LNG BINNENVAART
Deployment in Inland Waterway Transport

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# Breakthrough LNG Deployment in Inland Waterway Transport

## 4.1 Analysis of the potential and sailing profiles of LNG using vessels in Europe

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# 1. Introduction

The objective of activity number 4 of the action “Breakthrough LNG deployment in Inland Waterway Transport” is to elaborate the preliminary business case calculations into mature, reliable business cases by means of thorough desk and field analysis. The business case calculations consist of the following components:

**4.1 Analysis of the potential and sailing profiles of LNG using vessels in Europe;**
4.2 Development of total cost-of-ownership model and financing constructions;
4.3 Market and stakeholder analysis.

This report puts the focus on the first part and will consequently analyze and identify at European level the potential LNG propelled vessels and the related sailing profiles. In this report it is assumed that the potential LNG fleet consists roughly of the inland waterway vessels with a relatively high fuel consumption (approximately 500m$^3$ and more). This group had been tracked for a certain period of time to analyze the regular navigational routes of these vessels. Consequently, this report will answer the following research questions:

1. Who are current and potential users of LNG in the inland waterway transport (IWT) sector?
2. Where do current and potential users of LNG sail?
3. Where should future LNG bunker stations be deployed?

The answers on these questions and this analysis in general will be used to promote the standardization of tank sizes and location, the optimization of LNG refueling locations, maximizing the further roll-out of LNG vessels, and study the optimization of the supply chain. This will contribute to the elaboration of the preliminary business case calculations into mature, reliable business cases, in turn contributing to the key objective of this action; namely reducing the investment barrier for the ship owners with the aim to facilitate large scale implementation of LNG in IWT and eventually forcing a breakthrough in the LNG market.

# 2. Current and potential users of LNG in inland waterway transport

Chapter 2 of this report will provide an answer to the first research question. Potential users of LNG in IWT will be identified based on their fuel (gasoil) consumption. A fuel consumption of at least 500 $m^3$ per year is taken as threshold value and this resulted in a selection of 324 vessels. The necessary data is obtained from the list with fuel bunker volumes over the year 2013 in the Netherlands, which represents 42% of the European fleet and is representative for the Western-European fleet.

## 2.1 Current LNG-fleet

As of 2016, there are six inland vessels which sail on LNG, these are[1]:

### Argonon

| | |
|---|---|
| Fleet family[2]: | Motor tank vessel ≥110m length |
| Type: | Tanker type C (chemicals) |
| ENI number: | 02334277 |
| Owner: | Argonon Shipping B.V., Zwijndrecht |
| Construction year: | 2011 |
| Length: | 110 meter |
| Width: | 16,2 meter |
| Depth: | 5,13 meter |
| Tonnage: | 6100 ton |
| Engine: | 2 x Caterpillar 3512 (B) DI-TA electronic, 1119 kW, 1600 rpm |
| LNG-application: | Dual fuel (80% LNG and 20% diesel) |

The Argonon is the first inland vessel which started to sail on LNG in 2011, it is a bunker vessel predominantly operational in the ports of Rotterdam and Antwerp.

[1] Information is obtained from Vlootschouw, Vereniging De Binnenvaart, Weekblad Schuttevaer, Argonon Shipping, Interstream Barging, Danser Group, Chemgas, Sandfirden and Damen

[2] The categorization based on fleet families is derived from the project PROMINENT; D1.1 List of operational profiles and fleet families (2015)

## Greenstream and Green Rhine

| | *Greenstream* | *Greenrhine* |
|---|---|---|
| Fleet family: | Motor tank vessel ≥110m length | |
| Type: | Tanker type C | |
| ENI number: | 02335315 | 02335378 |
| Owner: | C.V. NFT I-Tanker 1, IJsselmuiden | C.V. NFT I-Tanker 2, IJsselmuiden |
| Construction year: | 2013 | |
| Length: | 110 meter | |
| Width: | 11,44 meter | |
| Depth: | 3,46 meter | |
| Tonnage: | 2877 ton | |
| Engine: | 4 x Scania SGI-16M gas generator sets, 285 kWe | |
| LNG-application: | LNG Electric | |

The first LNG electric driven inland vessels are the sister vessels Greenstream and Green Rhine, which are commissioned by Interstream and sail for Shell on a trajectory between Basel and Rotterdam.

## Eiger-Nordwand

| | |
|---|---|
| Fleet family: | Coupled convoy |
| Type: | Container coupled convoy |
| ENI number: | 02324957 (Eiger) / 02326710 (Nordwand) |
| Owner: | Danser Switzerland, Basel |
| Construction year: | 2000 (retrofit: 2014) |
| Length: | 104,92 meter (Eiger) + 73,45 meter (Nordwand) |
| Width: | 11,45 meter |
| Depth: | 2,55 meter (Eiger) / 2,29 meter (Nordwand) |
| Tonnage: | 5300 ton / 348 TEU |
| Engine: | 2 x Wärtsilä 6L20 DF, 900 kW |
| LNG-application: | Dual fuel (99% LNG and 1% diesel) |

The coupled convoy Eiger-Nordwand owned by the Danser Group is the first inland vessel retrofitted with LNG engines. The vessel is operational on a trajectory between Basel and Antwerp/Rotterdam.

## Sirocco

| | |
|---|---|
| Fleet family: | Motor tank vessel ≥110m length |
| Type: | Tanker type G (LPG-tanker) |
| ENI number: | 02335784 |
| Owner: | Chemgas Barging S.a.r.l., Luxemburg |
| Construction year: | 2013 |
| Length: | 110 meter |
| Width: | 11,4 meter |
| Depth: | 2,7 meter |
| Tonnage: | 1692 |
| Engine: | 2 x Wärtsilä 6L20 DF, 900 kW |
| LNG-application: | Dual fuel (99% LNG and 1% diesel) |

The Sirocco is a dual fuel driven tanker commissioned by Chemgas Shipping and performs the transportation of LPG in the Rhine area.

## EcoLiner

| | |
|---|---|
| Fleet family: | Motor tank vessel ≥110m length |
| Type: | Tanker type C |
| ENI number: | 02336631 |
| Owner: | QaGroup, Netherlands |
| Construction year: | 2015 |
| Length: | 110 meter |
| Width: | 11,5 meter |
| Depth: | 3,6 meter |
| Tonnage: | 3100 |
| Engine: | 4 x Stamford with gas engine, 280 kW |
| LNG-application: | LNG Electric |

The EcoLiner is an LNG Electric driven tanker very recently commissioned by QaGroup.

## 2.2 Composition of the potential LNG-fleet

The 6 vessels discussed in the previous subchapter form together the current LNG-fleet. However, given the relatively larger potential for LNG driven vessels this research puts the focus predominantly on the potential LNG-fleet. The potential fleet is selected based on the yearly fuel consumption, which has to be at least 500 $m^3$ . This volume is taken as a threshold, while – according to first calculations – in order to earn back the LNG investment a vessel has to consume in the first place at least 500 $m^3$ of gasoil per year. This can be seen as the first and foremost condition for investing in an LNG installation. For the identification of the vessels that comply with the abovementioned requirement a list has been used with fuel bunker volumes over the year 2013 in the Netherlands.

Figure 1 illustrates the distribution of the yearly fuel consumption of vessels consuming at least 250 $m^3$ of gasoil per year. In 2013 this consisted of a group of 1133 vessels and together they consumed a total volume of 534.979 $m^3$ gasoil. It can also be seen from the horizontal axis that a select group of vessels consume a relatively large proportion of the total fuel consumption.

*Figure 1: Fuel consumption*

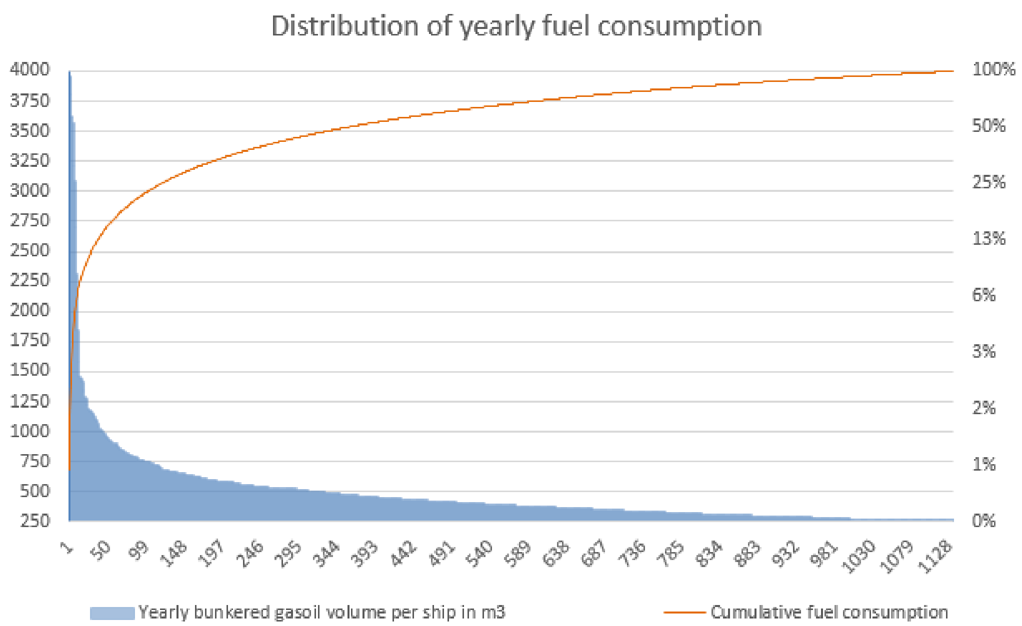


*Table 1: Fuel consumption*

| Consumption equal to or larger than: | Consumption less than: | Number of ships: | Total consumption: | Average consumption: |
|---|---|---|---|---|
| 250 m3 | 500 m3 | 809 | 282.885,27 m3 | 349,67 m3 |
| 500 m3 | 750 m3 | 225 | 132.478,52 m3 | 588,79 m3 |
| 750 m3 | 1000 m3 | 57 | 48.344,82 m3 | 848,15 m3 |
| 1000 m3 | 1250 m3 | 20 | 22.312,00 m3 | 1.115,60 m3 |
| 1250 m3 | 1500 m3 | 10 | 13.720,61 m3 | 1.372,06 m3 |
| 1500 m3 | 1750 m3 | 1 | 1.580,29 m3 | 1.580,29 m3 |
| 1750 m3 | 2000 m3 | 1 | 1.848,86 m3 | 1.848,86 m3 |
| 2000 m3 | 4000 m3 | 10 | 32.059,20 m3 | 3.205,92 m3 |

Table 1 provides a more detailed overview and it appears that the threshold in fuel consumption, i.e. the point that using LNG becomes more favorable than using gasoil, is strongly determining for the demand. A shift in the threshold from $500m^3$ to $250m^3$ will roughly result in a doubling of the potential demand for LNG. However, currently the threshold is set at $500m^3$ which results in a potential LNG fleet of 324 vessels with a total fuel consumption of $252.344,31m^3$ in 2013.

## Type of vessels

The composition of the potential LNG fleet is categorized based on the vessel type[3], these are:

- Motor tank vessel
- Motor vessel dry cargo
- Push boat
- Coupled convoy
- Passenger vessel
- Ferry
- Others

Diagrams are presented on the next page, which clearly illustrate the distribution of the vessels with a yearly fuel consumption of $\geq 500m^3$ and the distribution of their fuel consumption. It can be seen that push boats, coupled convoys, motor vessels dry cargo

[3] Fleet statistics can be found on e.g.: http://www.informatie.binnenvaart.nl/schepen/vlootstatistiek

and motor tank vessels together make up a large majority of the overall group in terms of vessels (278 vessels) and fuel consumption.

*Figure 2: Distribution of vessels*

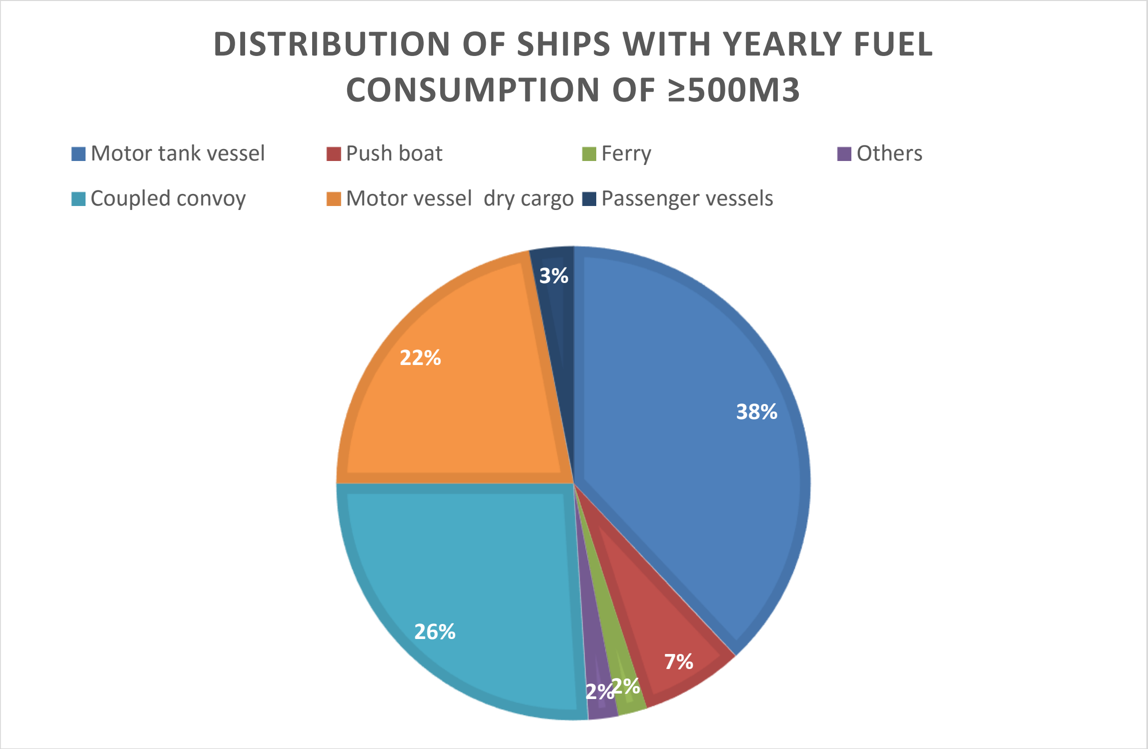
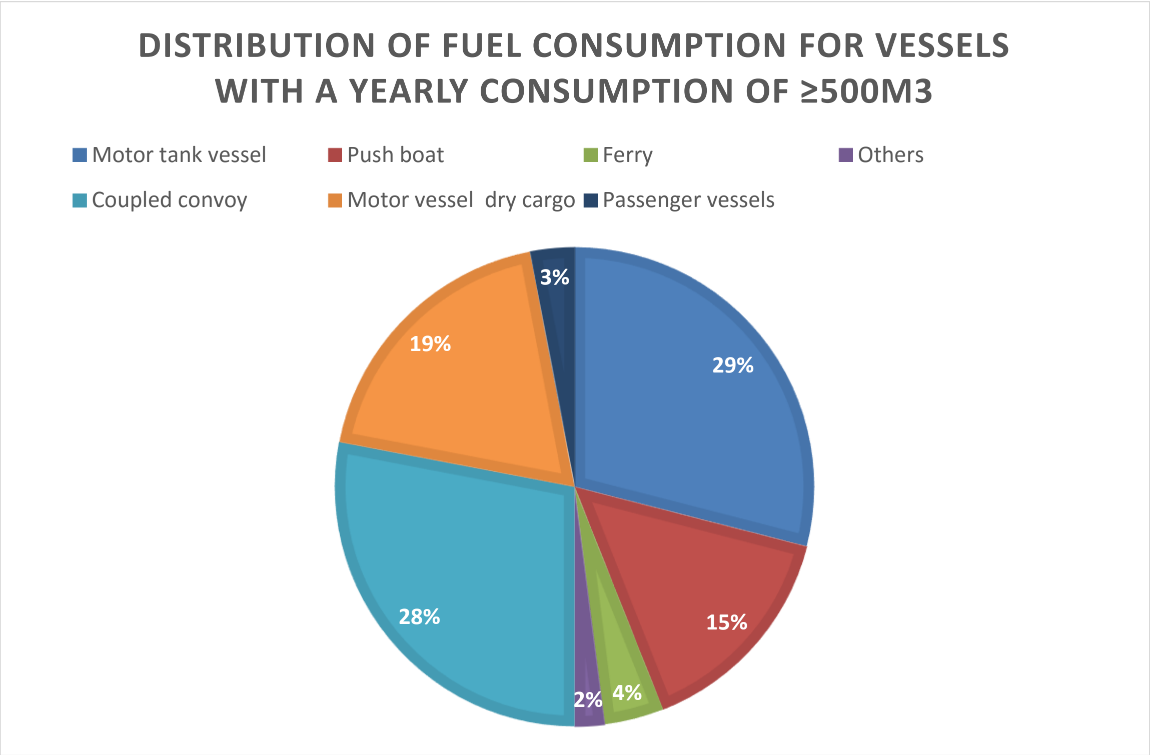
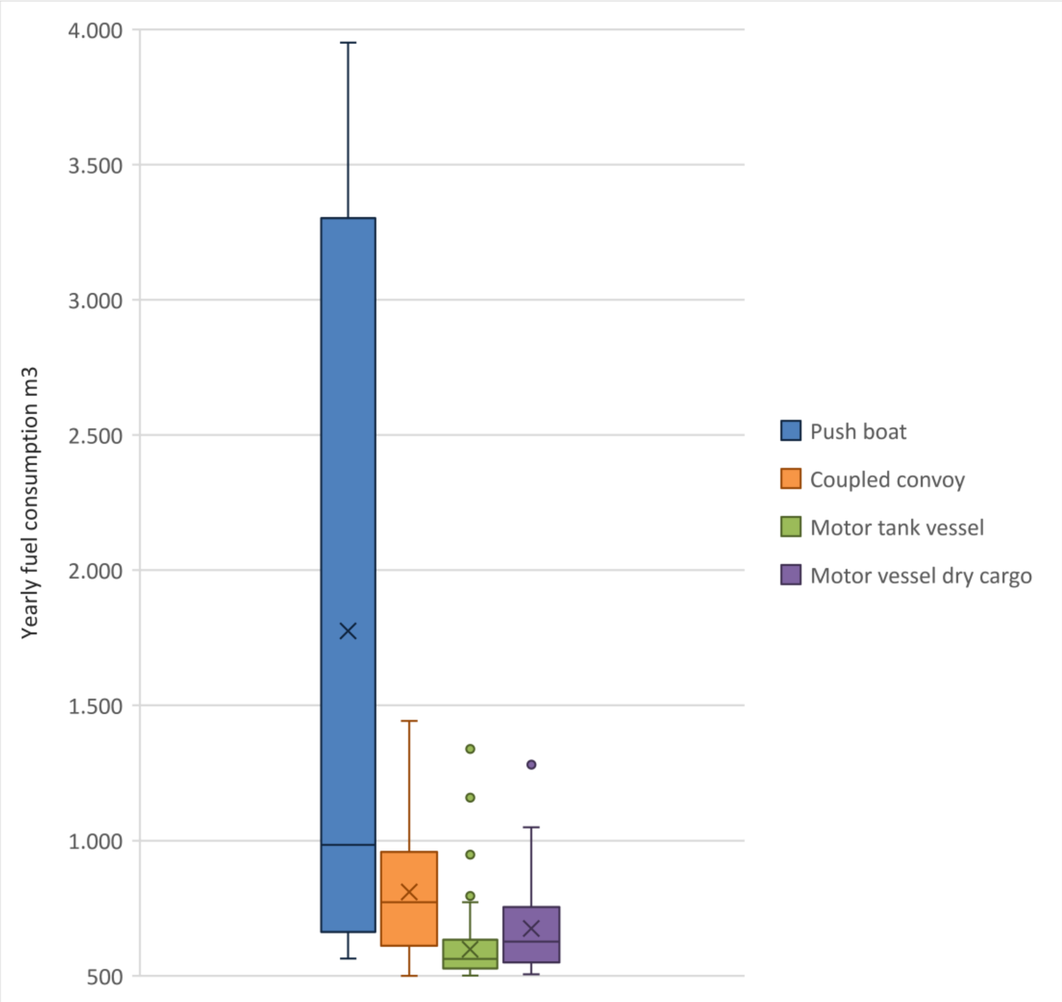



*Figure 3: Distribution of fuel consumption*



Given the relative importance of push boats, coupled convoys, motor vessels dry cargo and motor tank vessels a more detailed overview has been created concerning their fuel consumption. Figure 4 provides this overview in the form of a boxplot.

*Figure 4: Boxplot of yearly fuel consumption (in cubic meters) with the mean (X), 25% - 75% interval (and median), maximum and minimum, and outliers for vessels with a yearly consumption of ≥500m3*




The first thing that stands out is the relatively large range in the yearly fuel consumption of push boats as compared to the other three groups. This is due the fact that there is a significant difference in the average fuel consumption between push boats with a relatively low installed total engine power (kW) as compared to push boats with a relatively high installed total engine power (kW). This appeared from previous research done for the project PROMINENT[4], in which it was stated that within the groups of

push boats and motor cargo vessels (tank and dry), in particular the large push boats with a total engine power of ≥2000Kw and large motor cargo vessels with a length of ≥110m have the highest average fuel consumption figures per year. Building on this, it can be stated that within the potential LNG fleet, LNG is in particular an interesting alternative fuel for:

- Push boats ≥2000 kW (total engine power)
- Motor tank vessels ≥110m length
- Motor vessels dry cargo ≥110m length
- Coupled convoys

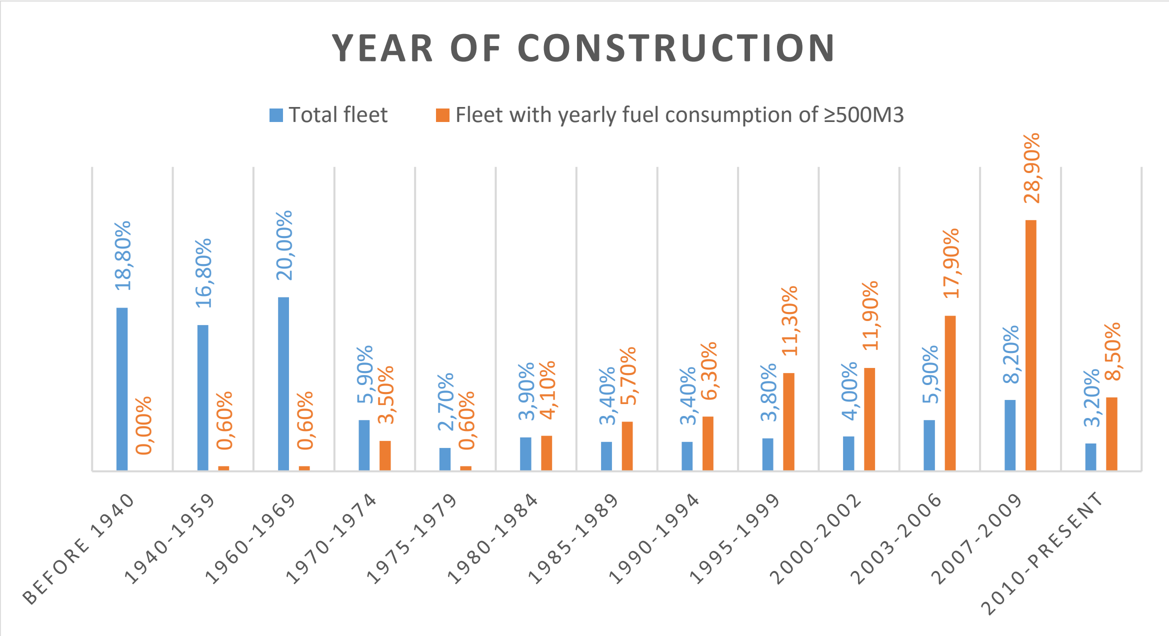
While given their fuel consumption, saving on fuel costs for these four fleet families is very important.

## Year of construction

The year of construction is also a point of interest while it may have an impact on the fuel consumption. Figure 5 illustrates this relation, the horizontal axis shows the time period while the vertical axis indicates which percentage of respectively the total fleet and the fleet with a yearly consumption of ≥500m$^3$ were built in that specific time period.

[4] PROMINENT; D1.1 List of operational profiles and fleet families (2015)

Figure 5: *Year of construction of vessels with a yearly fuel consumption of ≥500m³ as compared to the total fleet*

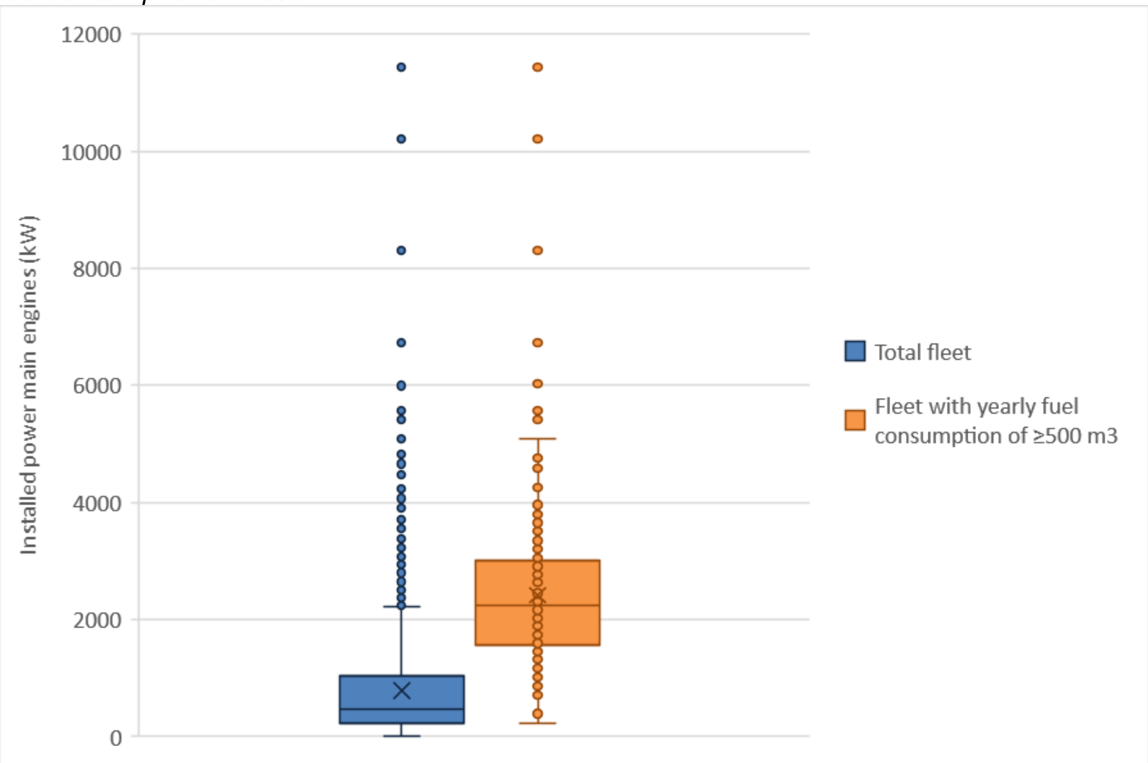



It can be seen from the figure that the fleet with a yearly fuel consumption of ≥500m³ is relatively new. Most of these vessels were built after 2000 and a majority even in 2003 and later, which was the introduction year of CCNR Stage-1 emission norms for vessel engines. Thus, approximately 50% of the fleet with a yearly consumption of ≥500m³ was built in or after 2004, whereas approximately 50% of the total fleet was built in or after 1965.

## Engine power

The installed engine power is another important point of interest regarding the fuel consumption of a vessel. It can be seen from figure 6 that the installed power of the main engines is relatively higher for the fleet with a yearly fuel consumption of ≥500m³. It can therefore be argued that the installed power and fuel consumption are positively related to each other and that vessels with a relatively higher installed power consume relatively more fuel on a yearly basis.

*Figure 6: Boxplot of the installed power of main engines (in kW) with the mean (X), 25% - 75% interval (and median), maximum and minimum, and outliers for the total fleet and fleet with yearly fuel consumption of ≥500m³*

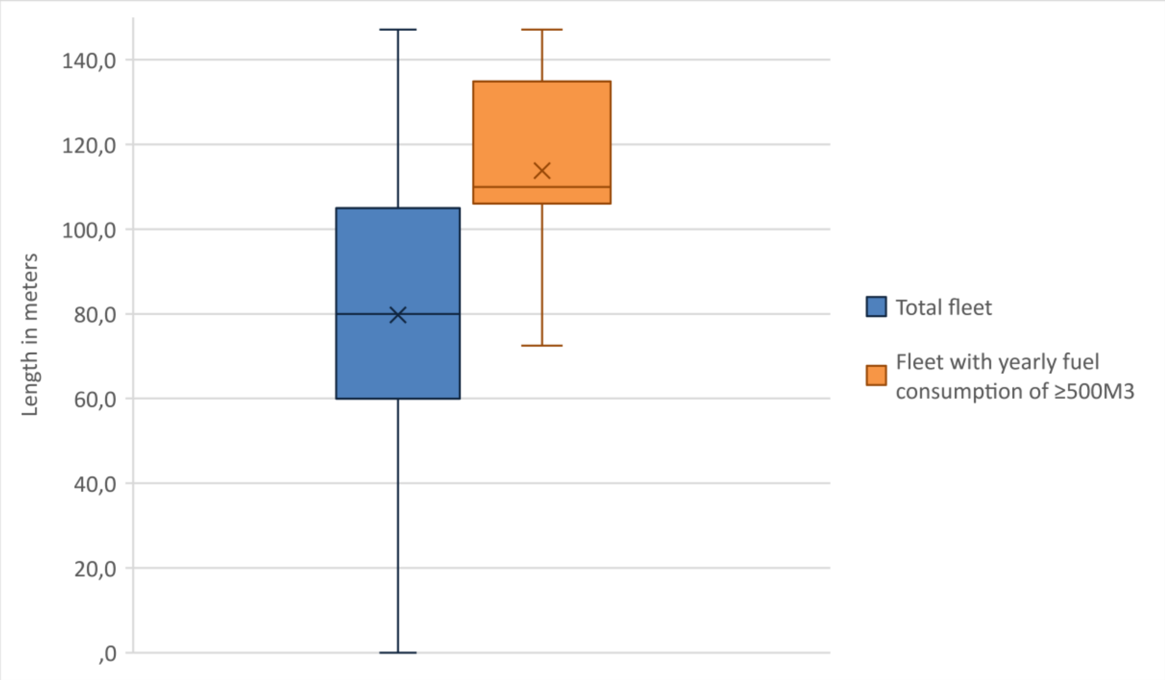



*Note: The data regarding the installed engine power is lacking and consequently the installed power of the main engines is unknown for a relatively small part of the fleet.*

## Length

It is most likely that the yearly fuel consumption is also related to the length of a vessel. This relation can be seen in figure seven, which illustrates the length of the total fleet and the fleet with a yearly fuel consumption of ≥500m$^3$.

*Figure 7: Boxplot of the vessel length in meters with the mean (X), 25% - 75% interval (and median), maximum and minimum for the total fleet and fleet with yearly fuel consumption of ≥500m$^3$*




*Note: The data regarding the vessel length is lacking and consequently the length is unknown for a relatively small part of the fleet. Push boats are not included in the data while this may give a distorted view.*

It can be seen from the figure that the length of a vessel is positively related to the yearly fuel consumption. It appears that large-scale fuel consumers, i.e. vessels with a yearly fuel consumption of ≥500m$^3$, are relatively longer as compared to the total fleet. This fleet consists predominantly out of (large) Rhine vessels, consequently this also restricts the number of waterways on which potential LNG driven vessels can sail (namely from CEMT V-class waterways on). Whereas the fleet that consumes a yearly amount between 250m$^3$ and 500m$^3$ still consists of relatively lot vessels from the middle class (CEMT-class III and IV, 'Dortmunder' and 'Rhine-Herne canal' vessels respectively).[5]

[5] Research LNG fueling stations, Expertise and Innovation Centre Inland Shipping (2014)

## 2.3 Conclusion

Chapter 2 discussed the current and potential LNG fleet and provides thereby an answer to the first research question, which is “Who are current and potential users of LNG in the inland waterway transport sector?”

Currently there is only a relatively small amount of LNG driven vessels. There are in total 6 LNG driven vessels, 5 of them are motor tank vessels whereas the remaining one is a coupled convoy.

Potential users of LNG are identified based on a threshold for yearly fuel consumption, which has to be at least 500 $m^3$ . This can be seen as the first and foremost condition for investing in an LNG installation, while in order to earn the LNG investment back a vessel has to consume in the first place at least 500 $m^3$ of gasoil per year.

324 vessels comply with the threshold for the yearly fuel consumption, these vessels together can be defined as the potential LNG fleet. The majority of these vessels consists of motor tank vessels, motor vessels dry cargo, push boats and coupled convoys. Together, the motor tank vessels make up the largest part and consume the most fuel on a yearly basis in absolute terms. However, push boats are on average the largest consumer of fuel on a yearly basis.

The potential LNG fleet differs in three different aspects from the total fleet, these are the year of construction, installed power and length of the vessel. As compared to the total fleet, vessels that belong to the potential LNG fleet are on average younger, have more installed power and are also longer (excl. push boats). It appears that all three factors are positively related to the yearly fuel consumption. Building on this, it can be stated that within the potential LNG fleet, LNG is in particular an interesting alternative fuel for:

- Push boats ≥2000 kW (total engine power)

- Motor tank vessels ≥110m length
- Motor vessels dry cargo ≥110m length
- Coupled convoys

# 3. Sailing profile of potential LNG fleet

In order to get insight into the potential of LNG bunker stations along the core inland waterway network in Europe, or also for places outside the core network, research is done on the sailing profiles of vessels which belong to the potential LNG fleet. This will provide among others an answer to the second research question, namely where potential LNG driven vessels sail.

## 3.1 Research design

On the basis of fuel bunker volumes over the year 2012 in the Netherlands a selection has been made consisting of 304 vessels, in 2012 those were the vessels which bunkered the most fuel. Given their fuel consumption these vessels are suitable candidates for sailing on LNG. Some vessels were not traceable, mainly concerning a number of sand dredgers and crane vessels. In addition, it was not possible to observe the position of a couple of vessels. Consequently, it was possible to track 283 vessels out of the selection of 304 vessels. These vessels were tracked during a time period of one month (20 October – 20 November 2014).

During this time period the position of each vessel is recorded every hour, eventually resulting in the following data:

- The longitude and latitude of each last observed position;
- The speed (in knots) during each last observed position;
- The course (in degrees) during the last observed position;
- The status (sailing/idling);
- And the exact date/time of each observation

## 3.2 Research results

The obtained results can be visualized in different manners, however in order to provide an appropriate overview a heat map (figure 8) is set up in order to visualize the locations where most vessels remain for most of the time. The color red is an indication of intensity at the highest level, diminishing to yellow-green-blue. The spots in dark purple indicate core ports in the surrounding environment.

*Figure 8: Heat map showing intensity of potential LNG driven vessels and in addition some core ports (dark purple)  in the surrounding environment*


The heat map clearly shows some red spots, indicating areas of intensive inland shipping of the potential LNG fleet. The most characterizing hereby is the axis starting at the Rhine in Germany – via Waal, Merwede and Meuse – to Amsterdam, Rotterdam and Antwerp (ARA). This axis also contains shipping in between the seaports. This confirms the sailing profiles of the potential LNG driven vessels, which almost all sail between the Rhine and the seaports of Rotterdam and Antwerp.

With regard to this axis a selection of representative journeys has been made previously for the project PROMINENT, mainly based on freight flows (in tonnes and tkm). This has resulted in amongst other the following list of 25 representative Rhine journeys.

*Table 2: Selection of representative journeys in the Rhine/ARA region*

| | Port A | Port B | Type | Vessel type | Commodity | mln tkm |
|---|---|---|---|---|---|---|
| 1 | Rotterdam | Duisburg | Dry bulk | Push B4 | Ore | 4074 |
| 2 | Rotterdam | Antwerp | Container | C3L/B | Containers | 3067 |
| 3 | Rotterdam | Karlsruhe | Liquid Bulk | MTS 135m | Crude oil | 2478 |
| 4 | Amsterdam | Karlsruhe | Dry bulk | C3L/B | Coal | 2219 |
| 5 | Rotterdam | Basel | Container | C3L/B | Containers | 1094 |
| 6 | Antwerp | Thionville | Dry bulk | MVS110m | Coal | 1075 |
| 7 | Amsterdam | Antwerp | Container | C3L/B | Containers | 983 |
| 8 | Rotterdam | Krotzenburg | Dry bulk | C3L/B | Coal | 976 |
| 9 | Amsterdam | Rotterdam | Liquid Bulk | MTS 135m | Oil | 968 |
| 10 | Antwerp | Mainz | Container | MVS 135m | Containers | 827 |
| 11 | Breisach | Cuijk | Dry Bulk | MVS 110m | Sand&gravel | 803 |
| 12 | Antwerp | Duisburg | Container | C3L/B | Containers | 677 |
| 13 | Rotterdam | Duisburg | Container | MVS 110m | Containers | 620 |
| 14 | Rotterdam | Ludwigshafen | Liquid Bulk | MTS 86m | Chemicals | 571 |
| 15 | Rotterdam | Kampen/Zwolle | Liquid Bulk | MTS 110m | Oil | 282 |
| 16 | Rotterdam | Strassbourg | Dry Bulk | MVS110m | Agribulk | 254 |
| 17 | Amsterdam | Heilbronn | Dry bulk | MVS 105m | Animal Fodder | 196 |
| 18 | Duisburg | Antwerp | General cargo | MVS 110m | Metal products | 181 |
| 19 | Rotterdam | Alphen a/d Rijn | Container | MVS 105m | Containers | |
| 20 | Terneuzen | Rotterdam | Liquid Bulk | MTS 110m | Chemicals | 166 |
| 21 | Wesel | Enkhuizen | Dry Bulk | MVS 67m | Sand&gravel | |
| 22 | Rotterdam | Herne | Dry Bulk | MVS 86m | Metal (scrap) | 43 |
| 23 | Dusseldorf | Antwerp | Dry Bulk | MVS 110m | Agribulk | 40 |
| 24 | Antwerp | Gent | Dry bulk | MVS 110m | Coal | 98 |
| 25 | Rotterdam | Duisburg | Dry bulk | MVS 86m | Agribulk | 14 |

For many of these representative journeys a power distribution over time has been generated, providing insight into the needed power – for upstream and downstream – for each of these journeys. In turn providing the required detailed knowledge about the operational profile of vessels on distinct journeys. This knowledge is necessary for the selection and implementation of greening technologies like LNG. More detailed information about the representative journeys and operational profiles can be found in PROMINENT; D1.1 List of operational profiles and fleet families (2015).

In addition to the abovementioned journeys there are also other less intensive areas where potential LNG driven vessels sail, such as in the Limburg region and the Wadden islands. The shipping intensity surrounding the Wadden region concerns the intensive ferry services of a limited number of vessels, which sail daily on relatively short trajectories and eventually end up in the same port.

## 3.3 Motor tank vessels

*Figure 9: Heat map showing intensity of potential LNG driven motor tank vessels*


Motor tank vessels are interesting to look at while they make up the largest category within the fleet with a yearly fuel consumption of ≥500m³. In addition, motor tank vessels are together also the largest consumers of fuel in absolute terms within the potential LNG fleet.

When comparing figure 9 with figure 8 it appears that motor tank vessels, within the potential LNG fleet, sail in general on the same trajectory as the overall potential LNG fleet, namely between the Rhine and the ARA region and within the ARA region itself.

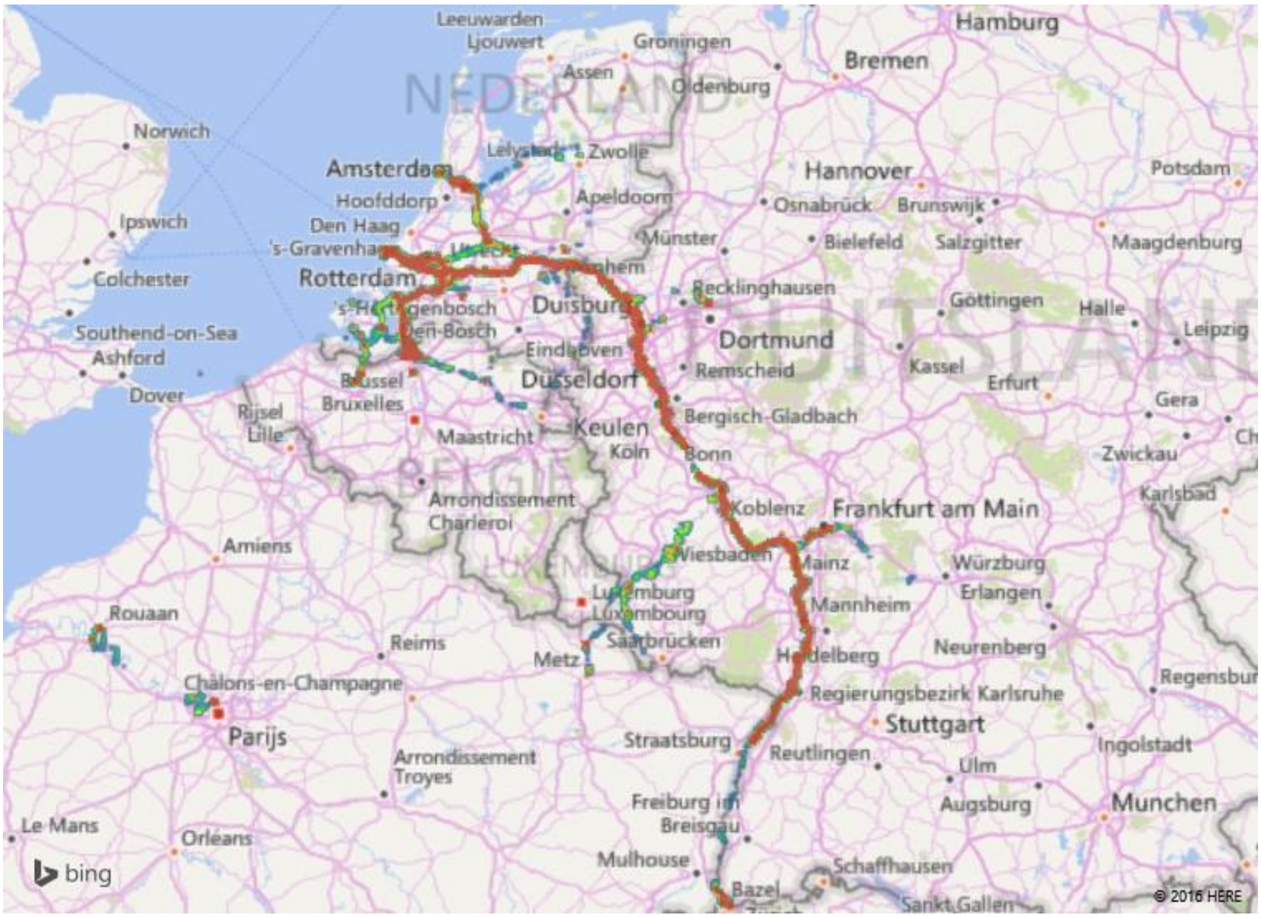
## 3.4 Motor vessels dry cargo

*Figure 10: Heat map showing intensity of potential LNG driven motor vessels dry cargo*


Similar to motor tank vessels, also motor vessels dry cargo sail in general on the same trajectory as the whole potential LNG fleet does. Namely between the Rhine and the ARA region and within the ARA region itself.  However, it can be seen from the figure that motor vessels dry cargo are relatively more operational in the northern part of the Netherlands as compared to motor tank vessels.

## 3.5 Coupled convoys

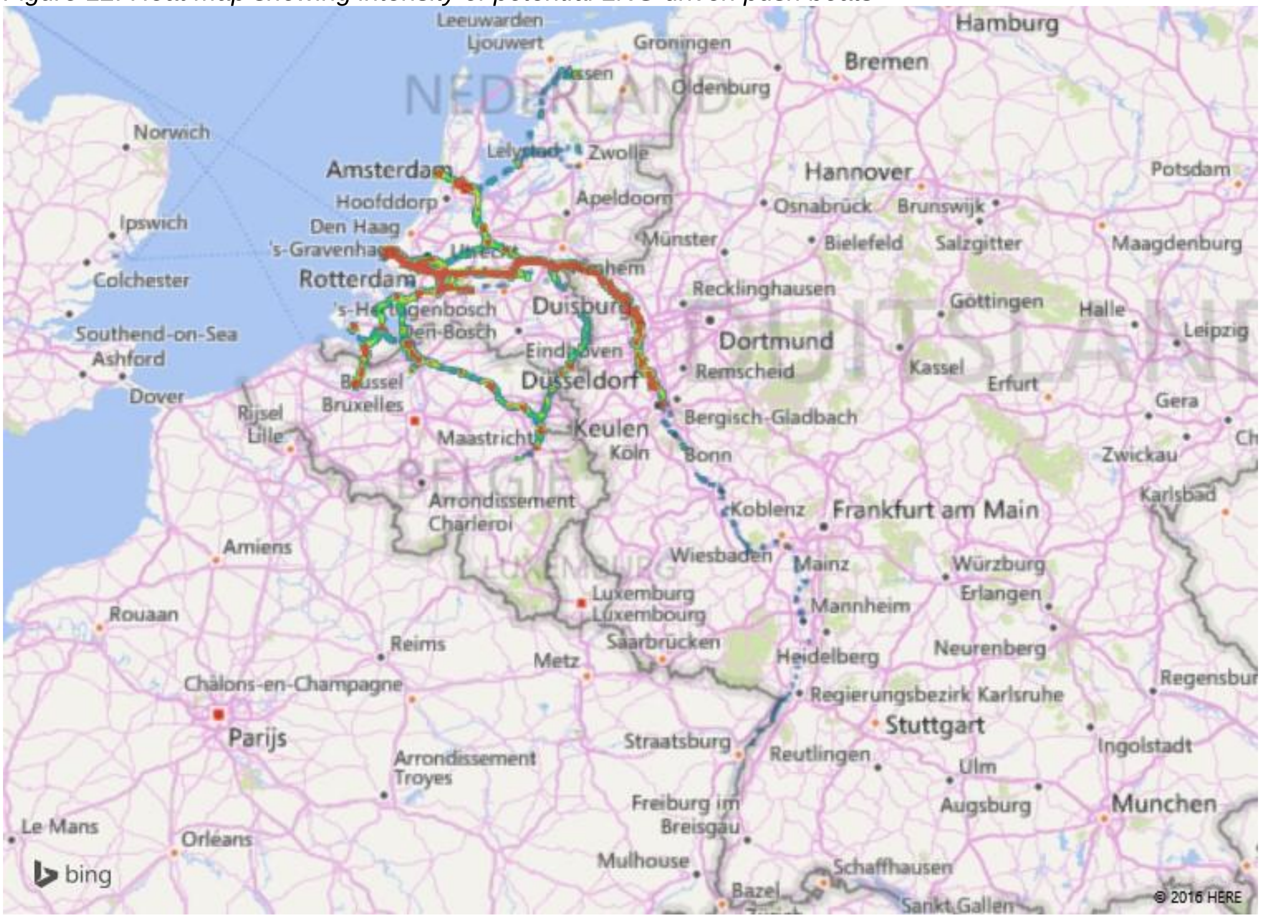
*Figure 11: Heat map showing intensity of potential LNG driven coupled convoys*




The heat map of coupled convoys shows strong similarities with the maps of motor tank vessels and motor vessels dry cargo. A notable difference as compared to the abovementioned two fleet categories however is the intensity in the southern part of Germany; the upper Rhine area. An explanation for this could be that more economies of scale (i.e. more cargo) is required to sail further upstream on the upper Rhine, starting at one of the seaports in the ARA region for example.

## 3.6 Push boats

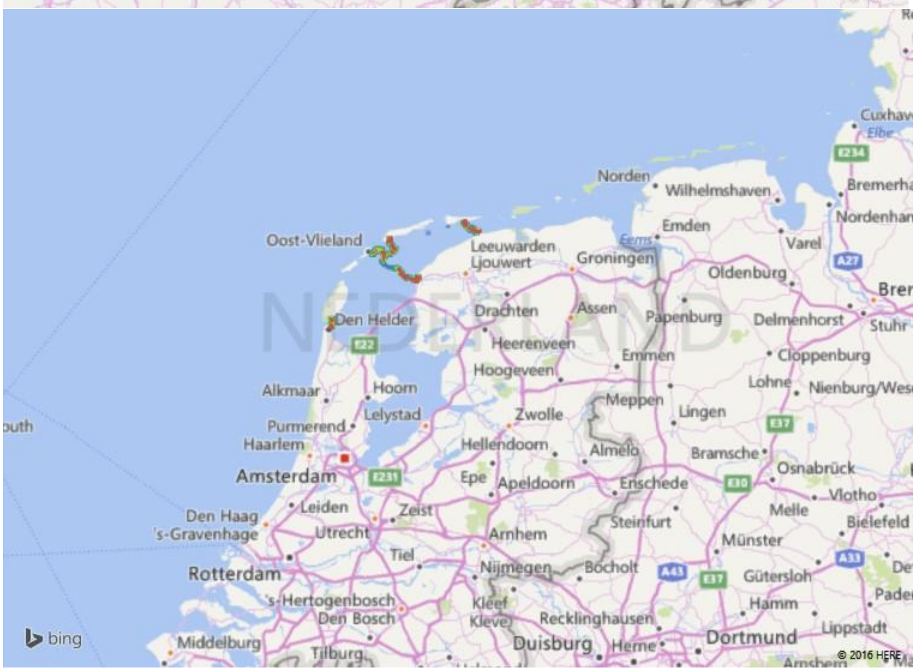
*Figure 12: Heat map showing intensity of potential LNG driven push boats*




It can be seen from figure 12 that the push boats within the predefined selection, i.e. the potential LNG fleet, sail mainly between Rotterdam and Germany (predominantly to and from Duisburg). An explanation could be that push boats predominantly transport raw materials (coal and iron ore), starting at the port of Rotterdam and with the Duisburg area as final destination. The intensity in other Dutch seaports (e.g. Amsterdam, Zeeland and Moerdijk) as well as in the port area of Antwerp is therefore limited.

## 3.7 Passenger vessels & Ferries

*Figure 13 & 14: Heat maps showing intensity of potential LNG driven passenger vessels and ferries*

Both figures show less intense areas of operation in comparison to the before mentioned vessel categories. Passenger vessels are merely operational on the same trajectory as the other vessel categories, although it is far less intense. Whereas the ferries are predominantly active in the area surrounding the Wadden islands.

## 3.8 The large-scale fuel consumers

*Figure 15 & 16: Heat maps showing intensity of potential LNG driven vessels with a yearly fuel consumption of >1000m$^3$ (left) and >2000m$^3$ (right)*


The large-scale consumers of fuel have the best business case for a switch towards LNG as alternative fuel. These vessels are grouped into two categories, namely a group with a yearly fuel consumption of >1000m$^3$ and a second group with a consumption of >2000m$^3$. Important to note is that both groups consist of a relatively small number of vessels (42 and 10 vessels respectively). These vessels sail predominantly on the Rhine, between Rotterdam (and Antwerp) and Germany, mainly with the Duisburg area as final destination. These vessels sail only limited to and from the seaport of Amsterdam.

## 3.9 Conclusion

Chapter 3 discussed the sailing profile of the potential LNG fleet and provides thereby an answer to the second research question, which is “Where do current and potential users of LNG sail?”

As of 2016, there are six inland vessels which sail on LNG. Five of these vessels are motor tank vessels whereas one ship is a coupled convoy. These vessels are predominantly active in the ARA region and/or on the Rhine between the Netherlands and Basel. Consequently, the current LNG fleet is limited and in order to exploit LNG bunkering stations in an economically feasible way, more insight is required in the potential users of LNG.

On basis of the fuel consumption over the year 2012 a selection has been made of suitable candidates for sailing on LNG. 283 vessels were tracked during a time period of one month (20 October – 20 November 2014).

It appeared that there are certain areas of intensive shipping by the potential LNG fleet. The most characterizing hereby is the axis starting at the Rhine in Germany – via Waal, Merwede and Meuse – to Amsterdam, Rotterdam and Antwerp (ARA). This axis also contains shipping in between the ARA seaports. This confirms the sailing profiles of the potential LNG driven vessels, which almost all sail between the Rhine and the seaports of Rotterdam and Antwerp. There are however some differences concerning the sailing profiles between the different vessel categories.

Table 2 provides a list with 25 representative journeys in the mentioned Rhine/ARA region, where the majority of the potential LNG fleet is operational. More detailed information about the representative journeys and operational profiles in this region can be found in “PROMINENT; D1.1 List of operational profiles and fleet families (2015).”

# 4. Potential LNG bunkering stations along the IWW core network

The overall action contributes to the implementation of the TEN-T network, which in turn specifies that LNG bunkering stations should be present in all core seaports by 2025 and core inland ports by 2030.  The aim of this chapter is therefore to identify potential LNG bunkering stations along the IWW core network.

*Figure 17: Heat map showing intensity of potential LNG driven vessels and core ports (dark purple) in the surrounding environment*

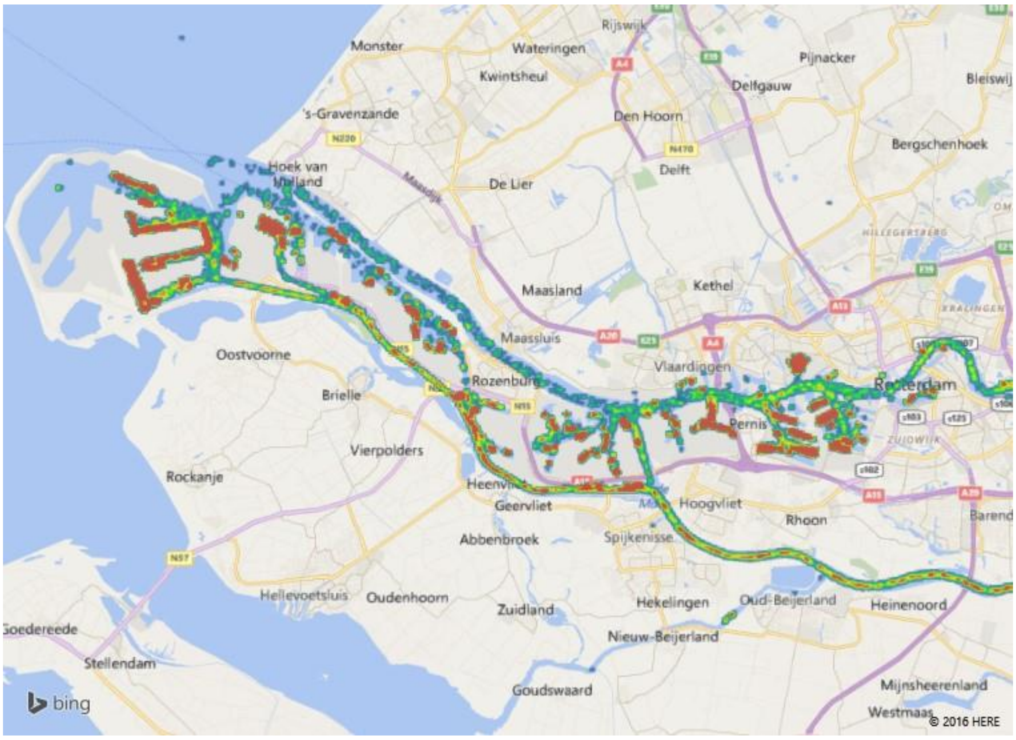

Figure 17 presents the intensity of the potential LNG fleet and the core ports in surrounding environment, these are indicated with dark purple colored spots. Close-ups will be provided of the core ports with a relatively high intensity of potential LNG driven vessels. Important core ports like the ARA-ports and the inland ports of Duisburg and

Basel will be discussed in the main text whereas close-ups of the remaining relevant ports are included in the appendix.

## 4.1 Overview core ports

### Port of Rotterdam (inc. Rijnmond)

*Figure 18: Heat map showing intensity of potential LNG driven vessels in the port area of Rotterdam*



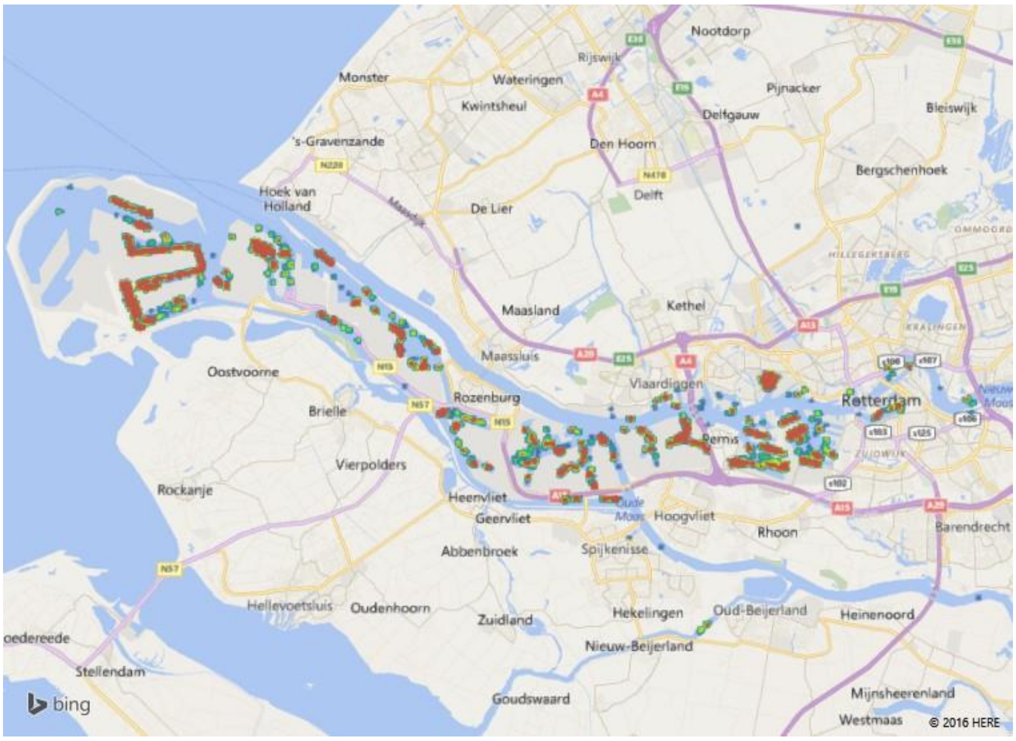

The port of Rotterdam is being characterized by a high intensity of potential LNG driven vessels, while the majority of these vessels call on the port of Rotterdam, usually a starting point for these vessels concerning the trajectory between Rotterdam and Germany or within the ARA region itself (Amsterdam to a lesser extent). The areas with relatively the highest intensity are the locations with a lot of transshipment activities, namely:

- Maasvlakte, where container terminals ECT, APMT and Euromax and the coal and iron ore terminal EMO are established. The high intensity can be related to the high presence of motor cargo vessels, coupled convoys and push boats;
- Europoort, there is especially a high intensity observable in the Dintelhaven where the coal and iron ore terminal EECV is established. Usually there is a high presence of push boats at this location;

- Botlek, there is a high presence of motor tank vessels observable near ETT and Vopak and in addition some Ro-Ro activities at Cobelfret;
- Pernis, another popular destination for motor tank vessels due to the presence of Shell and Argos;
- Eemshaven and Waalhaven, being characterized by a high presence of container carrying vessels at the terminals of RST, UWT, ECT and Uniport.

All these mentioned locations are also characterized by the presence of motor tank vessels, such as in the Merwehaven, being mostly bunkering ships present for refueling sea-going vessels.

*Figure 19: Heat map showing intensity of idling potential LNG driven vessels in the port area of Rotterdam*




It is also interesting to look at the intensity of idling potential LNG driven vessels, the intensity is the highest at locations for transshipment.

## Port of Antwerp

*Figure 20: Heat map showing intensity of potential LNG driven vessels in the port area of Antwerp*

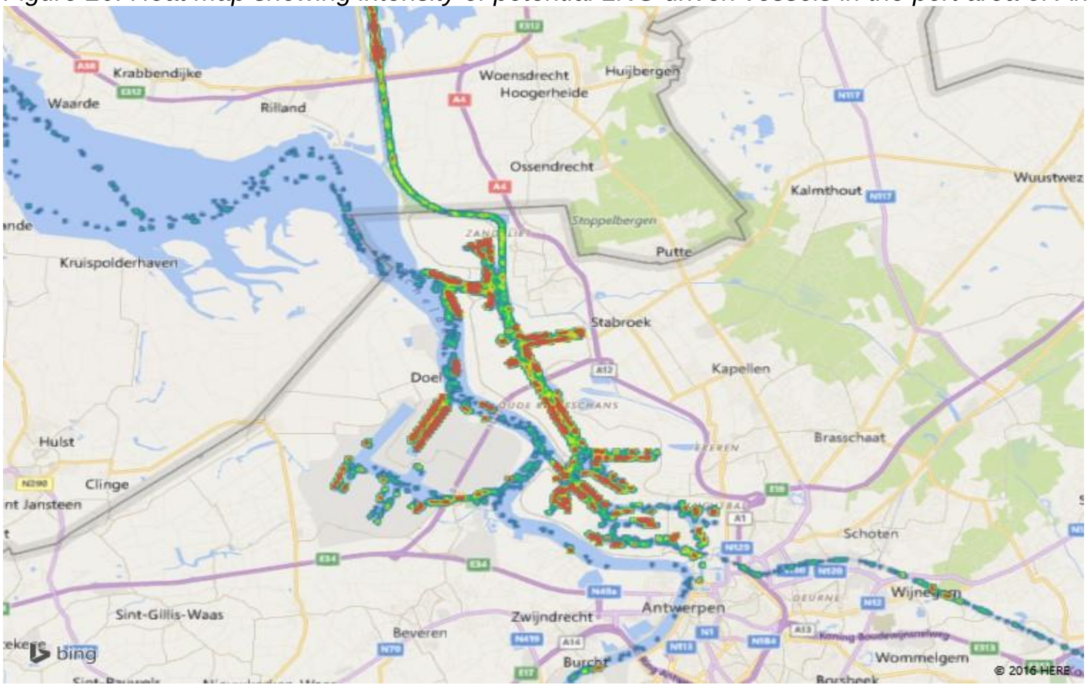



Figure 20 shows high levels of intensity in areas where container terminals are located and transshipment activities occur, such as in Deurganckdock, Delwaidedock which include terminals like MPET and IMT. This can be related to the presence of motor cargo vessels dry cargo and coupled convoys transporting containers. The intensity surrounding Kanaaldok B3 and Hansadok can be related to the presence of motor tank vessels due the petrochemical industry in those areas.

*Figure 21: Heat map showing intensity of idling potential LNG driven vessels in the port area of Antwerp*

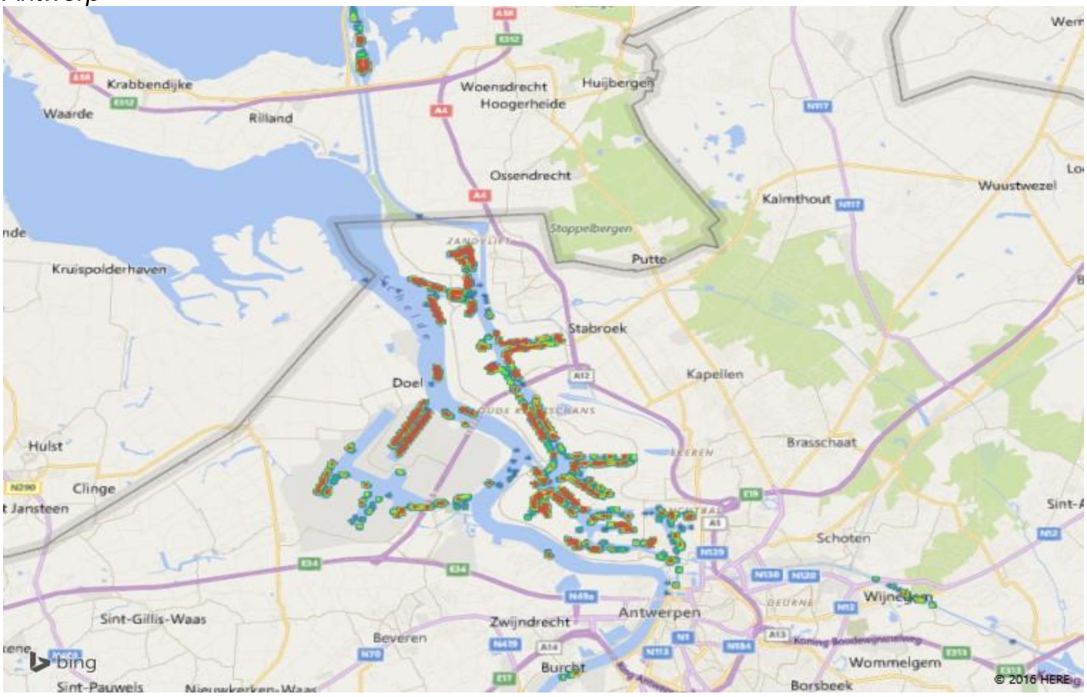


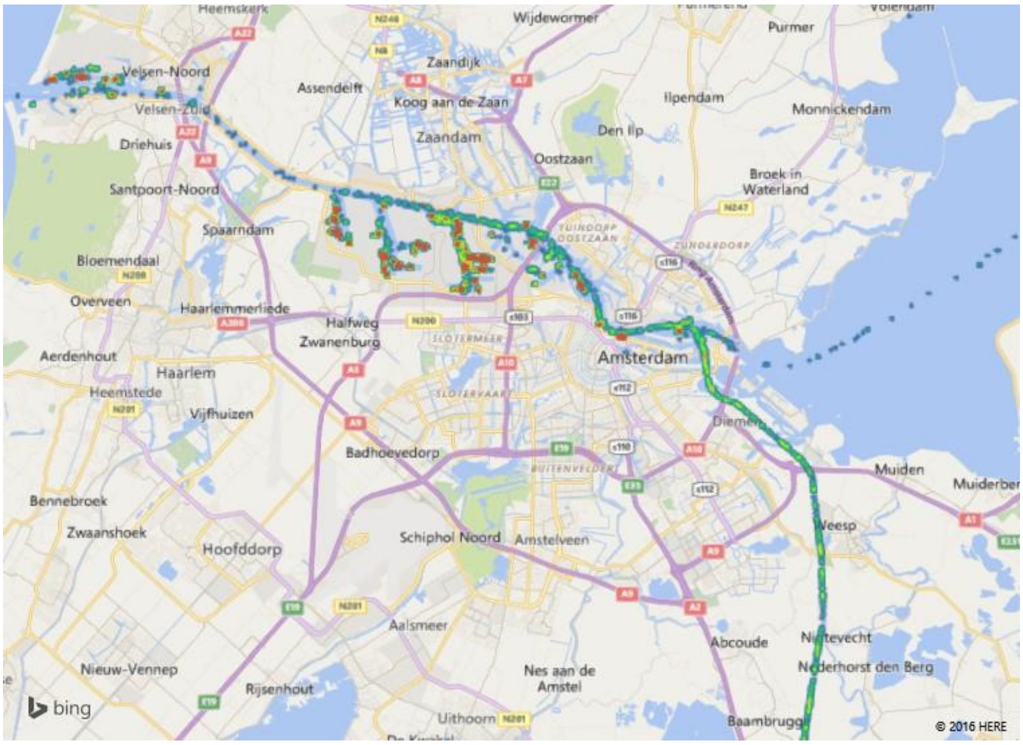

Figure 21 with idling vessels shows strong similarities as compared to figure 20. The intensity is the highest at locations for transshipment.

## Port of Amsterdam

The highest intensity of potential LNG driven vessels can be found in the western areas of the port, which include different locations for transshipment activities. This can be seen in:

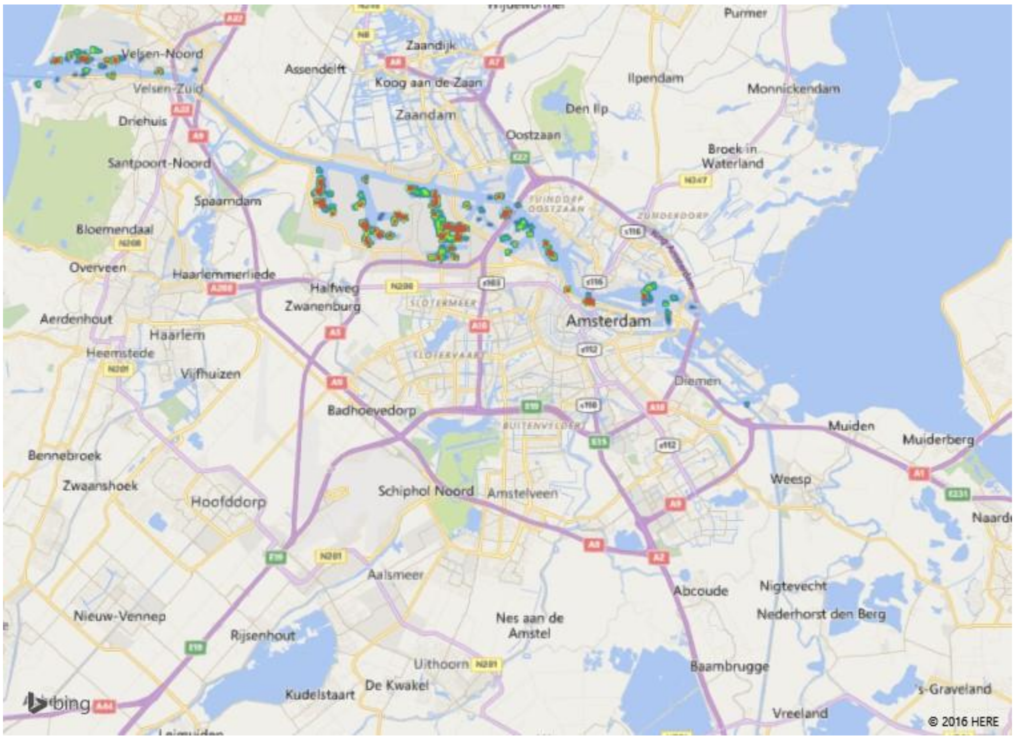
- Westhaven, near the bulk terminal of OBA where predominantly push boats arrive for the transportation of coal. Another busy point within the Westhaven is the container terminal of CTVrede-Steinweg;
- Amerikahaven, near the bulk terminal of Rietlanden and near Oiltanking which receives a lot of motor tank vessels;
- Afrikahaven, near Rietlanden Terminals and near Vopak which just as Oiltanking experiences a high intensity of motor tank vessels.

*Figure 22: Heat map showing intensity of potential LNG driven vessels in the port area of Amsterdam*



In addition, there is relatively a high presence of motor tank vessels which refuel sea-going vessels. This also applies to the ports in Velsen, IJmuiden and Beverwijk. This situation in Amsterdam is also confirmed on figure 23 which illustrates the idling vessels.

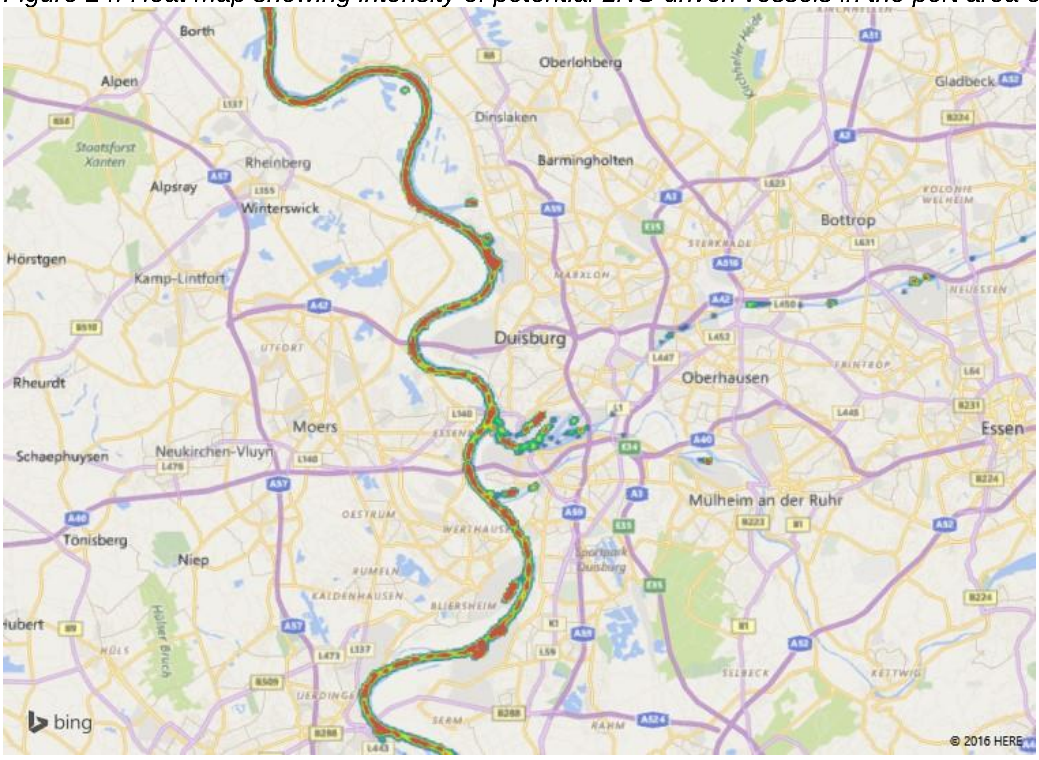
*Figure 23: Heat map showing intensity of idling potential LNG driven vessels in the port area of Amsterdam*



## Port of Duisburg

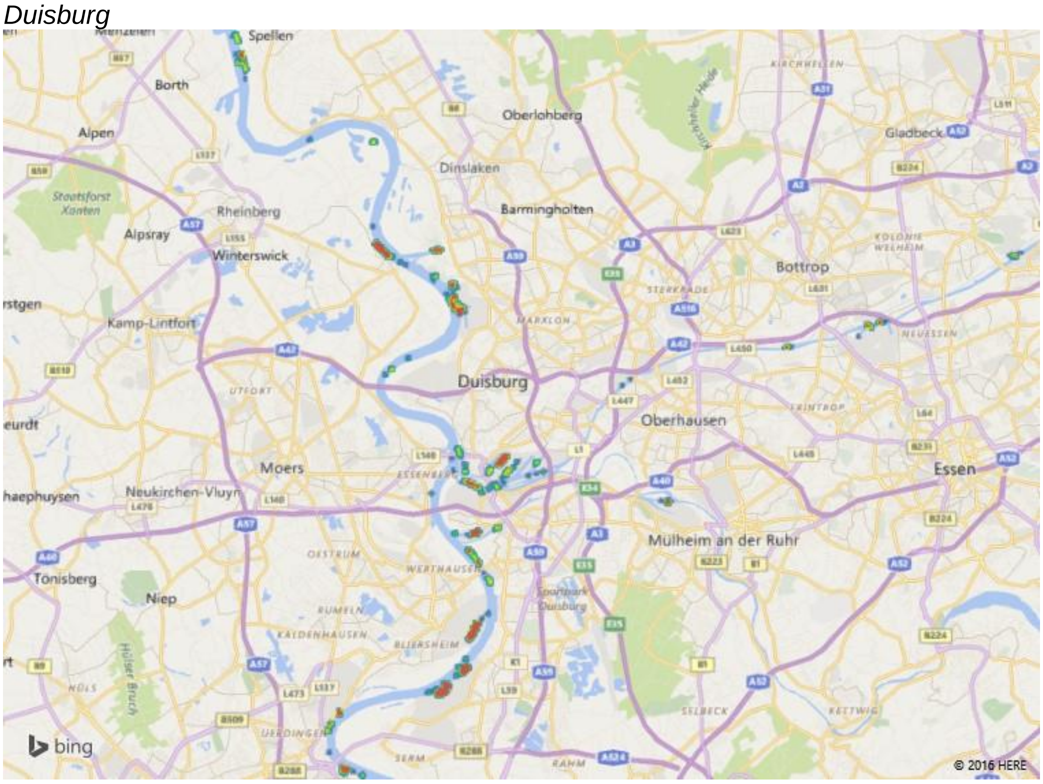
The Rhine flowing through Duisburg shows quite some intensive spots. The intensity in the northern parts can be related to the heavy industrial activity. For example, the large red spots in the northern part near the complex of Thyssen-Krupp Steel AG can be related to the presence of large number of push boats which are unloading dry bulk like iron ore and coal. There is also a large presence of coupled convoys north of Thyssen-Krupp which supply the coal fired Duisburg-Walsum Cogeneration Plant and unload coal at the coal terminal at the other side of the river.

*Figure 24: Heat map showing intensity of potential LNG driven vessels in the port area of Duisburg*




The intensity in the centre of the port can be related to the presence of motor tank vessels and motor cargo vessels dry cargo. Vessels belonging to the first category are mainly present in Becken A near the tank terminals, whereas the second category is mainly active in the Sudhafen and surroundings near the container terminals. The intensity in the lower parts of the figure can be mainly related to activities in container terminals, like in the DIT terminal. The intensity in the diagonally-opposite direction from the DIT terminal can be related to the presence of push boats and coupled convoys unloading coal and iron ore for the heavy industrial activity (e.g. Hüttenwerke Krupp Mannesmann) at that site. The activities in the terminals mentioned above can been more clearly in the figure 25 below, which shows these vessels in idling status.

*Figure 25: Heat map showing intensity of idling potential LNG driven vessels in the port area of Duisburg*

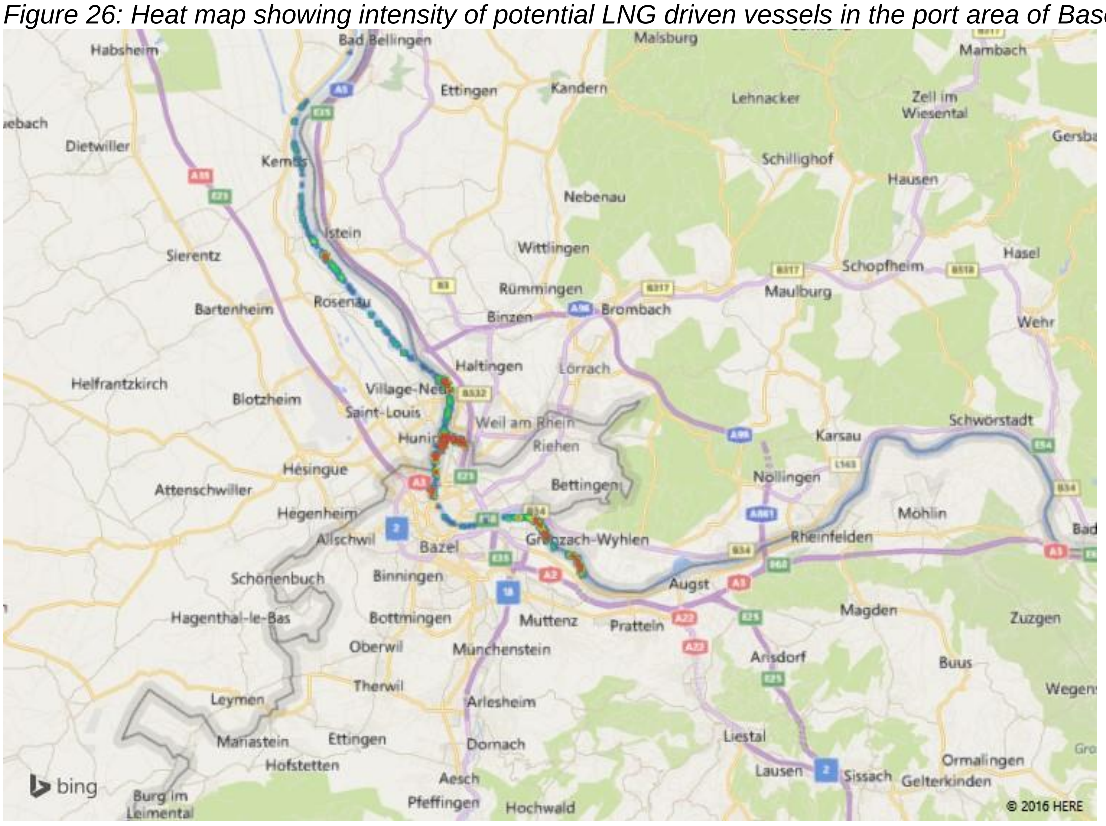


## Port of Basel

The inland port of Basel (officially the Port of Switzerland), being the first major city in the course of the Rhine stream, is an important gateway for Switzerland. The river connects the country to the sea ports of Amsterdam, Rotterdam and Antwerp, approximately more than 10% of all Swiss imports flow through these sea ports.

The Port of Switzerland consists of three ports, namely the ports of Birsfelden, Muttenzand Basel-Kleinhuningen.[6] It can be seen on figure 26 below that the intensity is relatively high at three different sites, representing the three mentioned ports.

*Figure 26: Heat map showing intensity of potential LNG driven vessels in the port area of Basel*



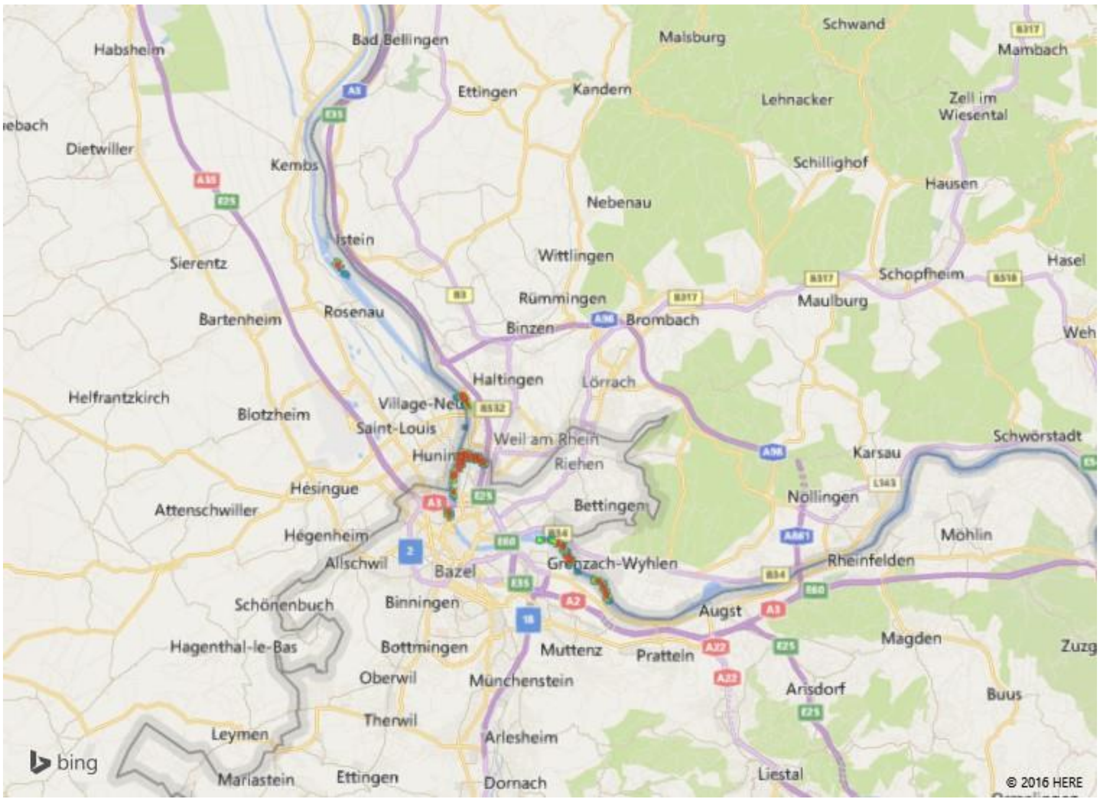

The intensity in the port of Basel-Kleinhuningen (the most northern port) can primarily be related to the intensity of coupled convoys which are present there for the three

[6] http://www.portofbasel.ch/en/

container terminals. But also dry and wet bulk products are handled and stored at this port.

The intensity in the port of Birsfelden can mainly be related to the handling and storage activities of steel and other metals associated with production facilities and trimodal logistics. The port of Muttenz-Au (the most southern port) is known for the handling and storage of liquid fuels an propellants, but also serves traffic in food-grade oils as well as other dry goods.[7] The intensity in this port can be related to the presence of coupled convoys and motor tank vessels. Figure 27 below provides a better overview of the locations of the discussed three ports.

*Figure 27: Heat map showing intensity of idling potential LNG driven vessels in the port area of Basel*




[7] http://www.port-of-switzerland.ch/en/ueber-uns/rheinhaefen.php

## 4.2 Conclusion

Chapter 4 discussed the potential for LNG bunkering stations along the IWW core network and consequently provides an answer to the third research question, which is "Where should future LNG bunker stations be deployed?"

Given the objective of TEN-T, LNG bunkering stations should arise along the IWW core network. Figure 17 illustrates areas with intensive shipping activities of the potential LNG fleet and as well as (sea)ports belonging to the core network. The intensity, i.e. the potential demand for LNG, is the highest in the ARA ports and between these seaports and the Rhine in Germany (approximately till Duisburg). This is approximately the region where the majority of the potential demand for LNG sails. There is however also a significant intensity of potential LNG driven vessels between Duisburg and Basel.

The intensity within the mentioned port areas along the core network is the highest at transshipment locations, and to a lesser extent at berths and locks (e.g. Volkerak, Kreekrak and Beatrix lock). It is therefore preferable to deploy LNG bunkering stations near locations with the highest potential demand, namely the transshipment locations. Current (mobile) LNG bunkering activities confirm this, while these often happen in the port area of seaports. This also appears from plans for future LNG bunkering facilities[8], for e.g. the planned deployment of an LNG fueling point on the terrain of the power plant and container terminal in the port area of Nijmegen.

In determining potential locations for LNG bunkering stations it is crucial to take the safety regulations into consideration, while this may have an effect on the precise location. Currently there are two important publications which are published by the LNG masterplan and PGS and can be found on their website.[9][10]

[8] http://www.gie.eu/index.php/maps-data/gle-sslng-map
[9] http://lngmasterplan.eu/masterplan/activities/16-masterplan/97-technical-evidence-safety-and-risk-assessment
[10] http://www.publicatiereeksgevaarlijkestoffen.nl/publicaties/PGS33-2.html

# Conclusion

The objective of activity 4.1 is analyzing the potential and sailing profiles of LNG using vessels in Europe. This analysis will be used to promote the standardization of tank sizes and location, the optimization of LNG refueling locations, maximizing the further roll-out of LNG vessels, and study the optimization of the supply chain (in combination with other modes). This will contribute to the elaboration of the preliminary business case calculations into mature, reliable business cases, in turn contributing to the key objective of this action; namely reducing the investment barrier for the ship owners with the aim to facilitate large scale implementation of LNG in IWT. Eventually forcing a breakthrough in the LNG market.

First, the current and potential users of LNG in the IWT sector were identified. The current fleet only consists of 6 vessels, whereas the potential LNG fleet is considerably larger and consists of 324 vessels. These vessels are identified based on their fuel consumption and tracked for a period of one month.

Second, the sailing regions of the current and potential LNG fleet were identified. The current LNG driven vessels predominantly sail in the ARA region and/or on the Rhine between the Netherlands and Basel. The potential LNG fleet shows strong similarities and is mainly active in the axis starting at the Rhine in Germany – via Waal, Merwede and Meuse – to Amsterdam, Rotterdam and Antwerp (ARA). This axis also contains shipping in between the ARA seaports. There however some differences concerning the sailing profiles between the different vessel categories.

Third, it is analyzed where future LNG bunkering stations should be deployed. Given the objective of TEN-T, these bunkering stations should arise along the IWW core network. Along this core network, the potential demand is the highest in the ARA ports and between these seaports and the Rhine in Germany (approximately till Duisburg). The intensity within the mentioned port areas along the core network is the highest at transshipment locations. It is therefore preferable to deploy LNG bunkering stations near locations with the highest potential demand, namely near such transshipment locations. In determining potential locations for LNG bunkering stations it is however crucial to take the safety regulations into consideration, while this may have an effect on the precise location.

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