Work Package 4

Activity 4.6

EXPANSION AND COOPERATION OPPORTUNITIES FOR NORTH SEA REGION COMPREHENSIVE PORTS WITHIN THE 2014 CEF CALL

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Summary

This report aims at investigating the opportunities of expansion and cooperation for Comprehensive Ports in the North Sea Region, thereby strengthening their role on both the Core and the Comprehensive network.

The main focal area addressed in the study is availability and use of LNG (liquefied natural gas or biogas), as one of the most potential alternative fuels for the maritime sector. It is of particular importance due to the fact that shipping is a large and still growing source of the greenhouse gas emissions (GHG) (EC, 2015a), including sulphur dioxide (SO_2), nitrogen oxide (NO_x) and particulate matter (PM). Another concrete focus of the report will be on shore-side power supply.

1 Introduction

In 2013 EU (28) ports handled over 3.7 billion tonnes of cargo (Eurostat, 2015) and the volume is estimated to increase further by 50% by 2030. Therefore, *"All ports across the trans-European network will be needed to help accommodate this growth"* (EC, 2013a), meaning that the development of ports as efficient and sustainable entry and exit points fully integrated with the land infrastructure has to be supported.

Currently, GHG emissions caused by shipping account for around 4% of the total EU GHG emissions and are expected to increase significantly in the future. The CO_2 emissions from the EU maritime transport sector increased by 48% between 1990 and 2008. In accordance with the growth projections, emissions from EU shipping are expected to increase further by 51% by 2050 compared to the level of 2010, if no minimum ship efficiency standards or alternative fuel actions are adopted. (EC, 2013b)

The focal area though is sulphur dioxide emissions, which cause acid rain and generate fine dust. As a result, it affects human health, causing respiratory and cardiovascular diseases, and reduces life expectancy in the EU by up to two years. (EC, 2015b) Simultaneously, it triggers environmental problems such as eutrophication and associated losses in biodiversity.

Air pollution from shipping is regulated primarily by the International Convention for the Prevention of Marine Pollution (MARPOL) through a dedicated Annex VI, which deals with emissions and energy efficiency. One of the introduced measures is the concept of Sulphur Emission Control Areas (SECAs), including the Baltic Sea, the North Sea and the English Channel, which are recognised as unusually vulnerable and where sulphur emissions are controlled (see Figure 1). With regards to the challenging environmental problem that maritime is recently facing, significantly stricter limits have been applied: from 1st January 2015 EU Member States have to ensure that ships in SECAs are using fuels with a sulphur content of no more than 0.1%. Higher sulphur contents are possible only if appropriate exhaust cleaning measures are taken. (EC, 2015b)

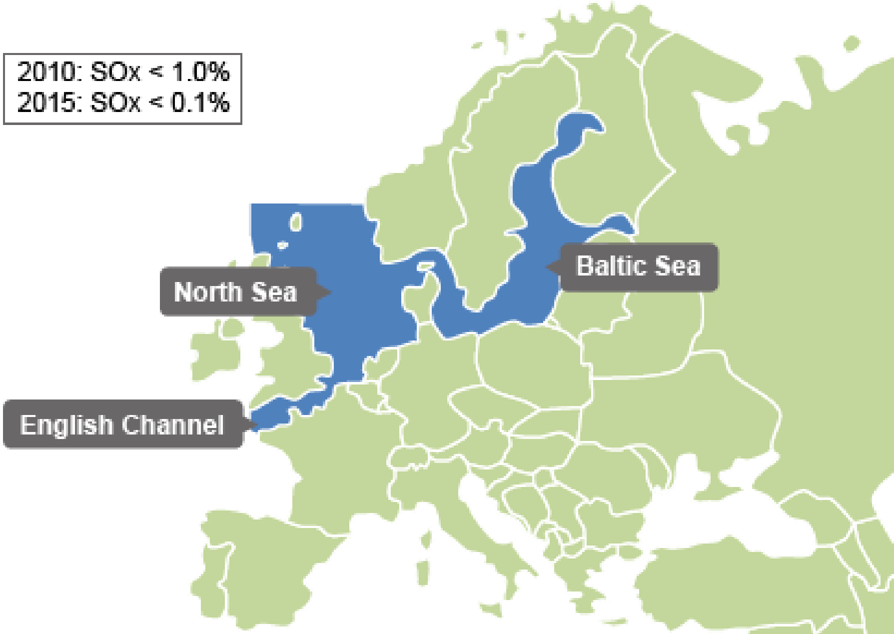

Figure 1: SO_X Emission Control Areas – SECA (Journal of commerce, 2015)

Two aspects will be discussed in this study: 1) application of LNG as an alternative fuel for shipping and 2) installation of shore-side electricity supply. These are, according to the findings of the TEN-TaNS Toolbox, among the most interesting development opportunities for Comprehensive Ports determined by the Connecting European Facility (CEF) funding programme.

2 Definitions

Comprehensive Port

"Maritime ports shall be entry and exit points for the land infrastructure of the comprehensive network. They shall meet at least one of the following criteria:

(a) the total annual passenger traffic volume exceeds 0,1 % of the total annual passenger traffic volume of all maritime ports of the Union. The reference amount for this total volume is the latest available three-year average, based on the statistics published by Eurostat;

(b) *the total annual cargo volume – either for bulk or for non- bulk cargo handling – exceeds 0,1 % of the corresponding total annual cargo volume handled in all maritime ports of the Union. The reference amount for this total volume is the latest available three-year average, based on the statistics published by Eurostat;*

(c) *the maritime port is located on an island and provides the sole point of access to a NUTS 3 region in the comprehensive network;*

(d) *the maritime port is located in an outermost region or a peripheral area, outside a radius of 200 km from the nearest other port in the comprehensive network."* (EC, 2013c)

Core Port

The criteria for being a Core Port are not defined in TEN-T Guidelines. Generally, *"(40) The core network should be a subset of the comprehensive network overlaying it. It should represent the strategically most important nodes and links of the trans-European transport network, according to traffic needs. It should be multimodal, that is to say, it should include all transport modes and their connections as well as relevant traffic and information management systems.*

(41) The core network has been identified on the basis of an objective planning methodology. That methodology has identified the most important urban nodes, ports and airports, as well as border crossing points. Wherever possible, those nodes are connected with multimodal links as long as they are economically viable, environmentally sustainable and feasible until 2030. The methodology has ensured the interconnection of all Member States and the integration of the main islands into the core network." (EC, 2013c)

The revision of the Core network implementation will be carried out by 2023, where the Commission, after consulting the Member States, will evaluate whether to include other parts in the network, especially the priority projects mentioned in Decision No 661/2010/EU. (EC, 2013c)

According to the above mentioned methodology (EC, 2014a), the main nodes for freight traffic of the Core Network among others are sea ports *"<...> with an annual transhipment volume of at least 1 % of* *the total transhipment volume of all EU seaports, if interpolating linearly between bulk and non-bulk complies with the formula: $v_b/t_b + v_n/t_n \geq 1$ (where v_b is the volume of bulk, t_b the threshold for bulk, v_n the volume of non-bulk and t_n the threshold for non-bulk)."* (EC, 2014a) Also, *"Seaports which are immediate neighbours and together fulfil the volume threshold, even if individually they would not, may be considered as a cluster, if they have common hinterland connections, except for the "last mile", or if they cooperate closely, e.g. under common management, or supplement each other in function."* (EC, 2014a)

Freight Terminal

"a structure equipped for transhipment between at least two transport modes or between two different rail systems, and for temporary storage of freight, such as ports, inland ports, airports and rail-road terminals." Its annual transhipment of freight exceeds 800.000 tonnes for non-bulk cargo. (EC, 2013c)

LNG

Natural gas or biogas *"<…> cooled and liquefied occupying only 1/600th of its normal volume in gaseous form at a temperature of around -162°C."* (Linde, 2012a) 1 ton ≈ 2.2 m^3 of LNG (Maritime Authority, 2012), meaning the density of around 0.45 kg/litre.

Logistics Platform

"'logistics platform' means an area which is directly linked to the transport infrastructure of the trans-European transport network including at least one freight terminal, and which enables logistics activities to be carried out" (EC, 2013c)

Motorways of the Sea (MoS)

Motorways of the sea *"<...> shall consist of short-sea routes, ports, associated maritime infrastructure and equipment, and facilities as well as simplified administrative formalities enabling short-sea shipping or sea-river services to operate between at least two ports, including hinterland connections. Motorways of the sea shall include:*

(a) maritime links between maritime ports of the comprehensive network or between a port of the comprehensive network and a third-country port where such links are of strategic importance to the Union;

(b) port facilities, freight terminals, logistics platforms and freight villages located outside the port area but associated with the port operations, information and communication technologies

(ICT) such as electronic logistics management systems, and safety and security and administrative and customs procedures in at least one Member State;

(c) infrastructure for direct land and sea access." (EC, 2013c)

"The "Motorways of the Sea" are the maritime dimension of the TEN-T. As far as they fulfil the function of core network links or of sections thereof (e.g. linking core network main nodes across the sea), they are considered part of the core network, as well." (EC, 2014a)

Neighbouring Country

"'neighbouring country' means a country falling within the scope of the European Neighbourhood Policy including the Strategic Partnership, the Enlargement Policy, and the European Economic Area or the European Free Trade Association" (EC, 2013c)

Third Country

"'third country' means any neighbouring country or any other country with which the Union may cooperate to achieve the objectives pursued by this Regulation" (EC, 2013c)

3 EU Requirements for Ports

According to Article 22 of *the Union guidelines for the development of the trans-European transport network*, *"Member States shall ensure that:*

- *(a) maritime ports are connected with railway lines or roads and, where possible, inland waterways of the comprehensive network, except where physical constraints prevent such connection;*
- *(b) any maritime port that serves freight traffic offers at least one terminal which is open to users in a non-discriminatory way and which applies transparent charges;*
- *(c) sea canals, port fairways and estuaries connect two seas, or provide access from the sea to maritime ports and correspond at least to inland waterway class VI.*

2. Member States shall ensure that ports include equipment necessary to assist the environmental performance of ships in ports, in particular reception facilities for ship-generated waste and cargo residues in accordance with Directive 2000/59/EC of the European Parliament and of the Council and in compliance with other relevant Union law." (EC, 2013c)

In relation to the environmental performance, alternative fuel deployment for shipping is outlined in the Directive on the deployment of alternative fuels infrastructure, where the target is to make LNG available at maritime and inland ports of the TEN-T Core Network by the end of 2025 and 2030 respectively (EC, 2014b). "*Refuelling points for LNG include, inter alia, LNG terminals, tanks, mobile containers, bunker vessels and barges. <u>The initial focus on the core network should not rule out the possibility of LNG also being made available in the longer term at ports outside the core network</u>, in particular those ports that are important for vessels not engaged in transport operations.*" (EC, 2014b) The map of Core and Comprehensive Ports in the North Sea Region can be seen in Figure 2 (ports in Norway do not have a status Core or Comprehensive and therefore are not included in the map).

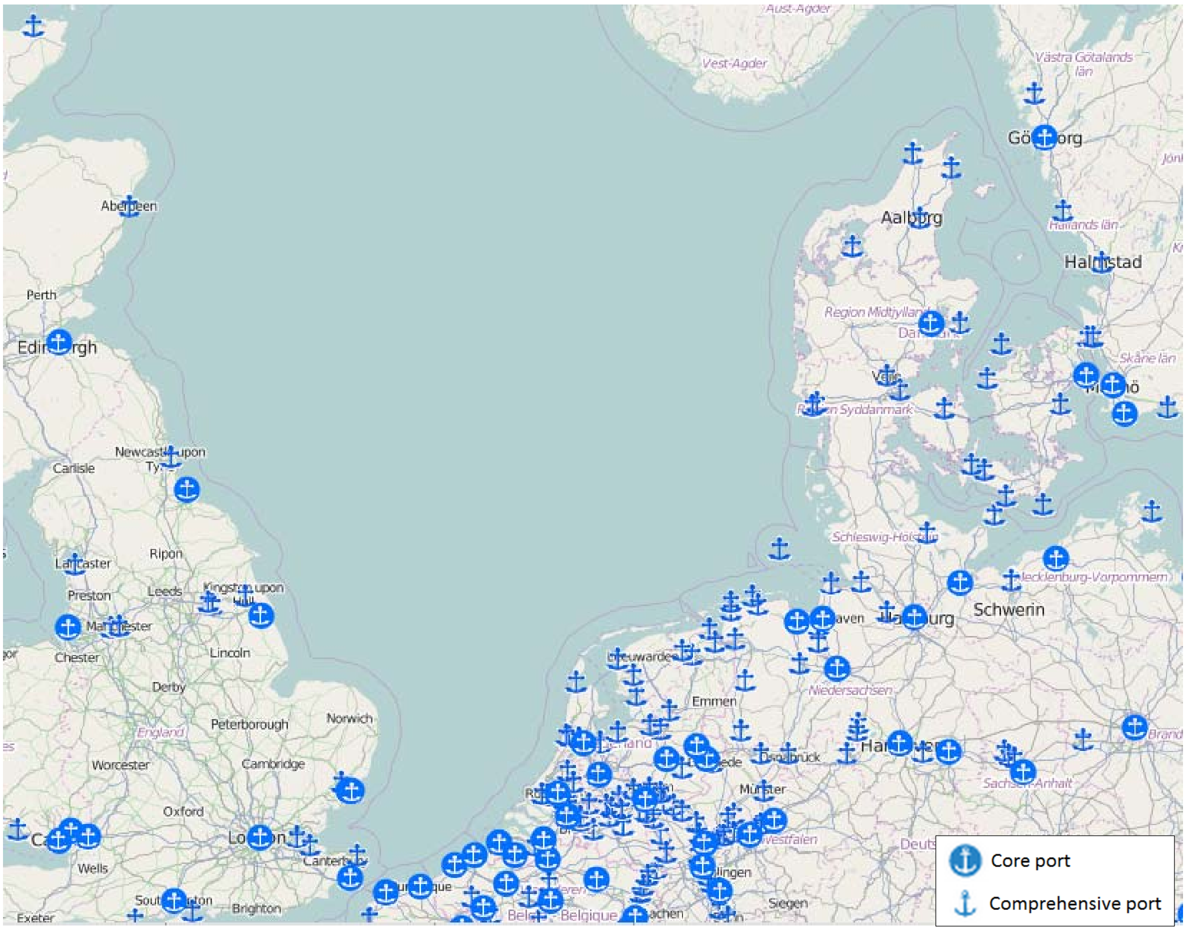

Figure 2: Core and Comprehensive Ports in the NSR

Source: (TENtec, 2015)

As evident from the map, the North Sea Region is structured upon a network of mainly comprehensive ports, which are guided by different rules that the Core Ports. The Clean Power for Transport Directive give concrete legally binding requirements for the deployment of alternative fuels along the TEN-T network.

"Member States shall ensure, by means of their national policy frameworks, that an appropriate number of refuelling points for LNG are put in place at maritime ports, to enable LNG inland waterway vessels or seagoing ships to circulate throughout the TEN-T Core Network by 31 December 2025. Member States shall cooperate with neighbouring Member States where necessary to ensure adequate coverage of the TEN-T Core Network." (EC, 2014b)

Apart from the LNG deployment, other energy efficiency improvement measures in the maritime sectors include shore-side electricity. *"Member States shall ensure that the need for shore-side electricity supply for inland waterway vessels and seagoing ships in maritime and inland ports is assessed in their national policy frameworks. Such shore-side electricity supply shall be installed as a priority in ports of the TEN-T Core Network, and in other ports, by 31 December 2025, unless there is* *no demand and the costs are disproportionate to the benefits, including environmental benefits."* (EC, 2014b).

The above requirements are set for Core ports, with a view to enabling Comprehensive ports to also install such facilities. For this CEF funding under the Annual Programme is available.

4 Funding

Comprehensive Ports are mainly targeted under the Annual Work Programme (EC, 2014c). There is also a call priority linked to Comprehensive Ports under Multi-Annual Work Programme (EC, 2014d), addressing Motorways of the Sea (MoS), yet it must be linked to a Core Port.

In order to be eligible for Multi-Annual Work Programme funding for the period 2014-2020, the ports are required to belong to the Core network. (EC, 2013a) Here, Comprehensive Port on Core Network is not eligible, since it is core network port, but not Core Port, meaning that the TEN-T status is determined by the status of the node and not of the network. An example is Frederikshavn port in Denmark, which is placed on the Core network, yet its status is still comprehensive.

Funding opportunities are presented in Table 1.

Table 1: CEF Funding opportunities relevant to Comprehensive Ports

Priority	Specific objectives/ Covered areas	Key notes
Annual Programme Objective 1: Removing bottlenecks, enhancing rail interoperability, bridging missing links and, in particular, improving cross-border sections		
1.2. Projects on the comprehensive network (railways, inland waterways, roads, maritime and inland ports) Indicative amount: €250 million	-Actions which contribute to bridging missing links, facilitating cross-border traffic flows and/or improving safety, or removing bottlenecks -Actions which contribute to the development of the core network or interconnect core network corridors -Preparation of future projects on the comprehensive network (feasibility studies, permission procedures, implementation and evaluation in sections of the comprehensive network)	-Studies (50%) funding rate Works (20%) funding rate - Comprehensive Network
Annual Programme Objective 2: Ensuring sustainable and efficient transport systems in the long run, with a view to preparing for expected future transport flows, as well as enabling all modes of transport to be decarbonised through transition to innovative low carbon and energy-efficient transport technologies, while optimising safety		
2.1. Deployment of new technologies and innovation, other than those covered by the multiannual Work	-Decarbonisation of all transport modes by: stimulating energy efficiency, introducing alternative propulsion systems,	-Enabling the achievement of forward-looking policy objectives -Especially support in implementing the Clean Power

Programme Indicative amount: €20 million	including electricity supply systems, providing corresponding infrastructure. -Safe, secure and sustainable transport solutions for the transport of goods -Advanced concepts for operation, management, accessibility, interoperability, multi-modality and efficiency of the network -Enhancing resilience to climate change, reducing external costs caused by congestion, damage to health and pollution (noise and emissions)	for Transport (CPT) Directive – notably in the framework of the corridor approach -Pursuing a market-oriented approach and promoting the deployment of innovative technological and organisational solutions in accordance with the provisions of article 33 of the TEN-T Guidelines Works (20%) funding rate
Annual Programme Objective 3: Optimising the integration and interconnection of transport modes and enhancing the interoperability of transport services, while ensuring the accessibility of transport infrastructures		
3.4. Connections to and development of multimodal logistics platforms Indicative amount: €10 million	-Effective interconnection and integration of the infrastructure, including where necessary through access infrastructure and so called “last mile” connections	-Multimodal logistics platforms cover maritime ports, inland ports, airports and rail-road terminals, as per the definitions of the TEN-T Guidelines -The priority covers all connections by road, rail and inland waterways to these logistic platforms Works (20%) funding rate
Multi Annual Programme Objective 3: Optimising the integration and interconnection of transport modes and enhancing the interoperability of transport services, while ensuring the accessibility of transport infrastructures		
3.4. Motorways of the Sea (MoS) Indicative amount: €250 million	Among others: -Infrastructure development in ports and the promotion of “wider benefits” of the MoS development -Implementation of projects addressing the environmental challenges faced by the maritime sector, e.g. actions supporting the deployment of alternative fuels, the development of reception facilities, upgrades of vessels, etc.	-Studies, pilot actions or implementation measures as well as a combination of studies and implementation are eligible (but not research and development projects) Studies (50%) funding rate Works (30%) funding rate

Source: (EC, 2014c), (EC, 2014d)

Shortly, Comprehensive Ports are eligible for the following areas under CEF funding:

- **Hinterland connections** to the Core network (rail, IWW or road if other hinterland connections are not an option) with adequate capacity and efficiency;
- **Reception facilities** for oil and other waste, including residues from scrubbers, to meet environmental requirements;
- New facilities and technologies regarding use of **alternative energy** (LNG bunkering, shore-side electricity, etc.). (EC, 2014e)

Comprehensive Ports are not eligible for:

- **Port access** aiming at providing safe maritime access (breakwaters, capital dredging activities, access channels, locks and navigational aids);
- **Basic infrastructure** (internal basins, quay walls, jetties, backfills and land reclamation). (EC, 2014e)

The two latter activities are only eligible for funding for Core Ports.

5 Possibilities using LNG

Due to the EU goal of gradual decarbonising the transport sector and strict regulations of SECA, oil-based fuels should be replaced with alternative fuels. According to the Directive on the deployment of alternative fuels infrastructure, LNG is recognised as one of several fuels suitable for shipping and LNG utilisation can give a 10% to 25% reduction in CO_2 emissions compared to similar conventional fuels. Moreover, replacing conventional fuel with natural gas reduces the amount of NO_X, SO_2, particulates and other harmful and toxic substances emitted. NOx and particulate matter is the major issue for air quality. However, to deploy LNG as one of the maritime transport propulsions, an associated infrastructure for LNG production or import must be set up within the ports, including storage, distribution and filling stations. Possible configurations of LNG infrastructure are presented in Figure 3.

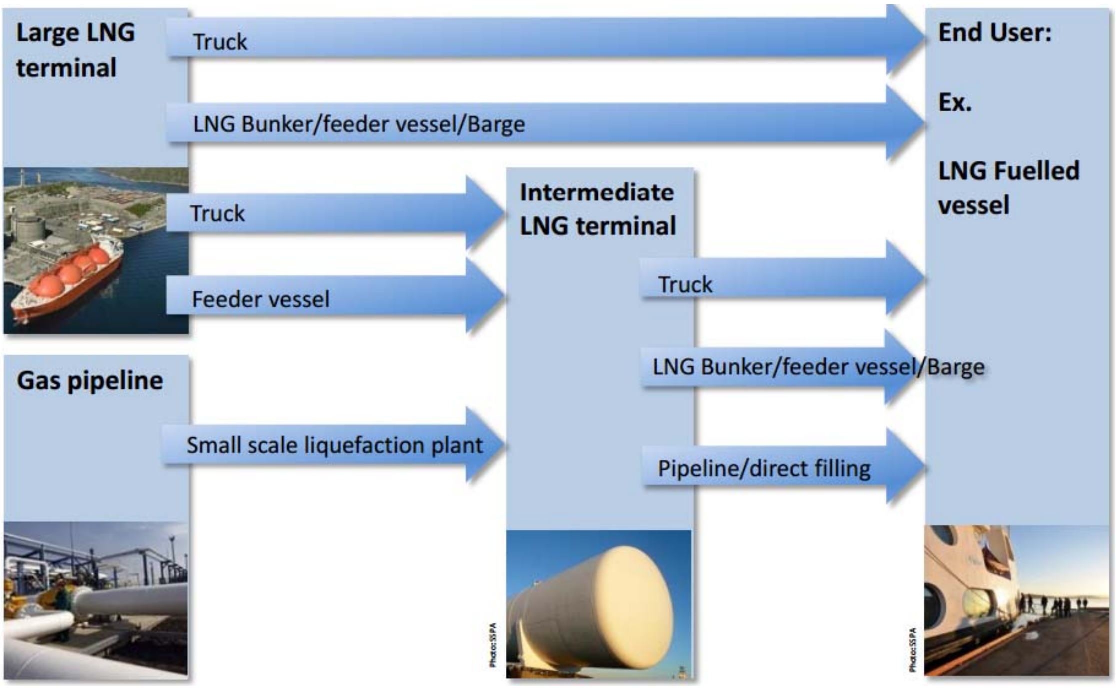

Figure 3: LNG infrastructure configurations

Source: (SSPA, 2012)

There are two main options for the reception of LNG as a marine bunker fuel:

- Sea-based or land-based import;
- On-site production (liquefaction plants).

One of the main criteria that a port must consider before deciding on establishing a LNG terminal is the available market for LNG bunkering. The potential market must be evaluated not only on the basis of the current situation, but also with respect to future perspectives, taking into account stricter regulations for the conventional fuels and the growing demand for alternative fuels as a maritime propulsion.

Moreover, as seen from the figure above, establishment of an LNG infrastructure within the port may have synergy effects, additionally serving land transport means, such as LNG trucks, and thus creating a multi-purpose utilisation option for LNG.

5.1 Current Situation of LNG Infrastructure

Before describing different LNG reception configurations, the current situation is presented first, in order to understand the scale of ongoing activities related to LNG for shipping. Table 2 and Figure 4 illustrate LNG import terminals in operation, import terminals planned to be established in the upcoming years and existing liquefaction plants in the NSR countries in 2015. (GIE, 2015)

Table 2: LNG infrastructure in the NSR: type, status and construction year

	LNG import terminal		Liquefaction plant
	Operational	**Planned**	**Operational**
Belgium	**Zeebrugge** (1987)		
Denmark		Hirtshals (2018)	
Germany		Hamburg Rostock	
Netherlands	**Rotterdam** (2011)		
Sweden	Lysekil (2014)	Gothenburg (2015)	
UK	**Isle of Grain** (2005) **Teesside*** (2007)		
Norway	Mosjoen (2007) Fredrikstad (2011)		**Snohvit** (2007) *Hammersfest* Snurrevarden (2003) Kollsnes 1+2 (2003, 2007) *Bergen* Risavika (2011) *Stavanger*

Bold – Large scale - * Gasport for FSRU – Floating Storage & Regasification Unit (Submerged Turret Loading Buoy), Source: (GIE, 2015)

There are seven existing import terminals in the NSR, yet more LNG terminals are expected to be established in the NSR, more particularly Denmark, Germany and Sweden in the near future (Maritime Authority, 2012).

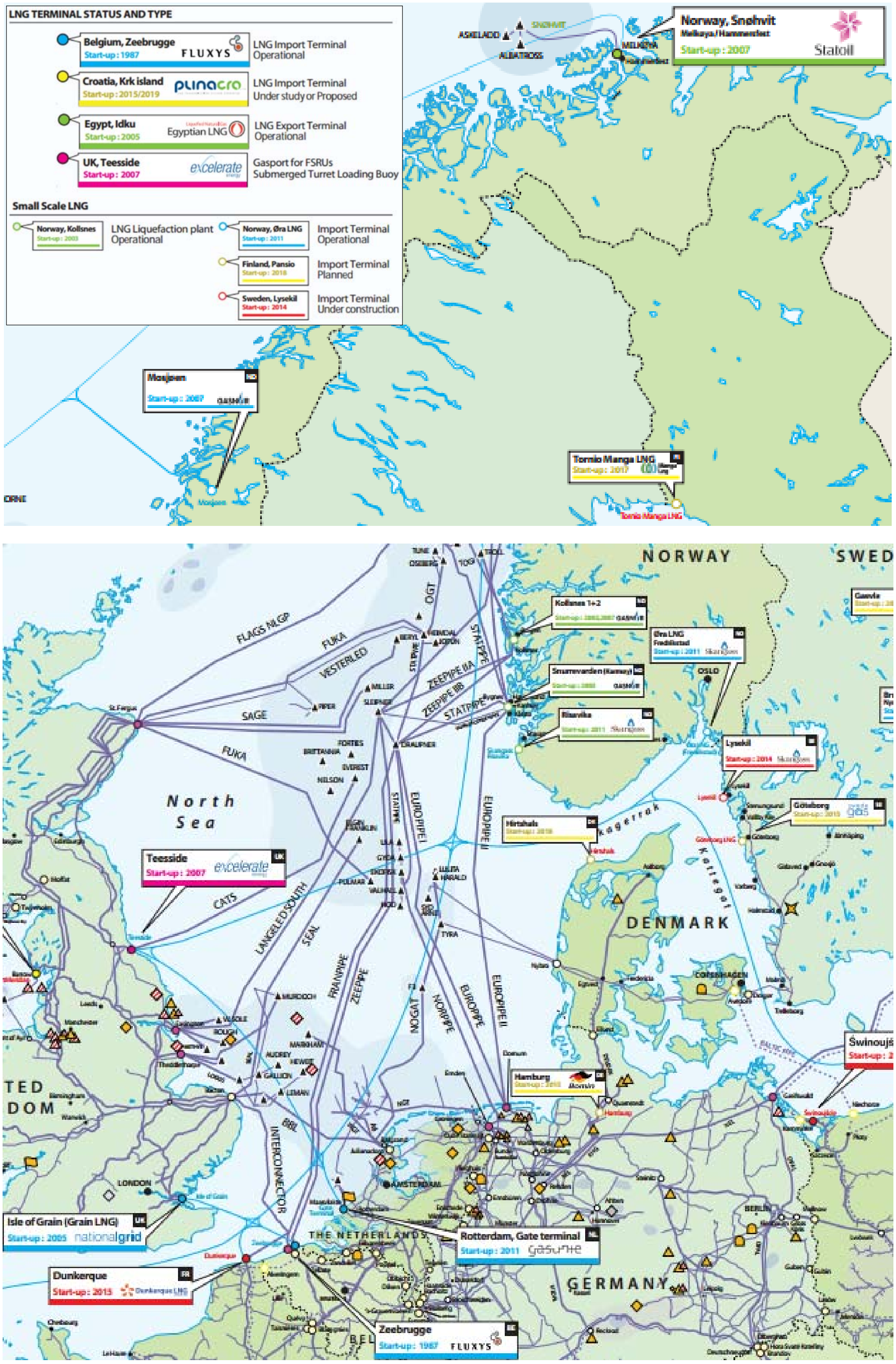

Figure 4: LNG infrastructure in the NSR

Source: (GIE, 2015)

5.2 Sea- or Land-Based Import

When a natural gas grid does not exist or is not technically available on the location of the use, LNG should be imported from other remote liquefaction plants in order to supply the transport sector with the fuel. As far as the NSR is concerned, to date there are only four small-scale and one large-scale liquefaction plants established in Norway. Outside the NSR, there are LNG export terminals in Russia, Algeria, Egypt, etc. (Maritime Authority, 2012)

LNG can be imported by sea-born or land-born transportation, from liquefaction plant directly or from import/intermediary LNG terminal, which is usually necessary due to long and economically unfeasible distances and is fed from the sea side or the land side respectively. A few categories of LNG handling systems can be distinguished in Table 3 (Maritime Authority, 2012). Since Comprehensive Ports are generally smaller in scale, small-scale or medium-scale LNG handling is most relevant.

Table 3: LNG terminals by scale

LNG capacity	Large-scale	Medium-scale	Small-scale
Onshore storage capacity	Import terminal >100,000 m^3	Intermediary terminal 10,000-100,000 m^3	Intermediary terminal <10,000 m^3
Ships	LNG carriers 100,000-270,000 m^3	LNG feeder vessels 10,000-100,000 m^3	LNG bunker vessels 200-10,000 m^3
Tank trucks			40-80 m^3
Pipe dimension	Loading pipes ø ≥ 16 inches (41 cm)	Loading/bunkering pipes ø 8-15 inches (20-38 cm)	Bunkering pipes ø 2-7 inches (5-18 cm)

Source: (Maritime Authority, 2012), (SSPA, 2012)

Onshore terminals are usually stationary LNG tanks. Intermediary terminals could also be offshore (vessels or barges), which have advantages over stationary tanks in terms of lower investment costs, easier way to find a suitable location and flexibility to move if necessary. While tank trucks normally have the same size of LNG storage, LNG vessels and intermediary terminals can vary a lot, depending on bunkering location, distance of supply or total bunker volume. The economically feasible distance for LNG carriage from import/intermediary terminal to the end-user is approximately up to 185 km for bunker vessels and up to 500 km for trucks. It depends on the sizes of trucks allowed in the country though. If this is not possible, intermediary terminals need to be set up. Intermediary terminals are also beneficial when faster rate bunkering is needed. (Maritime Authority, 2012)

Currently, the most common type of LNG tanker is vessels with the size of 80,000-260,000 m^3. However, these are usually too large to serve smaller scale terminals and therefore, feeder vessels with the size of 7,500-20,000 m^3 are becoming more common, especially in Northern Europe. These types of vessels fit the smaller coastal traffic and therefore can be used to distribute LNG to smaller terminals. (SSPA, 2011)

Example – Samsø Case

So far, Norway is among the leaders to use LNG ferries and Denmark is currently joining the trend with the domestic M/F Samsø ferry running on LNG.

Samsø is a Danish island in the Kattegat, 15 km from the mainland, aiming at becoming 100% renewable and therefore switching from conventional fuels to LNG. Recently, a route between the island and the mainland has been upgraded by introducing a new ferry sailing on LNG.

Currently, Samsø is supplied with LNG by road tank trunk coming from Rotterdam, where the distance is around 820 km one way. The gas is pumped into the ferry by the containerised pump, as illustrated in Figure 5 (Kosan Crisplant, 2014). The configuration shown in the figure is easy and fast to install and operate. The only current issue is a large distance from the import terminal and necessary accuracy of the delivery.

For that reason, a liquefaction plant is planned to be built on the island within a few years, where LBG (liquefied biogas) will be produced. Once it is built, the container pumping module will be moved to the island, where trucks will then run between the liquefaction plant and the ferry, rather than between Rotterdam and Samsø harbour. (Passenger Ship Technology, 2015)

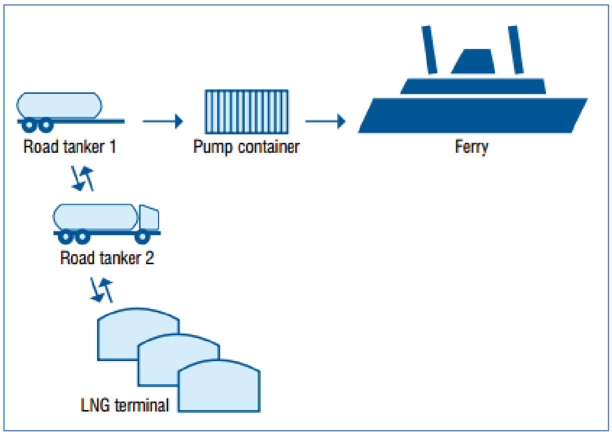

Figure 5: Samsø LNG infrastructure

Source: (Kosan Crisplant, 2014)

5.3 On-Site Production (Small-Scale Liquefaction Plants)

LNG can be produced in and supplied from on-site liquefaction plants under the condition that there is natural gas grid available with potential capacity in that area. Based on the map provided by GIE (Gas Infrastructure Europe) (GIE, 2015), the majority of the NSR countries have favourable conditions for natural gas access from the national grid near the coastline, including Denmark, Germany, Belgium, the Netherlands, UK and Sweden. In Norway, meanwhile, the natural gas grid is not developed and natural gas is liquefied on the seashore near the place where natural gas, coming from the gas reserve fields in the sea, enters the country.

Small-scale liquefaction plants are sometimes advantageous due to reasonable capital investments as well as their compact sizes, which allow building it up close to the areas where it will be used. Small-scale liquefaction plants should be more relevant for Comprehensive Ports, which, as a rule, are smaller in scale. If it is built up close to the end-use area, normally LNG from these plants is transported to the ships by trucks, due to the short distance of supply. (Maritime Authority, 2012)

In connection to this, a few examples of small-scale liquefaction plants are given below.

Example – Kosan Crisplant Turnkey Solution

Figure 6 represents the solution of Kosan Crisplant, which is one of the first to venture into small-scale LNG development. The main features of the small- or medium-scale Kosan Crisplant liquefaction plants are:

- Modular solution, meaning that the plant can be expanded along with the increasing production capacity;
- LNG production ranging from 17 to 51 tonnes/day;
- The required area of 10,000 m^2 for the complete configuration (including LNG storage of 500 m^3 and truck loading);
- Possible turnkey installation. (Kosan Crisplant, 2014)

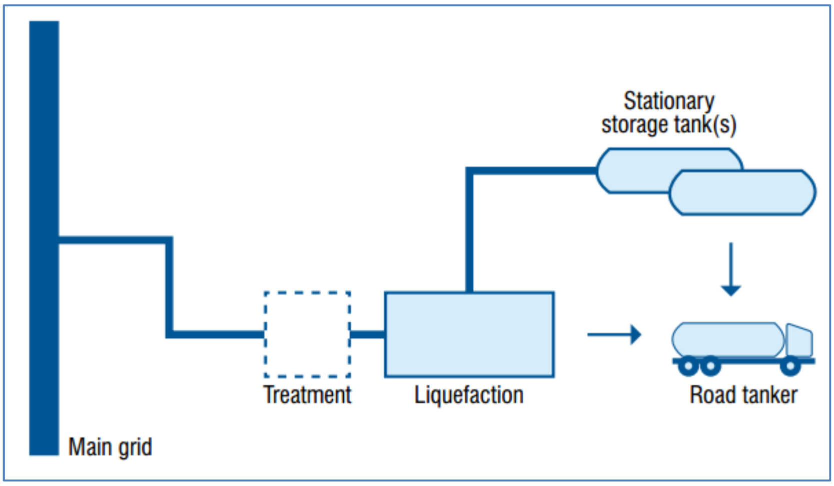

Figure 6: Liquefaction plant infrastructure

Source: (Kosan Crisplant, 2014)

Example – Linde Engineering Solution

Linde Engineering has been supplying small-to-mid scale standard LNG plants for many years, with a capacity ranging between 100 and up to 3,000 tonnes/day. Among these, a few recent examples of smaller-scale plants are described below.

Bergen (Kollsnes), Norway

LNG production in Kollsnes plant is 120 tonnes/day. Apart from LNG distribution to satellite stations by trucks and by small LNG transport ships, LNG is also used as fuel in ferry boats along the Norwegian coast. (Linde, 2012a)

Figure 7: Bergen LNG infrastructure

Stavanger (Risavika), Norway

The LNG production plant in Stavanger (Norway) is based on one of the most energy-efficient systems and is built by Linde's Engineering. It consists of natural gas treatment and liquefaction, LNG storage tank, two loading stations (one for ship loading and one for truck filling) as well as utilities.

Figure 8: Stavanger LNG infrastructure

- The LNG production capacity of the plant is 900 tonnes/day.
- The LNG storage capacity is 30,000 m³, which is equivalent to approximately 12 days production.
- The capacity of the distribution system meets the requirement of loading 25-100 m³/h from the facility to the truck and 150-1,000 m³/h from the facility to the ship. The loading system for the trucks is designed to load 10 trucks with a capacity of 50-58 m^3 within 12 hours. For LNG ship loading, 2 x 100% loading pumps are used ensuring up to 1,000 m^3 loading. (Linde, 2012b)

The majority of LNG is shipped to the mid-scale terminal located in Nynäshamn, near Stockholm, Sweden, by specially equipped tankers. The terminal sells and distributes LNG to customers along the eastern coastline, where the natural gas grid does not exist. At the moment, it feeds only city grid of Stockholm as well as LNG vehicles. (Linde, 2012c)

Figure 9: Nynäshamn LNG terminal

Linde Engineering is also responsible for building the large-scale baseload LNG plant at Hammerfest in Norway with the LNG production of 4.3 mtonnes/year.

5.4 Bunkering

When it comes to bunkering (ship refuelling), there are three solutions (see Figure 10):

- Ship-to-ship bunkering;
- Tank truck-to-ship bunkering;
- LNG terminal-to-ship via pipeline.

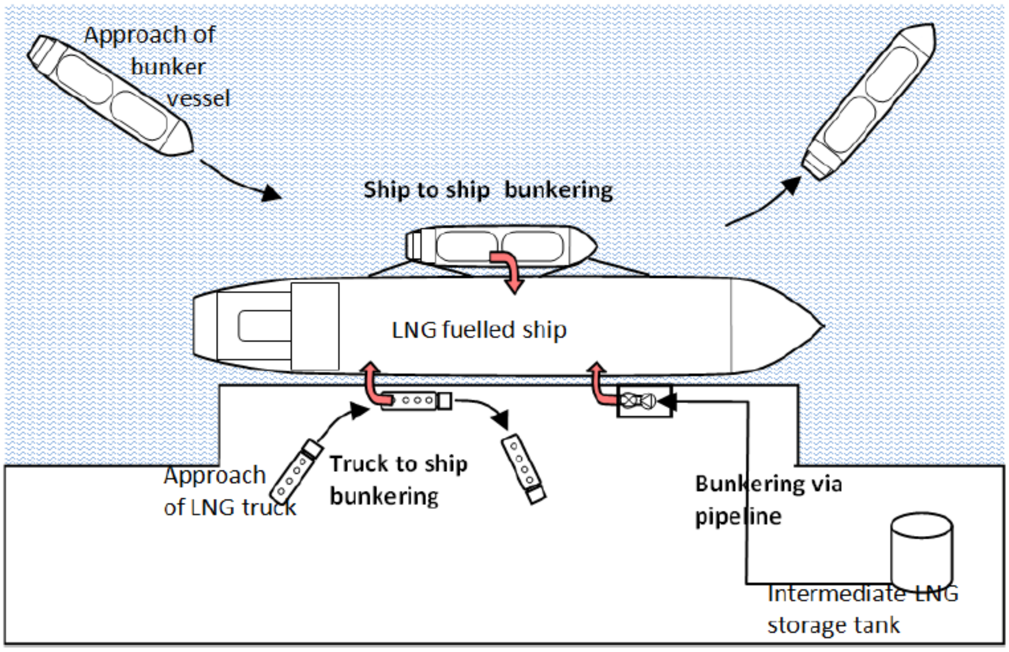

Figure 10: LNG bunkering solutions

Source: (Maritime Authority, 2012)

Bunkering still remains the main issue in a LNG supply chain to the end-users. A number of factors have to be taken into account when choosing a suitable bunkering solution. These are distance, traffic intensity, size and bunkering volume of receiving vessel, frequency of bunkering, safety, etc.

1. While onshore installations can be difficult to integrate into the port infrastructure, tank trucks can deliver only a small amount of LNG per time. Bunker vessels thus seem to be a suitable and effective choice of bunkering to provide sufficient amount of LNG within a reasonable period of time. (SSPA, 2011)

2. However, the location of the port in relation to the traffic and potential market are the main geographical issues to consider. Also, terminal's design, layout and other activities within the port need to be taken into account when it comes to bunker vessels manoeuvring and turnarounds. This is important in order to ensure reasonable level of safety, as LNG handling is potentially dangerous work, even though there have been only a few incidents and no accidents throughout the history.

3. As far as the loading time of bunkering is concerned, the higher the capacity of a bunkering solution is the higher speed can be reached. For instance, the loading time can take 1 hour for tank trucks with 50 m^3 size tank (50 m^3/h) and 3 hours for medium size bunker vessels with 3,000 m^3 size tank (1,000 m^3/h). (SSPA, 2011)

The main advantages and disadvantages of each bunkering solution are summarised in Table 4.

Table 4: Advantages and disadvantages of different bunkering solutions

	Ship-to-ship	Tank truck-to-ship	LNG terminal-to-ship
Advantages	- Flexibility - High loading rate - Large bunkering volumes possible - Bunkering at sea (enlarged market)	- Flexibility - Low costs (investment and operation)	- Availability - Large bunkering volumes possible
Disadvantages	- Manoeuvrability in port basin - High costs (investment and operation)	- Small quantity - Low loading rate	- Fixed to certain quay - Occupy terminal space - Sunk costs

Source: (SSPA, 2012)

When deciding on LNG bunkering at the ports, a number of criteria need to be considered (see Table 5).

Table 5: Critical port criteria for LNG bunkering

Criteria type	Parameters
Market	- Import volumes/storage, taking into account import flows and consumption - Size of terminal, evaluating future capacities - Physical attributes in port, including port layout to make vessels able to call at the port - Potential local/regional customers, which might have a positive impact on interest in the terminal's construction; passing traffic outside the port is also a potential customer - Localisation of terminal, taking into account hinterland demands and possibilities to distribute the fuel to end-users as well as the distance to competing LNG bunkering providers - Bunkering volumes, which depends on demand and frequency - Security of supply - Number of passengers, where the ports with higher passenger circulation as well as regular traffic and passenger ferries are prioritised to be converted into LNG
Economic	- Investment and operational cost - Price of LNG, which is expected to be advantageous in case of lower distribution costs and large volumes - Financing, taking into account potential dedicated partners, e.g. region/country, that can provide part of the investments as well as considering the feasibility of LNG bunkering from the bank's point of view
Technical	- Proper vessel dimensions, taking into account manoeuvrability and traffic density - Fairway and basins characteristics - Land area availability for jetty and LNG terminal - Port infrastructure (other activities) and surrounding infrastructure (well-functioning road infrastructure in case of tank truck bunkering) - Bunkering capacity

Source: (Maritime Authority, 2012)

There are also other factors, which need to be taken into account when deciding on LNG bunkering configurations, such as safety, environmental or regulatory.

5.5 Economics

There are significant investments associated with setting up LNG infrastructure within the port. Below, Table 6 and Table 7 summarise the main costs associated with the different bunkering solutions. The costs given below are very general and should be investigated on case-by-case basis. However, it can provide a guide on an order of magnitude of necessary investments.

Table 6: Costs of bunker vessel and tank truck

Parameter	Vessel 3,000 m^3 LNG	Vessel 10,000 m^3 LNG	Tank truck
Operating lifetime [years]	20	20	10
Average speed [km/h]	16	17	70
Turnaround time [hours]	12	12	2
Availability	97%	97%	80%
Capital cost [€]	38,100,000	55,200,000	500,000
Daily fuel cost [€]	7,400	13,300	-
Running cost [€/km]	19	33	4[1]
Annual operating cost [€]	1,990,000	2,450,000	1.5% of capital cost
Driver salary [€] **Driver annual hours**			35,000 1,760

Source: (Maritime Authority, 2012)

[11] Fuel and depreciation

Table 7: Costs of small- and medium-scale terminals

Parameter	Small terminal 700 m^3	Medium terminal 20,000 m^3
Operating lifetime [years]	40	40
Tank turnover [times/year]	50	50
Availability	100%	100%
Capital cost, tanks [€]	7,000,000	40,000,000
Capital cost, other [€]	685,000	35,870,000
Pipeline operational cost [€]	50,000	50,000
Maintenance [€]	100,000	1,000,000
Administration [€]	180,000	900,000
Tank operation [€/ton]	2.20	2.20
Transhipment from import terminal [€/ton]	66	110

Source: (Maritime Authority, 2012)

As far as small-scale liquefaction plants are concerned, according to (Maritime Authority, 2012), the costs of the liquefaction should be investigated on a case-by-case basis, but it can vary from 150-300 €/ton up to 500 €/ton, excluding the procurement of gas.

6 MoS Routes

Deployment of alternative fuels in Comprehensive Ports can also be funded under the MAP under the condition that the port belongs to a MoS route. For those who want to apply for MoS, the main rule is that *"Proposed Actions submitted to this call for proposals under Priority "Motorways of the Sea" must include applicants from and be supported by a minimum of two different Member States"* (INEA, 2014).

A priority is given to studies, implementation and pilot projects, which address the environmental challenges faced by the Maritime sector. More particularly, it includes deployment of alternative fuels (such as LNG), shore-side electricity, other energy efficiency measures, reception facilities for oil and other waste at ports or upgrades of vessels. (EC, 2014d) It should be noted that this priority contributes to the LNG deployment bunkering facilities for ships, possible in combination with other means of transport, e.g. LNG bunkering barge, but not to the fuel import and transportation over a long distance or related operations, e.g. LNG tankers/carriers. The funding share will depend on the share of gas capacity used for provisioning ships only. Therefore, it is recommendable to apply under MoS priority only if LNG infrastructure strictly serves bunkering ships and/or connect the main terminal with the end-user. (INEA, 2014)

In relation to the above, the main identified ferry routes from *Europe Ro-ro & Ferry Atlas*, which also include Comprehensive Ports, are presented in Table 8. It is important to recognise the main ports and ferry routes, which could be reasonably converted into LNG. As mentioned, one of the criteria is localisation of LNG terminal, meaning that setting up LNG infrastructure should be viable. The map of North Europe ferry routes are shown in

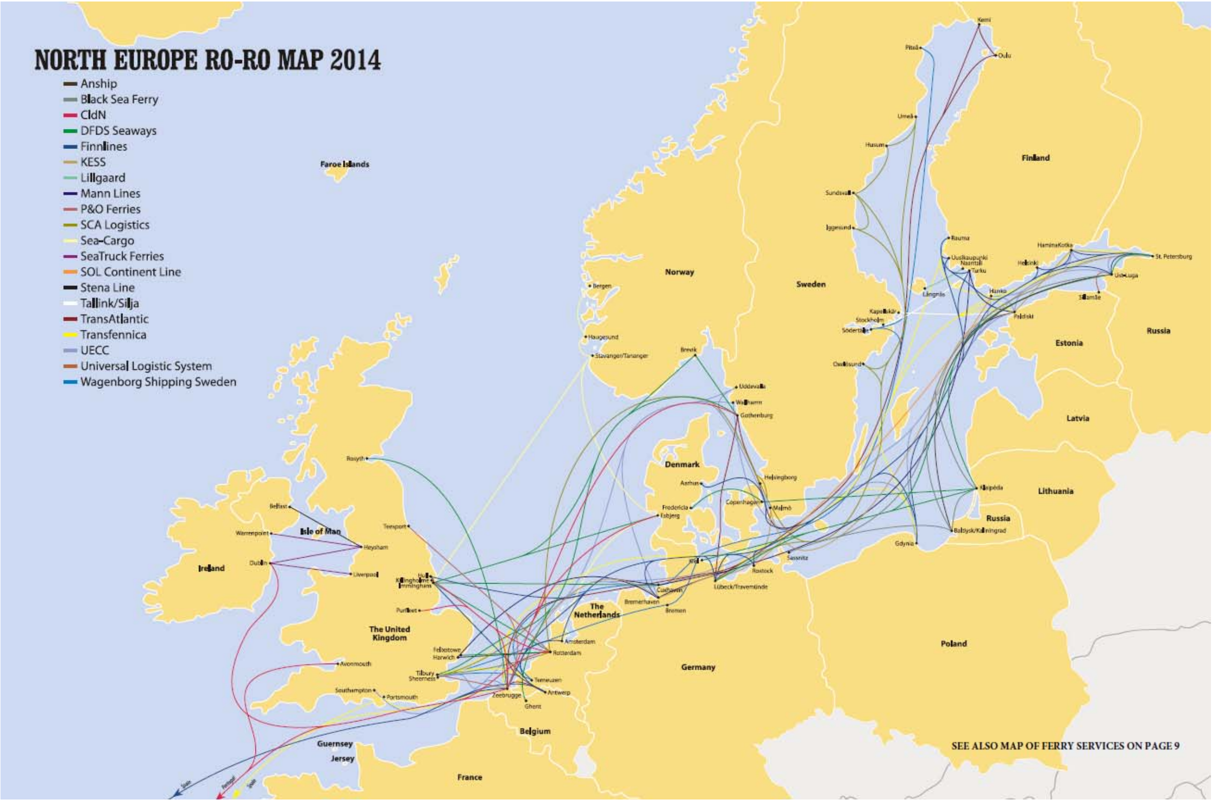

Figure 12, which might help to identify areas with the highest potential interest for LNG.

Table 8: Ferry routes that include Comprehensive Ports and operators

	DFDS Seaways					
(DE)	Cuxhaven	**(UK)**	**Immingham**			ro-ro
(DK)	Esbjerg	**(UK)**	**Immingham**			ro-ro
(SE)	**Gothenburg** LNG	(NO)	Brevik	**(BE)**	**Ghent**	ro-ro
(SE)	**Gothenburg** LNG	(NO)	Brevik	**(UK)**	**Immingham**	ro-ro
(UK)	Newcastle	**(NL)**	**Amsterdam**			ro-pax
	Color line					
(DE)	Kiel	(NO)	Oslo			ro-pax
(DK)	Hirtshals LNG	(NO)	Larvik			ro-pax
(DK)	Hirtshals LNG	(NO)	Kristiansand			ro-pax
(SE)	Stromstad	(NO)	Sandefjord			ro-pax
	Færgen					
(DK)	Køge	(DK)	Rønne			ro-pax
(SE)	Ystad	(DK)	Rønne			ro-pax
(DE)	Sassnitz	(DK)	Rønne			ro-pax
	P&O Ferries					
(UK)	Hull	**(NL)**	**Rotterdam** LNG			ro-pax

(UK)	Hull	**(BE)**	**Zeebrugge** LNG			ro-pax
	Scandlines					
(DE)	Puttgarden	(DK)	Rødby			ro-pax
(DK)	Helsingør	(SE)	Helsingborg			ro-pax
(DE)	**Rostock**	(DK)	Gedser			ro-pax
	Stena Line					
(UK)	**Harwich**	(NL)	Hoek van Holland			ro-pax
(UK)	Killingholme	(NL)	Hoek van Holland			ro-pax
(DK)	Frederikshavn	(NO)	Oslo			ro-pax
(SE)	**Gothenburg** LNG	(DE)	Kiel			ro-pax
(SE)	**Gothenburg** LNG	(DK)	Frederikshavn			ro-pax
(DE)	Sassnitz	**(SE)**	**Trelleborg**			ro-pax
	Sea-Cargo					
(NL)	**Amsterdam**	(DK)	Esbjerg			ro-ro
(UK)	**Immingham**	(NO)	Stavanger	(NO)	Bergen	ro-ro
	North Link Ferries					
(UK)	Aberdeen	(UK)	Lerwick			ro-pax
(UK)	Aberdeen	(UK)	Kirkwall			ro-pax
(UK)	Lerwick	(UK)	Kirkwall	(UK)	Aberdeen	ro-ro
	Mann Lines					
(UK)	**Harwich**	(DE)	Cuxhaven	(FIN)	Turku	ro-ro
	Fjord Line					
(DK)	Hirtshals LNG	(NO)	Stavanger	(NO)	Bergen	ro-pax
(DK)	Hirtshals LNG	(NO)	Kristiansand			ro-pax
(DK)	Hirtshals LNG	(NO)	Langesund			ro-pax
(SE)	Stromstad	(NO)	Sandefjord			ro-pax

Notes: Ro-Pax vessels are designed for transport of both freight (wheeled cargo) and passengers;

Ro-Ro vessels (roll-on/roll-off) are designed for transport of wheeled cargo.

Legend: **Core Port**, Neither core nor comprehensive; Port outside NSR

Neighbouring Norway (NO) ports do not have a status Core or Comprehensive. Participation of the third country does not fulfil the requirement of MoS actions to include at least two Member States (INEA, 2014)

Source: (Baltic Press, 2015)

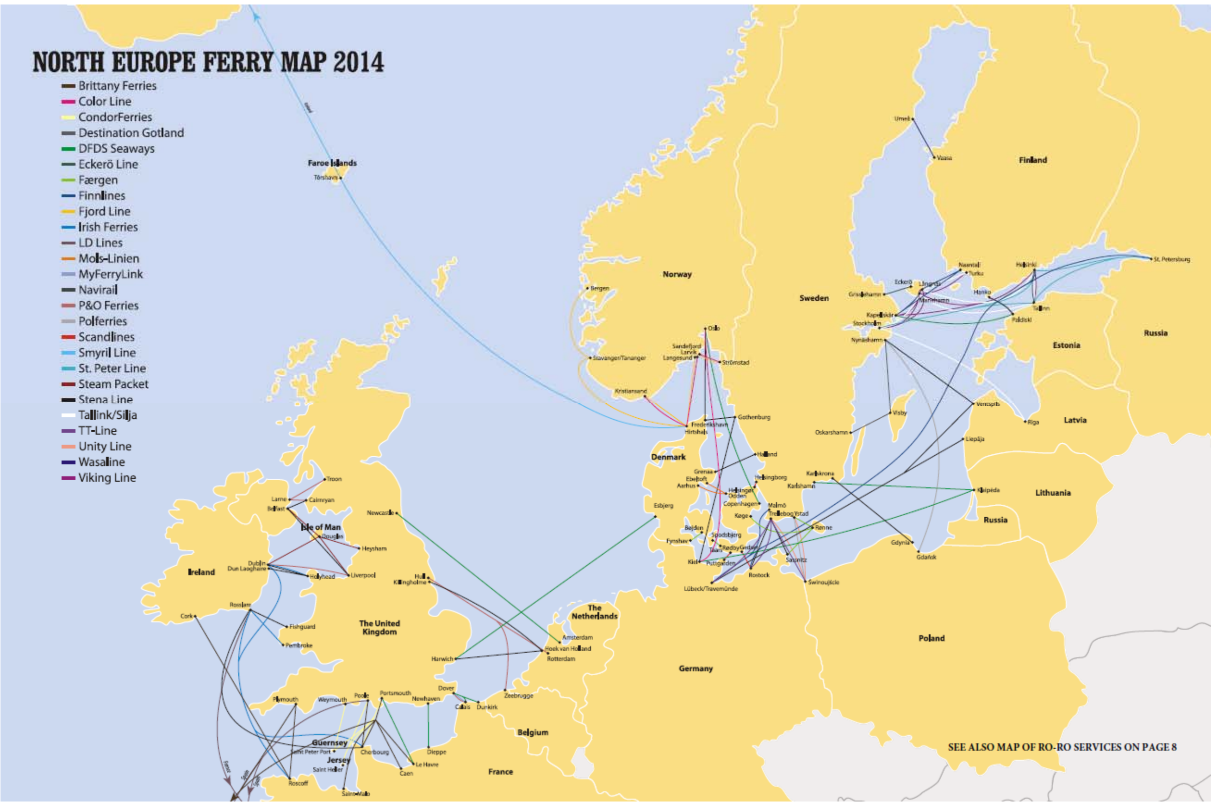

Figure 111: North Europe International Ferry routes 2014 - Source: (Baltic Press, 2014)

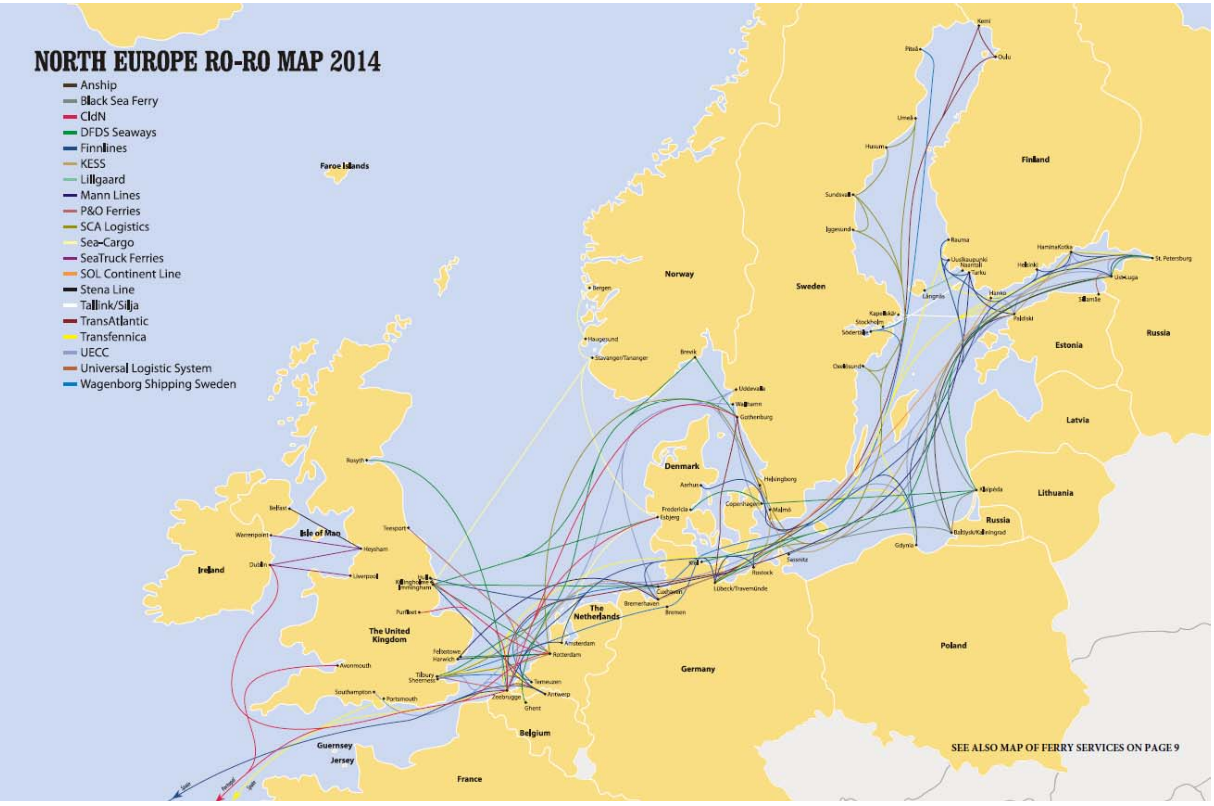

Figure 122: North Europe International Ro-Ro routes 2014 - Source: (Baltic Press, 2014)

7 Shore-Side Electricity

When at berth, vessels typically use the auxiliary engines to generate electricity and supply energy for lightning, ventilation, communication and other on-board functions. Moreover, they use boilers based on conventional fuels to produce heat for hot water supply or ensuring that the heavy fuels are not getting solid. These activities contribute to air and noise pollution in the port areas, which are usually located closely to urban areas, and thus leads to negative environmental and human health effects. (Winkel, et al., 2015)

A solution to the above is shore-side electricity, which is also recognised in the Directive on the deployment of alternative fuels infrastructure (EC, 2014b). It ensures that when at berth, instead of using the auxiliary engines, the ship is plugged into the shore electricity network. The shore-to-ship electricity supply infrastructure is presented in Figure 133.

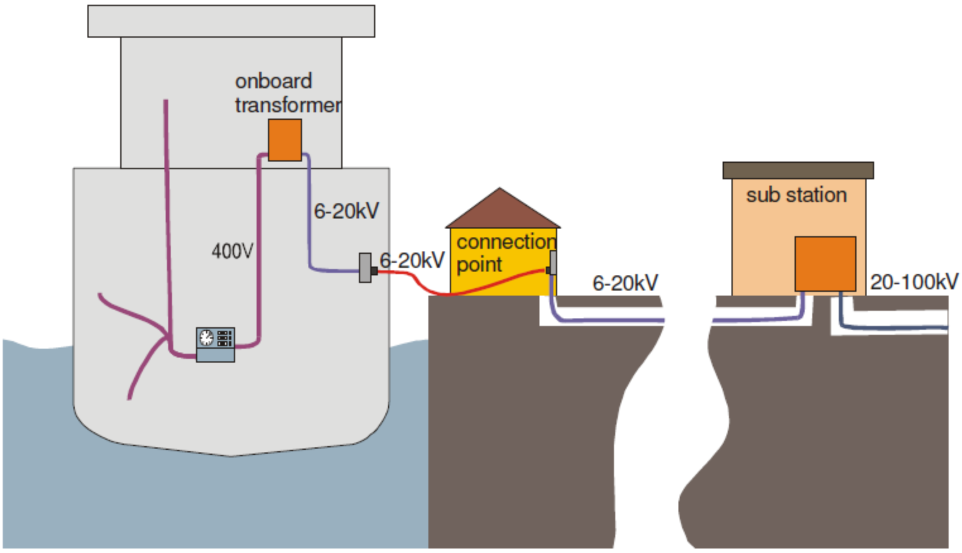

Figure 133: Shore-side electricity connection principle

Source: (Jivén, 2004)

The power comes from the electricity grid through the high voltage sub-station. High voltage cables make it possible to transfer higher rates of power and therefore is used for shore-to-ship connections. High voltage power (6-20 kV) is likely to be available in all residential and industrial areas in Europe and therefore, most of the ports are likely to have a nearby access to it. At the quay, the connection point is needed, where a flexible cable can be attached between the shore-side installation and the ship. (Jivén, 2004)

At the ship, an entrance and a socket for the connecting cable are needed. Once the power reaches the ship, the voltage is reduced in the on-board transformer, preferably located close to the switch board, to meet the end-use power requirement (typically 400 V). (Jivén, 2004)

It would be advantageous if all the ports or the ports, which serve the same shipping routes, were supplied with the same high voltage level to ensure interoperability, since on-board transformers can meet only the voltage it is initially designed for. For instance, a vessel with a transformer for 10 kV incoming electricity cannot automatically be connected to 6 kV without special arrangements. On the other hand, vessels calling many different ports could be equipped with a number of different transformers to meet different voltage levels, but this would increase the total investments. (Jivén, 2004)

The main parameters to consider before deciding on shore-side electricity installation are summarised in Table 9.

Table 9: Parameters for shore-side electricity installation

Criteria type	Parameters
Power characteristics	- Shore-side frequency (50 Hz in Europe) - On-board frequency (50 or 60 Hz) - Shore-side supply of high voltage electricity (voltage) - Required maximum power level
Localisation	- Availability of the nearest high voltage supply point: distance and local conditions - Installation practicalities, including a connection point
Ship characteristics	- Available space for on-board transformer and weight restrictions of the vessel (it should be considered that the extra weight of equipment or loss of cargo space may result in reduced profitability or increased fuel consumption for some vessels) - On-board cable installation practicalities and distances
Economy	- Cost for shore supplied electricity in contrast to that for on-board generated electricity cost (investment, fuel, maintenance, etc.)

Source: (Jivén, 2004)

A few parameters have the greatest impact on the installation cost for shore-side electricity connections: the on-board frequency and the availability of high-voltage electricity supply. Firstly, additional installation is necessary, if the frequency used in the vessel differs from that of the on-shore grid. If the vessel uses a frequency of 60 Hz, a shore-located frequency transformer is needed to convert it from the standard 50 Hz. It is rather costly though, but can serve several berths as long as high-voltage connections between the transformer and the berth connections exist. Secondly, the cost for high voltage power supply can vary significantly, depending on the distances to the nearest high voltage stations, number of transformation stations/connections that need to be upgraded, local conditions, etc. If the new canalisation is necessary and the distance is long, the cost can increase significantly. (Jivén, 2004)

The main recognised costs related to shore-side electricity supply systems are presented in Table 10.

Table 10: Costs related to shore-side electricity supply system

Installation	Cost
Frequency transformers (that converts from 50 Hz to 60 Hz)	300,000-500,000 EUR
Harbour canalisation (to bury cables, etc. in the ground)	100-150 EUR/m
High voltage cable (10 kV)	10-15 EUR/m
Cable between the shore connection and the ship (10 kV)	20-25 EUR/m
On-board transformers (0.5-2 MW)	40,000-70,000 EUR
Total on-board installation cost, including the on-board transformer	60,000-140,000 EUR

Source: (Jivén, 2004)

The reduction in emissions due to the transition from conventional electricity supply to the shore-side electricity supply depends on the technology, which is used to generate onshore electricity. The highest benefit is achieved when electricity is produced form renewable energy sources, such as wind- or hydro-power plants, which have no or little environmental impact and are being widely deployed in some North Sea Region countries. In any case, shore-side electricity supply avoids local pollution at the port as well as closely located urban areas. Moreover, if there are problems with the shore-side electricity supply system, vessels can always use their own auxiliary engines to generate electricity. (Jivén, 2004)

There are a few ports in Europe, where the shore-side electricity is available. They are summarised in Table 11 with their main characteristics. It is common that smaller vessels tend to have 50 Hz electrical systems on-board, while larger ocean-going vessels calling at European ports are likely to have 60 Hz.

Table 11: Shore-side electricity supply in Europe

Port name	Year of introduction	Country	Capacity [MW]	Frequency [Hz]	Voltage [kV]	Ship types
Gothenburg	2000-2010	Sweden	1.25-2.5	50 & 60	6.6 & 11	Ro-Ro, Ro-Pax
Zeebrugge	2000	Belgium	1.25	50	6.6	Ro-Ro
Piteå	2004	Sweden	1.0	50	6	Ro-Ro
Kemi	2006	Finland		50	6.6	Ro-Pax
Kotka	2006	Finland		50	6.6	Ro-Pax
Oulu	2006	Finland		50	6.6	Ro-Pax
Antwerp	2008	Belgium	0.8	50 & 60	6.6	Container
Lübeck	2008	Germany	2.2	50	6	Ro-Pax
Karlskrona	2010	Sweden	2.5	50	11	Ro-Pax
Oslo	2011	Norway	4.5	50	11	Cruise
Rotterdam	2012	Netherlands	2.8	60	11	Ro-Pax
Ystad	2012	Sweden	6.25	50 & 60	11	Ro-Pax
Trelleborg	2013	Sweden	3.5-4.6	50	11	Ro-Pax
Hamburg	2015	Germany	12	50&60	6.6&11	Cruise

Source: (OPS, 2015)

8 Concluding remarks

This report has given an insight into the status of LNG and shore-side power supply in North Sea Region ports. According to latest EU regulations and directives these two fields are of key interest for both TEN-T Core and Comprehensive ports. Currently the deployment of facilities for LNG and shore-side power supply is underdeveloped and therefore requires attention to live up to EU goals and requirements stated in the TEN-T regulations and the Clean Power for Transport Directive.

The Connecting Europe Facility provides an efficient funding mechanics for providing financial assistance to TEN-T ports interested in constructing such facilities. The expected deployment of LNG facilities and vessels in the North Sea Region has been slower than expected by many stakeholders, due to the cut in oil prices in first half of 2015. But, already as of now (summer 2015), an increase in the prices can be seen again, providing a more valid financial background for companies to invest in new LNG and shore-side power supply facilities.

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