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Breakthrough LNG Deployment in Inland Waterway Transport

Activity 5 Study into best locations for LNG bunkering stations
&
Activity 6.1 Comparison study on refilling of the LNG bunker station by tanker truck and by bunker barge

Report

Zwolle; The Netherlands
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1 Executive summary

The mission of the consortium is to reduce the investment barrier for the ship owners with the aim to facilitate large scale implementation of LNG in Inland Waterway Transportation (IWT), thus forcing a breakthrough in the LNG market. A firm base LNG supply network will contribute and show commitment and confidence in the IWT sector for switching to LNG as fuel.

The IWT sector is facing new demands to drastically reduce air pollutant emissions NOX and particulate matter. The transition to LNG as alternative fuel provides the opportunity to attain this goal while at the same time improving the competitiveness of IWT.

Not all vessels are suitable to switch to LNG due to the higher investments costs for LNG equipment and therefore particular vessels which have a high fuel consumption (> 500 M3/year) to have a positive business case as the savings in fuel costs can compensate the additional investments in LNG equipment.
The use of LNG in IWT is however still under development, and LNG conversion is still a custom solution (case by case) and therefore requires high investments.

Also there are other uncertainties like the lack of LNG bunker infrastructure, technology development and standards for LNG propulsion equipment for IWT vessels. Most important is the emission regulations that will come into force and how policy makers in the different countries supporting LNG as transport fuel in the long term.

In practice these uncertainties prevent ship owners from switching to LNG as fuel and from investing in this transition.

One of the particular uncertainties is the lack of LNG bunker infrastructure along the Rhine-Alpine corridor, the corridor which encompasses the Rhine River as the key inland waterway in Europe. This study will discuss under which:

- The lack of LNG bunker infrastructure in the Rhine-Alpine and other corridors
- The drivers and barriers for realizing LNG bunkering stations
- The process steps for development of a location
- The most suitable and economical locations for LNG bunkering stations
- The process of selection of the ‘best locations’
- The financial and logistical cost analysis influencing the selection
- The conclusion of the selection of ‘best locations’

This study will show the current way of gasoil bunkering and the complexity to find the most suitable and economical locations for LNG bunkering shore to ship.

Current gasoil bunker fuels are supplied to inland waterway vessels through a mature and cost-efficient (floating) infrastructure of bunker facilities alongside a quay in major ports or along the waterway in the river itself. Such a cost-effective infrastructure does not exist yet for LNG.

At the moment there is not a cost-effective infrastructure established due to lack of demand for LNG as bunker fuel, the so called chicken and egg problem.
Adoption of LNG propelled vessels in the inland water way market however is still low and the hesitation to invest in LNG propulsion will also slow down the development of a secure LNG fuel infrastructure shore based.
The total number of LNG propelled inland vessels, in the market today, is supplied by tank-trailers and bunkered truck to ship, mainly in the seaports Rotterdam, Amsterdam and Antwerp. These seaports facilitated the LNG adoption to “create” or authorised an LNG truck-to-ship location in their port. This supply method at these specific locations is highly flexible and rather cost-effective and is more than suitable for the number of inland vessels sailing on LNG today.

Also inland vessels operating in an area of Mannheim, like the “Ecotanker1” and the “Ecotanker2” inland tankers, not sailing back to one of the mentioned seaports are bunkered by tank trailers. The only difference here is that those vessels need to be bunkered in their operational sailing area were the LNG cost price for supply will be higher because of the higher logistic costs (longer distance from LNG import terminal). Any additional investment needed for infrastructure will even more increase the supply costs for LNG to the inland waterway vessels upstream. Therefore it is important to determine the most important (economic) drivers for selecting a suitable LNG bunker location along the corridor upstream including possible launching customers for that location.

This report will show that not only supply and demand is an important driver for the development of LNG bunker infrastructure but also needed investments, regional LNG retail pricing, logistic costs, permitting, launching customers and development costs influences the choice of a bunker location and has impact on a positive return of investment. Upstream market pricing must be (needs to be) competitive with the LNG truck to ship prices offered today in the important seaports.
To balance higher logistic costs upstream in the LNG retail pricing today in the seaport areas, a significant higher LNG volume needs to be adopted into the market. Also the efficiency (bunker window and process) of an LNG bunker station is important in the total customer case to compete with the typical LNG Truck-To-Ship (TTS) bunkering.

To overcome the chicken and egg problem higher costs of a bunker station upstream can only be balanced with a significant higher launching customer volume, an optimized logistic chain for transporting higher volumes via tankers and a shorter and more effective operation of the station.

2 Revision History and Statement of Originality

Revision	Date	Author	Organization	Description
V0.0	26 -07-2017	Leon Sluiman	ENGIE LNG Solutions	Processing draft document
V0.1	06-11-2017	Leon Sluiman	ENGIE LNG Solutions	Processing draft document
V0.2	13-11-2017	Leon Sluiman / Erik Büthker	ENGIE LNG Solutions Pitpoint	Processing draft document
V0.3	15-12-2017	Leon Sluiman	ENGIE LNG Solutions	Processing chapter 6 & 7
V0.4	21-12-2017	Leon Sluiman	ENGIE LNG Solutions	Changes to comments
V0.5	11-01-2018	Leon Sluiman	ENGIE LNG Solutions	Changes to comments
V0.6	17-01-2018	Leon Sluiman	ENGIE LNG Solutions	Processing chapter 8 modelling
V0.7	01-02-2018	Leon Sluiman / Erik Büthker	ENGIE LNG Solutions Pitpoint	Editing & finalizing report
V1.0	05-02-2018	Leon Sluiman / Erik Büthker	ENGIE LNG Solutions Pitpoint	Final report

Statement of originality:

This deliverable contains original unpublished work except where clearly indicated otherwise. Acknowledgement of previously published material and of the work of others has been made through appropriate citation, quotation or both.

3 Abbreviations

ARA	Amsterdam Rotterdam Antwerp
CEF	Connection Europe Facilities
EICB	Expertise- en InnovatieCentrum Binnenvaart
IWT	Inland Waterway Transport
LNG	Liquefied Natural Gas
STS	Ship to Ship
PTS	Pipe (shore) to Ship
TTS	Truck to Ship

4 Introduction

The study into best locations for LNG bunkering stations, based on the Grand Agreement Breakthrough LNG deployment in Inland Waterway Transport.

A study to find the best locations for inland waterway LNG bunkering stations for inland vessels sailing in the area of North West Europe, in order to select the four best locations for the pilot study.

The study will focus on the strategic inland waterways and locations where a representative number of vessels are sailing that typically can be LNG propelled. The selection of the locations will be based on specific drivers important for the business case and the study will show which drivers impact more the decision making process than other drivers. The number of vessels complying with specific criteria, sailing in an area will be used as starting point for this study. Inland vessels bunkering behaviour is followed and sailing routes in Benelux, Germany and France are evaluated. Next to the fuel consumption other drivers, like logistics costs, permitting, volumes, launching customers, etc., are taken into consideration.

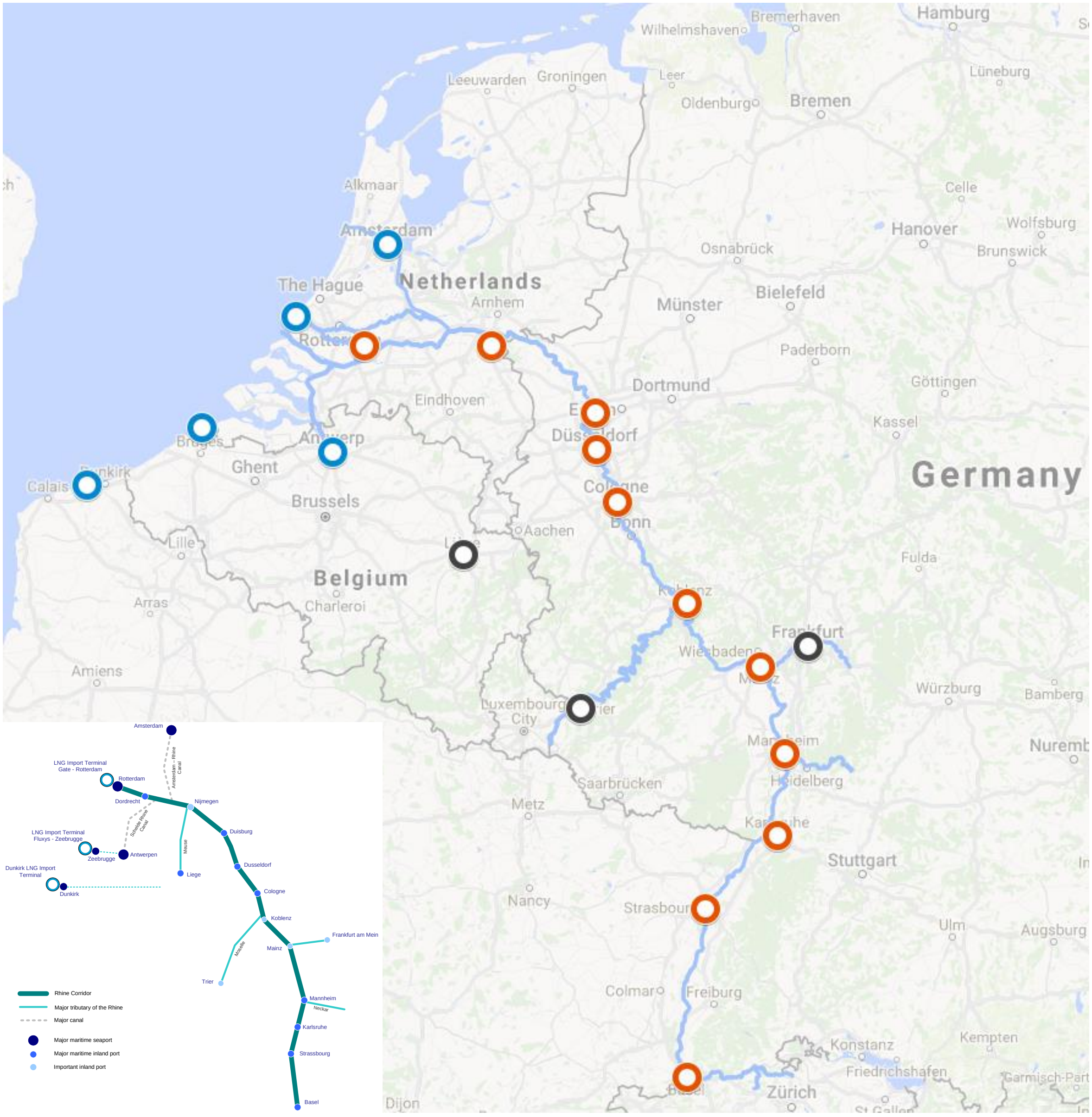
The study of possible fuelling by means of flexible exchangeable containers (cartridge system) will be taken into account when choosing the optimal locations. After a site is selected an evaluation of the location is carried out to ensure that the site is suitable for the purpose of LNG bunkering. Aspects that are important in the evaluation of the location are focussing on internal and external safety distances of the LNG bunker station towards external vulnerable objects like schools, offices and houses. The possible selection of vessels is carried out by the consortium and based upon running hours per year and fuel consumption.

Current gasoil bunker fuels for Inland Waterway Transport (IWT) sector are supplied through a mature and cost-efficient infrastructure of bunker stations and barges in European ports. Such a cost-effective infrastructure does not exist yet for liquefied natural gas (LNG). LNG providers cannot establish an infrastructure until sufficient demand for LNG as bunker fuel arises, chicken and egg. Also ship owners cannot invest until the LNG will become available through a suitable and sustainable fuel infrastructure.

This study will support the development of LNG infrastructure for inland waterway transport and providing information and maps with indication of the best location corresponding with concentrated inland waterway vessel sailing in Benelux, Germany and France and the current bunker locations for gasoil.

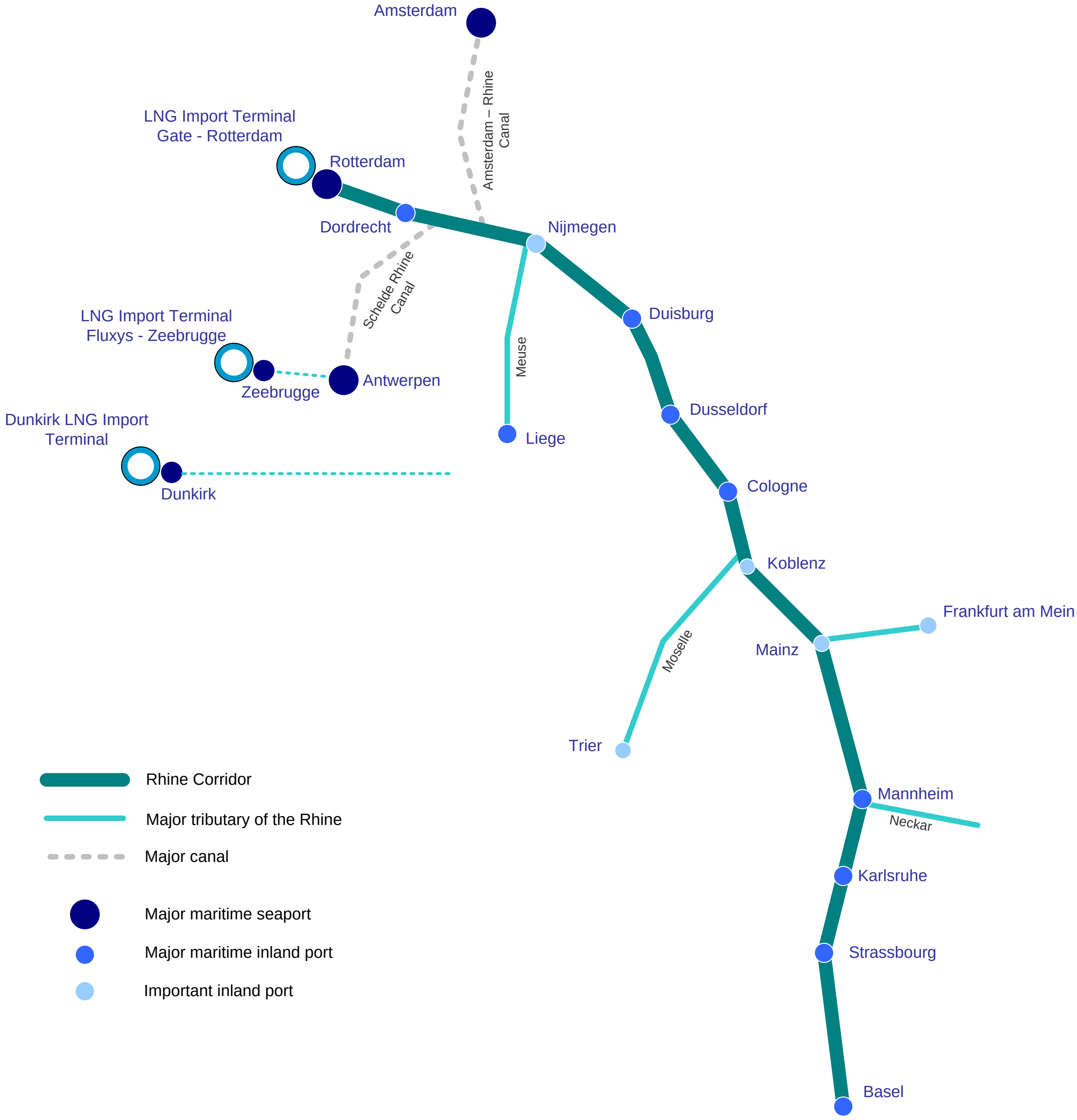
4.1 The Rhine – Alpine corridor

Below part of the Rhine – Alpine corridor with most important cities and cross sections to other waterways from Rotterdam to Basel. The Rhine – Alpine corridor is an important transport route for inland waterway transport en therefore the most important corridor for potential LNG fuelled vessels.



Map No 1 - partial Rhine – Alpine corridor, Source Google Maps

Above map shows the Benelux – Germany part of the Rhine – Alpine corridor including the LNG import terminals in Rotterdam, Zeebrugge and Dunkirk and the important maritime sea ports and important inland maritime ports along the river Rhine from Rotterdam to Basel.



Picture of Rhine – Alpine corridor ARA seaports – Basel

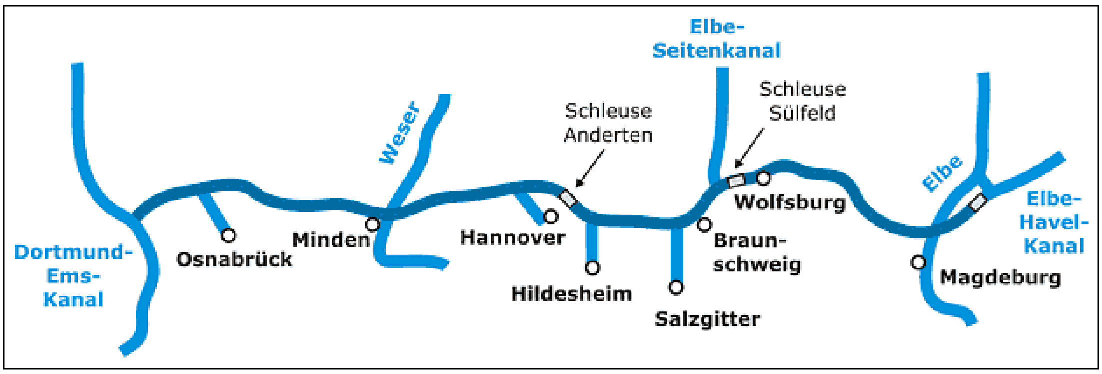
The logistic and infrastructure hotspots Rotterdam, Amsterdam and Antwerp are close to LNG import terminals like Gate at Maasvlakte Rotterdam and Fluxys at Zeebrugge. In principle a short logistic chain or an effective logistic chain (logistic cost) is very important for the actual customer retail LNG price for bunkering. In chapter 8 'Analysis and methodology' the balance between logistic costs and molecule costs are modelled to show the impact when LNG bunkering further upstream the Rhine – Alpine corridor is developed. In this chapter the relation with logistic costs will be explained resulting in an effective costs per region for logistic costs impacting the way how to build (develop) and execute the logistic chain in the most effective way. Choices for a best location to implement an LNG bunkering station further upstream is not always straight forward and direct balanced with the impact of costs. Other drivers are sometimes more important than only the logistic costs.

The import terminal Fluxys in Zeebrugge was the first to adopt LNG truck loading at their terminal in so called LNG truck loading bays. Gate terminal followed quickly in this small scale / retail LNG development. Not much later the important ARA seaports followed to facilitate an LNG truck to ship bunkering location in their ports. This was the starting point of the LNG as marine fuel retail market and now the LNG breakthrough for inland waterway vessels project is pushing this retail market further upstream the Rhine – Alpine corridor as follow up the LNG Masterplan project. Also in the northern part of Germany in the important seaport Hamburg LNG as marine fuel is under development in parallel with the development of an LNG import terminal. In the next chapter explanation is given why the Port of Hamburg should be included in this study project as well.

4.2 Connecting the Northern part of Germany

(from: Jahresbericht 2016 Europäische Binnenschifffahrt Marktbeobachtung; ZKR)

The Mittellandkanal is Germany's largest artificial waterway and connects a large number of important cities, connecting the Rhine area, Ruhr area Berlin and the Oder area.



(from: Wikimedia Commons; Jörg Schönebaum)

The total amount of goods that passes through the Mittellandkanal is 22.2 mio tonnes per year (2015) (*JAHRESBERICHT 2016 EUROPÄISCHE BINNENSCHIFFFAHRT MARKTBEOBACHTUNG, Zentralkommission für die Rheinschifffahrt*), this is equally shared in both directions. This number has been fairly constant in the period 2004-2015, with a low of 20 mio tonnes in 2009 and a high of 23.5 mio tonnes in 2005. The most important connections where ships come from or go to are: Port of Hamburg. Rhine, Elbe and Elbe-Seitenkanal.

The Rhine corridor connects Europe’s largest sea harbours (ARA region) to intensive industrial sites in Germany. The same applies to the Mittellandkanal. It is not only connected to the Rhine corridor, from the North it is well connected to sea harbours like Bremerhaven, Hamburg, Lübeck and Emden. This provides synergies for the bunkering infrastructure because the supply of LNG to seagoing vessels can be combined in the mentioned locations.

There is a number of LNG developments arising in this area and the Port area of Hamburg where developments for LNG import and storage and bunkering is under development. The Elen Gas project entails the retrofitting to LNG of 100 inland waterway vessels that run between Hamburg, Braunschweig and Berlin between 2018 and 2022 and is co-financed by the EU under the CEF program. Another project is pusher tug operator that is planning to convert up to 100 pushers to LNG.

4.3 The retail fuel market

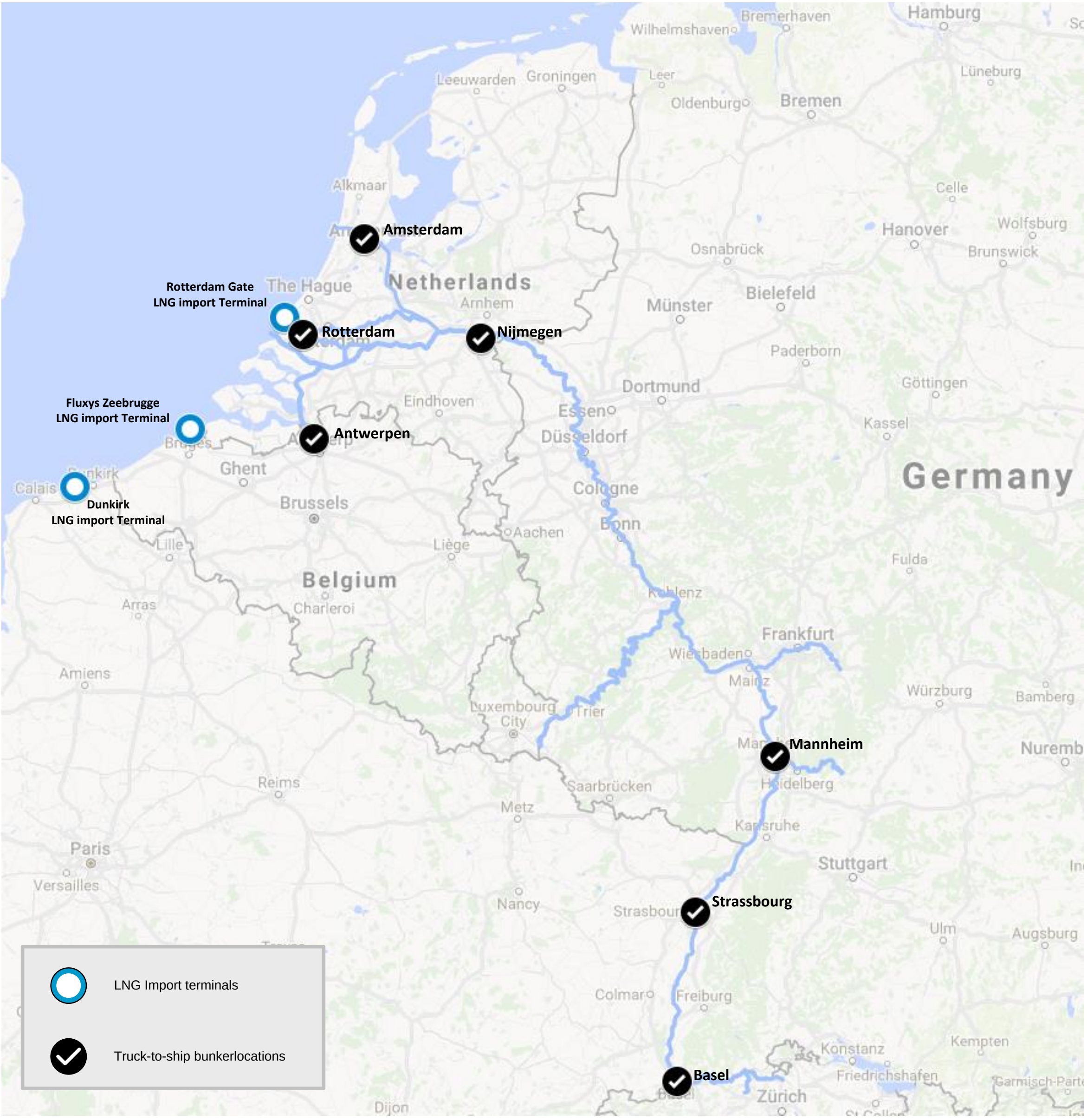
Inland vessels bunkering gasoil today at typical inland bunker stations located in seaports or inland ports but also along the waterway at strategic locations. The bunker station is often a floating object; barge or pontoon including mooring arrangements, marine supply facilities, like lubricants and spare parts and a shop just like a normal tank station along the highway. Also bunker boats are used more often upstream the river Rhine for bunkering inland vessels.

Development of LNG infrastructure for inland bunkering (filling) stations cannot be developed in the same way as for gasoil. Demand for LNG as inland marine fuel needs to increase substantial to justify investments in the LNG infrastructure. The start of development of an LNG fuel infrastructure will focus on the balance between costs for logistics, technology demands and bunker methods to ensure a level of LNG fuel pricing for customers competing to the current gasoil prices and the LNG retail prices known in the ARA seaport area.

To meet customer demands for using LNG as a Fuel in the Inland Waterway Transport (IWT) there is a need to develop and build the logistic chain and infrastructure for LNG in an economical and modular way. This development of the chain was started a few years ago with LNG trailers enabling the supply for LNG truck to ship (TTS). When the market will grow not enough slots will be available to facilitate the demand truck-to-ship, therefore is a need to ensure LNG availability in a port (security of supply) and the balance between volume demand and storage & supply capacity. Permanent bunker facilities for inland vessels are therefore needed on strategic locations.

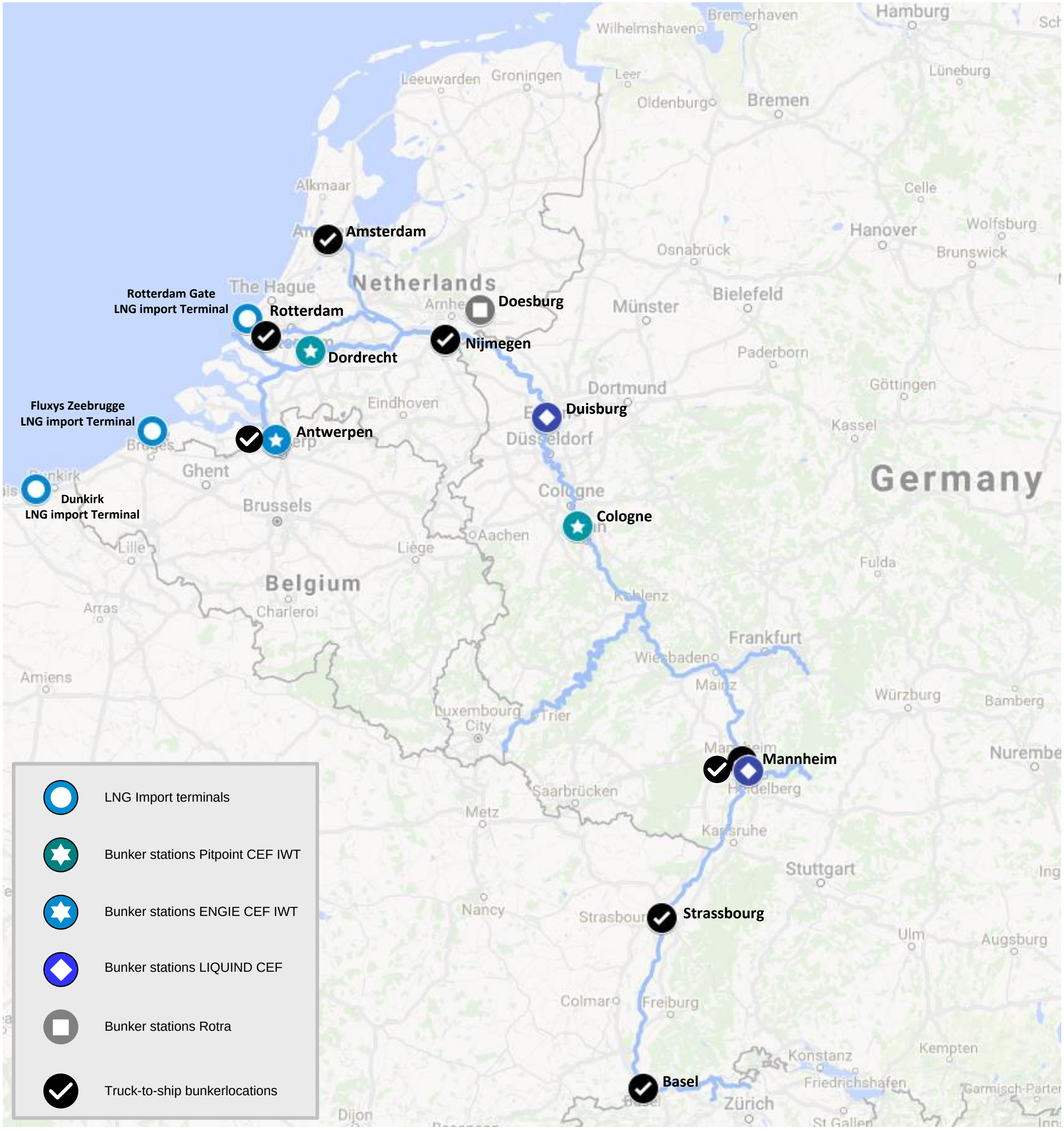
LNG is transported and stored in cryogenic tanks and basically that's the LNG infrastructure. The debate is about the number, size and degree of mobility of those tanks. That debate is primarily influenced by economical, physical and logistical aspects.
Due to the cryogenic demands and safety demands of LNG (-162°C) the development of the infrastructure (bunker stations) is cost-intensive. There is a need for increasing LNG volume demand in the inland shipping market to balance the cost for development of LNG bunker facilities and to ensure an economic feasible supply chain.

For the Benelux, Germany and France the LNG terminals in Rotterdam (Gate), Zeebrugge (Fluxys), Dunkirk or Elengy in Montoir and Fos are the most nearby terminals that can facilitate road trucks and small LNG barges.
Today a number of inland vessels are bunkered by the truck-to-ship (TTS) method in different European harbours from a designated quay side, authorized by the port authorities (see below "map no. 1" of current TTS bunker locations).



Map No. 2, current LNG truck-to-ship (TTS) bunker locations, Source Google Maps

A system of flexible, small- and medium-scale bunker facilities are needed to supply the LNG bunker fuel to inland waterway vessels. In parallel an adequate number of LNG propelled inland vessels (clients) are needed in bringing down associated supply costs of the LNG from import terminal to the bunker stations upstream and end customer.
Map No.3 below shows the (intended) LNG bunker station development by the two project partners and by third parties outside this project like Rotra and Liquind.



Map No. 3, Current LNG truck-to-ship (TTS) and planned LNG bunker locations shore-to-ship (PTS), source Google Maps.

In the seaports; Amsterdam, Rotterdam and Antwerp, regulations for LNG TTS bunkering was already available in an early stage and logically these ports wanted to extend their LNG activities by pushing small scale LNG players to invest in LNG bunker infrastructure. In map No. 3 is shown the relevant locations under development by the project partners including third party developments. Rotterdam port area (including Dordrecht) and Antwerp port area are the most obvious area's to develop the first LNG bunker stations on shore or as a floating solution because the LNG retail price was set in these areas and the port areas are close to the LNG import terminals which minimizes logistics cost, especially for Rotterdam port were the LNG terminal Gate is in the port area.

This development is now also pushed by the port of Hamburg and Mannheim in Germany were the Ports are facilitating small scale LNG players to invest in LNG bunker infrastructure. The mention ports; Rotterdam, Antwerp and Mannheim were also active in the LNG Masterplan project pursuing LNG developments for their port areas. In Germany the important inland ports are following this development as well but they are more dependent on launching LNG customers in their area to create a sufficient starting volume to hedge the necessary investments.

In this report the different locations and the developments are descripted how the process with the important stakeholders took place and which drivers where influencing the decision to develop or invest in an LNG bunker station. Also locations where the decision was taken not to develop LNG bunkering will be described to better understand the results in total for selecting the locations as shown in the map.

To understand the current bunker market for IWT and how this infrastructure has been developed and what important drivers are, it was necessary to investigate the current gasoil bunker infrastructure and the way they are operated. This will be explained in chapter 5.

5 Current situation

5.1 Bunker locations Benelux /Germany and France

Below map shows the most important current inland bunker locations for gasoil bunkering of inland vessels.[1] The bunker locations are either shore based or executed as bunker barge. The current bunker infrastructure provides a good coverage for bunkering inland waterway vessels between Rotterdam and Antwerp to Basel.
In the main ports like Rotterdam, Amsterdam, Antwerp in the Netherlands and Belgium the number of bunker stations is the most dense and likely related to the high number of inland waterway vessels in the Netherlands.

Map No. 4[(1)], Current Diesel / Gasoil bunker locations

[1] Map No. 4 provides a selection of existing important inland bunker locations for diesel/gasoil, not all bunkering facilities are incorporated in the map, source Google Maps.

Interesting to see the total coverage of present bunker services (bunker stations or bunker boats) along the Rhine River, from Duisburg, Dusseldorf, and Cologne to Mainz, Mannheim all the way upstream to Basel. The further upstream less bunker stations for gasoil or diesel are present and likely in the past there has never been the need for more bunker services for inland waterway vessels more upstream. An important reason can be the fairly short shipping route from Rotterdam to the most important nearby industrial port cities and vice versa and the type of vessels or cargo needed for the industry in the mentioned port cities, and the specific inland vessels that sail all the way to Basel and back.

Most important current bunker stations in France

Source: Voies navigables de France, http://www.vnf.fr/sigfed/carto/cartes/298

5.2 Most Important current bunker locations Benelux /Germany

To understand the inland waterway segment and the need for bunker stations and locations a thorough desk research was performed to see which the important bunker companies are and where they have bunker stations located along the Rhine corridor. Also the link with oil mayors like Total and Shell are important to show.

Naturally there are more bunker suppliers and locations active in Germany than mentioned in this report and also present in Port of Hamburg and along the Mittellandkanal, an important inland waterway connecting the Rhine corridor with the northern and eastern part of Germany and Port of Hamburg.

Hereunder the listing of most important bunker companies with locations between Port of Rotterdam, Amsterdam, and Antwerp up to Basel along the river Rhine:

Reinplus Fiwado bunker stations are positioned along the waterways of the Netherlands, Germany, Austria, Hungary, Bulgari, (Rhein-Main-Donau), Belgium (ARA) and France. Fiwado was until December 2016 a 100% subsidiary of TOTAL Nederland N.V. but taken over by Varo Energy and merged in the company VARO Energy Inland Bunkerservice B.V. This company is the largest independent bunker company for the inland waterway segment in Europe now called: REINPLUS FIWADO Bunker.

- Fiwado, Plaatweg 10 Botlek Rotterdam
- Fiwado, Maasboulevard 1 Zwijdrecht
- Fiwado, Nieuwendammerdijk 256, Amsterdam
- Fiwado, Rijndijk 7 Millingen a/d Rijn
- Fiwado, Zuider IJdijk 100 Amsterdam
- Fiwado, Loswal Millingen a/d Rijn
- Fiwado, De Willem Ruysstraat Vlissingen
- Fiwado, Kaai 1 Breskens
- Fiwado, bunkerboot Koblenz
- Fiwado, bunker barge Rüdesheim
- Fiwado, bunker barge Mainz
- Fiwado, bunker barge Neckarplus
- Fiwado, bunker barge Mannheim
- Fiwado Antwerpen
- Fiwado Basel

A. Nobel & Zn. Is a family company located in Zwijdrecht with a bunker barge along the quay and a maritime shop at the quay for lubricants, filters and typical nautical supplies for inland waterway segment.

- Nobel & Zn, Uilenkade 100 Zwijdrecht

The company Slurink, also a family company, is associated with inland shipping for more than one and a half centuries. Since 1970 Slurink started to become a bunker company and from 1985 the company took over several bunker locations in Dordrecht, Gorinchem, Zaltbommel and Amsterdam from Zwaans BV and extended their network Schore, Lobith and Vlissingen.

Slurink Bunker stations are positioned in the western and south western part of the Netherlands.

- Slurink, Merwedestraat 485 Dordrecht
- Slurink, Waalkade Zaltbommel
- Slurink, Zuider IJdijk 100A Amsterdam
- Slurink, Kaai 85 Schore
- Slurink, Europakade 1 Tolkamer Lobith
- Slurink, 2e Binnenhaven Vlissingen

Heijmen, a family company, started the bunker service in 1953 with a small bunker barge.
The end of the 60's Heijmen converted the tow truck Lombardia into a bunker retailer vessel with 560 m3 gas oil storage. The old bunker vessel service served until 1998 in Millingen a / d Rijn. In 1998, the new bunker retailer vessel was launched. The new station is completely double-walled and equipped with state-of-the-art bunker-boom.

In Rotterdam Heijmen started a joint venture between SBH and Bunker station Heijmen BV, called SBH Heijmen Rotterdam BV.

- Heijmen, Loswal 5 Millingen a/d Rijn
- SBH Heijmen, Bunschotenweg 127 Rotterdam
- Heijmen + partner Neptun, Havenweg 18 Nijmegen
- Heijmen, Merwedesingel 48 Papendrecht
- Heijmen + partner Oliehandel Anton van Megen, Havenstraat 109 Zaandam
- Heijmen + partner A.M. van der Kolk, Sasdijk 16 Dinteloord

Dekker & Stam is a company selling lubricants and fuel like diesel and gasoil and inland waterway supplies for inland barges. The company is located in Hardinxveld-Giessendam along the Beneden Merwede and operates two small bunker barges.

- Dekker & Stam, Langeveer 1 Hardinxveld-Giessendam

The Wit Bunkering NV and Belgian Trading and Bunkering (BTB) are European bunker companies for shipping, inland shipping & industry and part of the family company the Wit group. De Wit Bunkering is active since 1947 as inland bunker company. De Wit Bunkering NV is a bunker company in Belgium exclusively cooperating with refinery products from Exxonmobil and Total.

- De Wit Bunkering, Lichterweg 3 Antwerpen

NWB, Nord und Westdeutsche Bunker GmbH is present in almost whole of Germany but mainly in the northern and western part of Germany. Along the river Rhine the company has bunker stations or bunker boats present.

- NWB Nord- und Westdeutsche Bunker GmbH, Duisburg
- NWB Nord- und Westdeutsche Bunker GmbH, Düsseldorf
- NWB Nord- und Westdeutsche Bunker GmbH, Cologne
- NWB Nord- und Westdeutsche Bunker GmbH, Koblenz
- NWB Nord- und Westdeutsche Bunker GmbH, Mainz
- NWB Nord- und Westdeutsche Bunker GmbH, Mannheim

Rheintank GmbH, Duisburg, founded in 1951, is today a member of the RETHMANN Group. As part of RHENUS Logistics' inland shipping activities, Rheintank GmbH is managed by Rhenus Partnership GmbH & Co. KG, Duisburg.

- Rheintank bunkerdienst, Duisburg
- Rheintank bunkerdienst, Koblenz
- Rheintank bunkerdienst, Mainz
- Rheintank bunkerdienst, Mannheim

The listed bunker companies above are using oil and fuel products of Shell, Exxonmobil, Esso and Total. Fiwado Reinplus is using oil and fuel products of Varo Energy group mainly.

Existing oil based bunkering locations or future LNG bunkering locations in France will not be discussed further in this report because they are less relevant to the case. The study for best locations was based upon target vessels with a specific yearly fuel consumption of 500 m3 gasoil per year or higher and the type of vessel and the trade area were also important selection drivers. In this case study we see the larger number of target vessels mainly along the river Rhine between Amsterdam – Rotterdam – Antwerp and Basel. Some inland barges sailing on the rivers in France could be complying with the study criteria but the numbers are too long to further investigate the possibilities for LNG fuel bunkering locations at this moment.

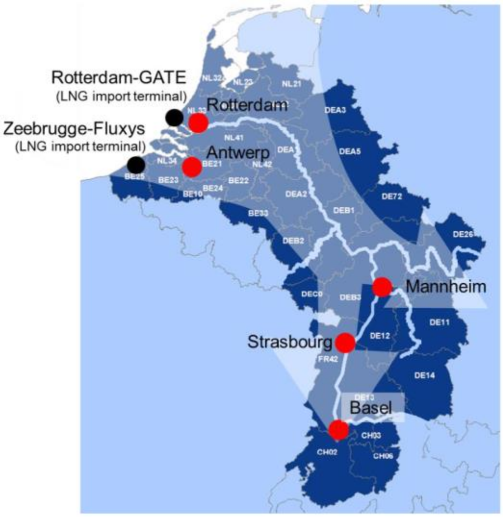
6 Methodology determining best locations

Several sources have been consulted to give basic information for determination of the best locations. The most important studies consulted for this report are the heat map analysis of the EICB and the LNG Masterplan study.

6.1 Input from other studies

ENGIE has taken the Study DNV-GL LNG Masterplan as a basis to determine the best physical locations along the river Rhine. This project "Breakthrough LNG Deployment in Inland Waterway Transport" is a follow-up project of the TEN-T LNG Masterplan project.
The objective of the DNV-GL LNG Masterplan study was to identify the LNG fuel infrastructure locations that might be required along the Rhine river corridor to meet future LNG fuel demand.

The geographical scope of the DNV-GL LNG Masterplan study was determined through an economic and risk analysis of the likely competitive locations for LNG fuel supply along the river Rhine. The geographical scope is shown in the figure below:



The study was aimed to assess the impact on LNG fuelling infrastructure requirements for inland waterway transport and other segments. The study is structured by the following topics:

- Analysis of the current status of LNG fuel adoption in the scope of the study
- Assessment of available LNG supply infrastructure and active suppliers
- A risk assessment and economic quantification of LNG fuel adoption in the regions.
- Operational and financial assessment of the required LNG fuel supply infrastructure

In 2014, while the study was executed, the IWT sector showed promising LNG adoption beyond 2020, especially for the high fuel consumers in the more or less fixed trading routes like inland fuel /chemical tankers and inland container vessels. The obvious economical drivers are mentioned in the LNG Masterplan study like;

- fuel costs = spread between diesel and LNG,
- switching costs = investment costs for LNG equipment,

And other drivers like;

- Regulatory policy = taxes and emission regulatory and technology innovation.

Part of the LNG Masterplan study is sub-activity 3.1 Terminal concepts & cost assessment. Based on the report D 3.1.3.1 and D 3.1.3.2, case study on bunker stations in the Port of Mannheim and the Port of Switzerland the risk analysis results in a number of preferable locations.
The methodology used in that study was based on the following steps: Quick scan of potential sites, Legislation and standard demands, screening of operational and safety considerations and at last the final selection of the preferred sites based on selection criteria following from the previous steps.

This study, to find the best LNG bunker locations, has focused on the results for best locations from the case study of the LNG Masterplan in relation to the LNG infrastructure needed in that specific area and costs for investments and logistics influencing the LNG fuel price at a specific bunker location.

First focus on locations in this study is: Rotterdam, Antwerp, Mannheim and Weil am Rhein.
ENGIE connected in an early stage to the stakeholders of the LNG Masterplan to investigate and discuss the possibilities of LNG infrastructure development in the different ports.

6.2 EICB research sailing areas inland vessels

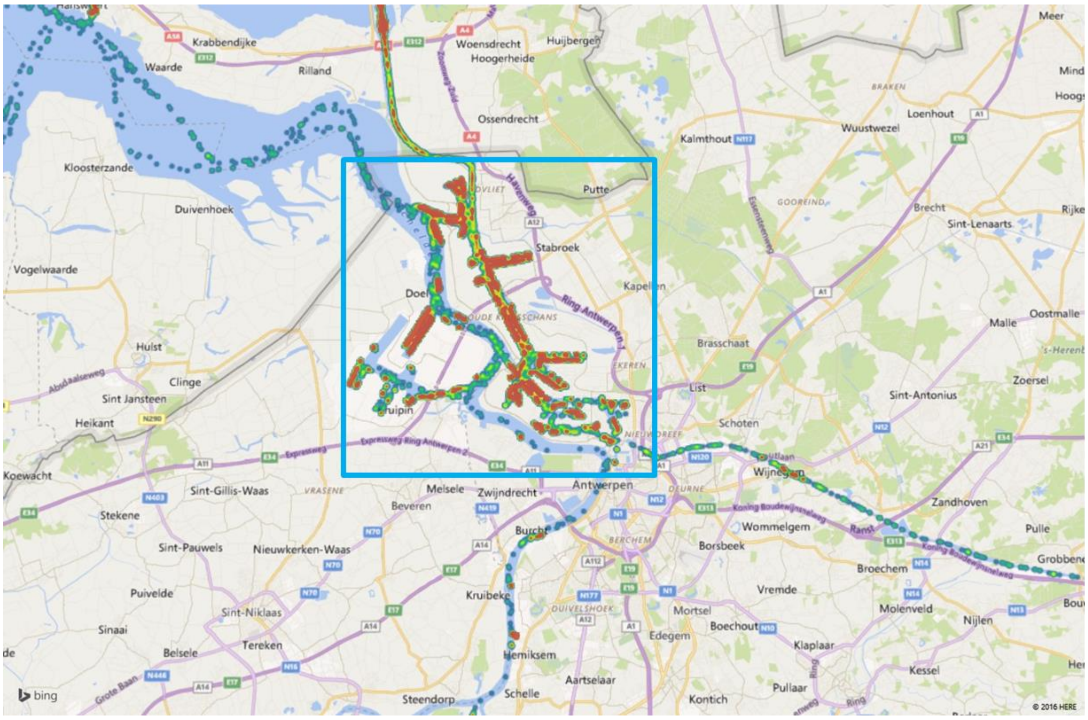
EICB performed a study into the sailing areas of inland vessels using yearly fuel consumption of >500 m3, in order to map the potential LNG using vessels. The reason to select vessels using more than 500 m3 gasoil fuels per year was mainly based upon the price difference between LNG and gasoil which results in a positive business case for the ship owners converting their ship to LNG propulsion. This study resulted in heat maps of the potential LNG using vessels, i.e. the geographical demand for LNG fuel in IWT, and consequently gives indications for the best LNG bunkering locations. The numbers of inland vessels complying with these criteria are 283 vessels. The inland vessels were studied over a period of two months; October and November of the year 2014. The intensity of the inland shipping traffic on the different inland waterways and ports indicated in the study were the locations are determined by the partners are plotted anomalously on so called heat maps to show the potential of inland vessels in that area with fuel consumption above 500 m3.
The study EICB performed covers more locations than mentioned in this report. The selection is made for the inland vessel sailing or mooring in the selected areas mentioned as “best location selected at this moment for the implementation of an LNG bunker station. In this chapter only one location is shown as example, all selected locations of the EICB research are included in Annexe 1.

1) *Antwerp, location Quay 528*

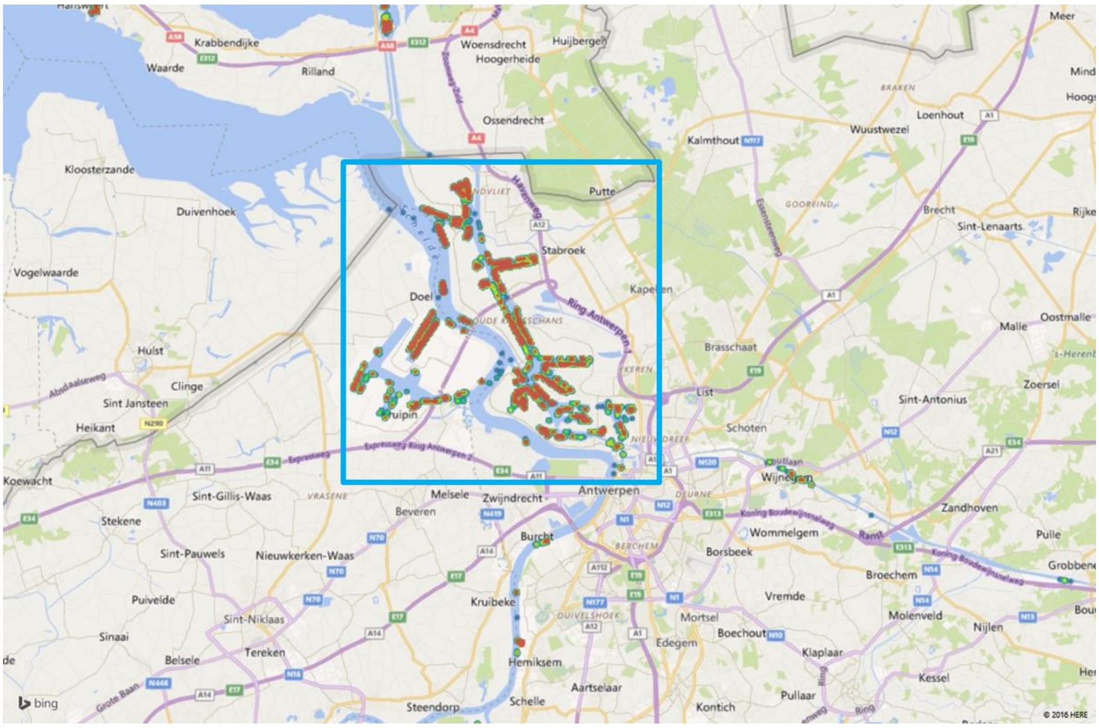
As environment is included for this area:

- 'Large-Antwerp ': Scheldt-Rhine connection south of Kreekraksluizen, Scheldt at Antwerp, Antwerp ports
- -'Small-Antwerp ': Idem, excluding Scheldt and western ports (only the eastern ports)

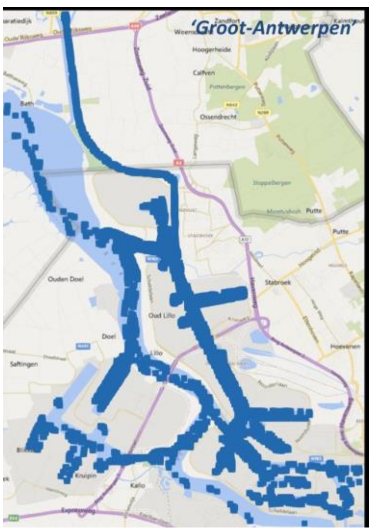
Heat map showing all inland vessels in that area from the selected 283 vessels:



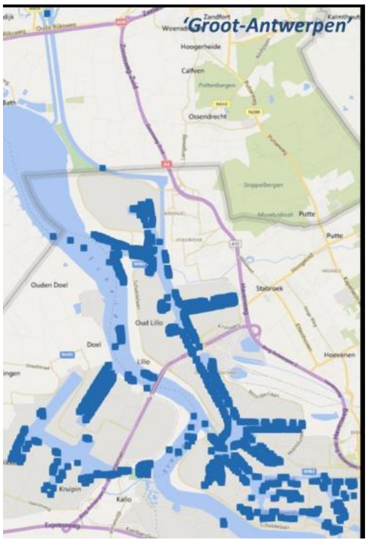
Heat map showing all idle (moored) inland vessels in that area from the selected 283 vessels:

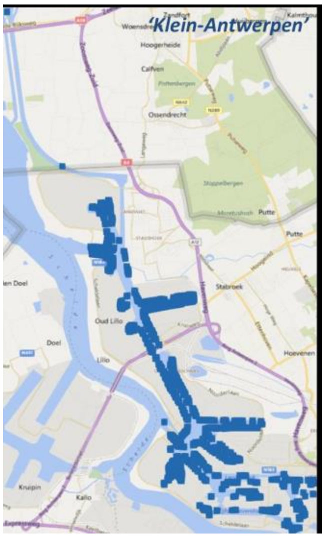


Antwerp observations all vessels:



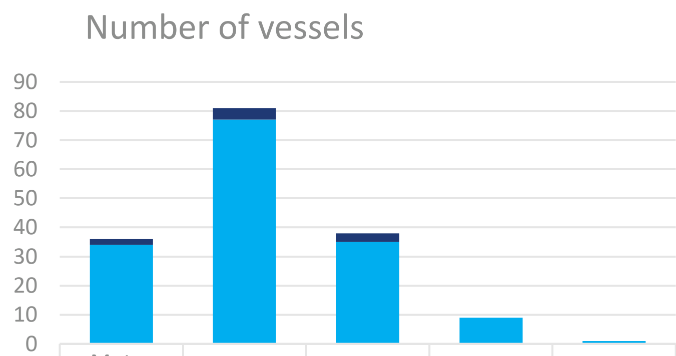
Antwerp observations moored vessels:



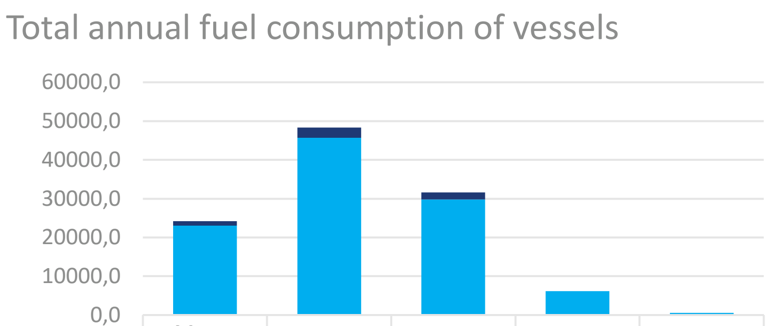


Out of the 283 tracked vessels:

- 165 vessels were in the area of Antwerp, of which:
    - 156 vessels also idle;
    - 9 vessels only passed by.
- These 165 vessels have a total annual fuel consumption of 110 954.0 m3 (average: 672.4 m3);
- These 84 'idle vessels' have a total annual fuel consumption of 105 305.7 m3 (average: 675.0 m3)



	Motor (dry) cargo vessel	Motor tank vessel	Coupled convoy	Pusher	Passenger vessel
Number of vessels (only passing by)	2	4	3	0	0
Number of vessels (Idle)	34	77	35	9	1



	Motor (dry) cargo vessel	Motor tank vessel	Coupled convoy	Pusher	Passenger vessel
Fuel consumption (only passing by)	1206,2	2611,1	1831,1	0,0	0,0
Fuel consumption (Idle)	23029,8	45728,6	29780,4	6176,8	590,0

Note: Only one location is included in this chapter for example, all results relevant for the selected locations are included in Annexe 1.

6.3 Drivers / barriers for selecting the best locations

What are the most important drivers and barriers to determine the best locations for an LNG bunker station? And which drivers or barriers are applicable for all the different locations and which drivers /barriers are only applicable for a specific location?

To understand what is influencing the decision making process of LNG infra /supply companies for investing in a certain location, hereunder explained the most import items that have substantial impact on the decision;

1) *Customer perspective / cooperation with (launching customers)*

Most important driver for the bunker operator is the investment. To overcome the valley of death a launching customer is essential and the (projected) LNG volume demand of this launching customer for the first 3 – 5 years. Without a basic starting volume no decision will be made for CAPEX intensive investments. Volume ramp-up after the first 3-5 years must be in line with the business case perspective in order to have a positive return of investment.

2) *Sailing area of the client vessels*

The launching customer(s) and the potential customers need to be active in the particular area of the bunker station or need to pass by the station. Making a detour for shippers is not an option. An LNG bunker station investment only makes sense in a good or busy sailing area with customers operating on long term logistic contracts for the specific businesses in that area.

3) *Support from regional government / authorities*

Every location is different and can be located in different municipalities or regions. Therefore regulation and political sentiment of the local (port) authorities can diver or demand intensive stake holder management. Naturally authorities that support the use of LNG because of the environmental benefits are more willing to manage or mitigate the potential risks for the development and operation of an LNG bunker station in their region or port. This is also important for the cost for development and permitting of the location.

4) *Cost for rent or leges (fees) of the location*

A perfect location does not exist, does it? Most locations are too big or too small and not always an optimal land-use-planning is possible for a specific location connected to the inland water way quay side or port quay side. Important part of the business case (feasibility) of a location is the costs for rent or land lease that are part of the operational costs. Because there is a need of a location with the right size located on a quay, next to the waterway, the costs are high related to the premium location. To build LNG infrastructure is CAPEX intensive, to prepare LNG sites including the necessary civil works like a quay are highly expensive and the premium location needed is often expensive to rent or lease. If all these elements have too much negative impact on the business case the location will not be selected as ‘best location’ even if the location is business wise and logistically the ‘best location’.

5) *Political environment of the country /municipality area (arrangements, taxes, in advantage of LNG as fuel)*

For the development of LNG infrastructure timing is important! Wrong timing can kill the business case. As explained earlier customers are playing a key role in the decision making process and customers need to directly connect to the planning of LNG infrastructure development and the proposed commercial operation date of the LNG bunker station. Customer involvement in this is crucial to align the authorities and political environment to the case in order to mitigate the risk for their investments and the investments for the infrastructure enabling the supply of LNG to that customer. Good stakeholder management is needed for this process and review moments of the feasibility of the development should be done frequently from an independent perspective. Actually you could say that if commitment of local authorities is lacking and the political environment is not positive about LNG, the risk for the case on the long term will be too high and the decision should not be made to go further. On the other hand if all (political) stakeholders are in line with the development it is not a guarantee that the business case is successful but the time of the development is more easy to manage and therefore also the risk for investments of potential customers.

6) *Type of location possible (function, hub)*

Depending on the area of the location and the possibilities for multi-model or retail functions of an LNG storage /installation it is analysed in the development process for LNG infrastructure and will influenced the actual purpose of the LNG installation. Further upstream and at specific port area's where the distance to the LNG import terminal is significant large the element of logistical costs for LNG as fuel are becoming demanding in the retail price of LNG to end customers. The balance between the molecule part and the logistic part in the retail price can shift to a negative level, which will be discussed in chapter 8 and 8.1. To overcome the negative impact of logistic costs the decision could be made to develop a larger storage of LNG at that location with a multi-modal and retail "hub" function of the LNG installation in order to boost the LNG volume turnover of the location. In this case the way of transporting LNG to this location could or should change from road trailer supply to tanker vessel supply by water at a specific time and at a specific volume turnover in the business case to balance the cost level between molecule and logistics again. Sometimes the location itself could demand to develop an LNG hub like solution instead of a bunker station only, most of the time driven by a launching customer or launching customers connected to a certain business or shippers in that area. These kinds of locations are more often to find in the larger industry ports or sea ports.

7) *Logistical aspects related to the location*

Best locations are depending on good road and highway connections to ensure efficient logistics to the location. Remote locations with restricted access of mayor roads or highways are too risky in a logistic perspective and too high logistic costs or loss of time could negative influence the business case. The more upstream locations should therefore be perfectly accessible close to interconnecting roads and highways to enable a positive case.

8) ADR routes to the location

Transport of LNG is restricted and not everywhere possible in principle. LNG semi-trailer or tank trucks are designed and suitable for transporting dangerous cargo's according ADR regulations. LNG transport is part of ADR or ADN regulations for transporting dangerous cargo's and LNG semi-trailers or tank trucks need to follow the ADR routes to a destination or location. Often additional safety studies need to be performed for the transport of LNG from the highway to the specific location when the location is located remotely or in an area where dangerous goods are not common. In that case an optimal route from the nearest highway connection to the locations needs to be determined and a safety study for this specific route needs to be performed. Restrictions or prohibitions can have a negative impact on the case.

9) Type of solution or technology / storage volume needed at the location

As mentioned above overcoming the negative impact of logistic costs the decision could be made to develop a larger storage of LNG at a specific location with a multi-modal and retail 'hub' function, in order to boost the LNG volume turnover of the location. Or the location itself is most suitable for an LNG hub like solution instead of a bunker station only. The launching customer or launching customers connected to a certain business or shippers in that area are the most important driver in this case. These typical 'HUB' locations are more often to find in the larger industry ports or sea ports connected to the activities of the industry in that area. A retail LNG hub will become necessary when larger LNG volumes are bunkered or distributed to that area most of the time for different market segments like water and road transport and off grid applications. The functions as re-distribution point were the LNG volume to the HUB is delivered in bulk by means of a tanker vessel will become effective with a larger LNG demand /turnover in that area driven by customers in the different market segments. At the same time connected to the HUB the Bunker station , fuelling station and Tank truck reloading functionality can be included to optimize the functionality of the HUB.

10) Multi modal possibilities of the location

Developing multi-model LNG infrastructure demands a specific type of location were traffic road routes, waterway and railway are connected to. These kinds of locations are most of the time not available because other industry is located here in the past for the obvious reasons. Multi-model locations are therefore valuable or on the other hand costly and could be developed when larger LNG volume in that area is emerging or a retail function is demanded for this area. Larger investments, larger storage and more functionality is needed for these kind of installations /locations and a longer period for return of investment can be the case involving higher risk for the business case.

11) Safety studies and permitting for the location

For all LNG activities a safety study or quantitative risk assessment (QRA) shall be performed to analyse the needed local or personal risk contour and possible impact on group risks and effect area's related to the LNG activity, storage capacity and LNG flows. The so called difficult locations, situated nearby vulnerable objects, busy public places or other hazardous locations could demand higher investments or a more costly development for LNG infrastructure to ensure that authorities will grant a permit or permission for the LNG activities at that location. The feasibility of this process should be investigated first before the location could become of interest for the business case. This to avoid long and costly development processes without any result and loss of time.

12) *Sensitivity of the location and possible land-use-planning (LUP)*

A location could be perfect for LNG infrastructure and related activities but still not the best location if reasons of sensitivity could be the case. For instance when local residents are against the LNG infrastructure or when locations are negative influenced by the zone planning of the municipalities. This is often the case were industry areas are coming closer and closer to the neighbourhoods of local residents. Also Land-use-planning for a specific location could be influenced by its surroundings resulting in a negative safety zoning of the LNG installation, for example when nearby office buildings are planned or projected for future holding more than 50 people. Very important is to identify all possible obstacles or influencing issues of the location as part of the first quick scan of the location in order to determine to move forward or not. The specific process steps are mentioned further in this chapter.

13) *Conditions for Permitting and zoning / safety assessment / noise restrictions / flooding conditions*

As mentioned before it is very important to identify all possible obstacles or influencing issues of the location as part of the first quick scan of the location in order to determine how to move forward how feasible a location is and to check the possibilities for a positive risk assessment for gaining a permit or not. The specific processes (steps) after performing the quick scan are mentioned further in this chapter. Extra attention is needed for the possible risks of flooding of the location and for Germany the possible explosives that can be in the ground of the location from the war. Because of climate change and more extreme weather conditions the river or other waterway could go beyond its banks and cause flooding of the location and area. In the development process should take into account the necessary measures to protect the LNG installation in flooding situations.
Another important aspect is the supply of LNG to the bunkering station. In the start-up of the station the delivery will be done by trucks. For example in Germany there are strict regulations for noise and delivery during festival days and weekends. To overcome this issue a larger storage capacity have to be installed.

14) *Cost for development of the location*

Many of the above explained barriers and risks are influencing the total cost for development of a location impacting the business case negatively. An open mind for all risks and changes is needed before taken the right decisions to proceed with the development or not.

15) *Possibilities for Cooperation at the location with partners)*

Possible cooperation between LNG supply companies with local based infrastructure companies is preferred to speed up the development and to share costs and risks. A good cooperation could be more successful than intensively competition for the years to come.

6.4 Driver ‘bunkering preferences of inland shipping companies’

To understand the needs /demands of inland shipping companies for bunkering the EICB consulted several bunker companies.

The following questions have been asked by the EICB to the bunker companies:

- Is there a preference in bunker companies /locations?
- What are the current trends & experience of inland gasoil /diesel bunkering
- What are the needs /demands of Inland shipping companies for bunkering
- How are bunker companies dealing with upcoming emission demands and how the communicate with the inland shipping market

Two bunker companies indicated that inland shipping companies generally do not have specific requirements for bunkering in terms of location and need for additional products / services. Inland shipping companies or operators bunker at the most convenient operational moments. Bunker companies offer, additional to the regular fuel, products like pumps, cleaning products, paint, ropes, various oils, etc. However, the availability of these products does not play a decisive role in the choice of the shipping company for a bunker station. Many bunker companies (stations) have a permanent clientele that has been built up over the years.
One of the companies, on the other hand, indicated that there is indeed a bunker pattern in their clientele. Inland shipping companies bunker mainly at the start of the trip. Another option is bunkering during sail, preferably during the day and at a bunker station along the river.

Bunkering at a bunker station is usually done on the river. Although the large inland couple barges on the rivers also make use of a bunker boat during sailing. In the ports of Amsterdam and Rotterdam, bunkering is mainly done by a bunker boat coming along side or customers sail to the bunker boat location itself. In cases of extreme heavy traffic in the ports the decision will be made to bunker during the sail, but usually the heavy traffic is not a problem. According to one of the bunker companies, the bunker fuel is mainly supplied via the bunker boats.

Because the bunker companies have the primary contact with inland shipping companies they might know how bunker companies dealing with upcoming emission demands and how the communication with the inland shipping market is usually done.

The consulted bunkering companies are all aware of the upcoming emission legislation NRMM Stage V. Communication to customers about the upcoming emission legislation is limited, inland shipping companies are aware of it, but the sense of urgency is not present and the general feeling is that there is no need for urgent action to switch to LNG but there is a sense of urgency to comply with the CCR-2 for diesel engines. The lack of willingness or action to switch to LNG will certainly have a negative effect on the willingness to invest in the LNG bunker infrastructure. Most inland shipping companies just wait and see. It is expected that the urgency will increase in the near future when stricter legislation (stage 5 in 2020) will come into force.
As a result, the demand for alternative clean fuels, like LNG, is currently lacking.

6.5 Organization and planning for location development

For the development of new locations to construct an LNG bunker station following steps are determined after an agreement with potential customers is reached:

1 | site survey, research (LNG Infra company, SITE OWNER / Municipality)

- Site visits
- Connect to stakeholders
- Consultation for location /operational demands, potential barriers
- Site survey, perform quick scan location
- Zoning or land use plan review /research / determine permit process / enforcement agencies
- Produce overview drawing / prepare QRA (quantitative Risk Analysis) and reporting of the location
- Report decisions, prospect, photo's + zoning plan

2a | quick scan, Sketch (LNG Infra company)

- Quick Scan forming the basis for the risk assessment (QRA) and Checklist
- Digital cadastral map
- Check ground cables and pipelines
- Sketch layout consultation, situation, routing and basis design layout and parameters LNG Solutions
- Quick scan document internal safety, external safety, PGS33-1
- Accessibility, land zoning plan and routing.
- Basic Engineering: drawings of situation | plan layout | Presentation of plan
- Final plan layout
- Final presentation of plan

2b | Zoning plan or land use check / request change

- Request change in zoning plan or land use (if necessary) + follow up.
- Special substantiation performed by third parties, include special substantiation effect
- To determine in consultation with the municipality or authorities:
    - Archaeological research
    - Available water test
    - ADR transport routes
    - Soil research for contamination
    - Stability research of the ground
    - Acoustic research
    - Quick scan Flora and Fauna
    - Landscape integration research
- Construction calculations and drawings

3 | QRA (risk analysis)

- Assessment of external safety
- External Safety research – QRA
- Noise attenuation
- Possible adjustments diverse factors

4 | Working out final lay-out drawings of the location and equipment / technical installation

- Detailed Engineering: location boundaries /Installation lay-out and footprint

5 | Design Check / LNG Infra company / SITE OWNER / Municipality

- Based on permanent or not permanent character, volume, footprint, connections, etc.

6 | Work out plant lay-out / (geographically)

- Consultation municipality / client
- Traffic flows location
- Access routes
- Special integration of the LNG plant
- Situation drawing environment
- Views of the location LNG plant
- Principal construction details architectural and civil (load and weight)
- Update final presentation of plan

7 | Economic impact / LNG Infra company / SITE OWNER /

- Consultation municipality / Possible subsidies
- Consultation location owners and other relevant stakeholders
- Commercial activities / potential base turn over volume and potential future volume and customers
- Financial accounting of the business case

8 | Detail design of the location & installation / LNG Infra company

- Final location /installation Layout
- Investigate expanding possibilities
- Draft P&ID (Process & Instrumentation Design)

9 | Environmental and construction permit (~ 6 months lead time, depending on country)

- Request permit for a LNG fuelling station / location including necessary notifications to authorities
- Subject to the LNG location
    - Environmental aspects
    - Advertising / communication
    - Location facilities, grounding, fencing, etc.
    - Marking of supply and access routes to the location
    - Signals and signs for the location, etc.

10 | Miscellaneous (for operational phase) / LNG Infra company / SITE OWNER /

- Emergency plan / communications
- Fuelling and offloading procedures
- Responsibilities location owner, exploitation and asset owner
- ESD (Emergency Shutdown) procedures and installation malfunction-processes.
- Training truck drivers (fuelling training LNG station)

Structure and phases / planning Permanent LNG installation location

De following phases need to be followed in this case:

- Sight Survey /Quick Scan (form) — 1 – 2 weeks
- Economical (feasibility) check / management approval — 1 – 2 weeks
- Basic lay-out / Design check — 2 – 3 weeks
- Zoning plan land use test / change — 2 – 4 weeks
- Assessment external safety - QRA — 4 – 6 weeks
- Final plant layout — 2 – 3 weeks
- Environmental and building permit — at least 26 weeks
- Detail design LNG installation / location — 6 – 8 weeks
- Realisation location / EPC (including delivery time long lead = 45 wk) — 45 – 50 weeks

Phase /Activity	LNG Infra company	LNG Infra company / Safety & Risk	Location owner
Sight Survey / quick scan	V	X	X
Economical (feasibility) check / management approval	V		X
Basic Layout / Design Check	V		X
Zoning plan land use test / change		V	
Assessment external Safety QRA	X	V	X
Plant Lay-out	X	V	X
Environmental and building permit	X	V	X
Detail design LNG installation / location	V		X
Realisation location / EPC	V		X

V = Owner / initiative
X = Support

LNG BINNENVAART Deployment in Inland Waterway Transport

7 Best locations studied and selected

7.1 Best locations in general

In general the larger number of inland waterway vessels are sailing in the Netherlands transporting chemicals, oil & fuels, containers and bulk from the main seaports to the hinterland via the important waterways like the Rhine. The LNG import terminals are present in or nearby the main seaports and obviously these ports were the first to start development of LNG fuelled vessels and LNG infrastructure in their ports. In the seaports, near the LNG import terminals, the logistic costs are rather small because of the short distance and the numbers of inland vessels sailing in that area are high. Therefore in general the main seaports are in principal the best locations for development of LNG bunker stations, those main seaports are:

- Rotterdam seaport (including Dordrecht are)
- Antwerp seaport (including left and right bank)
- Amsterdam seaport (including IJmuiden port)
- Moerdijk seaport
- Zeeland seaport (including Vlissingen, Breskens and Terneuzen)
- Hamburg seaport (emerging development in LNG import & storage and LNG bunkering)

To ensure enough coverage of LNG bunker infrastructure along the Rhine –Alpine corridor one or two additional LNG bunkering stations are needed in the most important inland ports like:

- Duisburg
- Cologne
- Mannheim
- Basel
- And in the area of the Mittellandkanal

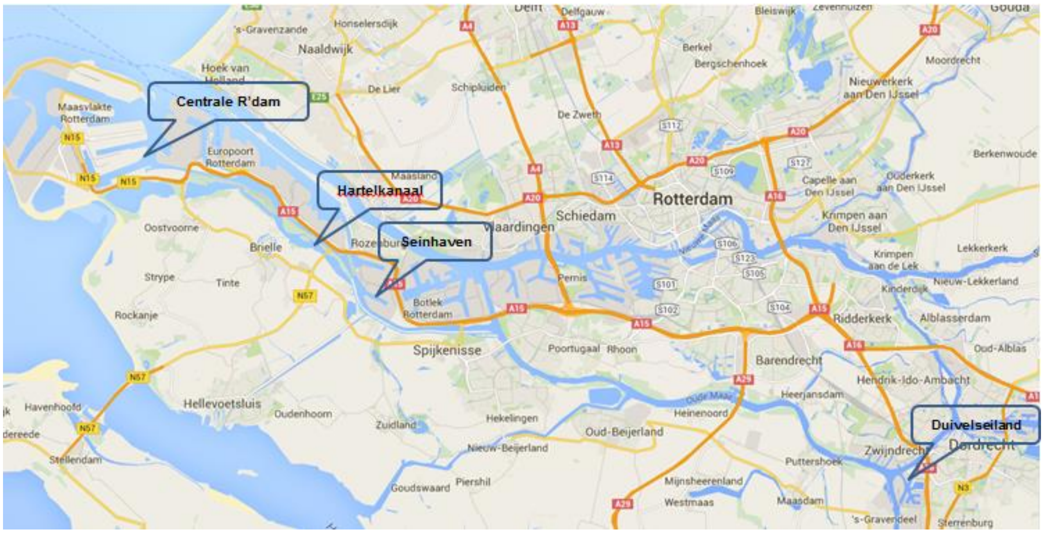
In those inland ports the costs for logistics will have a larger impact on the business case and will influence the decision if that location can be selected as best location. Of course other drivers can have more impact on the decision making process for selecting a best locations to develop and operate an LNG bunker station.
The most important drivers for selection of a location are explained in chapter 6.3 and the final conclusion how and which driver impacted the decision for the best locations are explained in chapter 10, Conclusion.

At this time only three locations where selected as “best locations” for development of an LNG bunkering station because of the slow adoption of LNG as fuel in the inland market. But a fourth location could still be chosen form the mentioned seaports or important inland ports upstream when changes in sailing areas or partners in the project are emerging. Therefore we would recommend taking into account the in principal best locations according above list of ports and the chosen best locations in this study so far are addressed in the following chapter 7.3, selected locations.

7.2 Studied locations

7.2.1 Port of Rotterdam, Development by ENGIE

In 2015 ENGIE LNG Solutions discussed with the department industry of Port of Rotterdam organisation the possible setup of cooperation for development of LNG bunker infrastructure for inland waterway transport in the port of Rotterdam.
The Port of Rotterdam organisation has supported ENGIE in the study for possible locations in the port including the ENGIE power plant location at Maasvlakte. Together with the port ENGIE set a functional program of requirements regarding the assumptions of the port for an LNG bunker location. Port of Rotterdam submitted several possible locations for development of LNG bunkering in the port area to study by ENGIE for technical and economic feasibility, see also below map.



ENGIE and the Port of Rotterdam discussed possible development paths for LNG bunkering in the port, for different market segments: inland, coastal and deep sea vessels. For coastal and deep sea vessels LNG bunker vessels and barges are (being) developed and built but for the inland shipping sector not a good solution has been developed or implemented yet. In the port of Rotterdam LNG bunkering for inland vessels is done truck to ship (TTS) in the Seinehaven, assigned location in the port dedicated for this purpose.

See picture LNG truck to ship bunkering by ENGIE LNG Solutions in Seinehaven port of Rotterdam.

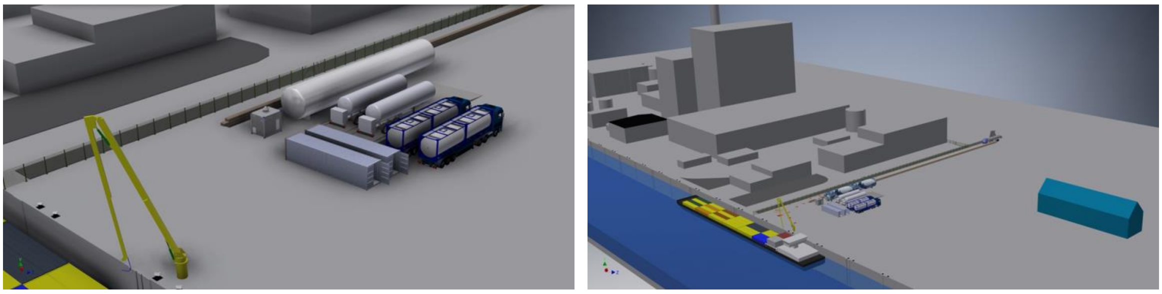
In order to follow and support the strategic development for LNG bunker infrastructure of the port of Rotterdam the focus was set to develop a fixed LNG bunker station for inland shipping in the port, preferably in the Seinehaven. For this development approach the following steps where discussed:

- Current LNG bunkering TTS of inland waterway vessels in the Seinehaven (accessible to all market parties) to be moved to the Hartel Canal - from 2016/17 operational;
- Development of the Seinehaven (longer and stronger quay, deeper water) to facilitate a first fixed bunker point for LNG shore to ship bunkering, with fixed LNG storage tank facilities, to be completed by a commercial operator - from 2017/18 operational;
- Research for development of location Duivelseiland, near Dordrecht, for a second fixed bunker point for LNG shore to ship bunkering, as in the Seinehaven with fixed LNG storage tank facilities, to be completed by a commercial operator - from 2018/19 operational;

For this strategic development approach the Port of Rotterdam need an open access formula for LNG supply and operations of the fixed LNG bunker station what could cause a complex development and investment structure for the station. Investment by commercial partners in LNG bunker stations at Port of Rotterdam owned locations comes with a risk because other third parties can also invest in private owned locations without the demand of the port for open access.
The current LNG truck-to-ship location in the Seinehaven is freely accessible and no terminal or location fee is charged for the bunker operation.
This situation will change when a fixed bunker station is developed and the cost for investments, operations & maintenance of the station /location will be included in the total cost (bunker fee) additional to the costs for bunkered LNG.
It goes without saying that truck-to-ship LNG bunkering is the most cost effective LNG bunker operation and bunkering from a fixed LNG bunker station is always more expensive. Therefore it is not logical to have both types of operations active in the same port. On the other hand the fixed LNG bunker station has other advantages like the permanent (larger) storage of LNG at a location

in the port and a higher flow for bunkering. Also advantages seen from an operational perspective are more effective and a higher standard can be archived with a fixed LNG bunker station.

The demand for LNG volume in the inland shipping sector was and is still not enough to invest in a fixed LNG bunker station in Rotterdam port by ENGIE. Therefore ENGIE proposed to setup a simple intermediate LNG bunker station (so called IBI = intermediate bunker station) that will use in first only LNG tank trailers or LNG ISO containers as storage and the system is modular built up. In a second phase, when LNG turn-over increases, a fixed LNG storage tank could be added. Or if another location was developed in the meantime the IBI installation could be moved to that location as well.

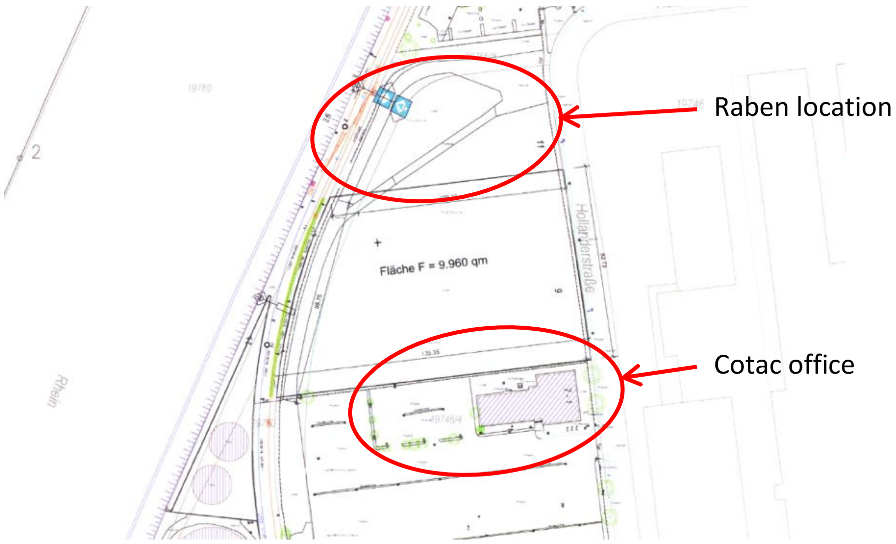


LNG IBI bunker station at the power plant location of ENGIE

Because of the complex situation and low demand for LNG volume in the inland bunker sector at short notice in Rotterdam, ENGIE decided not to proceed with the development in the port of Rotterdam or at Duivelseiland in Dordrecht, also part of the Port of Rotterdam area. The location at the ENGIE power plant at Maasvlakte was also not further developed because the space on the EMO area side could not be made available on short term and the water depth on the south side of the quay was not enough for the target vessels.
Despite the important advantages to develop LNG bunker facilities in a large seaport as Rotterdam the hurdles present are too difficult to take away at that time (2016/2017) to go ahead. In this case the important launching customers LNG volume demand is missing but is crucial to enable to invest in this development but also the port requirements for open access for all competitive LNG suppliers to supply LNG to their customers via this fixed bunker station makes the business case difficult and risky.

7.2.2 Mannheim, development by ENGIE

The location in Rheinauhafen in Mannheim at the Holländerstrasse is made available by the port of Mannheim for LNG development. In the LNG Masterplan project DNV-GL performed a quick scan study for this location and concluded that the location at the Holländerstrasse is available for LNG development.

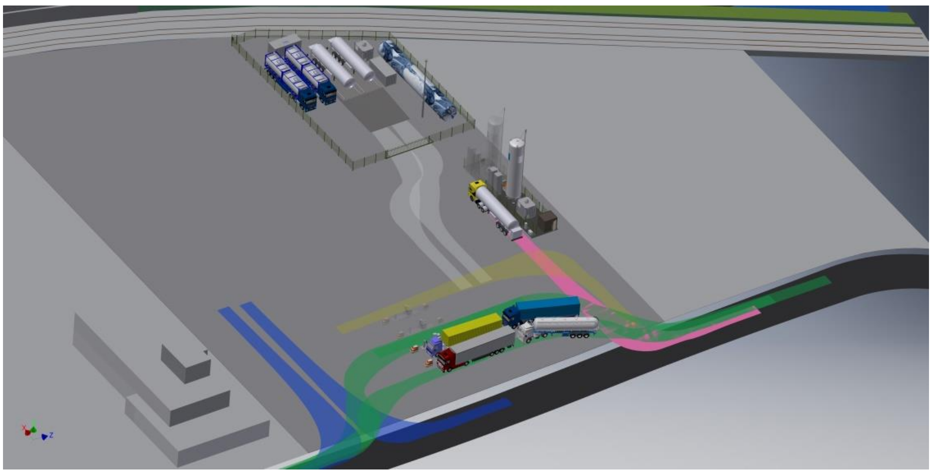


The location in Mannheim at the Holländerstrasse is next to the Cotac location, see above picture. The location on the top side of the LNG location is bought by Raben for future expansion of their existing site.

ENGIE is part of two CEF projects, one is “Connect2LNG” where Unilever is coordinator and 2 LNG fuelling station locations need to be developed in Germany. The other CEF Project is “Breakthrough LNG deployment in IWW transport” where EICB is coordinator and 2 LNG bunker stations need to be developed.
For both CEF projects the location in Mannheim at the Holländerstrasse seems to be suitable. But the location is for both applications too large (LNG bunker and fuelling station) and therefore only partly the location can be used to have an economical feasible business case.

The Total area space of the location is 9960 M2. Cotac is interested to gain part of the location area for necessary expansion of the Cotac location. Cotac wants to expand their location for logistics and storage of ISO containers and Port of Mannheim are focussing on the development of LNG for trucks and ships at this location. The total size of the location for LNG development is 9.960 m2 and the costs for rent for the whole area will have a too negative impact on the business case for LNG as fuel. Since Cotac is also interested to use (part of) the location ENGIE discussed with Cotac and Port of Mannheim to find the best layout /space dividing in able to share the location optimal with the neighbour Cotac (Hoyer group), see picture below.

Combined LNG bunker and LNG fueling station
Area needed = ~ 4530 M2 including entrance and exit to the site from Holländerstrasse,
Area of ~ 5430 M2 available for Cotac;



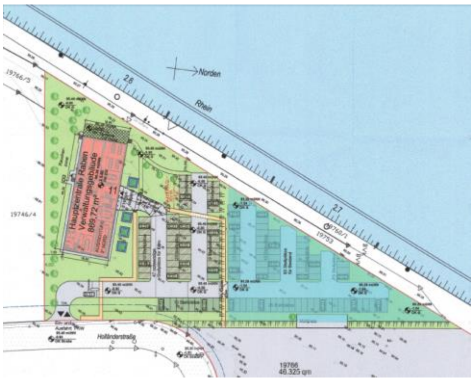
The LNG bunker & Refueling station are positioned at the right side of the location to enable optimum spacing of the location for Cotac and to ensure the necessary distance of at least 50 meters to the Cotac office building.
Entrance and exits of the site to the Holländerstrasse can be shared with Cotac what will result in reduction of needed area space.

The spacing plan has been discussed with Cotac and the Port of Mannheim in the meeting of May 2016, where ENGIE learned that the neighbor Raben intends to build an office unit for future expansion at the right side of the LNG location.
June 2016 ENGIE discussed with Stadt Mannheim the permit process details and the intention of Raben to build an office building, but no information was available at that time.

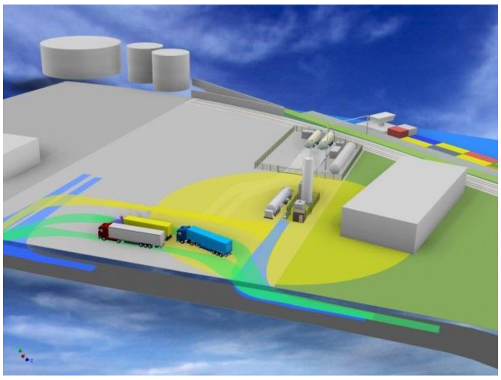
In the period from September – December 2016 information needed for the permit process was still not available. In that period we understood from Port of Mannheim and Stadt Mannheim that no permit request was issued yet by Raben for the office building.

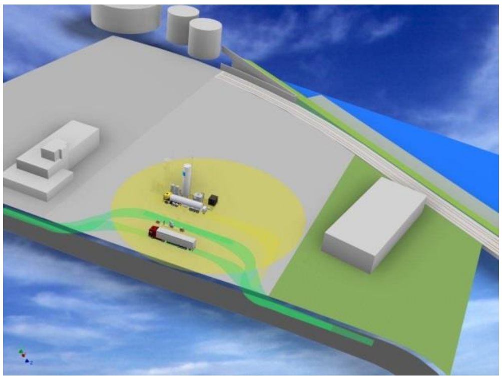
In the same period the rental contract conditions were also negotiated between Port of Mannheim and ENGIE resulting in a “Nutzungscontract” for the period of 01-10-2016 – 31-05-2017, signed by the Port of Mannheim and to be signed by ENGIE at latest on 27-01-2017 as indicated by the Port of Mannheim.

Finally in January 2017, ENGIE received the necessary information after consulting different stakeholders about the office building of Raben. The information directly received from Raben stated a fully permitted office building, see picture below;



The information received from Raben indicates that a new site layout is needed because the office building will be located to close to the LNG installation, and will be in the location-specific risk contour of the LNG installation, as show in below picture.
The office building of Raben is suitable for accommodating 150 employees and is therefore a vulnerable object that is not allowed in an LNG installation risk contour. The need has now risen to move the LNG installation away from the office building to the middle of the site as shown in below picture.





With this new information ENGIE needed to consult the Port of Mannheim, Cotac and the authorities again to indicate that the presented LNG site layout should change if Raben wants to build their office building at the location as shown above.

ENGIE visited the location at the Holländerstrasse later in January 2017 and learned that the build of the office building of Raben was already started, at least a few months ago (Sep.– Oct. 2016), see below pictures:

The perspective of the site and value of the site for LNG as fuel development has changed with this new information regarding the build of the office building of Raben.
The layout of the site, the LNG installation plot plan and the spacing of the site between Cotac and ENGIE turns out to have a negative impact on the spacing and area needed by Cotac and the larger area needed by ENGIE, in order to create a necessary safety distance between the LNG installation and the Raben office building, resulting in higher rental costs with a negative impact on the business case. For the realization of an LNG bunker station the business case became unclear and might not be possible taken into consideration the larger safety zones necessary and the spacing possibilities of the site between ENGIE and Cotac.

Before signing of the rental contract between ENGIE and the Port of Mannheim for the site at the Holländerstrasse in Mannheim additional research is needed. Therefore the possibilities regarding safety distances and spacing of the site are discussed with DNV-GL in Berlin in February 2017.

DNV GL – Reported the Safety Distances for the proposed LNG installations,

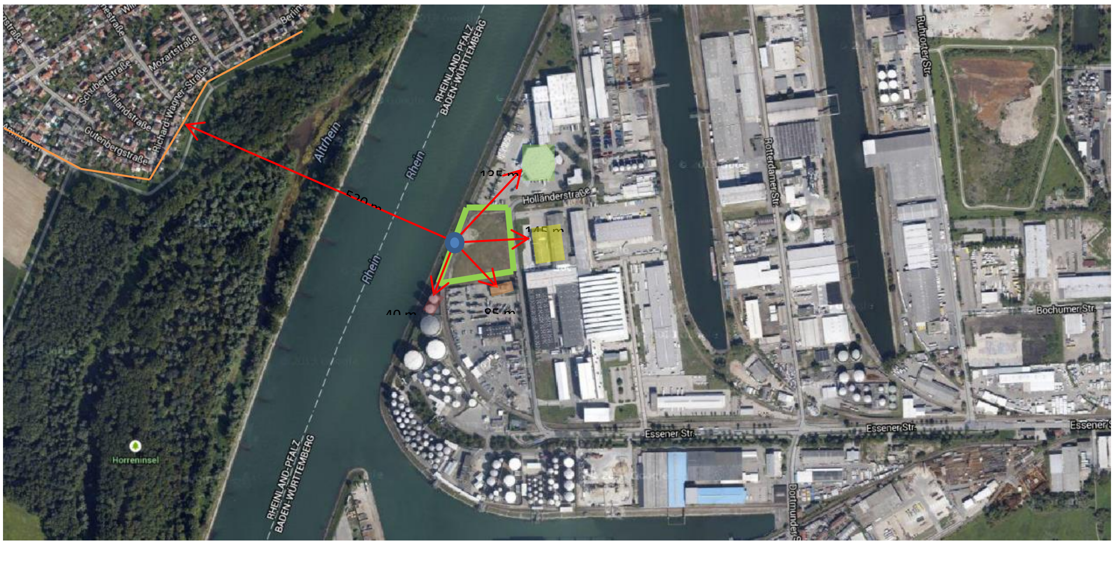
The following review focuses on the specific location selected by the Port of Mannheim and ENGIE for the LNG development planned in the port of Mannheim (Holländerstraße) next to Cotac and Raben sites and is based on the results summarized in the DNV GL reports:

- PP109062-9, Rev. 3 (LNG Masterplan for Rhine-Main-Danube – Safety and Risk Assessment)
- P127076-2, final (LNG bunkering in port of Switzerland and Mannheim – Risk Assessment)

First of all it needs to be pointed out that according article 12, paragraph 1, sentence 3 of the European Seveso II Directive the member states need to ensure that a minimum distance is given between operations that are regulated by the Seveso II Directive on the one hand and on the other hand residential areas, public buildings and areas, important transportation routes and recreation areas and sensitive areas with regard to environmental protection needs.

The German 'Störfallkommission' prepared guidelines in 2005 for implementing article 12 of the Seveso II Directive on land use planning and ensuring the necessary distances between major hazard establishments and vulnerable objects. The requirements of Seveso were transposed in the German law primarily through Article 50 of the Federal Immission Control Act (BlmSchG) and by amending Article 9 of the Federal building code (Baugesetzbuch, BauBG).

The area where the LNG installation is planned belongs to port of Mannheim with several other industrial operations. The planned location is shown in the subsequent figure (green lined box). The distance to the first building in the north (green box, Raben location) is approx. 135 m from the assumed location of the LNG tank. In east direction the closest building (yellow box) is located 145 m from the LNG tank. In south east in 85 m a building (orange box, Cotac office) and in south west in 40 m two tanks (red box) are shown on the satellite picture below. The closest residential area is located on the other side of the River Rhein, at about 520 m.



The selected area for the LNG installation is surrounded to the north, east and south by industrial area that belongs to the Port of Mannheim and on the first glance seems to be therefore no sensitive area according the description given in article 12, paragraph 1, sentence 3 of the Seveso II Directive.

Action: ENGIE needs to double-check together with the local authority whether the Raben and Cotac location within the port of Mannheim is a sensitive area according Seveso II Directive. In case the Raben and Cotac location is no sensitive area, no safety distances according KAS 18 needs to be applied. If it is decided that Raben and Cotac sites are sensitive and regulated by Seveso II Directive safety distances according KAS 18 needs to be applied.

In the above described case the closest vulnerable area (zone with special protection needs) according to article 50 BImSchG is more than 200 m away (in this case about 520 m). To measure the distances on the map, it has been assumed that the actual tank dimensions can be neglected (in principle, the required distance should be measured from the tank edge closest to the protected area).

As discussed in the above quoted reports for LNG (or methane) safety distances are currently not yet categorized in the KAS-18 guideline. **However, 200m would be the most credible safety distance class for LNG installations if no information would be available (with information it can be possible to recommend distances less than 200m for LNG installation).** The office building of Raben will always be within the recommended safety distance of 200 m and most likely also within a safety distance of 30 meter.

For the calculation of safety distances with information within the land-use-planning (LUP) process the loss of containment of the entire inventory caused by a catastrophic rupture of the tank or a very large connected pipeline shall be not considered according KAS-18. These events are not considered because such events are too unlikely assuming the implementation of the best available technologies.

Guidelines specifically intended to determine safety distances for an LNG installation have been published in the past but have since become obsolete. The TRB 801 Nr. 25 contains (in Appendix “Flüssiggaslagerbehälteranlagen”) safety distances for different types of LNG tanks and different connection sizes. These distances (see Table 3-6) can be used when the requirements described in the TRB are applicable. **That means with information it should be possible to recommend safety distances less than 200 m as would most likely be mandated if there is no information, but a minimal safety distance of 30 meters (according table 3-6) is most likely.** It must be noted that the Technical Rules for pressure vessels (TRBs) in Germany are invalid since 1st January 2013 and just partly substituted by other Technical Rules according to the Betriebssicherheitsverordnung” (German law). Some requirements of the TRB 801 Nr. 25 for LNG installations are adopted in the information sheet AD HP 801 (as part of the AD 2000 basic rules), others not, such as the appendix of the TRB 801 Nr. 25 (table with safety distances, see below table 3-6). Nonetheless, these distances (and their calculation background) are still used as an information source although they have no legal validity. The AD HP 801 does not contain any specific requirements related to safety distances. The requirements for the estimation of leak sizes and dispersion have not been adopted.

Table 3-6 Table with safety distances for LNG installations adopted from /22/ (no legal validity)

Group/ type	Capacity in t	Max. permissible connection size (DN)	Safety distance (m)
0 storage vessel	< 3	32 50 80	20 30 40
A storage vessel (withdrawal from the gas phase)	≥ 3 to ≤ 15 > 15 < 200	50 80 100	30 40 50

Group/ type	Capacity in t	Max. permissible connection size (DN)	Safety distance (m)
B storage vessel or turnover and distribution vessel (withdrawal from liquid phase)	≥ 3 to < 30	50 80 100	30 40 50
C storage vessel (withdrawal from liquid phase)	≥ 30 to < 200	80 100 125	40 50 60
C turnover and distribution storage vessel (withdrawal from liquid phase)	≥ 30 to < 200	80 100 125	40 50 60
D storage vessel or turnover and distribution vessel (withdrawal from liquid phase)	≥ 200	80 100 125	40 50 60

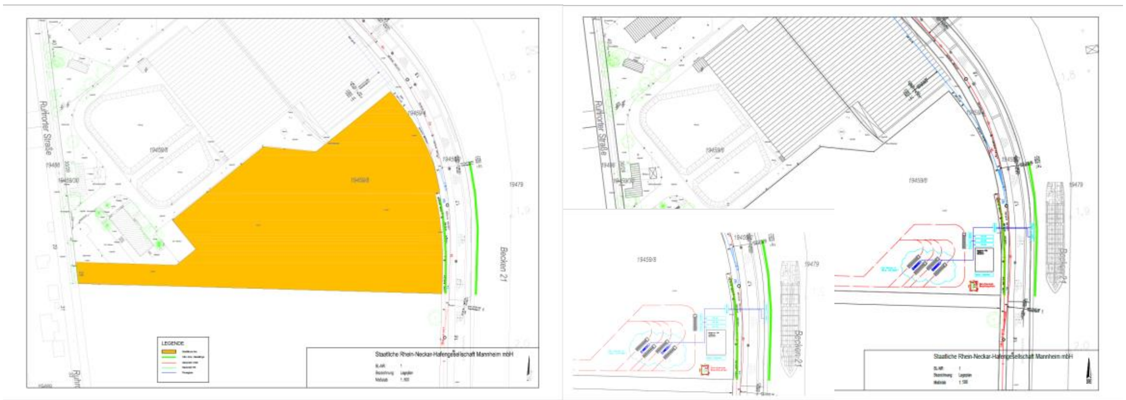
The review of DNV-GL confirmed ENGIE's assumptions and it was decided by ENGIE that the risk would be too high to pursue the development of LNG fueling and bunker infrastructure at Holländerstrasse.
ENGIE connected with the Germany (Berlin) based company LIQUIND to discuss possible cooperation between the two companies since LIQUIND received also an EU CEF- grant for LNG infrastructure development in Mannheim and Duisburg. Via this cooperation it would still be possible to setup an LNG bunker and fueling infrastructure in the port of Mannheim.

ENGIE discussed the decision to stop the development of Holländerstrasse location with Port of Mannheim and to go forward to develop another location in the port in cooperation with LIQUIND.

7.2.3 Cooperation ENGIE LNG Solutions & LIQUIND

LIQUIND is a Berlin-based company, founded in 2015. LIQUIND aims to build up an European-wide distribution infrastructure for LNG with the primary focus to supply inland navigation and heavy road traffic with LNG via distribution terminals along the German inland waterways. LIQUIND's main focus is to set-up an open excess LNG distribution infrastructure, but not to trade any volumes of LNG. LIQUIND has identified and contracted potential plots in Duisburg und Mannheim. Within the Connecting Europe Facility (CEF) Program of the European Commission, LIQUIND has received also a grant to set up small-scale LNG terminals in the port areas of Duisburg and Manheim in order to supply inland navigation (bunkering) and heavy road traffic (fuelling) and storage to re-distribute LNG.
ENGIE LNG Solutions is amongst others active in the field of storage and fuelling /bunkering of LNG for the road haulage sector and the shipping industry. ENGIE has the same focus as LIQUIND to build LNG infrastructure. The cooperation between ENGIE and LIQUIND will enable new distribution channels, with this infrastructure, to increase downstream LNG sales.

Both ENGIE and LIQUIND agreed to jointly develop the LNG-as-fuel market for trucks and ships in Germany, including the development of the end customer base and the development of the required LNG fuelling facilities, in particular in the ports of Duisburg and Mannheim.
ENGIE and LIQUIND will use in first the capacity contracted by ENGIE's launching customers but also allow to hold LNG infrastructure open for third parties which may be involved in the cooperation in future. With this cooperation between ENGIE and LIQUIND we were able to secure the development of LNG infrastructure in Mannheim but also in Duisburg. Of course this means that the CEF funding of LIQUIND will be used for these location and the CEF funding of ENGIE will be used for other locations including the port of Antwerp location.



Above pictures showing the location of LIQUIND in Mannheim.

7.3 Selected locations

Locations selected so far for development of an LNG bunker station by the two partners ENGIE and PitPoint in this study are:

- **Port of Antwerp by ENGIE**
- **Cologne by PitPoint**
- **Duivelseiland Dordrecht by PitPoint**

The process of selection of these locations is described in this chapter. As mentioned before, the most important drivers for selection of a location are explained in chapter 6.3 and the final conclusion how and which driver impacted the decision for the best locations are explained in chapter 10, conclusion.

The selected locations are the results of the first development of the two partners and a fourth location can still be selected when new information will become available.
The locations are selected based upon the criteria mentioned in chapter 6. Not all criteria are relevant or decisive for selection of the locations and therefore it is difficult to address a location as 'best location'. Drivers for this decision can change over time what can cause other drivers to become more important or decisive for selection of a 'best location'.

In principal we can say that the main sea ports are the best locations because of the larger number of vessels sailing in those areas and the relative lower logistics cost component in the LNG price compared to the location more upstream. But some drivers can be more important for other locations and more decisive what makes the locations more favourable for development of an LNG bunker station.

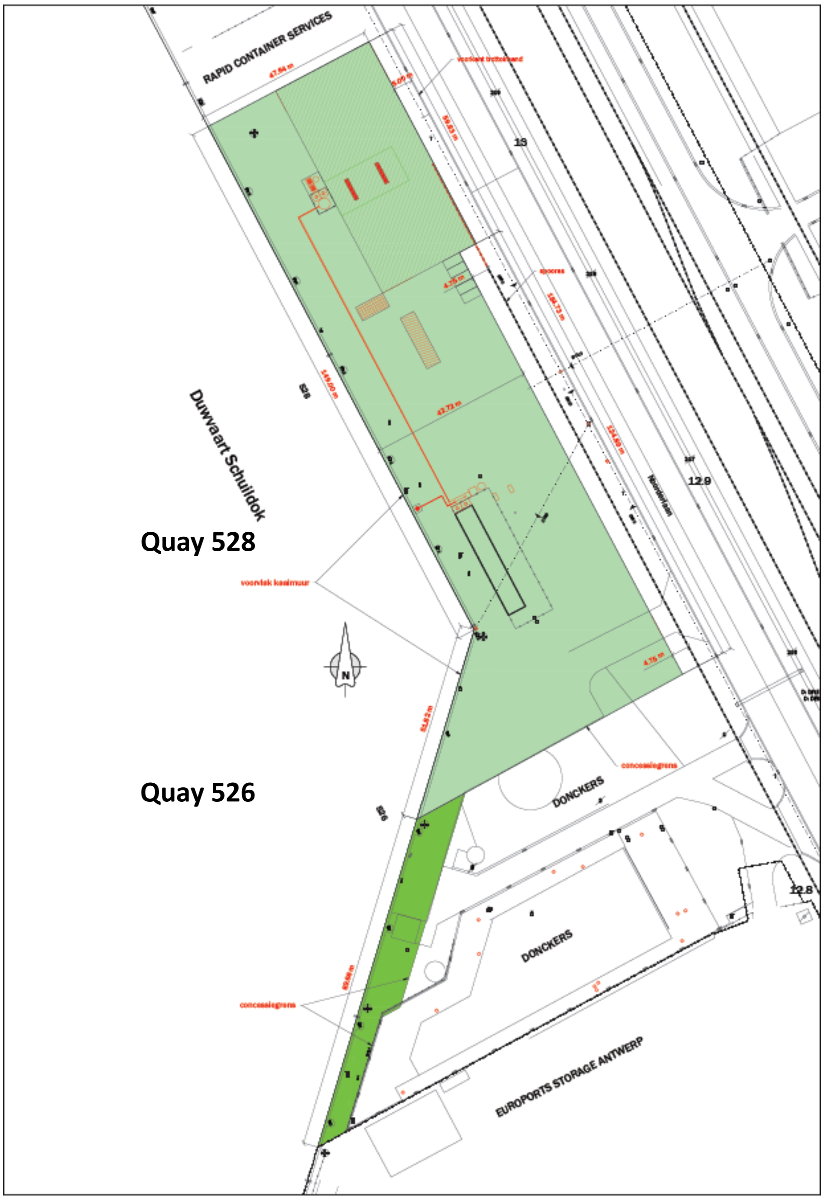
The important drivers that where decisive in the selection process, are explained more in detail in chapter 8 and 10.

7.3.1 Port of Antwerp, development by ENGIE

ENGIE LNG Solutions obtained the concession for 30 years, for the location at quay 528/526 at Noorderlaan (along Canal Dock B2) in the Port of Antwerp from a public tender of the port of Antwerp as shown and explained in below, to operate an LNG bunkering system at K528 in the port of Antwerp.

The Location

The LNG installation intended to build and operated by ENGIE on an area of approximately 8,863 m2 located at the Noorderlaan, at quay 528 (along Canal Dock B2) in the Port of Antwerp as coloured in below concession plan (the 'concession area');



	Oppervlakte concessie	ca 8.863 m²
	Oppervlakte inbegrepen in concessie	ca 1.656 m²
	Oppervlakte mogelijk latere uitbreiding	ca 774 m²

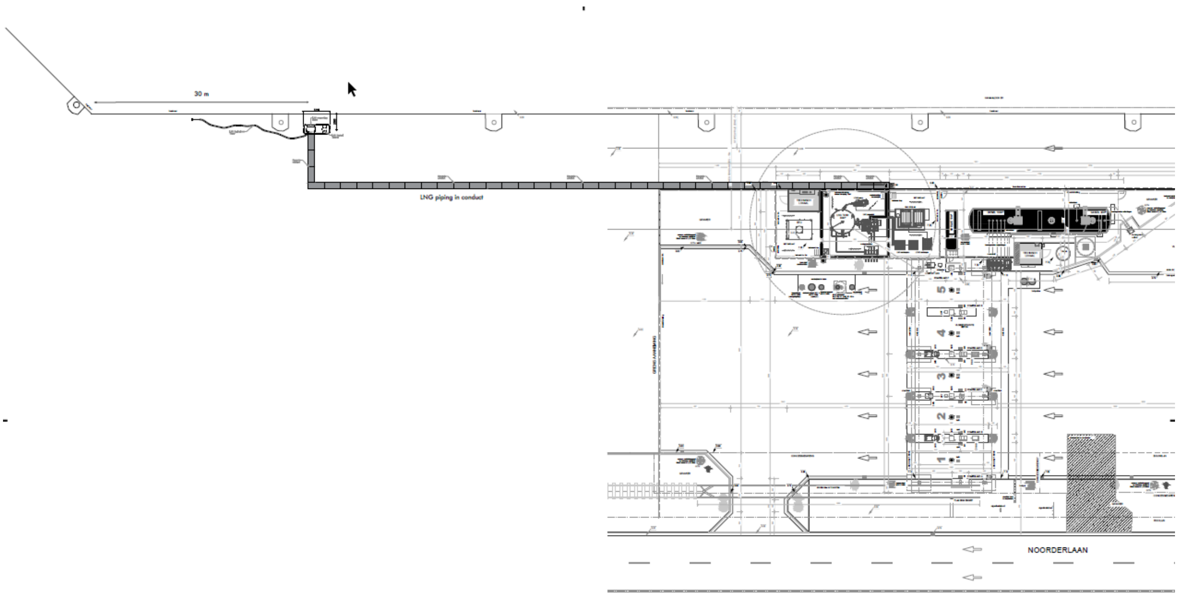
Quay 528 is the most important part of the concession terrain where the LNG bunker- and fuelling station will be placed. The final size of the overall concession site is part of Quay 528 + Quay 526 (extension southern part) and extension (northern part) by shortening the railway track. The site of quay 528 will be divided in a public part for the LCNG /Diesel fuelling station, free accessible and a private part for the LNG bunker station that will be fenced as a restricted area, access by means of registration and authorization.
For the public fuelling station additional one entrance and one exit are foreseen of each 7 meters wide. The railway track, located between road and site in the northern part of the terrain will be shortened with at least 30 meters in order to facilitate a better entrance to the site from the Noorderlaan. The restricted (fenced) bunker station area will have at least two access gates and one emergency gate. The access from the public area of the fuelling station to the quay (water) side will also be fenced and foreseen of one access gate to restrict an area of at least 10 meters wide from the water side to the public area in order to comply with local port regulations and firefighting regulations.

In below you will find an artist impression of the intended installation on site and its main installation parts.

The LNG infrastructure will facilitate bunkering, transfer and fuelling of LNG. It will allow LNG bunkering of all types of inland vessels, smaller short-sea vessels, dredging and towage vessels. In addition to the bunkering station, a public fuelling station for LNG & CNG trucks is foreseen to be deployed in combination with a diesel fuelling station build and operated by our partner G&V.

As a result of continuous changing business environment, the decision was taken to investigate the option to change the scope from a land based LNG bunkering installation to a floating LNG bunkering solution; an inland LNG bunker pontoon. In connection to the concession location ENGIE LNG Solutions intents to build an LNG bunker pontoon for LNG bunkering alongside seagoing vessels and an on-shore modular LNG bunker /fuelling station for LNG bunkering of inland and port related vessels at quay 528 and fuelling of heavy duty trucks in the Port of Antwerp at Quay 528, Noorderlaan Port of Antwerp.

In below the basic layout is shown of the on-shore bunker /fuelling station intended to be built at quay 528 and its main installation parts.



ENGIE LNG Solutions and Fluxys NV/SA joined forces to cooperate for the design, investment and operation of the LNG bunker pontoon solution in the Port of Antwerp.

The on-shore bunker /fuelling installation will be built and operated on the quay area 528. The LNG bunker pontoon will use the concession location quay 528 as berth location and in idle situation the pontoon will be moored at the concession location.
The site of quay 528 will be divided in a public part for the LCNG /Diesel fuelling station, free accessible and a private part for the LNG bunkering that will be fenced as a restricted area, access by means of registration and authorization and guarded by CCTV.
In combination with the LNG bunker /fuelling station, a public diesel fuelling station will be deployed in and operated by our partner G&V. In total a maximum of 136 tons of hydrocarbon fuels will be stored, not exceeding the 200 tons SEVESO limit, of which ~100 tons of diesel and ~36 tons of LNG in one fixed vertical LNG storage tank of ~ 80 M3 for the on-shore bunker /fuelling station.
The LNG bunker pontoon will have storage of ~ 1.000 M3 or ~ 450 tons of LNG stored on board divided over two c-type vacuum insulated horizontal placed cargo tanks of ~ 500 M3 each. In order to perform a zero venting policy a boil-off gas management system will be implemented for

the on-shore bunker /fuelling station, also suitable as a combined integrated system in the on-shore station, for possible boil-off management of the LNG bunker pontoon.

The LNG bunker pontoon (floating unit) is to be used to transfer LNG as fuel or to bunker LNG to client vessels alongside as the customer may require and is suitable for:

- Navigating and sailing in the port by means of a certified push boat
- Moored in idle situation at quay 528, the berth location of the pontoon
- Bunkering of Inland and port related vessels while moored at quay 528 POA
- Bunkering of (small) seagoing & dredging vessels alongside client vessel (SIMOPS)

The non-self-propelled LNG bunker pontoon shall be suitable to be moored at quay 528 in the Port of Antwerp, and is equipped for inland water navigational services pushed or towed by a suitable push boat to/ from its berth location, quay 528, within the port.

The PONTOON including its machinery, equipment and outfitting will be designed and constructed and build for LNG bunker operations in accordance with applicable rules of IMO – IGC code, ADN and regulations (edition and amendments thereto as of the date of signing of the contract) of the Classification society and under special survey of the Classification society's surveyors and be distinguished in the register by the symbol of Bureau Veritas for inland water services and limited trade in the Port of Antwerp – Zeebrugge:

The pontoon will be equipped with an LNG bunkering system suitable for bunkering inland and short sea going vessels, in the port of Antwerp. The LNG cargo tanks of the pontoon can be filled either by LNG tank trailer trucks and bunker / Feeder vessel at quay 528 in Port of Antwerp or at the small-scale LNG jetty at Fluxys terminal in Zeebrugge.
The pontoon is equipped to navigate through the port of Antwerp by a push boat and is suitable for inland navigation from Port of Antwerp to Fluxys terminal in Zeebrugge via the Gent-Brugge-Oostende Boudewijn canal for loading LNG in the cargo tanks.

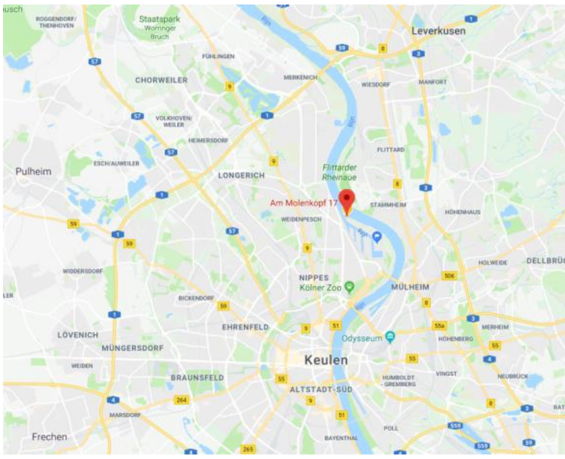
Below an artist impression of the intended pontoon is shown

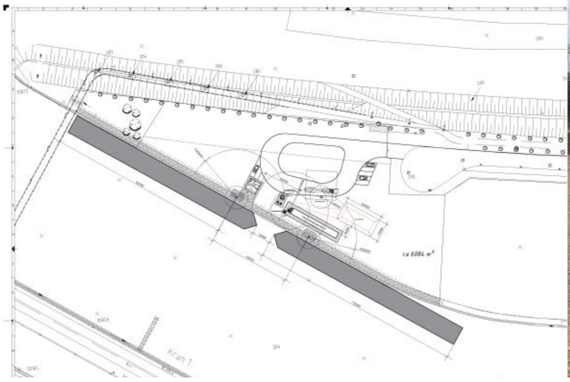
7.3.2 Cologne, development by Pitpoint

One of the LNG bunkering location selected by PitPoint is Cologne. The main reason for selecting this location is the fact the launching customer Shell is introducing 15 LNG powered tankers. Shell Trading Rotterdam BV (Shell) has signed a time-charter agreement with Plouvier Transport NV and Intertrans Tankschiffahrt AG for 15 new inland dual-fuel barges, which will predominantly run on LNG. These state-of-the-art barges, built by the Dutch shipyard VEKA Shipbuilding BV, will support Shell's growing business in trading and transporting mineral oil products in the ARA (Amsterdam-Rotterdam-Antwerp) and Rhinetrack (Germany/Switzerland) regions. This investment underlines Shell's confidence in LNG becoming a bigger part of the global transport fuel mix and supports the development of a new European LNG marine fuel industry for inland and coastal vessels.

The 110 metre long barges have been designed for improved environmental performance, safety and optimal cargo carrying capacity in various water conditions. Their main engines provided by Wärtsilä will run on 95- 98% LNG fuel with a small proportion of diesel used for ignition.

These tankers will mainly operate from the Shell refinery in Cologne. At the refinery itself there was not enough space available to realise a bunkering station. In the surrounding area was searched for a suitable location. In the harbour of Cologne a piece of land was available and suitable for the realisation of a LNG bunkering station. The sailing pattern study showed that 164 of the 283 tracked ships are passing Cologne. That is about 60 % of the target ships. The average consumption of these ships is about 700 m3/year. About 60 ships are tankers, comparable to the ships which are introduced by Shell. See chapter 6.2 for more details about this study.






The site is capable to handle two 110 meter long ships at the same time. However the realisation first is focussing on one bunkering slot, while the number of ships is still limited. However for the permit application two bunkering slots are requested.

The permit application is a time consuming activity. A lot of documents have to be prepared before the official permit application can be made. For example a HAZOP study has to be executed to identify the possible risks and mitigations, a safety management plan has to be submitted, a fire protection plan has to be set up, a noise plan, the safety zones has to be calculated, an investigation about unexploded items as remaining's of the 2nd world war, etc. In Germany a lot of authorities have to agree upon the realisation of the bunkering station. Therefore an German based consultant is hired to support the permitting process. Before the official application for the permit is submitted, the permit is reviewed by the TÜV. After approval by the TÜV the application for the permit can be submitted to the local government. It is expected that the official application will take a half year and is to be expected week 45 2018.

The capacity of the bunkering station can grow with the market demand. It is expected that in the beginning on average one ship per day will bunker. The LNG storage of the bunkering station has an capacity of 200 m3, which is capable to refuel 4 ships directly. The supply of LNG is brought in by truck, while it is the most economical option at the moment. In chapter 8 more explanation is given about the economics of fuel supply to the bunkering station.

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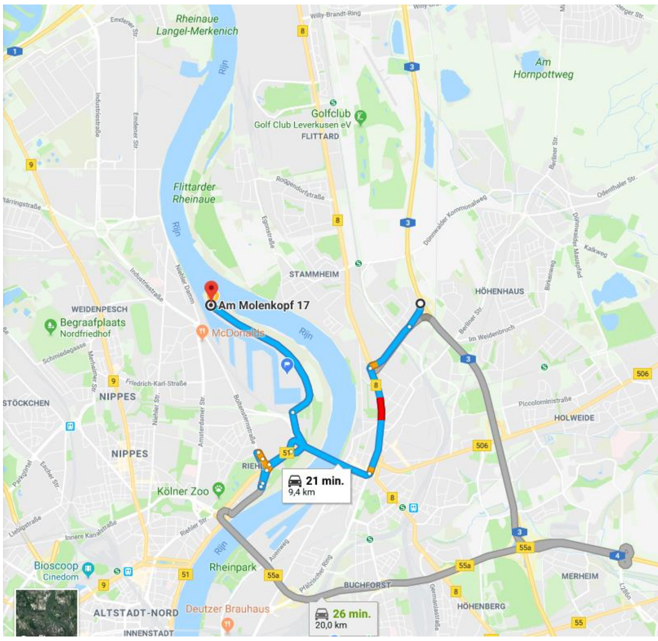
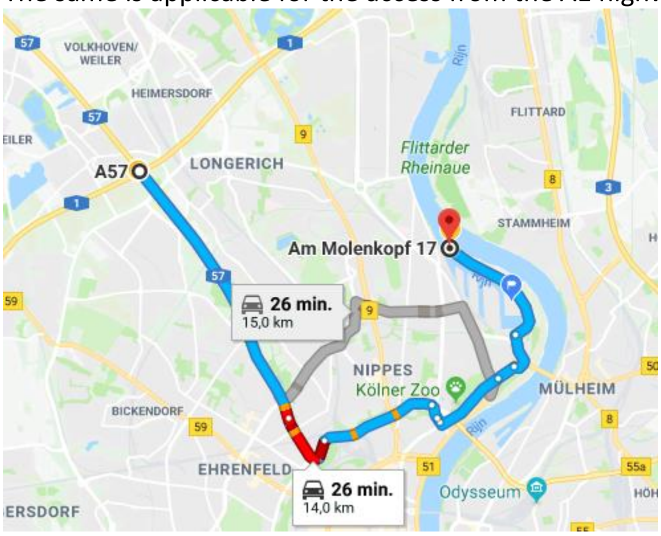
No LNG dispenser for trucks will be realised in Cologne. Due to the remote location at the end of the harbour the site is difficult accessible by trucks. The site is not near a highway or a distribution centre for goods. Also the access roads to the site are not suitable for a lot of trucks. Therefore it is not feasible to realize a truck refuelling dispenser at the site.
From the highway A 3 it will take about one hour to refuel, 20 minutes' drive without traffic jams, 20 minutes refuelling, and 20 minutes back to the highway.



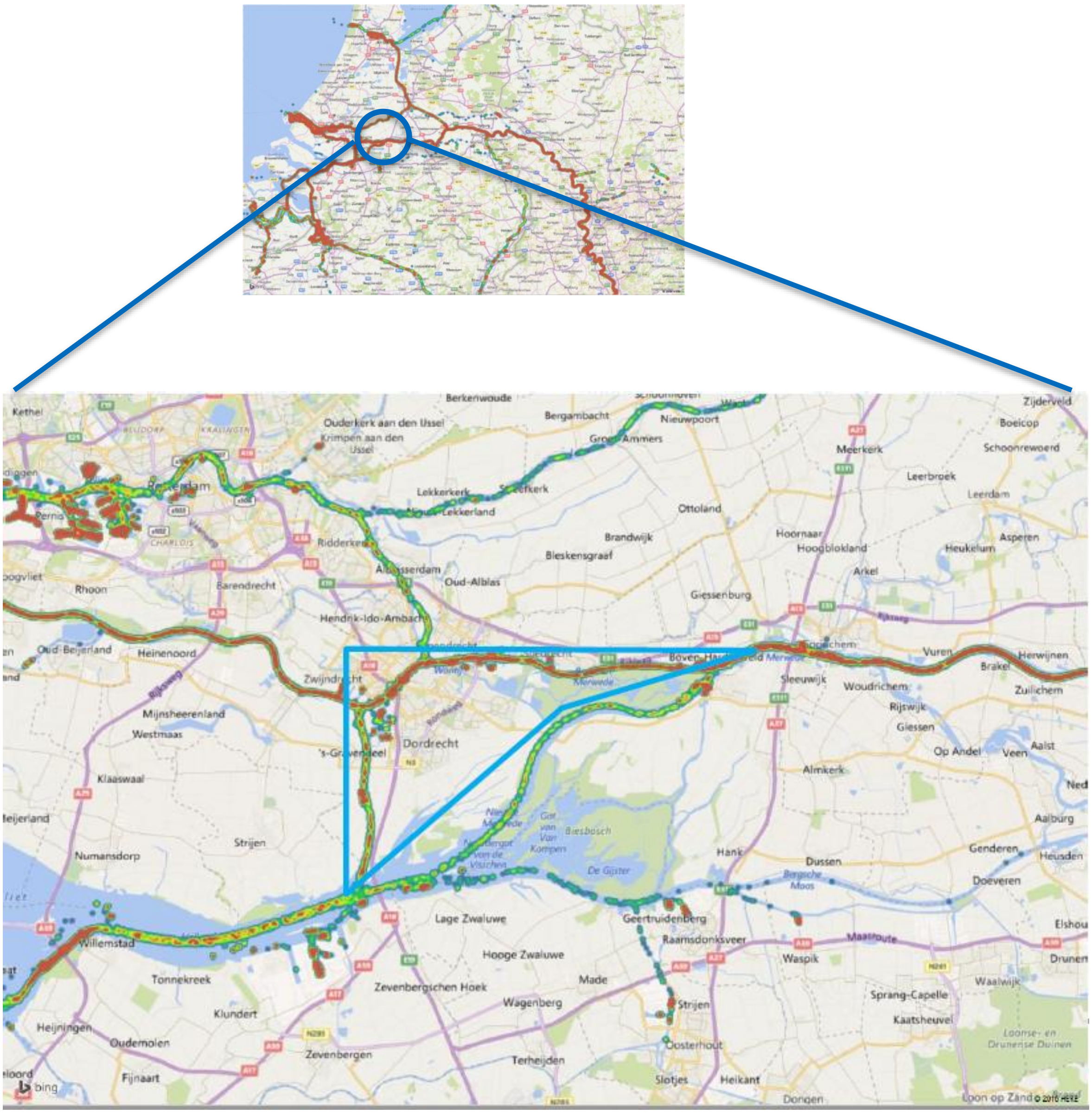
The same is applicable for the access from the A1 highway.



When in the future truck refuelling is needed, it is easy to install, while the design of the bunkering station foresees in the connection to a truck dispenser. There is enough space available at the rented site to install a dispenser for trucks.

7.3.3 Dordrecht (port of Rotterdam), Development by PitPoint

The basis for the selection of the locations are based upon the report: “Heat maps of best locations for LNG bunkering locations, Rotterdam 17 November 2016”
For Rotterdam area the heat map is showing the routes where the ships are sailing which have an average consumption of 500 m3 diesel/year. About 283 ships are tracked with this consumption and 226 passed by Dordrecht. That is about 80 % of the selected target ships. An interesting other information is that the average consumption of the ships is about 750 m3/year, which means that the business case for them more interesting. The investment in this case can be returned within 7 years. The location Dordrecht was selected because it is the crossing of the shipping routes between Antwerp Rotterdam and Amsterdam (ARA) and the route from Rotterdam to Germany and Switzerland.



In co-operation with the port of Rotterdam an area was selected to realise the bunkering station. Besides bunkering LNG to ships, the possibilities are researched to refuel trucks with LNG, but also to make CNG out of LNG also for ships and trucks.

The island has a sustainable goal in the development of the area. Therefore PitPoint proposed to add other activities to the bunkering station, like biodiesel for smaller ships for which LNG is not an economic option. Besides LNG also CNG will be made available for small ships like tugs. Not only the bunkering station will be made available for the maritime sector, also the possibilities for the automotive market are being researched. Together with the Port of Rotterdam a study will be carried out to look for the options for a multi fuel bunkering station. This study will be available beginning of April 2018. Another aspect which will be studied is the possibility to get the necessary permits. As operator of Europe's largest port, the Port Authority sees the establishment of a multi-fuel bunkering station as fitting in with its policy of pioneering European energy transition. It will help us stimulate the replacement of fuel oil by LNG as the fuel for shipping", says Ronald Paul, COO at the Port of Rotterdam Authority.

Duivelseiland in Dordrecht: a unique location
The anticipated location for this multi-fuel bunkering station is the Duivelseiland in Dordrecht where the Oude Maas, Dordtse Kil and the Beneden Merwede meet. Dordrecht Inland Seaport is the most landward sea port in the Netherlands. Laying at the heart of the Amsterdam - Rotterdam - Antwerp shipping area as well the being the starting point for shipping heading towards Germany, it is the perfect location for this kind of bunkering station. Aspects like permits, water depth, quay length, supply of LNG over water and other alternative fuels are researched at the moment. This will result in a multi fuel bunkering station. The planning is that the upcoming month a decision will be taken under what conditions the multi fuel bunkering station will be realised.

8 Analysis and methodology

Different drivers influencing the choice for a location as described in chapter 6.3 can have an impact on the actual retail LNG price needed to be charged to the customer, bunkering at those locations.

To understand the cost impact of a chosen location and the different parts of costs influencing the result on the actual LNG retail price needed for bunkering on the specific location, the LNG retail price is divided into the following main parts:

1) Molecules (sourcing costs, TTF price)
2) Service cost (administration, operational costs & margin LNG supplier)
3) Logistic cost (Terminal, transport & transhipment costs)
4) Location related costs (depreciation investments & rental costs)

Above mentioned (4) main parts of the LNG retail price have more or less impact when a location is chosen for LNG bunkering.

The molecule price (1) of LNG based on the TTF spot, day-ahead, week-ahead or month-ahead price formula is not influencing the drivers for choosing a best location but is important as incentive for switching to LNG as fuel.

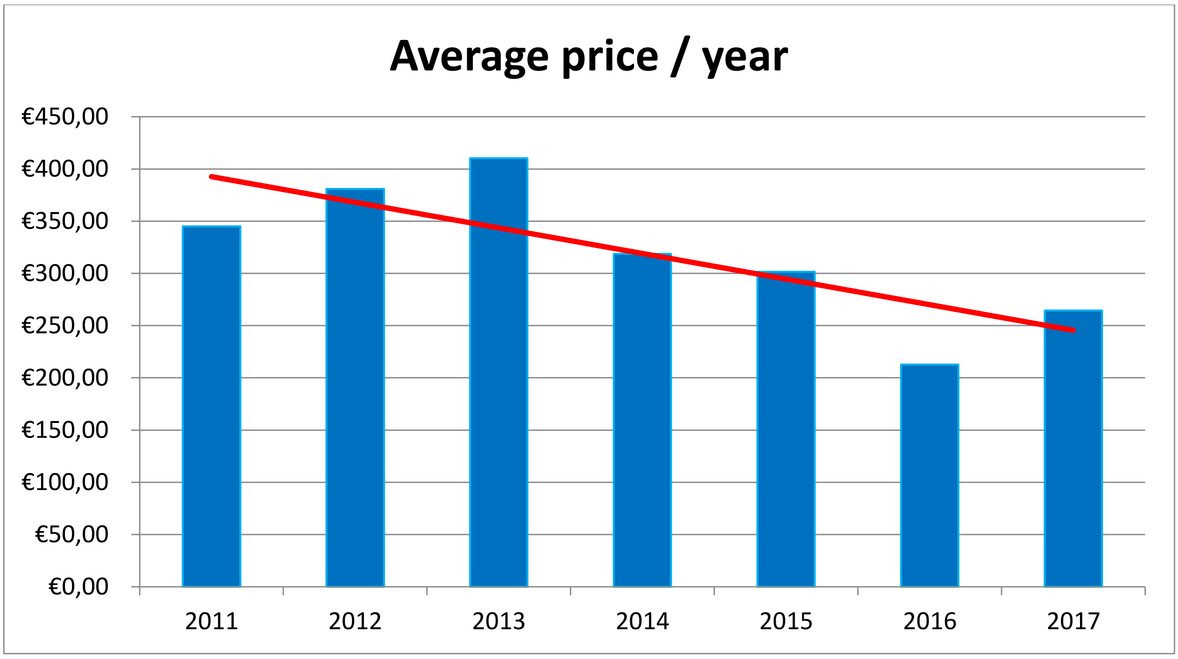
According the TTF spot price table and graph in Annexe 2, the average sourcing price of € /ton for LNG is showing medium fluctuation over the years were the years 2016 and 2017 are showing significant lower average prices indicating a stable pricing over the years and a continuous decline of the sourcing price

In general a lower and stable LNG sourcing price is in benefit of the incentive for ship owners to switch from gasoil to LNG.
On the other hand we have seen also very low oil prices in 2014 – 2017 resulting in a low gasoil price.
Low oil prices are influencing negatively the incentive to switch to LNG because a certain gap between LNG and gasoil prices is needed to pay for the switching costs and investments needed for the ship owner (client) and LNG infrastructure (LNG Supplier) to ensure a positive return on investments.
Of course the LNG supplier or client cannot influence the gap between LNG and gasoil or the molecule pricing, but other parts like logistic costs (3) or location related costs (4) can be influenced by the choice of location or the way the LNG is stored and transported. Fluctuation in the gap between LNG and gasoil is handled mostly by changing the service costs of the LNG supplier (2) because other parts cannot be changed so easily any more when a decision for a location has been made to develop a fixed LNG bunkering station.

This is the reason why the LNG truck-to-ship bunkering for the inland shipping market remains the most competitive way to bunker LNG. Only larger LNG volumes can change this situation.

The average TTF spot sourcing price over the 7 years 2011-2017 is **€ 319, 07** for a ton LNG and is lower than the average sourcing price of 2011, 2012 and 2013.

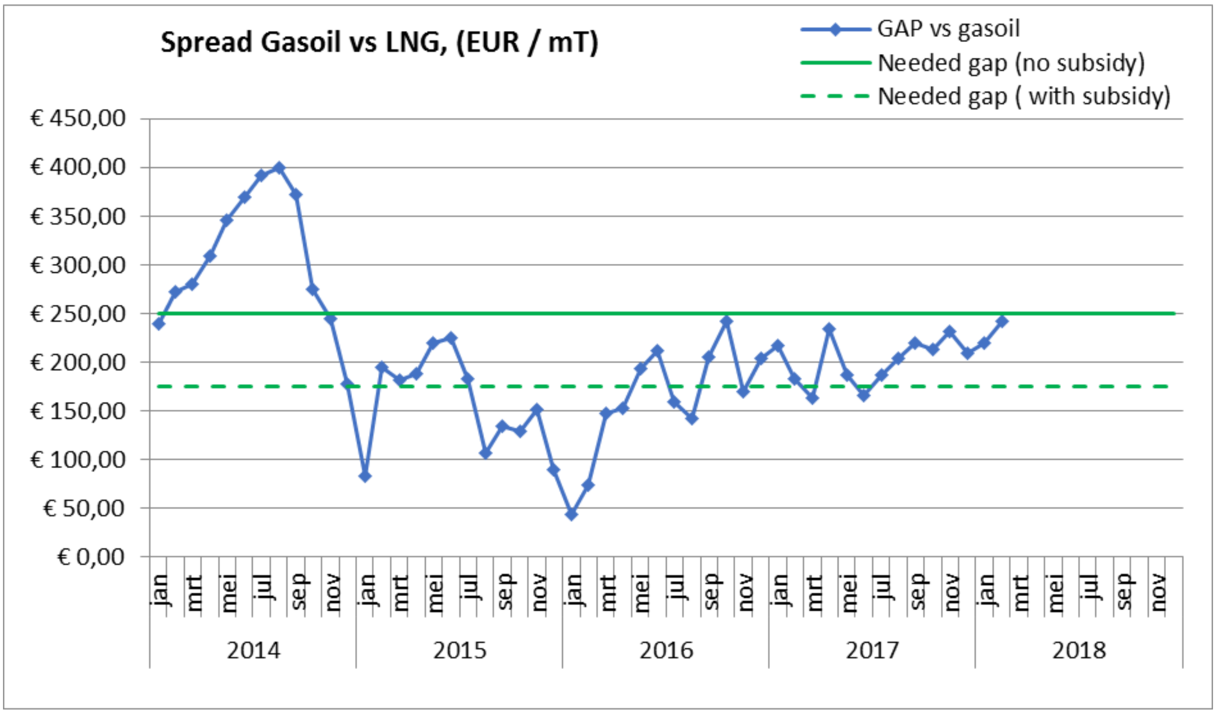
Year	2011	2012	2013	2014	2015	2016	2017	Average 7 years
Average price	€ 345,02	€ 380,77	€ 410,29	€ 318,59	€ 301,60	**€ 212,67**	**€ 264,52**	**€ 319,07**



To have a positive business case for the selected target ships a price difference of at least € 250,-/ton between LNG and Gasoil is needed.
The assumptions for the target ships are:
- A consumption of more than 500 m^3 gasoil /year,
- An additional investment of € 1.250.000,- for the LNG equipment,
- A payback time of 10 years.

Based upon these assumptions the calculations can be made for logistic costs and investment costs related to the location chosen as "best locations".
The actual business case is depending on the actual situation like fuels consumption, type of ship and sailing pattern. The calculations can only show the trend of fuel price development over the past years and the different costs parts of the retail LNG price.

The spread between the Gasoil price and the LNG bunkering price is shown below.
The green line in the graph below shows that needed spread. The blue line is showing that the price development is reaching the needed spread to ensure a positive business case.
In the graph the dashed line shows TCO for ship owners including the CEF subsidy.



In the financial part of the CEF project more details will be given how a positive business case for LNG propelled vessels is ensured and witch drivers are influencing the business case. In this study the focus will be on the logistic costs (3) and locations related costs (4) to elaborate the consequences of a chosen location.

8.1 Logistical costs analysis

In the Rotterdam – Dordrecht – Amsterdam area a retail-price for typical LNG TTS bunkering originated with a certain percentage of logistic costs as well as in the Zeebrugge – Antwerp area.

All other locations chosen more upstream need to compete or comply with the same originated LNG retail price as in the Rotterdam and Antwerp area because the same customers sailing in those areas upstream and to ensure a continuous positive business case for the client.
Other customers not sailing in the Rotterdam and Antwerp area depending on the LNG bunker infrastructure located more upstream probably are prepared to pay more for the same ton of LNG because of the higher logistic costs.

The only way to compensate the higher logistic costs upstream the corridor is to turn over larger volume of LNG in a different modality by using a small inland feeder vessel instead of LNG trucks, transporting larger LNG volumes to a larger storage volume upstream in one-time transhipment. In this way the higher logistic costs can be compensated upstream by using an inland tanker vessel.

When a location is considered for LNG bunkering these aspects are important to take into account.

In the following chapter, modelling is shown the different percentages of costs in the LNG price to different locations and by different logistic and infrastructural solutions.

8.2 Modelling

In this chapter the relation between logistics and the selected locations are explained. Logistic costs is an important part of the LNG retail price and an important driver for a location of an LNG bunkering station.

The model used for logistic cost calculations is based on three different supply solutions (infrastructural solutions) to show the different components of the LNG retail price between the LNG import terminals Fluxys and Gate and the locations studied for selection of best locations.

<u>Three different LNG supply solutions to end customer included in the model:</u>

1) Basic LNG truck tanker to client inland vessel supply (TTS)
2) LNG on shore bunkering station to inland vessel supply, storage filled by trucks (PTS – Truck)
3) LNG on shore bunkering station to inland vessel supply, storage filled by inland feeder tanker (PTS – inland feeder tanker)

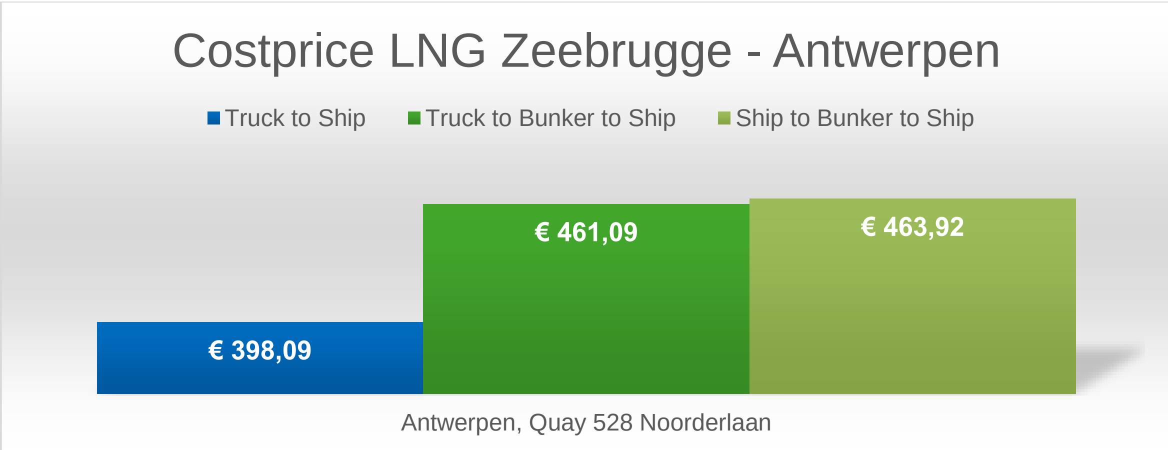
<u>The modelling is done with the following basic assumptions:</u>

1) LNG Molecules
   a) LNG sourcing price based on spot TTF price 12-2017, source Elexis.be
   b) Yearly turn – over of 5000 tons
2) Logistic costs
   a) Assumptions based on general 2017 market prices
   b) Terminal fee / loading /unloading hours and Toll included
   c) OPEX /hours personnel included
   d) Distances from LNG import terminal to a location via road = via waterway
3) LNG Volume
   a) Based on maximum annual technical turn-over of a 250m3 fixed storage
   b) Bunker flow TTS 15 T/h
   c) Bunker flow PTS 35 T/h
   d) Max. LNG volume transported per truck tanker in Germany 17 tons
   e) Max. LNG volume transported per truck tanker in Netherlands & Belgium 21 tons
4) CAPEX
   a) Investments bunker station and inland feeder vessel 100% conservatively
      i) Bunker station ~ 4,5 M€
      ii) Inland feeder vessel ~ 16,5 M€

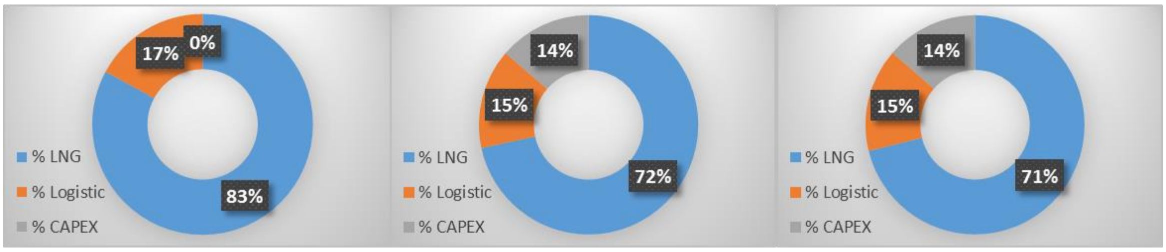
Only the locations selected in this study as ‘best locations’ will be explained and discussed. In this chapter only one location result is shown, the other selected locations are included in Annexe 3. In the model that is build and used for this study more locations are included.

The selected locations modelled on above assumptions results in the following accumulated LNG retail cost prices:

LNG Terminal Fluxys Zeebrugge – bunker location Antwerp, Quay 528



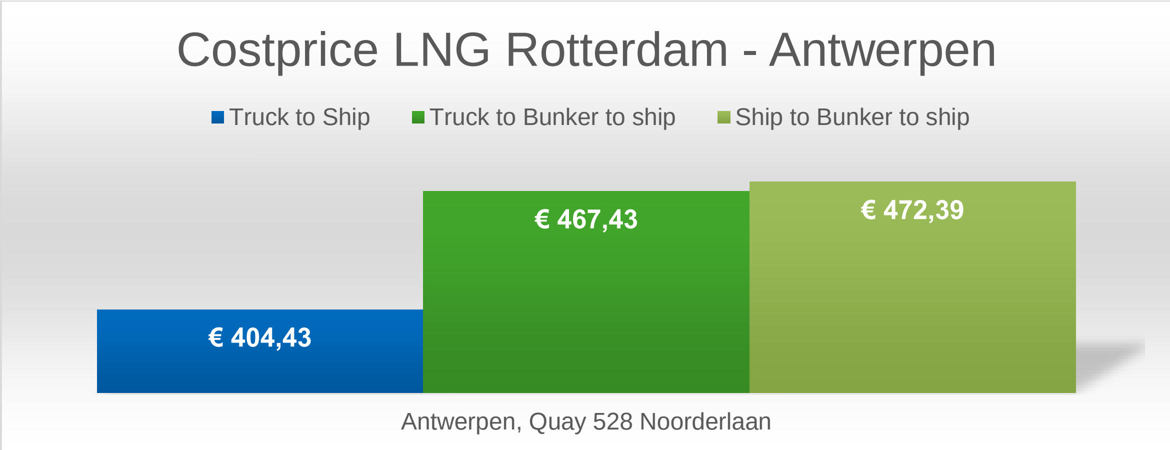
Gap in logistic costs between traditional LNG truck-to-ship bunkering and bunkering from a fixed onshore bunker station filled by LNG tank trucks or an inland LNG feeder vessel is € 63,- to € 66,- per ton.



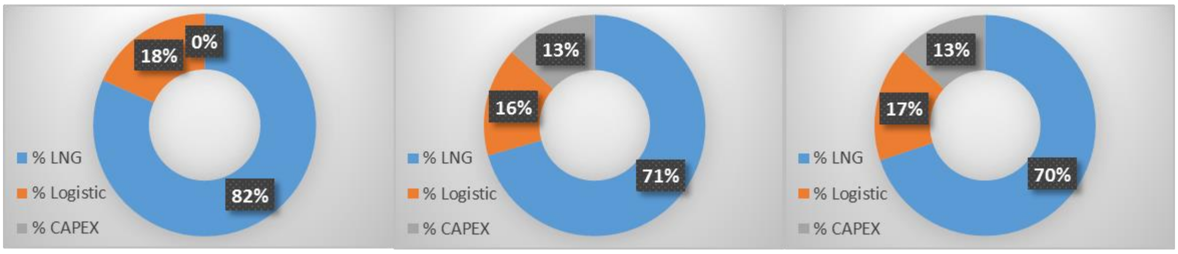
Truck to Ship **Truck to Bunker to Ship** **Ship to Bunker to Ship**

In above pie charts are shown that the logistic costs are respectively 16% or 14% of the total LNG retail cost price for Antwerp bunker location. CAPEX costs shown in the pie 'Truck to Bunker to Ship' is depreciation of investment costs for the bunker station and CAPEX costs shown in the pie 'Ship to Bunker to Ship' is hourly or rent costs of the LNG inland feeder vessel.

LNG Terminal Gate Rotterdam – bunker location Antwerp, Quay 528



Gap in logistic costs between traditional LNG truck-to-ship bunkering and bunkering from a fixed onshore bunker station filled by LNG tank trucks or an inland LNG feeder vessel is € 63,- to € 68,- per ton.

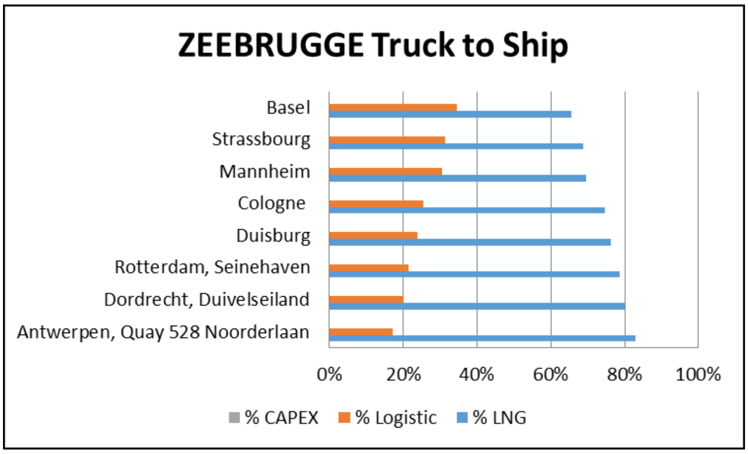


In above pie charts are shown that the logistic costs are respectively 18%, 16% and 17% of the total LNG retail cost price for Antwerp bunker location. CAPEX costs shown in the pie 'Truck to Bunker to Ship' is depreciation of investment costs for the bunker station and CAPEX costs shown in the pie 'Ship to Bunker to Ship' is hourly or rent costs of the LNG inland feeder vessel.

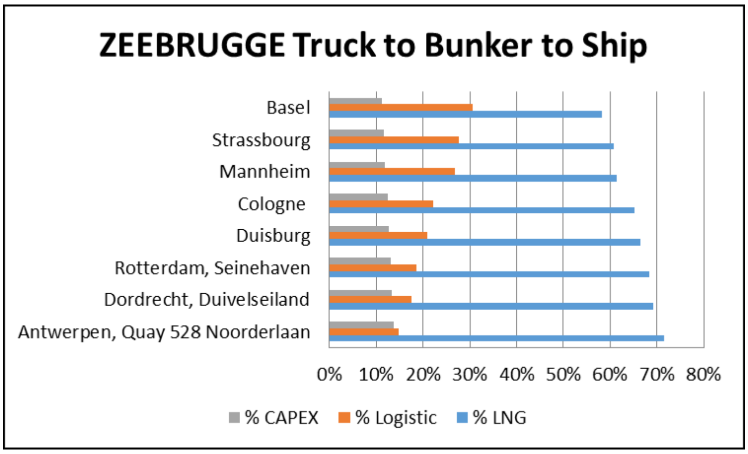
8.3 Results

Based on the above information, we can draw the following conclusions:

- Logistic costs are a substantial part of the LNG cost price and will influence choice of location
- CAPEX for a bunker station or inland feeder vessels has the same impact in the LNG cost price as the logistic costs for locations nearby the LNG import terminals
- CAPEX impact on the LNG cost price becomes (much) more positive related to the logistic costs when the location is based more upstream.
- Logistic impact of filling the bunker stations by LNG tank trucks is the same or higher when filled by an inland feeder vessel.
- Locations further upstream become more competitive when filled by inland feeder vessel compared to the cost of filling with tank trucks.
- When turnover of LNG will develop linear higher than 5.000 tons /year for a location the CAPEX impact of the bunker station or inland feeder vessel becomes less relevant and impact of these costs will decrease in the LNG cost price where the impact for logistic costs using tank trucks for filling the storage of the bunker station remains the same, see also below graphs.

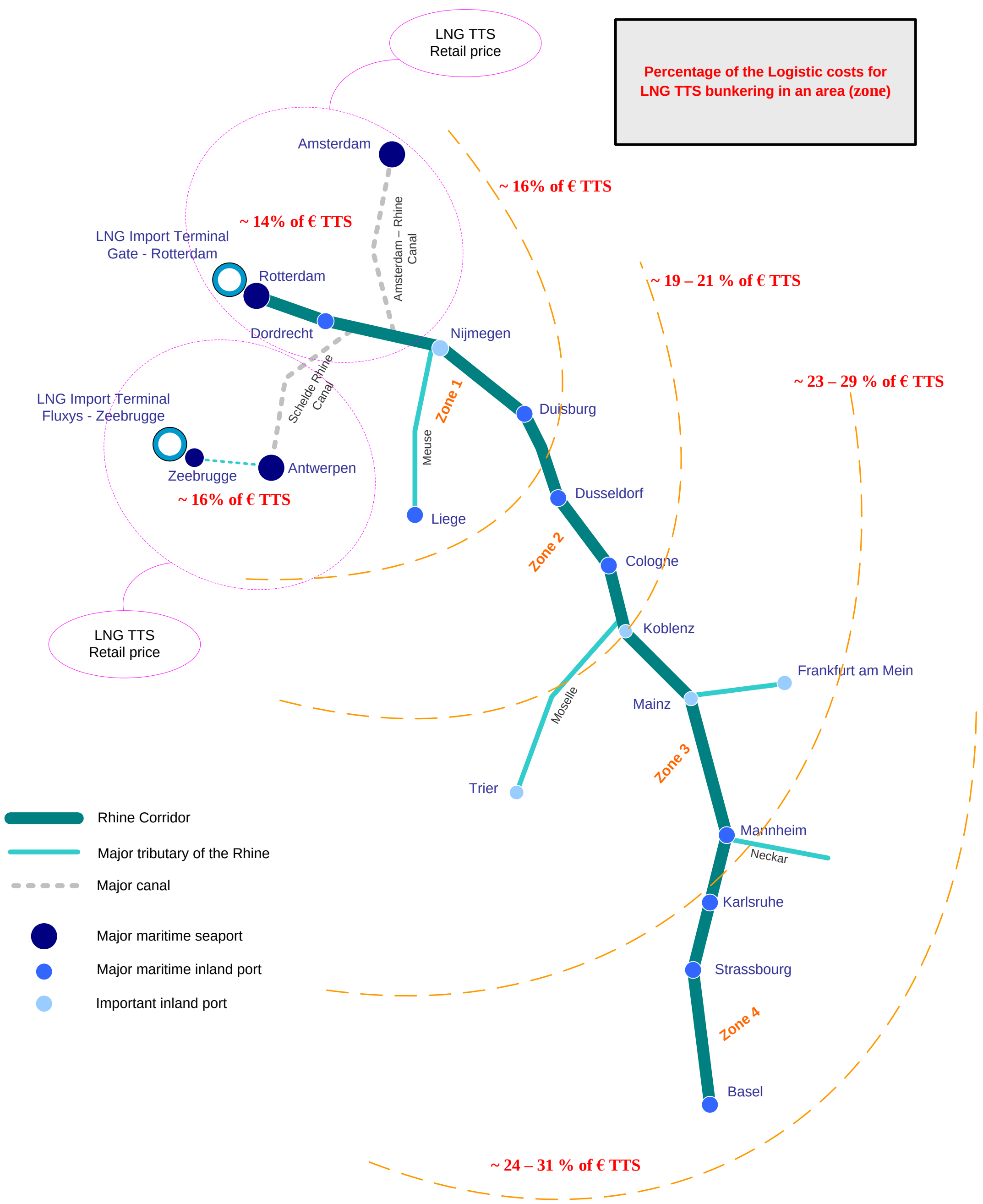


This graph shows the total overview of all logistic costs TTS from Zeebrugge terminal to all locations calculated in the model.



This graph shows the total overview of all logistic costs PTS from Zeebrugge terminal to all locations, storage filled by tank trucks, calculated in the model.

As result of the modelling described in chapter 8.2 the percentage of logistic costs of the retail LNG price calculated is shown in below picture for the different areas (zones). Logistics costs (3) will of course be higher when supplied to a client on a larger distance from the import terminals (upstream) Gate and Fluxys as indicated in the different zones in below picture.

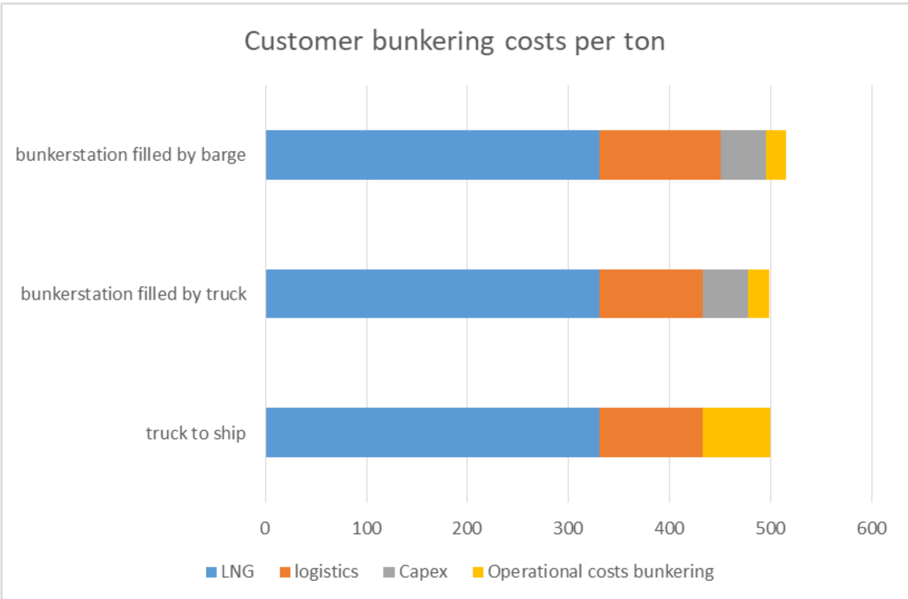


Operational costs of the client for bunkering are not included in the model and therefore the benefits for a client to bunker at a fixed bunker station instead of a traditional truck to ship bunkering are not shown.

For potential customers it is important that costs for bunkering are the same downstream and upstream. On the other hand we have seen from the information of the modelled data that logistic costs and CAPEX will increase the LNG cost prices for bunkering and even more upstream. Operations and bunkering time is more efficient for customers at a fixed LNG bunker station on shore or more upstream compared to the traditional LNG Truck to Ship (TTS) bunkering and will compensate these higher LNG cost prices for bunkering.

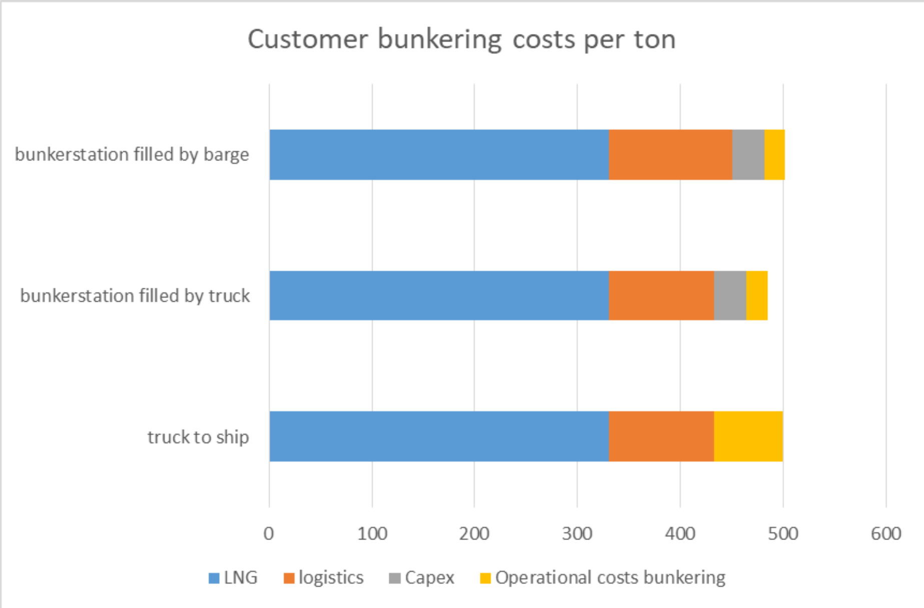
In the model the bunker flow indicated is for traditional truck to ship bunkering ~ 12 - 15 tons/hour and for a bunker station ~ 35 tons /hour. Also the pre-bunkering and aft-bunkering operations are more efficient at a bunkering station compared to the bunkering from a tank truck because connections and system conditions are always in place with a bunkering station and the client does not have to wait to prepare connection or dis-connection of a tank truck.

Because of the more efficient way of bunkering at a bunker station the customer will gain more time for sailing and cargo operation and the operational time saving of the customer compensates the higher LNG cost price, see also below graph:



The figures in above graph are based on an LNG turnover of 5.000 t/a of the bunker station.

With a higher LNG turnover of the bunker station the CAPEX impact in the LNG cost price will decrease and the station will become more competitive compared to the truck to ship bunkering.



The figures in above graph are based on a turnover of 10.000 t/a of the bunker station.

Not only the (best) location of an LNG bunker station for inland shipping companies is important for the LNG cost price but also other sensitivities can influence the LNG retail cost price for that particular area:

- Bunker station can be used as a hub with a larger storage tank and a retail distribution function to other transport segments
    - Filling of a larger LNG storage upstream can be done by inland feeder tanker for more optimized logistics.
    - Multiple segments to supply with one installation, like bunkering of inland vessels, refuelling of trucks and re-distribution to other locations in the area.
    - Impact of CAPEX in the LNG retail price is less relevant if more LNG turnover is established.

Note: in the modelling the total costs for CAPEX of an LNG bunker station is taken conservative 100% allocated to the LNG cost pricing in the model. The LNG feeder vessel is based on hourly rates dedicated for a certain volume. Of course when an inland feeder tanker has more customers or an LNG bunker station is used as an LNG HUB for other segments as well, the impact of those costs will decrease in the LNG pricing.
Therefore it would be unfair to compare only the logistic cost impact of a bunker location based on one transport segment or a particular low LNG turnover per year.

For the Cologne bunkering station it is concluded that from an LNG turnover of more than 5.000 t/a best way to bring LNG to the station is by inland LNG feeder tanker. In the model the 5.000 tons is only ~ 10% of the total capacity of the LNG bunker /feeder tanker. In the model the costs of the inland feeder tanker are based on the 5.000 t/a. Additional a separate research was performed for the different transport modalities to bring LNG to the station of Cologne and

concluded that transport of LNG to the station by LNG tank truck (road) is the most cost effective at low turnover volumes.
For transport in tank containers the extra handling costs additional to the basic logistic costs of LNG tank trucks are influencing the total business case negatively and was concluded not interesting as one of the logistic solutions. First the filling of the tank containers needs a transport by truck to the terminal for example Gate terminal. After filling the tank container at the terminal it needs to be transported to a barge or train enabling to transport the tank container to the location. The container has to be transferred from the barge or train to the location again by truck. These additional handlings makes it too expensive compared to traditional transport direct by truck for low volumes or transport by inland feeder tanker for higher volumes.

9 Conclusion

How to select the best location for an LNG bunkering station is not answered by one single solution. There is not one decisive driver that is applicable for all locations but some drivers are more important for a location than the other driver.

The first and most important factor to select a location is the sailing routes of the inland vessels. Based upon the sailing pattern of the inland vessels the first selection of locations was made. The major routes are based along the river Rhine and located in the sea ports, where LNG import-terminals are available and were the concentration of vessels is at highest.

The second important selection criterion is the availability of an area where it is possible to realize an LNG bunkering station. This is determined by a number of factors:

- A launching customer
- A positive Quantitative risk analysis of the site to ensure safe operation
- Enthusiasm of local authorities in supporting to get the necessary permits and introduce incentives for users of LNG as fuel.
- Location suitable for multiple activities like truck refuelling or introduce an LNG storage functioning as an LNG Hub.
- Logistical costs and aspects to access the site, is the site accessible by ADR transport routes or is it possible to bring LNG to the site over water by barge.
- A site survey consisting of a quick scan for safety zones, noise restrictions, zone planning etc.

At the moment three locations are selected as best locations. Antwerp, Cologne and Rotterdam-Duivelseiland. Several other locations are determined as possible locations but are not selected yet like Amsterdam, Duisburg, Mannheim or Hamburg. Some locations like Manheim, and Rotterdam Seine haven and Rotterdam Härtelkanaal did not meet the selection criteria as mentioned before in this report. In time this can change and in future these locations could meet the selection criteria if circumstances will change.

Mayor reason for selecting Antwerp was the fact that an exclusive concession was issued for LNG bunkering. The location in Antwerp will be in operation at the end of 2019.

Main reason for realizing a station in Cologne was the fact that 15 inland tankers are introduced which are mainly sailing from Cologne to Basel. Also a site was available in the Cologne harbour with enough space to realize a bunkering station. The bunkering station in Cologne will be in operation end of 2018.

The third selected location is Rotterdam- Duivelseiland, at the crossway of two important inland waterway sailing routes between ARA area and Rotterdam to Basel. The selected area will be developed by the Port of Rotterdam as Clean Energy Hub. In that concept fits perfectly the realization of an LNG bunkering station. Besides the realization of an LNG bunkering station the possibilities for a multi fuel bunkering station are researched like CNG for ships, bio methane, bio diesel but also LNG/CNG for trucks are options to realize.

For all three locations different drivers where decisive in the selection and all locations have different pros and cons. Still for all locations is the sailing route or density of potential inland barges with a higher consumption than 500 m3 gasoil per year important and obvious.

The choice of location is highly depending on the LNG supplier customer relation as well for other important stakeholder relations involved in the development of an LNG bunker station. In this upcoming market with still uncertain volume demand for LNG as fuel and not always fully implemented regulations for the different locations the risk to invest is high and we could say that the only driver that will force the decision for investing in an LNG bunker station is enough launching customers with a perspective in future for higher LNG volume ramp up to ensure a positive business case. Without this perspective no LNG bunker infrastructure will develop.

10 References

Sources for this study used are:

- EICB research sailing areas inland vessels
- DNV-GL LNG Masterplan
- Elexis Belgium TTF Prices
- Nijman-Zeetank Logistics
- Wikimedia Commons; Jörg Schönebaum
- Jahresbericht 2016 Europäische Binnenschifffahrt Marktbeobachtung; ZKR
- Voies navigables de France
- ENGIE
- PitPoint

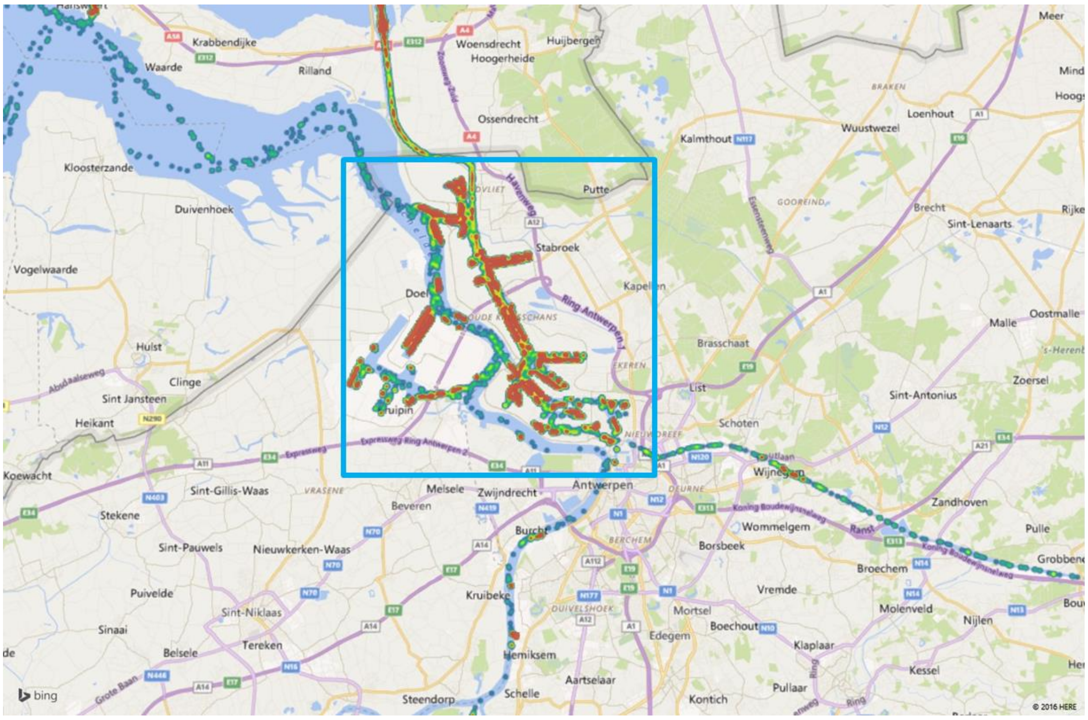
Annexe 1, Part of EICB research sailing areas inland vessels for the selected locations.

1) *Antwerp, location Quay 528*

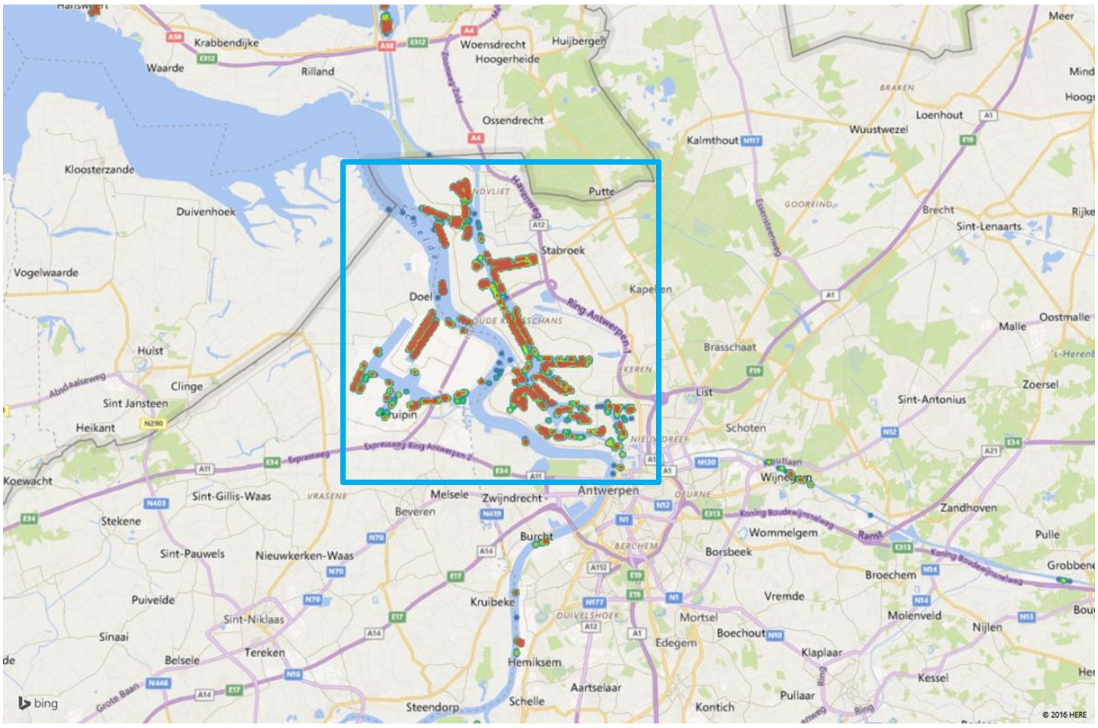
As environment is included for this area:

- 'Large-Antwerp ': Scheldt-Rhine connection south of Kreekraksluizen, Scheldt at Antwerp, Antwerp ports
- -'Small-Antwerp ': Idem, excluding Scheldt and western ports (only the eastern ports)

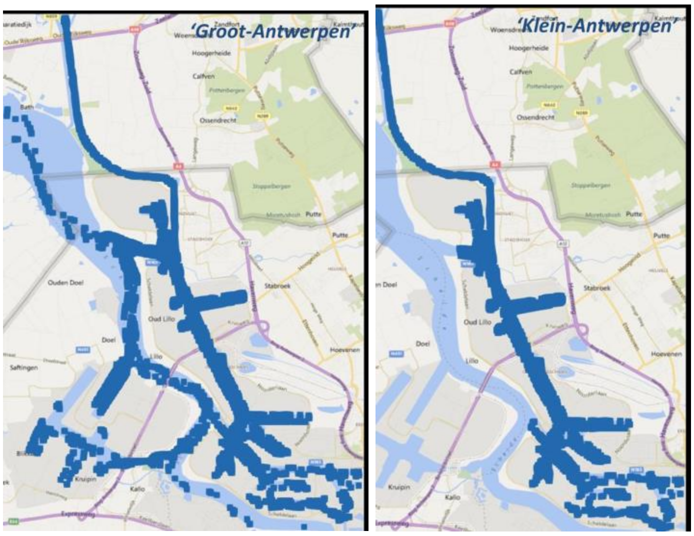
Heat map showing all inland vessels in that area from the selected 283 vessels:



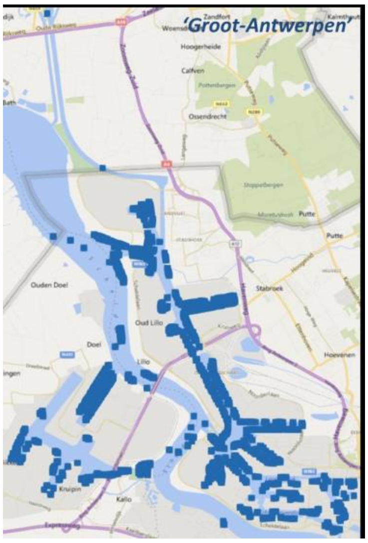
Heat map showing all idle (moored) inland vessels in that area from the selected 283 vessels:

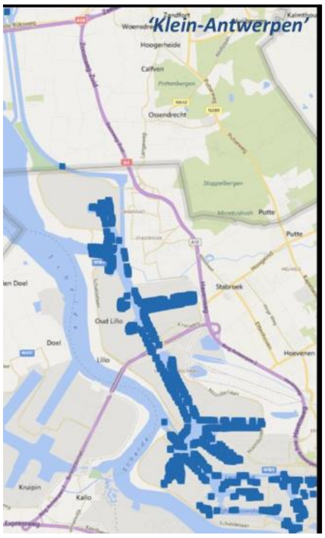


Antwerp observations all vessels:



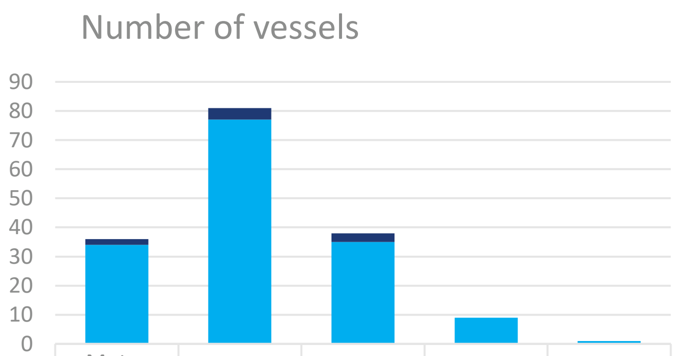
Antwerp observations moored vessels:



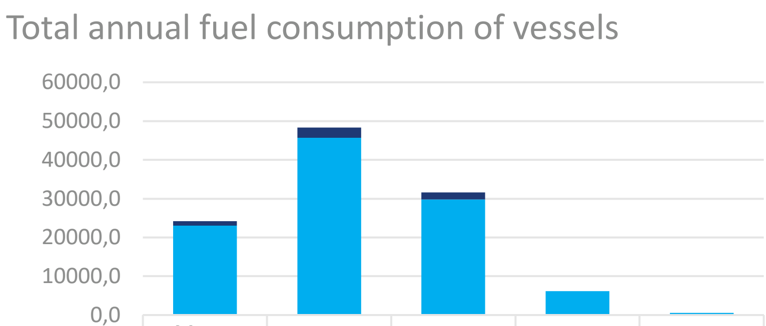


Out of the 283 tracked vessels:

- 165 vessels were in the area of Antwerp, of which:
  - 156 vessels also idle;
  - 9 vessels only passed by.
- These 165 vessels have a total annual fuel consumption of 110 954.0 m3 (average: 672.4 m3);
- These 84 'idle vessels' have a total annual fuel consumption of 105 305.7 m3 (average: 675.0 m3)



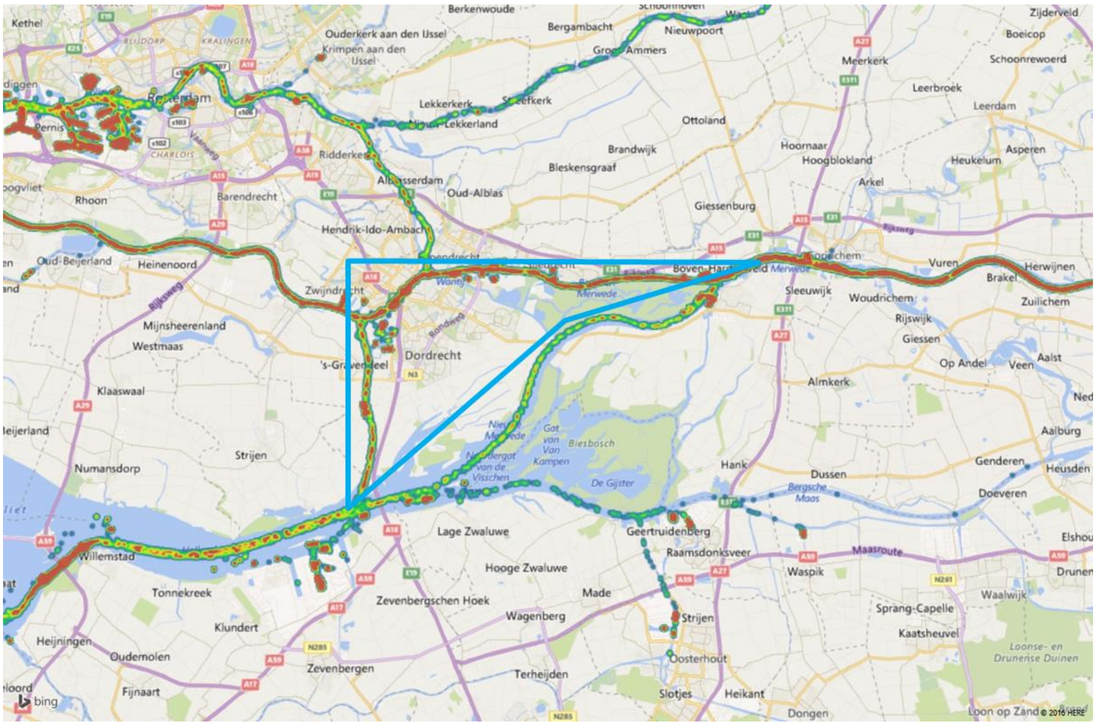
	Motor (dry) cargo vessel	Motor tank vessel	Coupled convoy	Pusher	Passenger vessel
Number of vessels (only passing by)	2	4	3	0	0
Number of vessels (Idle)	34	77	35	9	1



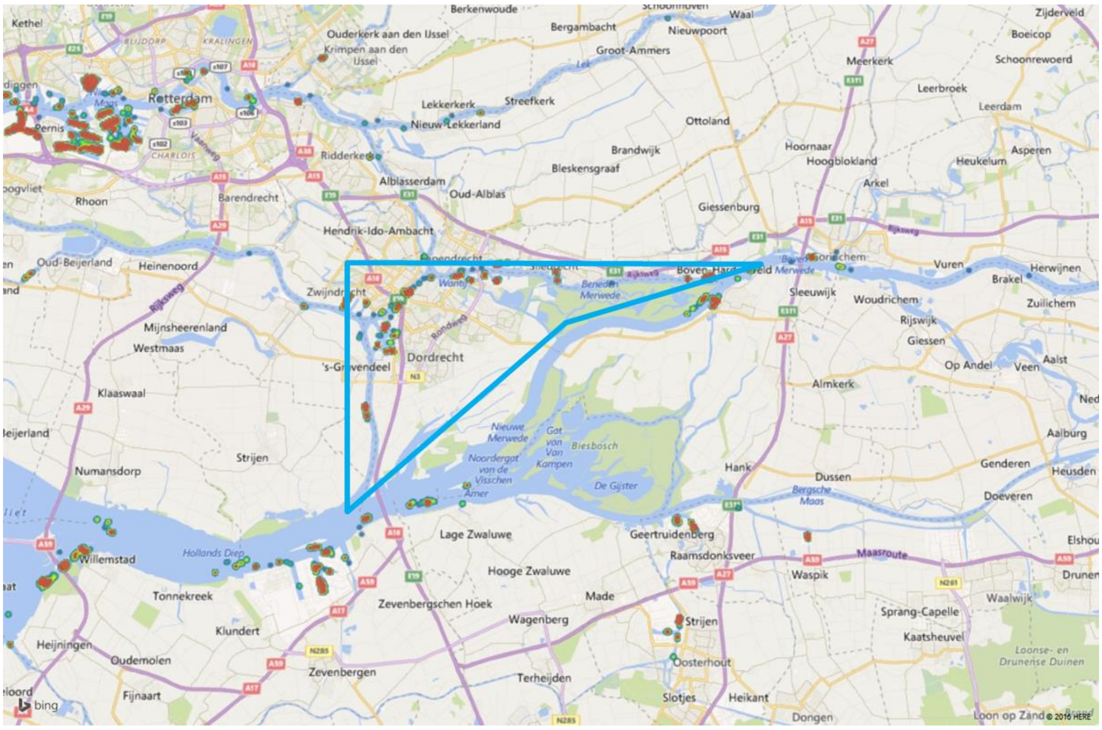
	Motor (dry) cargo vessel	Motor tank vessel	Coupled convoy	Pusher	Passenger vessel
Fuel consumption (only passing by)	1206,2	2611,1	1831,1	0,0	0,0
Fuel consumption (Idle)	23029,8	45728,6	29780,4	6176,8	590,0

2) *Dordrecht, area Drechtsteden*

Heat map showing all inland vessels in that area from the selected 283 vessels:

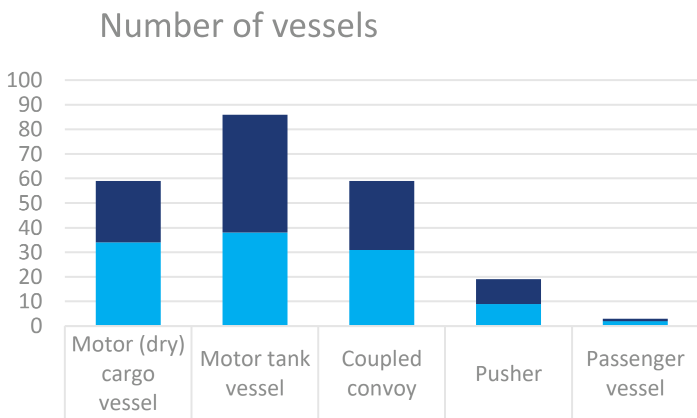


Heat map showing all idle (moored) inland vessels in that area from the selected 283 vessels:



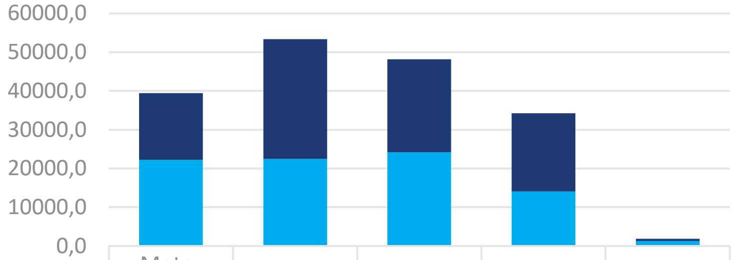
Out of the 283 tracked vessels:

- 226 vessels were in the area of the Drechtsteden, of which:
    - 114 vessels also idle;
    - 112 vessels only passed by.
- These 226 vessels have a total annual fuel consumption of 177 125.5 m3 (average: 783.7 m3);
- The 114 'idle vessels' have a total annual fuel consumption of 84 238.0 m3 (average: 738.9 m3)



	Motor (dry) cargo vessel	Motor tank vessel	Coupled convoy	Pusher	Passenger vessel
Number of vessels (only passing by)	25	48	28	10	1
Number of vessels (Idle)	34	38	31	9	2

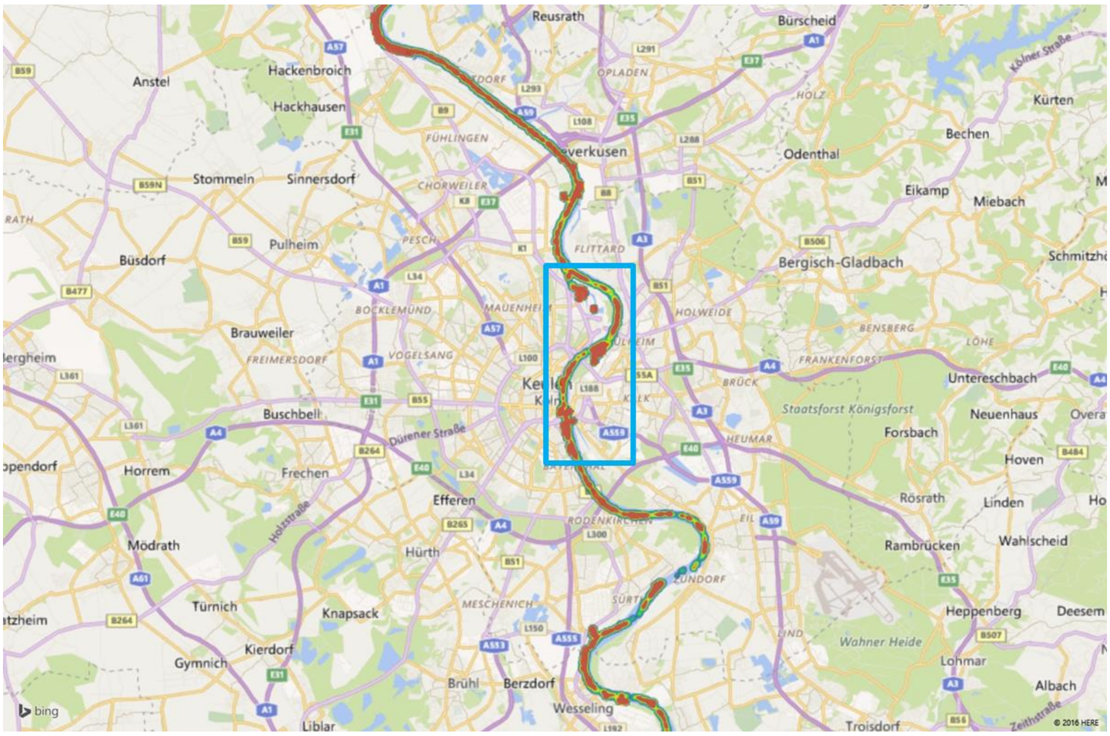
Total annual fuel consumption of vessels



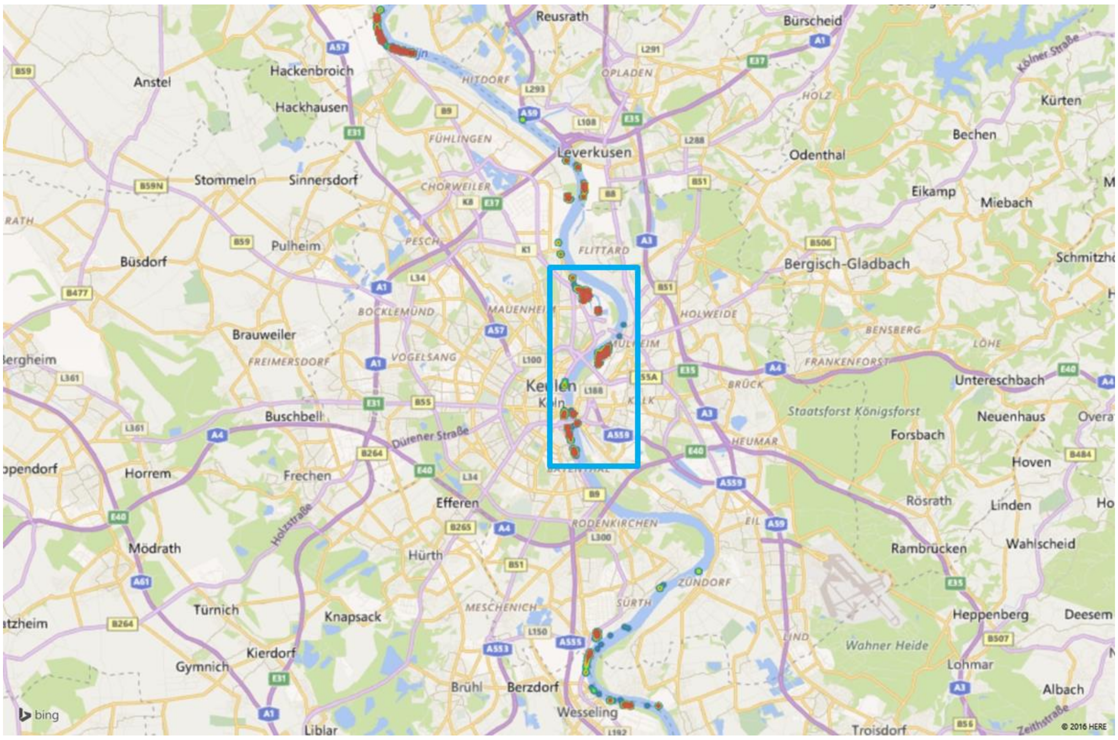
	Motor (dry) cargo vessel	Motor tank vessel	Coupled convoy	Pusher	Passenger vessel
Fuel consumption (only passing by)	17249,0	30856,9	23990,7	20201,0	590,0
Fuel consumption (Idle)	22204,7	22490,5	24214,2	14047,7	1280,8

3) ***Cologne, area upstream Rhine***

Heat map showing all inland vessels in that area from the selected 283 vessels:

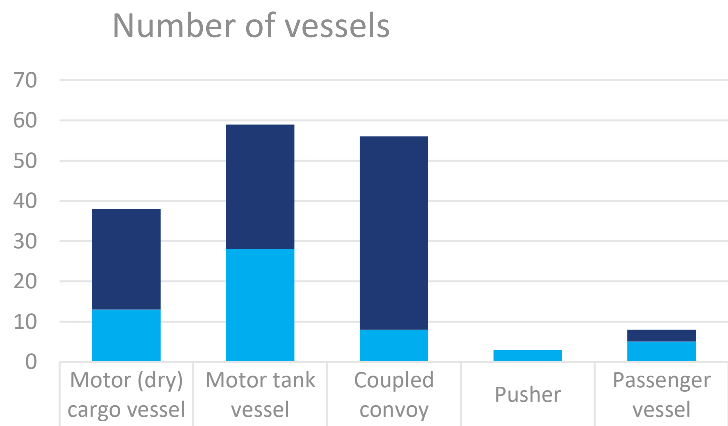


Heat map showing all idle (moored) inland vessels in that area from the selected 283 vessels:



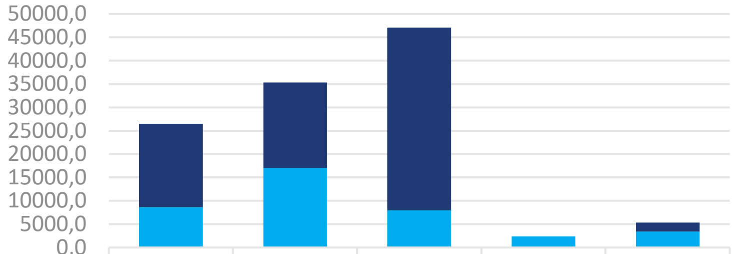
Out of the 283 tracked vessels:

- 164 vessels were in the area of Cologne, of which:
  - 57 vessels also idle;
  - 107 vessels only passed by.
- These 164 vessels have a total annual fuel consumption of 116 611.2 m3 (average: 711.0 m3);
- The 84 'idle vessels' have a total annual fuel consumption of 39 353.4 m3 (average: 690.4 m3)



	Motor (dry) cargo vessel	Motor tank vessel	Coupled convoy	Pusher	Passenger vessel
Number of vessels (only passing by)	25	31	48	0	3
Number of vessels (Idle)	13	28	8	3	5

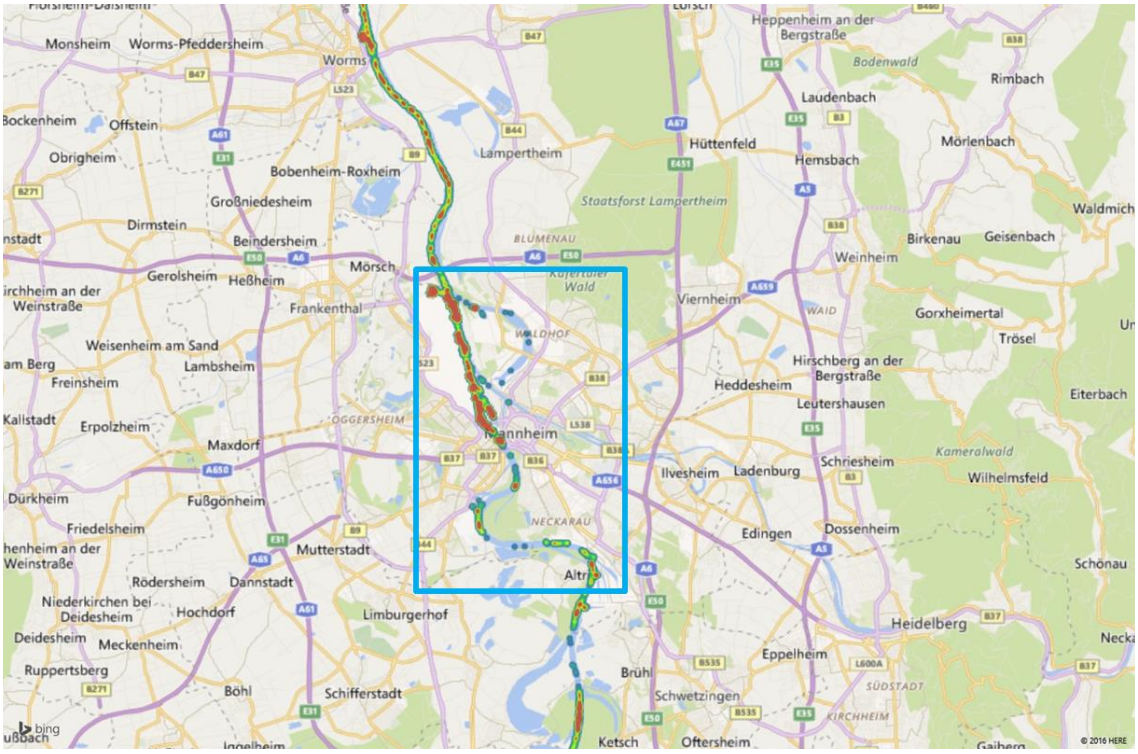
Total annual fuel consumption of vessels



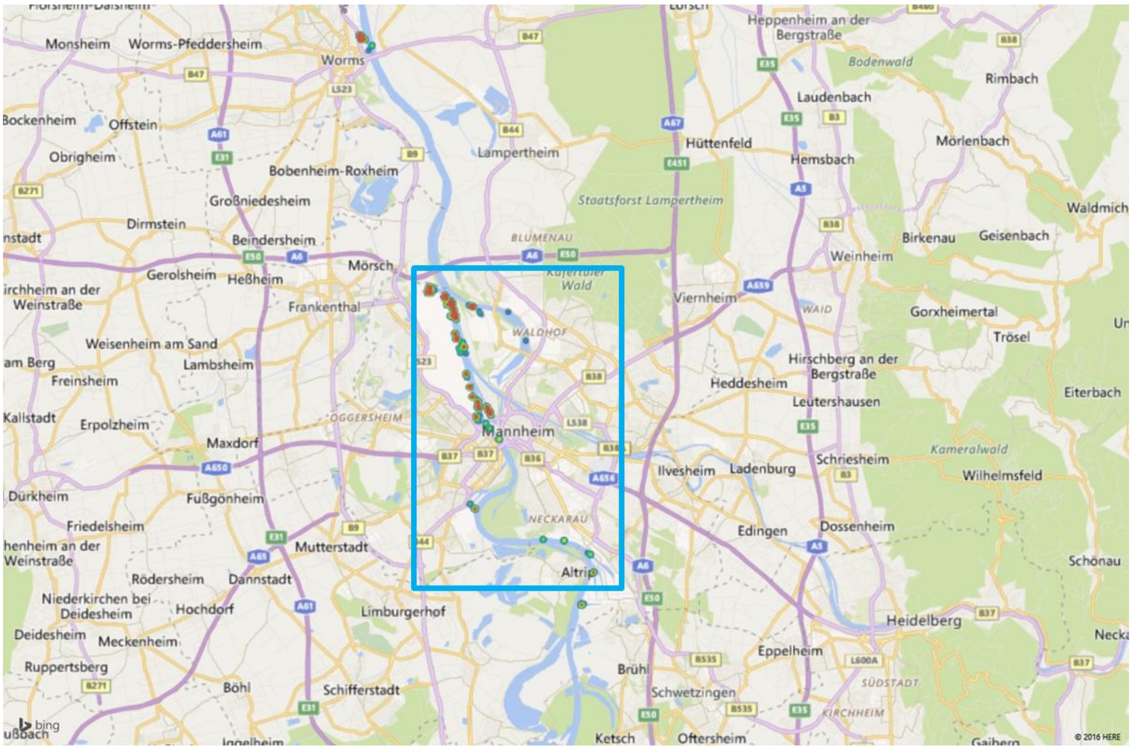
	Motor (dry) cargo vessel	Motor tank vessel	Coupled convoy	Pusher	Passenger vessel
Fuel consumption (only passing by)	17859,6	18371,0	39118,9	0,0	1908,4
Fuel consumption (Idle)	8622,4	16973,6	7951,9	2358,3	3447,2

4) *Mannheim, area upstream Rhine*

Heat map showing all inland vessels in that area from the selected 283 vessels:

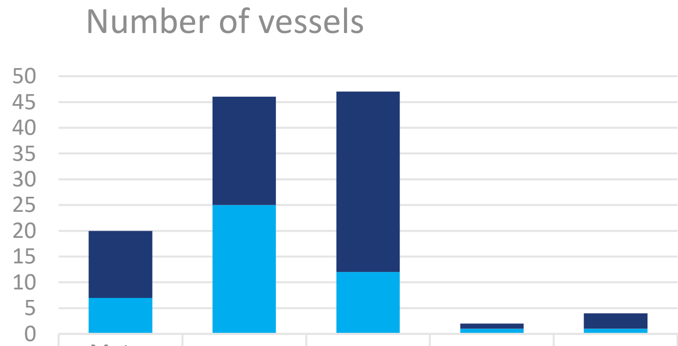


Heat map showing all idle (moored) inland vessels in that area from the selected 283 vessels:

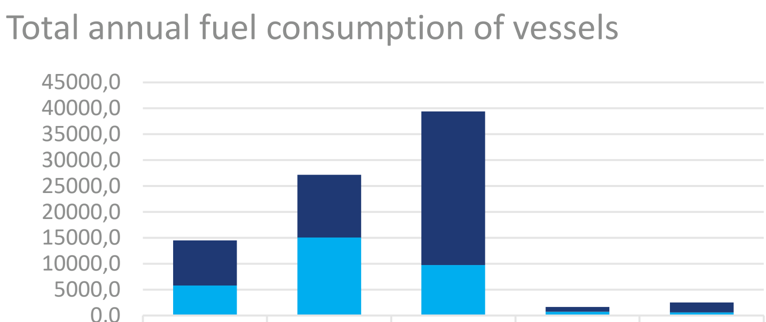


Out of the 283 tracked vessels:

- 119 vessels were in the area of Mannheim, of which:
    - 46 vessels also idle;
    - 73 vessels only passed by.
- These 119 vessels have a total annual fuel consumption of 85 251.8 m3 (average: 716.4 m3);
- The 46 'idle vessels' have a total annual fuel consumption of 31 910.2 m3 (average: 693.7 m3)



	Motor (dry) cargo vessel	Motor tank vessel	Coupled convoy	Pusher	Passenger vessel
Number of vessels (only passing by)	13	21	35	1	3
Number of vessels (Idle)	7	25	12	1	1



	Motor (dry) cargo vessel	Motor tank vessel	Coupled convoy	Pusher	Passenger vessel
Fuel consumption (only passing by)	8723,2	12127,4	29664,9	903,6	1922,7
Fuel consumption (Idle)	5780,7	15039,1	9746,5	744,0	599,9

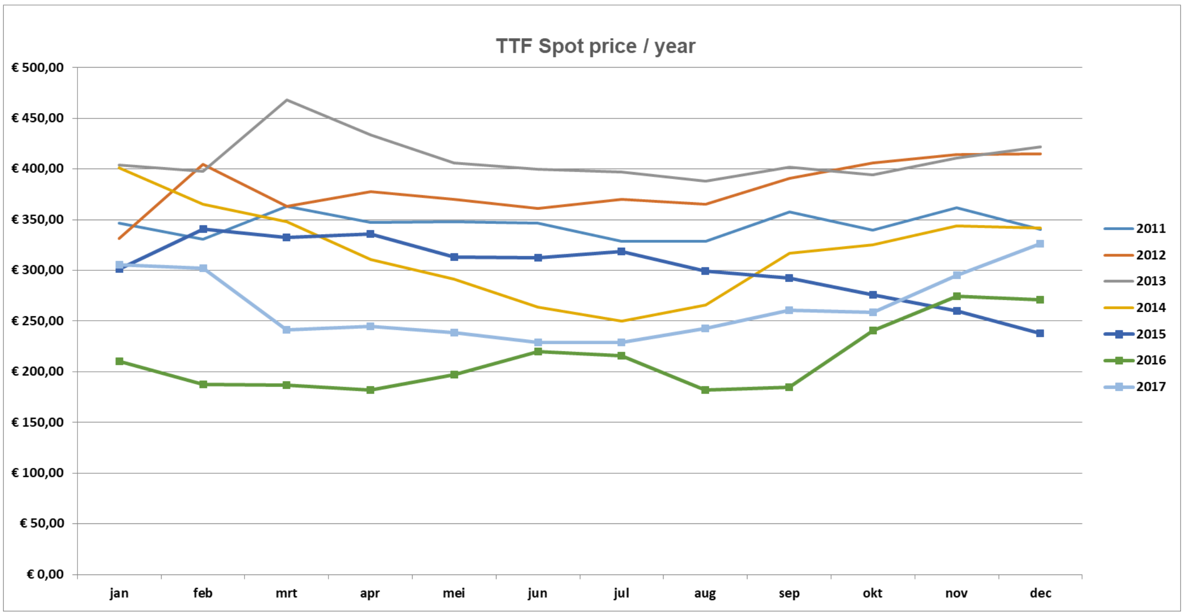
In this study these specific locations, mentioned above, are selected by the partners as ‘best locations’ for implementing an LNG bunkering station for inland shipping in the selected areas and ports related to the drivers discussed in chapter 6.3.

Annexe 2, TTF spot price information

In below table the TTF spot prices of 2011 – 2017 are listed, source Elexys Belgium.

Mounth / Year	2011	2012	2013	2014	2015	2016	2017
jan	€ 346,56	€ 331,32	€ 404,01	€ 401,12	€ 301,29	€ 210,01	€ 305,56
feb	€ 330,86	€ 404,77	€ 397,92	€ 365,30	€ 340,61	€ 187,76	€ 302,21
mrt	€ 363,17	€ 363,32	€ 468,02	€ 347,78	€ 332,54	€ 186,69	€ 241,55
apr	€ 347,62	€ 377,49	€ 433,73	€ 310,59	€ 335,58	€ 182,12	€ 245,06
mei	€ 347,93	€ 370,03	€ 405,99	€ 291,39	€ 313,18	€ 197,51	€ 238,66
jun	€ 346,56	€ 360,88	€ 400,05	€ 263,96	€ 312,27	€ 219,76	€ 229,21
jul	€ 328,88	€ 370,33	€ 396,85	€ 249,63	€ 318,52	€ 216,10	€ 229,06
aug	€ 328,88	€ 365,00	€ 387,86	€ 265,94	€ 299,16	€ 181,66	€ 242,47
sep	€ 357,84	€ 391,06	€ 402,03	€ 316,99	€ 292,15	€ 184,40	€ 260,76
okt	€ 339,39	€ 405,99	€ 394,41	€ 325,22	€ 276,15	€ 240,33	€ 258,62
nov	€ 362,10	€ 414,07	€ 410,72	€ 343,51	€ 259,69	€ 274,47	€ 295,05
dec	€ 340,46	€ 414,99	€ 421,84	€ 341,68	€ 238,05	€ 271,27	€ 325,98
Average /year	***€ 345,02***	***€ 380,77***	***€ 410,29***	***€ 318,59***	***€ 301,60***	***€ 212,67***	***€ 264,52***

Source: Elexys.be (in bijlage)



Annexe 3, Parameters and modelling

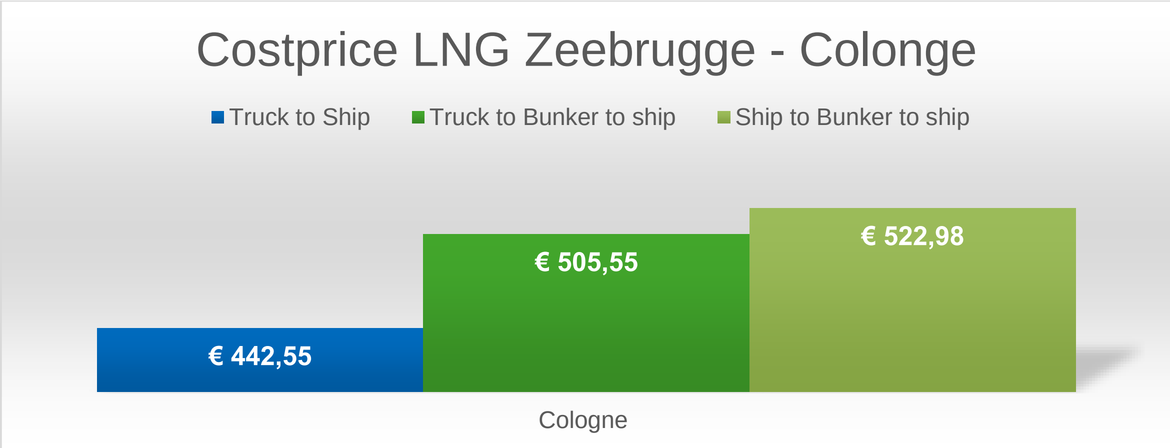
The following parameters /units are used in the model:

Parameter	Figure
1 ton LNG = m3	2,20
1 liter diesel = kg	0,84
1 kg lng = MJ	49
1 kg diesel = MJ	42
Energy conversion	0,86
1 kg diesel = liter	1,19
MWH - TON LNG	15,24
1 ton LNG = liter	2.381
Expansion LNG to gas	580
LNG M3 -> Ton	0,4600

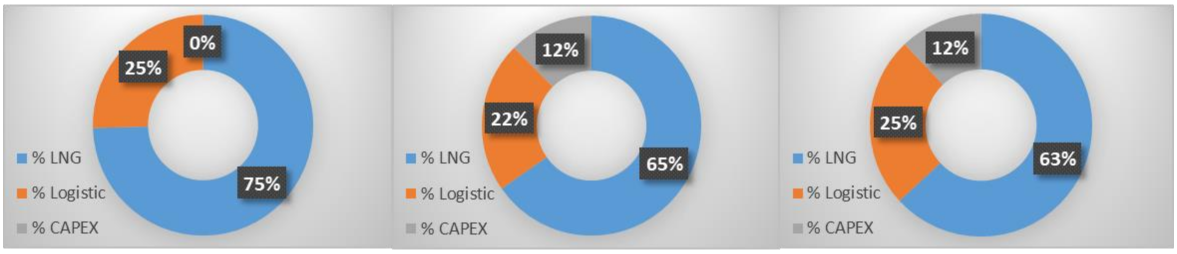
The following one way distances from LNG import terminal to locations are assumed in the model:

Distance table	Zeebrugge	GATE
Antwerp, Quay 528 Noorderlaan	196	266
Dordrecht, Duivelseiland	338	142
Rotterdam, Seinehaven	388	74
Duisburg	550	498
Cologne	684	606
Mannheim	1040	1052
Strasbourg	1130	1250
Basel	1386	1512

LNG Terminal Fluxys Zeebrugge – bunker location Cologne

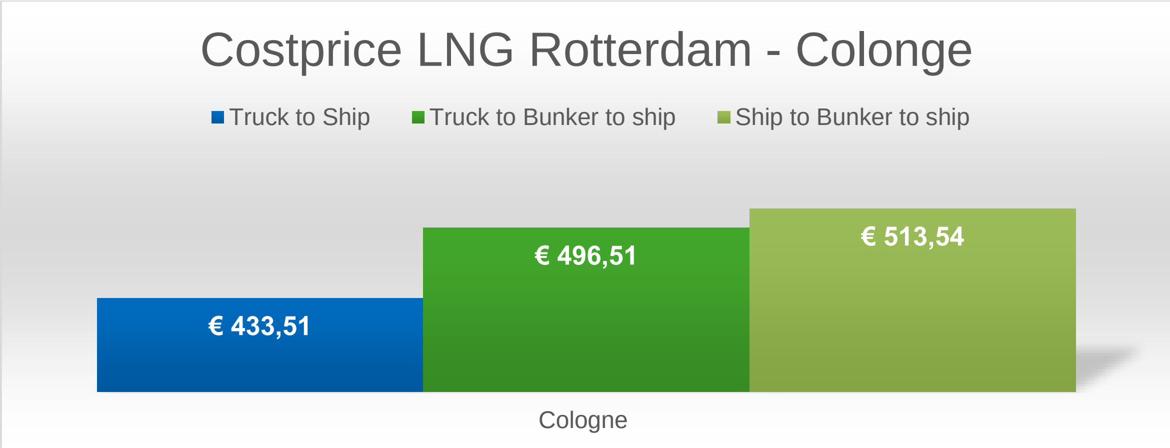


Gap in logistic costs between traditional LNG truck-to-ship bunkering and bunkering from a fixed onshore bunker station filled by LNG tank trucks or an inland LNG feeder vessel is € 63,- to € 80,- per ton.

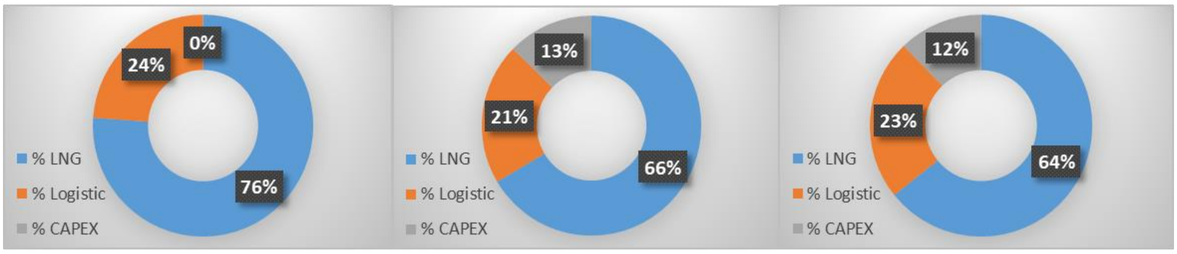


In above pie charts are shown that the logistic costs are respectively 25%, 22% and 25% of the total LNG retail cost price for Antwerp bunker location. CAPEX costs shown in the pie "Truck to Bunker to Ship" is depreciation of investment costs for the bunker station and CAPEX costs shown in the pie "Ship to Bunker to Ship" is hourly or rent costs of the LNG inland feeder vessel.

LNG Terminal Gate Rotterdam – bunker location Cologne

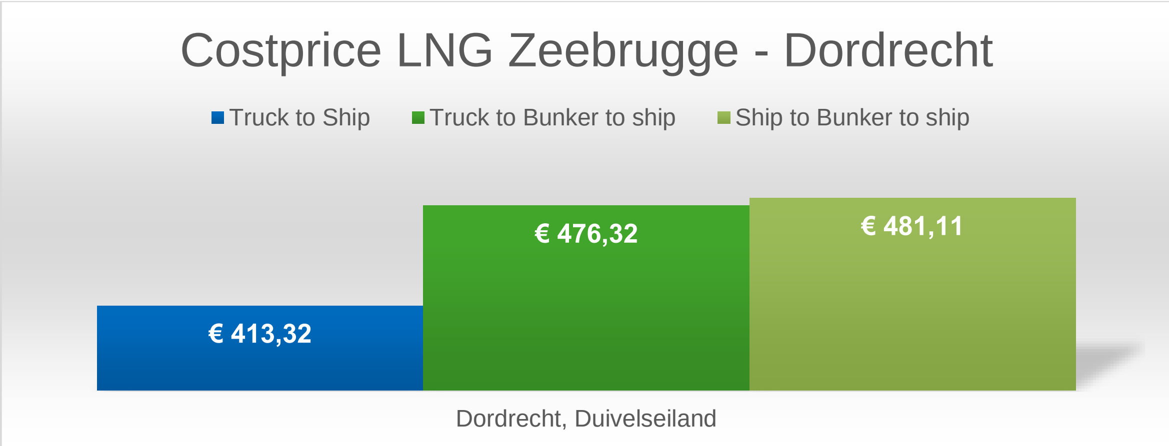


Gap in logistic costs between traditional LNG truck-to-ship bunkering and bunkering from a fixed onshore bunker station filled by LNG tank trucks or an inland LNG feeder vessel is € 63,- to € 80,- per ton.

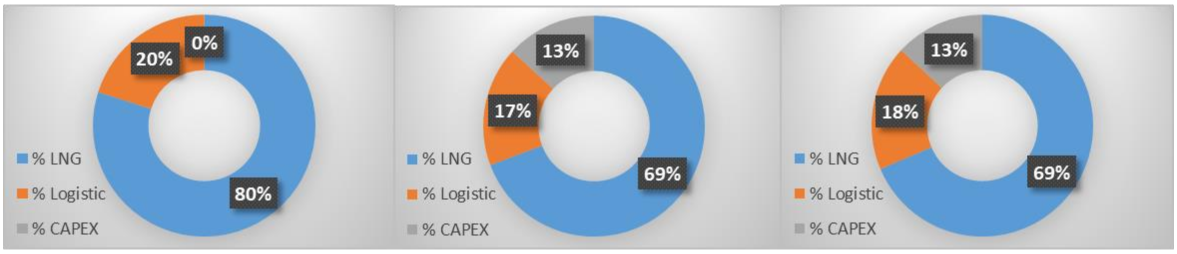


In above pie charts are shown that the logistic costs are respectively 24%, 21% and 23% of the total LNG retail cost price for Antwerp bunker location. CAPEX costs shown in the pie 'Truck to Bunker to Ship' is depreciation of investment costs for the bunker station and CAPEX costs shown in the pie 'Ship to Bunker to Ship' is hourly or rent costs of the LNG inland feeder vessel.

LNG Terminal Fluxys Zeebrugge – bunker location Dordrecht, Port of Rotterdam

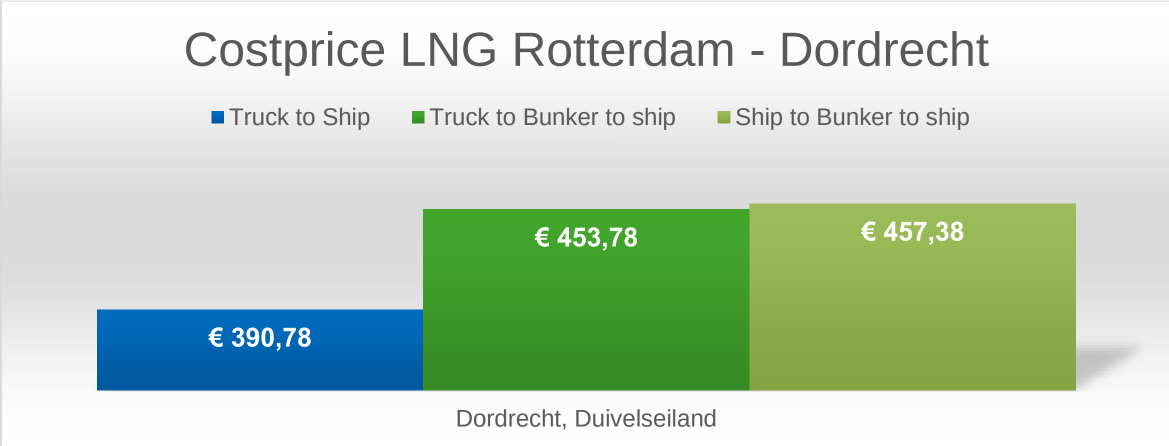


Gap in logistic costs between traditional LNG truck-to-ship bunkering and bunkering from a fixed onshore bunker station filled by LNG tank trucks or an inland LNG feeder vessel is € 63,- to € 68,- per ton.

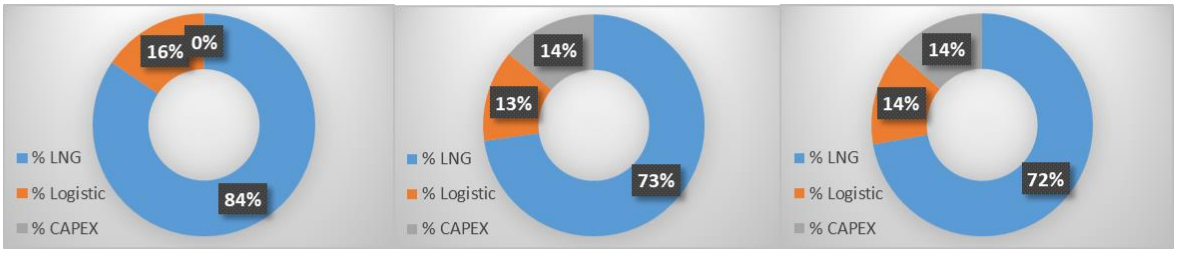


In above pie charts are shown that the logistic costs are respectively 20%, 17% and 18% of the total LNG retail cost price for Antwerp bunker location. CAPEX costs shown in the pie 'Truck to Bunker to Ship' is depreciation of investment costs for the bunker station and CAPEX costs shown in the pie 'Ship to Bunker to Ship' is hourly or rent costs of the LNG inland feeder vessel.

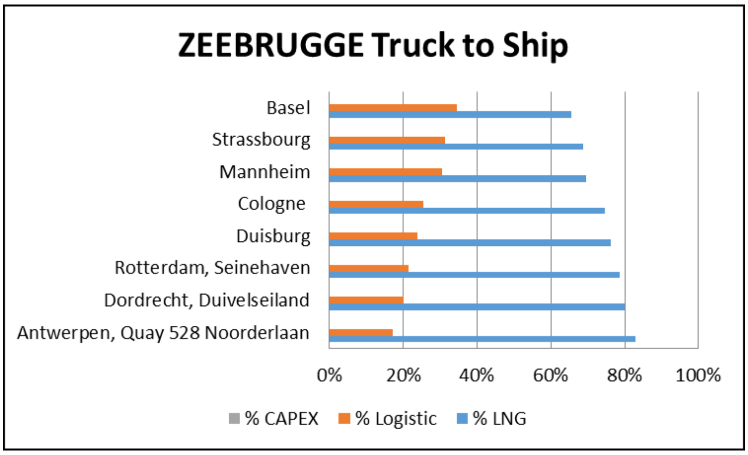
LNG Terminal GATE Rotterdam – bunker location Dordrecht, Port of Rotterdam



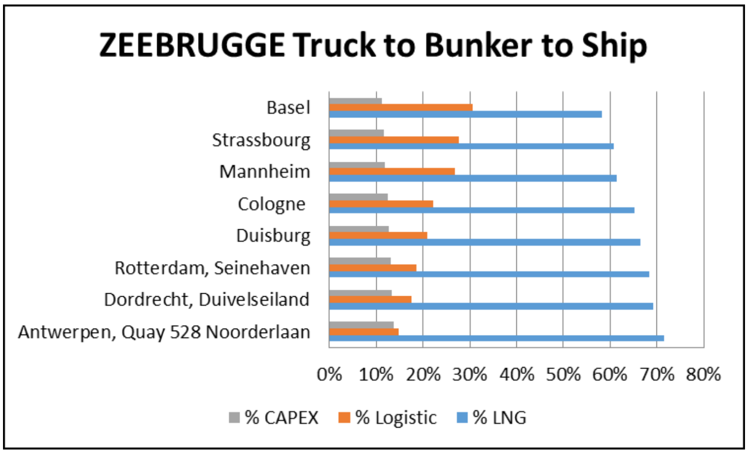
Gap in logistic costs between traditional LNG truck-to-ship bunkering and bunkering from a fixed onshore bunker station filled by LNG tank trucks or an inland LNG feeder vessel is € 63,- to € 67,- per ton.



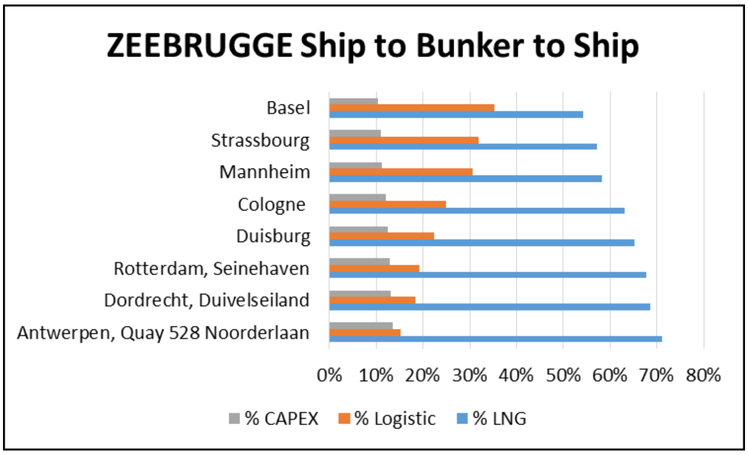
In above pie charts are shown that the logistic costs are respectively 16%, 13% and 14% of the total LNG retail cost price for Antwerp bunker location. CAPEX costs shown in the pie 'Truck to Bunker to Ship' is depreciation of investment costs for the bunker station and CAPEX costs shown in the pie 'Ship to Bunker to Ship' is hourly or rent costs of the LNG inland feeder vessel.



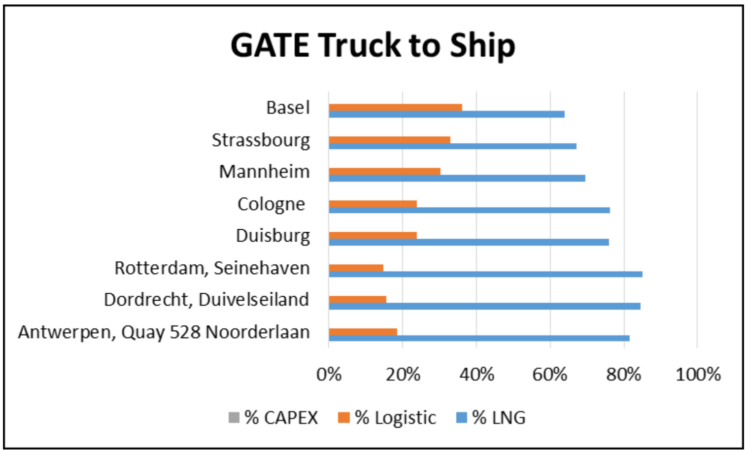
This graph shows the total overview of all logistic costs TTS from Zeebrugge terminal to all locations calculated in the model.



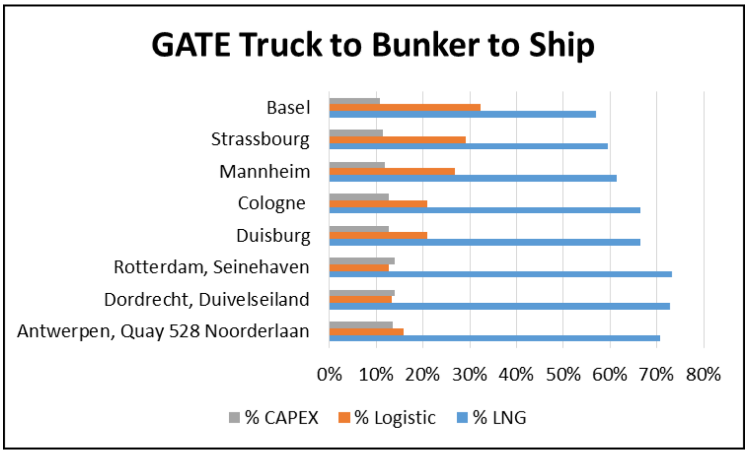
This graph shows the total overview of all logistic costs PTS from Zeebrugge terminal to all locations, storage filled by tank trucks, calculated in the model.



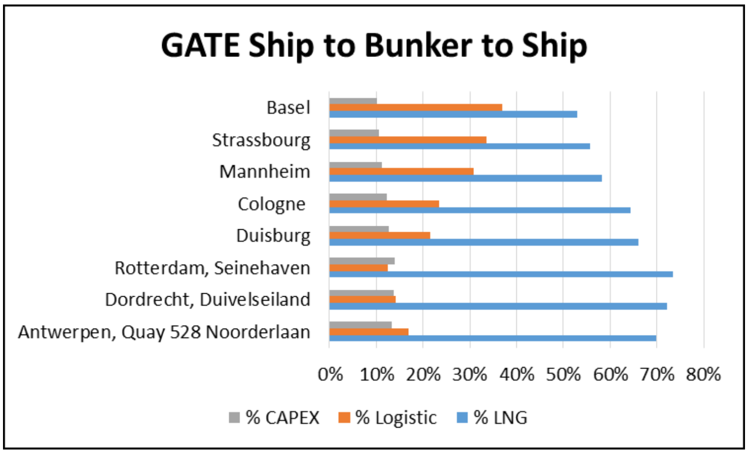
This graph shows the total overview of all logistic costs PTS from Zeebrugge terminal to all locations, storage filled by inland feeder vessel, calculated in the model.



This graph shows the total overview of all logistic costs TTS from Gate terminal to all locations calculated in the model.



This graph shows the total overview of all logistic costs PTS from Gate terminal to all locations, storage filled by tank trucks, calculated in the model.



This graph shows the total overview of all logistic costs PTS from Gate terminal to all locations, storage filled by inland feeder vessel, calculated in the model.