Rotterdam LNG Hub for Inland Waterway Transportation

Urban, Port & Transport Economics

Bachelor Thesis

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Introduction

Liquefied natural gas (LNG) is natural gas which has been liquefied for transportation by ships and to a lesser extent by trucks. Natural gas is being liquefied by cooling it down to -162°C at atmospheric pressure. By liquefying the natural gas, it shrinks to 1/600th of its original volume (IEA).

Total demand for natural gas has grown by 2.7% per year since 2000, however global demand for LNG (Liquefied Natural Gas) has grown nearly three times faster in the same period, at an estimated rate of 7.6%. This large increase in demand for LNG has been largely driven on a regional perspective by Asia, especially by Japan after its nuclear shutdown after the Fukushima disaster. From a broader perspective demand is driven by the desire to secure the national energy supply, to reduce emissions, to renew the domestic energy infrastructure and because of the increasing opposition to nuclear plants (Ernst & Young, 2013).

The port of Rotterdam is aware of the increasing importance of LNG and acts in this way. The port has the ambition of becoming an LNG hub and is investing in the logistics chain of it. In 2011 the first import terminal for LNG was taken into service (Gate, 2011). The European Union supports the port in their effort to become a hub and granted a subsidy of €40 million for the necessary infrastructure in the Rhine-Main-Danube area and another €34 million for the LNG break-bulk terminals in Rotterdam and Gothenburg. With this additional European support there are plans for further investments in the logistics chain for LNG in the port of Rotterdam (Port of Rotterdam Authority, 2013). One of the objectives hereby is the introduction of LNG as an alternative fuel for inland navigation. The National LNG Platform plays an important role in this and wants to introduce LNG as an alternative fuel for the transportation sector in the Netherlands. The goal for 2015 is that a minimal of 50 inland waterway ships, 50 sea ships and 500 trucks will run on LNG (Vopak, 2012). In this thesis I will concentrate on the inland waterway transportation. With an inland waterway fleet of approximately 5000 active vessels in 2010, the Netherlands has by far the largest fleet in North-West Europe (Rijkswaterstaat, 2013). The European Commission wants to improve the role of inland waterway transportation due to its efficiency and sustainability relative to road transport, more goods have to be transported by the waterways (Rijkswaterstaat, 2013). However this sustainable advantage is coming in danger, while other competitive modes undergo technological improvements. New emission norms for the IWT sector are lagging behind and its competitive position from a sustainability point of perspective is being contested.

The introduction of LNG as an alternative fuel for these ships can play a key role in reducing harmful emissions (C02, NOx, SOx and particulates). With stricter European emission norms and the Rotterdam climate initiative in sight, a reduction in these emissions is necessary. Next to this the price of LNG is relatively low compared to conventional diesel fuels and gas reserves are significantly larger in comparison to oil reserves. The introduction of LNG can also lead to additional economic growth and jobs (PWC, 2013). The other side of the story is that large investments are needed for the set up of the LNG infrastructure in the port area, waterways and of course for the LNG driven vessels which are much more expensive compared to vessels sailing on conventional fuels. The use of small scale LNG is still in its development phase.

Problem Definition

The port of Rotterdam has the ambition of becoming an LNG hub; the European frontrunner in importing, (re)exporting and bunkering of LNG. An important part hereby is encouraging inland shipping to use LNG as an alternative fuel, while it is much more environmental friendly compared to conventional diesel fuel. There is already some scientific research done on the use of LNG instead of conventional fuels for maritime transport. Some examples are articles written by Pauli, G (2010) and Burel, F.; Taccani, R; Zuliani, N. (2013). In their articles they evaluate the benefits of LNG as a marine fuel, with the first article focusing on the Rhine basin. Vessels sailing on LNG contribute to a significant reduction in harmful emissions, which is necessary with the coming of stricter emission norms (TNO, 2011). Sustainable development is one of the key tasks for the port of Rotterdam (Port of Rotterdam, 2013). However, at the moment there is nearly no infrastructure for the supply of LNG on a small scale. There is a lack of bunkering and distribution infrastructure for the supply of LNG to vessels (Wang & Notteboom, 2013). Providing this infrastructure requires significant investments, not to forget the investments in vessels. The initial investment in an LNG engine and system is approximately twice as much, compared to a conventional diesel engine and system (TNO, 2011). There are also uncertainties in the sector about future prices of LNG and the return on investment (Schuttevaer, 2014). In short, there are bottlenecks for LNG before it can be introduced on a large scale. In spite of these bottlenecks, how relevant is it for the port of Rotterdam and other relevant stakeholders to invest in the LNG infrastructure for the inland waterway transportation?

Research Question

This is the topic of my research, my main question in this thesis is: *To what extent should the port of Rotterdam and other relevant stakeholders invest in the LNG logistics chain for inland waterway transportation, in the ambition of transforming Rotterdam into a LNG hub.*

In order to answer this question I formulated a couple of sub-questions to help answer my main question, these questions are:

- What is the relevance of LNG as an alternative fuel for inland waterway transport?
- What are the pro's and con's of an LNG driven vessel? And costs and benefits?
- What is the current LNG infrastructure situation in the port of Rotterdam and the waterways?
- How does an optimal LNG infrastructure towards 2020 look like and what are barriers for the realisation of such an infrastructure?
- Who are the most relevant stakeholders responsible for investments in the inland waterway infrastructure?
- How do shippers and ship owners experience the possible switch to LNG as a transportation fuel?

Research Approach

In order to answer the above mentioned questions I will make use of existing scientific literature, (news) articles and expert views. I will use existing literature on the use of LNG as an alternative maritime fuel and on the developments of the small scale LNG sector.

Review of Literature:

Pauli, G (2010) wrote a paper about sustainable transportation in which he puts the focus on Rhine navigation. It is one of the busiest waterways in the world, connecting major European seaports with important European industrial areas. There is a lot of research being done on Inland navigation in the Rhine area, much of it from an economic and environmental point of perspective. A 'green' and sustainable transport mode will depend on several factors, some of them are: resource use, benefits and costs to the economy, direct ecological intrusion, output of emissions and noise. Fossil fuels and Diesel in specific is currently the most important fuel for IWT. However, the use of fossil fuels is not sustainable. Diesel is a pollutant fuel and oil reserves are shrinking, there may occur a peak in oil production by the year 2030. Currently LNG is the most realistic alternative for diesel fuels, gas reserves are significantly larger compared to oil reserves and LNG is less pollutant compared to diesel. However, LNG is still a fossil fuel and therefore it will be wisely to see it as a transitional fuel.

Verbeek, R; Kadijk, G; Mensch van P; Wulffers, C; Beemt van den B and Fraga, F. (2010) wrote a report commissioned by TNO. The report is about the environmental and economic aspects of using LNG as a fuel for shipping in the Netherlands. The part about the IWT sector is the main interesting part for me. Te report points out that LNG is relatively cleaner than the widely used EN590 (Diesel), it produces significantly less pollutant emissions and less C02. The LNG installation requires however significant investments and it will only be a economic viable solution if the LNG fuel price is low enough.

Panteia conducted a research and published a report in 2013 on behalf of the European Commission's Directorate-General for Transport. It is a contribution to impact assessment of measures for reducing emissions of inland navigation. The report points out that the environment friendly competitive position of the sector is being contested by other modes of transportation. New emission norms for IWT are lagging behind compared to the road sector. The European Commission set up clear environmental objectives for the transportation sector. The Europe 2020 Strategy and the White Paper 2011 are examples of it. However if nothing changes in the sector, then IWT will fail to contribute sufficiently to the EU objectives. According to the report, the pollutant emissions are the biggest problem in relation to the external costs created by IWT. However, with regard to C02 there are still huge advantages compared to road transportation. The study focuses on reducing air pollutant emissions like NOx and PM. The implementation of emissions norms for engines in inland vessels is the most effective way to reduce these pollutant emissions. The use of LNG can greatly contribute towards achieving these emission norms. After treatment techniques can also be an option, both methods have their pro's and con's.

CD Delft, EICB, Ecorys, MARIN and TU Delft conducted research and that report, called 'schone schepen,' was published by Rijkswaterstaat in 2013. The report points out that in order to transport the increasing freight (containers) in a sustainable way, it will be necessary that IWT gets a greater share as a transportation mode. The question was how the IWT sector could become more attractive for the decision makers in the logistical chain. Creating a cleaner IWT sector is essential for meeting this objective, reducing emissions is the key to it. Therefore the 'greening' of the fleet is necessary. The report points out multiple solutions like alternative fuels, after treatment techniques, ship design etc. The involved stakeholders and the attitude of shippers towards these solutions are also taken in to consideration.

PWC published a report in 2013 named 'The economic impact of small scale LNG,' commissioned by the Dutch Ministry of Economic Affairs. The research focuses on three market segments; short sea, IWT and road transportation. The research points out that investments in the lacking small scale LNG infrastructure can lead to significant increases in economic growth and job opportunities. The report focuses on the key drivers for the growth of the small scale LNG infrastructure. Policies, availability of alternatives, differential in fuel price and growth of the transportation sector are key drivers. Every driver is covered in detail.

These are the papers I mainly used during the writing process of my thesis. I chose for these articles while they are quite recent and cover a great part of my sub questions. The topic around LNG for inland navigation in the Netherlands and Europe is quite recent. There are a lot of ongoing developments with regard to LNG in IWT. This is the main reason why I will also make use of news articles from specialist journals like 'Schuttevaer' and 'De Binnenvaartkrant.' These journals are specialized in the IWT, (short) sea transportation, fishery, offshore, passenger transport by water and cruising. Both specialist journals published and are still publishing a lot of news articles related to LNG in the IWT sector. I could find especially a lot of relevant articles published by Schuttevaer, which are really useful in answering my sub-questions. However, despite the availability of these articles there is still a limited literature available on LNG as an alternative fuel for inland shipping in the Netherlands, most of the written articles are about the sea shipping sector. While the topic is current and there is a information gap, I will use expert views to fill up this gap.

Expert views:

I attended two information sessions on may 14 and 15, experts in field gave presentations during these sessions. During the presentations they published the results of research being done on ways for 'greening' the IWT sector. There were four working groups, each focused on a different solution. The groups were as follows: working group engine suppliers and after treatment techniques, working group alternative solutions, working group LNG and the working group on low engine power. The presentations of the first and third working group were very interesting for my thesis. The working group on engine suppliers and after treatment techniques consisted of four organisations and the group on LNG consisted of three organisations. The subjects of these presentations together with the related firms were as follows:

Figure 1: Information Sessions

Werkgroep Motorenleveranciers en nageschakelde technieken	
Generiek uitlaatgas nabehandelingssysteem binnen demper afmetingen	Paul Groeneweg/Discom
Uitlaatgasnabehandeling in de praktijk: Constructieve oplossingen	Alwin de Kock/Solfic
Uitlaatgasnabehandeling in de scheepvaart: Bewezen techniek of proefkonijn?	Hans van Burk/SootTech
Mogelijkheden op weg naar Euro Tier 4	Niko Dalpis/Emigreen
Werkgroep LNG	
Dual Fuel (Gas) Motoren - Reductie van methaanslip	Bram Kruyt/Wartsila
LNG toegankelijk voor binnenvaart?	Ingrid van Leeuwen/Provincie Z-H
Kennis- en ExpertiseCentrum LNG	Erwin van der Linden/EICB

I attended one more gathering on June 13 at the RDM Campus. Presentations were given by Khalid Tachi of the EICB, Bram Kruyt of Wartsila, Erik Buthker of LNG24 and Cees Dikker of Shell. The presentations were about LNG in IWT: the presentation of Khalid Tachi was about LNG as a promising alternative fuel, Bram Kruyt gave a presentation about LNG engines and the last two presentations were related to the LNG infrastructure. During these sessions I had a couple of conversations with some of these experts on the subject. I interviewed a couple of persons, which also contributed a lot to my thesis. The persons I interviewed are:

- Ed de Jong: COO of LNG Bunkering Services and Business Developer at Deen Shipping. The interview took place on May 17, 2014 and It was merely an open interview.
- Ad Schroot: Ship's supervisor at Danser Group. The interview took place on May 20, 2014. Just like with Ed de Jong, the interview was merely an open interview.
- Khalid Tachi: Managing Director Expertise and Innovation Centre inland Barging (EICB). The interview took place on May 27, 2014. It was an interview with a question form, the questions were open-ended.
- Erik Buthker: Business Development Manager at LNG24. The interview took place on June 20, 2014. It was an interview with a question form, the questions were open-ended.

I attended the maritime fair, which was also on may 14 and 15 just like the information sessions. There I came in contact with Wout van Wijnen of Veka Group, which is currently working on an inland LNG carrier together with Deen Shipping. I was advised to contact Ed de Jong, while he has a lot of knowledge on LNG driven vessels and LNG infrastructure. That is how I selected Ed de Jong for an interview. I had read an article about the first retrofit, the vessel 'Eiger-Nordwand' of Danser group. It will be the first European inland container vessel driven by LNG. Thereafter I have contacted Ad Schroot, the ship supervisor at Danser Group, for an interview. I came in contact with Khalid Tachi during the information sessions on may 14 and 15. He was the host during the information sessions and agreed to an interview. He also invited me to the gathering on June 13 at the RDM Campus and introduced me there to Erik Buthker of LNG24. Erik Buthker has a lot of knowledge on LNG infrastructure and helped me with an interview.

What is the relevance of LNG as an alternative fuel for inland waterway transport?

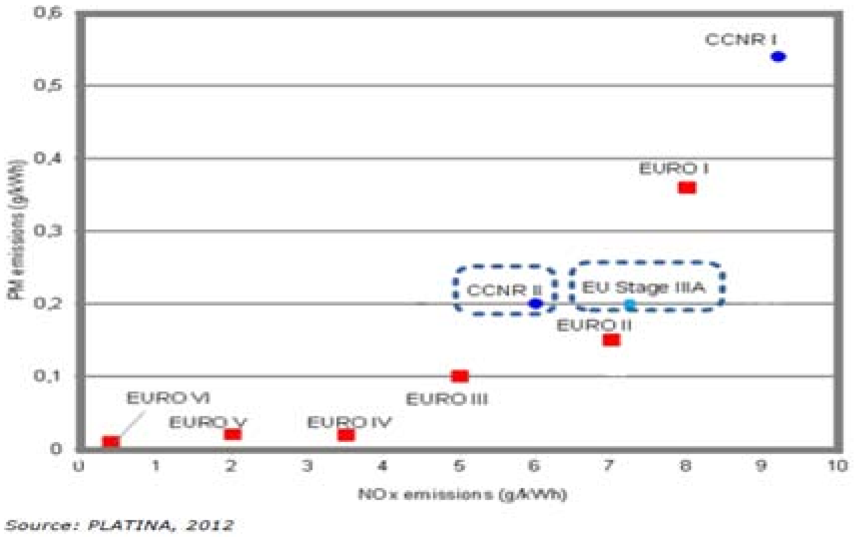
Chapter introduction

In this chapter I am going to talk about the environmental position of IWT, the competitive position on this subject is being contested mainly by road transportation. New emission norms are lagging, but eventually they will be implemented. Next to future emission norms an environment zone will be implemented in the port of Rotterdam, rejecting the entrance of polluting vessels in the port area. Thirdly, there is the expected growth of the sector. The European Union wants to fully utilize its potential by increasing its share as a transportation mode and at the same time improving the quality of IWT. As a consequence, polluting emissions has to be reduced in IWT. LNG could play a key role in the effort of reducing polluting emissions.

Emission Norms

IWT was for a long time accepted as an efficient, environmental friendly and safe modality. Especially in a water rich country with many waterways like the Netherlands, it is an highly appropriate mode of transportation. However, its environmental friendly advantage relative to road transportation is not any more that self-evident and its competitive position is being contested (Panteia, 2013). The IWT sector has to improve its environmental performance if it wants to hold its environmental friendly competitive position (Rijkswaterstaat, 2013). New emission norms for the sector are lagging behind. On the other hand new emission norms for road transportation are relatively strict, especially as of 2014 with the introduction of the Euro 6 norm (Totaaltrans, 2013). The Euro 6 norm includes that new trucks are allowed to have a maximal emission output of 0,4 g/kWh NOx and 0,01 g/kWh of particulates (PM). IWT vessels in the Rhine area and Belgium are currently operating under the CCR-2 emission norm for new built engines, which allows an maximal output of 6-11 g/kWh NOx, depending on the engines' revolutions per minute. The norm for PM lies between 0,2 and 0,8 g/kWh. This means that an IWT vessel is allowed to have a NOx output which is 15 to 27 times more than a truck. Regarding particulates, a vessel is allowed to push 20 to 80 times more particulates in the air (Totaaltrans, 2013).

Figure 2: Current emission standards for road transport and IWT: NOx/PM



Air pollution created by IWT makes up 17% of the total non-road emissions output with high levels of pollution in certain harbours and cities, like the city of Rotterdam and other certain cities in northwest Europe (excluding the U.K.) (Panteia, 2013). The environmental consequences in these areas are more severe due to the fact that relatively more residents are living along waterways. Air pollutant emissions like SOx and mainly NOx have a negative effect on air quality and also contribute to acid rain. Causing damage to buildings, crops and contributing to the loss of biodiversity (TNO, 2011). PM can negatively affect the lungs and forms a danger for people with asthma, triggers heart diseases and respiratory problems (Panteia, 2013). When we look at CO2 emissions, IWT has definitely an advantage over road transportation (Figure1, see Appendix). Road transportation contributes relatively more to climate change. But looking at air pollutant emissions like NOx, PM and SOx inland shipping has still a way to go (Figure 2,3 and 4, see Appendix). The external costs of these pollutant emissions (excluding CO2) are relatively higher for IWT. This gap will keep widening if further, emission reducing measures will not be applied (Figure 5, see Appendix). Within the Netherlands the pollution is concentrated in certain areas. The province of South-Holland is an example, there is a strong presence of IWT in this region. According to Ingrid van Leeuwen[1], (personal communication, May 15, 2014), the annual external costs of air pollution created by IWT is approximately 200 million euro's for South-Holland. However, important to note is that pollutant emissions created by IWT are just a fraction of the total pollutant emissions. The external costs created by road traffic are much higher.

[1] Ingrid van Leeuwen: Programmamanager Provinciaal Actieprogramma Lucht at Provincie Zuid-Holland.

Figure 3: Pollutant emissions to air by traffic and transport 2012

	Zwaveldi-oxide (SO_2)	Stikstofoxi-den (NO_x)	Ammoniak (NH_3)	VOS[3]	Fijn stof (PM_{10})	Koolmon-oxide (CO)[4]
Verzurende en grootschalige luchtverontreiniging [5]	miljoen kg					
Totaal	0,40	149	2,5	33	7,9	384
Wegverkeer	0,27	89	2,5	24	5,7	296
Beroepsbinnenvaart	0,01	27	0,01	3,2	0,94	5,9
Visserij [6]	0,00	6,1	0,00	0,27	0,15	0,83
Recreatievaart	0,00	2,3	0,00	2,1	0,05	21
Railverkeer [7]	0,00	1,5	0,00	0,07	0,06	0,25
Luchtvaart [8]	0,10	2,9	0,00	0,41	0,06	3,6
Landbouwwerktuigen	0,01	9,2	0,00	0,93	0,44	2,6
Overige mobiele werktuigen	0,01	11	0,00	2,8	0,50	55

Bron: CBS, Emissieregistratie. CBS/CLO/mei14/0129

1) Conform de IPCC-richtlijnen.
2) Alleen verplaatsingen met plaats van vertrek en van aankomst binnen Nederland.
3) Conform de NEC-richtlijnen.
4) Vluchtige organische stoffen exclusief methaan (ook wel NMVOS genoemd).
5) Geen verzurende stof; berekend volgens de NEC-richtlijnen.
6) Kottervisserij, inclusief emissies op het Nederlands deel van het Continentaal Plat (NCP).
7) Emissies door dieseltractie en slijtage van bovenleidingen.
8) Emissies door starts, landingen en taxiën van vliegtuigen en het gebruik van interne transportmiddelen op vliegvelden.

Reprinted from [Emissies naar lucht door verkeer en vervoer] [2012], by Compendium. Retrieved from http://www.compendiumvoordeleefomgeving.nl/indicatoren/nl0129-Emissies-naar-lucht-door-verkeer-en-vervoer.html?i=23-69

Looking at figure 3, we can see that road traffic has the greatest share in pollutant emissions. In 2012 road traffic created 89 million kg of NOx. Trucks were responsible for 37% of this amount, whereby passenger cars had a share of 18% (Compendium, 2014). This is the only pollutant emission whereby trucks have the greatest share, passenger cars are by far the most important source for the remaining emissions. Important to note is that sea-going vessels were not included in this study, but these vessels are significant contributors to pollutant emissions like PM and SOx (Compendium, 2014).

Another important factor is that truck engines have an average lifetime of 8 to 10 years, whereby engines in IWT vessels can last up to 35 years (Totaaltrans, 2013). This means that the truck fleet will renew in a relatively short time compared to the vessel fleet, resulting in a relatively clean and new truck fleet. As a consequence, IWT pushes more polluting emissions in the air compared to road transportation, per tonne kilometre for particular sorts of vessels (Panteia, 2013). In spite of economies of scale, the external costs per ton kilometre of air pollution (excluding CO2 emissions) are higher for IWT relative to road transport. Without further measures this gap would keep up widening and the advantages of IWT like safety, low CO2 emissions and no congestion problems could be overshadowed by harmful emissions like NOx, PM and SOx (Totaaltrans, 2013).

Initially proposed emission norms for the IWT are not implemented. The CCR-3 emission norm for 2012 is cancelled and the EU4 norm for 2016 is postponed for 3 or perhaps even 5 years

(Schuttevaer, 2013). However, the sooner or later new emission norms will be implemented. The proposed emission norm for 2016 was much more strict compared to the prior one.

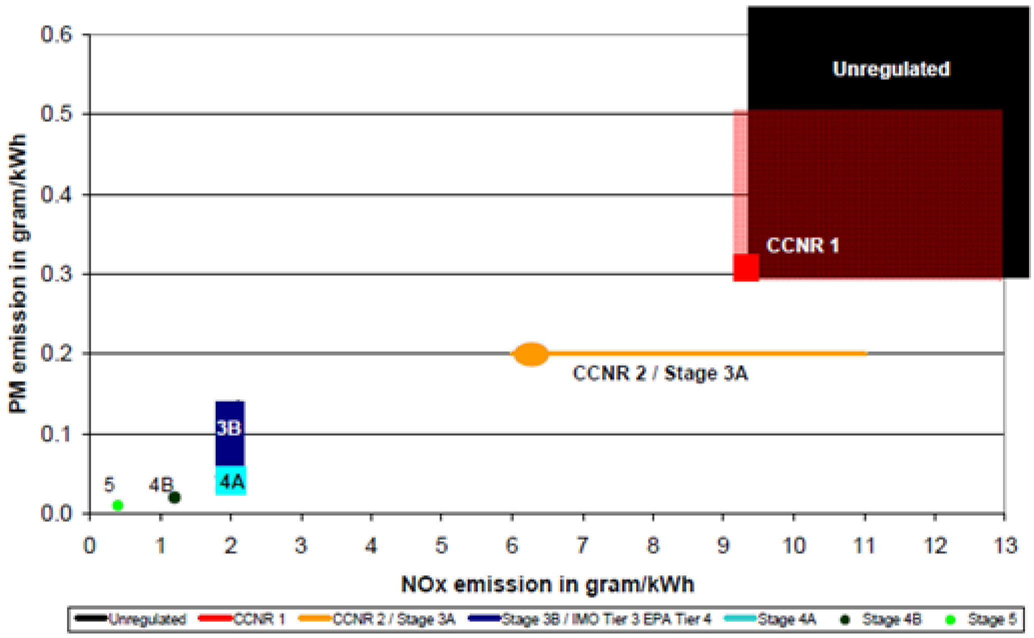
Figure 4: NOx and PM limits for the inland ship:

Inland ship	Unit	**CCNR II** (2007)	**CCNR IV** (2016)
NO_x limit	g/kWh	6.0 – 11.0	1.8 - 2.0
PM limit	g/kWh	0.2 - 0.8	0.025

Reprinted from [Nox and PM limits and estimated PM levels for the inland ship with diesel/LNG engines] [2011], by TNO. Retrieved from http://www.schonescheepvaart.nl/downloads/rapporten/doc_1370359071.pdf

The CCR has no plans to introduce new emission norms for the Rhine area on their own and decided to implement future norms in cooperation with the European Union (Schuttevaer, 2013). Therefore there will be no CCR emission norm anymore, but a collective EU emission norm for IWT. It could happen that the delay of the EU4 norm could lead to a much stricter implementation of an EU5 norm, by skipping the EU4 as next norm (Schuttevaer, 2013). On the graph we can see the current and some possible future emission norms:

Figure 5: Emission performance for existing and optional stages in future (3B, 4A, 4B, 5) regarding NOx and PM emission in gram per kWh



Reprinted from [*Emission performance for existing and optional stages in future (3B, 4A, 4B, 5) regarding NOx and PM emission in gram per kWh*] [2013], by Panteia. Retrieved from http://ec.europa.eu/transport/modes/inland/studies/doc/2013-06-03-contribution-to-impact-assessment-of-measures-for-reducing-emissions-of-inland-navigation.pdf

Rotterdam Environment Zone

When we look at the current Dutch fleet, most vessels don't even comply with the CCR-2 emission norm (De Scheepvaartkrant, 2013). As previously mentioned, vessel engines have a relatively long lifetime. As a result the overall replacement of the fleet's engines develops in a relatively slow way. Another factor which plays a role is the lagging technology in engine development caused by the limited market size of engines for inland shipping. This may lead to problems when the 'environment zone' in the port of Rotterdam will be implemented in 2025 (Rijkswaterstaat, 2013). With the introduction of the Second Maasvlakte the air quality in the area will deteriorate. In order to compensate for this deterioration the national government, municipality and PoR decided to implement an environment zone policy; as of 2025 polluting inland vessels are not allowed to enter Rotterdam (Port of Rotterdam). This regulation will affect the majority of the fleet, while 50% up to 80% of the Dutch fleet calls the port of Rotterdam. Inland vessels have to comply at least with the CCR-2 norm or the European Union's 2004/26/EC-directive, which is quite similar to CCR-2.
In 2009 only 1069 inland vessels complied with CCR-1, CCR-2 or the 2004/26/EC-directive emission norms. Of these 1069 vessels 70% satisfied the CCR-1 norm, 13% CCR-2 and 17% satisfied the 2004/26/EC-directive (Rijkswaterstaat, 2013). It was forecasted that approximately 22% of the total fleet in 2010 complied with the CCR or EU norms. This percentage will likely increase to roughly 32% for the year 2015 (Figure6, see Appendix), but the majority will still not meet the Central Commission for the Navigation of the Rhine (CCR) or EU norms (Rijkswaterstaat, 2013). However, in order to comply with the Rotterdam environment zone a majority of the fleet has to be renewed in a relatively fast way.

Expected growth for IWT

As previously mentioned IWT has a relatively good reputation as a transportation mode. The European Union wants to fully utilize its potential by increasing its share as a transportation mode. The gradual economic recovery in the EU (European Commission, 2014)(Figure7, see Appendix) and the ambition for a greater share in freight transport will likely show its results in coming years. The European Commission announced in her 'White Paper 2011' that by 2030, 30% of road transportation of goods over distances >300km have to be transported either by rail or water (European Commission, 2013). At the same time there is a desire to decrease the dependence on oil imports and reduce carbon emissions in the transportation sector by roughly 60% by 2050. In order to achieve this goal every modality has the objective to improve its efficiency. A relevant policy package here for the IWT sector is the Naiades-2 package. It is a follow-up of the first Naiades package implemented by the European Union. The package aims at improving the quality of IWT by creating the necessary conditions for it (European Commission, 2013). One of the key targets in the package is environmental quality which can be met through lower emissions (European Commission, 2013). Pollutant emissions has to be reduced in IWT, the Commission has ambitions for a 'green' fleet.

Chapter Conclusion

There has been a lot of research done for ways of reducing emissions created by IWT. The sustainability of a transport mode is to an important extent depending on its fuel (Tieman, 2013). Alternative fuels can lead to a significant reduction in emissions (Rijkswaterstaat, 2013). There are several alternative fuels which can be used by the sector, but according to Robert Tieman[2] LNG is the most promising one (Tieman, 2013). Alternatives like hydrogen are relatively more in their development phase compared to LNG. LNG is proved to be the cleanest fossil fuel compared to conventional diesel fuels (De Haven, 2013). LNG could play a key role in the effort of reducing harmful emissions, which is going to be necessary because of future emission norms, the Rotterdam environment zone and the EU's objectives.

[2] Robert Tieman: Policy advisor environmental affairs at Deltalinqs and previous director of Centraal Bureau voor de Rijn en Binnenvaart.

What are the pro’s and con’s of an LNG driven vessel? And costs and benefits?

Chapter Introduction

In this chapter I am going to point out the pro’s and con’s of an LNG driven vessel, together with the costs and benefits. The use of LNG as a fuel creates advantages like emission and noise reduction, resulting in compliance with future emission norms and lower harbour dues. Other advantages are subsidies for LNG installations and the relatively low fuel price of LNG. I will also mention the drawbacks like the methane slip problem, regulations, the high capital costs, availability of reasonable alternatives and some other important bottlenecks.

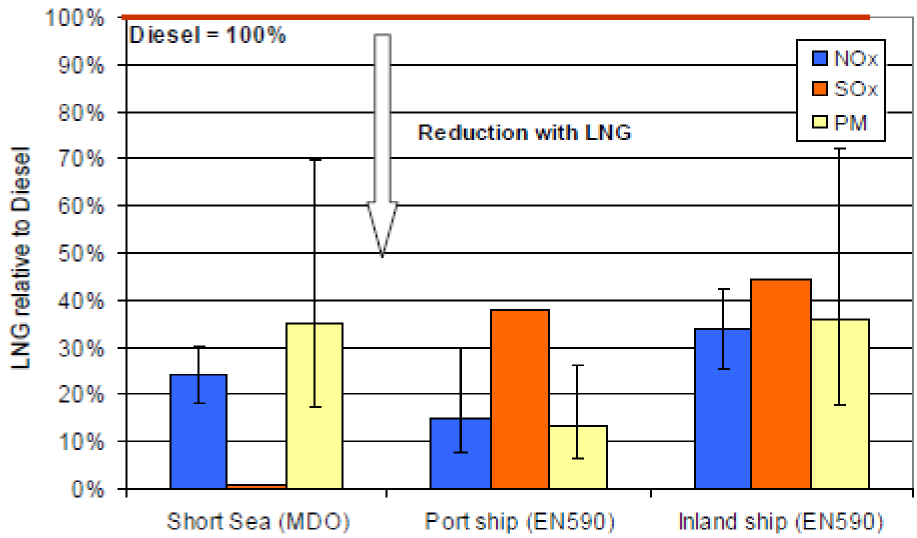
Emission Reduction

LNG as a marine fuel promises a favourable environmental achievement compared to conventional ship fuels. LNG is relatively cleaner compared to conventional diesel fuels and can reduce emissions like NOx, PM, SOx, CO2 and also noise (Panteia, 2013). Compared to high sulphur fuels like HFO the reductions are very significant:

- C02: ~20%
- NOx: ~90%
- PM: >95%
- SOx: >95%

But as a consequence of EU directive 2009/30/EC, inland waterway shipping in the EU is only allowed to sail on low sulphur fuel with a maximal amount of 10ppm (10 mg/kg). The sector has to comply with this guideline as of 2011 (IVR, 2010). According to conversations with various experts in field (Wartsila, Reinplus and Fiwado) and TNO (TNO, 2011) EN590 is currently the fuel used by the majority of the vessels. Initially the European Committee intended to introduce EN590 as the only allowed fuel, however this was let loose and they only gave a limit to the maximum amount of sulphur (IVR, 2010). By using LNG the reduction in pollutant emissions compared to EN590 will be as follows:

Figure 6: Comparison annual air pollutant emissions between diesel and LNG engines for 2011-2015



Reprinted from [*Comparison annual air pollutant emissions between diesel and LNG engines for 2011-2015*] [2011], by TNO. Retrieved from http://www.schonescheepvaart.nl/downloads/rapporten/doc_1370359071.pdf

These are significant reductions which makes LNG as alternative fuel very attractive. Thanks to its characteristics LNG doesn't need any additional after-treatment techniques like selective catalytic reduction (SCR), scrubbers and/or diesel particulate filters (DPF) to comply with the current emission norm. LNG driven vessels will clearly meet the current CCR-2 emission norm and likely even the coming EU-4 norm (TNO, 2011). The Rotterdam environment zone will be no obstacle for LNG driven vessels.

Subsidies

The Province of Southern Holland wants to improve the air quality in Rotterdam. As stated before, a significant part of the pollutant emissions is caused by the IWT sector. As a result the province set up a subsidy regulation of 6,2 million euro's for the IWT sector, which mainly aims at reducing NOx emissions (Provincie Zuid-Holland, 2014). Approximately 15% of the NOx and 13% of the PM emissions in the city area is caused by vessels in the port area and its surroundings. The subsidy is meant for vessels which call at the port of Rotterdam at least ten times a year (Provincie Zuid-Holland, 2014).

In order to stimulate economic growth and promote an attractive living environment, reducing pollutant emissions by measures like this is necessary (Gemeente Rotterdam, 2013). Ship owners have the opportunity for a subsidy, in case they invest in ways for reducing pollutant emissions. The subsidy is meant for technologies or alternative fuel systems like SCR's and LNG fuel systems (Provincie Zuid-Holland, 2014). Thanks to the regulation the purchase and maintenance costs could

be subsidized, depending on the reduction in emissions. While LNG as an alternative fuel is the most effective in reducing pollutant emissions, it is possible that investing in an LNG system may receive a relatively large subsidy.
According to Ingrid van Leeuwen (personal communication, May 15, 2014), the subsidy fund is already empty. The province is working on a second subsidy of around 4 million euro's. Approximately 40 vessels benefitted from the first subsidy, 98% of the applications were meant for after treatment techniques. Apparently LNG fuel systems were not that popular among the applicants. I think that lack of knowledge on LNG played a significant role. Another issue is the amount, 40 vessels represents less than 1% of the total Dutch fleet. A significant increase in the fund is necessary to transform the fleet on a larger scale, however this is not a realistic scenario.
'Milieu-investeringsaftrek' (MIA) and 'Willekeurige afschrijving milieu-investeringen' (VAMIL) are also examples of subsidies which grants financial support for investments in environmental friendly techniques. A full LNG or dual fuel installation and after treatment techniques could be considered for the subsidies. The MIA enables entrepreneurs to subtract up to 36% of the investment costs from the fiscal profit (De Scheepvaartkrant, 2013). With the VAMIL regulation entrepreneurs are able to write off 75% of the investment at a random moment (RVO, 2014). As a result the taxable profit can be reduced, which results again in lower taxes. The budget in 2014 is 93mln euro's for MIA and 38mln euro's for VAMIL (RVO, 2014).

Discount On The Harbour Dues

Relatively clean inland waterway vessels will receive a discount on the port dues in the Port of Rotterdam and several other ports in the Netherlands and Europe (Green Award). Ships and inland vessels which are extra clean and safe can receive a green award. A green award enables vessels to enjoy financial benefits like discounts on harbour dues and also non-financial benefits (Green Award). A main prerequisite for this award is that the vessel needs to comply with the CCR-2 emission norm. New vessels already have to comply with this norm, but also existing ones can comply by installing SCR's and scrubbers. Switching to an alternative fuel system like LNG is of course even better and will bring in even more points . Next to the CCR-2 prerequisite there are some other minor conditions like a smart meter and a course.

Focusing on the port of Rotterdam, the discounts are as follows:

Figure 7: Binnenhavengeld

No.	Description types of vessel	Raise/Discount
1	Does not meet emission standard CCR2	+10%
2	Meets emission standard CCR2	n.a.
3	Meets emission standard CCR2 and disposes of a Green Award Certificate	-15%
4	Surpasses emission standard CCR2 with 60%	-30%
5	No propulsion engine	n.a.

Reprinted from [Binnenhavengeld] [2014], by Port of Rotterdam Authority. Retrieved from http://www.portofrotterdam.com/nl/Scheepvaart/havengelden/Documents/binnenhavengeld2014.pdf

Vessels which don't meet the CCR-2 norm will even pay a higher price and vessels which surpass CCR-2 will even get a higher discount. The goal of this measure is to create financial benefits, in order that ship owners will invest in clean technologies. Investing in a LNG driven vessel may deliver even the highest discounts. But to what extent are these discounts effective? According to a research done by the Rijkswaterstaat, the measure is not really effective. The differentiation in port dues are not enough to stimulate investments in clean technologies (Rijkswaterstaat, 2013). However, more ports are willing to implement this measure and the port dues for pollutant vessels may even rise further. These extra revenues could be collected in a fund. Ship owners who want to invest in clean technologies can apply for a subsidy out of the funds (Rijkswaterstaat, 2013).

Regulations

Currently the use of LNG as an alternative fuel in inland shipping is forbidden. According to European agreements concerning IWT, it is forbidden to install engines using fuels with a flashpoint below 55°C. The flashpoint of LNG is -180°C, which means it is restricted to use LNG as a fuel for inland shipping (Wang & Notteboom, 2013). However, the European Commission gave a strong signal in favour of the use of LNG as an alternative fuel and the formation of LNG bunker stations along the waterways (European Commission, 2013). As a consequence it is expected that new policies on EU level in favour of LNG will soon come into force. For now it is possible to apply for a recommendation at EU or CCR level, in order to deviate from current regulations (Korvink, 2014).

Installing after treatment techniques for CCR1 and CCR2 certified engines has also some requirements (Emigreen, 2014). The engines have to satisfy with the original technical specifications, it is likely that installing after treatment techniques can alter these specifications (Emigreen, 2014). It is therefore necessary to apply for a recommendation just like in the LNG case.

Methane slip

An important issue is methane slip; the emission of unburned methane which is approximately 25 times more powerful than C02 as a greenhouse gas (Schuttevaer, 2013). This is mainly a problem for dual fuel engines, the methane slip could undo the initially realized CO2 reduction. A methane emission of approximately 6 gram/kWh results in a break even situation. Any emission output below 6 gram/kWh leads to a overall greenhouse gas reduction and vice versa (Ligterink, Patuleia, & Koornneef, 2013). The slip of methane is partly caused by the 'valve-overlap.' During the flush process the exhaust and inlet valve stays just a moment simultaneously open, and a small part of the gas finds its way out through the open valves (Schuttevaer, 2013). Another major cause is the poor combustion of gas in certain parts of the combustion chamber (Tyler, 2011). Currently there is no regulation regarding this methane emission, but methane norms could be implemented in the nearby future (Schuttevaer, 2013).

This is a problem but it can be fixed to a great extent (Schuttevaer, 2013). There are several methods to reduce the slip of methane; lowering the boost pressure and a better timing of the main fuel injection for example are major contributors to a lower methane slip (Tyler, 2011). With these methods It is certainly possible to fix the problem within the engine itself. According to Khalid Tachi[3] this is also the most appropriate way of solving the problem; the problem has to be solved within the engine and specifically the combustion chamber. Trying to solve the problem outside the engine make things more complicated. Looking for a solution in the exhaust system makes the case more complicated. Catalyzing Methane (CH4) is very complicated, it is a very strong molecule and requires very high temperatures (Tachi, 2014). As a result this can even lead to the creation of NOx emissions, leading to another kind of a 'NOx-paradox.'

New engines are already designed to minimize the methane slip, it is more a problem for retrofit engines (Tachi, 2014). However, there are companies working on a solution for retrofit engines, again the problem will be solved within the combustion chamber of the engine (Tachi, 2014). As a result also retrofit engines will be able to stay below the limit of 6 gram/kWh, which leads to an overall greenhouse gas reduction.

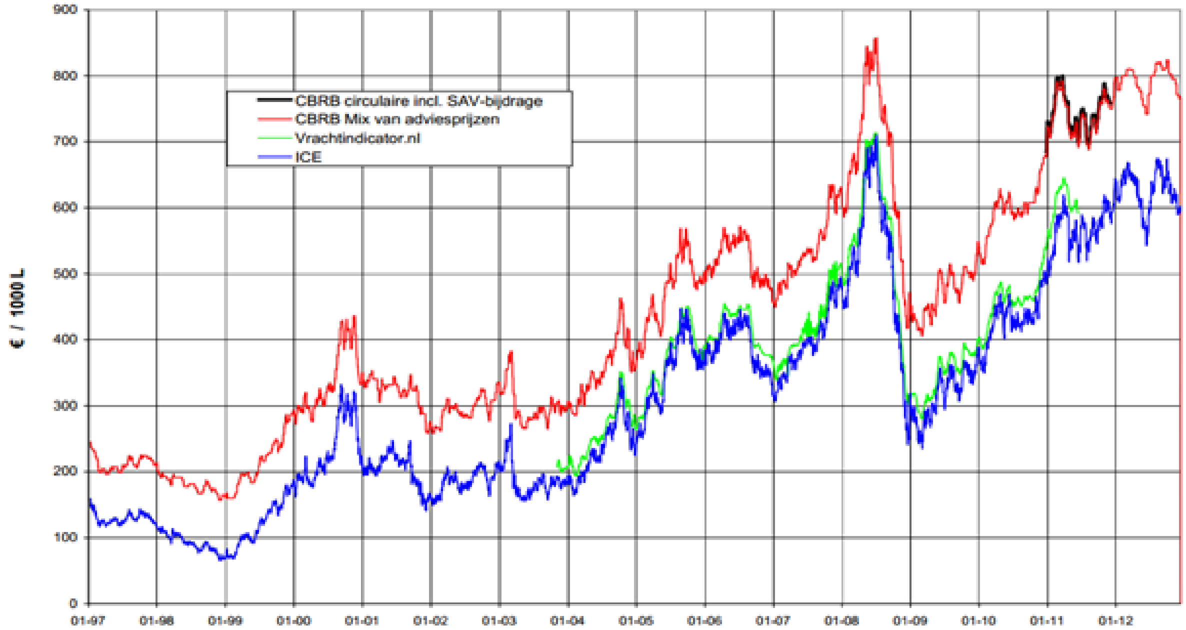
[3] Khalid Tachi: Managing Director Expertise and Innovation Centre inland Barging (EICB)

The Fuel Price

For transportation companies fuel costs represent the lion share of total transportation costs. For IWT fuel costs make up more than 40% of total costs per year (PWC, 2013). The price of LNG will play a key role in the consideration of a potential switch towards LNG as an alternative fuel. A competitive price compared to conventional fuels is necessary, there has to be a bright economic stimulus to consider LNG as a feasible alternative (Panteia, 2013). It is not easy to give an exact answer while there is a serious lack of bunker possibilities in the Netherlands. According to Ed de Jong [4], (personal communication, May 17, 2014), the current bunker price of LNG is around 600 €/ton. According to Khalid Tachi the price varies between 550 and 650 €/ton, whereby 550 is a more optimistic price and 650 would be a pessimistic price. The exact price depends on the market price of LNG and the bunker location (LNG24).

The current price for conventional diesel fuel/gas oil is on average 724,60 €/1000ltr (Klumpers, B, 2014). This price is being published by the 'Centraal Bureau voor de Rijn- en Binnenvaart' (CRBR) as part of their 'Gasoliecirculaire' in which they register the average fuel price per day. This price is based on the suggested retail price of several large oil companies (van Ommeren, 2013) However, it appears that the price being paid at the bunker station is on average 120 €/1000ltr lower compared to the fuel price being published by the CRBR (Tachi, 2014). This is a rough estimation and the exact paid price may vary, depending on the customer.

Figure 8: ''CBRB circulaire'', ''Mix van adviesprijzen'', ''Betaalde prijzen''(Vrachtindex.nl) en ICE gasolie notering



Reprinted from [Grafiek_Brent_&_Gasolie] [2013], by EVO. Retrieved from http://www.evo.nl/site/binnenvaart-tarieven-kosten/$FILE/Gasolieprijs_ICE_Advies_2012-12%20V2.pdf

[4] Ed de Jong: COO of LNG Bunkering Services and Business Developer at Deen Shipping.

This is mainly due to high discount rates at the bunker station, the price also depends on the customer. A customer with multiple vessels bunkering frequently will receive relatively higher discounts compared to a customer with one vessel (Tachi, 2014). However, an average price difference of 20% between gasoil and LNG is realistic according to the report of Panteia (Panteia, 2013). Price advantages of 35% and 30% respectively are also mentioned, but this would be a too optimistic scenario (Panteia, 2013).
Forecasting future prices for gasoil and especially LNG is difficult and depends on multiple factors. The price of gasoil strongly depends on the price of brent crude oil, but also on the refining capacity, the reserves and of course the demand and supply.

Figure 9: Europe Brent Spot Price FOB

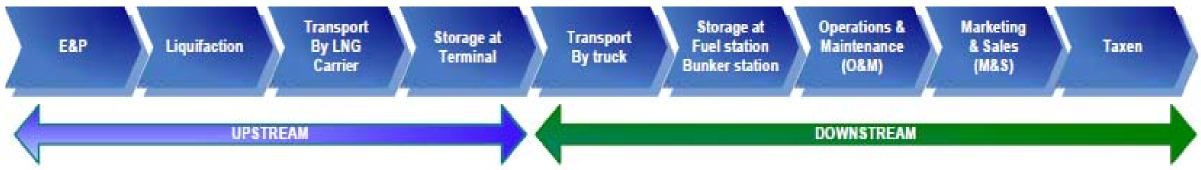
Reprinted from [Europe Brent Spot Price FOB] [2014], by EIA. Retrieved from http://www.eia.gov/dnav/pet/hist/LeafHandler.ashx?n=pet&s=rbrte&f=d

According to the U.S. Energy Information Agency (EIA) the average price of Brent crude was $108/bbl in April (EIA, 2014). There has been a steady decrease in the average price of Brent crude for the last 10 months. It is forecasted that the average price of crude oil will be $106/bbl in 2014 and $102/bbl in 2015 (EIA, 2014). But important to mention is that price forecasts for oil and energy in general are highly uncertain. Future prices of Brent crude could differ significantly from the prices mentioned above. Unexpected events like the current unrest in Iraq can have a major impact on oil and energy prices. The unrest resulted in a Brent oil price of $113/bbl on June 12, the highest level in six months (Hume, 2014). An further escalation of this unrest in Iraq and the whole region can have disastrous consequences for the oil price. Unexpected events like these makes price forecasts for oil and energy highly uncertain.
Another factor which could influence the price of gasoil is the introduction of Sulphur Emission Control Area's (SECAs). As of 1 January 2015 ships operating in the SECAs will not be able anymore to use relatively cheap high sulphur diesel fuels without after-treatment (De Scheepvaartkrant, 2013). Ships operating in the North- and Baltic Sea area for e.g. will not be allowed to emit more than 0.1% m/m of sulphur (SOx) (IMO, 2014). It is expected that a majority of the

carriers will switch over to low sulphur diesel fuels (e.g. MGO). Low sulphur diesel fuels like MGO are for carriers an 'immediate solution' (Ship & Bunker, 2014). However, the expected increase in demand for low sulphur diesel fuels could increase the fuel price and widen up the price gap between LNG and diesel (De Scheepvaartkrant, 2013).

LNG prices are currently attractive but it will be difficult to forecast future bunker prices of LNG, while many factors will play a role. Natural gas prices will play an important role, a favourable development in the prices of gas will positively affect the return on investment (PWC, 2013). Gas prices in Europe will increasingly be influenced by the LNG market. The reason for this is declining local gas production and the desire to reduce dependence on Russian gas (The Economist, 2014). The LNG price for the nearby future will probably be relatively high, while the market is currently supply constrained (TNO, 2011) (BG Group, 2014). This could change with the beginning of the second decade. New suppliers with significant reserves in North-America, East-Africa and the Eastern Mediterranean will likely enter the market by that time (BG Group, 2014). It is also expected that current suppliers like Russia and Australia will significantly increase their LNG production and export (Platts, 2014). However, LNG bunker prices will not be equal to LNG prices. According to Erik Buthker[5] (personal communication, June 20, 2014), this is a common mistake. Too many times is being referred to the LNG terminal in Zeebrugge for the LNG price. The LNG price at the terminal in Zeebrugge is not the same as the LNG bunker price. The whole supply chain has to be taken into consideration:

Figure 10: Supply Chain Small-Scale LNG



Reprinted from [Market approach from our directions] [2012], by GDF Suez. Retrieved from http://www.schonescheepvaart.nl/downloads/seminars/doc_1363970031.pdf

Please note that the 'taxen' part is only applicable to the heavy road transportation sector, while the IWT sector is exempted from taxes on fuel (Schuttevaer, 2012).

LNG bunker prices will also include the costs of infrastructure of the LNG fuel stations, the distribution and operation costs of the bunkering terminals. Currently there is a lack of such LNG bunkering infrastructure which makes it difficult to forecast LNG bunker prices (Wang & Notteboom, 2013). But it is not expected that long term LNG fuel prices will increase at a higher rate in relation to crude/oil prices (TNO, 2011).

[5] Erik Buthker: Business Development Manager at LNG24

The investment

It appeared from conversations with entrepreneurs in the IWT sector that economical details could not be shared while it is sensitive information. As a result I posses only limited information about the costs and benefits of a complete LNG installation.

To start with, it is important to note that every ship has its own solution. A retrofit or a new LNG driven vessel is currently not a viable solution for every ship owner. The investment decision will depend on multiple factors (Vonk, 2014). Some important factors are: The fuel price of LNG, capital costs, current fuel consumption, operating hours, power consumption and the vessel size.

First of all, there are two types of LNG engines; the single fuel and dual-fuel engine. The single fuel engine runs on LNG only, while the dual-fuel works on LNG and diesel. The distribution between gas and diesel will vary mainly between 80 up to 90% depending on the engine (Hoogvelt & Vries, 2011). According to Wartsila they can even deliver dual-fuel engines running for 95 up to 99% on LNG (Scheepvaartkrant, 2014). A complete LNG installation is approximately twice the price compared to a conventional diesel installation (InnovatieNetwerk, 2013). LNG engines and tank fuel systems require significant investments. This is partly caused by the fact that LNG as an alternative fuel is a relatively new phenomena in the IWT sector, which drives up the design-, construction-, and installation costs of LNG systems on board. The installation costs could drop by 10% up to 20% as the market for LNG systems will expand (InnovatieNetwerk, 2013). But for now LNG engines and tank fuel systems require significant investments. LNG fuel tanks are remarkably more expensive compared to diesel fuel tanks, partly due to its complex design. The price for Diesel tank systems are approximately just 10% of LNG tank systems (TNO, 2011). A complete gas train including LNG tank will cost approximately 570k euro's for a relatively large vessel (110m*11,5m) (TNO, 2011). However, note that the estimations made are for LNG tank fuel systems of the best quality, cheaper (up to 50%) alternatives are also available (TNO, 2011). It is likely though that these will not be able to meet the desired quality in the industry (TNO, 2011). The complex design makes things also more complicated, the tank will use significantly more space due to its size and round shape. This could be a problem for vessels with limited space available and especially for existing vessels. New vessels can be designed according to the installation of LNG fuel facilities, but this is no option for existing vessels.

A switch to LNG requires significant investments and it is hereby reasonable to determine the potential return on investment and consider possible alternatives. Navigating on LNG is currently not a viable solution for every vessel, the return on investment will depend on multiple factors. The bunker price of LNG will play a key role in the investment decision and payback time, other important factors are operating hours and power consumption (Vonk, 2014). For vessels operating less than 3000 hours per year there is no return on investment and alternatives like after treatment techniques will be a viable solution. The power consumption is also important, the average power consumption should not be too low in relation to the installed power. More precisely, the average power consumption should not be less than 50% of the maximum continues rating (MCR) (Vonk, 2014). If this is the case, then again LNG is not a viable solution.

The payback time for an LNG installation will especially be attractive with many operating hours at high power settings (Vonk, 2014). A study was conducted by Wartsila on the return on investment for a dual-fuel mechanical installation. With more than 5000 operating hours per year at high power settings and a favourable price difference of 20% in relation to gasoil, a return on investment can be achieved within 5 up to 8 years (Vonk, 2014).

According to Ed de Jong (personal communication, May 17, 2014), the total cost of an LNG installation in a relatively small ship will be approximately 500k euro's. The additional investment in a relatively larger ship will be around 1M euro's. According to Ed de Jong, fuel consumption plays a key role in the return on investment. While the price for LNG is currently lower compared to diesel/gas oil, LNG is mainly attractive for vessels which consume more than 500 cubic metres of gas oil per year. When the current fuel consumption is more than 500 cubic metres per year, LNG becomes an interesting solution. Looking at the fuel consumption, LNG will mainly be attractive for relatively larger ships consuming approximately 900 up to 1300 cubic metres per year. According to Wilco Volker[6] (personal communication, May 17, 2014), these could be ships in the category 'tonnage >2500/3000 ton.' Pusher tugs with high power capacities (>1000-2000 kW) could be an exception, those vessels are relatively small but consume a lot of fuel in combination with high operating hours (Panteia, 2013). Other relatively small vessels with a high fuel consumption could also be an exception, size is not per definition a requirement for LNG.

It is difficult to say what amount of the fleet is currently applicable for an LNG installation. In order to give an answer I refer to a study in which the EICB was involved. The following assumptions were made in the study:

- A price difference of 20% in favour of LNG
- An average investment of 1.2M euro's for an LNG installation, which is quite realistic for both a new vessel and a retrofit.
- Desired return on investment of approximately 7 up to 8 years, which is under normal conditions an acceptable time period.

[6] Wilco Volker: Marketing Manager at Bureau Voorlichting Binnenvaart.

Under these assumptions they came to the conclusion that LNG is currently an economic viable option for approximately 260 vessels in the total Dutch fleet (Tachi, 2014). In percentages it is approximately just 8% of the total Dutch fleet (Tachi, 2014). But looking at the fuel consumption, these vessels are responsible for approximately 25% of the total fuel consumption. While fuel consumption leads to emissions it is fair to say this 8% of the fleet causes 25% of the emissions created by IWT (Tachi, 2014).

There are currently two good examples of inland vessels running on LNG. The Argonon is an example, it is the first vessel running on dual fuel in the European inland waterways (DeenShipping, 2011). It is a relatively large vessel with a tonnage of around 6.100 tonnes. This vessel is already in operation and realizes approximately a 30% cut on fuel costs (De Scheepvaartkrant, 2013). Another example is the Greenstream, it is the first fully LNG driven inland waterway vessel (Bureau Voorlichting Binnenvaart, 2013). The vessel is relatively smaller compared to the Argonon and the tonnage is also lower; 2800 ton. It operates since 2013 and saves approximately 18% on fuel. Both are tanker vessels which have perhaps the lowest threshold for a conversion to LNG. The installation of an LNG tank is less problematic and can be installed on deck. Tankers also consume lots of fuel and have on average high operating hours per year (Panteia, 2013).

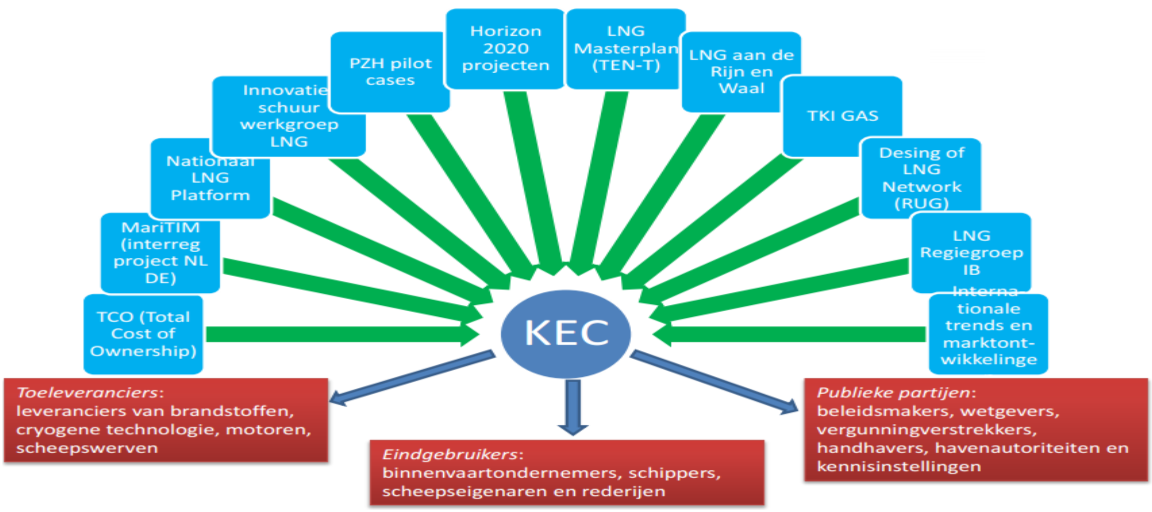
The alternative solution

As stated before there are other alternative fuels like hydrogen, but for now LNG is the most promising alternative fuel. After treatment techniques like SCR's and DPF's will probably be the main competitors for LNG. The installation of both after treatment techniques will make it possible for new and existing engines to comply with CCR-2 and the coming EU4 emission norm (Emigreen, 2014). The investments in these after treatment techniques are significantly lower compared to an investment in a complete LNG system (TNO, 2011). The costs of these techniques depend on the vessel and engine, a SCR after treatment system will cost approximately 90k euro's for an inland ship with a capacity of 1125KW @ 1300rpm and measurements of 110m*11.5m. This price will be higher for vessels with a higher engine power (TNO, 2011). The price of a DPF will be roughly around 100 up to 150k euro's (den Boer, Schroten, & Verbaak, 2010). The total investment will be significantly lower, but there will be no return on investment like with an LNG installation. The after treatment techniques will be used in combination with conventional diesel fuel, there will be no reduction in fuel costs. The installation of after treatment will also increase the maintenance cost (Panteia, 2013), while this is lower for an LNG engine even compared to a conventional diesel engine without after treatment (Wang & Notteboom, 2013). In short, these after treatment techniques would mainly be attractive for vessels with less than 3000 operating hours per year, average power consumption less than 50% of the MCR and/or a fuel consumption less than 500 cubic metres per year. An LNG installation is currently not an economic viable solution for these vessels and after treatment techniques could be an alternative solution.

Important bottlenecks

There are currently some important bottlenecks for the implementation of LNG as an alternative fuel. First of all there is a lack of knowledge about the use of LNG in IWT. Ship owners are not really aware of the developments around LNG. It is a relatively new fuel in IWT and many people have the wrong mindset (Jong, 2014). This lack of knowledge can result in a reluctant attitude towards LNG. However, measures will be taken to inform involved parties. One example is the founding of the ‘Kennis en Expertise Centrum LNG in de binnenvaart’ (KEC). The KEC is part of the EICB and supported by the province of South-Holland, its main goal is the acceleration of the transition towards LNG as an alternative fuel (EICB, 2014). A good starting point is the creation of a connection between knowledge, market and public parties. Starting a newsletter, publishing relevant studies and giving advice to contacts about the technical feasibility are some examples (EICB, 2014). The following picture summarizes the coming operations of the KEC;

Figure 11: Operations of KEC



Reprinted from [Kennis- en ExpertiseCentrum LNG] [2014], by EICB. Retrieved from http://www.eicb.nl/documenten/nieuws/78-15-mei-12-35-eicb/file

Another bottleneck is the technological possibilities, there are a lot of possibilities which makes it difficult to make a correct choice. There are mono-fuel and dual-fuel engines, furthermore it is possible to install one large engine or four smaller engines with a mechanical or electrical configuration, etc. In short, there are a lot of possibilities which make things more complicated (Tachi, 2014). A third bottleneck is the lack of standardization, which results in too much custom solutions. This lack of standardization keeps the investment costs at a relatively high level (Tachi, 2014). A fourth bottleneck is the funding for an LNG installation. There is a will and a positive business case, but without a lower entering threshold and funding possibilities it becomes difficult for entrepreneurs in the IWT sector. Banks are currently very reluctant towards providing loans for entrepreneurs in the IWT sector, which results in serious problems concerning the finance (Schuttevaer, 2014). Other problems in relation to this topic are the current economic situation, the low freight prices and the overcapacity (Rijkswaterstaat, 2013). These current economical/financial problems are creating a difficult situation for investments. The market situation will not start to recover until 2018 at the earliest (Panteia, 2013). The economic recovery in Europe (Figure7, see Appendix) and the expected growth in the IWT will probably boost the market situation, but likely only in the long term. There is one more important bottleneck, which is the long term contracts. According to Erik Buthker[7], (personal communication, June 13, 2014), the LNG is market is currently not adapted for small scale contracts. When it comes to the supply of LNG, especially now with a limited LNG infrastructure, there is a demand for long term commitments. Gas contracts require long term commitments, this can be a long term contract of 20 years which is very usual. Johan Algell[8] shares this view and thinks that the required long term contracts are a significant bottleneck. Both the shipping community and bunker fuel supply community are not used to do these long term commitments (Algell, 2013). Bunkering diesel fuel does absolutely not require such long term commitments. As a result there is not really a proven business model for supplying LNG as bunker fuel. Cooperation between the involved stakeholders will play a key role in overcoming this bottleneck (Algell, 2013).

Chapter Conclusion

In this chapter the advantages of an LNG driven vessel were summed up, it emits significantly less pollutant emissions. This is necessary to meet future emission norms and in order to gain access to the port of Rotterdam. There are subsidies available and also discounts on harbour dues for relatively 'clean' vessels, in order to support clean initiatives like an LNG installation. However, these measures will most likely have a limited effect while the financial incentive is relatively small. A lower

[7] Erik Buthker: Business Development Manager at LNG24
[8] Johan Algell: Business Development Manager – Marine LNG at Skangass AS

LNG fuel price compared to diesel on the contrary is a decisive factor. According to Erik Buthker[9] (personal communication, June 20, 2014), gas reserves are significantly larger than oil reserves and major gas reserves are not concentrated in a certain area, which is the case with oil reserves. This makes gas less sensitive for (geo)political events. Currently there is an average price difference of 20% between LNG and gasoil, in favour of LNG. Price forecasts for the nearby future are highly uncertain, but on the long run oil prices will probably rise at an increasingly higher rate in relation to gas prices. The limited oil reserves in relation to gas reserves will be a major cause of it.
There are however also con's and significant costs related to LNG installations in inland vessels. First of all, currently it is not even allowed to sail on LNG while regulations are lagging behind. European and national authorities are however working on it. Methane slip is also an issue, the emission of unburned gas can have large consequences for the climate. Unburned gas is a large contributor to the process of global warming. However, certain companies are currently working on it and it is a problem which can be fixed to a great extent. The large investments needed for an LNG installation are a major drawback for ship owners. The investment needed for alternative solutions like an after-treatment technique is just a fraction compared to an LNG installation. But on the other hand, an LNG installation has one major advantage over after-treatment techniques; the return on investment. There are some other bottlenecks remaining which have to be solved, it can all be summarized with the following overview:

Pro's and benefits	**Con's and costs**
Emission reduction	The investment
Lower fuel price	Alternative solution
Subsidies	Methane slip
Discount on harbour dues	Regulations
	Important bottlenecks

[9] Erik Buthker: Business Development Manager at LNG24

What is the current LNG infrastructure situation in the port of Rotterdam and the waterways?

Chapter Introduction

In this chapter I will focus on the current situation of the LNG infrastructure in the port of Rotterdam and the waterways. We will see that the large scale LNG infrastructure is to a great extent in place, but there are some issues with regard to the small scale/downstream LNG infrastructure. This is not a significant problem at the moment, while the introduction of LNG as a marine fuel on this scale is a relatively new phenomena. I will also compare the LNG infrastructure in the port of Rotterdam with other ports in the region.

The current situation of the LNG infrastructure

There is currently a limited infrastructure available in the Netherlands, while LNG as an alternative fuel is a relatively new phenomena in the Netherlands (PWC, 2013). There are a couple of refuelling stations for the road sector, but there is almost no infrastructure for the IWT sector. However, the LNG import terminal 'GATE' is already in operation since 2011. It is a large scale LNG terminal in the port area of Rotterdam and is owned by Vopak and the Gasunie. With the large scale infrastructure in place, Vopak and Gasunie also want to invest in the small scale infrastructure. They are currently working on a break-bulk terminal which is expected to be operational by 2015 (PWC, 2013). The break-bulk terminal will enable the distribution of LNG in relatively small volumes, it will load tank trucks and bunkering vessels with LNG (Vopak, 2014). According to Asselbergs[10], the break-bulk terminal will further develop confidence in the LNG market and the involved ministries. It will push the suppliers of LNG, but also the users, the whole chain is relevant (De Haven, 2013). The GATE terminal and break-bulk terminal will play a key role in the distribution of LNG, while it will be the starting point for the distribution. Those two terminals required significant investments, approximately 800M and 60M euro's respectively for the GATE and break-bulk terminal (Gate) (PWC, 2013). The realisation of these investments brings the ambition of transforming the port of Rotterdam into an LNG hub one step closer.

[10] Cees Jan Asselbergs: Director at Deltalinqs

Figure 12: LNG market in the port of Rotterdam

Reprinted from [LNG market in Port of Rotterdam] [2014], by Port of Rotterdam. Retrieved from http://webcache.googleusercontent.com/search?q=cache:3dv_zLwJUaoJ:www.vvm.info/file.php%3Fid%3D2413+&cd=1&hl=nl&ct=clnk&gl=nl

While the upstream part of the chain is in place, there is much work to do on the downstream part. There is a serious lack of bunker stations in the Netherlands and along the waterways, currently the only way of bunkering LNG is doing it by truckload (PWC, 2013). The port of Rotterdam became the first port in Europe where bunkering of LNG into inland ships was legally allowed (Wang & Notteboom, 2014). However this happens by truckload and there are no bunker stations for inland vessels yet. This is not a significant problem at the moment, while the number of LNG driven vessels are currently very limited. At this moment the most cost efficient method of bunkering LNG into a vessels is doing it by truckload (Tachi, 2014). The retrofit Eiger-Nordwand owned by the Danser group for e.g. can be bunkered in Rotterdam by truckload, the bunkered volume will be enough for a round trip Rotterdam-Basel (den Elt, 2014). For now it can be done by truckload, but according to Erik Buthker trucks are not favourable, fixed bunker stations and bunker barges are necessary for in the nearby future. With more LNG driven vessels these options can become economically viable, but also from a safety point of perspective are fixed stations and bunker barges more favourable than trucks.

The current situation of the LNG infrastructure in other ports

It is of course interesting to look at other ports close to Rotterdam, ports in North Europe. I will focus on eight ports, four large ones and four relatively smaller ones. The large gateway ports are Rotterdam, Antwerp, Hamburg and Bremen. Those four ports are very important gateways in the region and are serious competitors of each other. The smaller ports are Zeebrugge, Gothenburg, Stockholm and Helsingborg. The mentioned ports are all located within the two European Emission Control Areas (Wang & Notteboom, 2014). As of 1 January 2015 ships operating in the North sea and Baltic sea area's will not be allowed anymore to use relatively cheap high sulphur diesel fuels without after-treatment, while it will become forbidden to emit more than 0.1% m/m of sulphur (SOx) (IMO, 2014)(De Scheepvaartkrant, 2013). For ships operating in these area's LNG could become a serious alternative for the nearby future. Other similarities between those ports are that they share the Hanseatic culture, the corresponding port authorities are either public or hybrid public/private and the applied model in all ports is the landlord model (Wang & Notteboom, 2014).

When it comes to LNG infrastructure, the port of Rotterdam is definitely not the only one in the region. Other ports are also working on the take off of LNG in their region. While the introduction of LNG on this scale is quite new, cooperation between the ports is necessary. The port authority of Rotterdam formed a joint venture to support the take off of LNG, together with the port authorities of Antwerp, Mannheim, Strasbourg and Basel (Port of Rotterdam Authority, 2014). The authorities will collaborate on projects like legislation, bunker infrastructure, research, promotion and knowledge transfer. Cooperation is necessary for an healthy take off of LNG, but at the end ports like Rotterdam, Antwerp, Bremen and Hamburg are serious competitors of each other. Therefore it is important to keep an eye on developments in competing ports.

The port of Antwerp became the leader of the working group on LNG, which is part of the World Ports Climate Initiative (WPCI). The central goal of this working group is creating a standard concerning the port governance of LNG, appraise the risks related to LNG bunkering, and increasing the public awareness which is very important (Wang & Notteboom, 2014). In 2012 the port witnessed for the first time the bunkering of a vessel by truck. In 2013 the European Commission supported the port of Antwerp with a subsidy, in order to build a an LNG bunker station for IWT. The port authority has a partnership with EXMAR for building an LNG bunker vessel. This will enable the port of Antwerp to provide ship-to-ship bunkering to vessels by 2015 (Wang & Notteboom, 2014).

LNG is nothing new for the port of Zeebrugge, it hosts LNG terminals since 1987 (Wang & Notteboom, 2013). The introduction of LNG as marine fuel will be an opportunity for the port of Zeebrugge to improve its status as a LNG hub in North-America. The port is currently working on the second jetty which will load and unload LNG carriers. The ports of Zeebrugge, Antwerp and Singapore are currently cooperating on the development of LNG bunkering infrastructure. The port is well positioned to host pilot projects in the nearby future in order to support the kick-off of the market development (Wang & Notteboom, 2014).

The two German ports of Hamburg and Bremen have both plans for developing small to medium scale tanks for the storage of LNG to supply vessels and trucks. Both ports are working on the development of LNG bunkering facilities in cooperation with 'Bomin Linde LNG.' Both port authorities are supporting the developments and took initiatives to encourage the take-off of LNG as marine fuel, for example by investing in LNG driven port vessels (Wang & Notteboom, 2014).

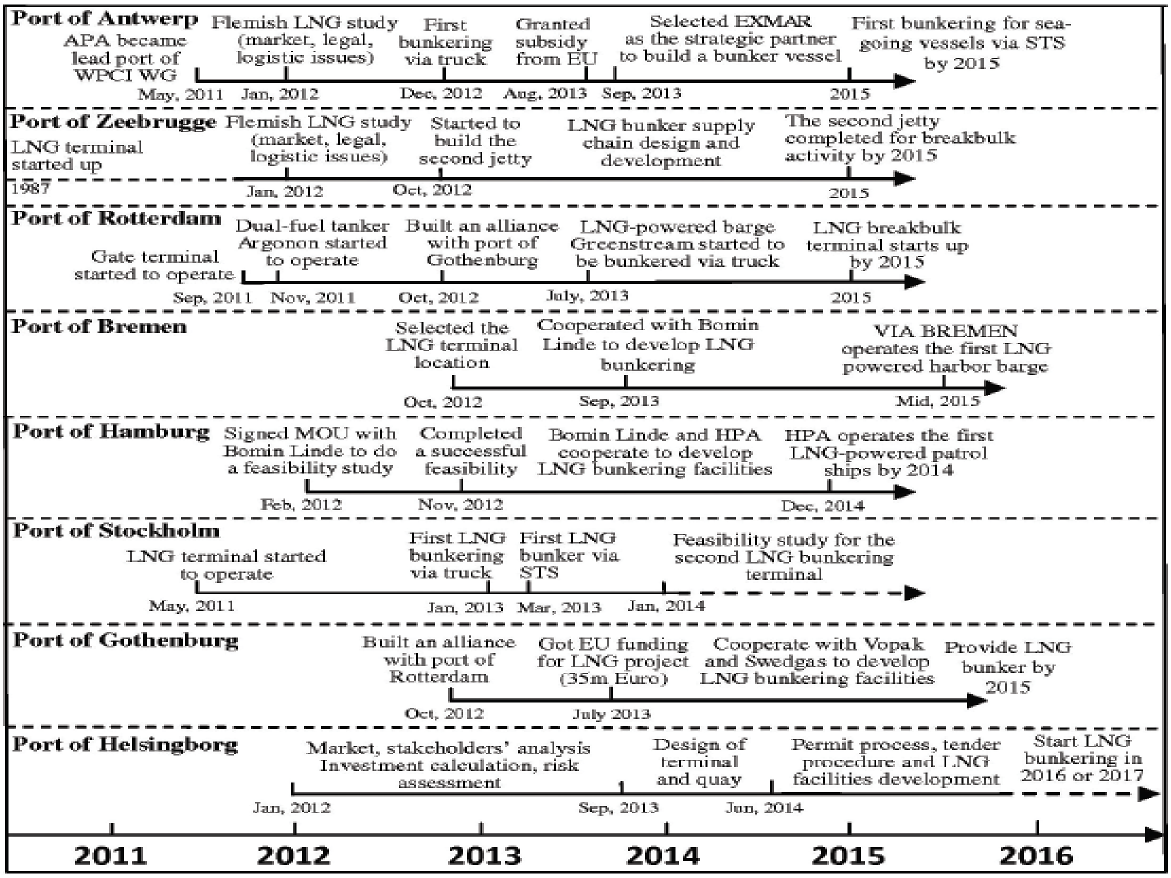
The port of Stockholm was one of the first ports worldwide in offering a possibility to bunker LNG to a large passenger ferry in 2013. The port gets the LNG mainly from the import terminal in the south of Stockholm. It is the first LNG infrastructure in the Baltic sea and the terminal started operations in 2011. The port of Stockholm is currently looking for ways to develop an LNG infrastructure at the port of Kapellskar, which is in the northern part of Stockholm (Wang & Notteboom, 2014).

The port of Gothenburg is a very active player in multiple co-operations for the take-off of LNG as marine fuel. The port works for e.g. together with the port of Rotterdam in developing the necessary port infrastructure for the bunkering of LNG. The EU supports this joint project with a subsidy of €35.5 million. The port of Gothenburg is currently working on a plan to build a medium-scale LNG terminal together with the companies Swedegas and Vopak (Wang & Notteboom, 2014).

The port of Helsingborg is a relatively small but very busy port in the waters of Northern Europe. The port is a relatively 'green' port in the area and wants to further improve this 'green' image. Therefore the port is very interested in offering LNG and Bio-LNG. In 2012 the port became the head of the project 'LNG in Baltic Sea', which is funded by the European Union (Wang & Notteboom, 2014).

The developments in above mentioned ports can be summarized with the following picture:

Figure 13: Overview LNG infrastructure in other ports



Reprinted from [The timeline of LNG bunkering projects in the eight ports] [2014], by Wang & Notteboom, 2014. Retrieved from http://porteconomics.eu/news/viewpoints/item/519-lng-bunkering-facilities-in-north-%C2%ADeuropean-ports-viewpoint-pti.html

Chapter Conclusion

While the introduction of LNG as a marine fuel on this scale is a relatively new phenomena, there is nearly no infrastructure for it. There is a serious lack of bunker stations and other downstream activities in the port of Rotterdam, the waterways and other ports in North-Europe (excluding Norway). The port of Rotterdam has the possession over large scale LNG infrastructure; an LNG import terminal and soon an LNG break-bulk terminal, which will open up the way for the missing small scale infrastructure. This is at the moment not a significant problem, while bunkering by truckload is the most economically viable solution. But trucks are not favourable, fixed bunker stations and bunker barges are needed for in the nearby future. The port of Rotterdam is not the only port in the region with a lacking LNG downstream infrastructure. The downstream activities are also lacking in the mentioned Swedish ports, but they are seriously working on it. The Scandinavian countries in general are especially eager in developing a broad LNG bunkering network. The port of Zeebrugge has currently a rather advanced LNG infrastructure compared to the port of Rotterdam. The port of Rotterdam has in comparison with competing ports like Antwerp, Hamburg and Bremen a favourable infrastructure. LNG import terminals and break-bulk terminals are currently missing in those ports. The presence of large scale LNG infrastructure in the port of Rotterdam will be used for export of LNG to vessels, the ports mentioned above have to import this LNG from a terminal elsewhere. An additional advantage is that the presence of this large scale infrastructure has established knowledge of LNG and collaboration between the relevant stakeholders. There is also significant presence of bunkering activities in the port of Rotterdam. These conditions will make it for investors more favourable to invest and take risk, because there is more transparency in the market (Danish Maritime Authority, 2012).

How does an optimal LNG infrastructure towards 2020 look like and what are barriers for the realisation of such an infrastructure?

Chapter Introduction

In this chapter I will have a closer look at the future of the infrastructure for LNG. How would an optimal LNG infrastructure look like for the near future? I will have a look at the barriers for the realisation of the LNG infrastructure, is there for e.g. enough demand to back the infrastructure? What is the current number of LNG driven vessels in the Netherlands? And a last important point will be that the LNG infrastructure should not be dedicated to IWT only.

An optimal infrastructure

First of all it is important to define what an optimal infrastructure actually is. The current bunkering infrastructure for gasoil/diesel is a cost-efficient infrastructure consisting of bunker tanks in port areas, bunkering vessels and bunkering stations alongside the quays (Danish Maritime Authority, 2012). This seems like an optimal infrastructure for gasoil/diesel. There is a wide variety of bunkering solutions, which makes bunkering easier for ship owners and at the same time it is a cost-efficient infrastructure. From an economic point of perspective such an infrastructure would not be optimal for LNG at the moment, while it will not be sustained by the necessary amount of vessels. An optimal LNG infrastructure in this case, from an economic point of perspective, would be an infrastructure with a sufficient return on investment, made possible mainly by the required demand for LNG. According to Erik Buthker, a LNG bunker station needs approximately at least 5 regular customers in order to have a positive business case. Currently there are only three inland vessels running on LNG in the Netherlands (VVA, 2013). This is where the famous ‘chicken-and –egg-problem’ emerges, providers of LNG will not invest in bunker stations and other downstream activities without the necessary amount of customers. Ship owners on the other hand will not invest in LNG driven vessels without bunkering solutions like bunker stations (Danish Maritime Authority, 2012). However I think this problem will be solved, the transition towards LNG needs some time. Suppliers of LNG and other relevant stakeholders are really convinced that it is a very promising fuel for in the near future. This is quite clear from all the interviews and the presentations during the information sessions. Gradually there is coming more movement in the market, cooperation between the involved stakeholders in the infrastructure is necessary to further improve this movement.

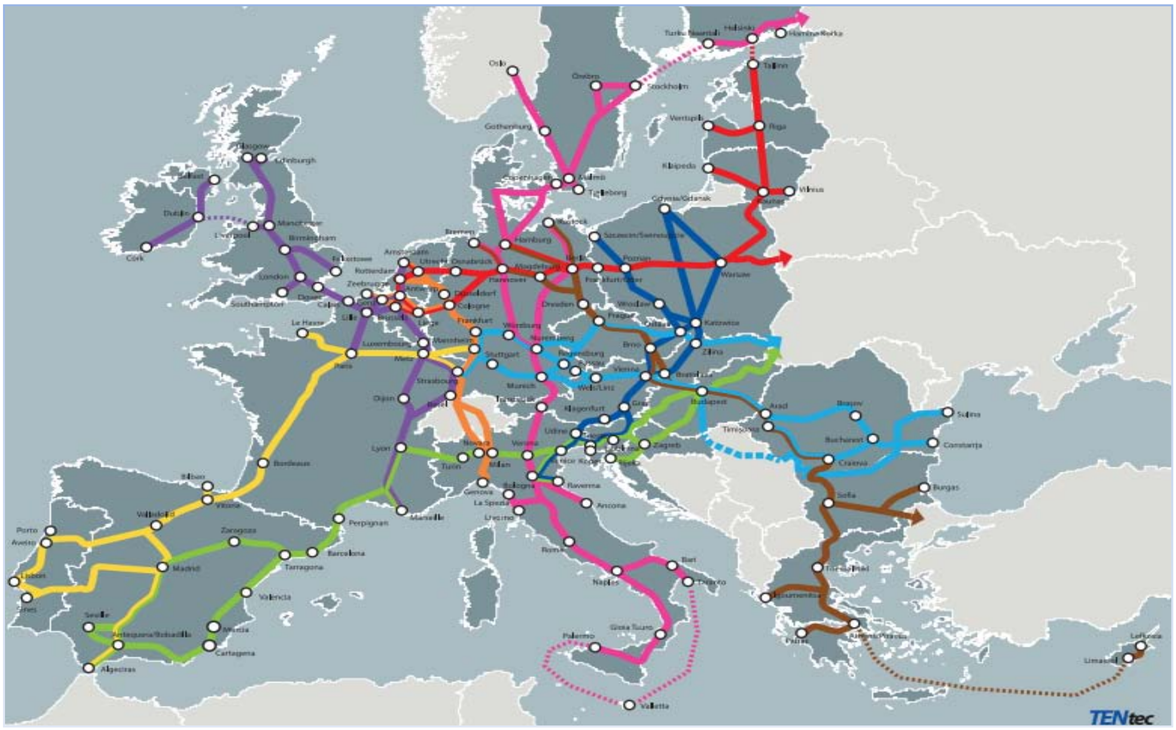
It will be very difficult to predict how an optimal LNG infrastructure towards 2020 will look like, while it depends on multiple factors. As previously mentioned, there are currently no bunker stations for IWT in the Netherlands. Bunkering LNG into inland vessels is done by truckloads and currently this is the most cost efficient method (Tachi, 2014). Investing millions in LNG bunker stations now would not be an economical viable option, while the number of vessels sailing on LNG are very limited. A significant increase in the numbers of LNG driven vessels could make investments in LNG bunker stations more attractive. There are in the Netherlands currently only three inland vessels running on LNG, those are the Argonon, Greenstream and Greenrhine (VVA, 2013). There are seven more vessels in construction, the previous mentioned Eiger-Nordwand is one of it (VVA, 2013). There are also bunker tankers in construction, which will form an important node in the supply chain. VEKA Group and Deen Shipping are working together on the construction of an inland LNG carrier, which will be able to bunker vessels in the Amsterdam-Rotterdam-Antwerp range and supply various small-scale LNG terminals along the inland waterways in Europe (Schuttevaer, 2013). Another example is the bunker tanker of Argos. The tanker of Argos will supply both inland and sea going vessels with LNG. This project is partly financed by the LNG-Masterplan (EU) and will be ready for operation by 2015 (LNG Masterplan, 2014). The 'Nationaal Platform LNG' has even the ambition of 50 sea ships, 50 inland vessels and 500 trucks running on LNG in 2015. The platform connects businesses and the government which work on the introduction of LNG as an alternative fuel for the transportation sector (Deltalinqs, 2012). The (partly) realisation of such ambitions could make investments in infrastructure more attractive. However, the required investments could still be a bottleneck. Financial support provided by the public sector could be necessary in this situation (Danish Maritime Authority, 2012).

A basic web of several bunker stations may be necessary to convince ship owners to invest in LNG driven vessels. Only a limited number of bunker stations would be enough (PWC, 2013). According to Lauran Wetemans[11], three up to four LNG bunker stations along the Rhine would be enough to create a reliable infrastructure for inland navigation (Pieffers, 2013). Three up to four stations at strategic locations along the Rhine may be enough to convince ship owners at the moment to invest in LNG driven vessels. This is another important point to note, a valuable infrastructure in the Netherlands alone is most likely not enough. A satisfying infrastructure along the Rhine in other countries may also be necessary. The European Commission proposes to install LNG bunker stations in all 139 seaports and inland ports connected to the Trans-European Transport Network (TEN-T) by

[11] Lauran Wetemans: General Manager Downstream-LNG at Shell International

2020 and 2025, respectively (European Commission, 2013). An LNG bunker station in every TEN-T connected sea- and inland port would be an ideal scenario, especially such an infrastructure along the Rhine area could be ideal for the Dutch inland fleet and other fleets. Ship owners would have the possibility to bunker at multiple locations along the Rhine and would thereby reduce time and fuel costs compared to a situation with just a few bunker stations. However this requires significant investments, the total cost will be approximately € 2.1 billion (European Commission, 2013). While the most relevant waterways for the Dutch fleet are likely in the country itself and the Rhine area , this amount will be lower for those regions but still requires a significant investment.

Figure 13: Trans-European Transport Network (TEN-T)



Reprinted from [Trans-European Transport Network] [2013], by European Commission. Retrieved from http://ec.europa.eu/transport/infrastructure/tentec/tentec-portal/site/maps_upload/09_01_2014SchematicA0_EUcorridor_map_outlined.pdf

Very important to note is that according to Johan Algell[12] it will be wisely to co-use a lot of the LNG infrastructure with not-shipping related industries (Algell, 2013). It will indeed be wisely that investments in LNG infrastructure for IWT should not be dedicated to the IWT sector only. The infrastructure has to be shared with other users of LNG, the chemical industry for example also uses LNG and bio-LNG. Power plants which are not connected to pipelines could also make use of the infrastructure (Algell, 2013). Others could be the road transportation sector and perhaps even the rail transportation sector. The LNG infrastructure for IWT has to be a part of a larger network and

[12] Johan Algell: Business Development Manager – Marine LNG at Skangass AS

should not be dedicated to the IWT sector only. The reason for this could be that while LNG infrastructure requires significant investments, the co-use of it would be an appropriate way for mitigating risk and creating a downward pressure on the distribution costs of LNG (Algell, 2013). As a result it will be more feasible to invest in the small scale infrastructure.

Chapter Conclusion

Currently there is a lack of downstream/small scale LNG infrastructure in the Netherlands. The current bunkering infrastructure for gasoil/diesel is a cost-efficient infrastructure consisting of bunker tanks in port areas, bunkering vessels and bunkering stations alongside the quays (Danish Maritime Authority, 2012). There is a wide variety of bunkering solutions, which makes bunkering easier for ship owners and at the same time it is a cost-efficient infrastructure. From an economic point of perspective such an infrastructure would not be optimal for LNG at the moment, while it will not be sustained by the necessary amount of vessels. An optimal LNG infrastructure in this case, from an economic point of perspective, would be an infrastructure with a sufficient return on investment, made possible mainly by the required demand for LNG. The problem here is that there are currently not enough LNG driven vessels and so not enough demand to set up a LNG bunker station. Bunkering by truckload is currently the most economically viable method. An optimal infrastructure for the near future will mostly depend on the number of LNG driven vessels. However, three up to four bunker stations at strategic locations along the Rhine may be necessary to convince ship owners at the moment to invest in LNG driven vessels. The endeavour to develop an infrastructure should efficiently be coordinated and communicated between the relevant stakeholders, in order to meet and support generating the maritime demand for LNG. It will also be wisely to co-use a lot of the LNG infrastructure with not-shipping related industries (Algell, 2013). The co-use of it would be an appropriate way for mitigating risk and creating a downward pressure on the distribution costs of LNG (Algell, 2013). As a result it will be more feasible to invest in the small scale infrastructure.

Who are the most relevant stakeholders responsible for investments in the inland waterway infrastructure?

Chapter Introduction

In this chapter I will focus on the most relevant stakeholders which are responsible for investments in the IWT infrastructure for LNG. Firstly I will present an overview with the most relevant parties which are involved in the LNG market for IWT in general. Afterwards I will focus on those parties who are responsible for investments in the LNG infrastructure. I will point out their roles with regard to the infrastructure and ways in which they can stimulate the roll-out.

The stakeholders

In the following scheme we can see the most relevant parties involved in the LNG market for IWT:

Figure 14: LNG stakeholders IWT

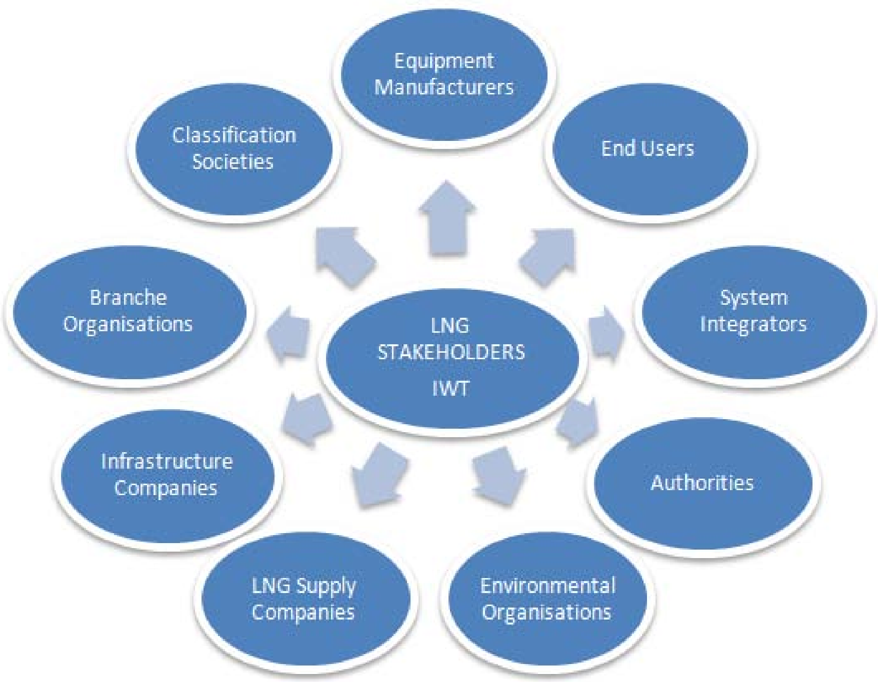


Figure 15: LNG stakeholders IWT.2

Equipment Manufacturers

Mono and dual fuel engines:

- Wartsila
- Caterpillar / Pon Power
- Scania
- Mitsubishi/ Koedood
- Anglo Belgian Corporation (ABC)
- MAN

LNG – Toolkits:

- ArenaRed

(Cryogenic) Hardware: tanks, pipes, valves etc.

- Cryonorm
- Cryostar
- Cryovat
- Cofely GDF Suez
- Airproducts
- Airliquide
- Willems RSV aluminium
- Chart Ferox

System Integrators

Knowledge institutions:

- TNO
- ECN
- Technical Universities
- Marin

Shipyards:

- Veka
- Trico
- Koedood
- Damen

Engineering Bureaus:

- Alewijnse
- Benteler
- Sandfirden Technics
- INEC

Environmental Organisations

- Natuur&Milieu
- Milieudefensie
- Greenpeace
- De natuur en milieufederaties

LNG Supply Companies

- GDF Suez - Electrabel
- Distrigas – LNG Europe
- Gasnor
- Gasterra – Gasunie/ Vopak

Infrastructure Companies

- GDF Suez
- Ballast Nedam
- Gasunie/ Vopak
- Shell
- Argos Oil
- Salland Oil

End Users

Shipowners and shipping companies in IWT (main focus in this thesis):

- Danser Group
- ThyssenKrupp Veerhaven
- Chemgas Shipping
- Interstream Barging
- Fluvia Holding
- Deen Shipping

Authorities

- The European Union, the European Commission is the main relevant body.
- The Dutch Government, the Ministry of Infrastructure and the Environment is the main relevant body.
- The Provinces
- The port authorities
- The Central Commission for the Navigation of the Rhine (CCR)

Branche Organisations

- Binnenvaart Logistiek Nederland (BLN)
- Deltalinqs
- Koninklijke Schuttevaer
- Centraal Bureau voor de Rijn- en Binnenvaart (CRBR)
- Expertise- en InnovatieCentrum Binnenvaart (EICB)
- Stichting Projecten Binnenvaart (SPB)
- Europese Schippersorganisatie (ESO)
- European Barge Union (EBU)
- Inland Navigation Europe (INE)

Classification Societies

- DNV GL
- Lloyd's Register
- Bureau Veritas

The scheme covers a great part of the involved stakeholders in the LNG market for IWT. I will not discuss every stakeholder, while I will focus on the most important stakeholders for the LNG infrastructure. As previously stated the set up of an LNG infrastructure requires significant investments. Investments in the Netherlands alone are not enough, the roll-out of the infrastructure in the rest of Europe is also necessary. Only under this condition, ship owners and producers will invest in LNG driven vessels (PWC, 2013).

While the infrastructure requires significant investments, public support in the initial stages could be necessary (Danish Maritime Authority, 2012). The government could provide financial support but also other non-financial instruments could stimulate the roll-out of the infrastructure. Regulations are important non financial instruments which can support or oppose the developments. Therefore it will be wise to set up favourable regulations at the initial stages, too stimulate the roll-out of the infrastructure. After all, the government is in favour of sustainable transportation and LNG contributes to that. Bodies of the government should also participate in research programmes together with market parties. The report 'schone schepen' published by Rijkswaterstaat in cooperation with CE Delft, EICB, Ecorys, Marin and TU Delft is an example. While there is still an information gap in small scale LNG infrastructure, such reports can help with filling up this information gap. Local authorities like the province of South-Holland also plays an important role. They have a role with regard to regulations, but can also participate in projects to stimulate the take off of LNG. Currently the province is working on two projects about the small scale LNG and total cost of ownership (van Leeuwen, 2014).

The EU also plays an important role with regard to the LNG infrastructure. The EU wants to give IWT a greater role as transportation mode, but at the same the environmental quality has to improve (European Commission, 2013). LNG can play a key role in this objective and therefore the European Commission supports the uptake of LNG. This can be financial, legislative and/or organisational support. The LNG masterplan for the Rhine-Main-Danube region is an example of European support for the roll-out of LNG, it is a project co-financed by the EU (LNG Masterplan, 2014). The LNG masterplan connects authorities and industry stakeholders in order to establish a platform for cooperation between those actors. The objective is the establishment of a harmonized EU regulatory structure for LNG as bunker fuel and shipment in IWT and to support the take off of LNG as a fuel and shipment for IWT (LNG Masterplan, 2014). The plan consists of various feasibility studies, technical concepts and trials, and the deployment of pilot terminals/vessels. Examples of financial support are the two European subsidies of €40 million and €34 million for the LNG infrastructure in the Rhine-Main-Danube region and the LNG break bulk terminals in Rotterdam and Gothenburg, respectively (Port of Rotterdam Authority, 2013).

Port authorities will also play an important role, in our case I will focus on the port of Rotterdam authority. First of all the port of Rotterdam authority wants to transform the port to the most sustainable port of its kind (Port of Rotterdam Authority, 2013). A lot of the freight consists of 'energy' such as oil, coal, bio mass and LNG. It is a true energy port and the 'energy' freight has increased enormously due the increased demand for energy (Port of Rotterdam, 2013). These developments with regard to energy leads to an increase in CO2 and other emissions. This in turn results in a louder call for a transition towards sustainable energy. The port of Rotterdam wants to play a leading role in giving the right example, the ultimate goal is to reduce CO2 emissions with 50% by 2025 (Port of Rotterdam, 2013). LNG as an alternative fuel can contribute to this objective, the port of Rotterdam authority supports the development of the market for LNG and wants to transform the port into an LNG hub (Port of Rotterdam Authority, 2013). The port authority provides green-awards for relatively clean ships and looks also in incentives like LNG credits to support the take off of the business (Platts, 2014). The port authority introduced the Port Bye Laws in July of 2013, in which they legally enabled the bunkering of LNG for inland vessels. As a result the port of Rotterdam became the first port in Europe where bunkering LNG was legally allowed (Port of Rotterdam Authority, 2014). Next to the regulatory framework, the port authority can further support the roll-out of LNG by providing the necessary port infrastructure like quays and terminal sites (Danish Maritime Authority, 2012). The port authority also formed a joint venture to support the take off of LNG, together with the port authorities of Antwerp, Mannheim, Strasbourg and Basel (Port of Rotterdam Authority, 2014). The authorities will collaborate on projects like legislation, bunker infrastructure, research, promotion and knowledge transfer. The port authority of Rotterdam wants to exploit the full potential of the market for LNG and create an LNG hub by 2015. In order to achieve this the authority invests in infrastructure, cooperation with relevant stakeholder and is involved in creating the necessary policies and legislation (Port of Rotterdam Authority, 2014). The above mentioned subsidies of the EU are also the result of close cooperation with relevant parties (Port of Rotterdam Authority, 2013).

The CCR has also some authority over IWT with regard to regulations and thus plays a role. The organisation approved the use of LNG as a fuel for the 'Argonon' in 2012. Furthermore the organisation conducted a research in 2012 to the risk potential of LNG and the positive effect on the environment compared to gasoil. During this research the CCR cooperated with companies in the maritime sector and classification bureaus (CBRB, 2012). The CCR also participated in setting up an European website, which monitors LNG related developments in IWT. This enables other stakeholders to be up-to-date of the developments. In this way the CCR has direct or indirect an effect on developments in the LNG infrastructure.

Environmental organisations can play a supporting or opposing role in the development of an infrastructure. Environmental organisations could oppose the construction of LNG terminals and bunker stations, while LNG is a fossil fuel. The use of LNG leads to reductions in pollutant emissions, but the CO2 emissions are still significant. However it seems like environmental organisations are not opposing the developments and are cooperating. The cooperation of various environmental organisations with the 'Nationaal LNG Platform' is an example (Nationaal LNG Platform, 2013). I think that most environmental organisations will cooperate with initiatives for developments in the LNG infrastructure, while LNG is less pollutant than diesel/gasoil and opens the way for bio-LNG which is much cleaner than LNG (PWC, 2013).

The above mentioned branch organisations will play a role with regard to the developments in the infrastructure. These organisations are protecting and promoting the interests of the branch, which will eventually be responsible for a significant share of the demand for LNG. Organisations like Deltalinqs and the EICB can bring parties together in research programmes for example. This is very important, because I think that cooperation between all the stakeholders will be very important. This will fill up the information gap and support the take-off of the business. The 'innovatieschuur' led by the EICB is an example. It is an agreement between 20 parties and they participated in various projects, one of the projects was about LNG in IWT (EICB, 2014).

The end users of LNG will play an important role, while they will eventually be the party who creates the demand for the infrastructure. If ship owners and shipping companies like the Danser group continues to invest in LNG driven vessels, it will become more attractive to invest in the LNG infrastructure. Shipping companies can also be part of the infrastructure by having inland LNG tankers. 'Chemgas Shipping' is an example, the shipping company is currently working on an inland LNG tanker which will be part of the LNG infrastructure in the Danube area (LNG Masterplan, 2014).

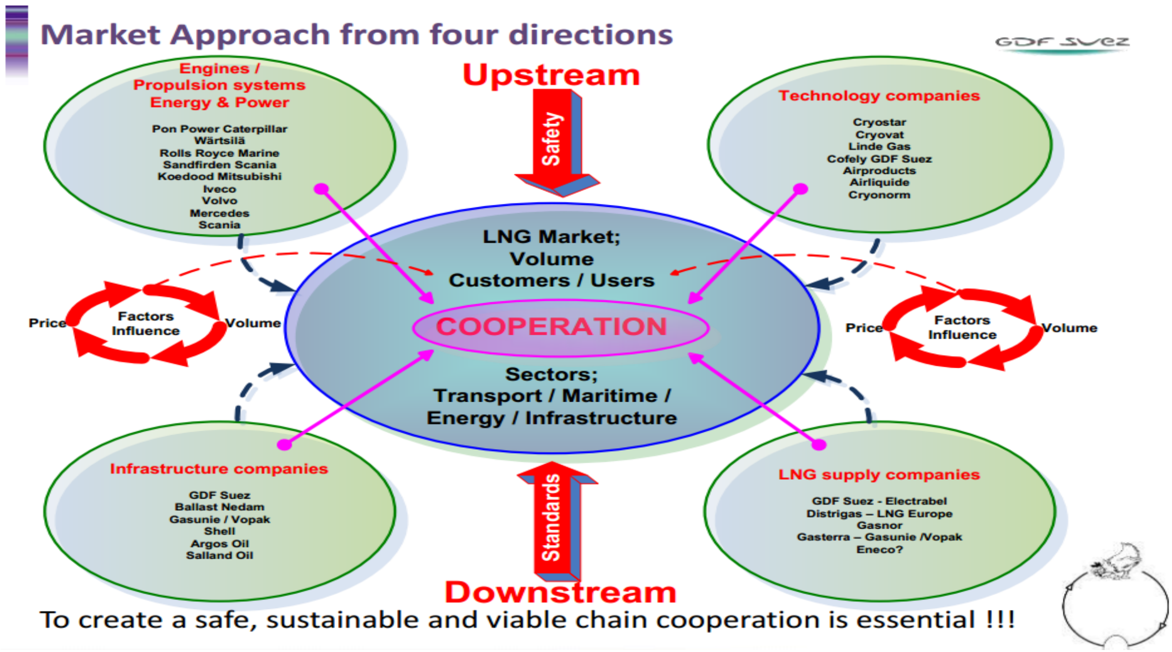
The involved parties mentioned above are important for the development of the LNG infrastructure, but at the end it will mainly be the private industrial sector which is responsible for the nfrastructure. The main relevant stakeholders will be the oil and gas companies like (Sluiman, 2012):

- GDF Suez
- Ballast Nedam (LNG24)
- Gasunie / Vopak
- Shell
- Argos Oil
- Salland Oil

Eventually companies like these will be mainly responsible for the roll-out of the infrastructure, while they will be the operators of the LNG bunkering facilities and will make profit out of it (Wang & Notteboom, 2014).

Cooperation between above mentioned stakeholders, producers of LNG installations, the shipping industry and other potential not-shipping related users of LNG is necessary to support the take off of the business (Wang & Notteboom, 2014). The roll-out of the infrastructure requires significant investments and brings risk, optimal cooperation between the involved parties can reduce this risk and make the ‘chicken and egg’ problem less significant (Wang & Notteboom, 2014).

Figure 16: LNG chain



Reprinted from [Market approach from our directions] [2012], by GDF Suez. Retrieved from http://www.schonescheepvaart.nl/downloads/seminars/doc_1363970031.pdf

When we look at gas and oil companies like Lng24 and Shell there will be mainly cooperation on regulations, according to Erik Buthker. This could be safety regulations for the set up of an LNG bunker station. While cooperation is key here, there could also arise conflicts between different stakeholders. A potential conflict could arise between the classification societies and shipping companies who are investing in LNG driven vessels. The established technical standards by classification societies may be too high from a shipping company’s point of perspective. High technical standards will drive up the investment costs. Conflicts like these could arise, but I think that in these initial stages the stakeholders will mostly cooperate with each other to realise an efficient roll-out of the infrastructure.

Chapter Conclusion

Various stakeholders are involved in the LNG market for IWT and a great part is also involved in the infrastructure of it. I think that key players here are the authorities, the shipping companies and mainly the oil and gas companies who will operate the LNG bunkering facilities. The authorities will mainly play a role with regard to regulations and subsidies, tools to make investments in LNG infrastructure more attractive. The shipping companies and especially the oil and gas companies will mainly play a financial role. Eventually companies like Shell and Argos will be responsible for the roll-out of the infrastructure, while they will be the operators of the LNG bunkering facilities and will make profit out of it. In these initial stages of the infrastructure roll-out most stakeholders will reinforce each other, which is necessary for an efficient roll-out.

How do ship owners and shippers experience the possible switch to LNG as a transportation fuel?

Chapter Introduction

In this chapter I will focus on the attitude of ship owners and shippers, with regard to a possible switch to LNG as an alternative transportation fuel. I will point out that both parties have rather a positive attitude towards LNG. There are however some bottlenecks towards switching and there are also costs tied to switching, namely the switching costs. A short description of these costs will be given and I will have a closer look at the role of these costs in our case.

The ship owners and shippers

According to Erwin van der Linden[13], the EICB conducted a survey and it appeared that ship owners experience the switch to LNG in a moderately positive way (EICB, 2014). The moderate attitude is probably mainly caused by the bottlenecks mentioned before. The required investments are significant and there are problems concerning the finance and market situation. Some shippers want to wait before deciding to invest, they wait for a developed and clear market situation. The installation of an LNG system in a vessel also requires quite some time, not every ship owner has this opportunity. This is part of the switching cost, which I will touch on later. A standardisation of the LNG installation for vessels in the same class, for the whole fleet is impossible, would probably increase the enthusiasm for LNG (Tachi, 2014).

There are two examples of positive views towards LNG as alternative fuel. According to Ad Schroot[14] of Danser Group, (personal communication, May 20, 2014), demand for sustainable transport is on the rise and LNG could play a key role. LNG can contribute to the creation of sustainable transport and according to Ad Schroot LNG is the future. Danser Group currently invests in a dual-fuel engine for the previously mentioned vessel 'Eiger-Nordwand.' According to Contargo Waterway Logistics, (personal communication, May 7, 2014), the use of LNG as fuel is a very important development and has to be supported. However, there are some bottlenecks with regard to the required LNG infrastructure which makes investments in LNG less attractive.

According to Ad Schroot, shippers definitely value the use of LNG as fuel while it results in less emissions compared to diesel fuel. The demand for sustainable transport is increasing and as a result

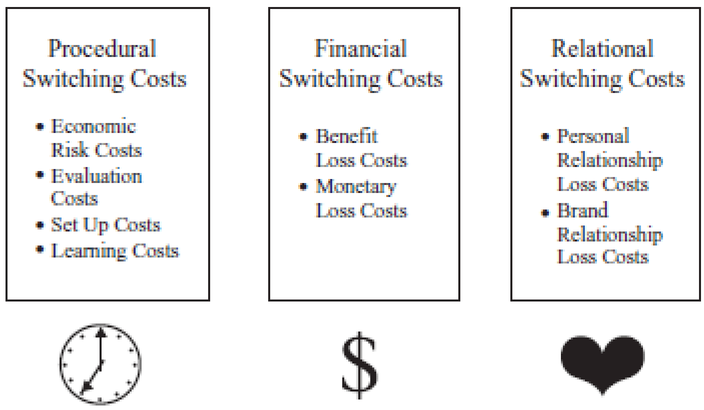
[13] Erwin van der Linden: Project Manager at Expertise- en Innovatiecentrum voor de Binnenvaart
[14] Ad Schroot: Ship's supervisor at Danser Group

transportation by LNG driven vessels is becoming attractive. Especially relative large firms attach value to sustainable transportation, probably due to their corporate social responsibility. An example of this is the chemical concern AkzoNobel N.V., which pays a premium for sustainable transportation. The concern pays an environment bonus to five vessels which installed after treatment techniques (Heynen, 2010). According to Jos Keurentjes[15], sustainability is becoming even more important, it is a new competition-element. AkzoNobel and other firms like DSM are pursuing an environment policy since several years (Heynen, 2010). During business negotiations ecological footprints also play a role, it is not only about the price anymore. Extra 'green' transportation is becoming an important competition argument. In coming years 'green' vessels will pull cargo in an easier way compared to 'grey' vessels (Heynen, 2010). According to Jos Kreuntjes, the price of CO2 and other emissions will change in coming years while the current price is not an appropriate reflection of the created damage (Heynen, 2010). However, firms which are willing to a pay a premium are just a few, probably only the very large ones due to their corporate social responsibility. According to Ad schroot and Erik Buthker, the majority of the shippers are not willing to pay a premium for transportation by LNG driven (cleaner) vessels. Shippers are very positive with regard to sustainable transportation but most of them are not prepared to pay a premium for it (Rijkswaterstaat, 2013).

Switching Costs

Coming back to the switching cost, investing in an LNG driven vessel can lead to switching costs. Three main types of switching costs are: procedural costs, financial costs and relational costs (Burnham, Frels, & Mahajan, 2003). The following figure summarizes the various switching costs:

Figure 17: Switching costs



Reprinted from [A Typology of Consumer Perceptions of Switching Costs] [2003], by Thomas A. Burnham, Judy K. Frels and Vijay Mahajan. Retrieved from http://jam.sagepub.com/content/31/2/109

[15] Jos Keurentjes: Former director for technology and open innovation at AkzoNobel Chemicals

Switching to an LNG driven vessel and especially retrofitting requires quite some time, not every ship owner has the opportunity to do this. Switching to LNG requires research and analysis in order to make the right decision. Ship owners have to evaluate potential suppliers of equipment, fuel etc. This takes time and effort, and is part of the evaluation costs. The inland container vessel 'Eiger Nordwand' is the first and currently the only retrofitted inland vessel (Danser Group, 2014). The retrofit process took approximately two months, during these two months the vessel was not operational. This is at the cost of sailing hours and is related to the set up costs. The vessel is in operation now and it will take time and effort in order to acquire new skills and knowledge to use the LNG installation effectively. The Danser group is also taking risk with the installation of an LNG system. It is the first retrofit till now, so there is uncertainty to some extent. The LNG installation may not perform as expected for example, there can be a performance risk. Other types of economic risk costs are financial risk and convenience risk (Burnham, Frels, & Mahajan, 2003). Some of these costs could also apply to organisations which want to transport their products with an alternative (sustainable) shipping company. The most obvious one would be the evaluation costs, while switching to an alternative shipping company requires research and analysis in order to make the right decision.

Financial switching costs include benefit loss costs and monetary loss costs (Burnham, Frels, & Mahajan, 2003). A ship owner may enjoy discounts on diesel/gasoil from a particular supplier or discounts on maintenance, because the ship owner is a regular customer. Switching to an entire new system will create new suppliers and relations which will result in a loss of discounts and points they have accumulated over time. Perhaps there are certain contracts between the ship owner and its supplier, the breach of this contract could lead to costs. This could also apply to companies which switch from shipping company for the transportation of their products. Companies like Akzonobel and DSM could incur these costs, but this could be problematic for smaller companies. It could discourage certain parties to switch towards a more (sustainable) shipping company.

Finally there are the relational switching costs, consisting of personal relationship loss costs and brand relationship loss costs (Burnham, Frels, & Mahajan, 2003). Personal relationship costs are the losses which arise due to the ending of bonds of identification, formed by the relationship between customer and supplier (Burnham, Frels, & Mahajan, 2003). Doing business with each other over a long period creates a level of trust and comfort between the two parties. This trust and comfort is missing when a customer chooses for a new supplier. This is again a type of switching cost which could have a discouraging effect on switching to a new supplier. Brand relationship costs are related to the brand itself rather than the relationship. I don't think this will be of significance in our case.

Chapter Conclusion

It appeared that ship owners experience the switch to LNG in a moderately positive way. Overcoming the bottlenecks in previously mentioned chapters could improve this attitude in positive way. Shippers definitely value the use of LNG as an alternative fuel, while it contributes to a more sustainable transport modality. However, most of the shippers are not prepared to pay a premium for it. Perhaps some of the large corporations, due to their corporate social responsibility. There are also costs related to switching. Switching to an LNG installation or alternative (sustainable) shipping company could lead to certain switching costs. There are three main types of switching costs; procedural switching costs, financial switching costs and relational switching costs. These costs could have a discouraging effect in some cases, making switching difficult. On the other hand, demand for a sustainable society and thus sustainable transportation is on the rise. This pushes parties towards more sustainable transportation, making switching necessary in some cases.

Conclusion and Recommendations

IWT was for a long time accepted as an efficient, environmental friendly and safe modality. Especially in a water rich country with many waterways like the Netherlands, it is an highly appropriate mode of transportation. However, its environmental friendly advantage relative to road transportation is not any more that self-evident and its competitive position is being contested. The IWT sector has to improve its environmental performance if it wants to hold its environmental friendly competitive position. The sector will be forced to do so, because new emission norms will be implemented in coming years and an environment zone will be implemented in the port of Rotterdam. Thirdly, there is the expected growth of the sector. The European Union wants to fully utilize its potential by increasing its share as a transport mode and at the same time improving the quality of IWT. As a consequence, IWT has to become a cleaner mode of transport and LNG could play a key role in achieving this goal.

There are several alternative fuels which can be used by the sector, but LNG is the most promising one. LNG is a much cleaner fuel to burn compared to conventional diesel fuels, which makes LNG very favourable. Compared to the widely used EN590 diesel fuel, the use of LNG leads to significant reductions in pollutant emissions and a less significant reduction in CO2. While it reduces emissions, the installation of an LNG system can benefit from subsidies and discounts on harbour dues. However, the financial effect of these measures will be minimal. The price of LNG as a fuel on the other hand, plays a decisive role. First of all gas reserves are significantly larger than oil reserves and major gas reserves are not concentrated in a certain area, which is the case with oil reserves. This makes gas less sensitive for (geo)political events. On the other hand, oil reserves are shrinking and there may occur a peak in oil production by the year 2030. LNG is currently cheaper than gasoil/diesel, an average price difference of 20% between gasoil and LNG is currently a realistic scenario. However, LNG bunker prices will not be equal to LNG prices. Too many times is being referred to the LNG terminal in Zeebrugge for the LNG price. The LNG price at the terminal in Zeebrugge is not the same as the LNG bunker price. The whole supply chain has to be taken into consideration: LNG bunker prices will also include the costs of the LNG infrastructure. Currently there is a lack of such LNG bunkering infrastructure which makes it difficult to forecast LNG bunker prices. But it is not expected that long term LNG fuel prices will increase at a higher rate in relation to crude/oil prices.

There are also con’s and costs related to the use of LNG as a fuel in IWT. First of all, it is currently legally not allowed to navigate on LNG. However, it is possible to apply for a recommendation and it is expected that new policies on EU level in favour of LNG will soon come into force. A major drawback for an LNG installation are the investment costs. A complete LNG installation is approximately twice the price compared to a conventional diesel installation. As a result navigating on LNG is currently not an economic viable solution for every vessel, there has to be an attractive return on investment. According to a study LNG is currently an economic viable option for approximately 260 vessels in the total Dutch fleet. This number will most likely increase as the market for LNG systems expands and the costs of a LNG installation drops. Currently tankers are the most attractive vessels for an LNG installation. An attractive alternative to LNG are after treatment techniques, which also contributes to significant emission reductions. However, a return on investment is not possible with after treatment techniques. It can all be summarized with the following overview:

Pro's and benefits	**Con's and costs**
Emission reduction	The investment
Lower fuel price	Alternative solution
Subsidies	Methane slip
Discount on harbour dues	Regulations
	Important bottlenecks

The mentioned drawbacks are hindering the developments but they are not that significant enough to stop the market development. Overcoming the current drawbacks though, could strongly boost the developments and make investments in LNG driven vessels and infrastructure more attractive. The current LNG infrastructure in the port of Rotterdam and the waterways is lacking. There is a serious lack of bunker stations and other downstream activities in the port of Rotterdam, the waterways and other ports in North-Europe. This is at the moment not a significant problem, while bunkering by truckload is the most economically viable solution. But trucks are not favourable, fixed bunker stations and bunker barges are needed for in the nearby future. There is however a large scale LNG terminal in the port area of Rotterdam and an LNG break-bulk terminal will be operational by 2015. The presence of this large scale infrastructure has established knowledge about LNG and collaboration between the relevant stakeholders. There is also a significant presence of bunkering activities in the port of Rotterdam. These conditions will make it for investors more favourable to invest and take risk in the LNG infrastructure, because there is more transparency in the market.
It will be difficult to predict how such an infrastructure should look like for in the near future. The current bunkering infrastructure for gasoil/diesel is a cost-efficient infrastructure consisting of bunker tanks in port areas, bunkering vessels and bunkering stations alongside the quays. There is a wide variety of bunkering solutions, which makes bunkering easier for ship owners and at the same time it is a cost-efficient infrastructure. From an economic point of perspective such an infrastructure

would not be optimal for LNG at the moment, while it will not be sustained by the necessary amount of vessels. An optimal LNG infrastructure in this case, from an economic point of perspective, would be an infrastructure with a sufficient return on investment, made possible mainly by the required demand for LNG. The problem here is that there are currently not enough LNG driven vessels and so not enough demand to set up an LNG bunker station. Bunkering by truckload is currently the most economically viable method. An optimal infrastructure for the near future will mostly depend on the number of LNG driven vessels. However, three up to four bunker stations at strategic locations along the Rhine may be necessary to convince ship owners at the moment to invest in LNG driven vessels. All the relevant stakeholders should cooperate at these initial stages in creating a minimum supply of LNG. It will also be wisely to co-use a lot of the LNG infrastructure with not-shipping related industries. The co-use of it would be an appropriate way for mitigating risk and creating a downward pressure on the distribution costs of LNG. As a result it will be more feasible to invest in the small scale infrastructure.

Both public and private market parities will be responsible for investments in the LNG infrastructure in financial and non-financial ways. The authorities will mainly play a role with regard to the regulations. However, financial support provided by the government and the EU could be necessary in initial stages. But at the end oil and gas companies like Shell and Argos will be mainly responsible for the roll-out of the infrastructure, while they will be the operators of the LNG bunkering facilities and will make profit out of it. In these initial stages of the infrastructure roll-out most stakeholders will reinforce each other, which is necessary for an efficient roll-out.

Looking at ship owners and shippers, it appeared that ship owners experience the switch to LNG in a moderately positive way and shippers in a very positive way. The reason for the moderate attitude of ship owners is mainly caused by the current bottlenecks in the market. Shippers definitely value the use of LNG as an alternative fuel, while it contributes to a more sustainable transport modality. However, most of the shippers are not prepared to pay a premium for it. Perhaps some of the relatively larger corporations, due to their corporate social responsibility. There are also costs related to switching. Switching to an LNG installation or alternative (sustainable) shipping company, could lead to certain switching costs. These costs could have a discouraging effect in some cases, making switching difficult. On the other hand, demand for a sustainable society and thus sustainable transportation is on the rise. This pushes parties towards more sustainable transportation, making switching necessary in some cases.

In short, it appeared that the competitive position of IWT, from an environmental friendly point of perspective, is being contested by other transport modes. Secondly, the IWT sector and the transport sector in general are looking for alternative fuels. LNG is currently the most promising alternative fuel for IWT. A major bottleneck however, is the missing LNG infrastructure in the port of Rotterdam and the waterways. The port of Rotterdam is an attractive port to invest in the LNG infrastructure, there is a significant presence of bunkering activities and a presence of large scale LNG infrastructure. This leads to more transparency in the market and makes the port of Rotterdam attractive to invest in. The imported LNG in the port of Rotterdam can also be exported to other areas and ports where LNG terminals are missing, transforming the port into a hub in the region. The LNG infrastructure in the port of Rotterdam is not enough, investments in other areas is also necessary. The European Commission favours the use of LNG as alternative fuel and has the ambition to install a bunker station in every TEN-T connected port. It is expectable that investments will follow in other areas too. For the Port of Rotterdam Authority and the government it will be important to develop a complete LNG infrastructure, while it will contribute to their objective of creating a sustainable port and transport mode. LNG is perhaps not very environmental friendly, but it will open up the way for Bio-LNG which is much cleaner. Even more important is the fact that there is a positive business case. This makes investing in the LNG infrastructure en LNG driven vessels attractive for the private sector. The main question in this thesis was: *''To what extent should the port of Rotterdam and other relevant stakeholders invest in the LNG logistics chain for inland waterway transportation, in the ambition of transforming Rotterdam into a LNG hub.''*

I think that despite the bottlenecks the market for LNG will continue to develop. The negative factors are significant, but I think that the positive factors will outweigh the negative ones. The port of Rotterdam has a favourable position for a complete LNG infrastructure. All involved parties should closely cooperate with each other to realise an efficient roll-out of the LNG-infrastructure in the port of Rotterdam. This infrastructure should also not be dedicated to the IWT only, the co-use of it with not-shipping related industries can reduce the risks and costs.

The chapter about cost and benefits was rather limited, due to the limited information I possessed. For further research It is recommended to make use of more detailed information regarding the cost and benefits of LNG driven vessels and LNG infrastructure. Economic details will make it very clear whether LNG is an attractive option for certain ship owners and investors in the infrastructure.

In my thesis I wrote that the infrastructure should not be dedicated to IWT only. However, the explanation for it was rather short and a more extensive analysis is favourable for further research.

Appendix

FIGURE 1:

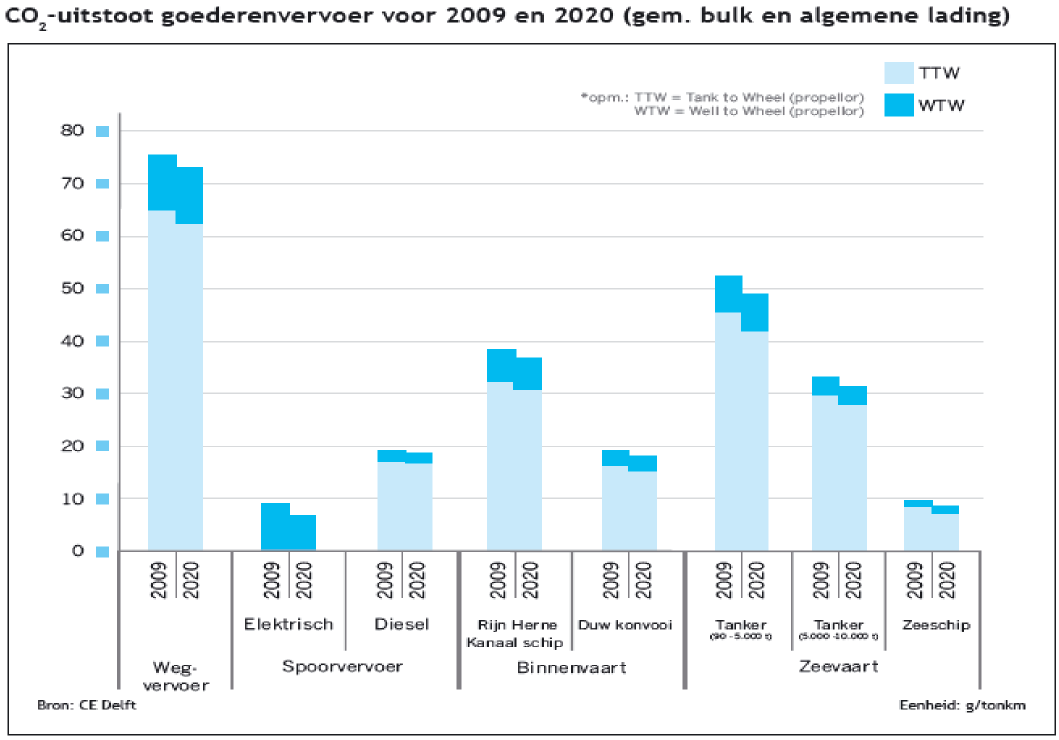


FIGURE 2

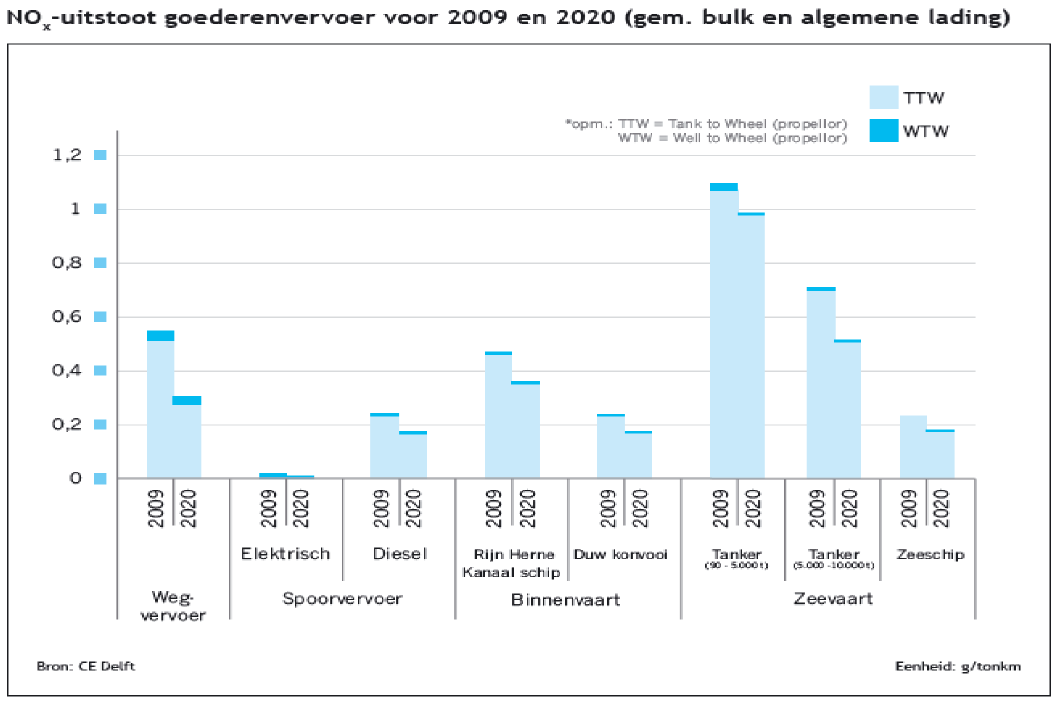


FIGURE3

SO_2-uitstoot goederenvervoer voor 2009 en 2020 (gem. bulk en algemene lading)

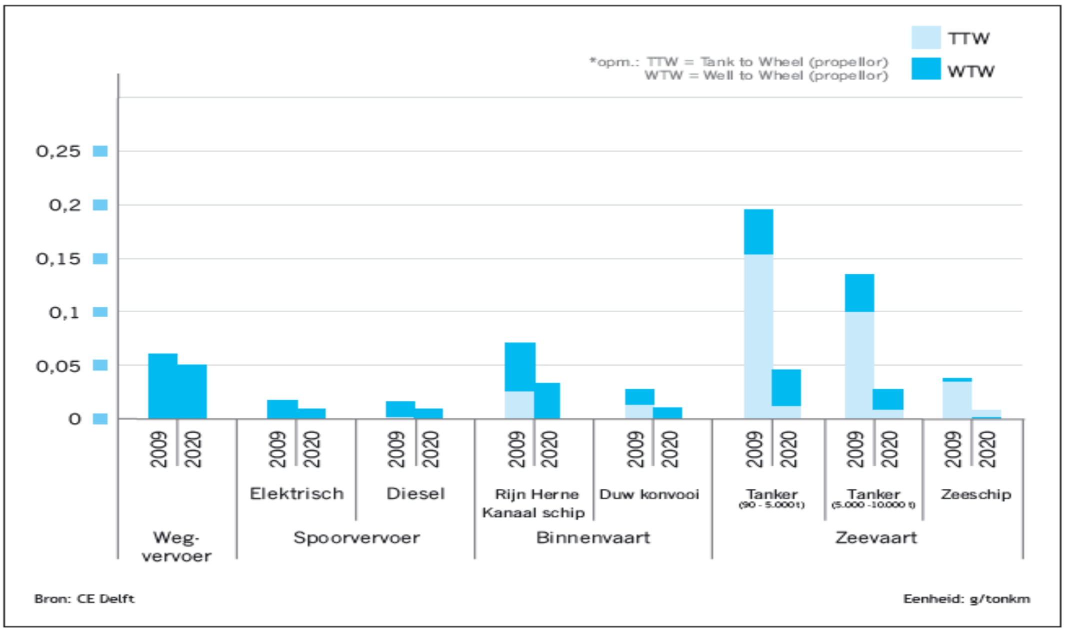


FIGURE4

$PM_{2,5}$-uitstoot goederenvervoer voor 2009 en 2020 (gem. bulk en algemene lading)

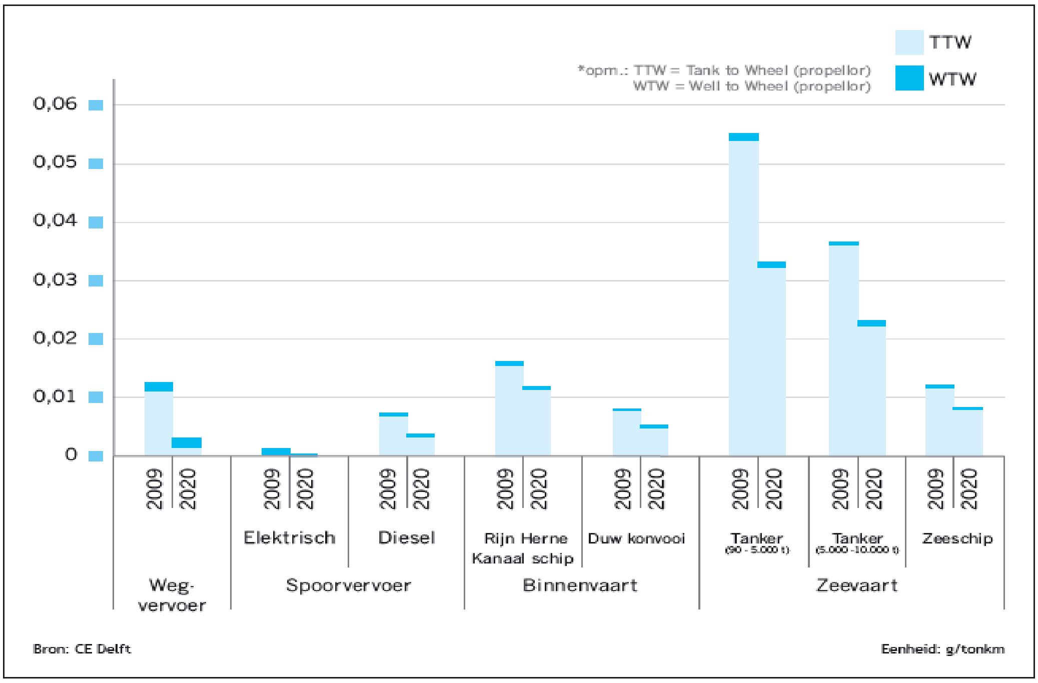


FIGURE 5

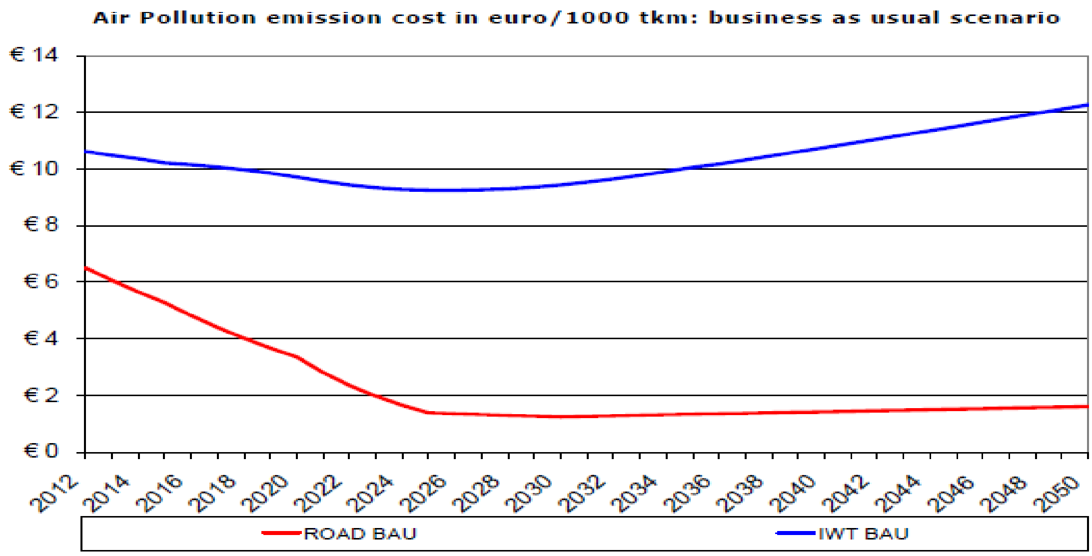


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FIGURE 6

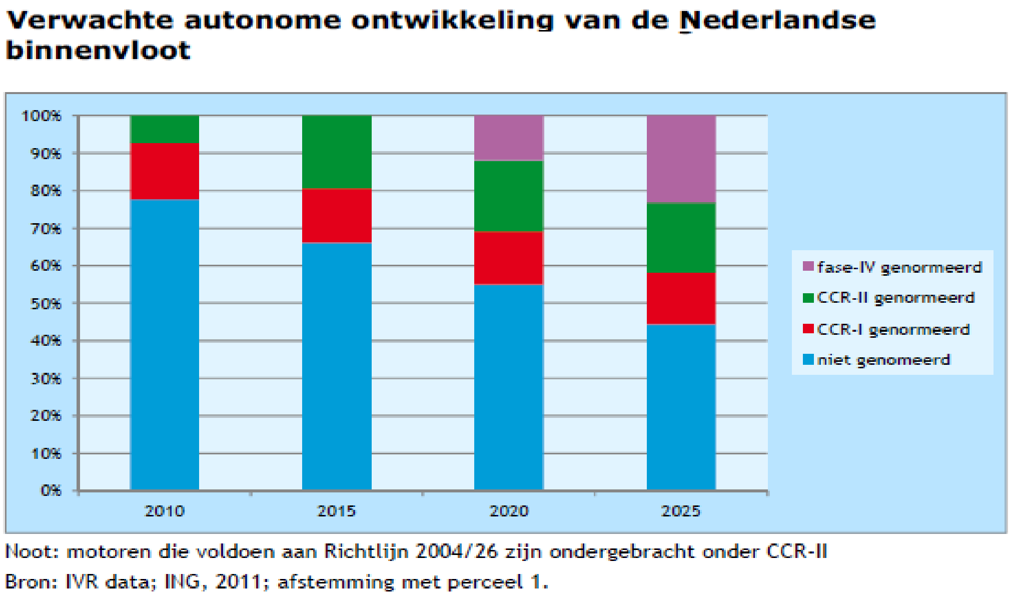

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FIGURE 7

Overview - the spring 2014 forecast

	Real GDP				Inflation				Unemployment rate			
		Spring 2014 forecast				Spring 2014 forecast				Spring 2014 forecast		
	2012	2013	2014	2015	2012	2013	2014	2015	2012	2013	2014	2015
Belgium	-0.1	0.2	1.4	1.6	2.6	1.2	0.9	1.3	7.6	8.4	8.5	8.2
Germany	0.7	0.4	1.8	2.0	2.1	1.6	1.1	1.4	5.5	5.3	5.1	5.1
Estonia	3.9	0.8	1.9	3.0	4.2	3.2	1.5	3.0	10.0	8.6	8.1	7.5
Ireland	0.2	-0.3	1.7	3.0	1.9	0.5	0.6	1.1	14.7	13.1	11.4	10.2
Greece	-7.0	-3.9	0.6	2.9	1.0	-0.9	-0.8	0.3	24.3	27.3	26.0	24.0
Spain	-1.6	-1.2	1.1	2.1	2.4	1.5	0.1	0.8	25.0	26.4	25.5	24.0
France	0.0	0.2	1.0	1.5	2.2	1.0	1.0	1.1	9.8	10.3	10.4	10.2
Italy	-2.4	-1.9	0.6	1.2	3.3	1.3	0.7	1.2	10.7	12.2	12.8	12.5
Cyprus	-2.4	-5.4	-4.8	0.9	3.1	0.4	0.4	1.4	11.9	15.9	19.2	18.4
Latvia	5.2	4.1	3.8	4.1	2.3	0.0	1.2	2.5	15.0	11.9	10.7	9.6
Luxembourg	-0.2	2.1	2.6	2.7	2.9	1.7	1.4	2.4	5.1	5.8	5.7	5.5
Malta	0.6	2.4	2.3	2.3	3.2	1.0	1.2	1.9	6.4	6.5	6.5	6.5
Netherlands	-1.2	-0.8	1.2	1.4	2.8	2.6	0.7	0.9	5.3	6.7	7.4	7.3
Austria	0.9	0.4	1.6	1.8	2.6	2.1	1.6	1.7	4.3	4.9	4.8	4.7
Portugal	-3.2	-1.4	1.2	1.5	2.8	0.4	0.4	1.1	15.9	16.5	15.4	14.8
Slovenia	-2.5	-1.1	0.8	1.4	2.8	1.9	0.7	1.2	8.9	10.1	10.1	9.8
Slovakia	1.8	0.9	2.2	3.1	3.7	1.5	0.4	1.6	14.0	14.2	13.6	12.9
Finland	-1.0	-1.4	0.2	1.0	3.2	2.2	1.4	1.4	7.7	8.2	8.5	8.4
Euro area	**-0.7**	**-0.4**	**1.2**	**1.7**	**2.5**	**1.3**	**0.8**	**1.2**	**11.3**	**12.0**	**11.8**	**11.4**
Bulgaria	0.6	0.9	1.7	2.0	2.4	0.4	-0.8	1.2	12.3	13.0	12.8	12.5
Czech Republic	-1.0	-0.9	2.0	2.4	3.5	1.4	0.8	1.8	7.0	7.0	6.7	6.6
Denmark	-0.4	0.4	1.5	1.9	2.4	0.5	1.0	1.6	7.5	7.0	6.8	6.6
Croatia	-1.9	-1.0	-0.6	0.7	3.4	2.3	0.8	1.2	15.9	17.2	18.0	18.0
Lithuania	3.7	3.3	3.3	3.7	3.2	1.2	1.0	1.8	13.4	11.8	10.6	9.7
Hungary	-1.7	1.1	2.3	2.1	5.7	1.7	1.0	2.8	10.9	10.2	9.0	8.9
Poland	2.0	1.6	3.2	3.4	3.7	0.8	1.1	1.9	10.1	10.3	9.9	9.5
Romania	0.6	3.5	2.5	2.6	3.4	3.2	2.5	3.3	7.0	7.3	7.2	7.1
Sweden	0.9	1.5	2.8	3.0	0.9	0.4	0.5	1.5	8.0	8.0	7.6	7.2
United Kingdom	0.3	1.7	2.7	2.5	2.8	2.6	1.9	2.0	7.9	7.5	6.6	6.3
EU	**-0.4**	**0.1**	**1.6**	**2.0**	**2.6**	**1.5**	**1.0**	**1.5**	**10.4**	**10.8**	**10.5**	**10.1**
USA	2.8	1.9	2.8	3.2	2.1	1.5	1.7	1.9	8.1	7.4	6.4	5.9
Japan	1.4	1.5	1.5	1.3	0.0	0.4	2.5	1.6	4.3	4.0	3.8	3.8
China	7.7	7.7	7.2	7.0	2.6	2.6	2.4	2.4	:	:	:	:
World	**3.2**	**2.9**	**3.5**	**3.8**	:	:	:	:	:	:	:	:

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