CORE LNGas hive

LNG demand and supply logistics chain (Mediterranean, Atlantic and Gibraltar Strait-peripheral regions)

Project info 1

Co-financed by the European Union
Connecting Europe Facility

Coordinator: enagas

Leadership: Puertos del Estado GOBIERNO DE ESPAÑA MINISTERIO DE FOMENTO

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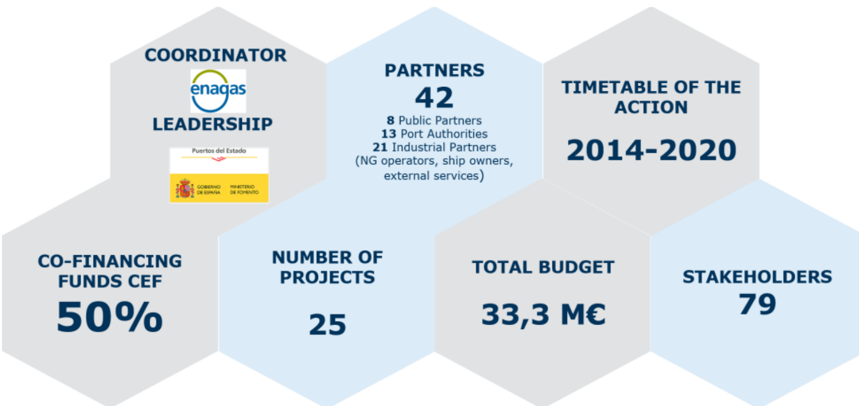
About CORE LNGas hive project

CORE LNGas hive is an initiative co-financed by The European Commission through the 2014 Connecting Europe Facility (CEF) Transport Call.

The aim of the project is to develop a safe, efficient and integrated logistic chain for the supply of LNG as a fuel for the maritime sector in the Iberian Peninsula. It fosters the use of this alternative fuel not only in vessels but also in the port environment.

Coordinated by Enagás with the leadership of Puertos del Estado, the project involves 42 partners from Spain and Portugal. It is a public-private partnership. With 21 public partners: 8 state-owned institutions and 13 port authorities. The 21 private partners are industrial companies such as ship owners, LNG operators and suppliers of different services in the value chain. The total budget is €33.3m and it will be finalized in 2020. This project info 1 deals with three of the 25 activities proposed within the project, mainly LNG demand and supply chain analysis.



Study on LNG demand and supply chain analysis for the roll out (Atlantic, Mediterranean and Gibraltar & peripheries Corridors)

ET2, 3, 4

Analyse potential LNG demand for transport and possible supply chains in the Atlantic, Mediterranean and Gibraltar & peripheries area.

The CORE LNGas hive project, coordinated by Enagas, aims at developing a set of studies with pilot tests in order to support the development of an integrated, safe and efficient logistics chain for the supply of LNG as marine fuel in the Iberian Peninsula. In accordance with EU Directive 2014/94 on the deployment of alternative fuels infrastructure (Clean Power for Transport), the project will contribute to the de-carbonization of the Mediterranean and Atlantic corridors.

Within the set of studies developed, a market analysis (demand study by DNV[1]) and a study of the optimal logistic chains required in the Iberian Peninsula and islands to respond to the potential of LNG demand (by SBC[2]) have been developed. These studies were executed in the framework of the project sub-activities ET2, ET3 and ET4 "Study on LNG demand and supply chain analysis for the Roll out (Mediterranean Corridor, Atlantic Corridor, Gibraltar Strait and peripheral regions)".

This document summarizes the key conclusions and results obtained.

Partners involved

Puerto Bahía de Algeciras · CEPSA · Puerto de Cartagena · Puertos de Tenerife · Puerto de Melilla · enagas · Puerto de Huelva · inega · Puerto de Santander · Puerto de Gijón · reganosa · REN · Port de Barcelona · Puerto de Vigo · Puertos del Estado · Gobierno de España, Ministerio de Fomento · Bilbao Port · renfe Mercancías · valenciaport Autoridad Portuaria de Valencia · Fundación Valenciaport

[1] DNV GL: consultancy firm leader in energy market studies. https://www.dnvgl.com/
[2] SBC (Shipping Business Consultants): consultancy firm experts in maritime logistics. http://sbc-spain.com/

1. Demand Study

A market assessment has been carried out combining a Bottom-Up (interviewing the key stakeholders of a future small-scale LNG market) and a Top-Down approach (with fuel demand in various ports as the starting point) merged into a Consolidation analysis (which combine the results of both studies into the final LNG demand). This activity produced the basis for the development of the study and analysis of the logistics chains capable of satisfying the LNG demand in the most efficient manner, reducing cost overruns and facilitating their development and implementation.

The demand study produced three plausible scenarios covering different LNG consumption volumes and the most likely locations of supply and demand. Only Iberian Peninsula local supply and demand has been studied in detail; terminals at larger distance from the Spanish and Portuguese small-scale market such as France, Italy, Morocco and Algeria have been screened out.

	Phase I
WP1	
Initial screening and common preparation	• Basis for Top-Down approach • Prioritized list of interviewees
Priorisation of interviewees and development of statistical surveys	• Starting point for Bottom-Up approach
Bottom-Up stakeholder survey	• Collected stakeholder views, opinions and expectations on demand, infrastructure and enablers for LNG bunkering
Top-Down model setup	• Model adopted to particular needs of study, key parameter for forecasting
WP2	**Phase II**
Bottom-Up Analysis	• Analyzed set of questionnaires
Bottom-Up demand forecast	• Demand forecast based on stakeholder replies
WP3	
Preliminary supply chain development	• Preliminary supply chain based on demand derived on Bottom-Up and on stakeholder views
WP4	
Top-Down scenario generation	• Scenarios for future LNG demand as mathematical models
Top-Down baseline development	• Current energy demand and traffic patterns
Top-Down demand forecast	• LNG demand in 2025, 2030 and 2050
WP5	**Phase III**
Synthesis Bottom-Up and Top-Down results	• Joint assessment of results from Top-Down and Bottom-Up approach • Combined forecast framework
Consolidation of demand forecast	• Consolidated set of demand forecasts in 2025, 2030 and 2050
Planning of supply chain implementation	• Plan for supply chain implementation and high level cost estimates

1 Block diagram DNV Project

1.1 Bottom-Up Analysis

The bottom-up approach delivered semi-quantitative data, based on stakeholder interviews, a survey and an analysis of publicly available data such as annual reports of relevant companies. The strength of the Bottom-Up approach is capturing non-quantitative aspects like opinions and expectations of key people in the development of the LNG bunkering market.

1.1.1. Interviews

50 interviews across 6 segments in Spain and Portugal were planned (see table 1). The focus was set on companies with international operations and main activities in Spain and Portugal. The selected set of interviewees aimed at achieving a good representation of companies with regular routes who are

considered first movers, like ferries and cruisers. Fishing companies were excluded from the interviews due to the big share of small companies operating only one vessel. For bunkering services, the focus was set on companies currently supplying fuel to ships. For port terminal operators, the interviews focused on the main players in the container terminal market to get a better understanding of the status with respect to fuel and electricity consumption, emission reduction and potential of LNG for (on land) port operations.

45 out of 50 interviews have been executed (90%); 18 companies contacted did not confirm their availability.

Table 1: Overview of the executed and planned interviews

	Spain			PORTUGAL		
SEGMENTS	Target	Done	n.a.*	Target	Done	n.a.*
Port authorities	8	8	1	5	4	1
Shipping companies	12	8	8	6	6	2
Natural gas suppliers	2	2		2	2	
Terminals LNG/Gas	3	3		2	2	
Bunkering suppliers	3	3	5	1	1	
Port and transport Infra	2	2	1	2	2	
Other	1	1		1	1	
	31	27	15	19	18	3

***n.a.: not available: for reasons of availability and/or no interest to participate (no interest in the subject/not willing to participate due to the potential commercial character of the study)**

Based on the results of the interviews an e-survey was defined. The e-survey was available in Spanish, Portuguese and English and was sent to over 400 respondents belonging to more than 250 companies (including Spanish Port Authorities and the members of the shipping association ANAVE).

Table 2 presents an overview of contacts, targets responses and completed responses.

Table 2 Overview of status e-survey

	Overview responses				
Segment	Nr. organisations Invited by mail	Targeted response rate	Nr. Targeted responses	Nr. Completed	% targets Completed
Port Authorities	30	80%	24	24	100%
Shipping companies	120	25%	30	30	100%
Natural Gas Suppliers	16	50%	8	5	62%
LNG & gas terminals	5	80%	4	4	100%
Bunkering services	22	50%	11	5	45%
Port terminals	31	33%	10	13	130%
Total	224		87	81	93%

Note that the figures in the table 2 represent unique responses (one per company).

The responses received by Port Authorities, Natural Gas suppliers and LNG terminals has been considered as high enough to be considered as representative. Taking into account the fact that all main port terminal owners in Spain and Portugal were interviewed (with exception of APM in Spain) and because of the great similarities in operations the results of Port terminals are also considered to be representative. The sample of bunkering companies was too small for a statistical representative result. Nevertheless, since the results are in line with results of interviews with bunkering companies and with the input from other segments, the results for this segment are considered accurate.

1.1.2. Conclusions

From the overall study results, it can be concluded that compliance with emission regulation is the main motivation driving the use of LNG as maritime fuel. The development of LNG fuelled shipping has been encouraged, so far, by a lower price of LNG compensating the higher cost for installation of LNG fuel equipment. Main findings per stakeholder's categories are elaborated below.

Port Authorities

- **Decarbonisation policies**

Interviewees (except 1) are convinced that Spain/Portugal will not be part of the ECA (Emission Control Area) zone before 2025. Policies on decarbonisation and emission reduction have to be global policies in order to guarantee a global level playing field. One Port Authority stated that new ECAs are inevitable and will reach the South Atlantic and Mediterranean corridor probably before 2025. Over 80% of the respondents to the e-survey do expect that ECA zones and other emission regulation will have a (very) high impact on port operations.

- **Current situation with respect to LNG as shipping fuel**

50% of the Port Authorities are already supplying LNG or will be shortly ready to supply LNG. 40% have plans to become active within 5 years. Several port authorities developed demand studies for LNG. Most Port Authorities are still working on internal sensitization and sensitization of the port community in forums and face-to-face meetings.

- **No significant use of LNG as shipping fuel before 2025**

The take-up of LNG is still in an early stage and no significant breakthrough is expected before 2025. First movers will be cruisers and passenger ferries. Fishery vessels and container ships on regular routes are likely to follow. LNG is not likely to be supplied to tugboats as they require special dynamics of motor operation. The investments needed (CAPEX), the remaining lifetime of assets and the bad economic situation will lead to a slow growth path. Financial support is needed to speed up the transition to LNG. 1/3 of the respondents expect a share of 5-10% LNG as shipping fuel in 2030, 1/3 expects a share of 10-25%.

- **Bunkering LNG starts with trucks**

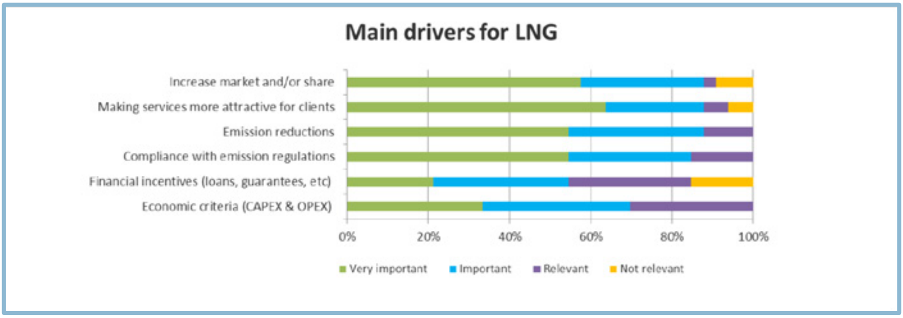
Bunkering infrastructure will be initially by trucks, but with growing demand the supply will be either by barge and/or via fixed terminals. It is expected that bunkering practices will be similar to other fuels. Fuel price, geographic situation and time at the port are considered the main criteria for shipping companies to select a bunkering port.

- **LNG for Port operations and transport (very) likely for some machinery**

Most Port Authorities participated in studies and pilots on LNG for port operations and transport. A majority of the respondents assess the use of LNG to fuel trucks (70% of the respondents), container trailers (60% of the respondents) and warming & cooling of buildings within 10 years very likely or likely. LNG competes with electrification as the main way to reduce future emissions. Almost 70% of the Port Authorities consider electrification of a substantial part of the terminal operations within 10 years likely or very likely. According to some Port Authorities LNG could be part of the energy mix of these ports. LNG will be a valuable and clean alternative for terminals running on solar and other renewable sources.

- **Main drivers: increase in market share and attractive services for clients**

Over 80% of the respondents to the e-survey indicate market share, attractive services for clients, emission reduction and compliance with emission reduction as a very important or important driver (see Figure below). Some Port Authorities feel pressure from local authorities demanding improved air quality and to create new market opportunities. Specific drivers for Port Authorities at islands are energy costs and sustainability. Islands use a lot of oil and want to become independent of oil since transportation of oil is expensive. Cities and industries are looking for cheaper alternatives. Tourist industry is emphasizing the negative impact of polluting factories on the city's image.



2. Main drivers for LNG- Port Authorities

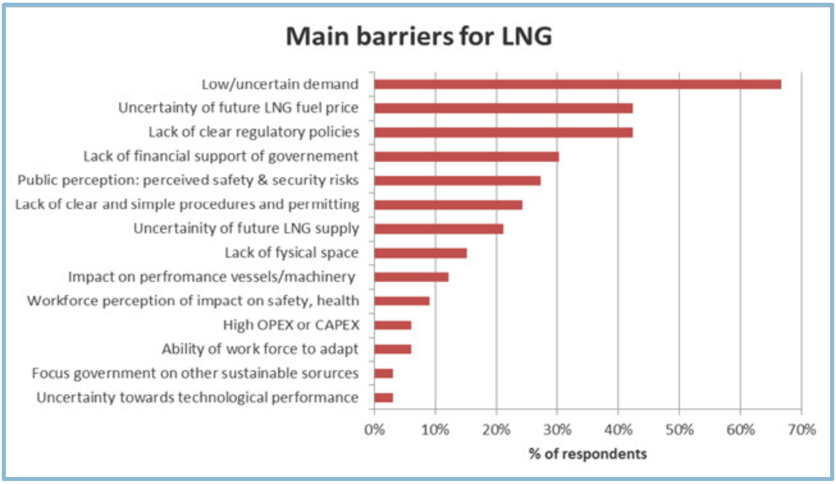
Main enablers for LNG demand & supply infra developments

The main enablers for use of LNG are tax discounts, funding for (pilot) projects, awareness campaigns from key industry players and local government, and stringent emission limits.

Main barriers

According to the e-survey the main barriers for Port Authorities to develop LNG services and infrastructure are (see Figure below):

- Lack of demand/market resulting in a negative impact of the LNG business case (in top 3 of barriers almost 70% of the respondents);
- Uncertainty on future LNG prices ((in top 3 of barriers of 40% of the respondents);
- Absence of policies defining the regulations towards the future of LNG (in top 3 of barriers of 40% of the respondents);
- Lack of support financial support of local government (top 3 of almost 40% of respondents). High Taxation, Port taxes, bunkering taxes and tolls for "small scale" nowadays are very high (around 50%).
- Sometimes local government is even actively opposing LNG initiatives or not including all stakeholders in the process. Arguments from local government for not supporting the LNG business case are: safety risk and the opinion that the support of gas will stop renewables;
- Stakeholder perception. Managers, crew, general public managers are concerned about the safety risks of the installation. Additional safety standards, processes and requirements are needed. Some Port Authorities lack the data (evidence) to assist in implementing safety (criteria) and safety management in general.



3. Main barriers for LNG- Port Authorities

Shipping companies

Sustainable Profit Margin

None of the involved respondents were confident with the feasibility of a business case for a LNG new build or retrofitting investment under the current economic circumstances. A lot of uncertainties have impact on this business case. The bottom line for not investing in LNG today is the lack of confidence in a minimum sustainable profit margin during the life cycle of an LNG powered ship.

Stricter Emission Regulation

Emission Regulations in combination with specific regulations for LNG as transport fuel and LNG infrastructure is perceived as the most important trigger or requirement to give an impulse to the use of LNG as shipping fuel. Success of this regulatory framework will depend on level of detail how emission levels will evolve in time and the region (coast-line) to which the regulation applies. Most Shipping companies expect that stricter emission regulation will be implemented with a realistic 'transition' time, long enough to adapt to the new circumstances. This is a remarkable finding as the date for European emission regulation to come into force has been defined (Directive 2016/806/EU) but apparently, awareness and sense of urgency among several shipping companies seems to be limited.

Economic circumstances

There are concerns how realistic stricter emission regulations are, given the current economic circumstances in shipping. The market is dealing with a surplus of available ships while the demand is still falling.

Risk of market disturbance

The paradox is that shipping companies are expecting stricter emission regulations in Europe and the Iberian Peninsula in specific. However, they do not expect the emission regulations to be so strict that it will significantly disturb current global shipping market equilibrium. This combination makes Shipping companies less confident that LNG investment will be profitable in the next 10 years.

Public Perception and Reputation

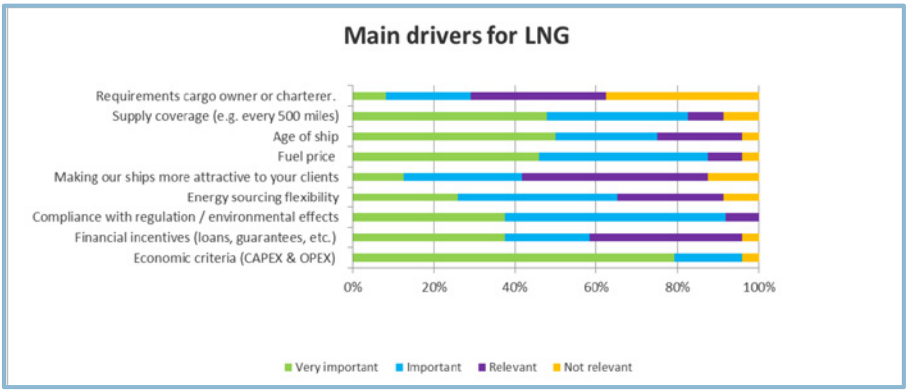
Shipping companies are actively improving their carbon footprint and environmental impact with 'low cost - high impact' initiatives, like energy usage reduction and using low resistant marine coating. Cruise ship operators emphasize the importance of an environmental friendly image or reputation and perceive this as an important unique selling proposition to attract customers.

Main enablers for LNG as a shipping fuel

The main enablers for uptake of LNG are financial incentives like lower cost because of significant price difference between LNG and other (clean) fuels, compliance with global or local emission regulation, public opinion and opinion of customers on environmental and sustainability issues and availability of LNG infrastructure at the ports.

Main Barriers for LNG as shipping fuel

The main barriers for uptake of LNG are uncertainty of LNG supply (in top 3 of barriers for more than 60% of the respondents) and uncertain future LNG prices compared to alternative clean propulsion variants (in top 3 of barriers for 60% of the respondents).



4. Main Drivers for LNG- Shipping companies

LNG and Gas Terminals

In this paragraph, the main findings of the e-survey and interviews conducted with LNG and gas terminals are listed:

- Nowadays only 20% of the total capacity of the LNG tanks are in use;
- In Portugal 80 UAGs (Unidade Autónoma de Gás - satellite units) are operated in the mainland. The LNG terminal in Sines is the main entrance for natural gas in Portugal, along with the pipeline entry point at Campo Maior;
- During the golden years, the LNG terminal contributed with 60% to the natural gas consumed in the country. Presently, it only supplies 30% of the internal demand. As a result, only +/- 30% of the potential storage and logistic capacity is used today;
- Currently LNG terminals are more focused on the regasification business, but this already has reached its full potential;
- The main natural gas demand in Portugal is the electricity sector. However, the primary future source of electricity will be more and more renewables instead of gas / coal fired power plants.

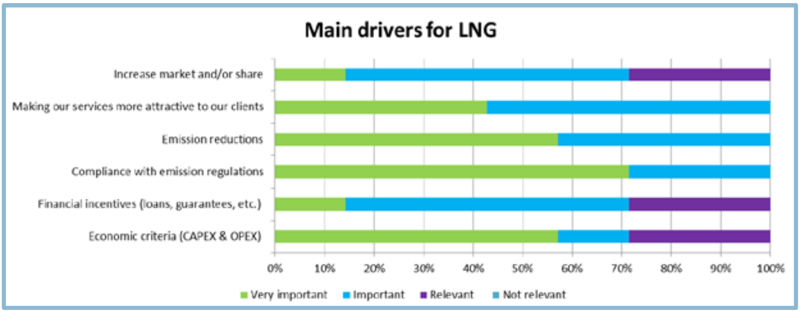
LNG as fuel		
Opportunities	2020	Demand is covered until 2020. Currently only 20%-35% of the production capacity is used. First vessels are supplied with LNG.
	(2025)	Supply to local fleet (small scale)
	2030	Current capacity should be enough to cover the demand until 2030.
Expected infrastructure for LNG	2020	Current LNG infrastructure is suitable to cover the demand Fishing vessels supply will be covered by Truck to Ship or small scale terminals No major action plans: study of the dock adaptation for LNG bunkering to ships, small modifications
	(2025)	More modifications to the terminal will be done if evidence of an increase of the demand is proven. (second jetty and additional storage tank)
	2030	More flexibility to storage will be needed

5. Expected infrastructure development- LNG and Gas Terminals

Natural Gas Suppliers

In this paragraph, the main findings of the e-survey and interviews conducted with Natural gas suppliers are listed:

- Natural gas suppliers continue to develop new business to residential and industrial clients;
- The Impact of emission regulation in the North and Baltic seas is an example for the Spanish and Portuguese situation. There is a strong believe ECA zones will come into force globally. It might take some time and will cause temporal market unbalances;
- Both Spanish and Portuguese regions face a situation of oversupply of natural gas (in stock). Demand is not expected to level the supply capacity for the next 10 years.



6. Main Drivers for LNG-natural gas Suppliers

Bunkering services

Current involvement in LNG business

Most bunkering companies (67%) are prepared to get involved in the LNG business (Figure 40). Some did a few operations, performed (feasibility) studies and/or designed processes and infrastructure (equipment and storage facilities). The main (international) companies are already supplying LNG for heavy road transportation and industry and are operating small regasification units.

Next 5 and next 10 years: no imminent plans

There are no imminent plans to expand the current fleet of barges or invest in new storage facilities. Once the market for LNG bunkering grows, it will be added to the bunkering mix gradually. LNG is considered as a significant opportunity; however, development of a LNG bunkering facility will only be initiated when the demand is there. According to several bunkering companies, shipping companies are still struggling with the LNG business case and most shipping companies do not 'demonstrate' a firm belief in LNG on the short term. The Maritime business world is a traditional world, with limited innovation. They repeat what works. Due to this and the very high CAPEX of LNG there will be a very long lead time/implementation time of LNG. Main opportunity for growth is to create an easy (fast) and cost competitive LNG alternative for big tankers and container ships to and from ECA zones. Until 2020 the LNG market in Portugal will be relatively small and LNG bunkering services are not expected to be profitable. Nevertheless, it is perceived as an interesting opportunity.

Next 10 years: no imminent plans

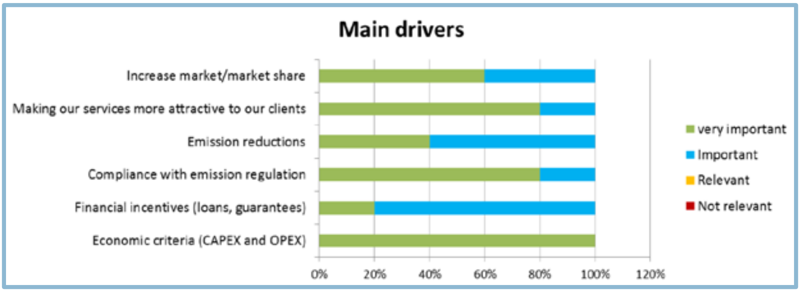
It is expected to be the same as the first 5 years.

2030 and beyond

In the far future LNG is likely to become an important clean fuel, also part of the bunkering mix in the region. The current examples and global development demonstrate LNG is an important clean shipping fuel of the future. New cleaner fuels like (ultra) low Sulphur variants are considered a strong competitor for LNG. Also for this type of fuels, the supplier specifications for storage and bunkering are strict and require modification of current infrastructure. Most of the volume will come from the spot market and the remainder will be associated with the supply of local ships (tugboats, river ferries and fishing boats).

- **First movers will be passenger and ferries companies**

First movers will be passenger and ferries companies. Other potential LNG users will be tugboats. Only 15% is passengers and RO-RO. 85% of bunkering volume (in the world) is cargo (containers, dry and bulk cargo). Growth of LNG in this segment is only possible if a global supply infrastructure is available. Tankers and container ships on regular international routes are also potential clients if services can be provided fast against cost competitive prices. Nevertheless, bunkering companies expect only a market share for LNG as a maritime fuel of 5-10%.



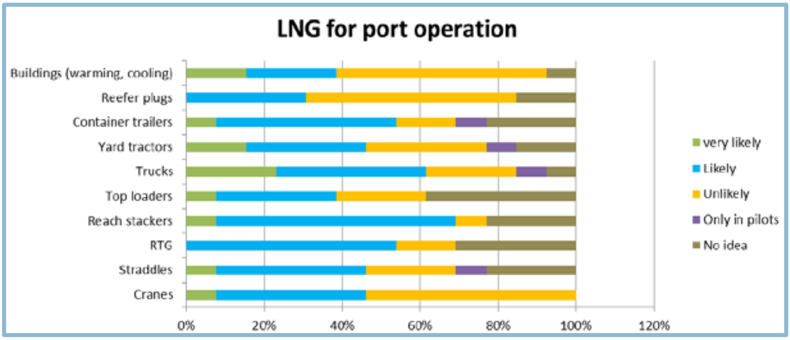
7. Main Drivers for LNG- Bunkering Services

Port Terminals

The companies interviewed do not expect major new innovative changes in terminal and port infrastructure although some are sensitive to environmental issues and have strategies to replace a part of the current machinery by LNG or electricity fueled machinery.

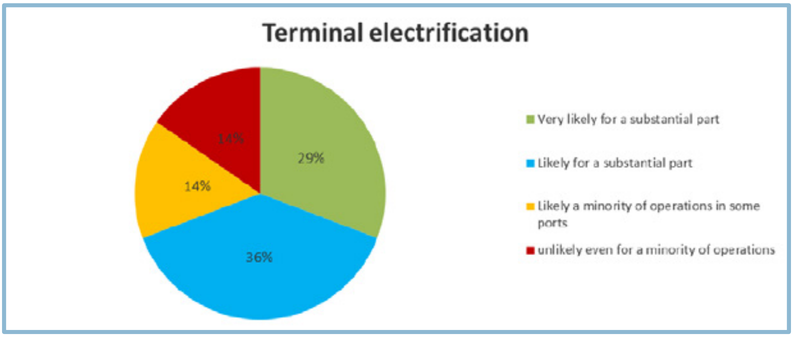
Terminal owners/operators will only replace machinery at end of the economic lifetime. Replacement could be done by cheap available second hand equipment, although the intention/strategy is to replace with electric driven vehicles or other eco-friendly solutions. Terminals with an electrification strategy do not have plans to adopt LNG as fuel for terminal equipment. Other terminals might consider gradually replacing machineries that needs a lot of power, like vessels, tugboats and some trucks with LNG. These decisions depend on a positive business case (both CAPEX and OPEX). For a positive OPEX, minimum availability of small LNG refuelling infrastructure is required. Currently available small terminals are not expected to be able to reach this critical mass. For these terminals LNG is not a viable option. Taking the available LNG infrastructure into account, LNG for port terminals seems to be an option for terminals in Barcelona, Valencia, Tenerife and maybe Las Palmas and Algeciras and in Sines.

Over 40% of the respondents assess the use of LNG for most machinery likely or very likely (see Figure below). The majority is only sceptical about the future use of LNG for reefer plugs (majority is already powered by electricity) and cranes (already powered by electricity), straddles and top loaders.



8. LNG for port operation and transport- Port Terminals

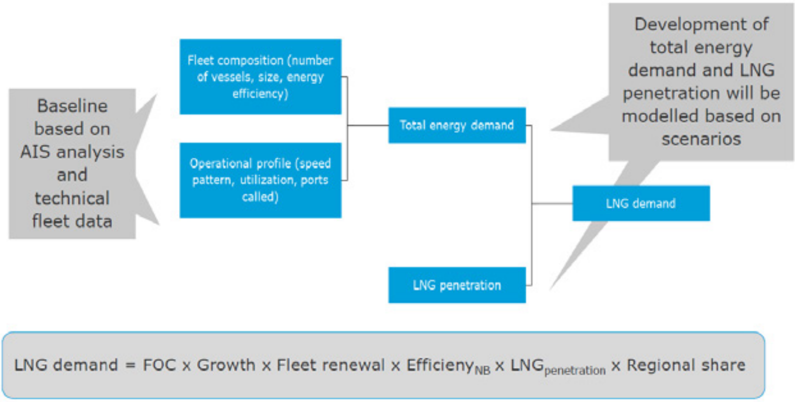
Terminal operators consider electrification of port machinery as an important option to reduce emissions. 65% of the respondents consider terminal electrification likely for a substantial part of the terminal operations (see Figure below). For several port terminals, electricity is the preferred option because of the possibility to recover energy (via batteries, fly wheels etc.). According to some respondents, they are not aware of equipment suppliers, supplying (standard) LNG fuelled terminal equipment. Equipment suppliers focus on hybrid solutions, batteries and fly wheels. This lack of attention and supply might prevent terminal operators to consider LNG fuelled machinery.



9. Likelihood terminal electrification- Port Terminals

1.2. Top-Down Analysis

The "Top-Down" analysis evaluated the existing demand for traditional fuel and estimated the development of its consumption in the period 2018-2050. The approach used for LNG demand analysis is carried out in four main steps and is reflected in the structure of the following sections.



10 Simplified illustration of model for shipping LNG demand forecast

Evaluation of current fuel oil demand – baseline.

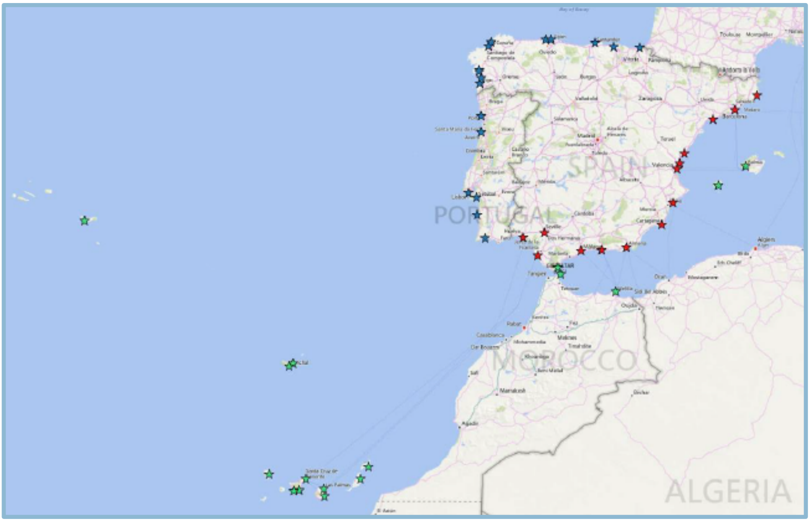
Based on an AIS based analysis (Automatic Identification System – an automatic tracking system used on ships that provides position data as well as other information) of more than 12,000 vessels that have called ports in Spain and Portugal in the two years studied. The estimated total energy demand from shipping in the area in scope amounts to around 6.1 million metric tons HFO equivalent annually today.

Starting point of the calculation of the relevant current fuel oil demand from shipping was the identification of all vessels that have called ports in Spain and Portugal in the period 2014-07-01 until 2016-06-30. Based on the chosen period, two full years of data are included in the analysis compensate for any seasonal differences of traffic or other peak effects.

Area in scope

The area in scope defined by the project includes the Iberian Peninsula and sea areas around it including Mediterranean Sea up to Mallorca and Atlantic Ocean up to the Azores and Canary Islands.

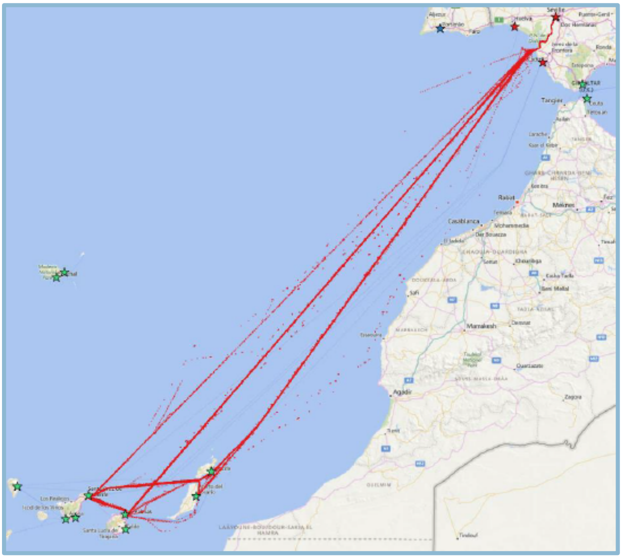
During the project a list of 46 relevant ports was defined, in addition these ports were allocated to three corridors, namely the Atlantic, the Mediterranean and the Gibraltar Strait (GS) and Islands corridor. The following map gives an overview of the area included in scope and the location of the ports.



11. Defined corridors Atlantic, Mediterranean and GS & Islands

AIS

More than 400,000 ships worldwide are equipped with Automatic Identification System (AIS) transponders as per International Convention for Safety of Life at Sea (SOLAS), issued from the International Maritime Organisation (IMO). The regulation applies for ships above 300 gross tonnage and passenger ships regardless of size involved on international voyages, as well as cargo ships above 500 gross tonnages not involved in international voyages (impact of smaller vessels will be discussed in the consolidation between bottom up and top down). SOLAS regulations require that AIS data provide information about vessel identity (IMO/MMSI number), vessel type, position, course and speed, navigational status and other safety related information. Introduction of the AIS creates a relatively simple way of collecting detailed ship traffic information.



12. Example of AIS data received for one container vessel

Calculation of fuel oil consumption

The calculation of fuel oil consumption (FOC) is performed for each vessel (independent of whether regular ports calls take place or whether the vessel is deployed in tramp trade) for a specific time frame.

By comparing the ship speed over ground and the ship capabilities (defined as the service speed) for any period, the engine load factor can be calculated using the speed power curve (this speed power curve is obtained via AIS and is vessel specific). By multiplying, the total engine power, engine load factor (load factor of an engine describes how long an engine can produce its maximum power output, a common way to describe the load factor of an engine is to give its power as an average over a certain period and is expressed as percentage and obtained via following formula, engine load factor = $(speed/service)^3$, where the database assumes 100% engine load for achieving service speed (due to aging of vessel, fouling, etc.) and specific fuel oil consumption (constant at 190g/kWh as per IMO EEDI calculation) for the given time period, the total amount of fuel oil consumed for this period is calculated.

For each vessel, this stepwise approach is performed for the full trajectory of the vessel during the study period (accumulating all AIS signals received from the vessel), to result in the total FOC of the subject vessel. This analysis is repeated for all vessels in the project area.

Estimation of development of fuel oil consumption.

The second step in determining the potential demand for LNG as a ship fuel is the estimation of the consumption trends for the coming years up to 2050. In estimating the consumption development, essentially two opposing effects are taken into account, growth of volumes of transport and development of energy efficiency in the fleet (mainly driven by replacement cycles and energy efficiency of newbuilding's replacing older tonnage).

Scenarios

Scenarios describe likely outcomes on technology developments and associated investment levels and strategies in the (maritime) industry resulting from policy options.

In order to reflect the uncertainty of future development, especially for such long time horizons, three scenarios are differentiated and developed in the assessment of consumption trends and LNG demand:

1) "Basic scenario" – All significant drivers of LNG demand evolve realistically
2) "Low scenario" – All significant drivers of LNG demand evolve negatively
3) "High scenario" – All significant drivers of LNG demand evolve positively

Transport growth

An increase in the demand for transport of important goods for the corridors and the assumption of similar share of modes of transport leads in a good approximation to an increase of consumption of marine fuels. Individual transport growth rates defined per segment are shown in Table 9. The data are extracted from DNV GL Maritime Global Scenario planning 2015 (/1/), which is a DNV GL analysis of IHS Fairplay data.

Vessel segment	All scenarios
1) Container ships	1,0%
2) Tankers	1,2%
3) Bulk carriers	1,9%
4) General cargo	0,1%
5) Car carriers	1,3%
6) Passenger ship	1,4%
7) Ro-Ro	0,8%
8) Ro-Pax	0,8%
9) Other	0,9%

13. Estimated annual transport growth rate by vessel segment (DNV GL in-house library)

Due to the limited influence of the transport growth rate on the overall forecast of LNG demand, the growth rates are – for reasons of simplification – chosen constant for the different scenarios.

Fleet renewal

Since LNG is considered a realistic option for newbuildings, the expected replacement age is a key driver for LNG potential as new tonnage that might be fuelled by LNG is replacing existing tonnage fuelled by HFO over time.

One key aspect regarding assumed scrapping ages is IMO's Ballast Water Convention entering into force September 2017, where newbuild vessels will be required to have an IMO approved ballast water management system (BWMS) upon delivery while existing vessels must retrofit and install systems on-board. While most vessels on order are 'BWMS ready', the cost of retrofitting vessels is estimated to be anything between $1M and $5M per vessel and greater demolition of older ships is expected in the short to medium-term as vessels approach their compliance dates.

Vessel segment	Basic scenario [a]	Low scenario [a]	High scenario [a]
1) Container ships	24	26	22
2) Tankers	26	28	24
3) Bulk carriers	28	30	26
4) General cargo	24	26	22
5) Car carriers	24	26	22
6) Passenger ship	28	30	26
7) Ro-Ro	25	27	23
8) Ro-Pax	30	32	28
9) Other	25	27	23

14. Average replacement age by vessel segment

Energy efficiency for newbuildings

The increase of fuel consumption caused by growth in transport volumes is partly compensated by an increase in energy efficiency. Progress in energy efficiency is another important factor that determines the LNG potential in the market. The fact that newbuildings replacing older tonnage are usually more efficient is generally obstructing LNG volumes, as newbuildings can be up to 30% more efficient compared to current vessels.

Efficiency used in the modelling focusses on efficiency gains by design of more efficient newbuildings. Additional operational efficiency gains have a more limited influence on the overall efficiency gain and are neglected in this model. Main operational fuel reduction measures, e.g. slow steaming, have been realized in the past and cannot account largely for future efficiency gains.

Assessment of the relevance of LNG as marine ship fuel.

One of the main drivers for the diffusion of LNG as a maritime fuel is the current focus on regulating ships' airborne emissions. Shipping companies are obliged to use marine fuel with low Sulphur content or need to ensure through technical measures equivalent limits of SOX emissions. Possible solutions include the use of LNG, the use of conventional low-Sulphur marine fuels such as Low Sulphur Heavy Fuel Oil (LSHFO), Marine Diesel Oil (MDO) and Marine Gas Oil (MGO) or the use of Heavy Fuel Oil (HFO) in combination with application of exhaust gas scrubbers.

The expected LNG penetration of newbuildings is one of the key determining factors for the LNG market potential. Each vessel owner has to make an individual decision on the choice of the technical option as to meet regulatory requirements. This decision is based on an evaluation of technical and economical (CAPEX and OPEX) pros and cons, which in turn depends on the operational profile of each vessel.

The Shipping 2020 simulation model developed in 2012, which has been revised and updated in 2015, takes into account a broad range of (quantitative and qualitative) variables, such as investment horizons, fuel burdens, operational patterns and risk appetite (some ship owners decide to invest in technology while other do not, for the same parameter set) within the industry. The model does not try to optimize the best path ahead, but simulates how each ship owner individually will seek to comply with regulations and increase energy efficiency.

Regarding the technologies uptake, we have also been forced to make some simplifications as, based on the survey; different stakeholders claim different effects and operational characteristics. The technology costs and other assumptions are based on a wide range of sources. The technologies have been quantified in terms of:

1. Costs/CAPEX and assumed energy and emission reduction effect
2. Regulatory compliance
3. Compatibility and overlap between technologies

Calculation method.

The following formula (LNG demand) is executed for aggregated vessels per year of construction for every individual segment in every single corridor:

$$\text{LNG demand} = \text{FOC} \times \text{Growth} \times \text{Fleet renewal} \times \text{Efficieny}_{NB} \times \text{LNG}_{penetration} \times \text{Regional share}$$

With

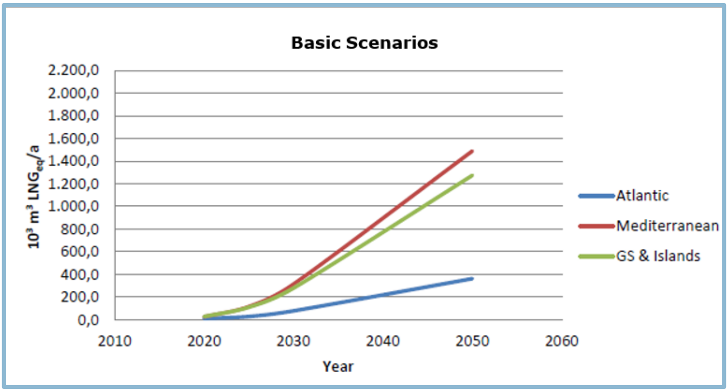
- **FOC:** Current energy demand, aggregated value per corridor and per vessel segment.
- **Growth:** Segment specific transport growth, e.g. 1% yearly for container vessels.
- **Fleet renewal:** Specific yearly fleet renewal rate of each vessel segment. The model screens for every year (2016 – 2050) the age structure of the segment fleet. According to the assumed renewal age it is checked, what the percentage of vessels is leaving the operating fleet (share of energy demand).
- **Efficiency NB:** Efficiency gain for newbuildings. The share of new

vessels replacing old tonnage and supplying additional demand caused by transport growth is multiplied by the appurtenant efficiency gain.

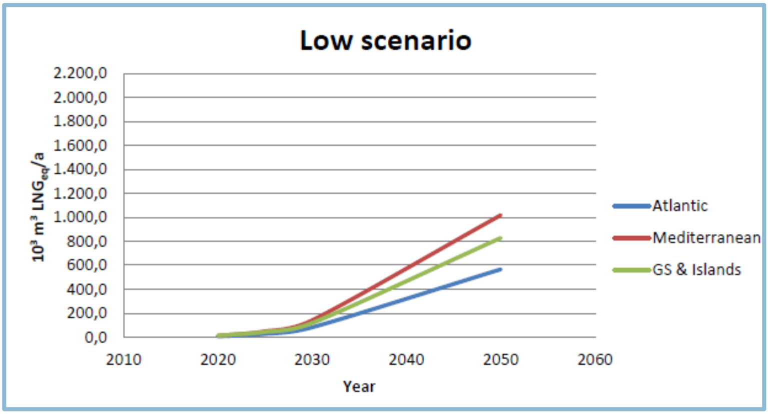
- **LNG penetration:** Factor applied to the share of new tonnage, as the model considers LNG only as an option for newbuildings.
- **Regional share:** not accounted for yet, "Fair share" vs actual bunkering behaviour, factor = 1.

Top-Down Results

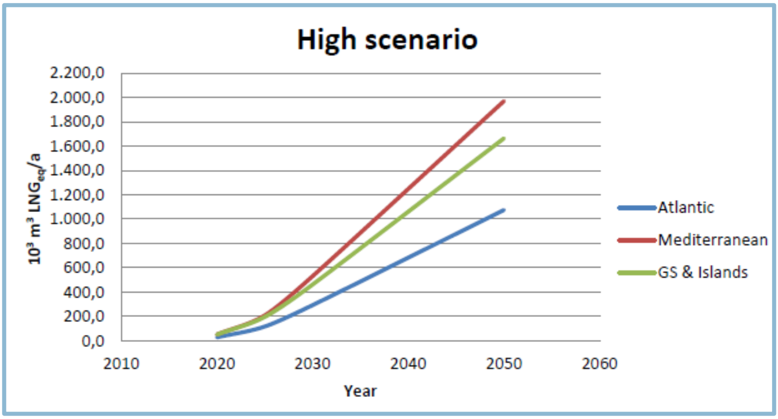
The future LNG demand scenarios indicate that aggregated over all corridors LNG driven ships calling ports in Spain and Portugal are using 0.2-0.6 million tonnes of LNG in the year 2030 and 1-2 million tonnes of LNG in the year 2050. For reference, the LOT3 report (Analysis of the LNG market development in the EUR, CE Delft, 2015) indicates that LNG ships in the EU will be using 1-5 million tonnes of LNG in the year 2030.



15. Energy demand by corridor Top-Down– Basic scenario



16. Energy demand by corridor Top-Down – Low scenario



17. Energy demand by corridor Top-Down – High scenario

1.3. Consolidation Top down and Bottom up Analysis

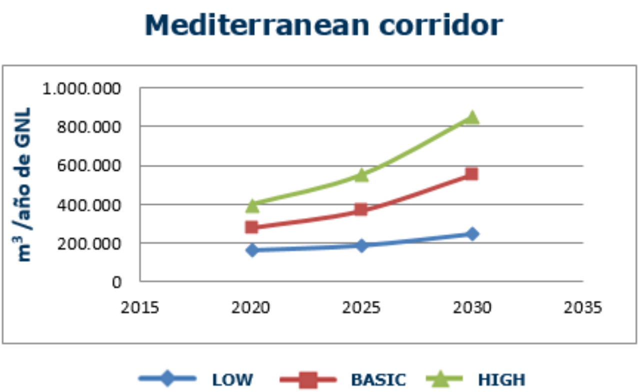
The purpose of this step is to combine the results from the Bottom-Up approach and the Top-Down approach into the study's final LNG demand. This forecast serves as the basis for the planning of the supply chain implementation. The consolidation is supposed to influence three key parameters from the top down analysis.

- LNG uptake rate
- Market share of the ports / geographical spread across Iberian Peninsula
- Overall fleet growth

The confrontation of the bottom-up and the top-down analysis has resulted in an updated forecast for the different scenarios. The scenarios from the top-down analysis are mainly the results of an independent and mostly objective analysis, but also largely theoretical in nature. Those scenarios were improved to reflect a more realistic development of the LNG uptake as the top-down analysis does not uncover step changes that may be expected in the early stages of developing small-scale LNG supply chain. In addition, LNG demand for small fleet and port operations has been accounted for.

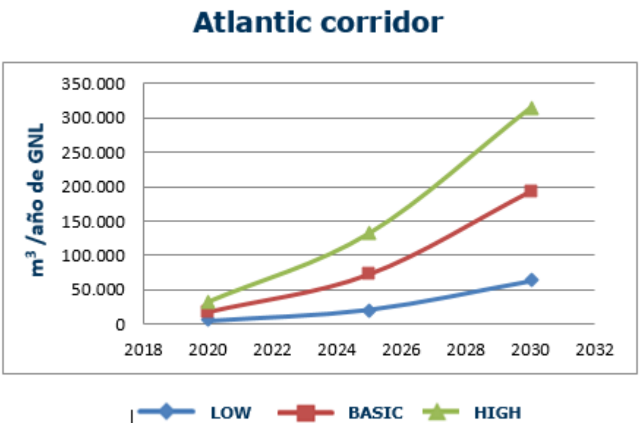
Consolidated forecast per corridor over time

Estimation results show for the basic scenario the highest demand of LNG in the GS & Islands corridor with 2.54 million tonnes of LNG in the year 2050, followed by the Mediterranean corridor with 0.75 million tonnes of LNG in the year 2050 and finally the Atlantic corridor with 0.38 million tonnes of LNG in the year 2050.



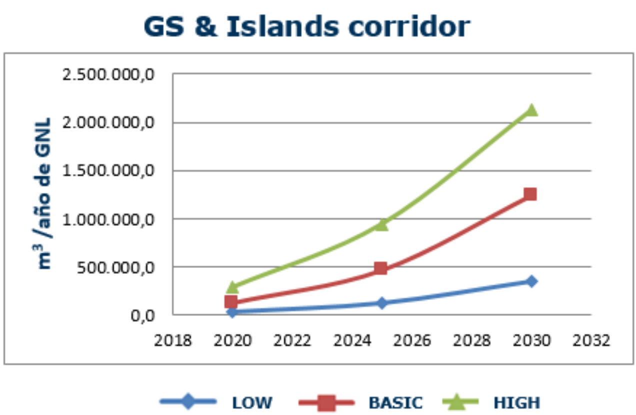
18. Consolidated forecast - Mediterranean corridor

The low scenario forecast is about half the basic scenario forecast with the demand in the GS & Islands corridor about 1.13 million tonnes of LNG in the year 2050, followed by the Mediterranean corridor with 0.36 million tonnes of LNG in the year 2050 and finally the Atlantic corridor with 0.18 million tonnes of LNG in the year 2050.



19. Consolidated forecast - Atlantic corridor

For the high scenario the following results are obtained, the highest demand of LNG in the GS & Islands corridor with 3.32 million tonnes of LNG in the year 2050, followed by the Mediterranean corridor with 1 million tonnes of LNG in the year 2050 and finally the Atlantic corridor with 0.51 million tonnes of LNG in the year 2050.



20. Consolidated forecast – Gibraltar Strait & Islands corridor

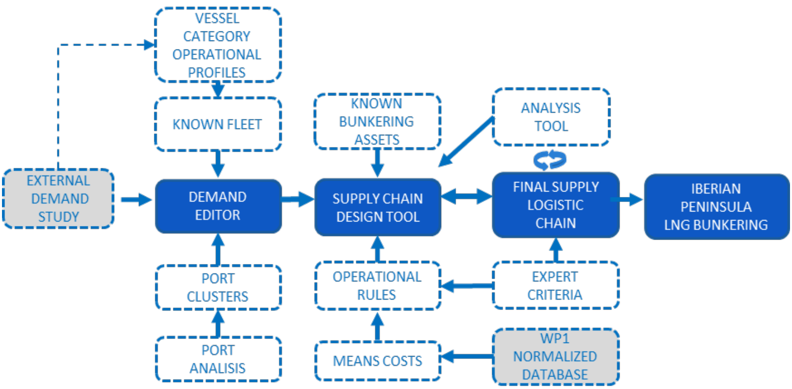
As the deployed fleet is very young in some segments, e.g. with an average age per vessel of just about 10 years for the tanker segment in all corridors in scope. For the bulker segment in the Atlantic and in the Mediterranean corridor, or for the Ro-Ro segment in the Atlantic corridor, the replacement of existing tonnage takes a significant amount of time and therefore the uptake of LNG demand is starting slowly.

Conclusion

The confrontation of the bottom-up and the top-down analysis has resulted in an updated forecast for the different scenarios. The scenarios from the top-down analysis are mainly the results of an independent and mostly objective analysis, but also largely theoretical in nature. Those scenarios were improved to reflect a more realistic development of the LNG uptake as the top-down analysis does not uncover step changes that may be expected in the early stages of developing small-scale LNG supply chain. In addition, LNG demand for small fleet and port operations has been accounted for.

2. LNG Supply Logistic Chain

The aim of this part of the study is the developing of a safe and efficient, integrated logistics and supply chain for LNG in the transport industry (small scale and bunkering), particularly for maritime transport of the Iberian Peninsula, Spanish and Portuguese islands and territories. A four-stage methodology was applied.

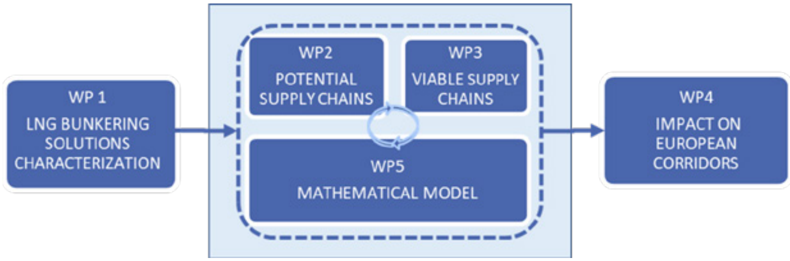


21. LNG Supply Logistic Chain

The project carried out is divided into the following documents:

- **WP1 "LNG Bunkering Solutions Characterization".** The first part consisted of an exhaustive review of existing technologies.

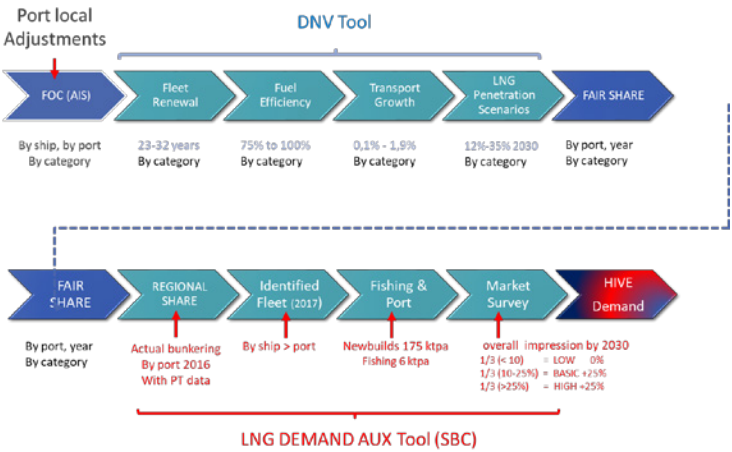
- **WP2-3 "Potential supply chains" and "Viable supply chains".** These technologies were grouped together to generate possible types of LNG supply chains as a maritime fuel. From these possible chains, groupings of ports that share the same import terminal (a cluster) were taken as a base. The most viable ones (technically and economically) were then chosen for each cluster.
- **WP4 "Impact on European Corridors".** A study of the European impact of the implementation and growth of LNG as a fuel at Iberian ports.
- **WP5 "Mathematical Model".** The project concluded with the creation of a digital tool to generate optimal supply chains for port LNG supply as from demand.



22. LOGISTIC SUPPLY CHAIN. Block Diagram

2.1. Demand adaptation

Before using the results of the demand study, made by DNV, 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 transformations applied by SBC aiming to refine the demand at the port level.

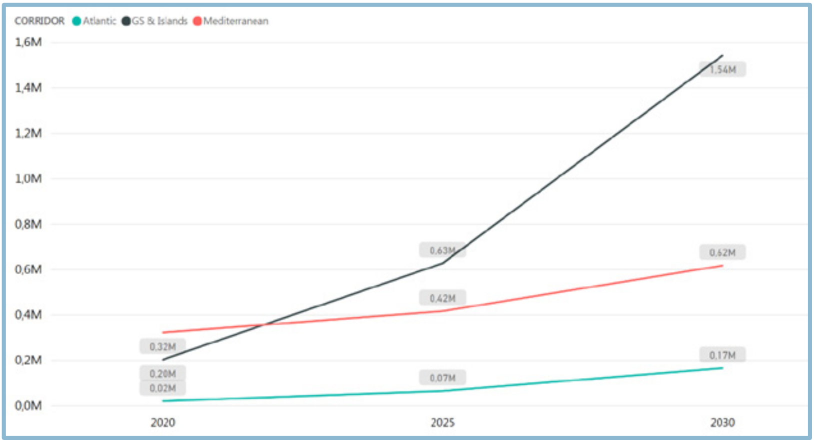


23. Demand Adaptation From DNV to HIVE

The demand generated from traffic between peninsula and Baleares and Madeira and Ceuta y Melilla was 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.

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.

Working meeting in Enagás to develop Supply Chain tool



24. Final demand forecast made by SBC

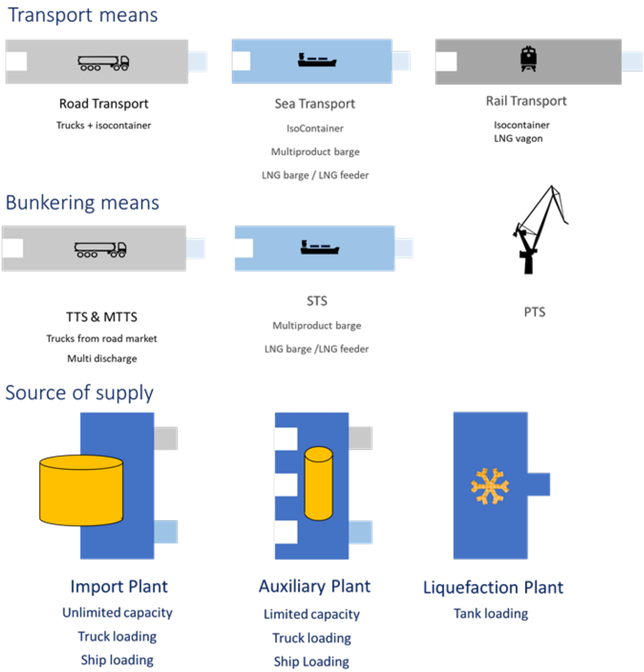
2.2. Bunkering Solutions Characterization

This stage was focus on the cost components of all the potential elements of the LNG bunkering supply chain. The methodology applied had three phases:

- **First** a thorough review of potential solutions based on existing literature and previous studies at international level.
- **Second**: Those solutions that can be considered market ready, counting with adequate regulatory support will be studied in detail obtaining both fixed and variable cost components.
- **Third**: The resulting technologies was normalized to provide input to the next stages. The results were provided in a database that can be dynamically adjusted should future information become available.

25. Truck to ship operation. Source: fleetsandfuels.com

The three components categories to be analysed are:



26. Transport, bunkering means and source of supply

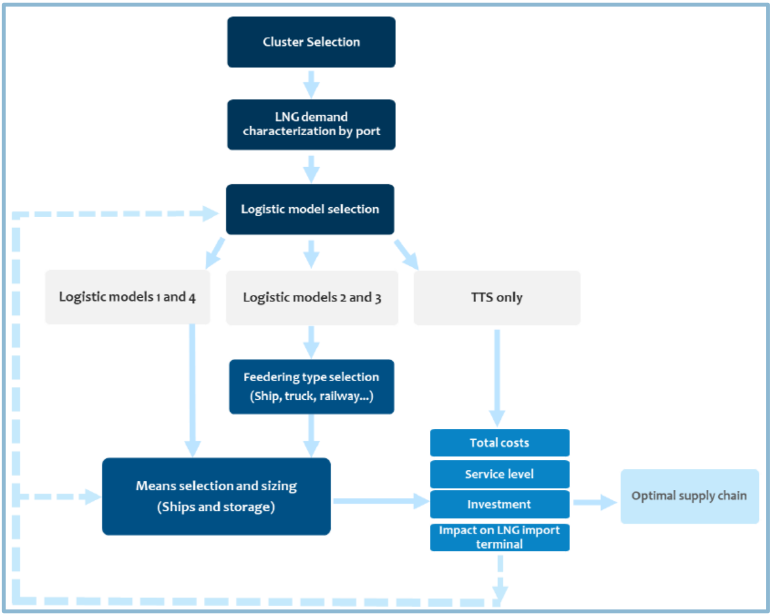
The analysis of each system category under this stage has placed the focus on modelling each component category to facilitate further design of supply chains. For each category, a set of specific elements have been calculated, but as market matures, costing data will become more accurate, and new elements could be added to the database. Due to the functional grouping of the elements, transport and bunkering means will be jointly modelled into a category to facilitate the construction of complex supply chains.

Additionally, the taxes and tariffs involved in the bunkering process and the Greenhouse Gases Emissions caused by the venting of the CH4 are also studied at this stage.

The assessment of investment costs in this study not only addresses the capital investment associated with the asset acquisition, but also makes a proper distribution of the assets costs over time, resulting in the yearly capital cost of it. This capital costs considers the equipment depreciation and the financial costs.

2.3. Feasible Supply Chains and Optimal Supply Chains

The technologies detected in the previous stage were grouped together to generate possible types of LNG supply chains as a maritime fuel. From these possible chains, groupings of ports that share the same import terminal (a cluster) were taken as a base. The most viable ones (technically and economically) were then chosen for each cluster base within the frame of a demand situation determined in the demand study.



27. Viable logistic supply chain design diagram.

2.3.1. Logistic models

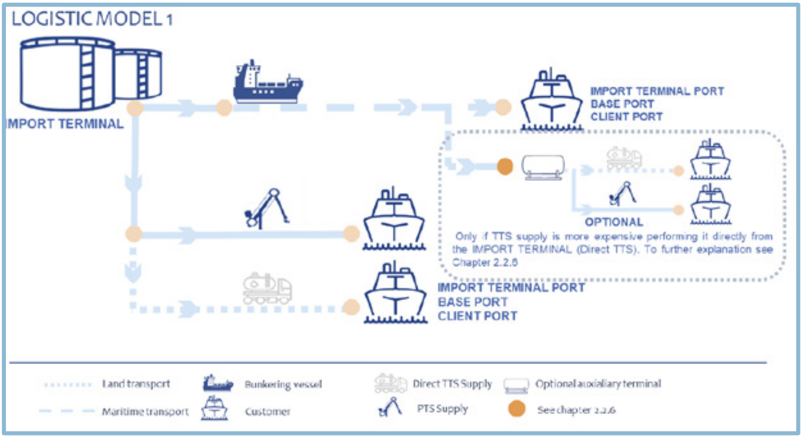
This study contains five predefined calculation models that cover most of the potential alternatives. Only two main logistic models exist, but the necessity of adding small adjustments requires adding three extra models to the study.

These models contain interactions between the different supply patterns, storage and distribution, allowing running the calculations necessary to evaluate the viability of each solution, next to its associated costs.

For calculation proposes, customer's vessels will only be supplied in their terminals of operation or in authorized anchoring areas, not considering second port manoeuvres for fuel supply. Based on this, PTS supply operation has not 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.

Logistic model 1: 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.



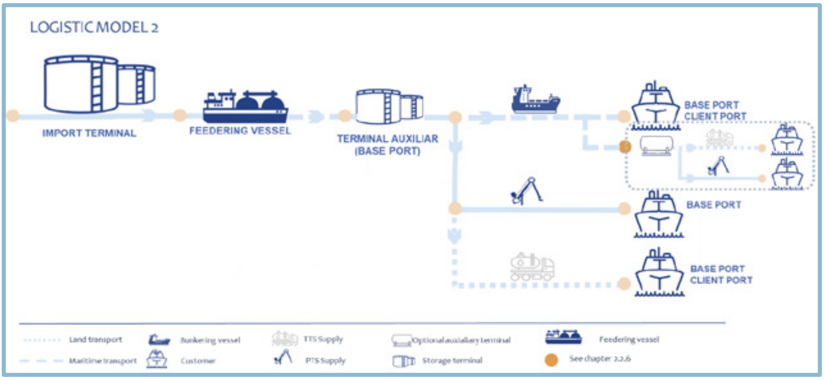
28. Logistic Model 1- STS supply + Reload in import terminals

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.

Logistic model 2: 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.



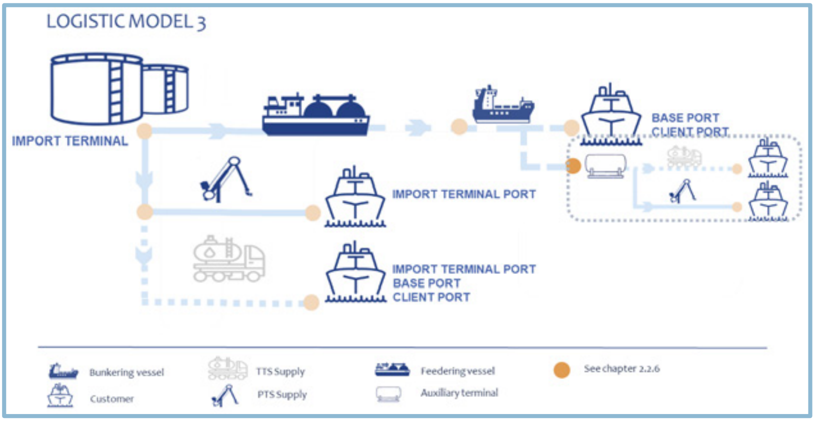
29. Logistic Model 2- Model 1 + Auxiliary terminal in the Base Port

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.

Logistic model 3: LNG provisioning is performed ship to ship from the feedering to the supply vessel

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.



30. Logistic Model 3- STS from the feedering to the supply vessel

Basic features:

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

Logistic model 4: Transport vessel

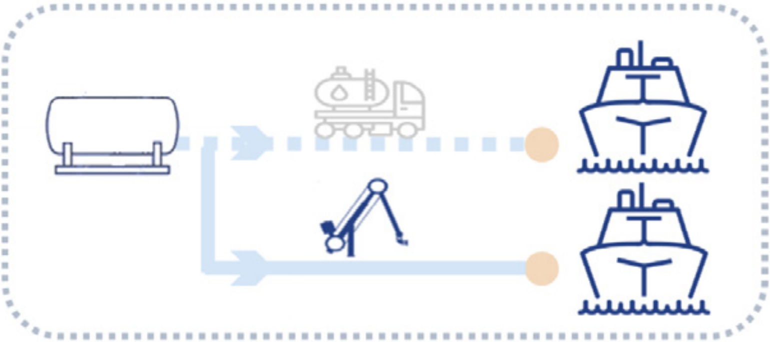
This model will be useful in a scenario where two or more ports within the same cluster, require independent supply ships but without its own auxiliary terminal. Logistic Model 4 serves as a tool that allows the computation model to divide a cluster into two different groupings, with Model 1 configuration.

Logistic model 5: TTS supply

Even though TTS supply is normally recommended for lower volumes, it is 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, ISO containers 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.



31. Logistic model 5- TTS supply

2.3.2. Cluster concept

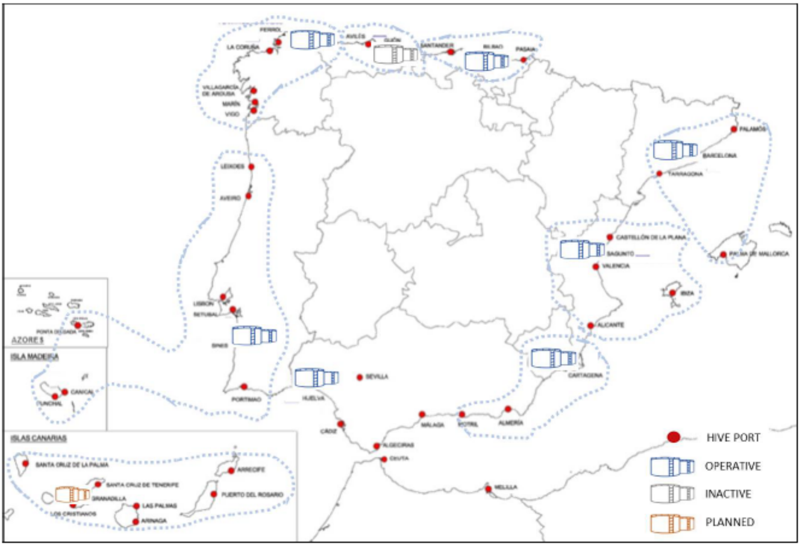
The concept of cluster in this project refers to a group of geographically close ports who share an import terminal, being able - or not- to generate operational synergies and cost reduction.

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



32 Geographic location and port aggregation

2.3.3. Solutions proposed per cluster

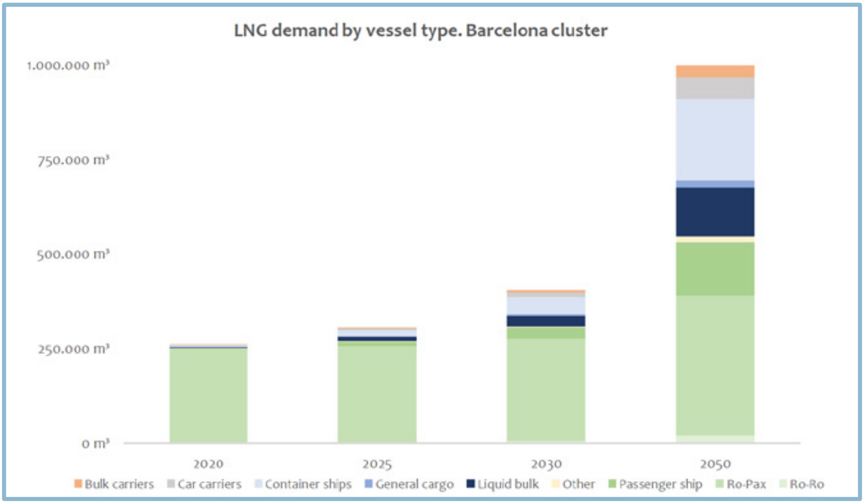
Geographic and demand conditions defining each cluster, would be important when determining the viability of the different logistic models to be implemented.

Barcelona Cluster

Barcelona cluster consists of 4 ports:

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

Port of Barcelona would gather between 95% and 99% of the cluster's total LNG demand for the time frame considered.



33. LNG demand by vessel type. Barcelona Cluster

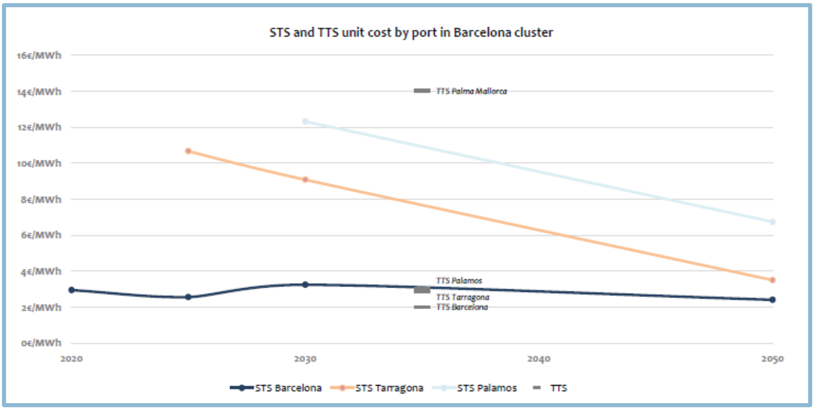
The fact of having an LNG plant already in place for the service to small-scale vessels and the quick development of LNG tanks in cruises and Ro-Pax ships, makes Barcelona a perfect port to deploy LNG supply ships. Besides this, its high storage capacity – avoiding extra trips for refuelling or construction 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 does not 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.

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 m3 and three over 1.000.000 m3.

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

- **Year 2020:** 3.000 m3 vessel with Base Port in Barcelona.
- **Year 2025:** 3.000 m3 vessel with Base Port in Barcelona.
- **Year 2030:** 2 x 3.000 m3 vessels with Base Port in Barcelona.
- **Year 2050:** 2 x 3.000 m3 vessel with Base Port in Barcelona.



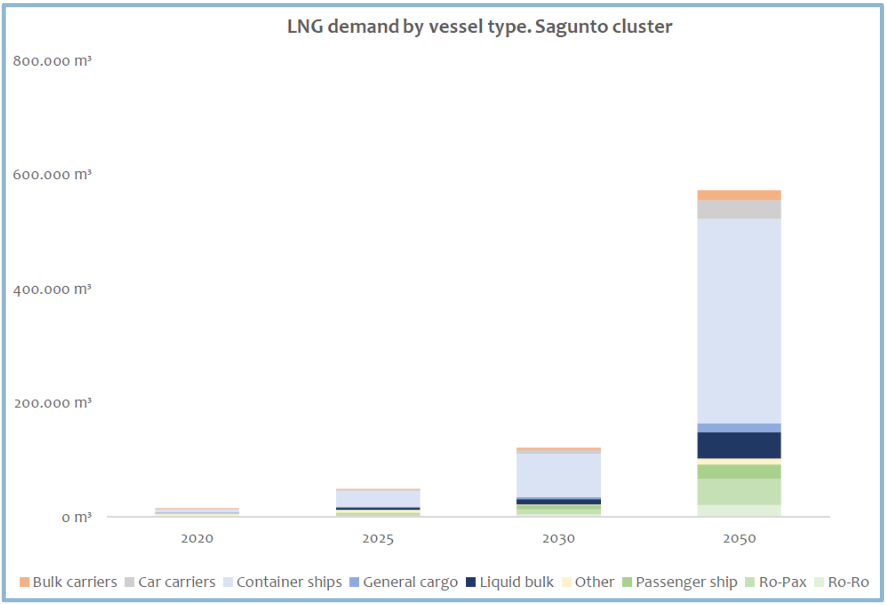
34. STS and TTS supply unit cost by port in Barcelona

Sagunto Cluster

Sagunto cluster consists of five ports:

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

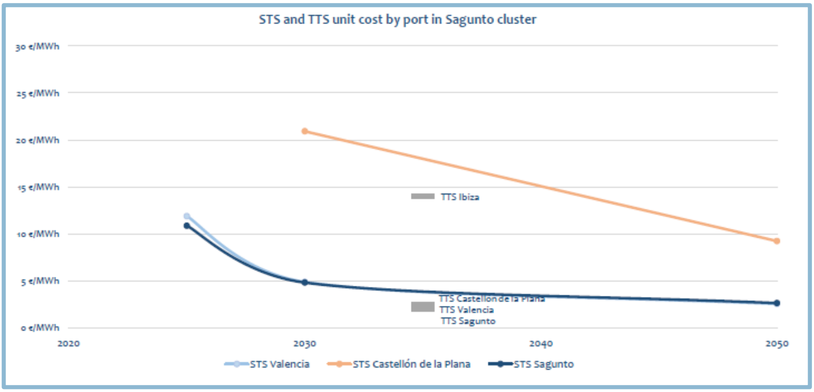
As in Barcelona cluster, these five ports present an uneven activity level. Valencia stands out with an important number of container ships and with and important number of passenger ships and a smaller, but also relevant number of Car Carriers. Valencia is followed by Ibiza in number of port calls, 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. Most of the expected demand is focused in a single port, Valencia.



35. LNG demand by vessel type. Sagunto cluster

Logistic Model 1 is considered the most suitable model for this cluster. The chosen solution for Sagunto Cluster is:

- **Year 2020:** TTS Supply.
- **Year 2025:** 3,000 m3 ship based in Port of Valencia.
- **Year 2030:** 3,000 ship based in Port of Valencia.
- **Year 2050:** 2 x 3,000 m3 based in Port of Valencia.



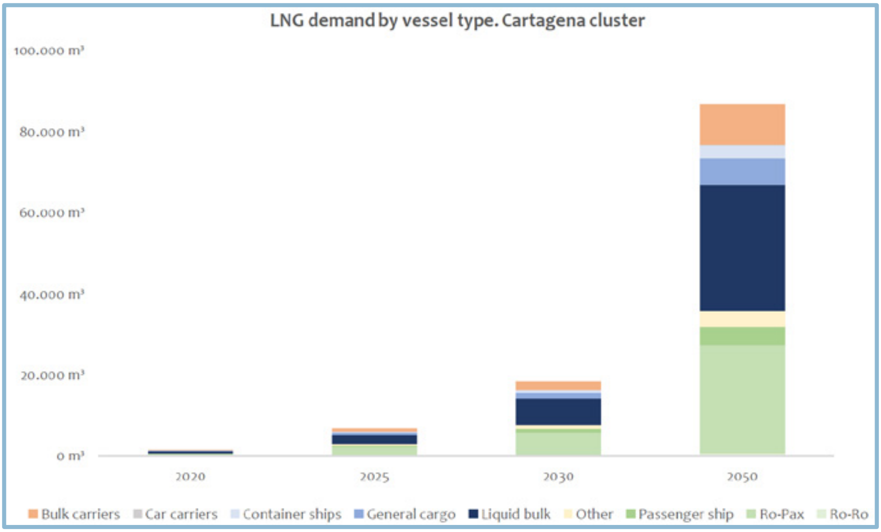
36. STS and TTS supply unit cost by port in Sagunto cluster

Cartagena Cluster

Cartagena cluster consists of 3 ports:

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

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. 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.

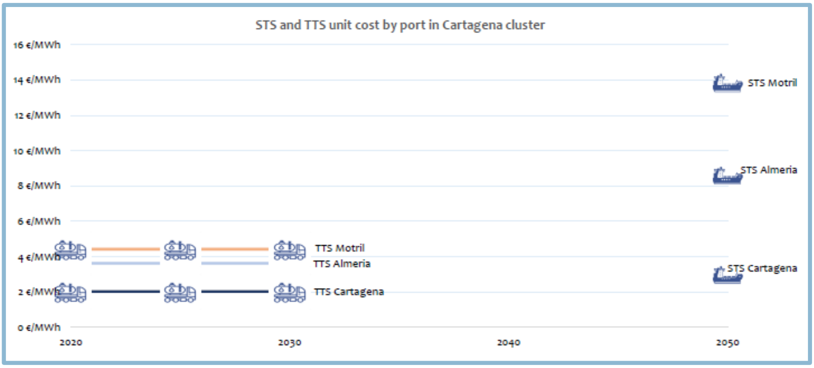


37. LNG demand by vessel type. Cartagena cluster

The chosen solution for this cluster is the following.

- **Year 2020:** TTS Supply.
- **Year 2025:** TTS Supply.
- **Year 2030:** TTS Supply.
- **Year 2050:** de 3.000 m3 ship with Base Port in 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 has not been considered.



38. STS and TTS supply unit cost by port in Cartagena cluster

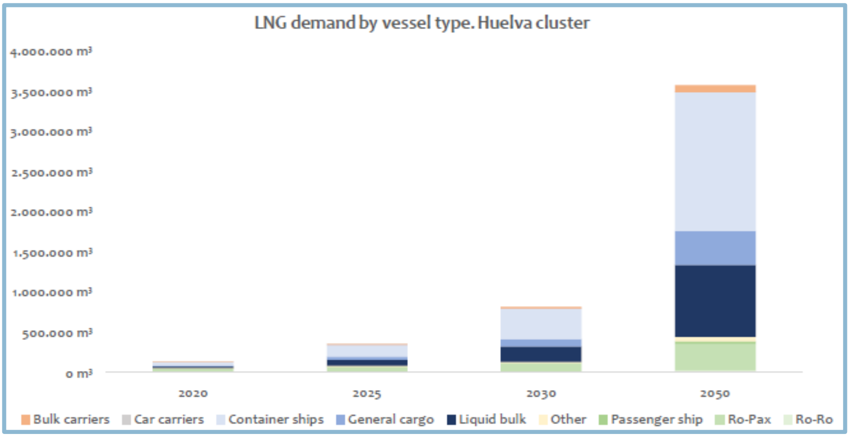
Huelva Cluster

Huelva cluster consists of seven ports:

- Algeciras **(Base Port)**
- Ceuta
- Cádiz
- Malaga
- Huelva **(LNG Import terminal)**
- Seville
- Melilla

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.

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.

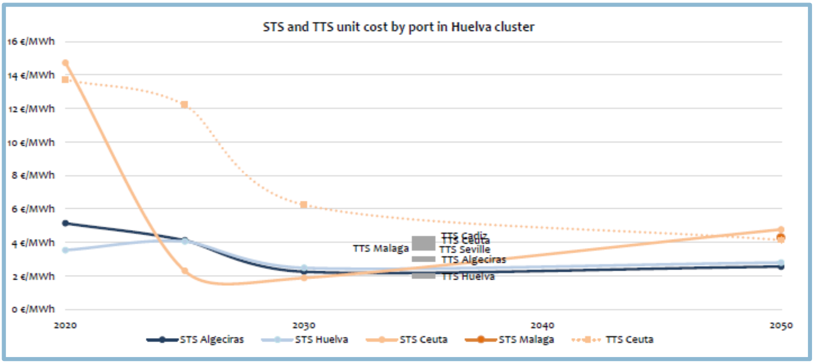


39. LNG demand by vessel type. Huelva cluster

The chosen solution for this cluster is the following:

- **Year 2020:** 3,000 m3 ship based on port of Algeciras.
- **Year 2025:** 2 x 3,000 m3 ship based on Puerto de Algeciras.
- **Year 2030:** 2 x 3,000 m3 ships based on Port of Algeciras.
- **Year 2050:** 1 x 30,000 m3 storage terminal and 3 x 5,000 m3 ships based on Port of Algeciras.

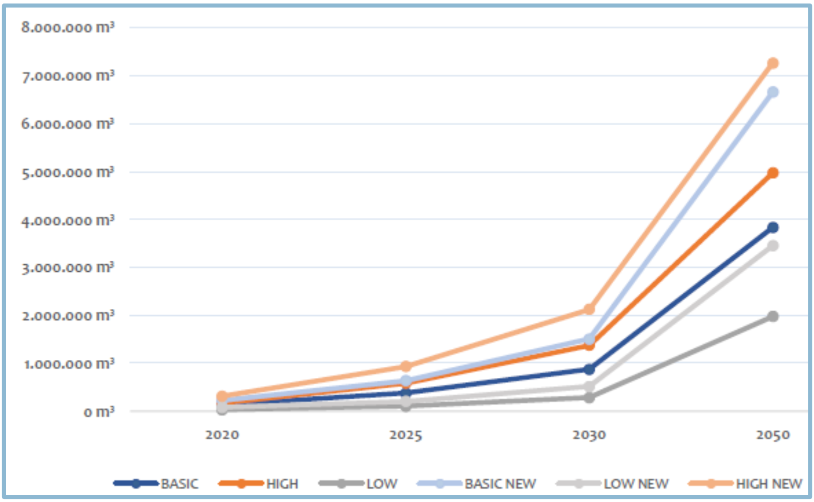
The solutions chosen for this cluster seek to achieve a level of service above 100% in the port of Algeciras at the lowest possible cost. Despite not being the cheapest solution, a dedicated storage terminal is planned for 2050 mostly fostered by the operative impact in Huelva's import terminal and not by a cost reason. With high demand and logistic model 1, the number of calls in the terminal could cause blockage in these facilities.



40. STS and TTS supply unit cost by port in Huelva

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, operators from the port of Gibraltar use the fuel storage facilities in Algeciras.

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



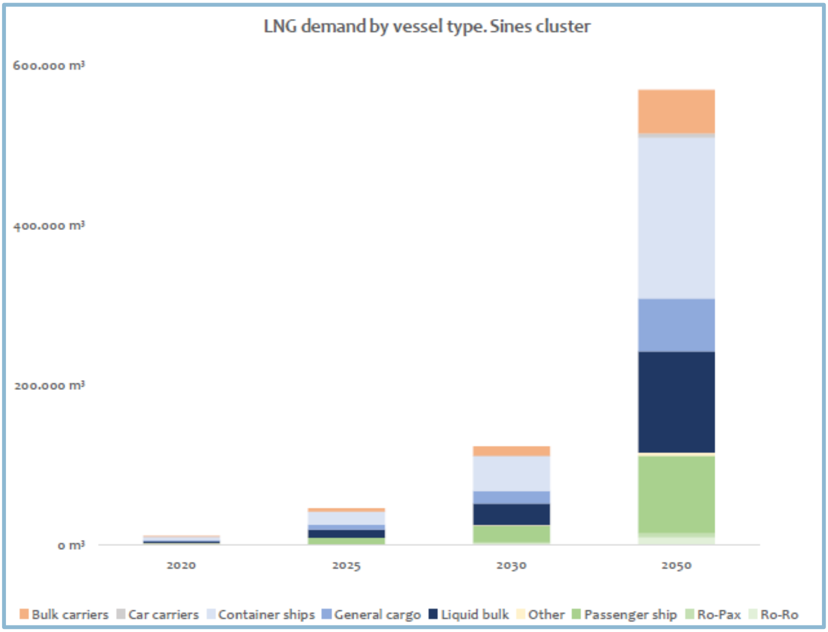
41. NEW LNG demand for modified Huelva cluster including Gibraltar's traffic

Sines Cluster

This cluster is formed by nine ports:

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

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. 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.



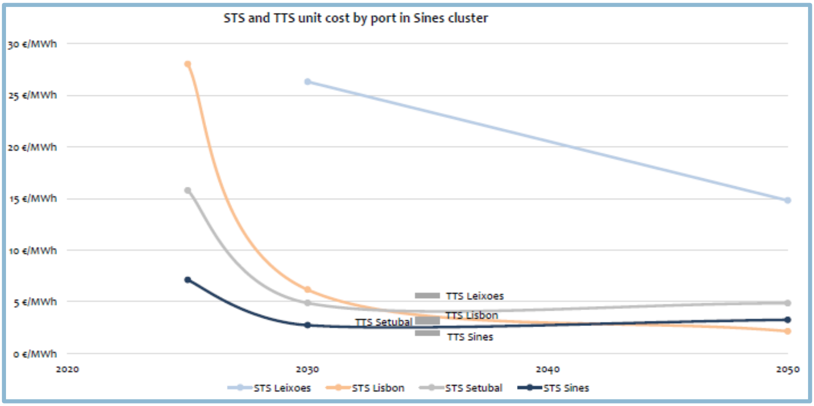
42. LNG demand by vessel type. Sines cluster

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.

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.
- **Year 2025:** 3.000 m3 ship based on port of Sines.
- **Year 2030:** 3.000 m3 ship based on port of Sines.

- **Year 2050:** 2 x 3.000 m3 based on port of Lisbon and 3.000 m3 ship based on port of Sines



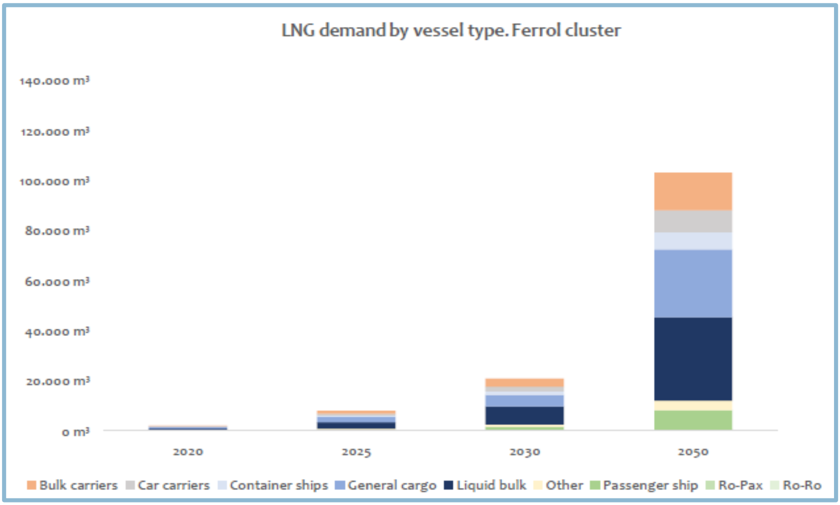
43. STS and TTS supply unit cost by port in Sines

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

Attending to the expected demand, this cluster is like Cartagena o Bilbao but with a more diverse traffic, featuring liquid and solid cargo ships. Demand is divided evenly between the three biggest ports – La Coruna, Vigo and Ferrol- consolidating more than 95% of the total expected demand.

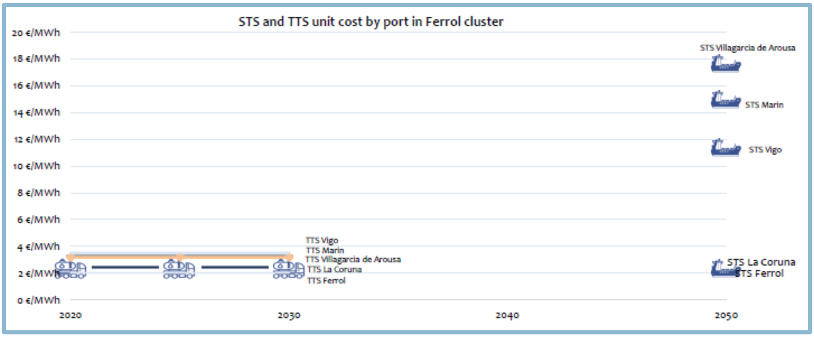


44. LNG demand by vessel type. Ferrol cluster

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 m3. 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.

TTS supply is the solution recommended until demand reaches the 100,000 m3 threshold to have a dedicated supply ship. Chosen solution for this cluster is the following:

- **Year 2020:** TTS supply.
- **Year 2025:** TTS supply.
- **Year 2030:** TTS supply.
- **Year 2050:** 3.000 m3 ship.

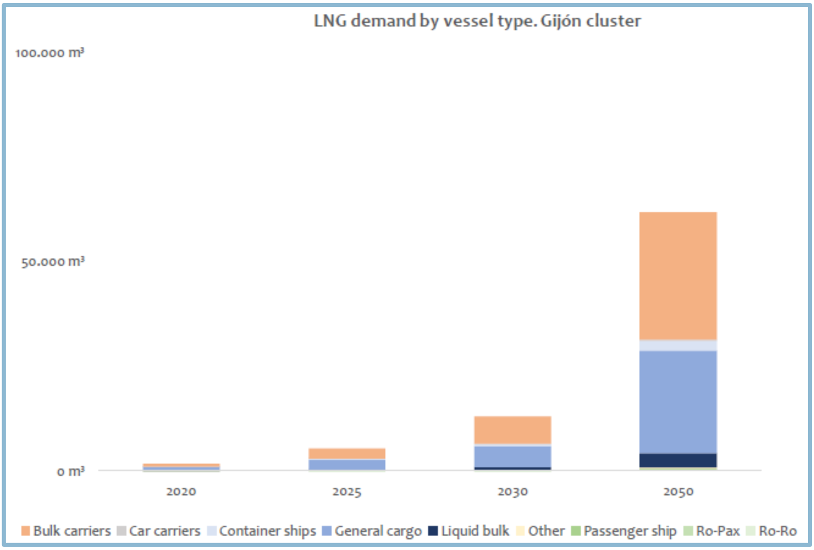


45. STS and TTS supply unit cost by port in Ferrol

Gijon Cluster

Gijon cluster consists of 2 ports:

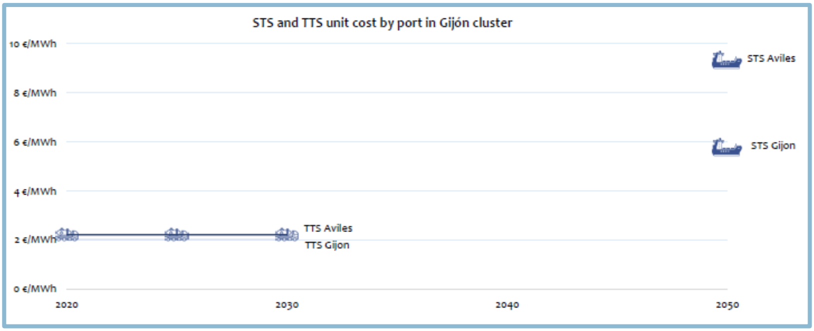
- Avilés
- Gijón **(LNG Import terminal in hibernation) (Base Port)**



46. LNG demand by vessel type. Gijon cluster

This is the cluster with the lower expected demand and only consists of 2 ports, closed to each other. 4 different supply chain analysis has been performed for a threshold volume above 20.840 m3. The solution chosen for this cluster is the following:

- **Year 2020:** TTS Supply
- **Year 2025:** TTS Supply.
- **Year 2030:** TTS Supply.
- **Year 2050:** 3.000 m3 ship.



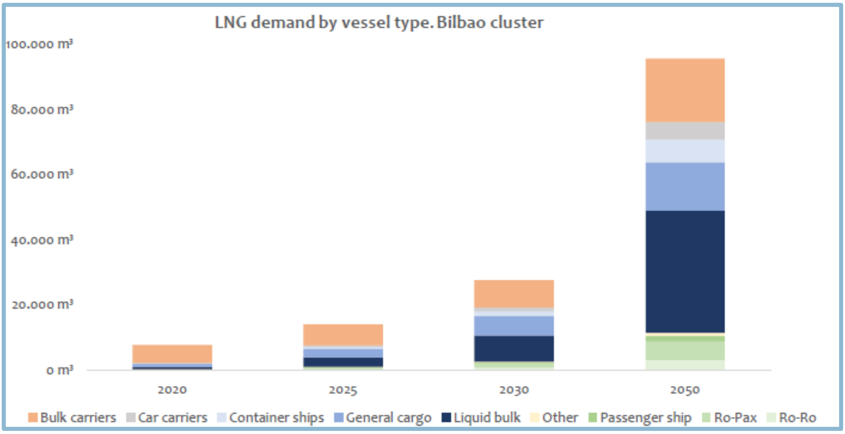
47. STS and TTS supply unit cost by port in Gijon

Bilbao Cluster

Bilbao cluster consists of 3 ports:

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

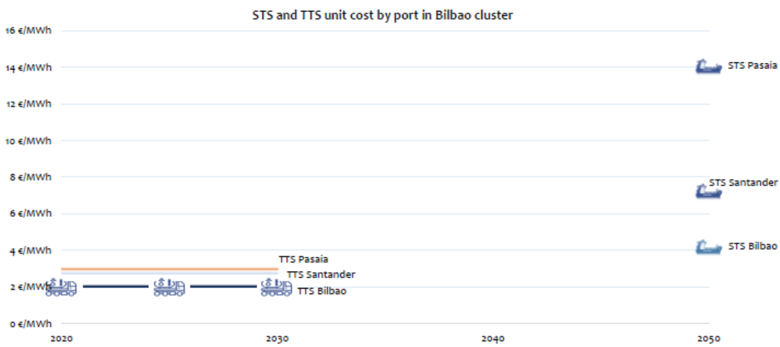
Ports within this cluster are mostly industrial, hosting non-containerized cargo, new vehicles and oil tankers and products in the port of Bilbao which hosts a refinery. Traffic and bunkering operations in this cluster are pretty similar to those observed at port of Cartagena but LNG expected demand 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.



48. LNG demand by vessel type. Bilbao cluster

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. Solution chosen for this cluster is the following:

- **Year 2020:** TTS Supply.
- **Year 2025:** TTS Supply.
- **Year 2030:** TTS Supply.
- **Year 2050:** 1 x 3.000 m3 ship.



49. STS and TTS supply unit cost by port in Bilbao cluster

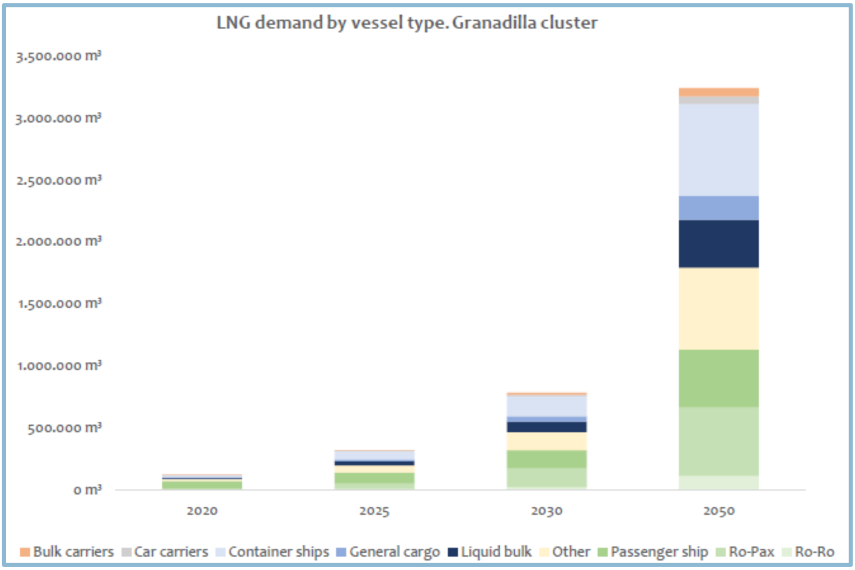
Granadilla Cluster

This cluster is formed by seven 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

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.

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.



50. LNG demand by vessel type. Granadilla cluster

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

2.3.4. 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.

2.3.5. Import terminal located in the Island of Tenerife, 70 nm from Las Palmas

2.3.6. Except ports of Tenerife and Los Cristianos, TTS bunkering would require sea transport of tankers.

2.3.7. Additional availability service requirements in the port of Las Palmas.

2.3.8. Minimum demand in smaller ports.

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:

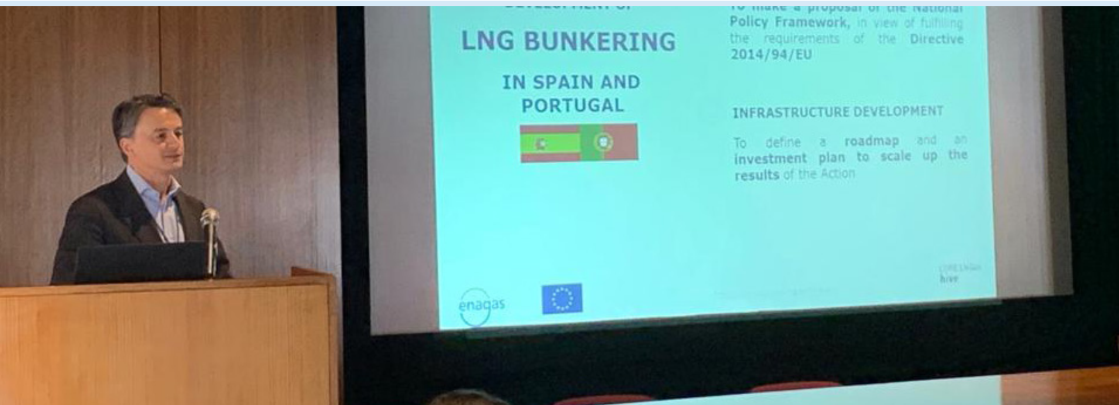
2.3.9. **Year 2020:** 3,000 m3 ship based on Las Palmas.

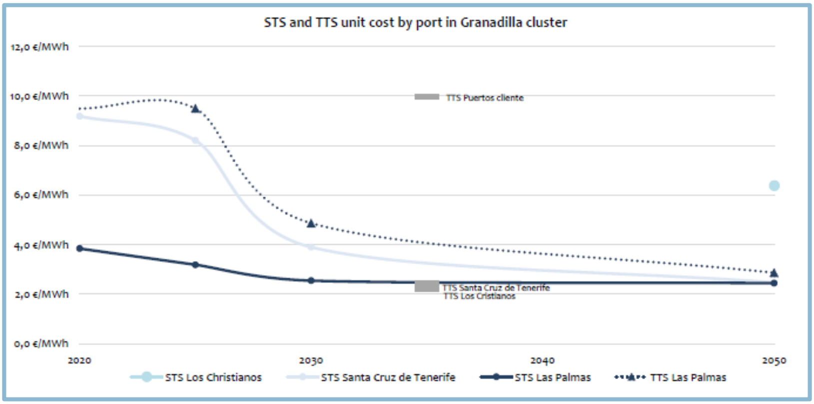
2.3.10. **Year 2025**: 1 x 3,000 m3 ship based in Las Palmas and 1 x 3,000 m3 based in Tenerife.

2.3.11. **Year 2030:** 2 x 3,000 m3 ships based on Las Palmas and 1 x 3,000 m3 ship based on Tenerife and 1 x 1,000 m3 auxiliary plant based in the port of Las Palmas.

2.3.12. **Year 2050:** 1 x 30,000 m3 storage terminal and 3 x 3,000 m3 ships based in Las Palmas and 2 x 3,000 m3 based in the port of Tenerife.

Presentation of LNG supply chain tool at WG meeting on ports and multimodal terminals Atlantic CORE Network Corridor in Lisbon by Fernando Impuesto, CORE LNGas hive Coordinator and Enagás General Manager





***51.* STS and TTS supply unit cost by port in Granadilla cluster**

52. EU MOS Markets

2.4. Impact on European LNG Bunkering Markets

A study of the impact on Europe of the implementation and growth of LNG as fuel at Iberian ports was produced. **The main conclusion achieved is that both Spain and Portugal are well positioned to become influential countries in the future LNG supply market.** Spain's annual LNG imports are the highest by annual volume of any European country.

From a macro perspective: high volume of imports, open TPA regulation and clear and competitive fees for small scale access to the national gas infrastructure will highly determine the competitiveness of a port in the yet to be developed LNG bunkering market.

In the **Mediterranean market**, Spain and France - with Barcelona, Valencia-Sagunto, Cartagena and Marseille-Fos - are currently the clear leaders. If Spain continues to develop competitive access tariffs, Portugal follows this path, and both countries complete the development of service standards, access to port services, security standards, etc., both countries will position themselves at the forefront of bunkering supply and small-scale distribution.

In the **Atlantic market**, the Iberian position would still be behind the ARA ports (Amsterdam-Rotterdam-Antwerp), the current leaders in conventional bunkering. The ports in the ARA area are also likely to lead the LNG bunkering market. The Iberian ports may be able to compete closely with Portsmouth and Le Havre, both of which are ports with distant access to LNG infrastructure.

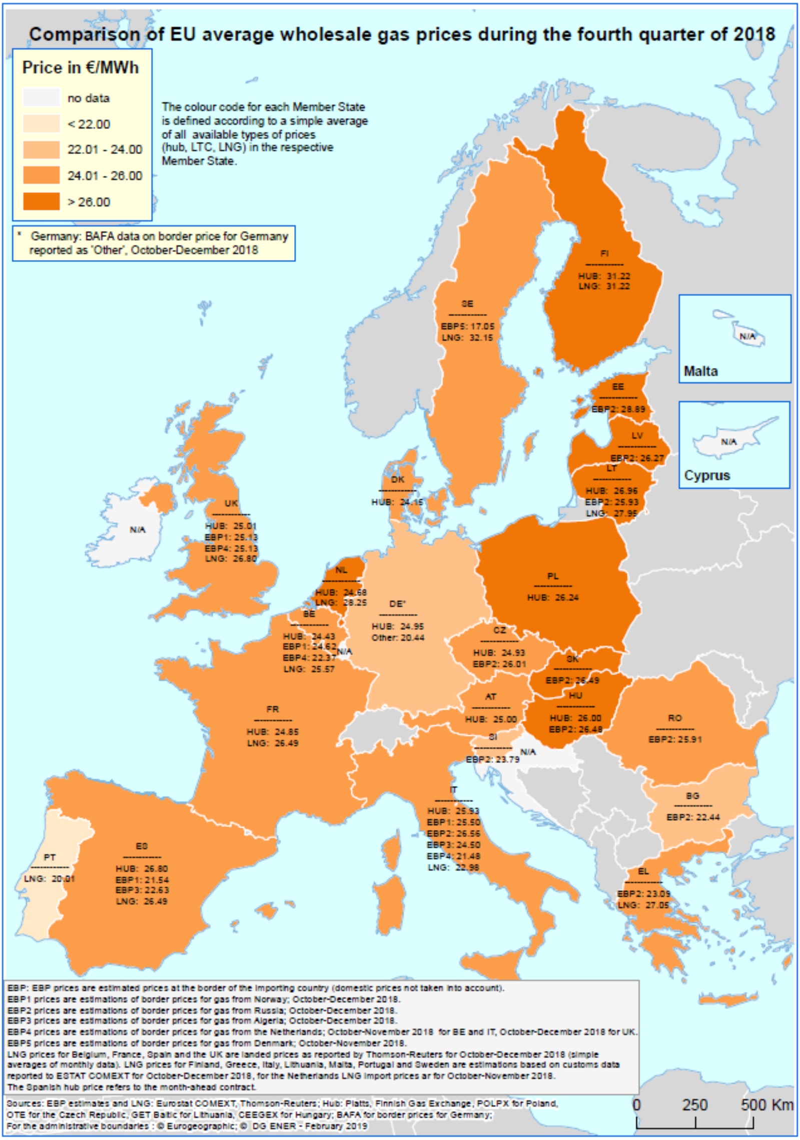
Finally, in the **Strait of Gibraltar market** - which stretches from the Suez Canal to the open waters of the Atlantic and is one of the most intensive maritime markets in the world - Algeciras' leadership seems highly feasible. Algeciras is defined as a group of four ports: Algeciras, Gibraltar, Tanger Med and Ceuta. All potentially supplied in the first phase from the Huelva import plant, these ports could offer high quality services at competitive prices. Although major competing ports such as Gibraltar (UK), Tangier Med (Morocco), Marshalock (Malta) and Gioia Tauro (Italy) have announced plans or intentions to develop LNG infrastructure to support fuel supply, only Huelva has real capacity in the region at the moment.

2.4.1. Analysis of European LNG Pricing Bunkering

Bunkering competitiveness will not fall only on logistics costs, but also in LNG wholesale prices. Spain is the main importer of GNL in the European Union, as it can be seen in the figure below.

This high LNG demand gives Spain a strong position within the LNG market and, along with a regulated and non-discriminatory TPA it creates a good situation for the entry of new players. Although Spain is the leader of LNG imports, as this is the main source for natural gas supply, prices are greater than in France, Belgium and UK, where it has been deployed a extensive pipeline grid, interconnected with other countries that allows to import gas from Norway and Russia downplaying the importance of LNG for conventional supply.

The figure below gives an idea of the differences between pipeline gas prices and LNG prices in every European Union country.



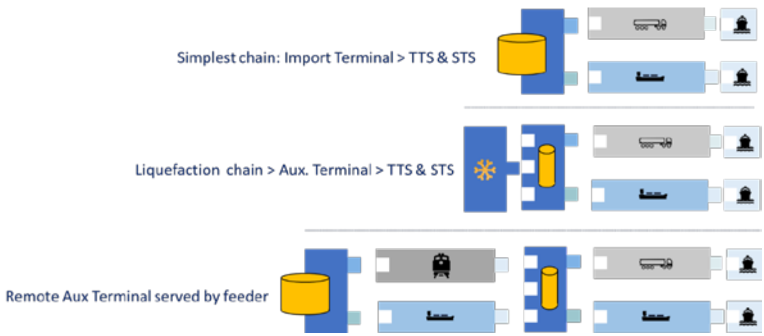
53. EU Average wholesale gas price Q4 2018. Source. DG ENERGY. Market Observatory

If the Far East Europe container traffic with the main operators and current routes is analysed, it can be pointed out that Algeciras – Tanger Med would be competing with Rotterdam, supported by a higher LNG activity in the national gas supply network.

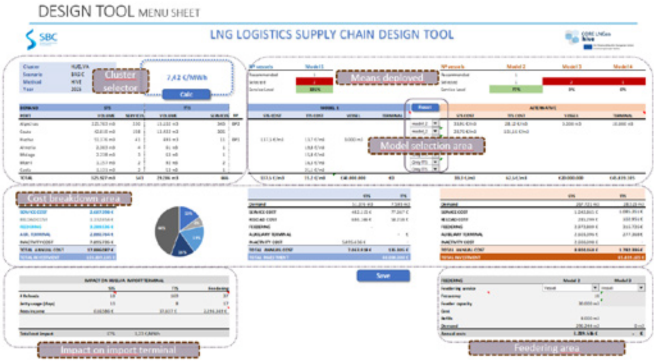
Public authorities therefore have a significant role in the impulse of the new LNG bunkering market and the competitiveness of their ports, by both attracting supply and demand initiatives.

2.5. Design tool

The final product developed allows users to design and simulate the economic and operational aspects of their own logistics chains from numerous and detailed input variables (means of supply, demand, regulated costs, port, fuel, etc ...), edit the market / demand assumptions and generate a database of analyses already carried out. It allows its subsequent revision and modification -allowing the adaptation of the results to the evolution of the market-, as well as generating reports and visualizations that include numerous analysis that meet the different demand scenarios expected in the 2020-2050 time frame. The result allows a sensitivity analysis of key operating parameters to be performed. Users can modify any input data. The tool uses a combination of heuristic and optimisation methods that give the end user total control in the design of supply chains.



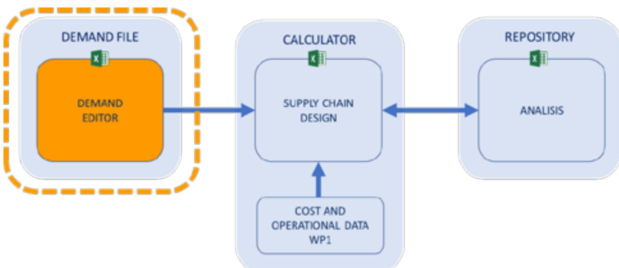
54 Building Chain



55. Design of the digital tool developed for the CORE LNGas hive project

The tool can be used in several ways. It could be used to simulate a simple supply chain at a port. It could also be used to simulate complex scenarios, such as the demand for LNG supply in the Iberian Peninsula, islands and territories. Ports are grouped into several clusters (sets of ports that obtain the product from the same import terminal and share bunkering assets). The use of clusters allows the tool to identify and calculate operational synergies between ports. Designing a supply chain requires several intuitive decisions on what logistic model to use; the tool will immediately produce an optimized proposal. Certain rules are implemented in the calculator code, but most parameters are exposed to the user and can be updated based on latest market information. In the design process, the user might choose to fix or force certain assets (vessels, terminals, feeder) to better reflect actual market conditions. The system allows changes to the cluster definition at a later stage.

Each designed scenario can be saved in the analysis tool. This module allows retrieving and comparing alternative solutions to meet demand within a cluster. Using the analysis tool, the user can determine and present the best solution to balance cost and level of service.



56. Basic architecture of the Tool

CORE LNGas hive

Co-financed by the European Union
Connecting Europe Facility