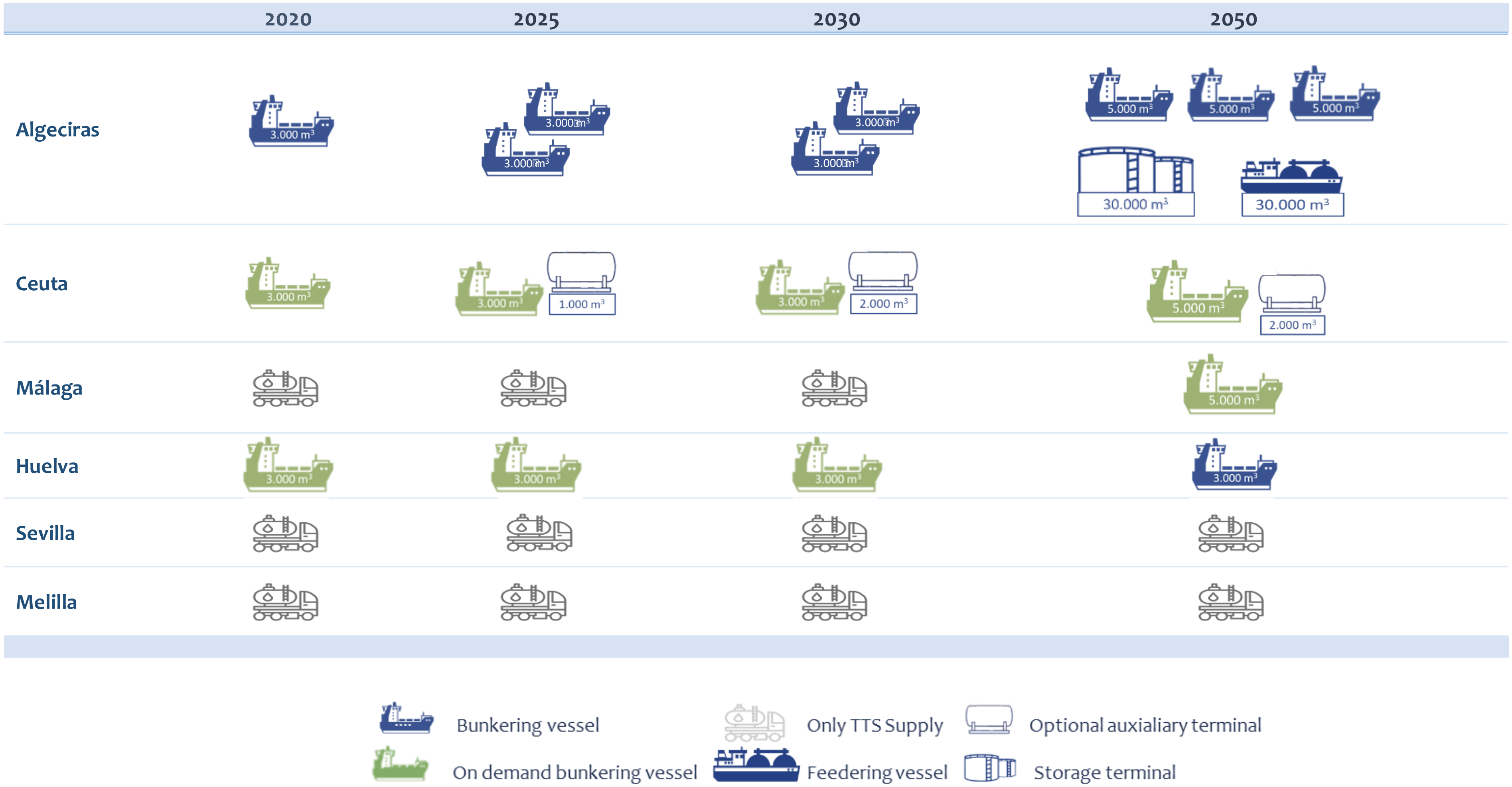
Selected solutions, total demand served and unitary costs for Barcelona cluster, detailed in section 4.4.2 are:

Table 5.7 Selected solutions for Huelva

Year 2020	Year 2025	Year 2030	Year 2050
1A	3A	5A	8B
126.995 m^3	352.956 m^3	816.240 m^3	3.578.642 m^3
5,53 €/MWh	4,52 €/MWh	2,70 €/MWh	2,76 €/MWh

Final allocation of supply resources and auxiliary terminals for Huelva Cluster are summarized in Table 5.8, while unitary costs per port and type of supply are reflected in Figure 5.22.

Table 5.8 Resources allocation in Huelva cluster



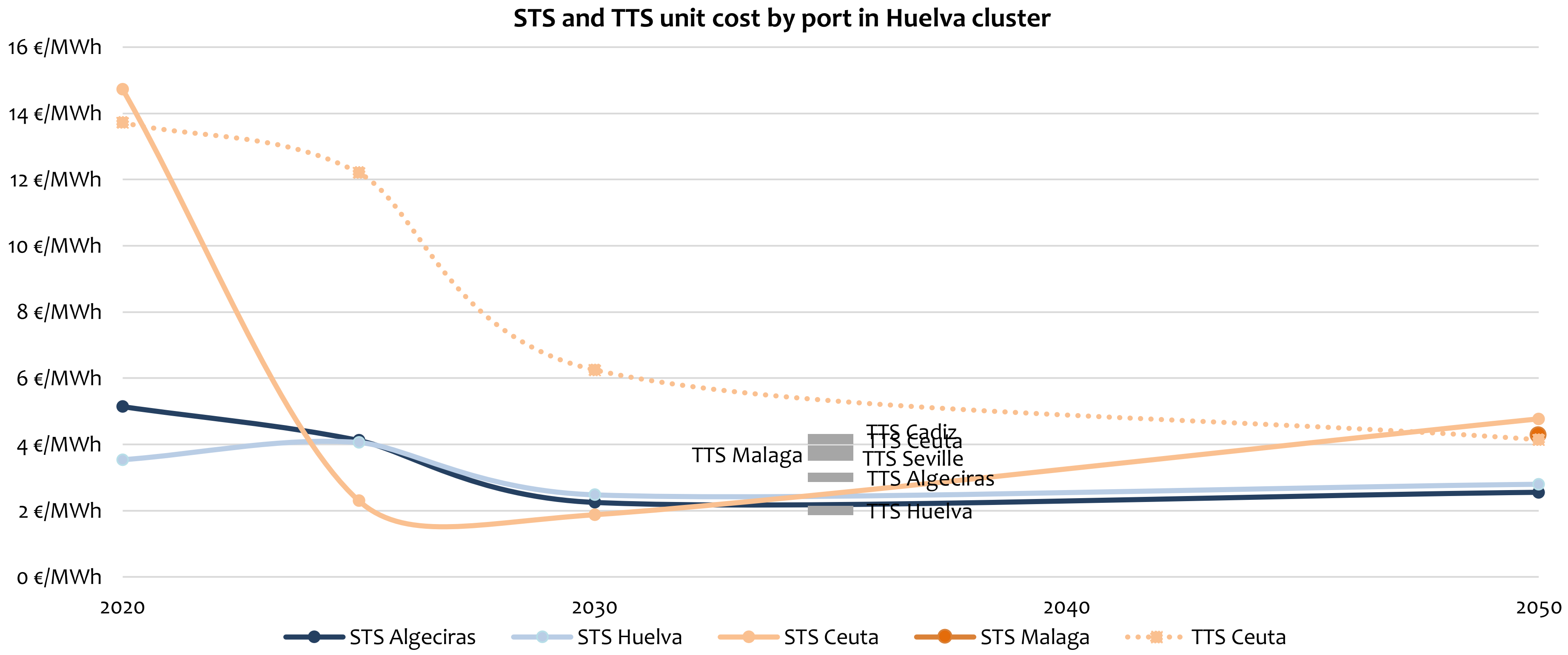


Figure 5.22 STS and TTS supply unit cost by port in Huelva

Since TTS supply in Ceuta will be carried out from an auxiliary storage terminal – beginning 2025 - and not from Huelva's import terminal, unitary costs will vary depending on the total demand served, thus, are represented by a continuous line unlike TTS supply costs for other ports – represented by a grey horizontal bar and constant throughout the expected demand-.

5.1.4.2 Bunkering supply annual costs

The following figure shows the total annual cost for bunkering supply separated by the 5 different activities included in a supply chain, at a cluster level.

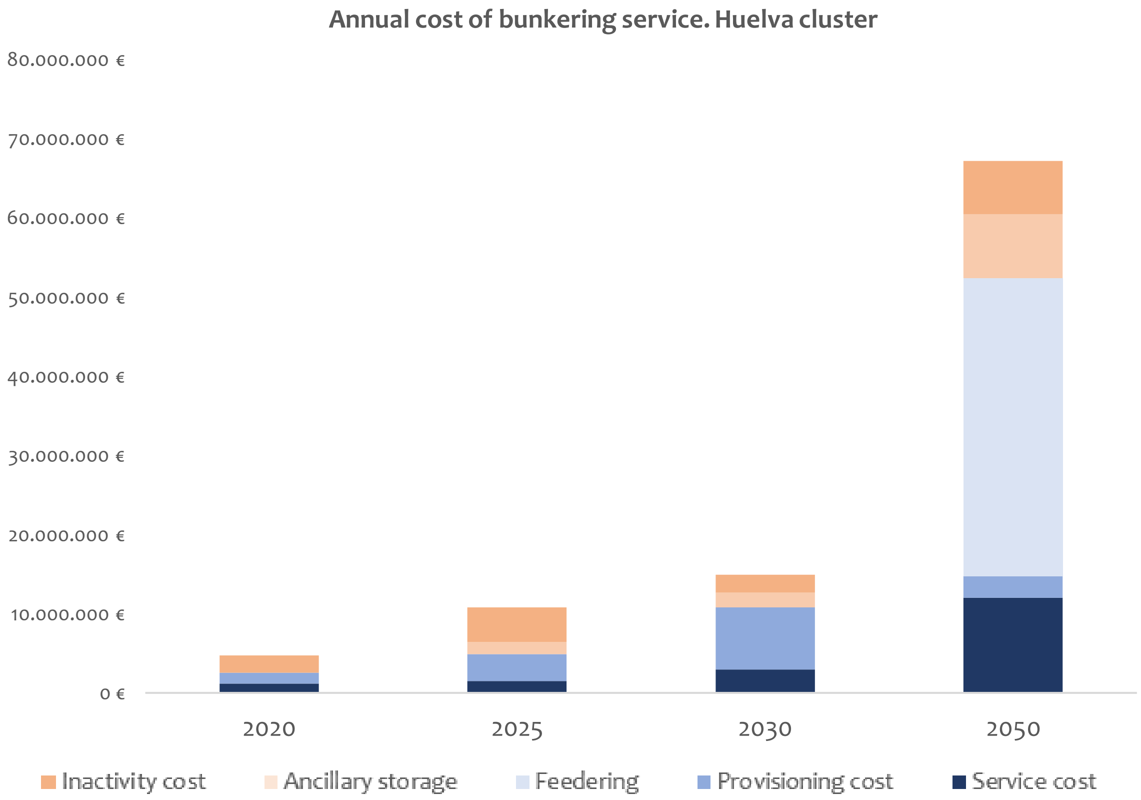


Figure 5.23 Annual cost of bunkering supply in Barcelona cluster

Most important cost for this cluster will be product provisioning or feedering – as of 2050 - because of the long distance separating the main port from the import terminal.

5.1.4.3 2020-2050 investment requirements

Expressed as a differential value, investment requirements for this cluster are shown in Figure 5.24

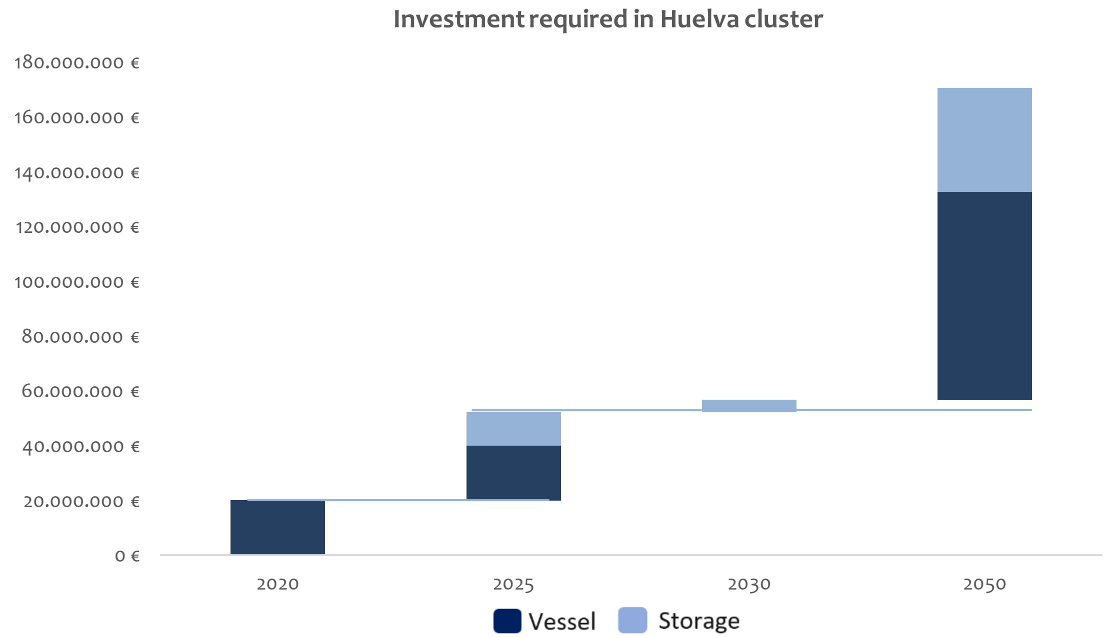


Figure 5.24 Investment required in Huelva cluster

5.1.4.4 Environmental impact.

An estimated environmental impact assessment of bunkering activity expressed in CO_{2eq} generated for each cluster has been generated using emission factors detailed in Annex 3 and results obtained from the design of supply chains. Total and unitary values are reflected in the next figure.

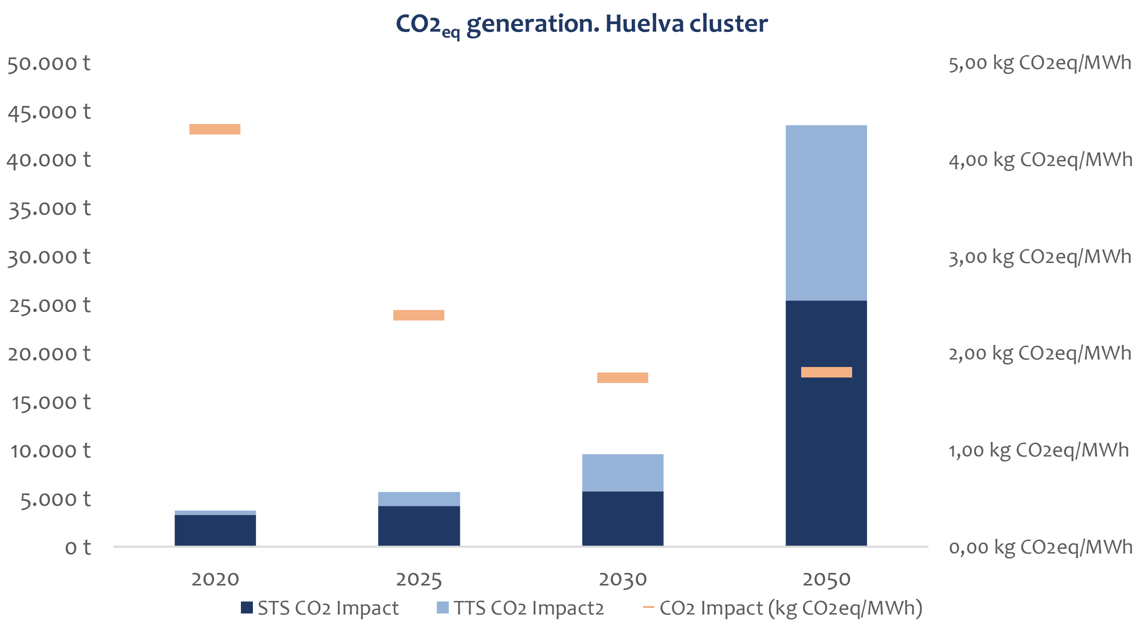


Figure 5.25 CO2eq generation. Cluster Huelva

5.1.4.5 Impacto en la terminal de LNG del puerto de Huelva

Using gas network's LNG loading and unloading facilities involves paying several tolls – Table 2.5-. This total cost is included within the provisioning activity and is reflected in Figure 5.26.

In addition to this, to predict if additional investments would be needed in the import terminals, current import terminal capacity will be contrasted with the extra activity generated by bunkering for both STS – Figure 5.27 – and STS – Figure 5.28-.

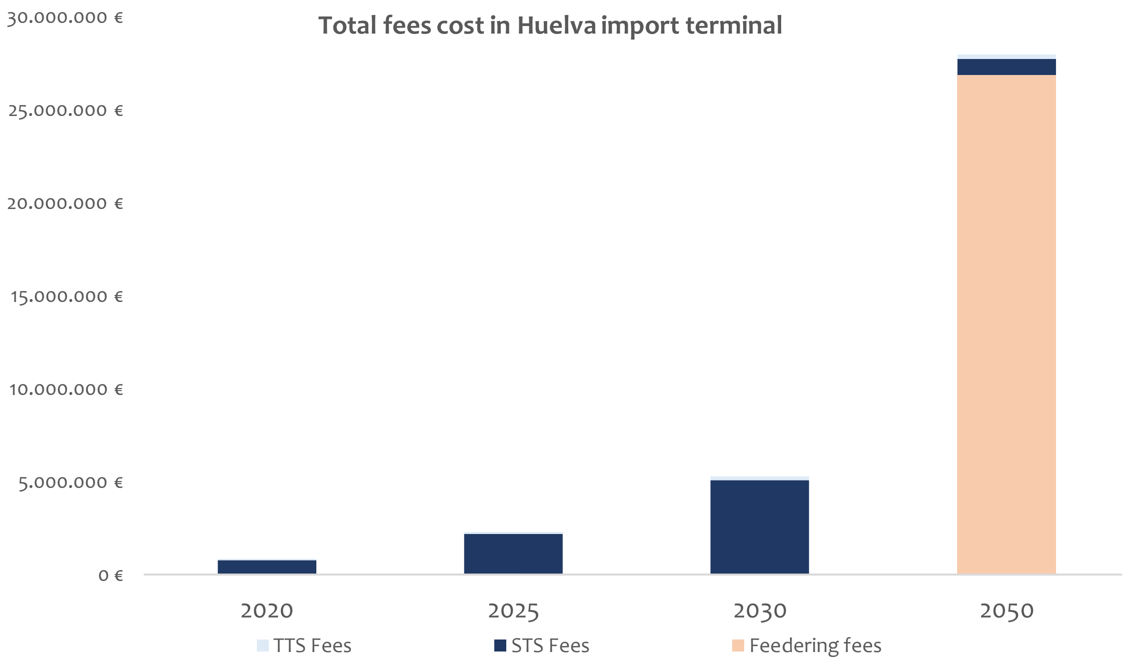


Figure 5.26 Total fees cost. Sagunto

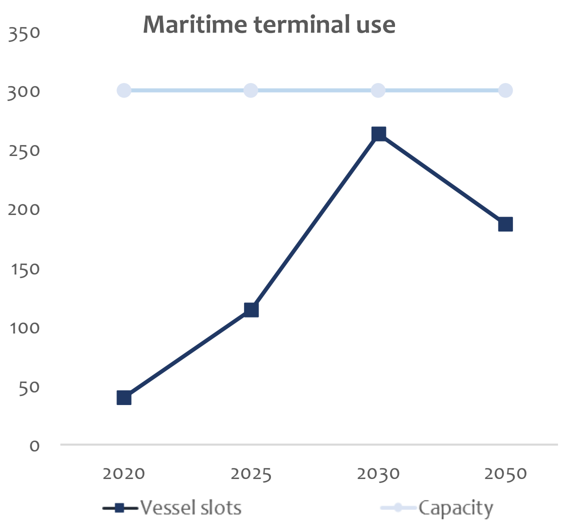


Figure 5.27 Maritime terminal use. (IT) Huelva

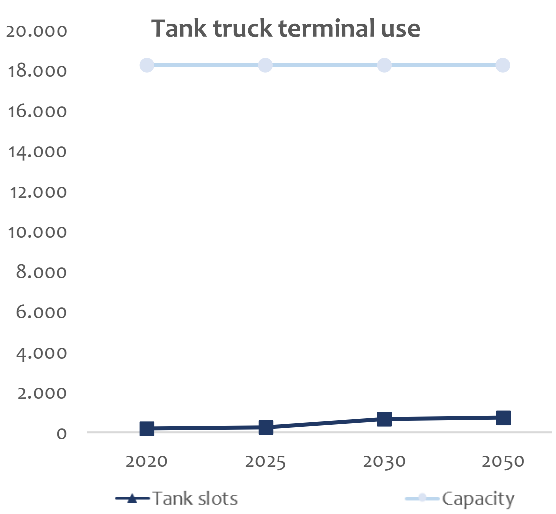


Figure 5.28 Tank truck terminal use. (IT) Huelva

The expected 263 expected reloads in Huelva's import terminal, second highest terminal in the domestic network – 57 methane ships load in 2017 – and with no small-scale terminal like Barcelona, can cause a considerable impact. Even though this level of demand is expected to decrease by 2050 because of the substitution of a 3,000 m^3 supply ship by a 30,000 m^3 transport ship, the amount of LNG serve in the terminal would triple and occupation and reload times would increase as well, producing a potential overload of the terminal if additional investment isn't considered.

5.1.5 Sines cluster

This cluster analysis was divided into peninsular and insular ports, generating two individual analysis with their own resources and supply chains but always supplied by the LNG import terminal in Sines. This section summarizes peninsular ports. Madeira archipelago results were analyzed in section 4.5.3.

5.1.5.1 Resource allocation and unitary cost by port.

Selected solutions, total demand served and unitary costs for Barcelona cluster, detailed in section 4.5.2 are:

Table 5.9 Selected solutions for Sines cluster

Year 2020	Year 2025	Year 2030	Year 2050
1T	1A	2A	5A
8.967 m^3	38.087 m^3	104.125 m^3	482.200 m^3
2,86 €/MWh	10,43 €/MWh	5,89 €/MWh	3,89 €/MWh

Final allocation of supply resources and auxiliary terminals for Barcelona Cluster are summarized in Table 5.10, while unitary costs per port and type of supply are reflected in Figure 5.29.

Table 5.10 Resources allocation in Sines cluster

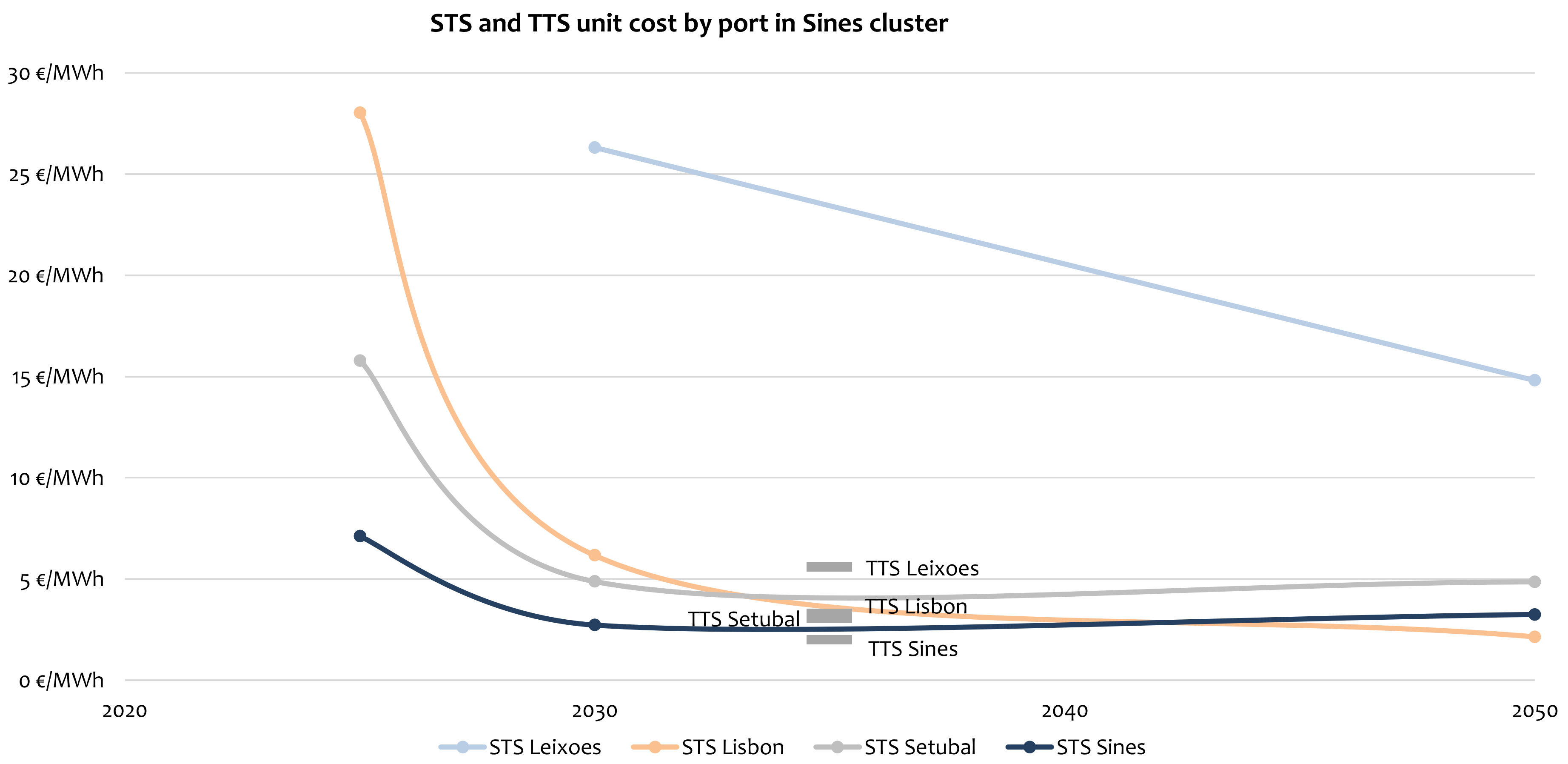


Figure 5.29 STS and TTS supply unit cost by port in Sines

Remoteness of import terminal and low expected demand increase supply costs considerably in port of Leixoes.

5.1.5.2 Bunkering supply annual costs

The following figure shows the total annual cost for bunkering supply separated by the 5 different activities included in a supply chain, at a cluster level.

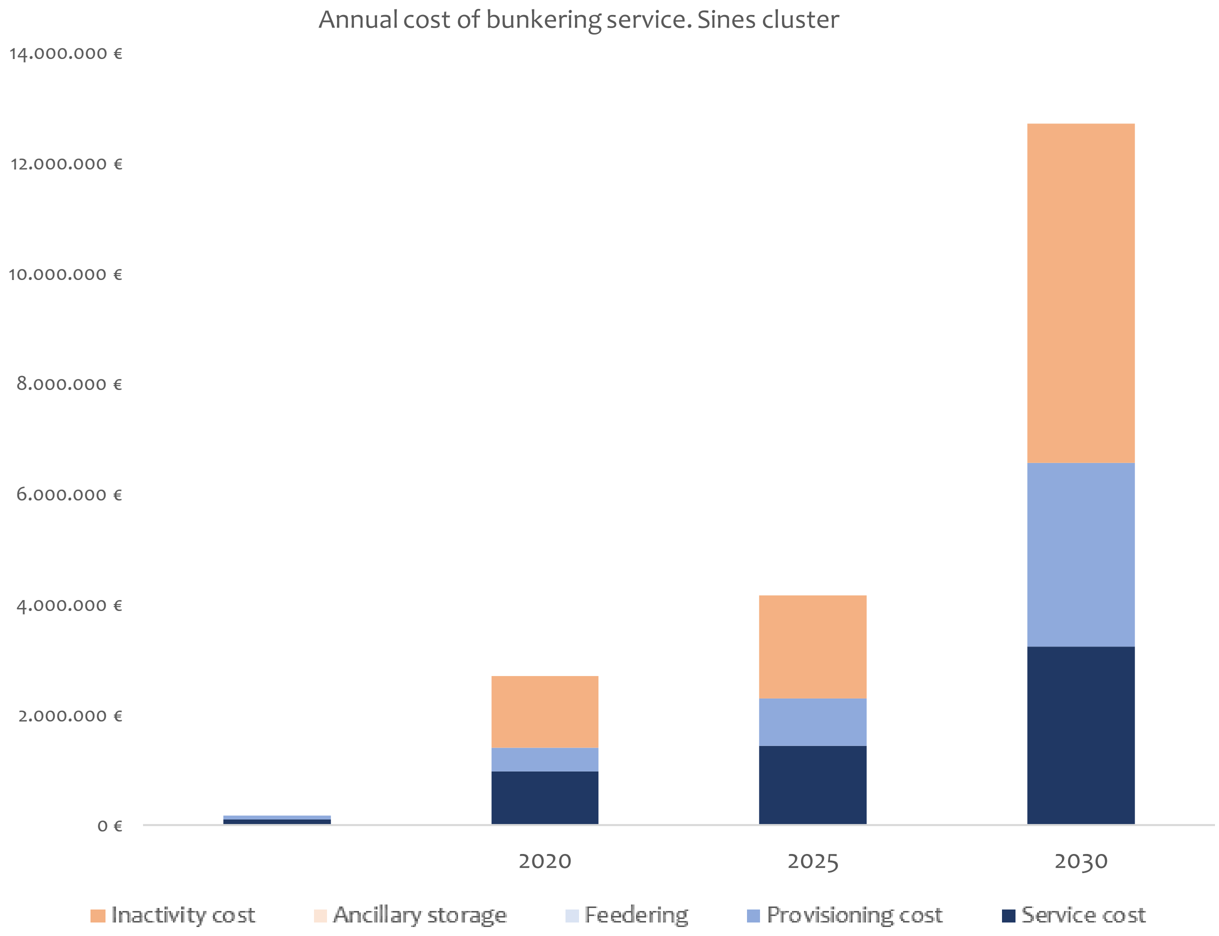


Figure 5.30 Annual cost of bunkering supply in Sines cluster

A higher geographic dispersion of demand in this cluster increases costs considerably, in a more relevant way than observed in other clusters.

5.1.5.3 2020-2050 investment requirements

Expressed as a differential value, investment requirements for this cluster are shown in Figure 5.31.

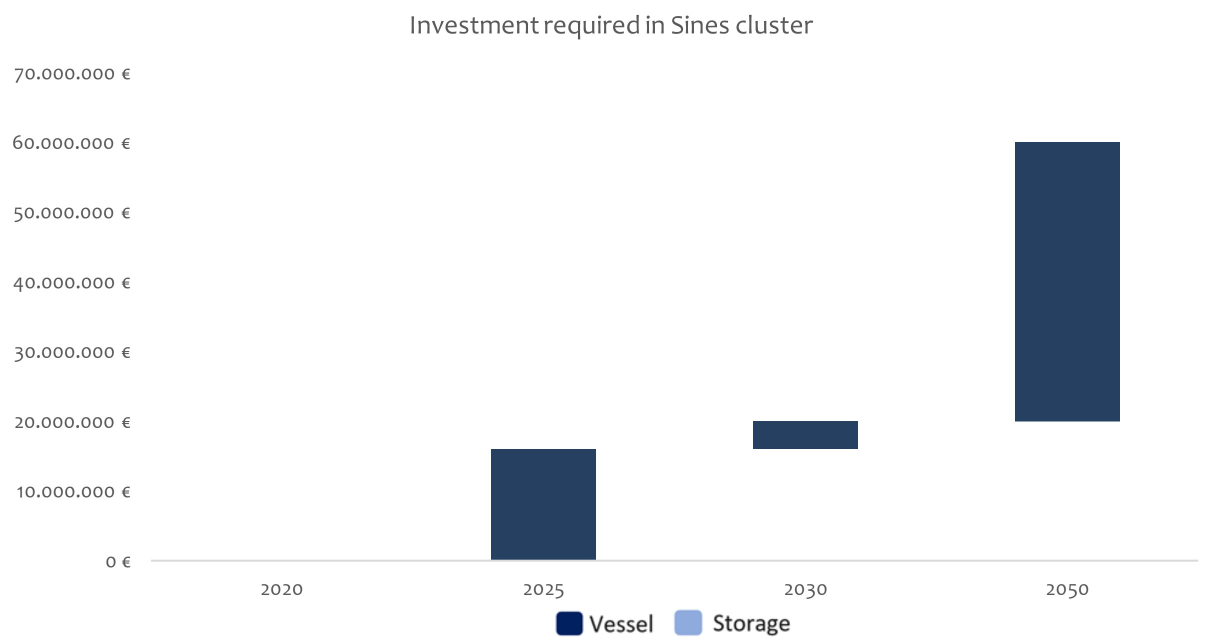


Figure 5.31 Investment required in Sines cluster

5.1.5.4 Environmental Impact.

An estimated environmental impact assessment of bunkering activity expressed in CO_{2eq} generated for each cluster has been generated using emission factors detailed in Annex 3 and results obtained from the design of supply chains. Total and unitary values are reflected in the next figure.

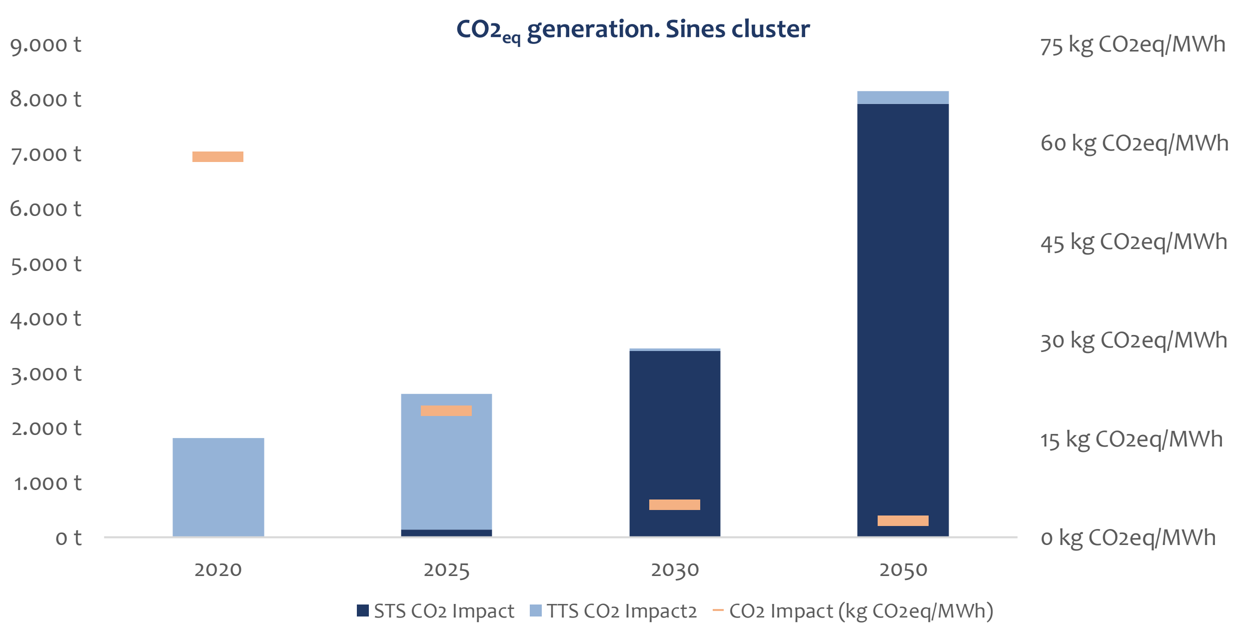


Figure 5.32 CO2eq generation. Cluster Sines

5.1.5.5 Impact in Sines' port LNG import terminal

Using gas network's LNG loading and unloading facilities involves paying several tolls – Table 2.5-. This total cost is included within the provisioning activity and is reflected in Figure 5.33.

In addition to this, to predict if additional investments would be needed in the import terminals, current import terminal capacity will be contrasted with the extra activity generated by bunkering for both STS – Figure 5.34 – and STS – Figure 5.35-.

Figure 5.33 Total fees cost. Sines

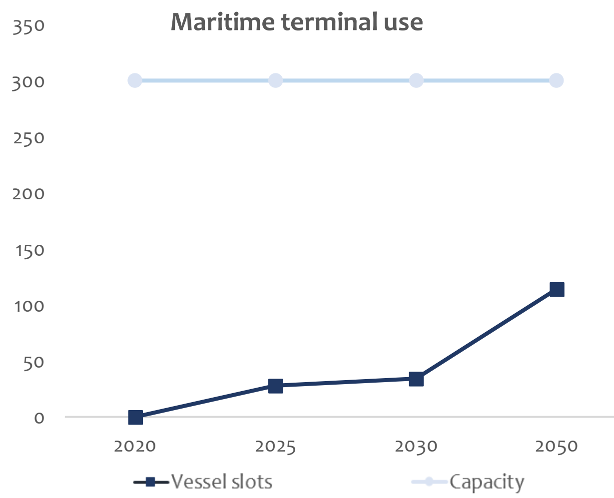


Figure 5.34 Maritime terminal use. (IT) Sines

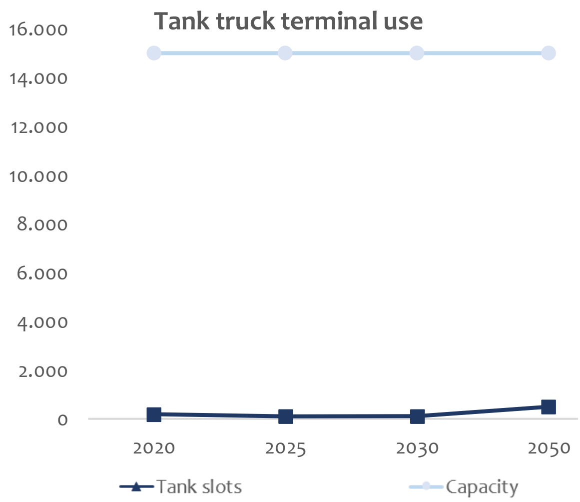


Figure 5.35 Tank truck terminal use. (IT) Sines

The estimated 114 cargos after 2030 may have direct impact on existing jetty availability and booked capacity for discharging slots. A specific assessment should be performed regarding the costs and benefit of providing new docking facilities for small scale ships.

5.1.6 Ferrol Cluster

Low demand expected in this cluster suggest keeping a TTS supply service until 2050, when demand levels are expected to rise above 100,000 m³ allowing the incorporation of a supply ship.

5.1.6.1 Resource allocation and unitary cost by port

Selected solutions, total demand served and unitary costs for Barcelona cluster, detailed in section 4.6.2 are:

Table 5.11 Selected solutions for Ferrol

Year 2020	Year 2025	Year 2030	Year 2050
1T	1T	1T	4A
2.182 m³	8.085 m³	20.986 m³	103.101 m³
2,58 €/MWh	2,60 €/MWh	2,61 €/MWh	5,99 €/MWh

Final allocation of supply resources and auxiliary terminals for Barcelona Cluster are summarized in Table 5.12, while unitary costs per port and type of supply are reflected in Figure 5.36.

Table 5.12 Resources allocation in Ferrol

	2020	2025	2030	2050
Vigo				3.000 m^3
A Coruña				3.000 m^3
Ferrol				3.000 m^3
Marín				3.000 m^3
Villagarcía de Arousa				3.000 m^3

Bunkering vessel
Only TTS Supply
Optional auxialiary terminal
On demand bunkering vessel
Feedering vessel
Storage terminal

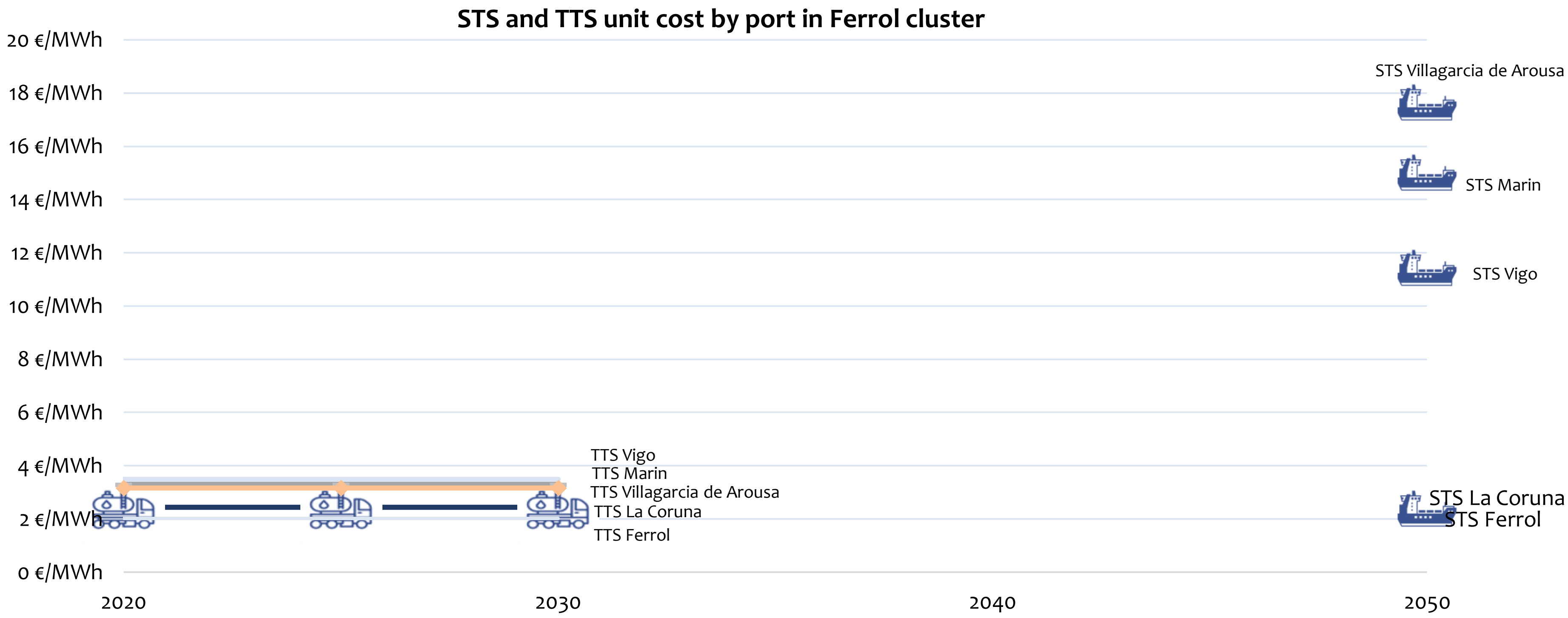


Figure 5.36 STS and TTS supply unit cost by port in Ferrol

5.1.6.2 Bunkering supply annual costs

The following figure shows the total annual cost for bunkering supply separated by the 5 different activities included in a supply chain, at a cluster level.

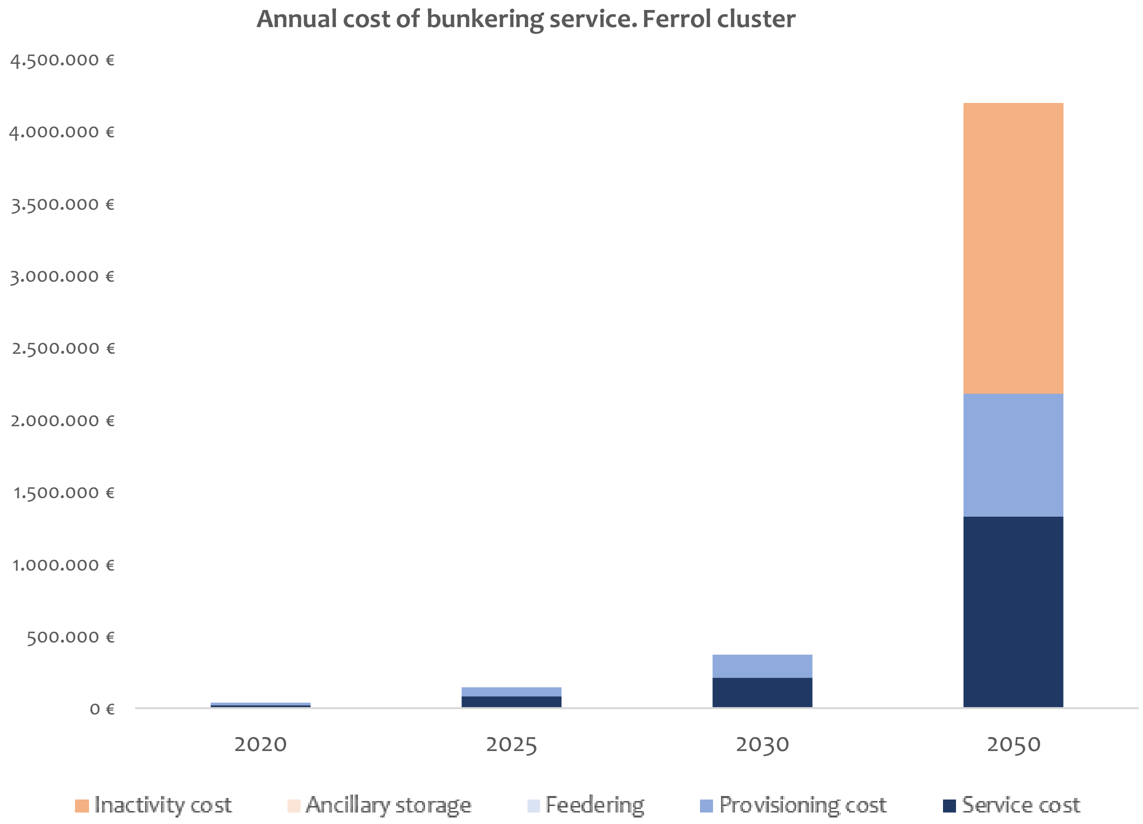


Figure 5.37 Annual cost of bunkering supply in Ferrol cluster

Looking at year 20105 – only year with TTS service available – demand decreases making inactivity costs higher and because of geographical spread, service costs are higher compared to other clusters.

5.1.6.3 2020-2050 investment requirements

Expressed as a differential value, investment requirements for this cluster are shown in Figure 5.38.

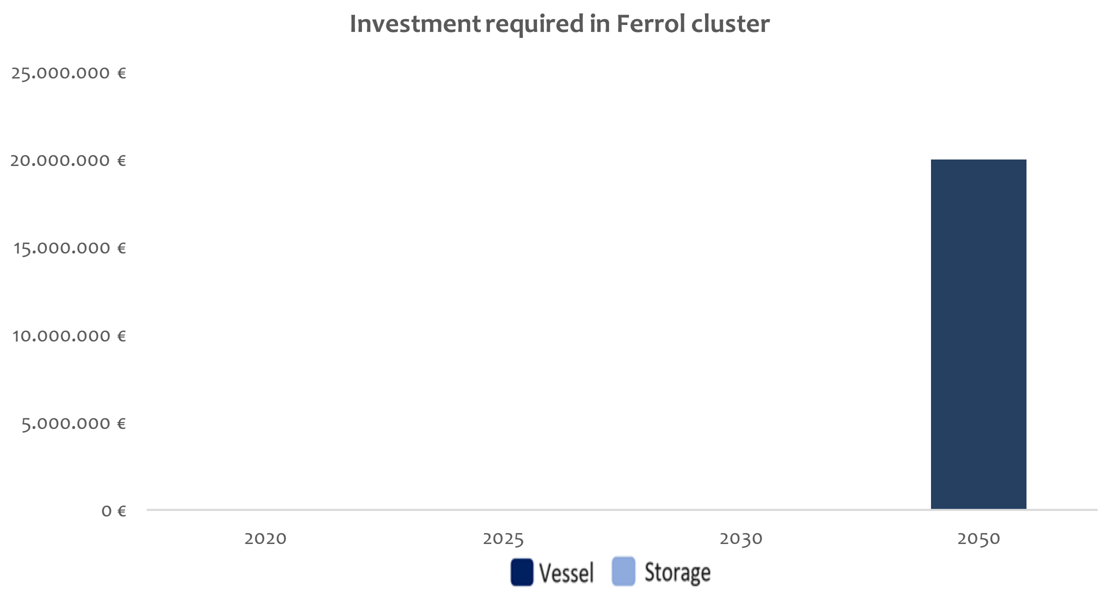


Figure 5.38 Investment required in Ferrol cluster

5.1.6.4 Environmental Impact.

An estimated environmental impact assessment of bunkering activity expressed in CO_{2eq} generated for each cluster has been generated using emission factors detailed in Annex 3 and results obtained from the design of supply chains. Total and unitary values are reflected in the next figure.

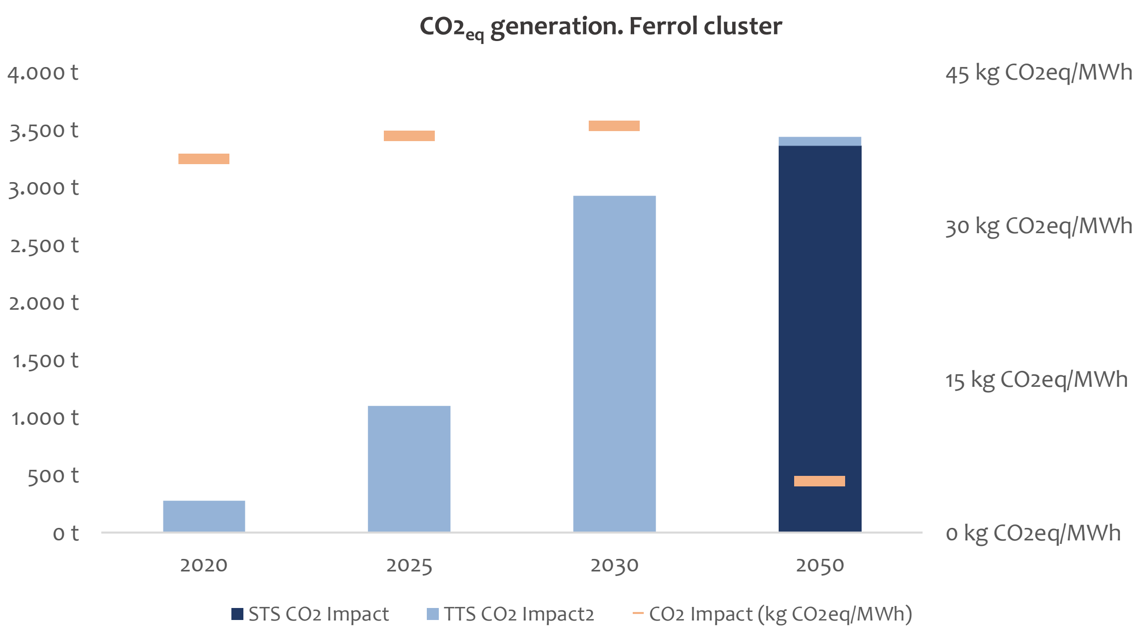


Figure 5.39 CO2eq generation. Cluster Ferrol

5.1.6.5 Impact in Ferrol's port LNG import terminal

Using gas network's LNG loading and unloading facilities involves paying several tolls – Table 2.5-. This total cost is included within the provisioning activity and is reflected in Figure 5.5.

In addition to this, to predict if additional investments would be needed in the import terminals, current import terminal capacity will be contrasted with the extra activity generated by bunkering for both STS – Figure 5.6 – and STS – Figure 5.7-.

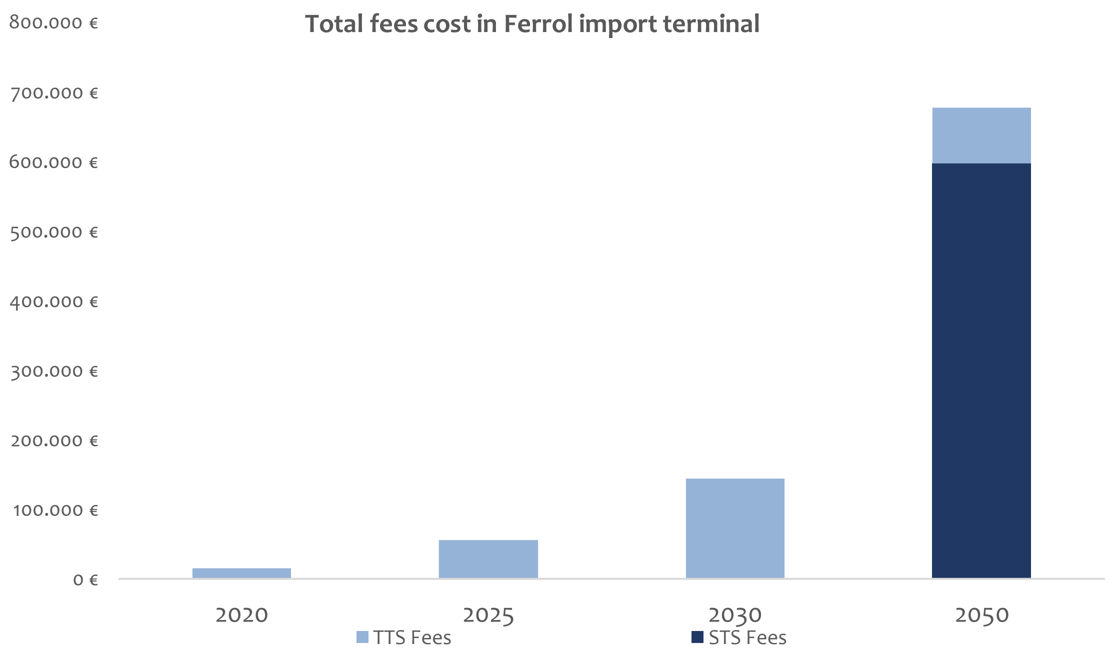


Figure 5.40 Total fees cost. Ferrol

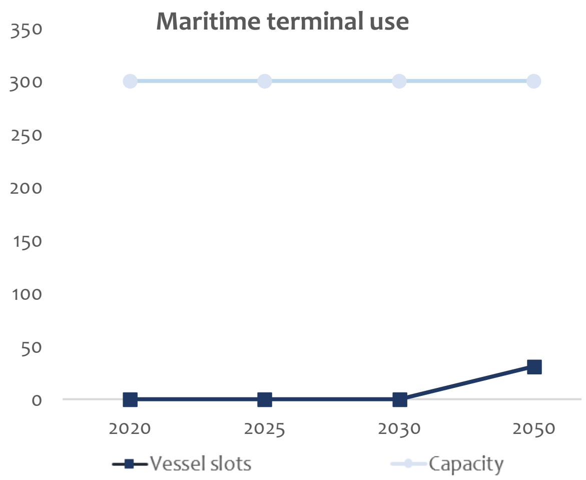


Figure 5.41 Maritime terminal use. (IT) Ferrol

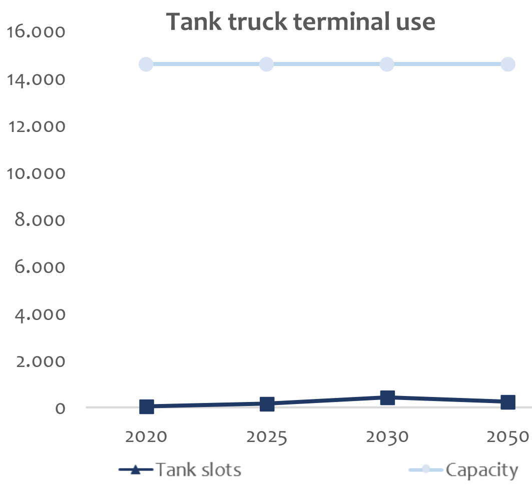


Figure 5.42 Tank truck terminal use. (IT) Ferrol

Expected additional activity in the terminal won't affect its current operation and no additional investment would be required.

5.1.7 Gijon Cluster

This is the cluster with the lowest number of ports and the lowest demand expected, therefore, the only solution proposed is the use of TTS supply until 2050. A demand level above 60,000 m^3 would be worth considering using a multiproduct barge.

5.1.7.1 Resource allocation and unitary cost by port.

Selected solutions, total demand served and unitary costs for Barcelona cluster, detailed in section 4.7.2 are:

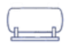
Table 5.13 Selected solutions for Gijón

Year 2020	Year 2025	Year 2030	Year 2050
1T	1T	1T	3A
1.639 m^3	5.335 m^3	13.043 m^3	61.848 m^3
2,09 €/MWh	2,08 €/MWh	2,07 €/MWh	6,22 €/MWh

Final allocation of supply resources and auxiliary terminals for Barcelona Cluster are summarized in Table 5.14, while unitary costs per port and type of supply are reflected in Figure 5.43.

Table 5.14 Resources allocation in Gijón

	2020	2025	2030	2050
Gijón				
Avilés				

 Bunkering vessel
 Only TTS Supply
 Optional auxialiary terminal
 On demand bunkering vessel
 Feedering vessel
 Storage terminal

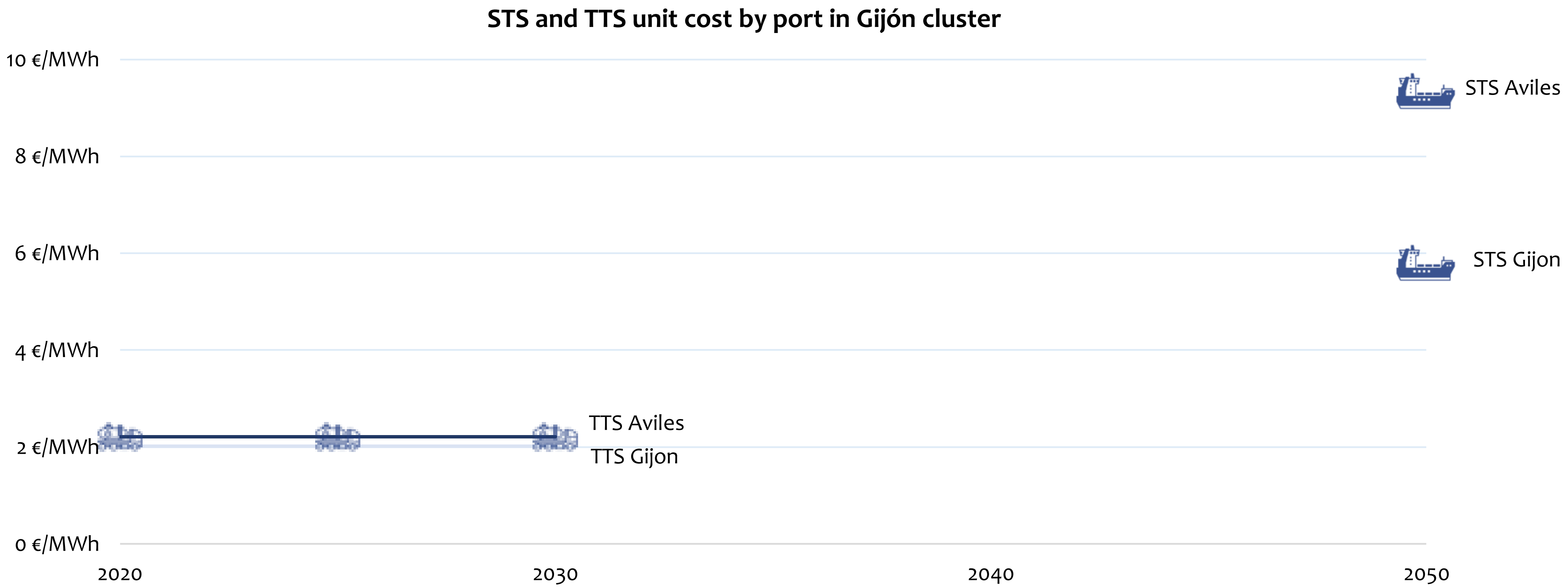


Figure 5.43 STS and TTS supply unit cost by port in Gijón

Even though both ports are close to the LNG import terminal, STS supply service would be too high for port of Aviles and more competitive in port of Gijon, where supply costs would be around 6 €/MWh. TTS supply cost has been calculated based on using Bilbao's LNG import terminal since the cluster's main LNG import terminal is currently inactive, resulting in a final supply cost of 4 €/MWh.

5.1.7.2 Bunkering supply annual costs

The following figure shows the total annual cost for bunkering supply separated by the 5 different activities included in a supply chain, at a cluster level.

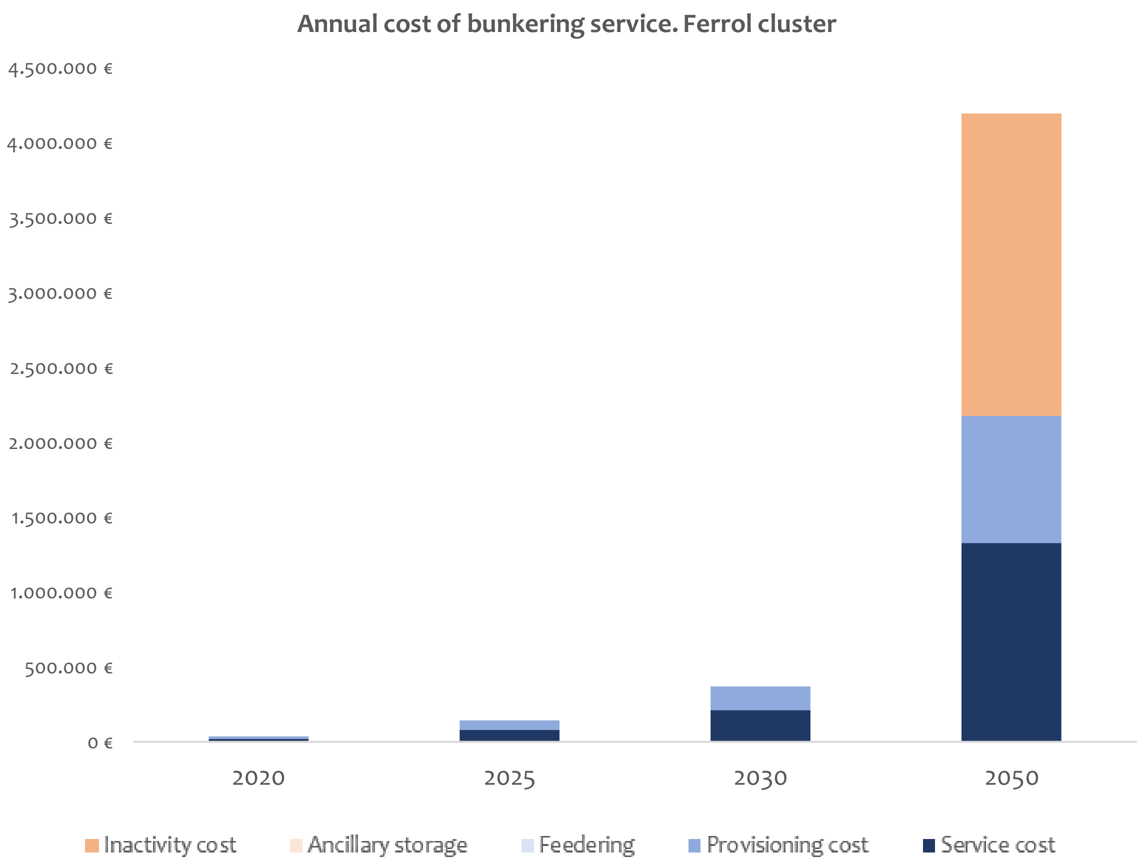


Figure 5.44 Annual cost of bunkering supply in Gijón cluster

As observed in other low-demand clusters, inactivity cost is the most relevant.

5.1.7.3 Requerimientos de inversión en el periodo 2020-2050

Expressed as a differential value, investment requirements for this cluster are shown in Figure 5.45

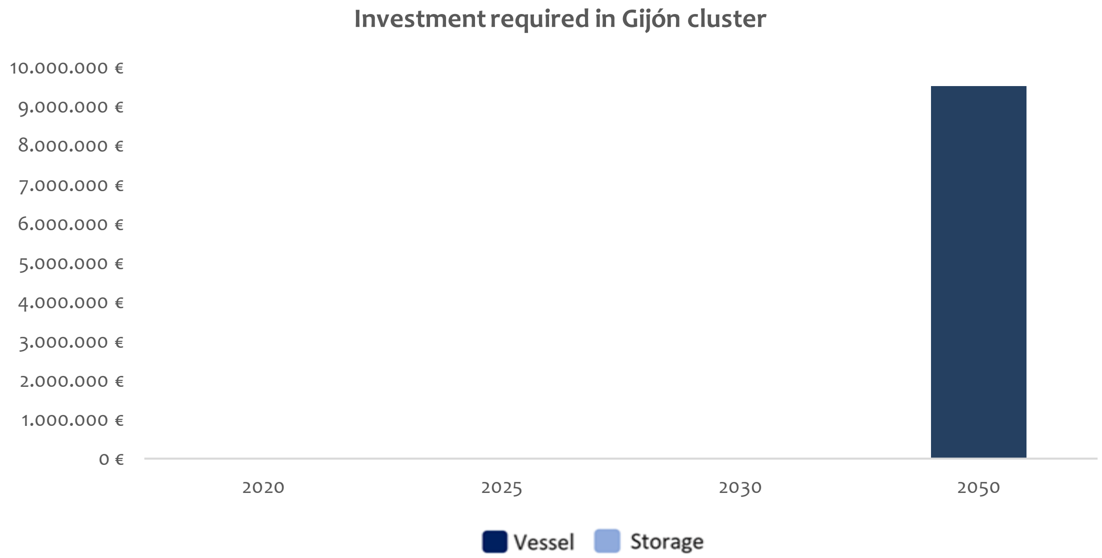


Figure 5.45 Investment required in Gijón cluster

5.1.7.4 Environmental Impact.

An estimated environmental impact assessment of bunkering activity expressed in CO_{2eq} generated for each cluster has been generated using emission factors detailed in Annex 3 and results obtained from the design of supply chains. Total and unitary values are reflected in the next figure.

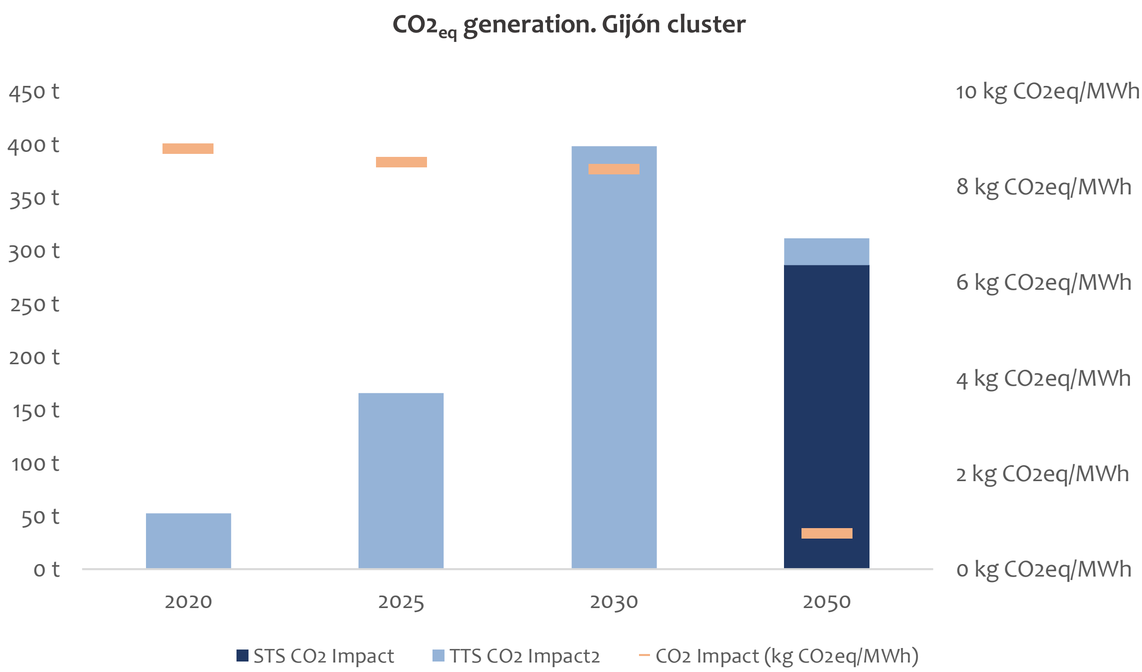


Figure 5.46 CO2eq generation. Cluster Gijón

5.1.7.5 Impact in Gijon's port LNG import terminal

Using gas network's LNG loading and unloading facilities involves paying several tolls – Table 2.5-. This total cost is included within the provisioning activity and is reflected in Figure 5.47.

In addition to this, to predict if additional investments would be needed in the import terminals, current import terminal capacity will be contrasted with the extra activity generated by bunkering for both STS – Figure 5.48 – and STS – Figure 5.49-.

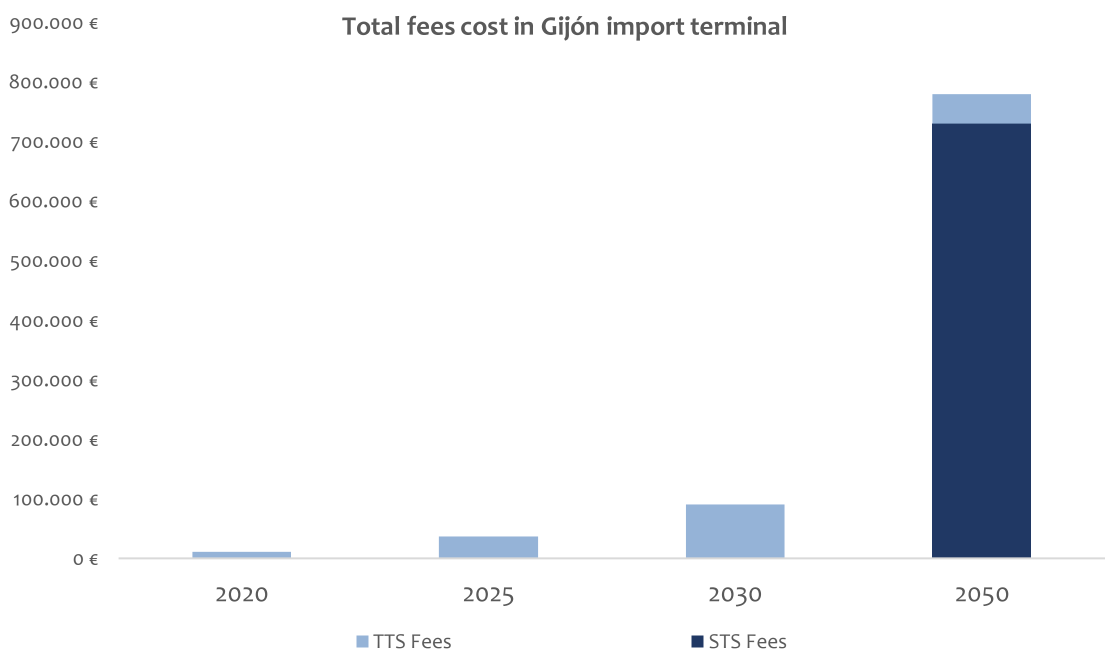


Figure 5.47 Total fees cost. Gijón

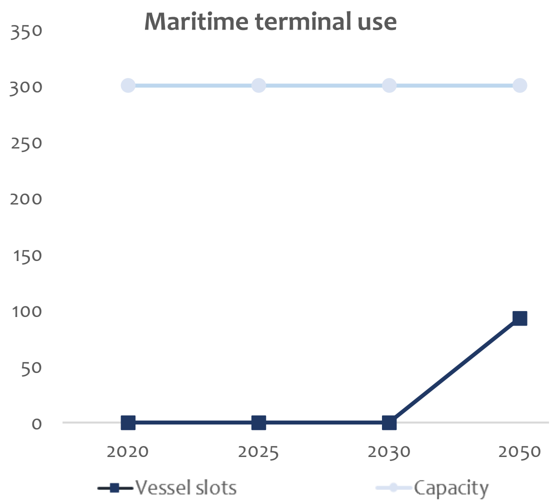


Figure 5.48 Maritime terminal use. (IT) Gijón

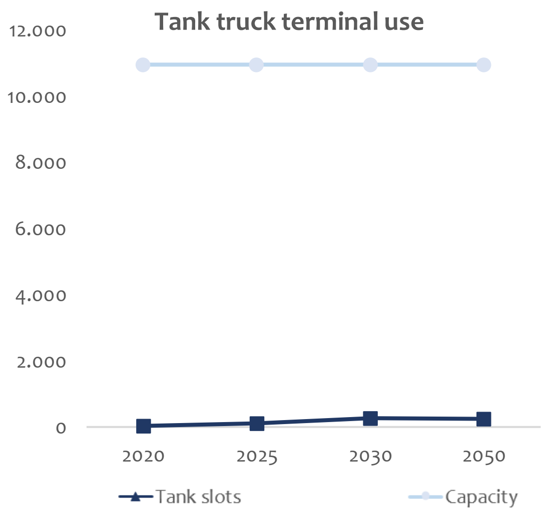


Figure 5.49 Tank truck terminal use. (IT) Gijón

Non-additional investment will be needed attending to these results.

5.1.8 Bilbao Cluster

Low expected demand in this cluster calls for a TTS supply chain until 2050 when a 100,000 m^3 expected demand would justify the addition of supply ship/.

5.1.8.1 Resource allocation and unitary cost by port.

Selected solutions, total demand served and unitary costs for Barcelona cluster, detailed in section 4.8.2 are:

Table 5.15 Selected solutions for Bilbao

Year 2020	Year 2025	Year 2030	Year 2050
1T	1T	1T	4A
7.622 m^3	13.851 m^3	27.489 m^3	95.479 m^3
2,11 €/MWh	2,17 €/MWh	2,19 €/MWh	4,91 €/MWh

Final allocation of supply resources and auxiliary terminals for Barcelona Cluster are summarized in Table 5.16, while unitary costs per port and type of supply are reflected in Figure 5.50.

Table 5.16 Resources allocation in Bilbao

	2020	2025	2030	2050
Bilbao				1.200 m^3
Santander				1.200 m^3
Pasaia				1.200 m^3

Bunkering vessel
Only TTS Supply
Optional auxiliary terminal
On demand bunkering vessel
Feedering vessel
Storage terminal

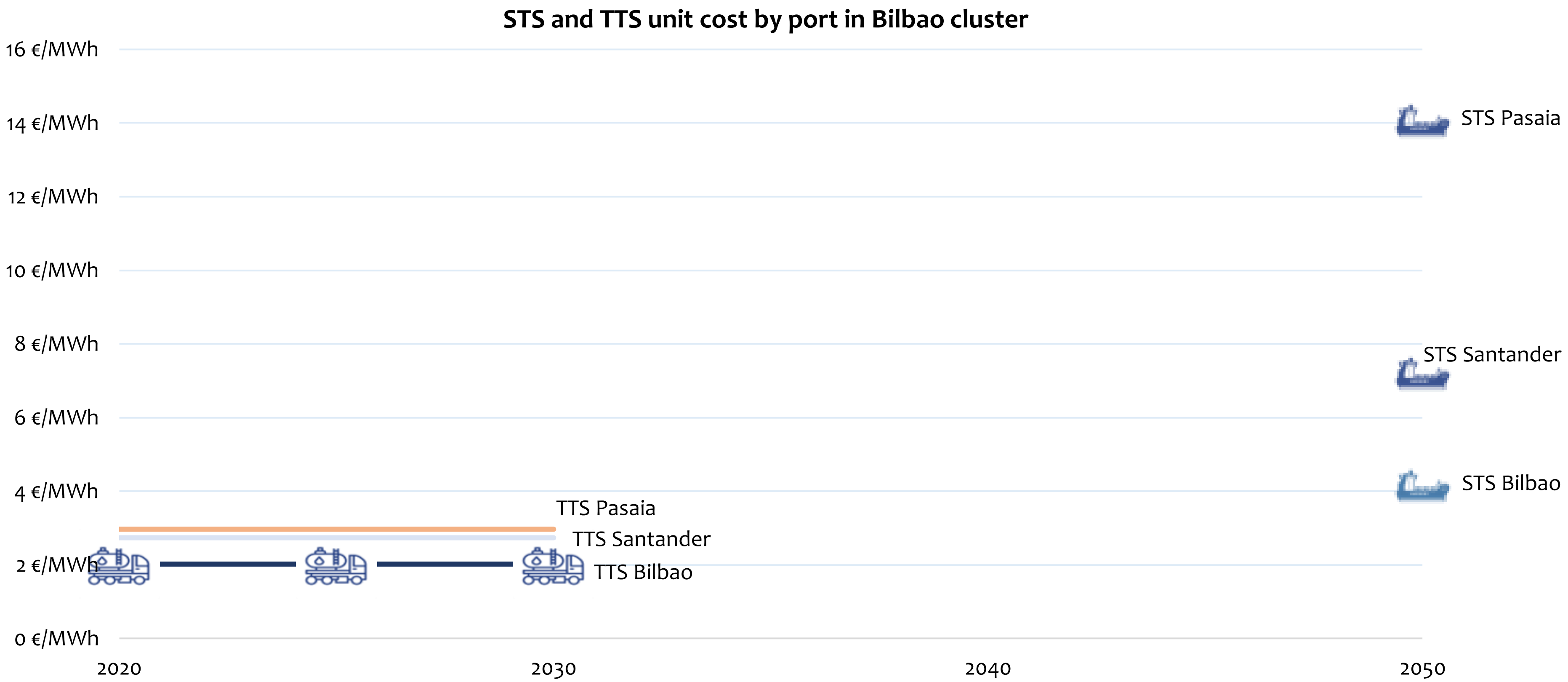


Figure 5.50 STS and TTS supply unit cost by port in Bilbao cluster

Demand levels expected for 2050 and the proximity between client port to import terminal, suggest that a competitive price could be reach in Santander and Bilbao ports – compared to MDO prices -.

5.1.8.2 Bunkering supply annual costs

The following figure shows the total annual cost for bunkering supply separated by the 5 different activities included in a supply chain, at a cluster level.

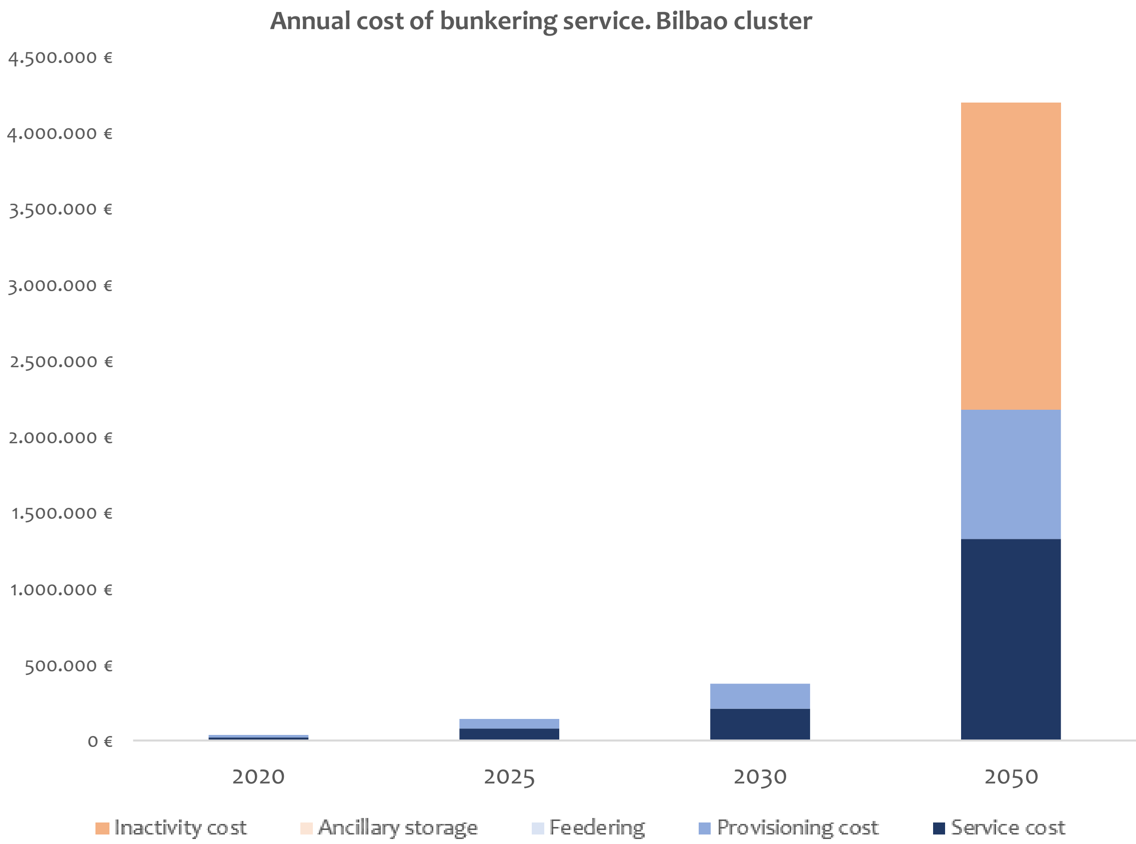


Figure 5.51 Annual cost of bunkering supply in Bilbao cluster

Cost allocation is identical to Cartagena's cluster with important inactivity costs since this is a low demand cluster.

5.1.8.3 Requerimientos de inversión en el periodo 2020-2050

Expressed as a differential value, investment requirements for this cluster are shown in Figure 5.52

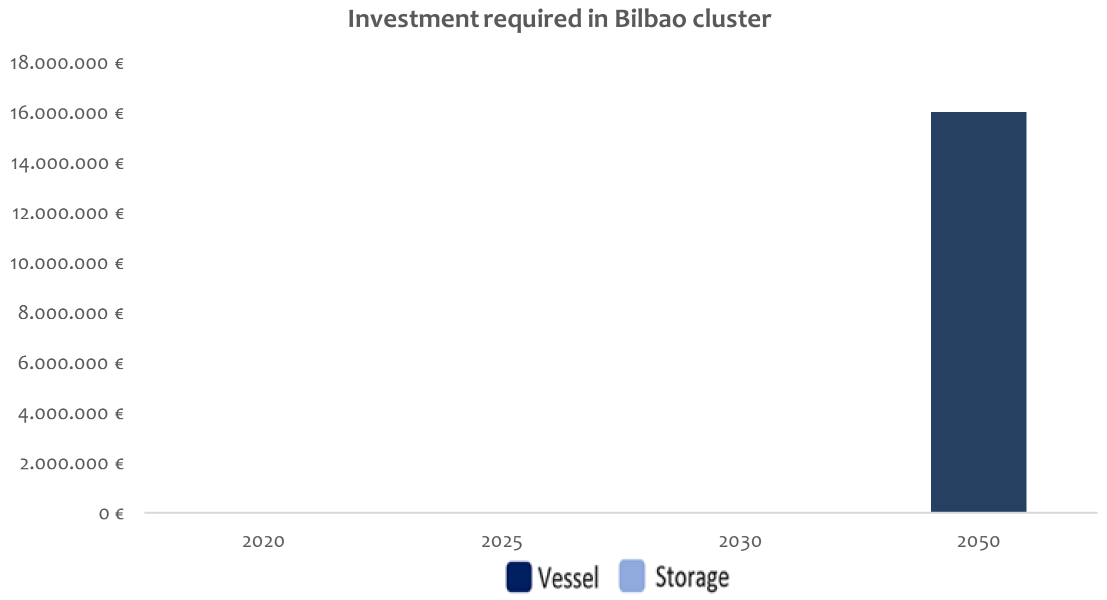


Figure 5.52 Investment required in Bilbao cluster

5.1.8.4 Environmental Impact.

An estimated environmental impact assessment of bunkering activity expressed in CO_{2eq} generated for each cluster has been generated using emission factors detailed in Annex 3 and results obtained from the design of supply chains. Total and unitary values are reflected in the next figure.

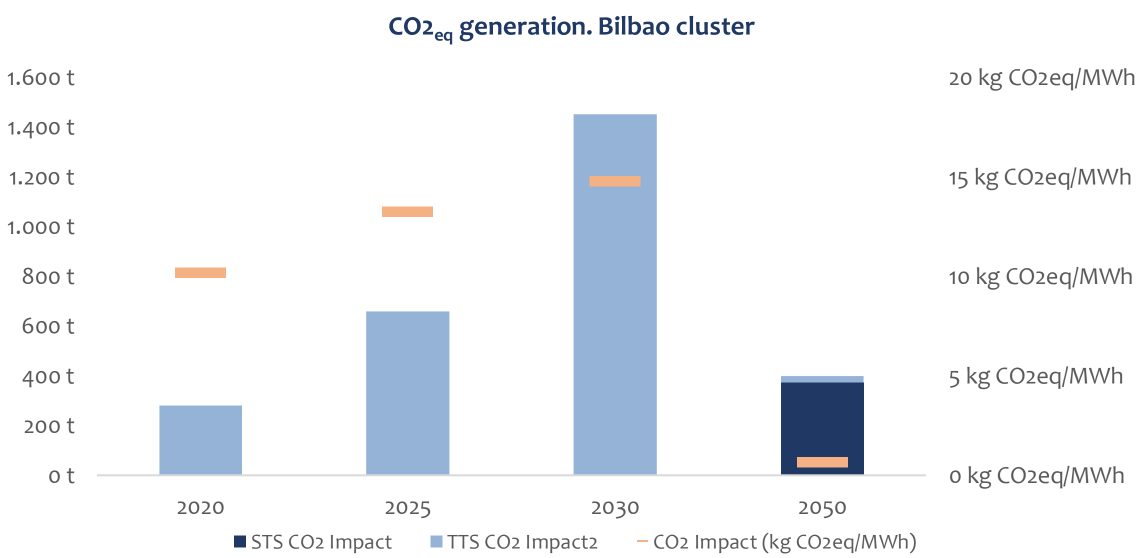


Figure 5.53 CO2 generation. Cluster Bilbao

5.1.8.5 Impact in Bilbao's port LNG import terminal

Using gas network's LNG loading and unloading facilities involves paying several tolls – Table 2.5-. This total cost is included within the provisioning activity and is reflected in Figure 5.54.

In addition to this, to predict if additional investments would be needed in the import terminals, current import terminal capacity will be contrasted with the extra activity generated by bunkering for both STS – Figure 5.55 – and STS – Figure 5.56-.

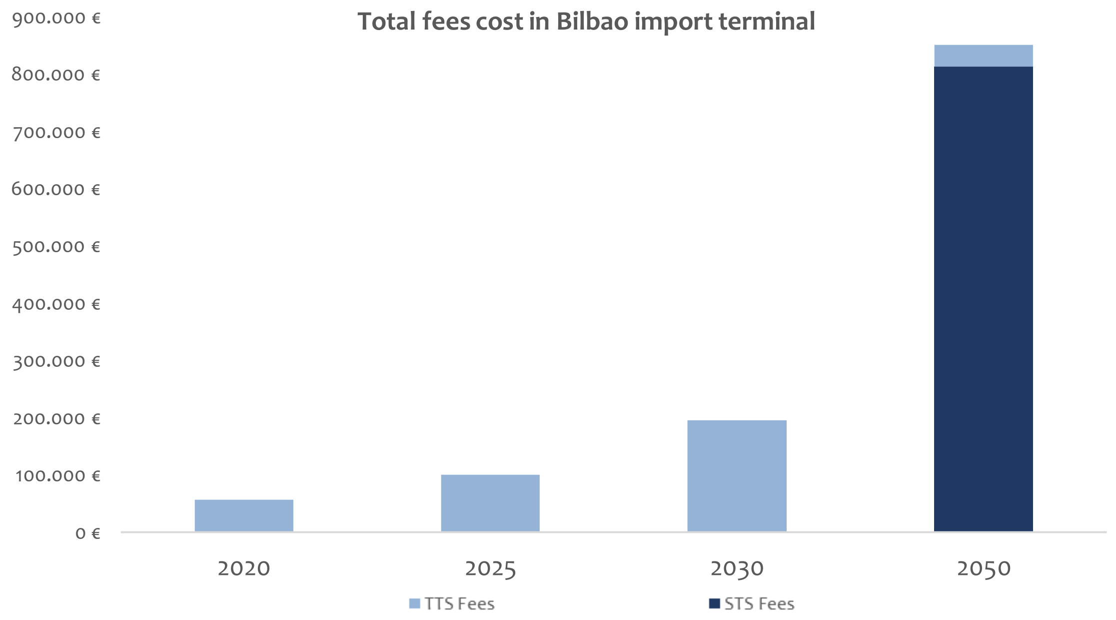


Figure 5.54 Total fees cost. Bilbao

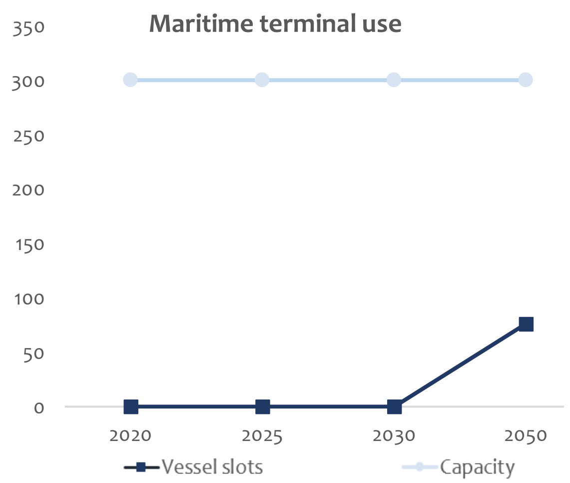


Figure 5.55 Maritime terminal use. Bilbao cluster

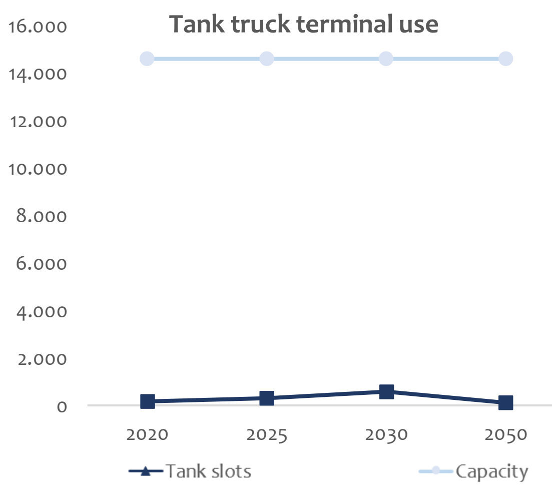


Figure 5.56 Tank truck terminal use. (IT) Bilbao

No additional investments would be required attending to the results above.

5.1.9 Granadilla Cluster

The high expected demand in port of Las Palmas and the long distance to LNG import terminal makes this cluster one the most relevant in terms of supply resource and also considered for the construction of auxiliary storage terminals.

5.1.9.1 Resource allocation and unitary cost by port

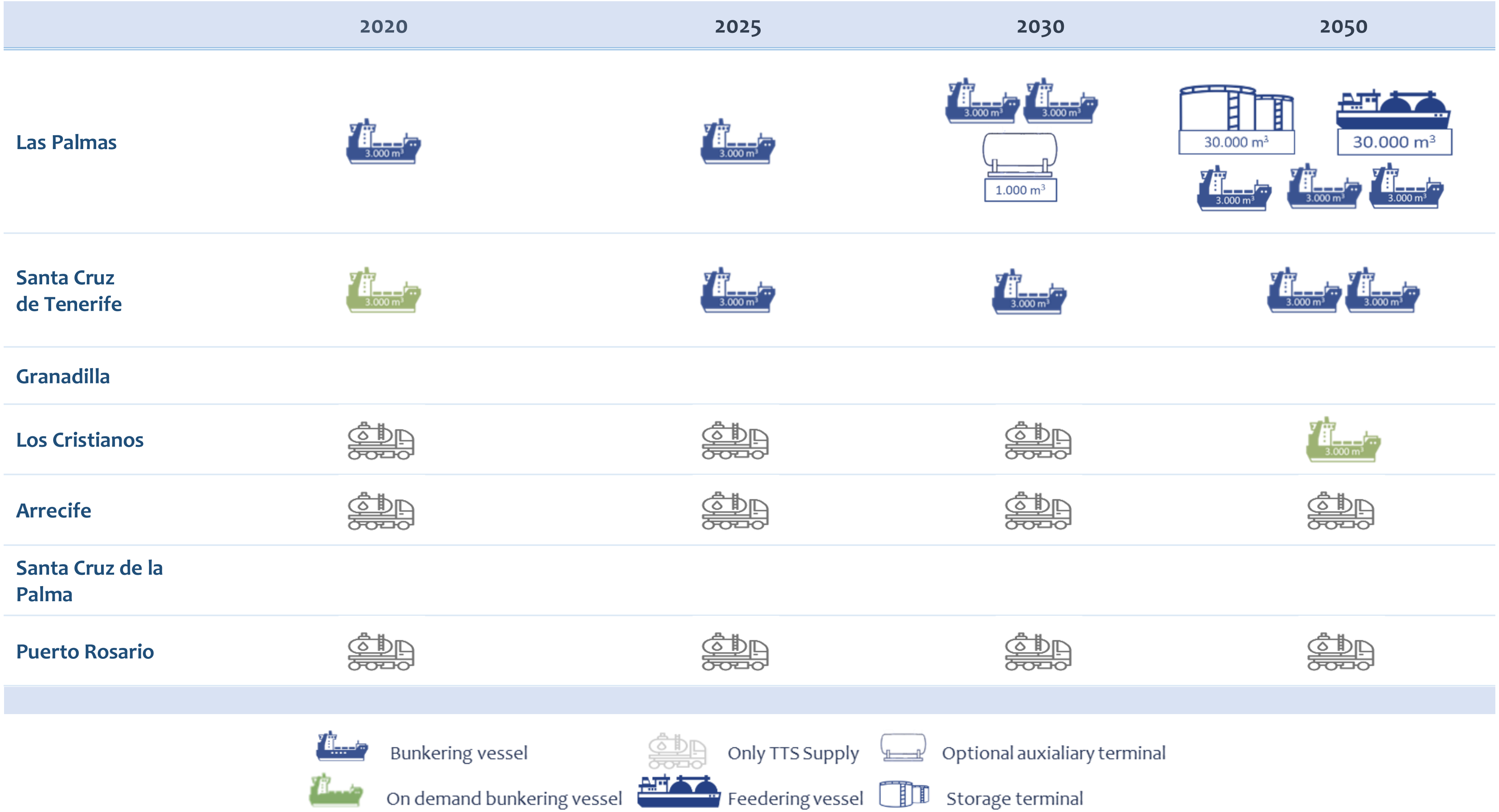
Selected solutions, total demand served and unitary costs for Granadilla cluster, previously detailed in section 4.9.2 are:

Table 5.17 Selected solutions for Granadilla

Year 2020	Year 2025	Year 2030	Year 2050
1A	3A	5A	6B
121.268 m³	322.438 m³	782.055 m³	3.233.165 m³
5,56 €/MWh	4,71 €/MWh	3,26 €/MWh	2,51 €/MWh

Final allocation of supply resources and auxiliary terminals for Barcelona Cluster are summarized in Table 5.18, while unitary costs per port and type of supply are reflected in Figure 5.57.

Table 5.18 Resources allocation in Granadilla



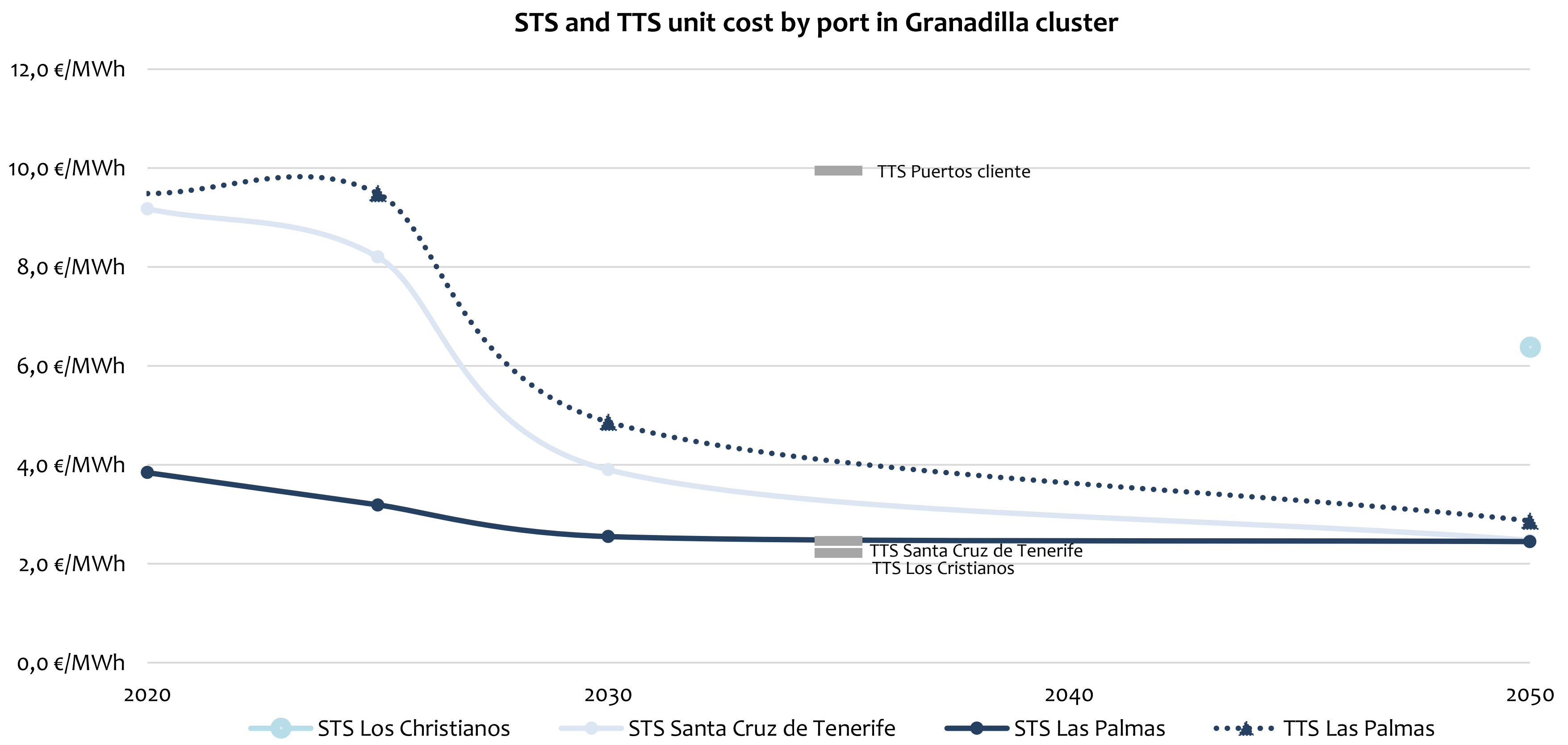


Figure 5.57 STS and TTS supply unit cost by port in Granadilla cluster

Like Ceuta, TTS supply service is variable since auxiliary storage terminals will be installed in port of Las Palmas. Is interesting to know how despite of evident differences in geographic locations, demand and resource allocation, Las Palmas and Tenerife ports tend to be very similar.

5.1.9.2 Coste anual del suministro de bunkering

The following figure shows the total annual cost for bunkering supply separated by the 5 different activities included in a supply chain, at a cluster level.

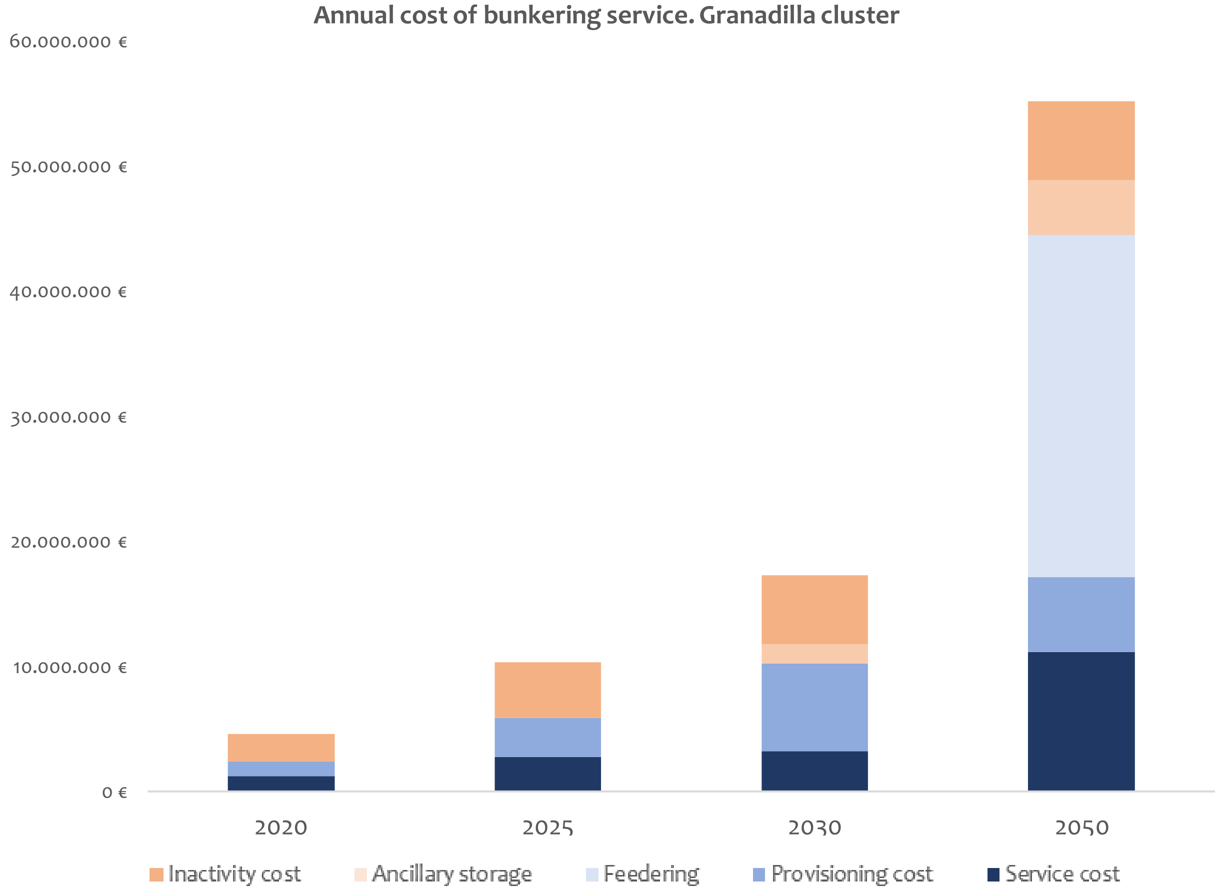


Figure 5.58 Annual cost of bunkering supply in Granadilla cluster

Granadilla cluster has a similar structure to Huelva's, with increasing provisioning costs for demand levels above 3,000,000 m^3, accounting for more than 60% of total costs (including feedering and provision costs).

5.1.9.3 Requerimientos de inversión en el periodo 2020-2050

Expressed as a differential value, investment requirements for this cluster are shown in Figure 5.59

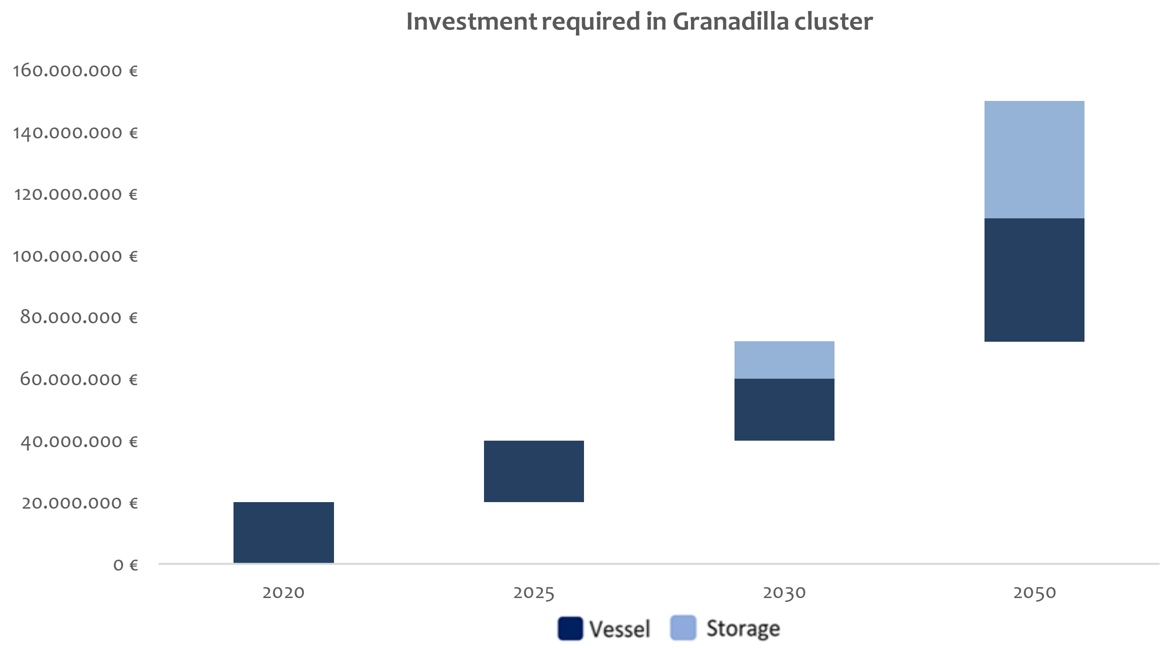


Figure 5.59 Investment required in Granadilla cluster

5.1.9.4 Environmental Impact.

An estimated environmental impact assessment of bunkering activity expressed in CO_{2eq} generated for each cluster has been generated using emission factors detailed in Annex 3 and results obtained from the design of supply chains. Total and unitary values are reflected in the next figure.

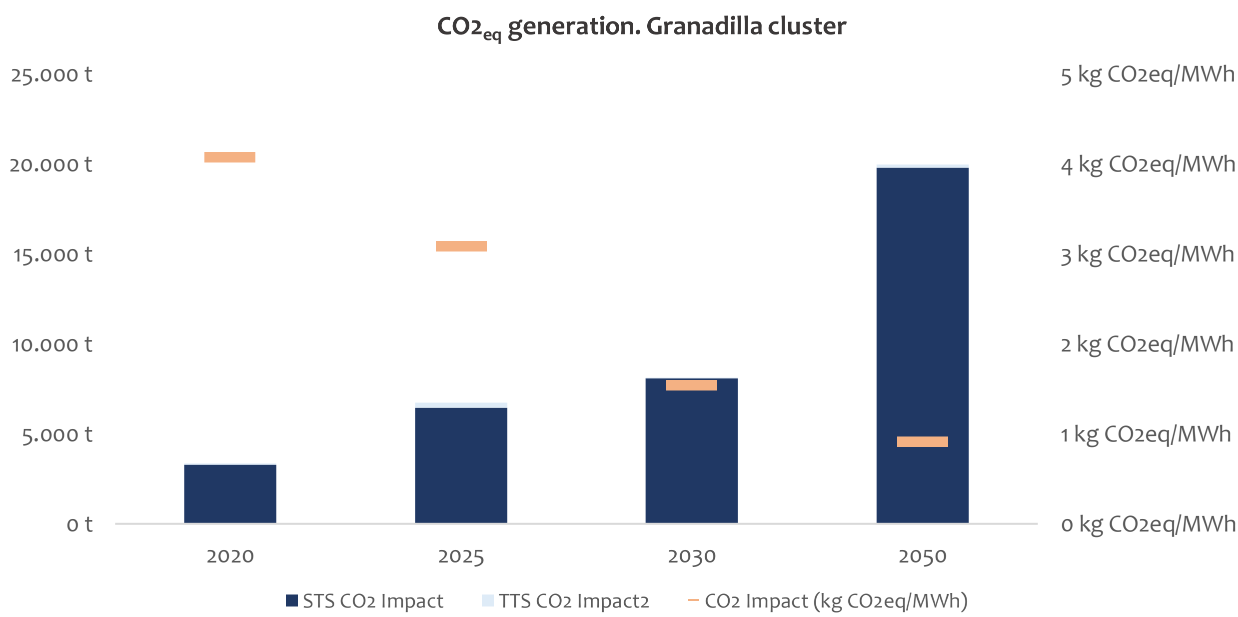


Figure 5.60 CO2eq generation. Granadilla cluster

5.1.9.5 Impact in Granadilla's port LNG import terminal

Using gas network's LNG loading and unloading facilities involves paying several tolls – Table 2.5-. This total cost is included within the provisioning activity and is reflected in Figure 5.61.

In addition to this, to predict if additional investments would be needed in the import terminals, current import terminal capacity will be contrasted with the extra activity generated by bunkering for both STS – Figure 5.62 – and STS – Figure 5.63-.

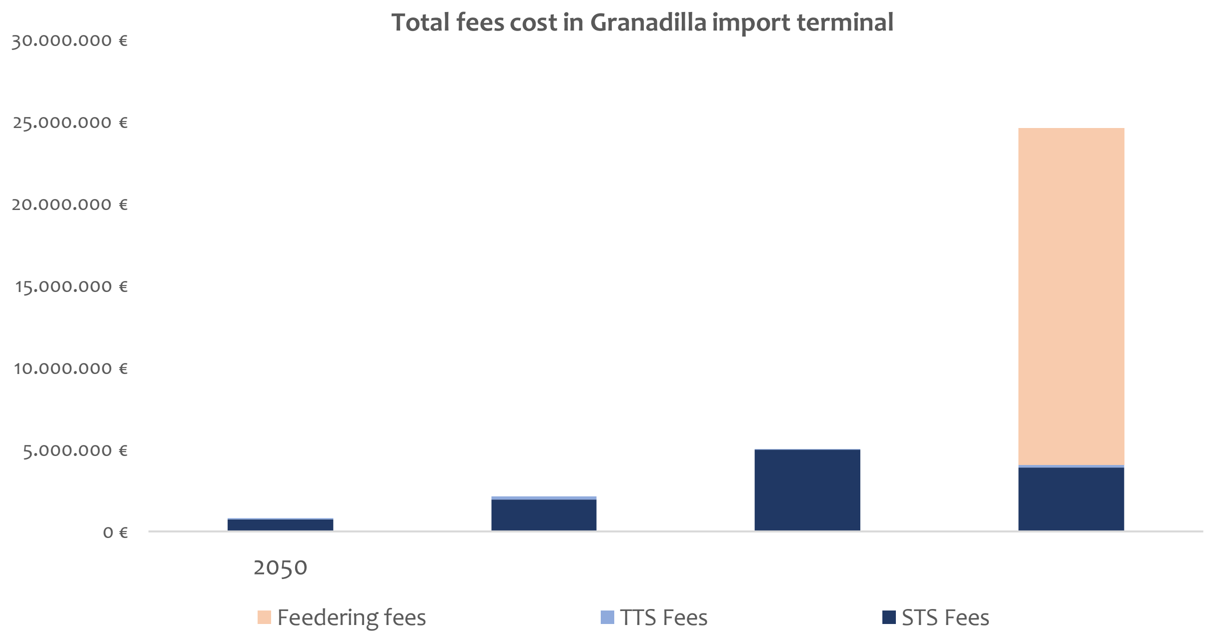


Figure 5.61 Total fees cost. Granadilla

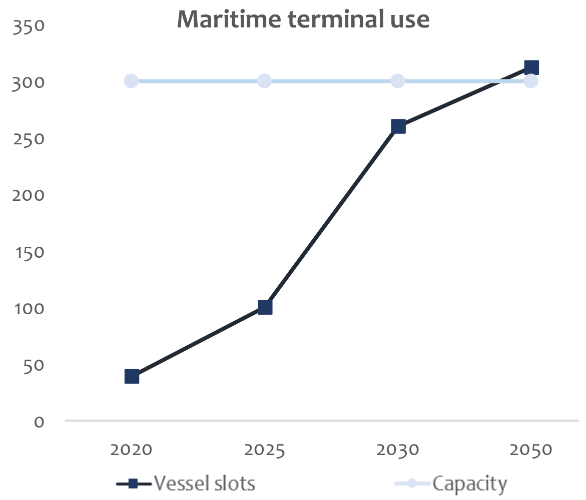


Figure 5.62 Maritime terminal use. Granadilla cluster

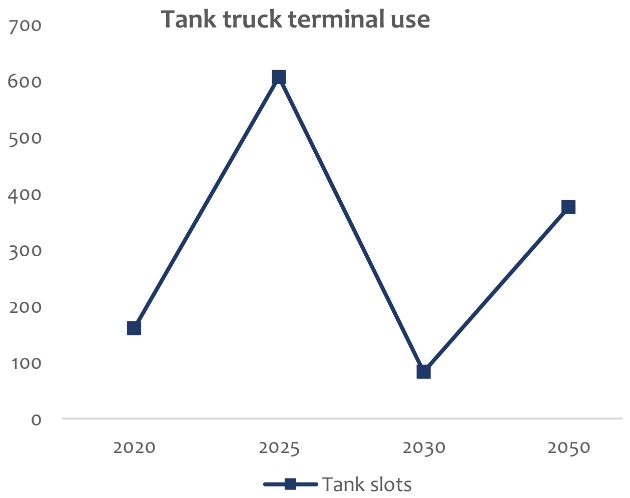


Figure 5.63 Tank truck terminal use. (IT) Granadilla[7]

[7] Final tank truck loading capacity at the future Granadilla import terminal is unknown

Attending to the expected activity levels in the future LNG import plant in Granadilla, a single jetty would be needed to attend the expected demand until the last time frame considered, when demand will exceed terminal's capacity despite adding a feedering ship to the solution.

Activity in the ground cargo terminal is not very high since it is cheaper to install an auxiliary storage terminal with a tank truck reload platform in the highest demand port.

5.2 *Aggregated results for Spain and Portugal*

This chapter aggregates all result obtained for Spanish pots.

5.2.1.1 Bunkering supply annual costs

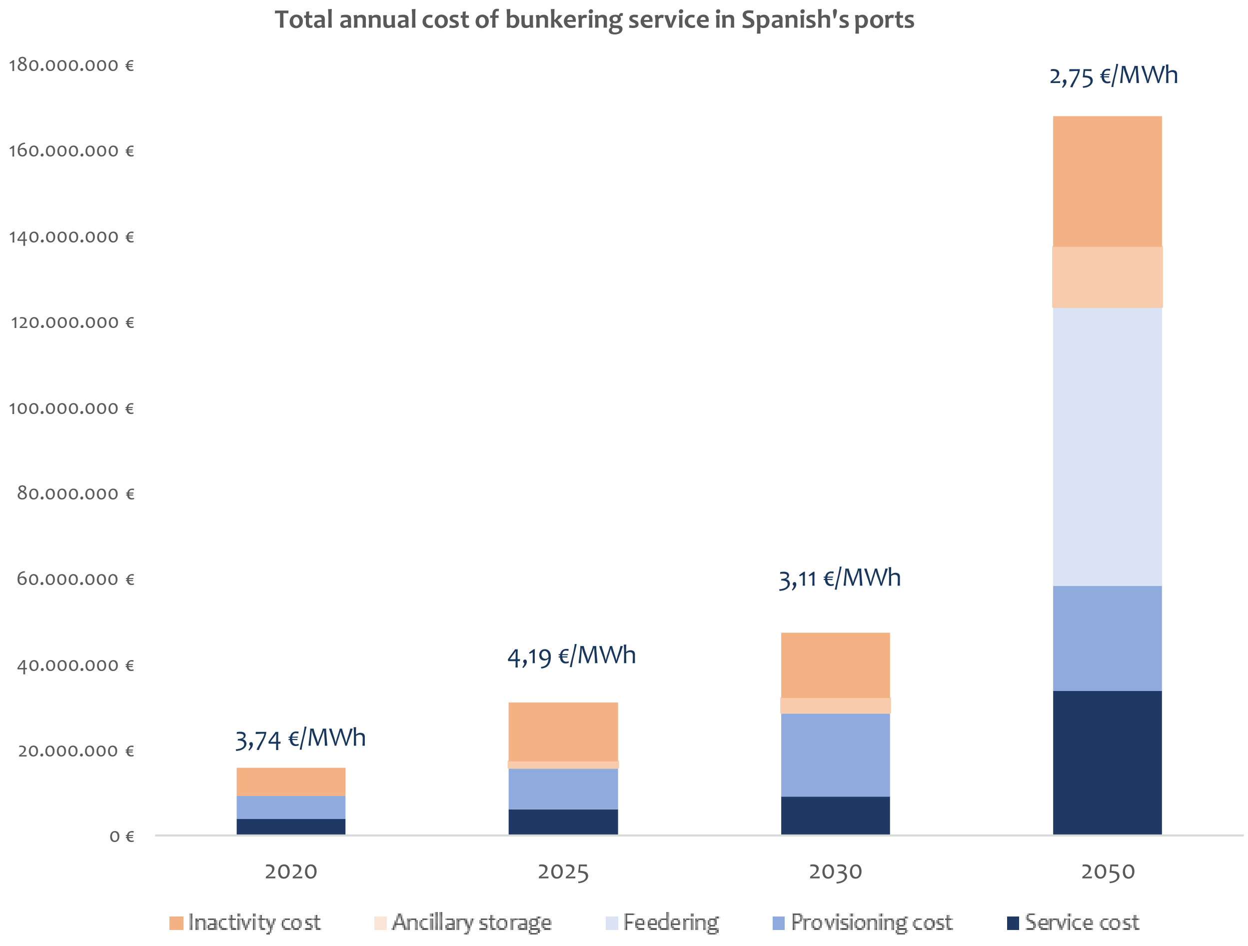


Figure 5.64 Total anual cost of bunkering service in Spanish's ports

The 8 import terminals considered in this study – 6 of them active – will provide storage capacity enough to procure LNG supply in most of the network's ports, making auxiliary terminal costs less important as a whole.

To develop a healthy supply activity in the largest supply ports will require a higher service availability during the first 10 years, which will require more resources, increasing inactivity costs until 2030. After 2050, the biggest supply cost component in the 2 largest ports of the network – Algeciras and Las Palmas – serving almost 7,000,000 m^3, would be provisioning.

Using TTS supply operations during the first years in lower demand ports in addition to a supply chain minimizing the number of auxiliary terminals needed would generate a competitive average unitary cost – 4.19 €/MWh and 2.75 €/MWh -.

5.2.1.2 2020-2050 investment requirements

Total investment amount for the Spanish port network is reflected in the following figure:

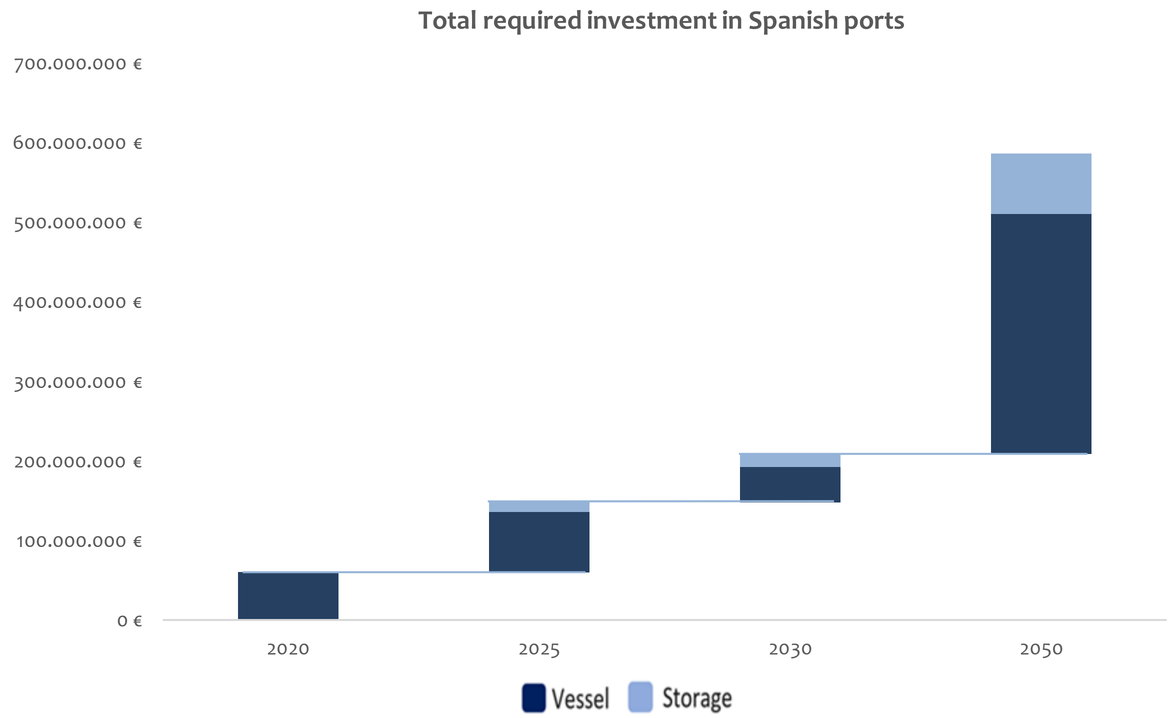


Figure 5.65 Total required investment in Spanish ports

Total necessary investment amount needed for deployment of optimal supply chains until 2050 will be 600,000,000 €. This investment amount will be achieved in a staggered way over time. This investment will be focused in ships during the earlier years and it will move towards the construction of new storage facilities after year 2030.

5.2.2 Environmental impact.

Next figure shows the total environmental impact generated by the optimal supply chains considered, expressed in both kg of $CO_{2\ eq}$/MWh of LNG supplied and total $CO_{2\ eq}$.

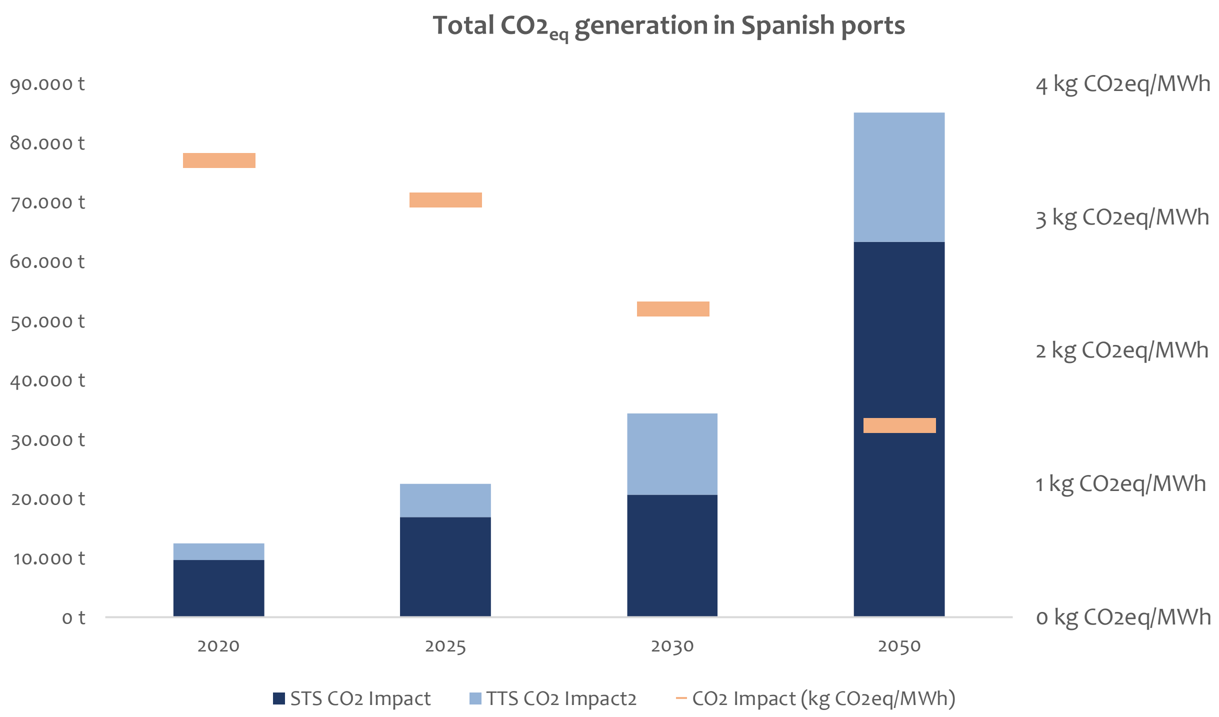


Figure 5.66 Total $CO2_{eq}$ generation in Spanish ports

Resulting emissions unitary values - 0.055 t $CO2_{eq}$/ t LNG a 0.022 t $CO2_{eq}$/ t – will only account for 1% to 2% of the total emissions generated by ships using LNG as a fuel source.

5.2.3 Impact of supply chains in the Spanish gas network

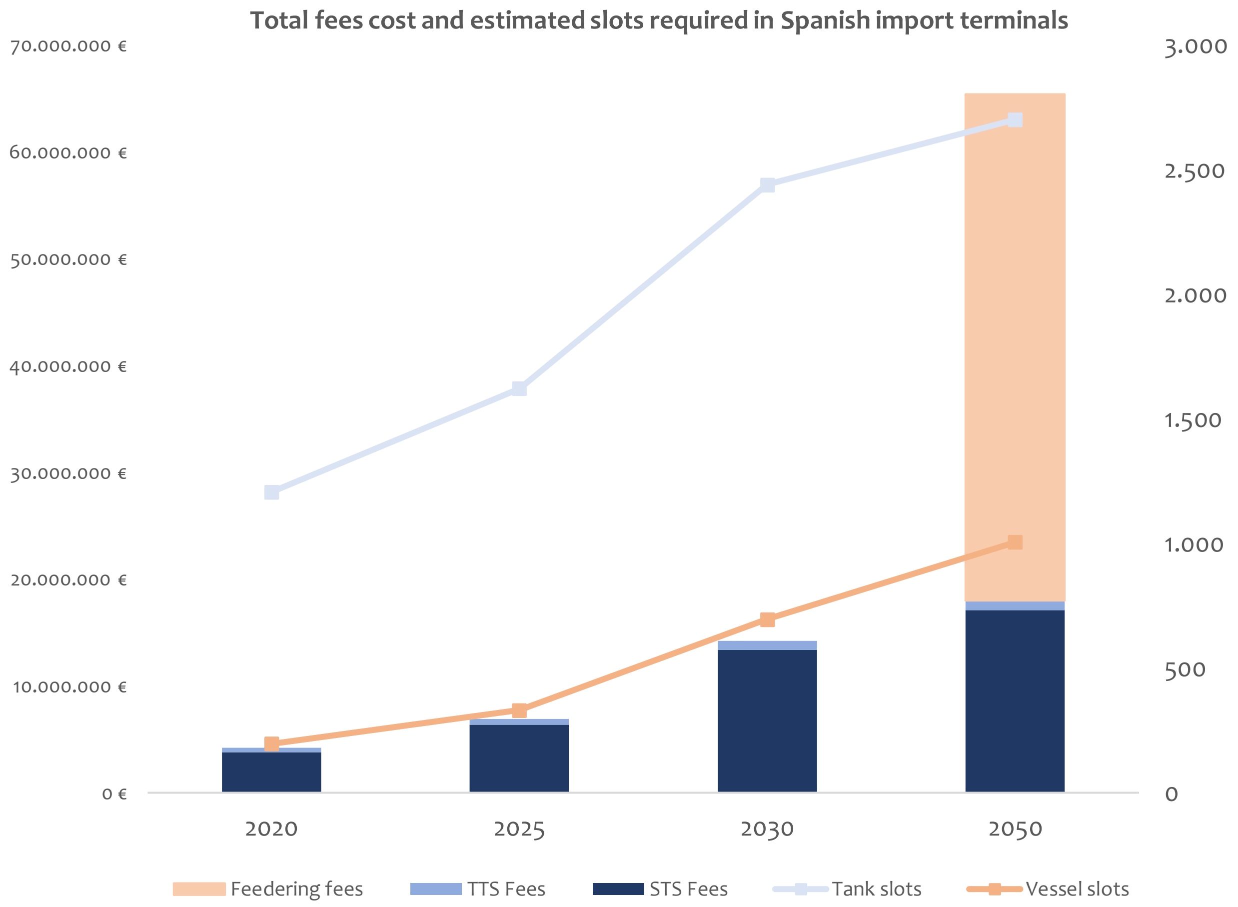


Figure 5.67 Total fees cost, and estimated slots required in Spanish import terminals

Deployment of ships with capacity below 5,000 m³ during the first 10 years of operation, reduces the impact of regulated costs in the final supply cost of the chain – 25% of total costs-. The use of feedering ships – 30,000 m³- required for the levels of demand expected in 2050 in Algeciras and Las Palmas would increase the impact of regulated costs in the supply chain up to 38%. This is explained by the difference in unitary reload costs for smaller ships – capacity under 15,000 m³ - paying 0.90 €/MWh and higher capacity ships – 1.14 €/MWh-.

Total revenue generated for the gas network is around 1,360,000,000 €, of which 115,000,000 € correspond to LNG terminals activity – Regasification, storage …-. Access tolls to the network would increase system revenue up to 55% thanks to import terminal activity, based on costs detailed in table 2.5.

6 Annexes

6.1 *ANNEX 1: SEA DISTANCES TABLE*

6.2 *ANNEX 2: ROAD DISTANCE TABLE*

6.3 *ANNEX 3: SPECIFICATIONS FOR CO_2 EMISSION CALCULATIONS IN THE SUPPLY CHAIN*

6.4 *ANNEX 4: CALCULATIONS IN EXCEL FORMAT*

6.5 *ANNEX 5: PORT DEMANAND CHARACTERIZATION AND ESTIMATION ON KNOWN FLEET FUELED BY LNG*

Table 6.1 Maritime distances considered

MILLAS NAUTICAS	Algeciras	Alicante	Almeria	Arrecife	Aveiro	Aviles	Barcelona	Bilbao	Cadiz	Canical	Cartagena	Castellon de la Plana	Ceuta	Ferrol	Funchal	Gijon	Granadilla	Huelva	Ibiza	La Coruna	Las Palmas	Leixoes	Lisbon	Los christianos	Malaga	Marin	Melilla	Motril	Palamos	Palma Mallorca	Pasaia	Ponta Delgada	Portimao	Puerto Rosario	Sagunto	Santa Cruz de la Palma	Santa Cruz de Tenerife	Santander	Setubal	Seville	Sines	Tarragona	Valencia	Vigo	Villagarcia de Arousa
Algeciras	0	302	153			738	520	865	75		242	411	15	626		752		123		621	702				66	537	139	104		451	914						722	835		144		486	391	522	530
Alicante	302	0	155			1033	288	1160	370		68	119	297	921		1047		418	120	916	997				247	832	222	205		166	1209				105		1017	1130		439		194	99	817	825
Almeria	153	155	0			884	373	1011	221		95	264	151	772		898		269		767	848				98	683	94	56		304	1078						868	981		290		339	244	668	676
Arrecife				0													200	596			120			188										33		226	160								
Aveiro					0															129		288	455			231															208			232	225
Aviles	738	1033	884			0	1251	138	681		973	1142	736	128		23		663		129	1098				796	236	864	831		1183	183						1132	104		725		1218	1123	240	232
Barcelona	520	228	373			1251	0	1378	586		285	132	515	1139		1265		636	152	1134	1215				465	1085	439	423	53	130	1427						1235	1348		657		50	164	1035	1043
Bilbao	865	1160	1011			138	1378	0	808		1100	1269	863	255		120		804		256	1248				923	363	991	960		1309	58						1246	36		852		1344	1249	366	358
Cadiz	75	370	221			681	586	808	0		310	479	73	570		695		58		565	685				133	481	201	196		519	857						702	789		78		554	459	463	471
Canical										0												720	582																		550				
Cartagena	242	68	95			973	285	1100	310		0	176	241	861		987		358		856	937				187	772	167	145		214	1149				160		957	1070		379		251	156	757	765
Castellon de la Plana	411	119	264			1142	132	1269	479		176	0	407	1030		1156		527	110	1025	1106				356	941	332	314		130	1318				25		1126	1239		548		88	40	926	934
Ceuta	15	297	151			736	515	863	73		241	407	0	624		750		121		619	700				66	535	131	98		444	912						720	833		142		482	390	520	528
Ferrol	626	921	772			128	1139	255	570		861	1030	624	0		142		551		11	1001	177	344		684	124	752	720		1070	305						999	225		613		1105	1010	127	119
Funchal															0							750	615																		580				
Gijon	752	1047	898			23	1265	120	695		987	1156	750	142		0		677		143	1111				810	250	878	843		1196	165						1109	86		739		1231	1136	253	245
Granadilla				200													0	830			73			19										175		42	35								
Huelva	123	418	269	596		663	636	804	58		358	527	121	551		677	830	0		546	700				181	462	249	217		567	839			627		748	715	760		95	200	602	507	453	461
Ibiza		120					152				161	110							0										196	70					111							140	112		
La Coruna	621	916	767			129	1134	256	565		856	1025	619	11		143		546		0	1001	176	343		679	119	747	715		999	305						999	226		608		1100	1005	122	109
Las Palmas	702	997	848	120		1098	1215	1243	685		937	1106	700	1001		1111	73	700		1001	0			92	760	926	828	795		1146	1303			105		150	52	1210		752		1181	1086	918	926
Leixoes					288					720				177	750					176		0	227			86						930	383						224		250			76	96
Lisbon					455					582				344	615					343		227	0			257						880	156						50		73			247	267
Los christianos				188													19				92													184		68	54								
Malaga	66	247	98			796	465	923	133		187	356	66	684		810		181		679	760				II	595	114	44		396	972						780	893		202		431	336	580	558
Marin	537	832	683			236	1085	363	481		772	941	535	124		250		462		119	926	86	257		595	0	663	631		981	412						933	333		524		1016	921	24	29
Melilla	139	222	94			864	439	991	201		167	332	131	752		878		249		747	828				114	663	0	90		364	1088						848	961		270		406	313	648	656
Motril	104	205	56			831	423	960	196		145	314	98	720		843		217		715	795				44	631	90	0		354	1006						815	929		238		390	294	618	649
Palamos							53												196										0	167												101			
Palma Mallorca	451	166	304			1183	130	1309	519		214	130	444	1070		1196		567	70	999	1146				396	981	364	354	167	0	1358						1166	1279		588		128	145	966	974
Pasaia	914	1209	1078			183	1427	58	857		1149	1318	912	305		165		839		305	1303				972	412	1088	1006		1358	0						1295	87		901		1393	1298	415	407
Ponta Delgada																						930	880									0									916				
Portimao																						383	156										0								90				
Puerto Rosario				35													175	627			105			184										0		232	154								
Sagunto		105										25							111																0								15		
Santa Cruz de la Palma				226													42				150			68										232		0	105								
Santa Cruz de Tenerife	722	1017	868	160		1132	1235	1246	702		957	1126	720	999		1109	35	715		999	52			54	780	933	848	815		1166	1295			154		105	0	1208		765		1201	1106	909	917
Santander	835	1130	981			104	1348	36	789		1070	1239	833	225		86		760		226	1210				893	333	961	929		1279	87						1208	0		822		1314	1219	336	328
Setubal																						224	50																0		33				
Seville	144	439	290			725	657	852	78		379	548	142	613		739		95		608	752				202	524	270	238		588	901						765	822		0		623	528	510	518
Sines					208					550					580			200				250	73									916	90						33		0			322	
Tarragona	486	194	339			1218	50	1344	554		251	88	482	1105		1231		602	140	1100	1181				431	1016	406	390	101	128	1393						1201	1314		623		0	126	1001	1032
Valencia	391	99	244			1123	164	1249	459		156	40	390	1010		1136		507	112	1005	1086				336	921	313	294		145	1298						1106	1219		528		126	0	906	914
Vigo	522	817	668			240	1035	366	463		757	926	520	127		253		453		122	918	76	247		580	24	648	618		966	415						909	336		510	322	1001	906	0	31
Villagarcia de Arousa	530	825	676			232	1048	358	471		765	934	528	119		245		461		109	926	96	267		558	29	656	649		974	407						917	328		518		1032	914	31	0

Table 6.2 Road distances considered

Distancias terrestres	Algeciras	Alicante	Almeria	Arrecife	Aveiro	Aviles	Barcelona	Bilbao	Cadiz	Canical	Cartagena	Castellon de la Plana	Ceuta	Ferrol	Funchal	Gijon	Granadilla	Huelva	Ibiza	La Coruna	Las Palmas	Leixoes	Lisbon	Los christianos	Malaga	Marin	Melilla	Motril	Palamos	Palma Mallorca	Pasaia	Ponta Delgada	Portimao	Puerto Rosario	Sagunto	Santa Cruz de la Palma	Santa Cruz de Tenerife	Santander	Setubal	Seville	Sines	Tarragona	Valencia	Vigo	Villagarcia de Arousa
Algeciras	-	611	346	-	721	998	1.137	1.063	113	-	537	859	-	1.120	-	990	553	243	-	1.110	-	775	647	-	143	935	-	246	1.242	-	1.108	-	445	-	818	-	-	1.015	622	191	563	1.049	753	914	957
Alicante	610	-	300	-	952	905	529	805	639	-	127	251	-	1.027	-	896	652	405	-	1.017	-	983	909	-	480	1.041	-	399	634	-	753	-	857	-	211	-	-	861	884	595	950	441	173	1.025	1.070
Almeria	347	300	-	-	945	1.030	799	957	437	-	199	521	-	1.152	-	1.021	739	223	-	1.141	-	999	856	-	201	1.166	-	108	904	-	1.002	-	675	-	480	-	-	1.004	832	413	793	710	443	1.150	1.195
Arrecife	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Aveiro	721	952	950	-	-	619	1.161	726	652	-	977	950	-	398	-	610	341	765	-	380	-	92	269	-	752	252	-	844	1.251	-	771	-	514	-	909	-	-	678	308	534	391	1.087	898	232	274
Aviles	999	905	1.030	-	618	-	901	280	930	-	930	900	-	231	-	24	456	943	-	256	-	544	819	-	1.018	360	-	963	991	-	392	-	1.025	-	862	-	-	202	835	812	902	827	851	384	343
Barcelona	1.137	530	799	-	1.159	900	-	626	1.118	-	626	282	-	1.099	-	885	902	932	-	1.089	-	1.163	1.246	-	1.007	1.175	-	897	122	-	574	-	1.257	-	334	-	-	708	1.221	997	1.287	107	356	1.159	1.176
Bilbao	1.063	804	957	-	725	280	626	-	994	-	844	626	-	508	-	266	521	869	-	533	-	728	883	-	944	637	-	889	716	-	118	-	1.089	-	606	-	-	88	899	876	966	553	630	661	620
Cadiz	112	638	436	-	652	929	1.116	994	-	-	582	839	-	1.051	-	921	484	270	-	1.041	-	705	577	-	233	865	-	336	1.222	-	1.038	-	376	-	798	-	-	945	552	121	494	1.028	787	845	887
Canical	-	-	-	-	-	-	-	-	-	-	-	-	-	-	50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Cartagena	537	127	200	-	978	930	625	845	585	-	-	348	-	1.052	-	922	678	351	-	1.042	-	1.009	935	-	391	1.067	-	298	731	-	849	-	802	-	307	-	-	887	910	540	920	537	269	1.051	1.096
Castellon de l	858	251	519	-	949	902	281	627	839	-	346	-	-	1.024	-	886	674	653	-	1.014	-	981	942	-	728	1.038	-	618	386	-	575	-	978	-	55	-	-	708	917	718	983	193	77	1.022	1.067
Ceuta	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	385	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Ferrol	1.120	1.027	1.151	-	400	232	1.101	508	1.051	-	1.051	1.024	-	-	-	252	577	1.064	-	54	-	326	635	-	1.139	162	-	1.084	1.191	-	621	-	877	-	984	-	-	430	671	933	754	1.027	972	185	145
Funchal	-	-	-	-	-	-	-	-	-	50	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Gijon	988	894	1.019	-	607	29	879	259	919	-	919	879	-	257	-	-	445	931	-	282	-	533	808	-	1.006	386	-	951	970	-	371	-	1.014	-	859	-	-	181	824	801	891	806	840	409	369
Granadilla	553	653	739	-	340	456	902	520	483	-	678	676	-	578	-	447	-	596	-	567	-	382	414	25	583	548	-	671	992	-	565	-	578	-	635	-	55	472	389	366	455	828	624	532	577
Huelva	242	405	223	-	759	942	931	869	271	-	349	653	-	1.064	-	933	591	-	-	1.054	-	812	670	-	79	1.078	-	99	1.036	-	914	-	489	-	613	-	-	917	645	227	607	843	548	952	1.107
Ibiza	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
La Coruna	1.111	1.018	1.142	-	380	257	1.092	534	1.042	-	1.042	1.015	-	52	-	278	568	1.055	-	-	-	306	615	-	1.130	142	-	1.075	1.182	-	646	-	857	-	975	-	-	455	651	924	734	1.018	963	165	125
Las Palmas	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Leixoes	775	993	1.004	-	90	545	1.164	729	705	-	1.018	991	-	325	-	536	382	818	-	307	-	-	326	-	805	179	-	897	1.254	-	774	-	568	-	950	-	-	647	361	587	445	1.091	939	158	201
Lisbon	634	911	863	-	271	818	1.247	883	564	-	936	945	-	632	-	810	416	677	-	614	-	326	-	-	664	487	-	756	1.337	-	928	-	282	-	904	-	-	835	52	446	159	1.173	893	466	509
Los christiano	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	25	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	82	-	-	-	-	-	-	-	-
Malaga	144	480	201	-	747	1.017	1.006	944	235	-	391	728	-	1.139	-	1.008	578	79	-	1.129	-	800	658	-	-	960	-	101	1.111	-	989	-	476	-	688	-	-	992	633	214	594	918	623	939	982
Marin	934	1.040	1.164	-	250	359	1.175	636	865	-	1.064	1.037	-	159	-	380	547	977	-	141	-	176	485	-	965	-	-	1.097	1.265	-	785	-	727	-	997	-	-	557	521	747	604	1.102	985	35	35
Melilla	-	-	-	-	-	-	-	-	-	-	-	-	385	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Motril	240	399	108	-	827	958	898	886	330	-	298	620	-	1.080	-	950	667	96	-	1.070	-	880	738	-	94	1.095	-	-	1.003	-	930	-	556	-	579	-	-	933	713	294	674	809	541	1.079	1.124
Palamos	1.243	636	905	-	1.251	991	123	718	1.224	-	732	387	-	1.191	-	977	994	1.038	-	1.181	-	1.255	1.337	-	1.113	1.266	-	1.003	-	-	666	-	1.363	-	440	-	-	800	1.312	1.103	1.379	213	462	1.250	1.268
Palma Mallorc	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Pasaia	1.109	753	1.002	-	770	392	575	118	1.039	-	848	574	-	620	-	377	566	915	-	644	-	774	928	-	990	785	-	935	665	-	-	-	1.134	-	554	-	-	200	945	921	1.011	501	578	769	731
Ponta Delgad	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Portimao	445	857	674	-	510	1.024	1.257	1.089	376	-	801	979	-	870	-	1.016	579	488	-	852	-	564	281	-	476	724	-	568	1.362	-	1.134	-	-	-	938	-	-	1.041	256	259	140	1.169	927	703	746
Puerto Rosari	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Sagunto	818	211	479	-	909	861	334	607	799	-	306	46	-	983	-	853	633	613	-	973	-	940	901	-	688	998	-	578	439	-	555	-	937	-	-	-	-	689	877	678	943	245	34	982	1.027
Santa Cruz de	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Santa Cruz de	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	55	-	-	-	-	-	-	82	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Santander	1.017	863	1.006	-	678	202	709	89	947	-	888	709	-	431	-	188	474	919	-	455	-	648	837	-	994	560	-	939	799	-	201	-	1.042	-	689	-	-	-	853	830	919	635	713	583	542
Setubal	606	884	835	-	308	834	1.220	899	537	-	908	918	-	667	-	826	389	650	-	649	-	361	51	-	637	521	-	729	1.310	-	944	-	255	-	877	-	-	851	-	419	132	1.146	866	501	543
Seville	191	595	412	-	534	812	997	876	122	-	539	719	-	934	-	803	366	227	-	923	-	588	460	-	214	748	-	306	1.102	-	921	-	259	-	678	-	-	828	435	-	377	908	667	727	770
Sines	564	952	793	-	389	903	1.288	968	495	-	920	986	-	748	-	894	458	607	-	730	-	442	159	-	595	602	-	687	1.378	-	1.012	-	139	-	946	-	-	919	134	378	-	1.214	934	582	624
Tarragona	1.049	442	710	-	1.085	826	106	552	1.029	-	537	193	-	1.025	-	811	828	844	-	1.015	-	1.089	1.172	-	919	1.101	-	809	211	-	500	-	1.168	-	246	-	-	634	1.147	909	1.213	-	268	1.085	1.102
Valencia	753	174	443	-	897	849	356	631	786	-	270	78	-	971	-	841	621	548	-	961	-	928	889	-	623	985	-	541	461	-	579	-	925	-	34	-	-	712	864	665	930	267	-	969	1.014
Vigo	915	1.026	1.150	-	230	383	1.161	660	845	-	1.051	1.023	-	183	-	403	533	958	-	165	-	157	466	-	945	37	-	1.083	1.251	-	771	-	708	-	983	-	-	581	501	727	585	1.088	971	-	59
Villagarcia de	957	1.069	1.194	-	273	342	1.177	619	888	-	1.094	1.067	-	143	-	363	577	1.106	-	125	-	200	509	-	988	36	-	1.126	1.267	-	731	-	750	-	1.026	-	-	541	544	770	627	1.103	1.015	59	-

ANEXO 3: ESPECIFICACIONES PARA EL CALCULO DE LA GENERACIÓN DE CO_2 EN LA CADENA DE SUMINISTRO

1.1. Emission Factors Calculating

Firstly, it is necessary the **emission factors calculating** of each element and bunkering chains operations, as the basis for subsequent carbon footprint calculation, the following steps have been taken:

➢ Direct emission elements identification.

- **Transport/Navigation-related combustion of fuels, i.e., mobile sources,** (diesel (MDO) ship, LNG ship, diesel tanker truck and natural gas tanker truck) have been considered.

  The combustion of fuels produces emissions of the following greenhouse gases: carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). The focus of this guidance is on direct emissions of CO_2 from fossil fuel combustion, including in this combustion the slid methane emission. Carbon dioxide accounts for the majority of greenhouse gas emissions from most mobile combustion units.

- Other emission sources believed such as **fugitive emissions** of methane from LNG are: valves, pumps and connectors.

  The fugitive emissions are unintended gas leaks from the transmission, and/or transportation of LNG. The focus of this guidance is on direct emissions of CH_4 from LNG fugitive emissions.

- Finally, other emission sources have been from **venting emissions** of methane from flat bottom storage tank, pressure storage tank and tanker truck, in order to control the storage over-pressure.

  Although there is another element that can produce venting, such as transfer pipe, this element will not be considered in chains carbon footprint calculation due to the transfer pipe venting, before disengaging, is transferred to the tank or tanker truck venting.

➢ Direct emission factor estimation for each element of bunkering chains.

For the calculating of this emission factor the following steps have been taken:

1. Collect activity data on the type and quantity of fuel combusted in ton for Ships.
2. Collect activity data on the type and quantity of fuel combusted for distance (km) for tanker truck.
3. Collect activity data on fugitive emissions per hour during operation from valves, pumps and connectors.
4. Collect activity data on venting from storage elements, such as flat bottom storage tank and pressure storage tank, per day and m^3, and tanker truck per day.
5. Estimate CO_2 emission in tCO_2e. Taking into account that in order to CH_4 emission (fugitive and venting emissions) has been considered the global warming potential (see WP1), adapted from the *IPCC Fifth Assessment Report, 2014*.

   The first two points are estimated by reference to *GHG Protocol. Calculation tool (version 2.6.)*, the third point is estimated by the document "*Consistent methodology for estimating greenhouse gas emissions. Energy API, 2015*" and the fourth point is estimated by providing information on *Safety valves (Herose)*.

Then, it sets out the results achieved by each element of bunkering chains:

ELEMENT	CO_2 emission factor	Time factor taken into account for the emission factor calculation	LNG LOGISTIC SUPPLY CHAIN DESIGN TOOL
Diesel (MDO) Ship (Navigation-related combustion)	3.46 tCO_2e/ton fuel consumed (1)	-	To input into calculation tool in order to calculate the emission of **fuel consumed**
LNG Ship (Navigation-related combustion)	2.85 tCO_2e/ton fuel consumed (1)	-	
Diesel tanker truck (Transport-related combustion)	0.000914 tCO_2e/km (2)	-	To input into calculation tool in order to calculate the emission of **distance travelled**
Natural gas tanker truck (Transport-related combustion)	0.00089 tCO_2e/km (1)	-	
Diesel rail (Transport-related combustion)	0.012 tCO_2e/km (3)	-	
Pressure storage tank (venting unit element)	0.049 tCO_2e/day (4)	2-valve (10 bar) shooting, at the same time, 1 min/week	To input into calculation tool in order to calculate the emission of **unit element**
Flat bottom storage tank (venting unit element).	0.107 tCO_2e/day (4)	2-valve (1bar) shooting, at the same time, 2 min/day	
Tanker truck (venting unit element)	0.046 tCO_2e/day (4)	1-valve (5 bar) shooting 30 sec/day	
Transfer pipe (venting unit element)	$0.000341 \cdot 10^{-3}$ $tCO_2e/(m^3/h) \cdot m$ (5)	Element not considered in carbon footprint calculation due to the transfer pipe venting, before disengaging, is transferred to the tank storage or tanker truck venting	**Not to input into calculation tool**
Valve (fugitive emission)	$0.825 \cdot 10^{-5}$ tCO_2e/h (5)	During 1 min in loading/unloading **operation** (1.5 h)	This value is in order to calculate the direct emission factor estimation of operation (Table 2). **Not to input into calculation tool**
Pump (fugitive emission)	$0.277 \cdot 10^{-4}$ tCO_2e/h (5)		
Connector (fugitive emission)	$0.235 \cdot 10^{-5}$ tCO_2e/h (5)		

Table 1. CO_2 emission factor catalogue for each element of bunkering chains.

(1) Source: GHG Protocol. Calculation tool (version 2.6.)
(2) Source: Market Observatory for road freight transport and MAPAMA footprint calculation
(3) Source: Cost comparative study of rail transportation in Spain, France and Germany. ANFAC (2008)
(4) Source: Herose. Safety valves
(5) Source: Consistent methodology for estimating greenhouse gas emissions. Energy API, 2015

- Direct emission factor estimation for operation.

Taking into account the following operations in the designed bunkering chains:

- **Recharge** (Import Terminal to Ship)
- **Recharge** ((Import Terminal to Truck)
- **Bunkering** (Ship to Ship)
- **Bunkering** (Truck to Ship)
- **Feedering** (Ship to Storage tank)
- **Feedering** (Truck to Storage tank)

With table 1 data and taking into account the direct emission of engines combustion (during ship recharge and discharge and tanker truck discharge), which are necessary to be working during these operations, and fugitive emissions of the required elements in each operation (valves, pumps and connectors), the following **operation emission per hour** are obtained:

OPERATION	Emission factor tCO_2e/h	LNG LOGISTIC SUPPLY CHAIN DESIGN TOOL
Recharge (Import Terminal to Ship)	0.0000212	To input into calculation tool in order to calculate the emission of operation
Recharge (Import Terminal to Truck)		
Bunkering (Ship to Ship)	0.0000701	
Bunkering (Diesel Truck to Ship)	0.0914	
Bunkering (Natural gas Truck to Ship)	0.0891	
Feedering (Ship to Storage tank)	0.0000701	
Feedering (Diesel Truck to Storage tank)	0.0914	
Feedering (Natural gas Truck to Storage tank)	0.0891	

Table 2. CO_2 emission factor catalogue for each operation of bunkering chains

Finally, these unitary data (Table 1, except fugitive emission, and Table 2) will be input into calculation tool (LNG LOGISTIC SUPPLY CHAIN DESIGN TOOL) in order to **calculate carbon footprint** (tCO_2e) by each designed bunkering chain. This calculating depends on:

- Emission of **fuel consumed** by ships during their navigation.
- Emissions of **distance travelled** by tanker truck and rail.
- Emissions of different **unit elements** that conform the bunkering chains.
- Emission of **operations** carried out in each bunkering chain.

The carbon footprint final result for each designed bunkering chain will be obtained as the sum of all these emissions.

1.2. Example of carbon footprint calculation

The carbon footprint calculation of a real chain, as a practical example, can be found below. It is considered a chain with the following characteristics:

- ✓ Location: between Huelva Port, Algeciras Port and Ceuta Port.
- ✓ Fuel consumed by ship in tons: 4,965.43
- ✓ Distances by tanker truck in kilometers: 3,509,000
- ✓ Operations in hours:
  - Ship to Storage Feedering: 314.54
  - Ship to Ship Bunkering: 282.12
  - Storage to Ship Feedering: 176.25
  - Truck to Ship Bunkering: 220.32
- ✓ The chain also consists in two storage tanks:
  - Flat bottom storage tank in Algeciras with a capacity of 5,000 m^3.
  - Pressure storage tank in Ceuta with a capacity of 2,000m^3.
- ✓ The chain demanded is 5,540,637 MWh.

This resulted with the data described in tables 1 and 2:

- Carbon footprint (tCO_2) = 4,965.43 * 2.85+ 3,509,000 * 0.000914 + 314.54 * 0.0000701+ 282.12 * 0.0000701 + 176.25 * 0.0000701 + 220.32 * 0.0914 + 17,88 (venting pressure tank) + 39,05 (venting flat bottom tank) = 17,435.85 tCO_2

Providing this data in $kgCO_2$/MWh, the final result of carbon footprint for this described chain is **3.15 $kgCO_2$/MWh.**

ANEXO 4 EXCEL FILES WITH ANALYSIS PERFORMED

Bound to this report, a group of Excel files are provided:

- **Demand files**: 3 different files have been used to perform the analysis. First, a general one with the demand for the majority of ports and two additional files, one for Madeira Islands -estimating demand for power generation- and another for Huelva cluster considering ports in Algeciras Bay that it does not belong to Spain (It adds Gibraltar and Tanger-Med).

    - *"HIVE LNG SC DEMAND EDITOR"*
    - *"HIVE LNG SC DEMAND EDITOR Madeira Energy"*
    - *"HIVE LNG SC DEMAND EDITOR -Revision 2 (GIB+TAN)"*

- **Supply chain design and cost calculation tool:** File provided in the WP5

    - *"HIVE LNG SC DESIGN TOOL"*

- **Analysis and results visualization tool:** All the analysis showed in the 4.x.2 chapters have been stored and are available to a deeper review using the ANALYSIS module, provided with the WP5. Using this module analysis performed can be opened in the DESIGN TOOL for extra modifications or sensitivity analysis.

    - *"HIVE LNG SC ANALYSIS Informe Corredor atlántico"*: Include all the analysis showed for Bilbao, Gijón, Ferrol and Sines clusters
    - *"HIVE LNG SC ANALYSIS Informe Corredor mediterráneo":* Include all the analysis showed for Barcelona, Sagunto and Cartagena clusters
    - *"HIVE LNG SC ANALYSIS Informe Huelva e Islas Canarias"*: Include all the analysis showed for Huelva and Granadilla clusters
    - *"HIVE LNG SC ANALYSIS Resumen cadenas óptimas"*: Include all the analysis showed in the Chapter 5 as they are considered as the optimal

ANNEX 5: PORT DEMANAND CHARACTERIZATION AND ESTIMATION ON KNOWN FLEET FUELED BY LNG

5.1 KNOWN LNG-FUELLED FLEET

SCENARIO LOW

PORT	SUM OF NEW BUILDS				SUM OF PORT ACTIVITIES				SUM OF FISHING				SUM OF TOTAL_ADJUSTMENT			
	2020	2025	2030	2050	2020	2025	2030	2050	2020	2025	2030	2050	2020	2025	2030	2050
Aviles									0,10	0,19	0,38	1,62	0,10	0,19	0,38	1,62
Barcelona	70,00	70,00	70,00	70,00									70,00	70,00	70,00	70,00
Gijon									0,09	0,19	0,37	1,58	0,09	0,19	0,37	1,58
La Coruna									0,14	0,28	0,57	2,42	0,14	0,28	0,57	2,42
Las Palmas									0,06	0,12	0,23	0,99	0,06	0,12	0,23	0,99
Ponta Delgada									0,05	0,10	0,20	0,85	0,05	0,10	0,20	0,85
Sines									0,04	0,08	0,15	0,66	0,04	0,08	0,15	0,66
Vigo									0,15	0,29	0,58	2,46	0,15	0,29	0,58	2,46
Total general	**70,00**	**70,00**	**70,00**	**70,00**					**0,62**	**1,24**	**2,49**	**10,57**	**70,62**	**71,24**	**72,49**	**80,57**

SCENARIO BASIC

PORT	Etique SUM OF NEW BUILDS				SUM OF PORT ACTIVITIES				SUM OF FISHING				SUM OF TOTAL_ADJUSTMENT			
	2020	2025	2030	2050	2020	2025	2030	2050	2020	2025	2030	2050	2020	2025	2030	2050
Algeciras					2,00	2,00							2,00	2,00		
Aviles									0,19	0,43	0,81	2,71	0,19	0,43	0,81	2,71
Barcelona	110,00	110,00	110,00	110,00	0,80	0,80							110,80	110,80	110,00	110,00
Bilbao	2,40	2,40	2,40	2,40									2,40	2,40	2,40	2,40
Gijon									0,19	0,42	0,79	5,31	0,19	0,42	0,79	5,31
Huelva	20,00	20,00	20,00	20,00									20,00	20,00	20,00	20,00
La Coruna									0,28	0,64	1,21	4,05	0,28	0,64	1,21	4,05
Las Palmas	13,80	13,80	33,80	33,80					0,12	0,26	0,49	1,65	13,92	14,06	34,29	35,45
Ponta Delgada									0,10	0,23	0,43	1,43	0,10	0,23	0,43	1,43
Santa Cruz de Tenerife	9,20	9,20	9,20	9,20									9,20	9,20	9,20	9,20
Santander									0,29	0,65	1,23		0,29	0,65	1,23	
Sines									0,08	0,17	0,33	1,10	0,08	0,17	0,33	1,10
Valencia					2,00	2,00							2,00	2,00		
Vigo									0,29	0,65	1,23	4,12	0,29	0,65	1,23	4,12
Total general	**155,40**	**155,40**	**175,40**	**175,40**	**4,80**	**4,80**			**1,53**	**3,45**	**6,52**	**20,38**	**161,73**	**163,65**	**181,92**	**195,78**

SCENARIO HIGH

PORT	Etique SUM OF NEW BUILDS				SUM OF PORT ACTIVITIES				SUM OF FISHING				SUM OF TOTAL_ADJUSTMENT			
	2020	2025	2030	2050	2020	2025	2030	2050	2020	2025	2030	2050	2020	2025	2030	2050
Algeciras					8,00								8,0			
Aviles									0,47	0,62	1,09	3,43	0,5	0,6	1,1	3,4
Barcelona	150,00	150,00	150,00	150,00	1,60	1,60							151,6	151,6	150,0	150,0
Bilbao	2,40	2,40	2,40	2,40									2,4	2,4	2,4	2,4
Gijon									0,23	0,61	1,07	3,35	0,2	0,6	1,1	3,4
La Coruna									0,36	0,92	1,64	5,12	0,4	0,9	1,6	5,1
Las Palmas	13,80	13,80	33,80	33,80					0,15	0,38	0,67	2,09	13,9	14,2	34,5	35,9
Ponta Delgada									0,13	0,33	0,58	1,81	0,1	0,3	0,6	1,8
Santa Cruz de Tenerife	9,20	9,20	9,20	9,20									9,2	9,2	9,2	9,2
Sines										0,25	0,44	0,14		0,3	0,4	0,1
Valencia					8,00								8,0			
Vigo									0,10	0,94	1,66	5,21	0,1	0,9	1,7	5,2
Total general	**175,40**	**175,40**	**195,40**	**195,40**	**17,60**	**1,60**			**1,43**	**4,04**	**7,15**	**21,14**	**194,4**	**181,0**	**202,6**	**216,5**

5.2 UNIT VOLUMES BY PORT AND VESSEL CATEGORY

PORT	VESSEL CATEGORY	TTS	250	400	600	1600
Algeciras	Bulk carriers	0,1%	0,3%	41,2%	21,0%	37,4%
Algeciras	Car carriers	0,0%	0,0%	94,7%	5,3%	0,0%
Algeciras	Container ships	0,0%	3,4%	6,3%	26,5%	63,7%
Algeciras	General cargo	39,7%	47,4%	12,9%	0,0%	0,0%
Algeciras	Other	11,2%	34,9%	48,3%	5,6%	0,0%
Algeciras	Passenger ship	0,0%	100,0%	0,0%	0,0%	0,0%
Algeciras	Ro-Pax	33,8%	22,7%	33,3%	0,0%	10,1%
Algeciras	Ro-Ro	0,0%	99,0%	1,0%	0,0%	0,0%
Algeciras	Tankers	8,9%	9,1%	24,7%	15,8%	41,6%
Alicante	Bulk carriers	0,3%	2,9%	10,5%	86,3%	0,0%
Alicante	Car carriers	0,0%	0,0%	100,0%	0,0%	0,0%
Alicante	Container ships	0,3%	68,3%	31,3%	0,0%	0,0%
Alicante	General cargo	29,2%	55,2%	15,7%	0,0%	0,0%
Alicante	Other	100,0%	0,0%	0,0%	0,0%	0,0%
Alicante	Passenger ship	0,5%	1,0%	37,4%	0,0%	61,1%
Alicante	Ro-Pax	0,0%	0,0%	82,7%	0,0%	17,3%
Alicante	Ro-Ro	8,0%	92,0%	0,0%	0,0%	0,0%
Alicante	Tankers	21,7%	31,2%	27,1%	20,0%	0,0%
Almeria	Bulk carriers	1,0%	0,6%	16,8%	81,7%	0,0%
Almeria	Car carriers	0,0%	0,0%	0,0%	100,0%	0,0%
Almeria	Container ships	0,8%	99,2%	0,0%	0,0%	0,0%
Almeria	General cargo	23,3%	72,3%	4,4%	0,0%	0,0%
Almeria	Other	15,4%	70,5%	14,1%	0,0%	0,0%
Almeria	Passenger ship	0,0%	9,8%	54,8%	0,0%	35,4%
Almeria	Ro-Pax	0,0%	2,0%	25,8%	0,0%	72,2%
Almeria	Ro-Ro	0,0%	100,0%	0,0%	0,0%	0,0%
Almeria	Tankers	10,1%	89,9%	0,0%	0,0%	0,0%
Arinaga	Bulk carriers	0,0%	0,0%	0,0%	0,0%	0,0%
Arinaga	Car carriers	0,0%	0,0%	0,0%	0,0%	0,0%
Arinaga	Container ships	0,0%	0,0%	0,0%	0,0%	0,0%
Arinaga	General cargo	100,0%	0,0%	0,0%	0,0%	0,0%
Arinaga	Other	100,0%	0,0%	0,0%	0,0%	0,0%
Arinaga	Passenger ship	0,0%	0,0%	0,0%	0,0%	0,0%
Arinaga	Ro-Pax	0,0%	0,0%	0,0%	0,0%	0,0%
Arinaga	Ro-Ro	0,0%	0,0%	0,0%	0,0%	0,0%
Arinaga	Tankers	100,0%	0,0%	0,0%	0,0%	0,0%
Arrecife	Bulk carriers	100,0%	0,0%	0,0%	0,0%	0,0%
Arrecife	Car carriers	0,0%	0,0%	0,0%	0,0%	0,0%
Arrecife	Container ships	0,0%	0,0%	0,0%	0,0%	0,0%
Arrecife	General cargo	100,0%	0,0%	0,0%	0,0%	0,0%
Arrecife	Other	100,0%	0,0%	0,0%	0,0%	0,0%

Arrecife	Passenger ship	100,0%	0,0%	0,0%	0,0%	0,0%
Arrecife	Ro-Pax	0,0%	0,0%	0,0%	0,0%	0,0%
Arrecife	Ro-Ro	0,0%	0,0%	0,0%	0,0%	0,0%
Arrecife	Tankers	100,0%	0,0%	0,0%	0,0%	0,0%
Aveiro	Bulk carriers	4,4%	30,0%	65,6%	0,0%	0,0%
Aveiro	Car carriers	0,0%	0,0%	0,0%	0,0%	0,0%
Aveiro	Container ships	80,4%	19,6%	0,0%	0,0%	0,0%
Aveiro	General cargo	46,2%	44,5%	9,4%	0,0%	0,0%
Aveiro	Other	98,0%	2,0%	0,0%	0,0%	0,0%
Aveiro	Passenger ship	0,0%	0,0%	0,0%	0,0%	0,0%
Aveiro	Ro-Pax	0,0%	100,0%	0,0%	0,0%	0,0%
Aveiro	Ro-Ro	15,6%	84,4%	0,0%	0,0%	0,0%
Aveiro	Tankers	50,6%	14,5%	35,0%	0,0%	0,0%
Aviles	Bulk carriers	0,3%	2,3%	32,9%	64,5%	0,0%
Aviles	Car carriers	0,0%	0,0%	0,0%	0,0%	0,0%
Aviles	Container ships	51,3%	48,7%	0,0%	0,0%	0,0%
Aviles	General cargo	23,4%	41,7%	34,9%	0,0%	0,0%
Aviles	Other	0,0%	100,0%	0,0%	0,0%	0,0%
Aviles	Passenger ship	0,0%	0,0%	100,0%	0,0%	0,0%
Aviles	Ro-Pax	0,0%	0,0%	0,0%	0,0%	0,0%
Aviles	Ro-Ro	0,0%	100,0%	0,0%	0,0%	0,0%
Aviles	Tankers	10,3%	41,0%	48,7%	0,0%	0,0%
Barcelona	Bulk carriers	1,0%	1,9%	21,1%	73,9%	2,1%
Barcelona	Car carriers	0,0%	0,5%	18,0%	81,6%	0,0%
Barcelona	Container ships	0,1%	8,7%	8,7%	16,4%	66,2%
Barcelona	General cargo	21,8%	53,9%	24,2%	0,0%	0,0%
Barcelona	Other	43,5%	34,3%	22,2%	0,0%	0,0%
Barcelona	Passenger ship	0,1%	0,4%	13,5%	0,0%	86,1%
Barcelona	Ro-Pax	0,0%	0,3%	20,4%	0,0%	79,3%
Barcelona	Ro-Ro	0,0%	16,4%	69,5%	14,0%	0,0%
Barcelona	Tankers	8,0%	9,0%	19,9%	26,5%	36,6%
Bilbao	Bulk carriers	0,0%	1,3%	18,9%	79,0%	0,7%
Bilbao	Car carriers	0,0%	0,0%	0,0%	100,0%	0,0%
Bilbao	Container ships	0,0%	85,2%	12,7%	2,1%	0,0%
Bilbao	General cargo	18,1%	49,1%	32,8%	0,0%	0,0%
Bilbao	Other	33,1%	0,0%	48,7%	18,1%	0,0%
Bilbao	Passenger ship	0,6%	3,2%	34,8%	0,0%	61,4%
Bilbao	Ro-Pax	0,0%	0,0%	9,7%	0,0%	90,3%
Bilbao	Ro-Ro	0,0%	35,8%	58,8%	5,4%	0,0%
Bilbao	Tankers	2,5%	4,7%	12,1%	10,6%	70,1%
Cadiz	Bulk carriers	0,0%	5,3%	52,8%	41,9%	0,0%
Cadiz	Car carriers	0,0%	16,4%	67,3%	16,2%	0,0%
Cadiz	Container ships	0,0%	23,7%	60,2%	16,1%	0,0%
Cadiz	General cargo	23,9%	63,1%	13,0%	0,0%	0,0%
Cadiz	Other	47,3%	17,2%	35,5%	0,0%	0,0%

Cadiz	Passenger ship	0,6%	0,8%	15,8%	0,0%	82,8%
Cadiz	Ro-Pax	0,0%	1,3%	0,0%	0,0%	98,7%
Cadiz	Ro-Ro	0,0%	26,7%	73,3%	0,0%	0,0%
Cadiz	Tankers	4,8%	8,0%	38,2%	15,5%	33,5%
Canical	Bulk carriers	100,0%	0,0%	0,0%	0,0%	0,0%
Canical	Car carriers	0,0%	0,0%	0,0%	0,0%	0,0%
Canical	Container ships	100,0%	0,0%	0,0%	0,0%	0,0%
Canical	General cargo	100,0%	0,0%	0,0%	0,0%	0,0%
Canical	Other	100,0%	0,0%	0,0%	0,0%	0,0%
Canical	Passenger ship	0,0%	0,0%	0,0%	0,0%	0,0%
Canical	Ro-Pax	0,0%	0,0%	0,0%	0,0%	0,0%
Canical	Ro-Ro	0,0%	0,0%	0,0%	0,0%	0,0%
Canical	Tankers	100,0%	0,0%	0,0%	0,0%	0,0%
Cartagena	Bulk carriers	0,8%	2,8%	27,4%	57,7%	11,3%
Cartagena	Car carriers	0,0%	0,0%	100,0%	0,0%	0,0%
Cartagena	Container ships	1,0%	69,7%	29,3%	0,0%	0,0%
Cartagena	General cargo	31,7%	53,7%	14,6%	0,0%	0,0%
Cartagena	Other	27,6%	32,9%	34,5%	5,1%	0,0%
Cartagena	Passenger ship	1,0%	1,2%	25,4%	0,0%	72,4%
Cartagena	Ro-Pax	0,0%	100,0%	0,0%	0,0%	0,0%
Cartagena	Ro-Ro	1,9%	98,1%	0,0%	0,0%	0,0%
Cartagena	Tankers	2,1%	4,1%	13,6%	11,8%	68,4%
Castellon de la Plana	Bulk carriers	0,0%	1,0%	60,4%	38,5%	0,0%
Castellon de la Plana	Car carriers	0,0%	0,0%	0,0%	100,0%	0,0%
Castellon de la Plana	Container ships	1,8%	13,1%	38,7%	46,4%	0,0%
Castellon de la Plana	General cargo	38,6%	56,2%	5,2%	0,0%	0,0%
Castellon de la Plana	Other	0,4%	54,5%	45,1%	0,0%	0,0%
Castellon de la Plana	Passenger ship	0,0%	0,0%	0,0%	0,0%	0,0%
Castellon de la Plana	Ro-Pax	0,0%	0,0%	0,0%	0,0%	0,0%
Castellon de la Plana	Ro-Ro	6,3%	8,8%	0,0%	84,9%	0,0%
Castellon de la Plana	Tankers	3,5%	13,5%	40,5%	23,9%	18,6%
Ceuta	Bulk carriers	5,9%	53,6%	36,5%	4,1%	0,0%
Ceuta	Car carriers	0,0%	0,0%	100,0%	0,0%	0,0%
Ceuta	Container ships	27,8%	68,8%	3,4%	0,0%	0,0%
Ceuta	General cargo	21,4%	76,0%	2,6%	0,0%	0,0%
Ceuta	Other	10,7%	77,2%	12,2%	0,0%	0,0%
Ceuta	Passenger ship	0,0%	9,2%	51,4%	0,0%	39,3%
Ceuta	Ro-Pax	0,0%	0,0%	0,0%	0,0%	0,0%
Ceuta	Ro-Ro	0,0%	0,0%	0,0%	0,0%	0,0%
Ceuta	Tankers	35,6%	45,8%	11,1%	7,4%	0,0%
Ferrol	Bulk carriers	0,0%	1,6%	1,9%	9,0%	87,5%
Ferrol	Car carriers	0,0%	0,0%	0,0%	100,0%	0,0%
Ferrol	Container ships	5,1%	6,0%	13,4%	0,0%	75,6%
Ferrol	General cargo	31,1%	51,1%	17,8%	0,0%	0,0%
Ferrol	Other	41,4%	40,6%	18,0%	0,0%	0,0%

Ferrol	Passenger ship	0,0%	2,2%	40,8%	0,0%	57,0%
Ferrol	Ro-Pax	0,0%	26,5%	0,0%	0,0%	73,5%
Ferrol	Ro-Ro	0,0%	7,1%	92,9%	0,0%	0,0%
Ferrol	Tankers	0,4%	1,8%	4,9%	9,4%	83,5%
Funchal	Bulk carriers	100,0%	0,0%	0,0%	0,0%	0,0%
Funchal	Car carriers	0,0%	0,0%	0,0%	0,0%	0,0%
Funchal	Container ships	0,0%	0,0%	41,7%	58,3%	0,0%
Funchal	General cargo	0,0%	0,0%	0,0%	0,0%	0,0%
Funchal	Other	83,0%	17,0%	0,0%	0,0%	0,0%
Funchal	Passenger ship	0,2%	1,3%	19,2%	0,0%	79,3%
Funchal	Ro-Pax	0,0%	98,9%	1,1%	0,0%	0,0%
Funchal	Ro-Ro	0,0%	0,0%	0,0%	0,0%	0,0%
Funchal	Tankers	5,3%	0,0%	94,7%	0,0%	0,0%
Gijon	Bulk carriers	1,2%	0,4%	5,6%	32,6%	60,1%
Gijon	Car carriers	0,0%	0,0%	14,8%	85,2%	0,0%
Gijon	Container ships	0,1%	87,0%	11,5%	1,3%	0,0%
Gijon	General cargo	23,1%	52,8%	24,1%	0,0%	0,0%
Gijon	Other	38,6%	2,9%	19,1%	39,4%	0,0%
Gijon	Passenger ship	0,6%	11,3%	30,3%	0,0%	57,8%
Gijon	Ro-Pax	0,0%	0,0%	35,1%	0,0%	64,9%
Gijon	Ro-Ro	0,0%	100,0%	0,0%	0,0%	0,0%
Gijon	Tankers	11,6%	8,2%	54,3%	25,9%	0,0%
Huelva	Bulk carriers	0,3%	2,8%	40,9%	53,7%	2,4%
Huelva	Car carriers	0,0%	0,0%	0,0%	0,0%	0,0%
Huelva	Container ships	21,1%	78,9%	0,0%	0,0%	0,0%
Huelva	General cargo	27,6%	44,9%	27,5%	0,0%	0,0%
Huelva	Other	100,0%	0,0%	0,0%	0,0%	0,0%
Huelva	Passenger ship	10,6%	0,0%	89,4%	0,0%	0,0%
Huelva	Ro-Pax	0,0%	0,0%	0,0%	0,0%	100,0%
Huelva	Ro-Ro	0,0%	0,0%	0,0%	0,0%	0,0%
Huelva	Tankers	6,2%	16,1%	20,6%	14,5%	42,5%
Ibiza	Bulk carriers	100,0%	0,0%	0,0%	0,0%	0,0%
Ibiza	Car carriers	0,0%	0,0%	0,0%	0,0%	0,0%
Ibiza	Container ships	0,0%	0,0%	0,0%	0,0%	0,0%
Ibiza	General cargo	100,0%	0,0%	0,0%	0,0%	0,0%
Ibiza	Other	100,0%	0,0%	0,0%	0,0%	0,0%
Ibiza	Passenger ship	100,0%	0,0%	0,0%	0,0%	0,0%
Ibiza	Ro-Pax	0,0%	100,0%	0,0%	0,0%	0,0%
Ibiza	Ro-Ro	0,0%	0,0%	0,0%	0,0%	0,0%
Ibiza	Tankers	0,0%	0,0%	0,0%	0,0%	0,0%
La Coruna	Bulk carriers	1,9%	1,2%	12,5%	73,8%	10,5%
La Coruna	Car carriers	0,0%	0,0%	0,0%	0,0%	0,0%
La Coruna	Container ships	2,7%	97,3%	0,0%	0,0%	0,0%
La Coruna	General cargo	36,9%	47,6%	15,5%	0,0%	0,0%
La Coruna	Other	18,2%	16,2%	0,0%	65,6%	0,0%

La Coruna	Passenger ship	0,6%	1,7%	21,7%	0,0%	76,0%
La Coruna	Ro-Pax	0,0%	0,0%	100,0%	0,0%	0,0%
La Coruna	Ro-Ro	0,0%	0,0%	0,0%	0,0%	0,0%
La Coruna	Tankers	3,8%	3,7%	12,0%	10,8%	69,7%
Las Palmas	Bulk carriers	1,1%	8,4%	37,5%	50,2%	2,8%
Las Palmas	Car carriers	0,0%	3,6%	91,7%	4,7%	0,0%
Las Palmas	Container ships	0,3%	21,5%	10,7%	23,9%	43,5%
Las Palmas	General cargo	14,5%	67,5%	18,0%	0,0%	0,0%
Las Palmas	Other	29,8%	64,0%	6,2%	0,0%	0,0%
Las Palmas	Passenger ship	0,3%	1,2%	24,8%	0,0%	73,7%
Las Palmas	Ro-Pax	0,0%	24,2%	24,3%	0,0%	51,6%
Las Palmas	Ro-Ro	0,1%	65,4%	34,4%	0,0%	0,0%
Las Palmas	Tankers	16,7%	35,8%	27,0%	18,6%	1,9%
Leixoes	Bulk carriers	0,6%	2,3%	26,1%	67,1%	3,9%
Leixoes	Car carriers	0,0%	0,0%	0,0%	0,0%	0,0%
Leixoes	Container ships	0,9%	35,9%	38,5%	24,6%	0,0%
Leixoes	General cargo	19,5%	47,3%	33,2%	0,0%	0,0%
Leixoes	Other	100,0%	0,0%	0,0%	0,0%	0,0%
Leixoes	Passenger ship	1,1%	4,4%	43,9%	0,0%	50,6%
Leixoes	Ro-Pax	0,0%	0,0%	100,0%	0,0%	0,0%
Leixoes	Ro-Ro	0,0%	49,3%	28,0%	22,6%	0,0%
Leixoes	Tankers	14,0%	16,8%	53,5%	7,0%	8,6%
Lisbon	Bulk carriers	0,1%	2,0%	28,2%	64,9%	4,8%
Lisbon	Car carriers	0,0%	0,0%	0,0%	100,0%	0,0%
Lisbon	Container ships	1,1%	22,6%	21,7%	37,4%	17,2%
Lisbon	General cargo	31,1%	63,2%	5,7%	0,0%	0,0%
Lisbon	Other	40,9%	25,2%	33,9%	0,0%	0,0%
Lisbon	Passenger ship	1,3%	3,6%	20,5%	0,0%	74,6%
Lisbon	Ro-Pax	0,0%	74,3%	25,7%	0,0%	0,0%
Lisbon	Ro-Ro	0,0%	1,3%	52,0%	46,6%	0,0%
Lisbon	Tankers	29,0%	20,1%	49,4%	1,4%	0,0%
Los Christianos	Bulk carriers	0,0%	0,0%	0,0%	0,0%	0,0%
Los Christianos	Car carriers	0,0%	0,0%	0,0%	0,0%	0,0%
Los Christianos	Container ships	0,0%	0,0%	0,0%	0,0%	0,0%
Los Christianos	General cargo	0,0%	0,0%	0,0%	0,0%	0,0%
Los Christianos	Other	0,0%	0,0%	0,0%	0,0%	100,0%
Los Christianos	Passenger ship	100,0%	0,0%	0,0%	0,0%	0,0%
Los Christianos	Ro-Pax	0,0%	70,9%	29,1%	0,0%	0,0%
Los Christianos	Ro-Ro	0,0%	0,0%	0,0%	0,0%	0,0%
Los Christianos	Tankers	0,0%	0,0%	0,0%	0,0%	0,0%
Malaga	Bulk carriers	2,2%	5,8%	44,6%	47,4%	0,0%
Malaga	Car carriers	0,0%	0,0%	25,4%	74,6%	0,0%
Malaga	Container ships	0,0%	17,7%	4,5%	25,4%	52,5%
Malaga	General cargo	31,4%	48,4%	20,2%	0,0%	0,0%
Malaga	Other	36,6%	63,4%	0,0%	0,0%	0,0%

Malaga	Passenger ship	0,5%	1,1%	26,5%	0,0%	72,0%
Malaga	Ro-Pax	0,0%	2,0%	15,7%	0,0%	82,2%
Malaga	Ro-Ro	0,0%	100,0%	0,0%	0,0%	0,0%
Malaga	Tankers	7,8%	13,8%	35,6%	42,8%	0,0%
Marin	Bulk carriers	1,0%	1,0%	26,2%	61,2%	10,6%
Marin	Car carriers	0,0%	0,0%	0,0%	100,0%	0,0%
Marin	Container ships	0,1%	1,3%	1,1%	97,6%	0,0%
Marin	General cargo	27,3%	42,1%	30,5%	0,0%	0,0%
Marin	Other	49,6%	25,0%	25,4%	0,0%	0,0%
Marin	Passenger ship	0,0%	0,0%	0,0%	0,0%	0,0%
Marin	Ro-Pax	0,0%	0,0%	0,0%	0,0%	0,0%
Marin	Ro-Ro	0,0%	100,0%	0,0%	0,0%	0,0%
Marin	Tankers	0,0%	0,0%	0,0%	0,0%	0,0%
Melilla	Bulk carriers	100,0%	0,0%	0,0%	0,0%	0,0%
Melilla	Car carriers	0,0%	0,0%	0,0%	0,0%	0,0%
Melilla	Container ships	0,0%	0,0%	0,0%	0,0%	0,0%
Melilla	General cargo	0,0%	0,0%	0,0%	0,0%	0,0%
Melilla	Other	0,0%	0,0%	0,0%	0,0%	0,0%
Melilla	Passenger ship	0,0%	0,0%	0,0%	0,0%	0,0%
Melilla	Ro-Pax	0,0%	0,0%	0,0%	0,0%	0,0%
Melilla	Ro-Ro	0,0%	0,0%	0,0%	0,0%	0,0%
Melilla	Tankers	100,0%	0,0%	0,0%	0,0%	0,0%
Motril	Bulk carriers	3,6%	8,3%	31,3%	56,8%	0,0%
Motril	Car carriers	0,0%	0,0%	0,0%	100,0%	0,0%
Motril	Container ships	3,7%	96,3%	0,0%	0,0%	0,0%
Motril	General cargo	28,9%	56,0%	15,2%	0,0%	0,0%
Motril	Other	23,4%	0,0%	76,6%	0,0%	0,0%
Motril	Passenger ship	16,2%	3,5%	70,5%	0,0%	9,9%
Motril	Ro-Pax	0,0%	6,2%	35,6%	0,0%	58,2%
Motril	Ro-Ro	0,0%	100,0%	0,0%	0,0%	0,0%
Motril	Tankers	4,8%	15,0%	69,2%	11,0%	0,0%
Palamos	Bulk carriers	0,0%	0,0%	13,8%	86,2%	0,0%
Palamos	Car carriers	0,0%	0,0%	0,0%	0,0%	0,0%
Palamos	Container ships	0,0%	0,0%	0,0%	0,0%	0,0%
Palamos	General cargo	7,6%	60,5%	31,9%	0,0%	0,0%
Palamos	Other	100,0%	0,0%	0,0%	0,0%	0,0%
Palamos	Passenger ship	100,0%	0,0%	0,0%	0,0%	0,0%
Palamos	Ro-Pax	0,0%	0,0%	0,0%	0,0%	0,0%
Palamos	Ro-Ro	0,0%	0,0%	0,0%	0,0%	0,0%
Palamos	Tankers	0,0%	0,0%	0,0%	0,0%	0,0%
Palma Mallorca	Bulk carriers	100,0%	0,0%	0,0%	0,0%	0,0%
Palma Mallorca	Car carriers	0,0%	0,0%	0,0%	0,0%	0,0%
Palma Mallorca	Container ships	0,0%	0,0%	0,0%	0,0%	0,0%
Palma Mallorca	General cargo	100,0%	0,0%	0,0%	0,0%	0,0%
Palma Mallorca	Other	100,0%	0,0%	0,0%	0,0%	0,0%

Palma Mallorca	Passenger ship	100,0%	0,0%	0,0%	0,0%	0,0%
Palma Mallorca	Ro-Pax	0,0%	100,0%	0,0%	0,0%	0,0%
Palma Mallorca	Ro-Ro	100,0%	0,0%	0,0%	0,0%	0,0%
Palma Mallorca	Tankers	0,0%	0,0%	0,0%	0,0%	0,0%
Pasaia	Bulk carriers	0,5%	15,4%	84,1%	0,0%	0,0%
Pasaia	Car carriers	0,0%	10,6%	89,4%	0,0%	0,0%
Pasaia	Container ships	33,2%	66,8%	0,0%	0,0%	0,0%
Pasaia	General cargo	37,5%	44,0%	18,5%	0,0%	0,0%
Pasaia	Other	100,0%	0,0%	0,0%	0,0%	0,0%
Pasaia	Passenger ship	0,0%	0,0%	0,0%	0,0%	0,0%
Pasaia	Ro-Pax	0,0%	0,0%	0,0%	0,0%	0,0%
Pasaia	Ro-Ro	0,0%	100,0%	0,0%	0,0%	0,0%
Pasaia	Tankers	0,0%	0,0%	0,0%	0,0%	0,0%
Ponta Delgada	Bulk carriers	0,0%	12,1%	61,7%	26,2%	0,0%
Ponta Delgada	Car carriers	0,0%	0,0%	0,0%	0,0%	0,0%
Ponta Delgada	Container ships	26,8%	73,2%	0,0%	0,0%	0,0%
Ponta Delgada	General cargo	33,3%	63,1%	3,7%	0,0%	0,0%
Ponta Delgada	Other	36,1%	61,8%	2,2%	0,0%	0,0%
Ponta Delgada	Passenger ship	0,5%	2,9%	22,4%	0,0%	74,3%
Ponta Delgada	Ro-Pax	0,0%	99,5%	0,5%	0,0%	0,0%
Ponta Delgada	Ro-Ro	0,0%	100,0%	0,0%	0,0%	0,0%
Ponta Delgada	Tankers	41,5%	1,6%	56,9%	0,0%	0,0%
Portimao	Bulk carriers	0,0%	0,0%	0,0%	0,0%	0,0%
Portimao	Car carriers	0,0%	0,0%	0,0%	0,0%	0,0%
Portimao	Container ships	0,0%	0,0%	0,0%	0,0%	0,0%
Portimao	General cargo	100,0%	0,0%	0,0%	0,0%	0,0%
Portimao	Other	100,0%	0,0%	0,0%	0,0%	0,0%
Portimao	Passenger ship	0,0%	0,0%	0,0%	0,0%	0,0%
Portimao	Ro-Pax	0,0%	0,0%	0,0%	0,0%	0,0%
Portimao	Ro-Ro	0,0%	0,0%	0,0%	0,0%	0,0%
Portimao	Tankers	0,0%	0,0%	0,0%	0,0%	0,0%
Puerto Rosario	Bulk carriers	100,0%	0,0%	0,0%	0,0%	0,0%
Puerto Rosario	Car carriers	0,0%	0,0%	0,0%	0,0%	0,0%
Puerto Rosario	Container ships	0,0%	0,0%	0,0%	0,0%	0,0%
Puerto Rosario	General cargo	100,0%	0,0%	0,0%	0,0%	0,0%
Puerto Rosario	Other	100,0%	0,0%	0,0%	0,0%	0,0%
Puerto Rosario	Passenger ship	100,0%	0,0%	0,0%	0,0%	0,0%
Puerto Rosario	Ro-Pax	0,0%	0,0%	0,0%	0,0%	0,0%
Puerto Rosario	Ro-Ro	0,0%	0,0%	0,0%	0,0%	0,0%
Puerto Rosario	Tankers	100,0%	0,0%	0,0%	0,0%	0,0%
Sagunto	Bulk carriers	7,1%	6,3%	20,3%	66,4%	0,0%
Sagunto	Car carriers	0,0%	0,0%	6,0%	94,0%	0,0%
Sagunto	Container ships	0,7%	75,9%	12,9%	10,5%	0,0%
Sagunto	General cargo	34,0%	46,8%	19,2%	0,0%	0,0%
Sagunto	Other	0,0%	74,4%	25,6%	0,0%	0,0%

Sagunto	Passenger ship	0,0%	0,0%	0,0%	0,0%	0,0%
Sagunto	Ro-Pax	0,0%	0,0%	0,0%	0,0%	0,0%
Sagunto	Ro-Ro	0,2%	89,6%	6,7%	3,6%	0,0%
Sagunto	Tankers	0,5%	2,2%	2,7%	6,3%	88,3%
Santa Cruz de la Palma	Bulk carriers	100,0%	0,0%	0,0%	0,0%	0,0%
Santa Cruz de la Palma	Car carriers	0,0%	0,0%	0,0%	0,0%	0,0%
Santa Cruz de la Palma	Container ships	0,0%	0,0%	0,0%	0,0%	0,0%
Santa Cruz de la Palma	General cargo	100,0%	0,0%	0,0%	0,0%	0,0%
Santa Cruz de la Palma	Other	100,0%	0,0%	0,0%	0,0%	0,0%
Santa Cruz de la Palma	Passenger ship	100,0%	0,0%	0,0%	0,0%	0,0%
Santa Cruz de la Palma	Ro-Pax	0,0%	0,0%	0,0%	0,0%	0,0%
Santa Cruz de la Palma	Ro-Ro	0,0%	0,0%	0,0%	0,0%	0,0%
Santa Cruz de la Palma	Tankers	100,0%	0,0%	0,0%	0,0%	0,0%
Santa Cruz de Tenerife	Bulk carriers	1,8%	6,1%	44,3%	47,9%	0,0%
Santa Cruz de Tenerife	Car carriers	0,0%	3,1%	92,8%	4,1%	0,0%
Santa Cruz de Tenerife	Container ships	0,0%	69,3%	30,7%	0,0%	0,0%
Santa Cruz de Tenerife	General cargo	19,2%	50,7%	30,1%	0,0%	0,0%
Santa Cruz de Tenerife	Other	18,7%	17,4%	63,9%	0,0%	0,0%
Santa Cruz de Tenerife	Passenger ship	0,1%	1,0%	21,5%	0,0%	77,4%
Santa Cruz de Tenerife	Ro-Pax	0,0%	52,8%	32,9%	0,0%	14,3%
Santa Cruz de Tenerife	Ro-Ro	0,0%	33,7%	66,3%	0,0%	0,0%
Santa Cruz de Tenerife	Tankers	13,4%	9,5%	47,0%	28,8%	1,3%
Santander	Bulk carriers	0,9%	2,2%	22,4%	65,1%	9,4%
Santander	Car carriers	0,0%	1,8%	27,3%	70,9%	0,0%
Santander	Container ships	8,1%	91,9%	0,0%	0,0%	0,0%
Santander	General cargo	35,3%	42,1%	22,7%	0,0%	0,0%
Santander	Other	45,1%	48,7%	6,2%	0,0%	0,0%
Santander	Passenger ship	1,9%	2,0%	47,7%	0,0%	48,4%
Santander	Ro-Pax	0,0%	0,0%	5,1%	0,0%	94,9%
Santander	Ro-Ro	0,0%	2,9%	92,1%	5,1%	0,0%
Santander	Tankers	31,5%	49,7%	15,0%	3,8%	0,0%
Setubal	Bulk carriers	1,7%	4,4%	27,2%	65,3%	1,4%
Setubal	Car carriers	0,0%	2,7%	0,8%	96,5%	0,0%
Setubal	Container ships	1,3%	53,0%	23,3%	9,0%	13,5%
Setubal	General cargo	22,4%	68,9%	8,7%	0,0%	0,0%
Setubal	Other	20,6%	75,1%	4,3%	0,0%	0,0%
Setubal	Passenger ship	0,0%	0,0%	100,0%	0,0%	0,0%
Setubal	Ro-Pax	0,0%	0,0%	0,0%	0,0%	0,0%
Setubal	Ro-Ro	0,0%	7,5%	2,9%	89,7%	0,0%
Setubal	Tankers	1,4%	3,0%	5,6%	23,2%	66,7%
Seville	Bulk carriers	0,6%	19,0%	80,4%	0,0%	0,0%
Seville	Car carriers	0,0%	0,0%	0,0%	0,0%	0,0%
Seville	Container ships	0,5%	99,5%	0,0%	0,0%	0,0%
Seville	General cargo	61,2%	34,6%	4,2%	0,0%	0,0%
Seville	Other	100,0%	0,0%	0,0%	0,0%	0,0%

Seville	Passenger ship	19,0%	15,0%	65,9%	0,0%	0,0%
Seville	Ro-Pax	0,0%	0,0%	100,0%	0,0%	0,0%
Seville	Ro-Ro	0,0%	100,0%	0,0%	0,0%	0,0%
Seville	Tankers	60,1%	39,9%	0,0%	0,0%	0,0%
Sines	Bulk carriers	0,1%	1,9%	1,3%	3,9%	92,8%
Sines	Car carriers	0,0%	0,0%	0,0%	0,0%	0,0%
Sines	Container ships	0,0%	2,5%	3,5%	15,6%	78,4%
Sines	General cargo	36,3%	49,3%	14,4%	0,0%	0,0%
Sines	Other	6,6%	51,2%	0,0%	42,1%	0,0%
Sines	Passenger ship	0,0%	0,0%	0,0%	0,0%	0,0%
Sines	Ro-Pax	0,0%	0,0%	0,0%	0,0%	0,0%
Sines	Ro-Ro	0,0%	0,0%	0,0%	0,0%	0,0%
Sines	Tankers	3,0%	6,7%	21,0%	14,5%	54,8%
Tarragona	Bulk carriers	0,3%	3,3%	17,4%	63,6%	15,4%
Tarragona	Car carriers	0,0%	0,3%	3,7%	96,0%	0,0%
Tarragona	Container ships	0,2%	6,3%	11,7%	81,8%	0,0%
Tarragona	General cargo	25,5%	51,0%	23,5%	0,0%	0,0%
Tarragona	Other	6,0%	9,0%	85,0%	0,0%	0,0%
Tarragona	Passenger ship	9,0%	9,4%	32,9%	0,0%	48,7%
Tarragona	Ro-Pax	0,0%	0,0%	35,4%	0,0%	64,6%
Tarragona	Ro-Ro	0,0%	91,5%	1,7%	6,9%	0,0%
Tarragona	Tankers	4,5%	17,9%	41,5%	23,5%	12,5%
Valencia	Bulk carriers	2,7%	0,9%	56,5%	30,7%	9,3%
Valencia	Car carriers	0,0%	0,1%	2,7%	97,3%	0,0%
Valencia	Container ships	0,1%	4,1%	6,8%	25,5%	63,6%
Valencia	General cargo	37,0%	44,1%	18,9%	0,0%	0,0%
Valencia	Other	2,3%	97,7%	0,0%	0,0%	0,0%
Valencia	Passenger ship	0,4%	0,4%	22,4%	0,0%	76,8%
Valencia	Ro-Pax	0,0%	4,8%	69,9%	0,0%	25,3%
Valencia	Ro-Ro	0,0%	10,0%	88,0%	2,0%	0,0%
Valencia	Tankers	12,9%	14,7%	51,7%	20,7%	0,0%
Vigo	Bulk carriers	18,6%	0,5%	11,1%	69,8%	0,0%
Vigo	Car carriers	0,0%	0,7%	36,9%	62,4%	0,0%
Vigo	Container ships	0,0%	34,8%	42,9%	22,3%	0,0%
Vigo	General cargo	10,7%	27,9%	61,4%	0,0%	0,0%
Vigo	Other	80,6%	16,9%	2,4%	0,0%	0,0%
Vigo	Passenger ship	0,2%	1,9%	6,7%	0,0%	91,3%
Vigo	Ro-Pax	0,0%	100,0%	0,0%	0,0%	0,0%
Vigo	Ro-Ro	0,0%	100,0%	0,0%	0,0%	0,0%
Vigo	Tankers	8,7%	22,0%	57,5%	11,8%	0,0%
Villagarcia de Arousa	Bulk carriers	21,6%	26,8%	41,9%	9,7%	0,0%
Villagarcia de Arousa	Car carriers	0,0%	0,0%	0,0%	0,0%	0,0%
Villagarcia de Arousa	Container ships	0,0%	55,6%	44,4%	0,0%	0,0%
Villagarcia de Arousa	General cargo	70,1%	29,9%	0,0%	0,0%	0,0%
Villagarcia de Arousa	Other	70,9%	29,1%	0,0%	0,0%	0,0%

Villagarcia de Arousa	Passenger ship	37,9%	0,0%	62,1%	0,0%	0,0%
Villagarcia de Arousa	Ro-Pax	0,0%	0,0%	0,0%	0,0%	0,0%
Villagarcia de Arousa	Ro-Ro	0,0%	0,0%	0,0%	0,0%	0,0%
Villagarcia de Arousa	Tankers	3,9%	8,5%	58,5%	29,0%	0,0%