Sustainable, safe and economically feasible energy concepts and technologies for European Inland Shipping

D 1.3 Analysis of barriers and facilitating factors for innovation uptake

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Abstract

This report presents the findings of sub work package 1.3 of the PROMINENT project. Barriers and facilitating factors to innovation uptake are assessed for each of the technologies that were selected in SWP 1.2. The assessment is based on desk research of recent IWT literature and the expert knowledge of the PROMINENT consortium.

A total of six categories of generic barriers to innovation uptake are identified in the innovation literature, namely technical, legal, financial, knowledge, market, and cultural barriers. These barriers are defined and a brief explanation is provided on why these barriers are relevant to consider for IWT technology uptake.

Consequently, the barrier categories are specified for each of the selected technologies. Differences between fleet families and operational profiles are discussed where relevant. In addition, the level (severity) of the barrier was assessed and quantified using the expert knowledge within the PROMINENT consortium. This quantitative assessment facilitates the comparison of technologies and indicates the feasibility of each technology per fleet family.

This report generally concludes that LNG, Dual fuel, Stage V engines, and hybrid-propulsion with buffer battery are technologies confronted by the highest barriers. The technologies that currently experience the lowest barriers are GTL fuel, right sizing, CCNR II engines, and SCR technologies (See table below). Substantial differences between fleet families can however occur and should be acknowledged.

	Fleet family / Technology	Passenger Vessels	Push boats <500 kW	Push boats 500-2000 kW	Push boats >2000 kW	Motor vessel dry >110m	Motor vessel liq. >110m	Motor vessel Dry 80-109m	Motor vessel liq. 80-109m	Motor vessel Dry <80m	Coupled Convoys
1	LNG	3,8	5,0	5,0	5,0	3,3	3,3	3,7	3,7	4,0	3,2
2	Dual fuel	3,5	5,0	5,0	5,0	2,7	2,7	3,5	3,5	3,8	2,7
3	GTL fuel	1,8	1,8	1,8	1,8	1,8	1,8	1,8	1,8	1,8	1,8
4	Right sizing	1,7	1,7	1,7	1,7	1,7	1,7	1,7	1,7	1,7	1,7
5	CCNR II engine	1,8	1,8	1,8	1,8	1,7	1,7	1,8	1,8	1,8	1,7
6	Stage V engine	3,2	3,2	3,2	3,2	3,0	3,0	3,2	3,2	3,2	3,0
7	Hybrid prop -	2,2	2,2	2,2	2,2	2,2	2,2	2,2	2,2	2,2	2,2
8	Hybrid prop +	2,5	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0
9	SCR	1,8	2,2	2,2	2,2	2,2	2,2	2,2	2,2	2,2	2,2
10	Wall flow DPF	2,0	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3
11	SCR and DPF	2,0	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3
12	Fairway data	2,8	3,0	3,0	3,0	2,8	2,8	2,8	2,8	2,8	3,0
13	Speed adaption	2,8	2,8	2,7	2,7	2,7	2,8	2,8	2,8	2,8	2,7
14	Optimised track	2,8	2,8	2,7	2,7	2,7	2,8	2,8	2,8	2,8	2,7

Table 1 Average height of barriers per fleet family *Five-point scale: 1. Very low / 2. Low / 3. Medium / 4. High / 5. Very high*

PROMINENT project aims to remove implementation barriers, and as part of the analysis of barriers, case evidence is provided on the innovation uptake in other (transport) sectors. The examples inform us on how several of the identified barriers were successfully targeted in these sectors. This report provides insights into the barriers and facilitating factors to innovation uptake, which will be used by the PROMINENT consortium partners who conduct pilot projects on selected technologies. Also, the findings of this report will contribute to WP6, where supporting mechanisms are defined and the roll-out plan is prepared.

Inhoud

1. Background and position in the project

Background
This report was prepared within the framework of the EU co-funded research and development project PROMINENT. PROMINENT ultimately aims at providing solutions which make inland navigation as competitive as road transport in terms of air pollutant emissions by 2020 and beyond. In parallel, PROMINENT aims to further decrease the energy consumption and carbon footprint of inland waterway transport (IWT), an area where IWT already has a strong advantage compared to road transport. PROMINENT aims at producing visible and physical results already during its project lifetime as well as on larger scale no later than 2020.

This report is the third and final deliverable of Work Package (WP) 1. The outcome of WP1 provides knowledge base and gives direction for the further work in the PROMINENT project. SWP 1.1 provided an analysis of the European Inland Waterway Transport (IWT) fleet. Ten fleet families were identified and the composition of the European inland fleet was analysed, as shown in Table 2.1.1. The analysis is instrumental to determining which fleet families should be targeted to achieve the PROMINENT targets.

Fleet families identified in PROMINENT	Total number of operational vessels in Europe	Operating fleet for Rhine and other waterways	Operating fleet for Danube countries
Passenger vessels (hotel/cruise vessels)	2.553	2.357	196
Push boats <500 kW (total engine power)	890	798	92
Push boats 500-2000 kW (total engine power)	520	332	188
Push boats ≥2000 kW (total engine power)	36	25	11
Motor vessels dry cargo ≥110m length	610	580	30
Motor vessels liquid cargo ≥110m length	602	599	3
Motor vessels dry cargo 80-109m length	1.802	1.713	89
Motor vessels liquid cargo 80-109m length	647	631	16
Motor vessels <80 m. length	4.463	4.285	178
Coupled convoy	140	140	n/a
Total	12.263	11.460	803

Table 2.1.1 Main fleet families of the European inland fleet for 2013/2014

SWP 1.2 investigated both state-of-the-art and promising greening technologies for inland waterway vessels. Based on five criteria, a long-list of technologies was narrowed down to 14 best available technologies. These technologies are deemed to have the greatest emission reduction potential, are applicable to a substantial share of the European inland fleet, have economic potential and are sufficiently mature in both technical and non-technical terms. Table 2.1.2 provides an overview of this analysis. On top of a comprehensive account on the greening potential of each technology, a first attempt was made to identify the barriers (non-technical maturity).

Area	Technology	Applicability on the fleet	Economic feasibility	Technical maturity	Non-tech maturity
Fuels	Use LNG	10 - 50%	++	6	---
	Apply dual fuel	10 - 50%	++	6	--
	Apply GTL fuel	> 50%	-	9	0
Propulsion system	Right sizing	100%	++	9	0
	Exchange to CCRN II	> 50%	0/-	9	0
	Exchange to Stage V	> 50%	-	5	--
	Diesel-hybrid prop. (-)	10 - 50%	+	7	0
	Diesel-hybrid prop. (+)	10 - 50%	+	9	0
	Apply SCR	10 - 50%	--	8	-
	Wall flow DPF	10 - 50%	---	7	-
	Combine SCR and DPF	10 - 50%	---	7	-
Waterway info	Real time fairway data	>50%	+	5/7	-
Sailing behaviour	Speed adaption	>50%	+	5	-
	Optimised track choice	>50%	+	5	-

Table 2.1.2 Overview of best available technology key characteristics (SWP 1.2)

Position in the project

This report builds on the findings of SWP 1.1 and 1.2 and elaborates further on the barriers towards innovation uptake. Based on an assessment of innovation literature, six barrier categories to innovation uptake are identified, namely technical, legal, financial, knowledge, market and cultural barriers. Based on desk research and the expertise of the PROMINENT consortium these barriers are thoroughly assessed for each of the 14 selected technologies. As part of the barrier analysis the relevance and importance of barriers are identified vis-à-vis each fleet family. In addition, case evidence on innovation uptake in other (transport) sectors is provided to derive relevant parallels and potential strategies to overcome barriers. The identified barriers and facilitating factors will be used as a basis for WP6, where the supporting mechanisms needed for eliminating the barriers are defined and the roll-out plan is prepared.

2. Methodology

This chapter provides the methodological background of the study and discusses six main barrier types for the uptake of greening technologies by the European IWT sector. After the barriers are defined, the literature is reviewed to explain why these barriers are important to analyse vis-à-vis the selected technologies.

2.1 Methodological background

SWP 1.2 of PROMINENT researched the best available technologies and concepts to raise energy efficiency and lower emissions in European inland navigation, resulting in a list of best available greening technologies and concepts. The assessment was based on an analysis of technologies, integrating expert knowledge, knowledge found in the consortium and input from key stakeholders. The best available technologies have been selected and assessed in terms of their:

- Effects on energy consumption and emissions;
- economic feasibility;
- technical feasibility;
- technological maturity (Technology Readiness Level 5 +); and
- non-technological maturity.

SWP1.2 also continued on the results of SWP 1.1, which identified the main European fleet families, and evaluates the technologies regarding their effects on those fleet families by means of "Technology Fact Sheets".

With the output of SWP 1.2 in mind, this study provides a more granulated analysis on the barriers and facilitating factor to technology uptake. To this end, desk research was undertaken to map the current literature on the barriers for the uptake of the 14 technologies. A list of literature references consulted is given in Annex I.

For each of the promising greening technologies the barrier height was assessed. Differences across the fleet families were highlighted too. The desk research informed an overall table on relevant barriers per technology (See Annex II) and an assessment of barrier heights per fleet family (See Annex III). These tables were discussed by PROMINENT experts who are involved in WP1, and was validated during a workshop. The outcomes of the desk research and expert panel are further discussed in the third chapter of this report. In chapter 4, an overview of facilitating factors identified, building on actions taken in the IWT sector itself as well as in other relevant sectors.

2.2 Description of six main barriers

The barriers for uptake of greening technologies are mainly characterised by their technical, legal and financial facets. Moreover, three additional generic barriers were identified. These are related to knowledge, market and cultural aspects. This division in six barrier types aligns with previous research for the Dutch Ministry of Infrastructure & Environment (IDVV, concluded in 2013) and the POLFREE study (Bastein, Kroes et al., 2014). An overview of these six barrier types is given in the table below.

Barrier type	Definition	Example
Technical	Barriers caused by immaturity of technology or operational requirements	Space requirements reduce payload substantially
Legal	Barriers caused by regulations and laws	Safety regulations concerning LNG bunkering
Financial	Barriers caused by access to capital or business case	Reluctance of banks to finance measures with low ROI
Knowledge	Barriers caused by a lack of expertise or skills	New navigation system requires new procedures to be learned
Market	Barriers caused by market conditions, infrastructure, and the supply chain	Ports do not allow ships with new technology to berth
Cultural	Barriers caused by behavioural routines	Reluctance amongst ship owners to consider new technology

Table 2.2 Overview of six barrier types

In the upcoming sections, references are made to the recent IWT literature that explain why these barriers should be considered to understand innovation uptake. The purpose of these brief discussions is to highlight the relevance of each barrier type, after which we specify the discussion in Chapter 3.

2.3.1 Technical barriers

SWP 1.2 selected technologies based on their technology readiness level (TRL) and excluded technologies that are not sufficiently developed to validate in a relevant environment. Several of the selected technologies are technically mature, and are close to market introduction. Many, e.g. GTL and right sizing, are even common technologies available *off the shelf*. Still, the market penetration of most of the 14 technologies selected in SWP1.2 is limited. One technical reason for this slow uptake of new technologies is found in the relatively long life span of both vessel hulls and IWT engines. Due to life spans of 30+ years, the technical urgency to replace currently used engines is low. (KiM, 2015)

Technical barriers for the uptake of certain greening technologies in the transport sector are found at the (i) technological, (ii) infrastructural and (iii) raw material level (Browne et al., 2012).

(i) Technical barriers can also relate to market barriers (section 2.3.5). Sometimes it is questionable whether a technology researched at R&D centres or Universities will ever become commercially feasible. Usually technologies need to evolve from prototypes into mass-scale production to become more competitive. This is the market aspect. Vice versa innovative technologies need to mature before the market will consider them.

(ii) The second aspect, of infrastructural barriers, is linked to specific greening technologies.

- Some ‘greening’ innovations, e.g. slow steaming, do not require specific infrastructure outside of the vessel.
- Others, e.g. LNG and CNG fuels, do require investments in for example a modified fuel bunkering supply chain. The production of fuel needs to be linked to the vessels via strategically located bunkering stations, preferably via a strategically designed geographic spread and a dense network (Ruester and Neumann, 2008). Gaseous fuels can be supplied via dedicated pipelines while liquefied hydrogen or LNG needs to be transported in tanks using ships, rail or trucking.
- Some technologies call for intermediate solutions, e.g. bio fuels. The bio fuels can be blended into the current fuel supply, limiting supply chain investments (in bunkering facilities or in the transport chain). GTL fuels can be used in current engines but need a different fuel supply chain. These innovations can be regarded as ‘technology compatible’ with current vessels and current fuel networks.

The use of LNG can also affect the vessel’s market competitiveness. As the technologies require not only a different fuel supply chain but also more in-vessel storage capacity (gaseous fuels require a more voluminous fuel storage), the commercial loading capacity of converted vessels is reduced, directly decreasing the vessel’s maximum payload.

The use of bio fuels can also cause undesired secondary effects, for the vessel operator and for society. The use of bio fuels sometimes causes a decrease in engine performance. The use of bio fuels can lead to lower engine temperatures, engine coking and increased tank sedimentation (Agarwal, 2007).

(iii) A third constraint on a technological level relates to the availability of raw material. This aspect is certainly of relevance for the provision of batteries for electric or hybrid propulsion. The long term availability of source materials, like platinum, needed for fuelling electric engines is uncertain (Tonn, Das et al., 2003; Browne et al., 2012). Indirect effects of bio fuel production could become a limiting factor for increasing its production volumes (Gallagher, 2008) Still, these aspects are of less importance for the market uptake of greening technologies, certainly in the short term.

2.3.2 Legal barriers

The second barrier type, legal barriers, is related to the institutional setting characterised by regulations, laws and operational requirements hindering or not facilitating a smooth uptake of certain technologies or solutions. The legal barriers could be vessel type specific, fuel specific (LNG, CNG, GTL or H2 for example), or operational (CCR RVIR prohibits the use of fuel with a flashpoint below 55°C) and can be valid at EU Member state level, at the EU level, or can be locally defined. (Bastein, Koers et al., 2014; DNV GL, 2015; Panteia, 2013) Additionally, the Central Commission for the Navigation of the Rhine (CCNR) and the Danube Commission exert influence on the legal framework concerning inland navigation, notably through the Mannheim Act (1868) and the Belgrade Convention (1948).

IWT regulations influence a range of topics such as safety, planning, and social matters. Several IWT stakeholders have voiced concerns that current regulations are outdated, as they were based on technology applied historically and have not adapted to recent IWT innovations. Another topic of concern is that the international character of IWT may act as a barrier to achieving legislative harmonisation as it requires a coordinated effort of several legislative authorities. Due to the fragmented nature of IWT it also occurs that different standards apply which can harm technology uptake. For example, the certification of environmental performance is performed by different standardization bodies, leading to higher costs for vessel owners. In this context is it noted that treaties like Mannheim have a legal status superior to National, Regional and European rules and legislation. A process of adapting these legal frameworks to facilitate the uptake of fuels like LNG is in progress.

2.3.3 Financial barriers

Financial barriers mainly relate to:

- The level of investment costs concerned
- The commercial feasibility of the investment from an investor perspective, i.e. whether or not the investment can be earned back within a reasonable time frame.

A number of new fuel technologies require considerable upfront investments by ship owners. Investments can then result in lower fuel consumption, allowing the investor to gain back the invested capital. However, the IWT market is overall characterised by a large share of SME's, owning and sailing their single vessels and having limited investment capacity. These smaller companies usually do not have funds at hand for e.g. overhauling engines, changing fuels or experimenting with innovations. (Van Bree and Colon, 2014) While the Danube is navigated mostly by SMEs and larger companies, they also experience several financial barriers. These barriers follow partially from the recent global recession, which resulted in the burning of own capital amongst vessel owners. Particularly the Danube fleet seems to be strongly affected. While the market situation has been steadily improving, the limited own capital and lack of collateral still limits the IWT sector to access external commercial financing. As a consequence, vessel owners are inclined to focus on the short term survival of their business, and high capital investments are either out of scope or delayed. Furthermore, financial institutions on the other hand are cautious and do not easily lend investment capital, while the majority of vessel owners have inadequate own resources.

As a result, green technologies, even though they could lower operating costs, are not widely implemented due to the financial limitations of the ship owners. Some technologies requiring investments from the vessel owner do not even provide savings in operating costs to them at all (e.g. the use of GTL fuel rather increases the fuel costs). Although being greener (reducing emissions), the ship owner does not benefit directly from the investment (CE Delft, 2010). The limited or absent direct cost savings might be balanced by authorities through offering lower port dues, easier or priority access to quays or by shippers through a willingness to pay higher prices for more sustainable transport. Still, the direct cost/benefit ratio for the vessel owners will limit enthusiasm to invest in these specific greening technologies.

Other limitations are also encountered. New fuel tanks can decrease the payload of vessels, as mentioned under technical barriers, resulting in lower freight revenues per trip. Especially for smaller vessels, this element is not to be overlooked (Panteia, 2013 and CE Delft, 2011).

Knowing that an (uncertain) share of the greening technologies are technically but also from a direct financial viewpoint beneficial for the vessel owners (e.g. lower fuel consumption or covering the depreciation costs), still those technologies have been implemented only on a minor share of the fleet. Consequently, there must be other reasons for the currently limited market uptake (CE Delft, 2011; IDVV, 2013). These barriers concern knowledge, market and cultural barriers.

2.3.4 Knowledge barriers

Generally, knowledge gaps relate to the innovative aspect of a majority of the greening technologies. Knowledge on the costs and benefits is mainly concentrated with the engineering companies and the science community developing these innovative approaches. It is difficult to find pioneering vessel owners. In many cases, the skipper/vessel owner is mainly focused on running its day-to-day activities and does not closely follow all innovative developments ongoing. Therefore, innovations need to be promoted to the end-users. This leads to the determination that knowledge sharing should receive as much attention as the R&D phase. The skipper/vessel owners are one of the stakeholders running behind in terms of information at hand on R&D developments.

The main limitation for uptake is the uncertainty inherently linked to new innovations. The information on emission savings, shown upfront of market uptake, is not always reliable, or impacts are questionable (e.g. business cases reasoned from for example fuel price hypothesises, may not be realistic any more in the present market situation). (CE Delft, 2011)

Finally, the legislation is rather slowly catching up with market setting. There is a technological and institutional lock-in to existing fuels or technologies (Browne et al, 2012). Due to the delayed transfer of knowledge, outdated rules and regulations could become a barrier for uptake of innovations (E.g. newer fuels are not yet regarded in regulations). So, also there, knowledge sharing is needed. (Panteia, 2013)

2.3.5 Market barriers

Another general barrier relates to the economic organisation of the IWT sector. The transport sector in general is highly (price) competitive. Therefore, freight rates are low and uni- and multimodal competition is fierce. Moreover, the market hardly shows willingness to pay higher freight rates for 'greener' transport. Sustainability is less of an argument for choosing an operator, than price. Moreover, only a few economic incentives for greening measures exist (only some technologies have an earn-back potential). On the positive side, subsidies are sometimes given to support the use of green technologies.

The current market, characterised by a gradual recovery after a crisis with plummeting tariffs and tonnages, is still confronted with an overcapacity. This overcapacity results in less sailing hours, or lower capacity utilisation per transport unit. This results in increasing pay back times when fuel oriented greening approaches are regarded. (Van Bree & Colon, 2014) Moreover, costs and benefits of certain changes are not always equally levelled among stakeholders (Bastein, Kroes et al., 2014; KiM, 2015).

Research also confirmed that firm size is one of the factors influencing companies' propensity and capacity to invest in R&D. The adverse effect is clearly seen in the transport sector. Especially for industries with lower demand (IWT vessels and locomotives for example) the opportunities to recover investments in innovations are low. The freight transport firms moreover are confronted with demand for cheap and reliable services, rather than sustainable services. The transport service providers invested in 2011 only 0.3% of their turnover in R&D. The transport service providers were the only submarket of the transport sector not increasing R&D investments during the years of economic downturn. (Wiesenthal et al., 2015).

The market barrier is also seen in the development, production and commercialisation of technologies. Innovative technologies require considerable investments in R&D. These expenses, made by the manufacturers, need to be recovered by selling the technologies. As the inland shipping market is rather small, e.g. in comparison with the number of vehicles in the trucking sector, it is very difficult for innovators and manufacturers to regain their original R&D investment. Moreover, the market structure with its limited number of suppliers is acknowledged by a low level of competition. The small market and low level of competition could lead to increasing prices and decreasing investments in innovations for inland waterway vessels.

2.3.6 Cultural barriers

The final set of barriers are found in the cultural facets of the transport sector. It can be observed that the transport industry is in general slow in implementing changes in their day-to-day business. Certainly, own-account innovations are limited. So is the uptake of process or technological changes. This more than average conservative behaviour is slowing down market uptake of technologies.

The opinion of the general public is also a factor affecting the uptake of new technologies. For example the planning and building of fuel stations, especially for supplying LNG and CNG, is regarded by local policy makers and inhabitants living closely to such a stations as a high risk. (Paltrineiri et al., 2009; Panteia, 2013) Bunkering CNG and LNG fuels also requires some knowledge on the procedures and risks. (DNV GL, 2015; Panteia, 2013) The different procedures can result in reluctance from end users. Such positions can be overcome by increasing knowledge and awareness.

3 Barrier analysis of selected greening technologies

The intensity (severity) of each of the six barrier types vis-à-vis each of the 14 selected technologies is depicted in the matrix hereafter. The colour codes indicate the level of the barrier (the darker the shading, the more important the barriers is for the specific technology), which is based on the literature review and validated in an expert workshop.

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				Barriers					
			TRL	Technical	Legal	Financial	Knowledge	Market	Culture
Ship-related technical measures	Fuels, standardised solutions	Use LNG (Liquefied Natural Gas) - single fuel/ spark ignition	6						
		Apply dual fuel (LNG and diesel)	6						
		Apply GTL fuel	9						
	Propulsion system, standardised solutions	Right sizing	9						
		Exchange of main diesel engine (CCR I by CCR II engine)	9						
		Exchange of main diesel engine (by Stage V engine)	5						
		Diesel-hybrid propulsion (no buffer batt.)	9						
		Diesel-hybrid propulsion (+ buffer batt.)	7						
	Auxiliary systems	Apply SCR (selective catalytic reduction)	8						
		Wall flow DPF	7						
		Combine SCR and DPF	7						
Infrastructure	Waterway Information	Real time info on fairw. data (link to energy.eff.nav.)	5/7						
Ship-operational measures	Sailing behaviour	Smart and energy-eff.nav. (speed adaption)	5						
		Smart and energy-eff.nav. (optimised track choice)	5						

An elaborated table is included in Annex II, where in every cell more information on the barrier is given.

This chapter specifies for each of the selected technologies which barriers apply. If relevant, differences between fleet families and operational profiles are discussed. Each paragraph starts with a general summary per technology area (fuels, propulsion systems, waterway information and sailing behaviour), followed by a discussion on the barriers per technology. Consequently, a quantitative assessment and ranking of barrier height is provided to facilitate the comparison of technologies and to indicate the applicability of each technology per fleet family. The results of the fleet family assessment are given in section 3.5.

3.1 Fuels

The use of other fuels than diesel is a promising approach for IWT to become greener. The technologies are established in other markets, rapidly develop in the IWT sector and have proven in practice to significantly reduce local air pollution. The barriers are numerous though. The fluctuating diesel prices (in particular the narrowing price gap with LNG) and the reluctance of several IWT stakeholders (e.g. ports, bunkering, ship owners) limits market uptake. For LNG fuel technologies international legislation may pose limitations and it limits the development of a supportive fiscal policy. At the same time there are ports that establish environmental zones, acting as an incentive to the uptake of these alternative fuels. The non-technological maturity regarding for example legal, financial, knowledge and cultural aspects limits investments (e.g. port bye-laws are strict on LNG bunkering, safe passing etc.). While the comparative advantage of LNG over diesel is widely acknowledged, the long term barrier for LNG remains its limited effect on greenhouse gasses and especially the (concerns over) methane slip.
GTL on the other hand has several advantages over LNG, but the uptake is hindered by the price premium over diesel, as well as the limited knowledge and awareness of this technology.

3.1.1 LNG and dual fuel

Within the TEN-T project LNG Masterplan for Rhine-Main-Danube, an “LNG Implementation Strategy & Recommendations” is being developed, the so-called Masterplan document that describes five main themes, listing barriers and the necessary actions and measures to overcome those. The five themes are:

1. LNG Governance & Legislation
2. Markets & Financing
3. Jobs & Skills
4. Vessels & Equipment
5. LNG Infrastructure

The below description builds on the Masterplan document´s draft technical content.

Several vessels with LNG and dual fuel engines are currently operational on the Rhine. Though the technology can be developed further, it is already possible to exchange main diesel engines for either an LNG or dual fuel engine. However, some technical barriers apply. One element is that push boats cannot be retrofitted with LNG engines due to the impact on the ship’s stability, so that the technology is only relevant for purposefully constructed LNG push boats. This limitation does not apply to motor vessels, which can in principle be retrofitted with LNG engines. For motor vessels the applicability is determined by the amount of space that the LNG tank requires. The spatial requirements decrease the vessel’s payload considerably, therefore rendering the technology unattractive for smaller ships. A final technical barrier is the absence of a standard for bunkering facilities and LNG fuel quality. LNG vessels can therefore encounter difficulties when refuelling at different locations across Europe. It should however be noted that standardization works in this field are ongoing in the respective bodies, and progress is expected by 2020.

When discussing standardisation issues the legal barriers for LNG uptake should be considered. Both the Rhine Vessel Inspection Regulation (RVIR) and Directive 2006/87/EC are under review to regulate LNG as a fuel for inland waterway vessels. For the time being, the Central Commission for Navigation on the Rhine (CCNR) provides exemptions for LNG operated ships to sail on the Rhine.

Despite the support for LNG uptake by the CCNR and the European Commission, the exemption system does not sufficiently accommodate the uptake of LNG. A legal framework is however expected by 2020, allowing LNG vessels as a rule, rather than an exemption. This framework also should foster the standardization of bunkering facilities and fuel quality, leading to lower technical barriers.
As it stands, the cost of installing an LNG or dual fuel engine starts at approximately 1 mil EUR, depending on the size of the ship/the engine capacity concerned. Importantly, if the final version of the updated NRMM Directive mandates after-treatment installations for LNG engines, an additional EUR 200-300k should be added, which would strongly impact the business case for LNG. Limited capital reserves in the IWT sector and the reluctance of the financial sector to provide large loans for engine retrofitting inhibit the uptake of LNG. Fluctuating diesel prices and the high logistics costs to deliver the fuel to the vessel cause moreover that the comparative price advantage of LNG over diesel cannot be assumed. From various case studies it is found that LNG needs to in the order of 15% cheaper than diesel to make the business case viable, or in other words to have the high investment costs compensated by lower operating costs. Without such a fuel price advantage an important incentive to move towards LNG disappears.

In terms of knowledge on LNG and dual fuel, several barriers were identified. Both ship owners and financiers are insufficiently informed that of the safety aspects of LNG, which complicates the communication on the business case for LNG. The limited number of operational LNG vessels also makes that there is a limited practical evidence of the operational costs and benefits of LNG technologies. LNG engines therefore receive interest of a limited group of early-adopters who are willing to explore the technology. On another account, skippers need to be educated on the sailing ranges, refuelling, bunker locations and challenges of using LNG. Similarly, ports require education on LNG bunkering regulation and operations. The knowledge gap on LNG technologies thus necessitates training/knowledge sharing for a range of IWT stakeholders. A difference can be expected between tanker vessel crew and dry bulk cargo or container vessel crews, as the former are generally more experienced with ADN regulations.

Market barriers that apply to LNG technologies include the limited number of bunkering facilities and supporting infrastructure. In the Netherlands the first LNG bunkering facilities for inland shipping are operational and sailing on the Rhine is possible till the upper Danube. Yet, the limited presence of LNG bunkering facilities along other European waterways influences the widespread uptake. Alternative bunker solutions, through tanker trucks, are nevertheless possible. Another market bottleneck concerns the limited availability of engines. Dual fuel systems and pure LNG-powered engines are being developed by four engine manufacturers with different configurations. These engines are nevertheless produced in very small quantities, effectively limiting the uptake potential of LNG technologies if market demand rises. Further standardization is needed to result in lower LNG (dual fuel) engine and equipment costs.

The cultural barriers for LNG technologies entail a general perception amongst the general public towards LNG. In light of the limited knowledge on the safety hazards of LNG bunkering, local stakeholders might object the construction of bunkering facilities in ports. Reluctance towards adoption is also seen amongst shippers. The reason is that while the environmental benefits of LNG are clear, there is uncertainty regarding the division of benefits amongst the adopters. This suspicion of split incentives challenges future uptake.

3.1.2 GTL fuel

Gas-to-Liquid (GTL) entails a process during which natural gas is transformed into a liquid fuel. GTL is commonly considered as a technology that is relatively easy to adopt because there are no substantial bottlenecks to implementation. In terms of technical barriers it should be noted that conventional engines do not need to be modified and GTL fuel is in fact already used by inland waterway vessels. In terms of knowledge and culture barriers, no substantial hurdles are identified. This follows from the similarity to diesel in operational terms, so that no additional training is required and the reluctance to change is minimized.

The financial barriers for GTL fuel are however stronger. On the positive side, GTL fuel burns more efficiently than conventional diesel fuels so that engine maintenance costs decrease. Yet GTL is, and is expected to remain, between 5-10% more expensive than conventional diesel fuel. Because the price premium is not covered by lower operating costs and only marginally by lower maintenance costs, ship owners who use GTL fuel are competitively disadvantaged. So while the environmental benefits and the ease of implementation speak in favour of the widespread adoption of GTL fuel for inland waterway vessels, the split incentive makes that ship owners are less likely to bunker GTL without the existence of a supportive legal and financial framework.

The market, finally, is currently only able to distribute GTL along the lower Rhine. There is moreover only one provider, namely Shell. The existing market is indeed small which explains the limited involvement of other suppliers and distributors. Developing a more extensive GTL distribution network is however relatively easy. As such, market barriers in terms of supply and distribution are limited.

On a final note, current river conventions hinder the introduction of fuel charges, that could act as financial incentives for cleaner fuels (as they do in the passenger car sector). This is important because the financial barriers to uptake are considerable.

3.2 Propulsion systems

The introduction of propulsion system innovations using conventional fuels is considered to have less greening potential than alternative fuels, but is technically less challenging. The selected technologies are indeed more developed in technical terms and proven in practice. At the same time there are several barriers that hinder the widespread uptake. Innovation challenges follow from the considerable lifespan of ship engines, that last up to 30 years. For most ship owners it is financially impossible to retrofit engines before this is technically required. The introduction of propulsion system technologies is therefore likely to occur slowly as long as no framework is in place that incentivises their introduction.

3.2.1 Right sizing

Right sizing entails a technology through which engines are (re)designed in line with the operational profile of the vessel. It counters that engines are oversized while ensuring sufficient power/torque delivery. Similar to GTL the technical barriers for right sizing are limited, because the technology is mature and established. Also in legal, knowledge, and cultural terms there are no substantial obstacles identified.

The technology however does require the ship owner to make considerable investments in the engine. Though right sizing typically leads to lower fuel and maintenance costs, it needs to be considered that low capital reserves in the IWT industry limit the adoption rate. Most importantly, right sizing is usually only undertaken when the existing engine needs to be replaced or overhauled. Considering that the life span of IWT engines can last up to 30 years and overhauls may take place only once or twice in between, the contribution of right sizing to greening the IWT fleet is limited without supportive measures.

3.2.2 Exchange of main engine to CCNR II engine

Existing and new vessels need to comply with current CCNR II criteria on IWT emissions. New diesel engines comply with these criteria. Similar to right sizing, the exchange to a CCNR II engine is an established and proven practice. To date, 16% of the European IWT fleet has a CCNR II engine. Notable differences do however exist between fleet families. Especially the larger vessels evidence an uptake of CCNR-II engines between 34 and 57%. A more detailed view on the division of engine types per fleet family is shown in Figure 3.1. The uptake barrier therefore seems applicable to smaller vessels, smaller push boats, smaller motor vessels and passenger ships.

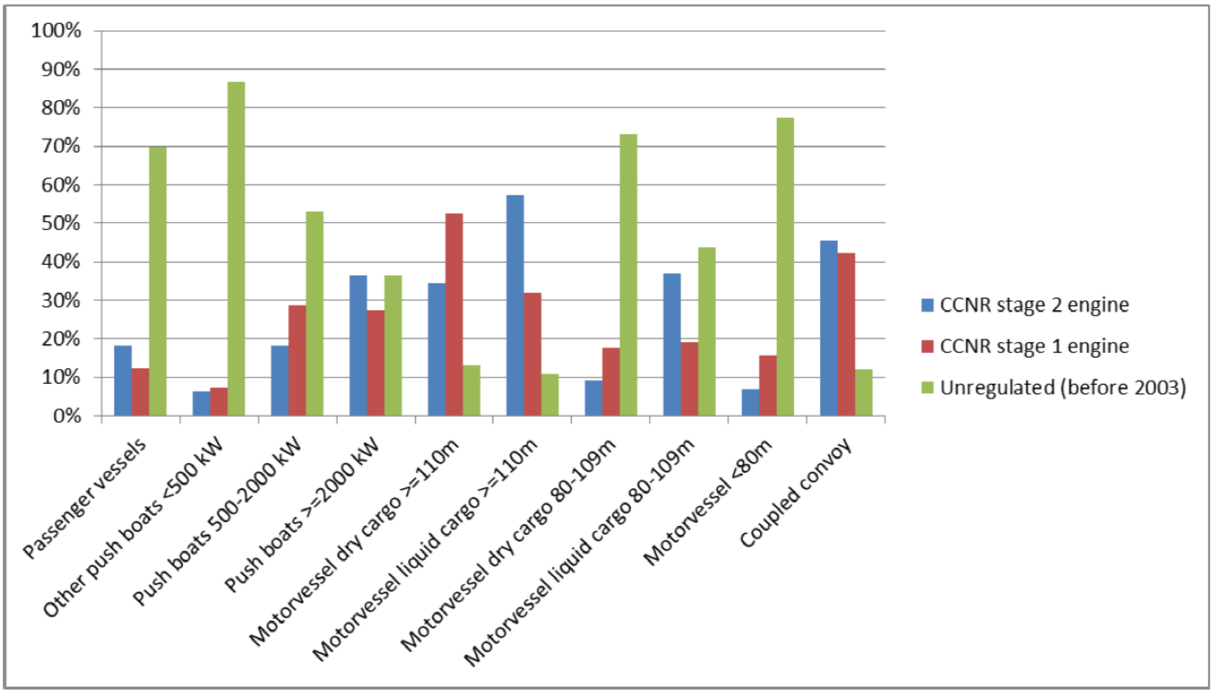


Figure 3.1 Engine type per main fleet family (source SWP 1.1)

Despite the different uptake rates between fleet families there are low knowledge and cultural barriers. But also here, the life span of engines, and the limited financial means of ship owners, hinder the uptake of CCNR II technology beyond what is expected due to the natural engine replacement rate. Moreover, there are stories among skippers that CCNR II engines are consuming a bit more fuel on average compared to CCNR I engines in order to reach the emission limits without (expensive) after treatment systems. This fuel consumption penalty may not help the uptake of CCNR II engines either.

3.2.3 Exchange to Stage V engine

Currently new standards on emission limits for non-road mobile machinery (NRMM) are being considered by the European Parliament, and these may or may not include a stage V requirement level. The so-called Stage V emission criteria will impose more stringent requirements for IWT engines. Because the regulation is still under discussion there is no definitive answer on the exact criteria and on when the regulation will go into effect. Still, it is expected that technical barriers will need to be overcome to ensure compliance.

The development of Stage V engines is hindered by the legal uncertainty in two ways. First, too low criteria would deter the development of new, less polluting engines, because similar results can be reached through cheaper, proven technologies. A recent example concerns a ship with a CCNR-I engine that achieved CCNR-II status by using GTL fuel. Second, it is not clear how compliance will be ensured and into what extent there will be limits implemented on the emissions for the engines of the existing fleet. Strong incentives will support the demand for new engines in case the old engines can not comply anymore. The urgency to develop new engine technologies is therefore limited, because the incentives to comply might be too limited. The absence of a definitive legal framework on Stage V NRMM criteria and uncertainty what measures will be undertaken to address the existing engines therefore slows the development of new engines, which imposes technical barriers. In principle, the legal uncertainty also fosters some market barriers, as the Stage V engine market is currently too small for developers to make production economically feasible.

The uptake of Stage V diesel engines may also be limited by several financial barriers. Just as low diesel prices limit the uptake of LNG or dual fuel engines, low LNG prices can negatively impact the uptake of diesel engines. The long-term volatility of fuel prices thus has a restraining effect on the uptake of certain technologies. This holds especially true for Stage V diesel engines, as NRMM emission criteria can also be reached by certain LNG engines. In terms of knowledge and culture barriers are low because no additional training is expected to use Stage V engines and engine changes is an established practice.

3.2.4 Hybrid propulsion (with and without buffer batteries)

With hybrid propulsion technology an auxiliary engine can be switched off when not needed, leading to a higher average engine load and greater fuel efficiencies. Hybrid propulsion systems come with and without a buffer battery. The buffer battery enables vessels with irregular operational profiles to store energy that can be reused when needed. This application is mostly seen in sea ferries, and is considered to be relevant for a limited number of inland passenger vessels. Besides this differences, the barriers to uptake for hybrid propulsion technologies with and without buffer battery are similar.

Technical barriers follow from the difficulties to implement the technology in existing vessels. While new vessels are relatively easily equipped with hybrid propulsion systems, old vessels require a considerable overhaul. Importantly, the benefits of retrofitting vessels with hybrid propulsion systems are not sufficiently known. It is therefore unclear whether the benefits outweigh the costs, which limits the interest to invest. This knowledge gap thus acts as an important barrier to uptake. Yet, when vessels are equipped with the system, little training is needed to educate shippers on how to sail with the system.

On the legal and cultural levels, finally, the barriers are limited. There is no legal framework that prohibits the use of hybrid propulsion, nor are there any additional legal requirements that need to be met in order to operate vessels with hybrid propulsion.

3.3 Auxiliary systems

Leveraging auxiliary systems to make IWT fleets greener has a proven potential. Still, due to the higher uncertainty on the likely (financial) benefits, the market will be reluctant to invest. Also the earn back potential is limited, because no fuel efficiencies are reached. Hence, the barrier to the uptake of auxiliary systems is primarily financial.

3.3.1 SCR

Selective catalytic reduction (SCR) is a technology to reduce the NOx emissions of diesel engines. Specifically, the system uses urea-water solutions to convert NOx into nitrogen and water. The technology is widely applied and proofs to be very efficient. Limited technical barriers are therefore identified. Medium speed engines do however need more voluminous installations in the exhaust system. In particular at smaller vessels the limited space could be a barrier. On the legal, market and cultural dimensions SCR is considered to be a technology that is easily implemented. Ports are moreover experimenting with port due models that provide discounts to vessels that are SCR certified. Such incentives can promote the further uptake of SCR, although the certification costs might stop vessels owners from going after a certification.

The widespread uptake of SCR is moreover hindered by the considerable investment costs and the split incentives. While the environmental benefits are substantial, ship owners are unlikely to be sufficiently compensates to recover the investment costs, commonly exceeding €30.000,-, and accepting values of up to several hundred thousands of Euros. A final note is that SCR could alter the performance of the vessel, which would necessitate additional training for the vessel crew, adding to the costs. Because no fuel economies or operational improvements are realized by SCR, it is unlikely that this technology will be widely introduced without the existence of a supportive policy framework.

3.3.2 Wall flow DPF

Diesel Particulate Filters (DPF) are installed in automobiles and non-road machines to reduce particulate matter (PM) emissions. One type of particulate filters are Wall flow DPFs, which have a honeycomb structure with porous walls that capture and remove particulate matter. In contrast to SCR, Wall flow DPF technology is not fully mature so that technical progress is needed before it can be widely adopted by inland waterway vessels. Besides the technological readiness, the barriers to uptake are mostly similar to the ones discussed for SCR, meaning that the financial barriers are high.

While the upfront investment costs for Wall flow DPF are lower than for SCR, the maintenance costs are higher because of a periodic clean-up of residue ashes. Also, no cost savings are achieved so that the business case for the ship owner is negative. The uptake of wall flow DPF is therefore mostly dependent on the establishment of a financial and legal infrastructure that promotes vessels with less PM emissions.

3.4 Infrastructure and ship-operational measures

In this paragraph waterway information, speed adoption and track choice are discussed. The waterway information system concerns the critical infrastructure for the collection and processing of waterway data. The speed adaption and optimised track choice technologies are the practical applications that build on this system. These technologies are strongly interconnected depend on each other for the system to be successful. Also, the technical readiness level is the lowest of all selected greening technologies. As a consequence these technologies are surrounded by several uncertainties that will be addressed in PROMINENT pilot studies.

3.4.1 Waterway information

The provision of real-time waterway information based on measurements carried out by commercial vessels can be associated with great technical barriers if a great number of vessel classes as well as greater parts of the waterways under consideration are to be considered. Water depth data can be obtained by echo-sounder measurements. Flow-velocity data can be obtained by using dedicated measurement devices, e.g. Acoustic Doppler Current Profiler (ADCP). The proper placement of the measurement devices is of great importance as the signals received may be influenced by air-bubbles (echo-sounder measurements), or turbulence and ship-induced flows (flow-velocity measurements), leading to unreliable results. This holds in particular true for pushers where the flow around the vessel is influenced by the lighters in front of the pusher. Another technical barrier arises from lack of knowledge on the squat of some vessel types, e.g. pushed convoys, which, depending on the approach used, is needed for correction of the depth measurements. One of the most significant technical barriers relates to the availability of proper models for consideration of water-level (water-depth), morphologic as well as flow-velocity changes in time and space, covering essential parts of the waterway under consideration. These models are one essential basis for provision of dynamic fairway information of sufficient quality and extent. In addition, issues relating to automatic data processing and quality control may pose greater technical challenges. The development and application of such models, and depth, as well as flow-velocity measurement programmes is part of one pilot study within the PROMINENT project.

The height of the legal barrier is dependent on the conditions that guide the sharing of echo sounder data. If the collection and sharing of data occurs on a voluntary basis, the legal barriers are considered to be low. Should this occur on a mandatory basis, however, a legal framework should be developed that applies to several countries. In light of the uncertainty regarding the governance model of the waterway information system it is unclear how high the legal barriers will be. Other legal aspects, like national privacy regulations concerning data storage and encryption, should be taken into account regardless of the governance model.

Similarly, the financial barriers to implementation are dependent on the governance model. High investment costs are nevertheless required to make the system operational. On top of the research and development costs, the technology requires the installation of a certain number of echo sounders on vessels, an information exchange system to transfer vessel data to a central data centre, which in turn needs to be staffed and maintained. The question is who carries the costs. One model is that ship owner purchase echo sounders, some additional system-components (e.g. for data storage and transmission) and a waterway information subscription. An independent institute would then be responsible for managing the data centre and would receive the subscription fees. Due to the ongoing developments of the technology, including the NEWADA DUO approach and the

PROMINENT approach, such examples should be considered as tentative. Assessing the height of financial barriers for different IWT stakeholders is therefore also complicated.

In terms of knowledge it is expected that ship owners and waterway managers require new skills for proper usage and operation of the real-time waterway-information system. These trainings need to be developed and given to a large number of shippers because of the high number of vessels that need to participate for the system to work. These knowledge barriers are present, but relatively low considering that most vessels already have echo sounders installed. The market and cultural barriers, finally, are found to be low as well.

3.4.2 Speed adaption and optimised track choice

Similar to waterway information systems, the speed adaption and optimised track choice technologies are under development. In particular the data models that transform waterway information into reliable recommendations on speed and track choice need to be improved and tested before they can be used in practice. Additionally, research needs to identify whether the envisaged energy savings outweigh the costs. These points are currently underdeveloped so that the technical barriers to uptake are high.

In terms of legal barriers the liability of shippers should be considered. In the case that shippers are delayed or damage the vessel because of speed adoption or track choice information, a legal framework should exist to determine which party is responsible for the costs. These points also need to be considered in light of insurance policies for shippers, clients, and ship owners. Considering the novelty of the technology and the multiple stakes involved, it is thought that these barriers are substantial.

Similar to the discussion for waterway information systems, it is hard to make definitive statements on the financial barriers for these technologies in light of their ongoing development and uncertainties on how costs are divided between the involved stakeholders. That observation also highlights the urgency of the pilot project on energy efficient navigation in PROMINENT. That being said, the costs of using the data (which leads to speed adaption and track choice recommendations) should not be seen independently from the costs for the waterway information infrastructure. The financial barrier of setting up and maintaining the infrastructure also affects these technologies.

When active, vessel crew needs to be trained on how they should sail with the system. Because both track and speed are influenced by the technologies, it can be expected that trainings should be provided. Besides the trainings to teach crew members new sailing skills, there is a considerable knowledge gap on the benefits of the technologies. As said, these benefits still need to be clarified and if the technologies prove to be economically feasible, IWT stakeholders should be informed on the benefits.

3.5 Quantitative assessment of barrier height

Based on the barrier analysis, a quantitative assessment of the barrier height was performed. Experts assessed for each technology the six barriers on a five-point scale, with 5 indicating that the barriers are very high and 1 meaning very low. Special attention was given to differences that may exist between fleet families. The analysis facilitates the comparison of technologies and highlights the limitations of some technologies for certain fleet families. Table 3.1 provides an overview of this assessment.

	Technology \ Fleet family	Passenger Vessels	Push boats <500 kW	Push boats 500-2000 kW	Push boats >2000 kW	Motor vessel dry >110m	Motor vessel liq. >110m	Motor vessel Dry 80-109m	Motor vessel liq. 80-109m	Motor vessel Dry <80m	Coupled Convoys
1	LNG	3,8	5,0	5,0	5,0	3,3	3,3	3,7	3,7	4,0	3,2
2	Dual fuel	3,5	5,0	5,0	5,0	2,7	2,7	3,5	3,5	3,8	2,7
3	GTL fuel	1,8	1,8	1,8	1,8	1,8	1,8	1,8	1,8	1,8	1,8
4	Right sizing	1,7	1,7	1,7	1,7	1,7	1,7	1,7	1,7	1,7	1,7
5	CCNR II engine	1,8	1,8	1,8	1,8	1,7	1,7	1,8	1,8	1,8	1,7
6	Stage V engine	3,2	3,2	3,2	3,2	3,0	3,0	3,2	3,2	3,2	3,0
7	Hybrid prop -	2,2	2,2	2,2	2,2	2,2	2,2	2,2	2,2	2,2	2,2
8	Hybrid prop +	2,5	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0	5,0
9	SCR	1,8	2,2	2,2	2,2	2,2	2,2	2,2	2,2	2,2	2,2
10	Wall flow DPF	2,0	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3
11	SCR and DPF	2,0	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3	2,3
12	Fairway data	2,8	3,0	3,0	3,0	2,8	2,8	2,8	2,8	2,8	3,0
13	Speed adaption	2,8	2,8	2,7	2,7	2,7	2,8	2,8	2,8	2,8	2,7
14	Optimised track	2,8	2,8	2,7	2,7	2,7	2,8	2,8	2,8	2,8	2,7

Table 3.1 Average height of barriers per fleet family
Five-point scale: 1. Very low / 2. Low / 3. Medium / 4. High / 5. Very high

The table indicates that for most technologies there are only minor differences between the average barrier height per fleet family. GTL fuel, right sizing, and diesel hybrid-propulsion (without buffer battery) are exceptions as the barriers are considered to be equally high for each fleet family. Three technologies show however significant differences between fleet families, namely LNG and dual fuel technologies, and hybrid-propulsion systems with buffer battery. The latter technology, as discussed, is only suitable and useful for vessels with irregular operational profiles, such as certain passenger vessels and ferries. The limited applicability to other fleet families is indicated by the high ratings. The applicability of LNG and dual fuel engines is determined by other criteria. For push boats it was noted that such engines are only useful when they are constructed as an LNG vessel. Retrofitting push boats with LNG engines is impossible because of the negative effects on the stability of the vessel. The analysis also conveys that LNG technologies are considered most applicable to motor vessels of over 110 meters in length.

Table 4.1 also informs us on the technologies that encounter the highest barriers. To make the comparison of barrier heights easier the numbers are ranked, with 1 meaning the lowest barriers and 14 implying that barriers are the highest of all technologies. The results are provided in Table

3.2. Take note that barrier height is ranked per fleet family and that equal numbers imply that the barriers were assessed equally high.

	Technology \ Fleet family	Passenger Vessels	Push boats <500 kW	Push boats 500-2000 kW	Push boats >2000 kW	Motor vessel dry >110m	Motor vessel liq. >110m	Motor vessel Dry 80-109m	Motor vessel liq. 80-109m	Motor vessel Dry <80m	Coupled Convoys
1	LNG	14	12	12	12	13	13	13	13	13	13
2	Dual fuel	13	12	12	12	8	8	12	12	12	8
3	GTL fuel	2	2	2	2	3	3	2	2	2	3
4	Right sizing	1	1	1	1	1	1	1	1	1	1
5	CCNR II engine	2	2	2	2	1	1	2	2	2	1
6	Stage V engine	12	11	11	11	12	12	11	11	11	11
7	Hybrid prop -	7	4	4	4	4	4	4	4	4	4
8	Hybrid prop +	8	12	12	12	14	14	14	14	14	14
9	SCR	2	4	4	4	4	4	4	4	4	4
10	Wall flow DPF	5	6	6	6	6	6	6	6	6	6
11	SCR and DPF	5	6	6	6	6	6	6	6	6	6
12	Fairway data	9	10	10	10	11	9	8	8	8	11
13	Speed adaption	9	8	8	8	8	9	8	8	8	8
14	Optimised track	9	8	8	8	8	9	8	8	8	8

Table 3.2 Ranking of barrier height per fleet family

With 1 for the lowest barriers, 14 for the highest

By ranking the barrier height per fleet family it becomes clear that LNG, dual fuel, Stage V engines, and hybrid-propulsion with buffer battery are the technologies that overall experience the highest barriers. The technologies that currently experience the lowest barriers to uptake across all families are GTL fuel, right sizing, CCNR II engines, and SCR technologies.

4 Facilitating factors to innovation uptake

The previous chapter identified and discussed a range of barriers vis-à-vis the implementation of the selected greening technologies in the IWT sector. While doing so, several remarks were made on the required steps to facilitate further uptake, and as barriers are not new, actions have already been undertaken (or tried) to overcome them. This chapter focuses explicitly on the facilitating factors to innovation uptake. Case evidence both from within the IWT sector and from other (transport) sectors as well as recent studies are explored to provide insights into factors that can contribute to PROMINENT's target to develop cost-effective solutions applicable to 70% of the fleet. Specifically, five different types of facilitating factors (emission standards, emission charges, incentive schemes, financial products, and infrastructure development) are explored. The selection of these factors follows from desk research and the expert workshop, where these factors were repeatedly identified as instrumental to innovation uptake. This is however not to say that these are the only facilitating factors to innovation uptake.

This chapter does not aim to provide a complete overview of all potential facilitating factors, but does highlight several examples on how barriers to innovation uptake have been targeted in the IWT sector and elsewhere. In this context a look is taken at the agriculture and maritime shipping sectors. These sectors are selected because they bear several similarities with the IWT sector and provide several suggestions on the possibilities and limitations of facilitating innovation uptake. This chapter thereby draws attention to several options to realize impact towards 2020. In WP5 the PROMINENT project will focus in greater detail on how promising innovations can be facilitated.

4.1 Innovation uptake in other sectors

4.1.2 Innovation uptake in maritime shipping

The maritime sector is often seen as the example of ship technology uptake. Also in this sector technologies are being developed and deployed aiming at a greener performance of the sector – either driven by market conditions (fuel cost savings) or by regulatory measures.[1] Typically, while the size and scope of technologies is wider, their characteristics bear similarities with the technologies considered for IWT (smart navigation/slow steaming, LNG and dual fuel engines, SCR and scrubbers). As in IWT, partly such technologies provide a commercial benefit (lower fuel costs) and as a result ship owners have invested in those technologies as a means to beat competition. For technologies not providing such benefits however, regulatory measures were the means to incentivize uptake. Examples are the Ballast Water Management Convention, the introduction of Sox and NOx emission control areas (ECA's) in Europe and North America and IMO efforts towards more strict global emission regulations to be introduced (EEDI/SEEMP as well as lowering thresholds of Sulphur content in marine fuel).

A number of commonalities with IWT can be found:

- Uptake is easiest as part of the newbuilding process, while retrofit technologies are more complex and more costly.

[1] Ecorys et al (2012), Green growth opportunities for European shipbuilding

- The operating life of a seagoing ship is some 30 years, shorter than in IWT but still fairly long. While the global shipping market also grows a few percent per year, the replacement rate is thus fairly low.

In terms of uptake, a few differentiating factors should however be understood:

- The marine sector is much larger than the IWT sector, with 10 times as much as ships and with a global market, whereas IWT typically works as a regional (European)market, not harmonized or standardized with US or Chinese systems.
- Companies are usually larger, operating a fleet of ships. Often these are financed through commercial investor funds, which may indirectly be financed from private capital as venture investments (in some countries in Europe fiscally promoted)
- Due to regional variations in regulations as well as market conditions, ships may shift markets in the course of their lifetime, for example operating in Europe in its early years and then transferred to other markets with lower technology, environmental or safety thresholds or competitive requirements.
- In terms of regulatory and policy development, maritime transport truly is a global sector, and global measures would need consent of the major IMO members to become effective. This has in the past resulted in fairly slow developments when it comes to tightening safety or environmental regimes, an issue that would be less a problem for IWT as a European scope can already be effective. In the maritime sector this is also tried (examples are emission trading, ship recycling), but those may come at a cost.

4.1.1 Innovation uptake in agriculture

The characteristics of the agriculture sector have a number of similarities with the IWT sector, at least in many parts of Europe. This can be seen for instance in the fact that most companies are SMEs, often owned and operated by a single person or family, who invest almost all their capital and their time into the company. Furthermore most farmers are heavily indebted because of the high capital intensity (land, buildings, machinery) required, while vulnerable to fluctuations of prices for their outputs.

At the same time, the European agriculture industry is considered to be highly advanced, and a circle of innovative technology developers can be found especially in the Netherlands but also in a number of other northern European countries, that develop, manufacture and export worldwide. These are not just machinery companies but also seeds and nutrients providers as well as bio-technology.

Finally, a trend of increasing company size can be observed, with smaller farms being closed once the owner retires and younger farmers only being able to operate at feasible levels with higher amounts of land to work. The question can be asked what this means for the uptake of new technologies in the agriculture sector? And, more interestingly,are there parallels with IWT through which lessons could be learned?
A variety of European research indicates the wide range of opportunities that innovation provides to the agriculture sector.[2] As in IWT, also in the agriculture sector various programmes exist that aim to raise the uptake, through pilot projects, subsidies or promotion campaigns.[3][4] These may be government-organised (in the Netherlands for instance such support measures exist both at national and provincial level), but also be initiated by sector organisations directly. Furthermore, the

[2] See the EIP-AGRI platform for an overview. http://ec.europa.eu/eip/agriculture/
[3] http://www.agriholland.nl/subsidies/
[4] https://www.brabant.nl/loket/producten-en-diensten/detail.aspx?id=11334

banking sector is active in promoting innovation.[5] It is noted that a number of the (financial) support programmes are of generic nature, not targeted to agriculture alone. Also at European level, the available funds and policy support for agriculture development are massive, and the number of R&D projects under FP-7 and Horizon-2020 is high.

It is however not easy to conclude that the agriculture sector is strong in uptake of technology. A measure that is used in literature is the output achieved (production volume per hectare of land), which shows to be the highest in western parts of Europe, and ever increasing. This result is then attributed to technology advancement. Furthermore the potential of exporting across the globe is an important driver to invest in technology development, piloting and uptake, and a factor that is much less present in the IWT sector today.

At a more down to earth level, popular science suggests that indeed the intensity of technology use in agriculture has moved to very high levels.[6] Reasons given are the continuous attention for technological development in sector magazines, education and a close relation between scientific community, equipment suppliers and the farmers themselves. The latter also are more and more highly educated, and actively engaged in knowledge exchange with their colleagues, suppliers and clients.
Another remarkable notion is the openness of entrepreneurs when it comes to sharing ideas and developments. Farmers within a country do not see their neighbours as their competitors, but as partners or colleagues. Cooperation between farmers, for sharing equipment or pooling labour, has been common for centuries.

A feature found widely within agriculture is that of the ‘pilot farm’, a research institute effectively operating as a farm including all practical elements, but with the means to try out and take risk of using new seeds, equipment, etc.

Important to understand is that the uptake of technology has a clear relation to commercial interest: there is a gain of using new technology – ultimately leading to higher outputs at lower operating costs. Such relation appears less direct in parts of the greening technology drive within IWT, which means that a direct copy of approach is not easily made effective.
A factor pointed to by Poppe (2012)[7] is that innovation in agriculture includes not only R&D itself but also smart organization, creativity promotion and (de)regulation.

4.2 Emission standards

The CCNR was the first intergovernmental organisation to set emission standards for inland shipping. The first stage came into force in 2002, and the second became effective in 2007. In addition to CCNR standards, EU standards on non-road mobile machinery are regulating vessel emissions. As pointed out in the previous chapter, new CCNR Stage V and EU NRMM standards are under discussion and potentially could foster greening innovations.

[5] https://www.rabobank.com/nl/press/search/2014/20140530-YFMC.html
[6] Elsevier (2015), De Nederlandse boer loopt voorop in innovatie (Dutch farmer ahead in innovation). http://www.elsevier.nl/Kennis/achtergrond/2015/5/Slimme-boer-Nederlandse-boer-voorop-in-innovatie-1758608W/
[7] http://www.boerenbusiness.nl/columnisten/krijn-j-poppe/column/10769163/innovatie-vraagt-meer-dan-enkel-onderzoek

The effectiveness of legal standards to facilitate innovation remains nevertheless a topic of intense debate in the IWT sector and beyond. Concerns include that the costs of enforcement are too high, sanctions too low, and that regulations are not demanding enough (POLFREE, 2014). Vessel owners might for instance take the risk of being sanctioned because it is cheaper than implementing green innovations (see for instance a recent call from the Danish maritime sector lobby to enforce ECA zone requirements)[8]. Alternatively, when regulations are not sufficiently ambitious, vessel owners can implement older technologies rather than state-of-the-art solutions with greater impacts. This in turn limits the interest of the manufacturing industry to invest and develop novel greening technologies. From a societal point of view, such behaviour can be seen as undesirable. Setting emissions standards therefore does not necessarily contribute to innovation uptake and might even be detrimental to it if done unwisely. This concern was for instance expressed when the CCNR Stage 1 criteria were introduced, and over 70% of the German and 80% of the Dutch fleet were already compliant (CE Delft, 2004).

At the same time there are positive examples on how emission standards drive innovation and decrease environmental impacts. A relevant and notable case in point concerns road transport. Since 1993,the CO_2, NOx and PM emission norms have considerably dropped following six consecutive regulatory stages that capped emissions (the so-called EURO-norms). Despite opposition of road transport operators towards these standards, there were many innovations introduced that make road transport today substantially less polluting and, importantly, more competitive. Hence, despite that setting emissions standards can paradoxically result to fewer incentives to innovate, there is considerable evidence that setting sufficiently high standards does in fact facilitate technology development and uptake. By 2020, the new NRMM and CCNR Stage V standards could therefore, depending on how they are set and structured, also contribute to the facilitation of green innovations. The local policy set by the Port of Rotterdam, banning CCNR-I and lower performing engines from the port, is also an example of setting emission standards, and might be followed by other ports or regions.

A specific road transport measure is the designation of Low Emission Zones (LEZ), one of the most drastic measures taken by local governments to reduce road transport emissions within their vicinities. LEZs are defining an area where higher polluting vehicles, e.g. trucks of lower EURO classes, are completely banned, or where the more polluting vehicles have to pay more if they enter the area. Most LEZs operate 24 hours a day, 365 days a year, except some of the Italian LEZs which are not in operation permanently. No examples of low emission zones were retrieved for the rail transport sector.

4.3 Emission charges

An alternative to legally defined emission standards is to levy emission charges as a more market based approach to foster innovation uptake. In one study on emission charges for the IWT sector (CE Delft, 2004) it was found that setting an incentive price of €2,5 per kg NOx is likely to facilitate the uptake of NOx reduction technologies such as SCR. Likewise, it could promote alternative fuels like LNG and GTL, as the yearly costs per vessel would increase by 2% with SCR technologies, instead of 8% on average without emission reduction technologies. In a similar way, one could expect that

[8] Bunkerworld, 1-10-2015, Danish shipowners: Tougher ECA enforcement needed. http://www.bunkerworld.com/news/Danish-shipowners-Tougher-ECA-enforcement-needed-139074

emission pricing for PM exhausts promote the uptake of DPF technologies. Emission charges are therefore believed to be a powerful instrument to promote greening technologies.

At the same time the adverse effects of emission charges should be carefully considered. The IWT sector currently operates with low margins and a price increase due to emission charges would decrease profit even more, and affect the competitive position vis-à-vis other modes. If the costs are transferred to clients, a decrease of inland transport is expected of 2.4 to 9.6% (CE Delft, 2004). This effect is attributed to a drop in transport demand and to a modal shift towards rail and road transport. The considerable risks should be carefully acknowledged and need to be mitigated by other instruments. An option would be to use the revenues that are generated through emission charges to invest into R&D on greening technologies (as for instance in the NOx fund in Norway) or to subsidise state-of-the-art greening measures (taking account of EU state aid legislation).

Besides the cost issue, it should be emphasized that international law currently prohibits emission charges to facilitate innovation uptake. In fact, hardly any taxes or pricing for infrastructure usage or access to IWT exist compared to road and rail transport. Obviously this offers a competitive advantage for IWT, but the drawback is a lack of possibilities to differentiate charges and to provide incentives to support the greening of the fleet. Of key importance is article 3 of the Mannheim Convention, which prohibits duties that exclusively apply to shipping. Any levy on inland shipping is therefore likely to experience considerable legal barriers. At the same time there are legal developments, such as the adoption of new conventions, that may enable such developments. Emission charges should therefore be considered as a potentially facilitating factor to innovation uptake, despite the hurdles it encounters.

In road transport, congestion- and emission charges are more and more frequently levied. This policy is framed within the “Directive on the charging of Heavy Goods Vehicles in the EU” (EC, 1999) which lays down certain rules defining the conditions under which user charges ("Eurovignette") and tolls may be applied. Moreover, Directive 2011/76/EU allows Member States to levy external costs of road congestion, emissions and noise to freight vehicles sized above 3.5 tonnes. Road tolling per km is existing for years. Examples are for example the French *péage* system or road tolling for using tunnels, and applies to both passenger and freight vehicles. In the last decade, more advanced ICT systems allow governments to collect differentiated tariffs from road users. Examples are seen in Germany (LKW Maut) or Czech republic. Belgium is implementing an advanced km pricing system for trucks in 2016. These fairly new systems make use of mobile data and/or GPS tracking via On Board Units (OBUs), and allow governments to differentiate levies (based on emission standards and vehicle classes). Rail transport users are paying track access charges, which are differentiated on the weight of the train, time of the day and importance of the track section. Emission based charges could be levied but are currently not mentioned in the Network Statements published by the Infrastructure providers.

4.4 Incentive schemes

Rather than charging for emissions, innovation uptake can also be facilitated through incentives for greener vessels. For instance, several ports offer rebates of 5 to 30% on port fees to vessels that have been certified for their green performance. Several ports in the Netherlands now use a differentiated certification scheme with three environmental performance categories, which are connected to different levels of rebates (Green Award, 2015). Besides that these incentive systems can raise the awareness and knowledge of several green technologies for IWT, they also improve the business case for implementing some technologies. Moreover, from a legal point of view, the relative advantage of incentive schemes over emission charges is that they are not limited by international regulations and can be determined at a local level (e.g. by a port authority).

Several risks exist as well. One element that requires attention relates to the potentially high certification costs, and the existence of competing certification systems. As a consequence, a vessel might be eligible for a rebate in one port but not in another. Another worry is that vessel owners move towards ports with less strict environmental standards, which causes the measure to be less powerful in promoting the greening of the IWT sector. Despite these concerns increasing support exists within port-city regions to promote the greening of the IWT sector. As a consequence, a growing number of ports introduced incentive schemes that facilitate greening technologies.

In the road transport sector we encounter the *Lean and Green* approach. This 'contest' kind of measure offers an interesting opportunity to learn how to significantly reduce emissions and/or noise in supply chains. The original Dutch programme which runs in Belgium and the Netherlands, is an approach to the uptake of green technologies. Companies can propose their own approach to lowering their CO_2 emissions by 20% in 5 years. If this plan is approved by an independent reviewer, and the company also realises its goal, lean and green then awards the applicant a highly esteemed lean and green star award. The star award gives visibility to green front-runners while contributing to greater environmental goals.

4.5 Financial products

Throughout chapter 3 financial barriers, in terms of access to capital and the availability of resources to invest, were found to hinder the greening of the IWT sector. Within this context it is important to look at alternative financial solutions for green technologies. With respect to technologies that improve fuel efficiency it is possible to consider the Energy Service Company (ESCO) vehicle. In this set-up the ESCO company provides a loan to the operator to enable him to install environmental friendly technologies. The technologies enable the vessel owner to reduce fuel consumption and the money saved through fuel efficiencies is consequently used to repay the loan. The ESCO model is a form of joint risk sharing and focuses on solutions where the savings are guaranteed to cover the costs. Such financial products can facilitate the uptake of technologies such as LNG, dual fuel engines, or changes to propulsion systems, and deserve to be analysed for further consideration.

In the past, The Commission adopted the PACT regulation and Marco Polo programmes (I and II) in an attempt to promote the sustainability of Europe's freight transport market developments, i.e. by shifting freight from road transport to other modes (modal shift actions) and by avoiding unnecessary transport (traffic avoidance projects). In this respect, inland waterways, short sea shipping and rail transport were the main alternatives to unimodal road transport. The PACT programme ran from 1997-2001, with the Marco Polo programmes following between 2003 and 2013, and it can be concluded that while the strategy of these programmes changed slightly over time, the overall policy strategy remained short-term and project-by-project oriented. A follow-up to the Marco Polo scheme is foreseen in the 2014-2020 financing period (Regulation(EU) No 1316/2013). A new funding scheme (NFS) for freight transport services will be fully integrated within the framework of the revised Trans-European Transport Network programme (TEN-T) and implemented via the Connecting Europe Facility (CEF), a dedicated instrument for financing EU policies in the area of transport, energy and telecommunication. Funding for increasing sustainability and innovativeness will be dedicated to the IWT market as well.

Within the European context, also the Reserve Fund in the IWT sector should be mentioned. The fund was established in the framework of a Community-fleet capacity policy and was funded by the IWT industry itself. This fund still could be leveraged to support innovation initiatives. Also, the European Fund for Strategic Investments and EIB financing offer options for innovating the IWT sector. These financing options and how they could serve an enhanced uptake of green technology shall be analysed in more detail within the PROMINENT project under WP5.

4.6 Infrastructure development

Technology uptake can also be facilitated by improving supply conditions and by developing critical infrastructure, which can be both public and private infrastructure. For several of the selected greening technologies in PROMINENT this is an important factor, most notably for fairway information systems and LNG solutions. These technologies shall be analysed in greater detail throughout the PROMINENT project, but in this chapter it is worthwhile to refer to the LNG Masterplan for the Rhine-Main-Danube axis.

The LNG Masterplan emphasizes the need for a critical mass of investments in terminal infrastructure and LNG vessels for the technology to be feasible. Investments include the development of bunkering facilities along the Rhine and Danube regions, and truck fuelling stations. The latter will enable a more flexible delivery of LNG fuels to inland waterway vessels and at the same time provide LNG solutions to road transport as well. As a consequence, innovation investments in the IWT sector can create positive spill-over effects for other modes of transport.

The feasibility of infrastructure investments is also confronted with several difficulties. The fact that the development of IWT infrastructure often concerns several jurisdictions and competing interests, makes it very challenging. On another level, infrastructure development usually is costly and the return on investments by private operators might be small due to the small market size. Private sector interest might therefore be small, and public investments along the Rhine-Main-Danube axis cannot be assumed automatically. At the same time, underdeveloped infrastructure is likely to act as a deterrent to innovation. Promoting infrastructure investments should therefore be considered to facilitate promising technologies.

4.7 Discussion

The abovementioned factors provide an insight into several frequently mentioned options to facilitate innovation uptake in the IWT sector. As said, the chapter did not intent to provide an exhaustive overview and several factors could be considered in future work. Although it was often overlooked in the consulted literature, education and the dissemination of innovation know-how could be instrumental to green technology uptake towards 2020. The EICB, an Netherlands based IWT expertise and innovation centre, is an example of an organization that contributes to innovation uptake in the IWT sector through courses, thematic gatherings and educational materials. The impact of such instruments could be significant for those technologies where knowledge gaps are considerable. Future work on innovation uptake should therefore assess which facilitating factors are most relevant for the technology and maintain a wide scope when considering alternatives.

In addition it should be considered that facilitating factors do not stand in isolation from each other and can reinforce each other's effect. The development of a coherent package of emissions standards, education, and financing should therefore be considered. Equally so it could be discussed which organisation should take ownership when developing such 'packages'. On another account, innovation uptake could be promoted by harmonising certain technologies across geographical regions or sectors. Technology harmonisation efforts could greatly improve the attractiveness and feasibility of technologies. At the same time it poses the question which organisation(s) should be responsible for such standardization efforts. These are complex topics of debate that need to be further explored within the PROMINENT project and beyond.

Finally, in light of the PROMINENT objectives, for each technology the factors should be assessed in function of their ability to contribute to the greening of the IWT sector by 2020. For instance, mandating emission charges on the European level is restricted by international law, which requires a concerted international political effort. Using port by-laws to establish emission charges is arguably more easy to implement and therefore a more feasible and expedient alternative to promote IWT greening by 2020, but may deliver smaller overall emission reduction impacts. Such considerations need to be made when comparing alternative facilitating factors.

5 Concluding remarks

The analysis undertaken in SWP 1.3 showed the following:

- **Barriers:** Innovation uptake in IWT is hampered by technical, legal, financial, knowledge, market, and cultural barriers. Desk research on recent IWT literature confirms that these barriers are critical to understand the (limited) uptake of innovations in the IWT sector.

- **Fuels:** LNG and dual fuel solutions are confronted with considerable legal, financial and market barriers. Currently, the legal framework for IWT is being reviewed to enable and promote the uptake of LNG. Financial barriers are expected to remain because fluctuating diesel prices make that the comparative price advantage of LNG is by times too narrow to legitimize investments in an LNG engine. Moreover, suppliers produce too few engines to enable a massive transition towards LNG technologies by 2020. GTL fuel is an LNG based solution of which the market uptake is mostly limited by the price premium of 5-10% over conventional diesel fuel.

- **Propulsion systems:** Right sizing and the exchange to CCNR II engines are established technologies that encounter relatively few barriers. Hybrid propulsion and Stage V engines encounter relatively greater technical difficulties. For Stage V engines this mainly depends on the mandated emission standards. The uptake of all propulsion innovations is mainly limited by the lifespan of engines, which can last up to 30 years. Due to financial constraints it is considered unlikely that innovations are implemented before an overhaul is technically needed.

- **Auxiliary systems:** SCR and Wall flow DPF are technically and legally easily implementable innovations that significantly reduce NOx and PM emissions. Apart from technical limitations that vary between ship types, the massive uptake of these technologies is particularly limited due to the split incentive and high investment costs for ship owners. The fact that a growing number of ports provide (financial) incentives for cleaner vessels may reduce this, but the financial barrier remains substantial.

- **Infrastructure and ship-operational measures:** Speed adaption and track optimization technology, as well as the fairway and data management infrastructure that these technologies require, have the lowest TRL levels of the selected technologies in the PROMINENT project. The technical barriers are therefore highest. Because the technology is being developed there are still many uncertainties about the legal and financial requirements. Depending on the governance model that is used to provide these technologies, the legal and financial barriers can be substantial.

- **Quantitative barrier assessment:** LNG, dual fuel, Stage V engines, and hybrid-propulsion with buffer batteries are the technologies that are confronted by the highest barriers. The technologies that currently experience the lowest barriers to uptake apply to GTL fuel, right sizing, CCNR II engines, and SCR technologies. Though each technology is confronted with specific challenges, this comparison highlights where barriers are most substantial.

- **Facilitating factors:** Emission standards, emission charges, incentives, financial products, and infrastructure development were explored as facilitating factors to innovation uptake. The PROMINENT project considers facilitating factors in greater detail in future deliverables.

- **Next steps:** The pilot studies on LNG, SCR, DPF and energy efficiency navigation technologies will build on the insights of this report to better determine their potential. Additionally, the findings contribute to the preparation of counter-measures to be taken up in the roll-out plan in WP6.

Annex I : Literature consulted

Author	Title	More information	Year published
Browne, O'Mahony and Caulfield	How should barriers to alternative fuels and vehicles be classified and potential policies to promote innovative technologies be evaluated?	Journal of Cleaner Production, 35, 140-151	2012
CCNR - Economic Committee	Green in inland navigation from an economic perspective - synopsis of the thematic meeting on 8 October	ECO (13)m 32 22 October 2013	2013
CE Delft	Charges for Barges	Preliminary study of economic incentives to reduce engine emissions from inland shipping in Europe	2004
CE Delft - Eelco den Boer	Instruments to reduce pollutant emissions of the existing inland waterway fleet	Position paper for international workshop 'Emissions from the Legacy fleet'	2011
Commission staff working document	Greening the fleet: reducing pollutant emissions in inland waterway transport	SWD(2013) 324 final	2013
CCNR - Hans van der Werf	LNG as fuel in inland navigation	MariTIM - Vorbereitung einer LNG-Initiative Nordwest	2013
CE Delft	EU transport GHG: Routes to 2050? Economic instruments Paper 7	Sponsored by DG Env.	2010
DNV GL	LNG Masterplan For Rhine Danube		2015
IDVV	Impuls Dynamisch Verkeersmanagement Vaarwegen (IDVV) - Versneld vergroenen binnenvaart Schone schepen		2013
Gallagher, Ed	The Gallagher Review of the indirect effects of biofuels production		2008
KIM	Naar een duurzame zee- en binnenvaart in 2050 (Reductieopties en beleidsopties voor vermidnering van de CO2, SO2, NOX en PM10 emissies)		2015
Ruester, S. and A. Neumann	Next Year, Next Decade, Never? The Prospects of Liquefied Natural Gas Development in the US.	Energy Policy, Vol. 36, No. 8, pp. 3150-3158.	2008
Bas van Bree and Peter Colon	Stimulus for SME innovations in inland navigation	Innovations in general, not specifically for reducing energy consumption in iwt	2014, TRA Paris

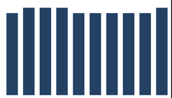
Author	Title	More information	Year published
Jannicke Baalsrud Haugea, Kostas Kalaboukasb, Kahina Hamadacheb, Paola Lupieric, Margherita Forcolinc, Hans Westerheimd, Nils Meyer-Larsene, Alberto Capellaf ,Gunnar Stefanssong, Violeta Rosog	Development of a holistic approach fostering innovation uptake in the logistics area		Transport Research Arena 2014, Paris
Tonn, Das et al.	An assessment of waste issues associated with the production of new, lightweight, fuel-efficient vehicles	Journal of Cleaner Production Volume 11, Issue 7, November 2003, Pages 753-765	2003
Tobias Wiesenthal, Ana Condeço-Melhorado, Guillaume Leduc	Innovation in the European transport sector: A review	Innovations in transport sector, more than waterborne transport alone	Elsevier Transport Policy, 2015
Bastein, Koers, Dittrich, Becker, Lopez	Business barriers to the uptake of resource efficiency measures	Polfree / collaborative project	2014
Various partners and authors	LNG Masterplan for Rhine-Main-Danube		2013-2015
DST, ÖIR, UB, SVA, SDG, PDI	Innovative Danube Vessel		2013-2015
Nicola Paltrinieri et al.	Risk reduction in road and rail LPG transportation by passive fire protection	Journal of Hazardous Materials	2009
Panteia et al. (Planco, Via Donau, SPB / EICB CCNR)	CONTRIBUTION TO IMPACT ASSESSMENT of measures for reducing emissions of inland navigation		2013
Polfree	Policy Options for a Resource-Efficient Economy		2014
IDVV	Platina 1 & 2		2013
Ecorys	Green growth opportunities for European shipbuilding	EC DG ENTR (now DG GROW)	2012
Elsevier	De Nederlandse boer loopt voorop in innovatie (Dutch farmer ahead in innovation).	http://www.elsevier.nl/Kennis/achtergrond/2015/5/Slimme-boer-Nederlandse-boer-voorop-in-innovatie-1758608W/	2015

Annex II : Overview of spreadsheets analysis

28 October 2015 SWP 1.3

		TRL	Average height of barriers per fleet family (1 2 3 4 5 6 7 8 9 10)	Barriers: Technical	Barriers: Legal	Barriers: Financial	Barriers: Knowledge	Barriers: Market	Barriers: Culture
Fuels, standardised solutions	Use LNG (Liquefied Natural Gas) - single fuel/ spark ignition	6	High / Med / Low	The technology is established; benefits are proven in other markets (esp. maritime shipping). Technical requirements on the Rhine are regulated by the Rhine Vessel Inspection Regulation (RVIR) and for the whole EU via directive 2006/87/EC. Both are under review to be adapted to LNG as fuel for inland vessels. Standardisation of fuel quality is needed as well as standarisation of the tanks and bunkering facilities. The availability of Bio LNG is regarded as a solution to lower the environmental footprint. LNG is a solution not fitting smaller ships.	Mannheim and Belgrade conventions are limiting financial policy approaches to enable higher uptake of the technologies. Uptake of these alternative fuels could be stimulated via other policy approaches: e.g. via environmental zoning in ports (local measure) or the adoption of EU wide emission levels. Ship-to-ship (un)loading is prohibited or restricted in some European ports (e.g. port by-laws Antwerp, Rotterdam and Strasbourg). Currently exemptions are given. CCNR and eu are developing policy to allow lng fueled vessels, which may take a few years but is likely before 2020	Installing LNG requires an investment of about 1 mil. EUR (D1.2, maybe more for existing ships - and usually only considered when engine replacement) is needed. Fluctuating diesel fuel prices can kill business cases as the price gap between LNG and diesel prices is shrinking (and create uncertainty). LNG should at least be 15% cheaper to make the business case viable. Hence, high investment costs, but lower operating costs (fuel costs). Currently vessel owners have hardly any means to invest and the financial sector is not willing to provide the means needed due to the uncertainty (D 1.2).	Limited knowledge of (potential/actual) benefits by users and financiers; Limited number of first movers. Skippers lack the knowledge on sailing ranges, refueling, bunker locations and risks. The CCNR RPN defines training requirements for vessel crew involved with bunkering. Other trainings are not sufficiently enough developed. There is no common approach in requesting risk assessments for LNG bunkering operations. LNG bunkering requires a much higher focus on safety and planning than conventional bunkering because of the hazards (cryogenic, explosion etc.).	Slight reduction of payload due to double fuel tanks or larger LNG tanks. Bunkering of alternative fuels is difficult due to limited number of bunkering facilities. Limited number of suppliers of engines and tanks (as a result of small market - chick vs egg)	Reluctance in the market for risks/change; mainly because of uncertainty in business cases and unbalanced benefits among owners/investors. The technical barriers are limited, but the non-technological barriers are more important (e.g. legal, financial, knowledge, market, culture). General public percieves risk
	Apply dual fuel (LNG and diesel)	6	High / Med / Low						
	Apply GTL fuel	9	High / Med / Low	Convential engines do not need to be modified. TRL is high as the technology is already applied in several fleets.	no possiblity for fuel taxation	GTL would not require large investments in material. The fuel though would cost appr. 10% more compared to standard fuel. Emissions benefits but no financial benefit.	Few knowledge problems concerning application, acceptance is high, risks similar to diesel fuel. Benefits are however not widely known	GTL is readily available on the market (but only one supplier Shell) - not used much outside NL - still tiny market.	Very similar to diesel, so step to GTL is quite easy to take. However reluctance to pay higher price
Propulsion system, standardised solutions	Right sizing	9	High / Med / Low	Limited technical barriers. When investing, it might be better to opt for more innovative engines/fuels.	Limited legal barriers as the approach is mature and legally embedded.	Market does not have means to invest in engines. The investment (done when technically needed) will eventually result in lower fuel- and maintenance costs, though aditionnal investmentss in for e.g. a gearbox could limit the benefits.	Limited barrier. The market is aware of the right sizing technique.	Small market due to low replacement rate due to long life span of engines,	Limited barrier. The market is aware of the right sizing technique. The engine replacement rate is low due to long life span of vessels.
	Exchange of main diesel engine (CCR I by CCR II engine)	9	High / Med / Low			Fluctuating diesel fuel prices creating uncertainty; Market does not have means to invest	Limited knowledge barrier as the approach is mature and legally embedded.	The engine replacement rate is low due to long life span of low speed engines 50-75.000 hours = 30-40 years |(much shorter for newer high speed engines). However when replacing, legally required to move to CCR-II	Limited cultural barrier as the approach is mature and legal. The engine replacement rate is low due to long life span of vessels.
	Exchange of main diesel engine (by Stage V engine)	5	High / Med / Low	Technical challenges are present as the solution is technically possible but stage V engines are not yet available for IWT (+- 2020).	Measure is technically possible but stage V engines are not yet available for IWT; no clarity on legal criteria whether they will be implemented	Fluctuating diesel fuel prices make business case uncertain; Market does not have means to invest in engines. The investment will eventually result in lower fuel- and maintenance costs though.	Limited knowledge as stage V engines for IWT are not yet available.	Market is also small and therefore engine producers are not very likely to produce large numbers of engines.	Limited knowledge as stage V engines for IWT are not yet available. The engine replacement rate is low due to long life span of vessels.
	Diesel-hybrid propulsion (no buffer batt.)	9	High / Med / Low	Technical challenges are low. Medium uncertainty on benefits as technology is not implemented a lot; but tests are well documented. Switch to hybrid more complex than switch just normal engine\ relativey big impact of conversion	No legal barriers	Investment in dual engine can be considerable. Certainly the battery option might result in high investment costs. Benefits not known/not determined.	Limited barrier. Could be promoted more in the sector. No knowledge of business case / benefits	Slightly less payload when implemented in small ships, but effect is negligible.	Reluctuance in the market for risks/change.
	Diesel-hybrid propulsion (+ buffer batt.)	7	High / Med / Low	Idem. Technology not ready and only relevant for ships with specific operational profile			Limited barrier. Could be promoted more in the sector. Uncertainty on effects of buffer battery.		

Annex II. PROMINENT technologies linked to main barriers (part 1)

		TRL	Average height of barriers per fleet family (1 2 3 4 5 6 7 8 9 10; High / Med / Low)	Barriers: Technical	Legal	Financial	Knowledge	Market	Culture
Auxiliary systems	Apply SCR (selective catalytic reduction)	8		limited technical challenge; space required	Limited barrier; no legal requirement in place yet; technology not stimulated by current legislation	Barrier as market has limited financial means to invest, on side of financial sector no willingness to provide means needed (no earning back potential)	Unknown if the performance of the vessel will indeed increase (and, if so, how much)	Limited barrier	Market does not have means to invest: Reluctance of stakeholders; benefit of emission savings not linked to investment
	Wall flow DPF	7		technical challenge, space required; back pressure may be an issue					
	Combine SCR and DPF	7							
Waterway Information	Real time info on fairw. data (link to energy.eff.nav.)	5/7		install echo sounders on all ships - positioning is critical esp for push boats because of turbulence; challenge with data collection & modelling. complex structure of integrated database (fairway, fleet ,velocity etc.) & modelling	Limited barrier as long as the sharing of information is based on a voluntary basis. In case the system becomes compulsory, privacy issues should be considered. ; liability in case advice proves wrong (data errors, modelling error margins)	Limited barrier for participants. Part of the investment is done by skippers (obtaining the data collection software) and the waterway authority (enabling the sharing of information). Business case for potential (commercial?) operator highly uncertain. benefits for users also uncertain, for now high	Medium barrier; Currently knowledge on the technology and benefits is limited	Limited barrier; setting up such a system is a joint effort of the skippers (providing the necessary information) and the waterway authority (collecting information and sharing it again with the participants).	Reluctuance in the market for risk/change
Sailing behaviour	Smart and energy-eff.nav. (speed adaption)	5		Technology is still under development. Especially optimised track choice models.Investments and cooperation in the supply chain are required to fully realise the potential savings via the technology.	Limited or non-existing legal barriers. Liability issue from ship's perspective	Limited barrier. Investment sums are rather low in comparison to other technological approaches. Investments should be undertaken by waterway management authorities (ensure information sharing)	Limited barrier. Currently knowledge on the technology and benefits is limited. More promotion is needed. Missing information on fairway / fleet behaviour (esp. Danube), uncertainty over benefits	Limited maket barrier. The whole supply chain incl. terminals (berth planning etc.) should be involved in the optimising of sailing speeds.	Reluctance in the market for risk/change. Though, investments are relatively low, it is of key importance that all supply chain stakeholders cooperate. Willingness for system uptake might differ across Rhine and Danube regions
	Smart and energy-eff.nav. (optimised track choice)	5							

Annex II PROMINENT technologies linked to main barriers (part 2)

Annex II : Breakdown of barrier assessment

Height of barriers	Passenger vessels	Other push boats <500 kW	Push boats 500-2000 kW	Push boats >=2000 kW	Motor vessel dry cargo >=110m	Motor vessel liquid cargo >=110m	Motor vessel dry cargo 80-109m	Motor vessel liquid cargo 80-109m	Motor vessel <80m	Coupled convoy
1 Use LNG (Liquefied Natural Gas) - single fuel/ spark ignition	**3,8**	**5,0**	**5,0**	**5,0**	**3,3**	**3,3**	**3,7**	**3,7**	**4,0**	**3,2**
Technical barriers	5	5	5	5	3	3	4	4	5	3
Legal barriers	4	4	4	4	4	4	4	4	4	4
Financial barriers	4	4	3	3	3	3	4	4	5	3
Knowledge barriers	3	2	2	2	2	2	3	3	3	2
Market barriers	4	4	4	5	5	5	4	4	4	4
Culture barriers	3	3	3	3	3	3	3	3	3	3
2 Apply dual fuel (LNG and diesel)	**3,5**	**5,0**	**5,0**	**5,0**	**2,7**	**2,7**	**3,5**	**3,5**	**3,8**	**2,7**
Technical barriers	4	5	5	5	2	2	3	3	4	2
Legal barriers	4	4	4	4	4	4	4	4	4	4
Financial barriers	4	4	3	3	3	3	4	4	5	3
Knowledge barriers	3	2	2	2	2	2	3	3	3	2
Market barriers	4	4	3	3	3	3	5	5	5	3
Culture barriers	2	2	2	2	2	2	2	2	2	2
3 Apply GTL fuel	**1,8**	**1,8**	**1,8**	**1,8**	**1,8**	**1,8**	**1,8**	**1,8**	**1,8**	**1,8**
Technical barriers	1	1	1	1	1	1	1	1	1	1
Legal barriers	1	1	1	1	1	1	1	1	1	1
Financial barriers	3	3	3	3	3	3	3	3	3	3
Knowledge barriers	2	2	2	2	2	2	2	2	2	2
Market barriers	2	2	2	2	2	2	2	2	2	2
Culture barriers	2	2	2	2	2	2	2	2	2	2
4 Right sizing	**1,7**	**1,7**	**1,7**	**1,7**	**1,7**	**1,7**	**1,7**	**1,7**	**1,7**	**1,7**
Technical barriers	1	1	1	1	1	1	1	1	1	1
Legal barriers	1	1	1	1	1	1	1	1	1	1
Financial barriers	2	2	2	2	2	2	2	2	2	2
Knowledge barriers	1	1	1	1	1	1	1	1	1	1
Market barriers	3	3	3	3	3	3	3	3	3	3
Culture barriers	2	2	2	2	2	2	2	2	2	2
5 Exchange of main diesel engine (CCR I by CCR II engine)	**1,8**	**1,8**	**1,8**	**1,8**	**1,7**	**1,7**	**1,8**	**1,8**	**1,8**	**1,7**
Technical barriers	1	1	1	1	1	1	1	1	1	1
Legal barriers	2	2	2	2	2	2	2	2	2	2
Financial barriers	3	3	3	3	3	3	3	3	3	3
Knowledge barriers	1	1	1	1	1	1	1	1	1	1
Market barriers	3	3	3	3	2	2	3	3	3	2
Culture barriers	1	1	1	1	1	1	1	1	1	1
6 Exchange of main diesel engine (by Stage V engine)	**3,2**	**3,2**	**3,2**	**3,2**	**3,0**	**3,0**	**3,2**	**3,2**	**3,2**	**3,0**
Technical barriers	3	3	3	3	3	3	3	3	3	3
Legal barriers	4	4	4	4	4	4	4	4	4	4
Financial barriers	4	4	4	4	4	4	4	4	4	4
Knowledge barriers	2	2	2	2	2	2	2	2	2	2
Market barriers	4	4	4	4	3	3	4	4	4	3
Culture barriers	2	2	2	2	2	2	2	2	2	2
7 Diesel-hybrid propulsion (no buffer batt.)	**2,2**	**2,2**	**2,2**	**2,2**	**2,2**	**2,2**	**2,2**	**2,2**	**2,2**	**2,2**
Technical barriers	2	2	2	2	2	2	2	2	2	2
Legal barriers	1	1	1	1	1	1	1	1	1	1
Financial barriers	3	3	3	3	3	3	3	3	3	3
Knowledge barriers	4	4	4	4	4	4	4	4	4	4
Market barriers	2	2	2	2	2	2	2	2	2	2
Culture barriers	1	1	1	1	1	1	1	1	1	1
8 Diesel-hybrid propulsion (+ buffer batt.)	**2,5**	**5,0**	**5,0**	**5,0**	**5,0**	**5,0**	**5,0**	**5,0**	**5,0**	**5,0**
Technical barriers	3	3	3	3	3	3	3	3	3	3
Legal barriers	1	1	1	1	1	1	1	1	1	1
Financial barriers	4	5	5	5	5	5	5	5	5	5
Knowledge barriers	2	2	2	2	2	2	2	2	2	2
Market barriers	3	3	3	3	3	3	3	3	3	3
Culture barriers	2	2	2	2	2	2	2	2	2	2

Height of barriers	Passenger vessels	Other push boats <500 kW	Push boats 500-2000 kW	Push boats >=2000 kW	Motor vessel dry cargo >=110m	Motor vessel liquid cargo >=110m	Motor vessel dry cargo 80-109m	Motor vessel liquid cargo 80-109m	Motor vessel <80m	Coupled convoy
9 Apply SCR (selective catalytic reduction)	**1,8**	**2,2**	**2,2**	**2,2**	**2,2**	**2,2**	**2,2**	**2,2**	**2,2**	**2,2**
Technical barriers	2	2	2	2	2	2	2	2	2	2
Legal barriers	1	1	1	1	1	1	1	1	1	1
Financial barriers	3	4	4	4	4	4	4	4	4	4
Knowledge barriers	1	1	1	1	1	1	1	1	1	1
Market barriers	2	2	2	2	2	2	2	2	2	2
Culture barriers	2	3	3	3	3	3	3	3	3	3
10 Wall flow DPF	**2,0**	**2,3**	**2,3**	**2,3**	**2,3**	**2,3**	**2,3**	**2,3**	**2,3**	**2,3**
Technical barriers	3	3	3	3	3	3	3	3	3	3
Legal barriers	1	1	1	1	1	1	1	1	1	1
Financial barriers	3	4	4	4	4	4	4	4	4	4
Knowledge barriers	1	1	1	1	1	1	1	1	1	1
Market barriers	2	2	2	2	2	2	2	2	2	2
Culture barriers	2	3	3	3	3	3	3	3	3	3
11 Combine SCR and DPF	**2,0**	**2,3**	**2,3**	**2,3**	**2,3**	**2,3**	**2,3**	**2,3**	**2,3**	**2,3**
Technical barriers	3	3	3	3	3	3	3	3	3	3
Legal barriers	1	1	1	1	1	1	1	1	1	1
Financial barriers	3	4	4	4	4	4	4	4	4	4
Knowledge barriers	1	1	1	1	1	1	1	1	1	1
Market barriers	2	2	2	2	2	2	2	2	2	2
Culture barriers	2	3	3	3	3	3	3	3	3	3
12 Real time info on fairw. data (link to energy.eff.nav.)	**2,8**	**3,0**	**3,0**	**3,0**	**2,8**	**2,8**	**2,8**	**2,8**	**2,8**	**3,0**
Technical barriers	4	5	5	5	4	4	4	4	4	5
Legal barriers	3	3	3	3	3	3	3	3	3	3
Financial barriers	3	3	3	3	3	3	3	3	3	3
Knowledge barriers	3	3	3	3	3	3	3	3	3	3
Market barriers	2	2	2	2	2	2	2	2	2	2
Culture barriers	2	2	2	2	2	2	2	2	2	2
13 Smart and energy-eff.nav. (speed adaption)	**2,8**	**2,8**	**2,7**	**2,7**	**2,7**	**2,8**	**2,8**	**2,8**	**2,8**	**2,7**
Technical barriers	4	4	4	4	4	4	4	4	4	4
Legal barriers	3	3	3	3	3	3	3	3	3	3
Financial barriers	2	2	2	2	2	2	2	2	2	2
Knowledge barriers	3	3	3	3	3	3	3	3	3	3
Market barriers	2	2	2	2	2	2	2	2	2	2
Culture barriers	3	3	2	2	2	3	3	3	3	2
14 Smart and energy-eff.nav. (optimised track choice)	**2,8**	**2,8**	**2,7**	**2,7**	**2,7**	**2,8**	**2,8**	**2,8**	**2,8**	**2,7**
Technical barriers	4	4	4	4	4	4	4	4	4	4
Legal barriers	3	3	3	3	3	3	3	3	3	3
Financial barriers	2	2	2	2	2	2	2	2	2	2
Knowledge barriers	3	3	3	3	3	3	3	3	3	3
Market barriers	2	2	2	2	2	2	2	2	2	2
Culture barriers	3	3	2	2	2	3	3	3	3	2

Five-point scale: 1. Very low / 2. Low / 3. Medium / 4. High / 5. Very high / Red indicates that barrier is prohibitive to uptake