Assessment of the scalability of (hydrogen) retrofit solutions as a greening solution across the inland waterway fleet

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Figure 1. *3D image of the Maas, Waal, and Rijn in Rotterdam.*

Abstract

The central commission for navigation on the Rhine (CCNR) has set an ambition of a 35% reduction in emissions by 2035. This paper aims to translate these ambitions into clearer targets for the industry. The paper analyzes how many vessels in the Dutch inland waterway fleet need to be zero emissions (ZE) by 2035 to meet the goal, and investigates two pathways to reach that number: retrofitting and replacement by newbuild. This paper then discusses the integration of hydrogen (H2) into non-port (re)fuelling infrastructure for inland waterways, with the aim of achieving 100% emission reduction. The focus is on proton-exchange membrane fuel cell (PEFMC) propulsion systems and key parameters for retrofitting vessels to hydrogen propulsion, such as H2 production and shipyard capacity. Our findings show that while hydrogen propulsion technologies and Green H2 production will be available at sufficient capacity, the clear bottleneck is shipyard (retrofitting) capacity.

1. Introduction

This paper addresses the integration of hydrogen (H_2) into non-port (re)fuelling infrastructure for inland waterways in combination with the industry's stated goals and ambitions. To achieve these aims, it is necessary to evaluate a number of aspects, including H_2 infrastructure, crew trainings as well as H_2 vessel integration on a macro scale that is still to be developed.

The focus is on the fleet requirements to meet the goals using proton-exchange membrane fuel cell (PEFMC) propulsion systems fuelled by green H_2 as a 100 % emission reduction solution. All other emission-reduction solutions would require dedicated analyses and can be scaled up correspondingly. A solution that provides 50% emission reduction would require a fleet twice as large to achieve similar levels of emissions reductions. Based on its experience in inland waterway navigation and conversion of the FPS Maas to hydrogen propulsion, Future Proof Shipping analysed the industry goals and identified the main challenges in this complex scaling-up process.

The Central Commission for the Navigation of the Rhine has set a goal of 35% reduced emissions in its region by 2035 (CCNR, 2022) for the industry. What does this mean for inland waterways and their operators in the coming 12 years?

Surprisingly, it is not always clear how this goal translates into reality. To try to establish this, we first investigated how many vessels in the Dutch inland waterway fleet would need to be zero emissions (ZE) by 2035 to meet the 35% emission reduction goal. To estimate this number, we performed two analyses: an estimation based on energy consumption and an estimation based on total number of vessels. Next, we investigated two possible pathways to reaching the number of estimated ZE vessels: retrofitting and replacement by newbuild. Thirdly, since the number of required ZE vessels is substantial, we investigated the shipping routes that would have highest impact on the emission reduction. In addition, we explored key parameters for retrofitting vessels to hydrogen propulsion such as H_2 production, and shipyard capacity. While forecasted hydrogen production can accommodate the general goal, the clear bottleneck seems to be the required capacity of shipyards.

2. Sizing the future zero emission fleet

While several available studies indicate certain goals in terms of CO_2 reduction (35% by 2035), it is not clear what this means for the inland waterway fleet. For example, how many ships need to be converted to ZE solutions to achieve the set goals?

The 35% reduction envisaged by the CCNR pertains to all active vessels. However, not all vessels have the same carbon footprint. This means that we have two possible means via which to achieve the desired reduction.

According to CCNR (2022), total transport in NL is around 48,000 million ton-kilometers (tkm) per year. Looking at the reference case of FPS Maas (Godjevac & Veen, 2021), for a 200 km trip approximately 674 kg of H_2 is required. Assuming the ship transported around 2,000 tons of goods, the specific consumption of H_2 is around 600 tkm/kg. The 35 % of annual transport is 16,800 million tkm per year or 46 million tkm per day which equals around 76,67 tons of H_2 per day.

Looking back at the case of the FPS Maas and estimated daily transport, 115 ships like FPS Maas need to be converted to zero emission. In the case of 135 m vessels with double the cargo capacity, the figures are somewhat lower; then the required number would be roughly 58.

These numbers (58 and 115) consider only the sailing times and, as a result, refer to the number of vessels that need to be sailing on any given day (to transport 46 million tkm per day). In order to come to an estimate, we need to consider the total number of ZE vessels in the fleet that would ensure 46 million tkm are transported per day, waiting times in harbours and asymmetric cargo load profiles (upstream/downstream). When harbour times are considered, the number of vessels needs to be corrected by a factor of 2. When the asymmetric cargo load profile is considered, the number should be corrected by additional factor of 2, resulting in a total estimated ZE fleet size of 232 FPS Rijn type vessels (135m) or 460 FPS Maas type vessels (110m).

Another approach to estimate the number of ships that need to be converted to zero emission is to look at the Dutch fleet size. According to CCNR (2022) there are 1,683 dry cargo vessels with capacity larger than 1,500 tonnes. If all emissions are uniformly distributed over the fleet, then 589 vessels need to be converted to ZE propulsion.

3. What it takes to get to zero

There are several aspects that need to be considered with regards to achieving the ZE fleet. These aspects are related to the H_2 production, shipyard capacity, prioritisation of most promising ship candidates and shipping routes, technology readiness of ZE technology and regulatory aspects.

3.1 H_2 production

Let us consider the feasibility of each of these scenarios. In the first instance, it is crucial that there be sufficient hydrogen production to fuel the required number of vessels. Given its strategic location on the Rhine Basin network, and its ambitions to advance the hydrogen revolution, it is likely that the Netherlands will play a key role in fuelling the clean inland vessels of the future. The country already stands at the forefront of the European hydrogen transition, thanks to the energy resources it enjoys and the subsequent infrastructure and expertise it has developed in the field.

The Netherlands is currently Europe's second largest producer of hydrogen, with an output of 9 million m^3 per year. Presently, this is completely fossil-based. However, The Netherlands has the ambition to have 3-4 GW of electrolyser capacity available by 2030, capable of producing 540.000 tonnes of clean H_2. Assuming the country is successful in its ambitions, and given its current capabilities there is every reason to do so, then the outlook for hydrogen availability for the inland fleet is promising.

3.2 Shipyard capacity

The average annual registrations of newbuild dry cargo vessels (>1500 tonnes) between 2017-2021 was roughly 19.2 per annum (CCNR, 2022). If we assume that 60% of those vessels were built in the Netherlands, we can estimate a newbuild capacity of Dutch shipyards of 11.5 vessels per year. At this rate it would take in the region of 40-51 years to replace the required 460-589 vessels in the Rhine fleet with ZE vessels, with only 138 ZE vessels newly built by 2035.

Against this context, the case for retrofitting is significantly more favourable. Based on our experience retrofitting the FPS Maas, we estimate that retrofitting a vessel to hydrogen propulsion takes roughly half the time of newbuilding a vessel. Using the estimated 11.5 vessel newbuild capacity at Dutch shipyards, this would translate to roughly 23 retrofits per year, resulting in a maximum total of 276 vessels retrofitted to ZE propulsion by 2035. Here it is clear, that in order to achieve the 35% emission reductions goal, Dutch shipyard capacity will need to undergo a significant and rapid expansion of capacity within the decade. In the meantime however, we should prioritize which vessels and routes have the highest impact, so that the maximum feasible reduction in emissions can be achieved using existing shipyard capacity.

3.3 How do we prioritize which ship types should be retrofitted?

Cargo transport on the traditional Rhine (between Basel, Switzerland and the German border with the Netherlands) amounted to 168.6 million tonnes in 2021. The busiest part of this route was Emmerich with 138 million tonnes of cargo.

Further investigation reveals that around 60% of inland navigation is related to export and Emmerich takes around 82% of traditional Rhine transport, therefore is it plausible to assume that the Rotterdam-Duisburg section carries the largest share of cargo transport. The section forms part of the Lower Rhine route, which in 2021, saw transport of 138.1 million tonnes of cargo (CCNR, 2022). As a result, it is along this section that vessels are presently producing the most emissions.

Given that information, we are able to identify which vessels should be prioritised for conversion in order to have the largest impact on the overall emissions produced on the network.

4. Now that we know what to prioritise, what are the next steps?

4.1 Technical complexity

The main vessel types operating on this stretch of the inland waterway network are 110m/135m container, dry bulk and tanker vessels. Of these, dry cargo vessels, including container vessels make up the largest segment, representing 70% of the total. They have, therefore potential to contribute a significant emissions reduction.

From an emissions reductions and technical complexity standpoint, prioritising vessel types with the simplest relative conversion complexity would yield the largest reduction in emission in the shortest time possible given current shipyard capacity and retrofit knowhow.

In this context, of the three main vessel types, conversion of container vessels is the least complex. This is due to the available space on board. In our experience, inland container vessels are on average loaded to 80% capacity during regular operations. Therefore, the unutilised space in the cargo hold can be used to host a retrofit ZE propulsion system without a loss of earning capacity for the vessel. In addition, container vessels also operate between container terminals which makes them suitable for H2 swappable container solutions.

The next most appropriate vessel type is dry bulk cargo vessel. Readying this type of vessel for a retrofit system would not require any major overhaul of the hull, only minor customisations. However, the terminals where they operate will have to ensure availability of cranes for H2 swapable solutions or hydrogen bunkering facilities.

The tanker vessel type presents more of a challenge, requiring removal of some of the tanks, and potentially the custom creation of a resized tank to replace them, in order to make space for the retrofitted propulsion system.

4.2 Technology readiness

There are type approved PEMFC systems that are readily available in the market today. The FPS Maas and FPS Waal will both have such systems onboard. Regarding H2 storage, several different H_2 containers that can meet the technical requirements, such as 40 ft swappable containers, are also available in the market today and more advanced containers with larger storage capacities are currently being developed. Furthermore, as H_2 infrastructure develops further, other types of refuelling will be possible.

5. What could help speed up the process?

5.1 Shipyard Expertise

Many Dutch shipyards are already undertaking greening projects for inland vessels. These projects are diverse, covering different levels of emissions reduction and a wide range of different technology. This is all advantageous, as it means that the shipyards are gaining experience in the field. They are, however, still at an early phase and there is a long way to go.

5.2 Port preparedness

In general, there is open-mindedness regarding new fuels in ports and terminals. There remains, however, some scepticism. There are a number of reasons for this. In some areas there are concerns regarding investment in preparation at a stage when new fuels are at a stage of immaturity and there is a lack of certainty regarding customers' use of them in such a dynamic environment. This has been seen previously in the case of the well-known 'chicken and egg' LNG scenario.

A simple step that would make a large difference and speed up the transition, however, would be for each port to allocate one crane for dedicated swapping of H_2 containers.

5.3 Regulations

At the time of writing, the regulatory developments continue to follow the developments of technology. This is a logical approach because, as we have seen above, it is impossible to make accurate predictions regarding the timeline of capabilities. Governments and regulatory bodies need to develop new standards and guidelines for the use of hydrogen fuel in the maritime industry, and operators may need to invest in training and safety equipment to ensure the safe use of hydrogen propulsion systems. From experience, FPS Maas took about 2.5 years for approval while for the approval of the FPS Waal it is around 6 months. This demonstrates the preparedness of regulatory bodies to quickly adapt to new solutions.

6. Discussion and conclusion

In our analysis we used several assumptions to estimate the overall feasibility of 35% emissions reduction for the Dutch fleet. In our work we concluded that the biggest bottleneck for meeting the goal is the shipyard capacity. Besides the capacity, from experience we know that retrofitting an inland vessel to hydrogen propulsion is a steep learning curve, so many stakeholders need to develop knowledge first. We deliberately focused on H_2 and neglected to analyse other zero emission solutions and other emission reduction pathways as these require dedicated analysis. One of the candidates for zero emissions solutions are definitely batteries and we expect them to play a significant role in decarbonising on short distance applications and smaller vessels.

However, the main conclusion would still be the same even if the batteries are to be considered because the ships would have to go through electrification retrofit and/or be newly built. The important thing is to act fast and invest in retrofitting now in order to be sure of on-time completion. Another recommendation would be to identify the ship routes with highest impact today and expected impact in 2035 when hopefully the demand for fossil fuels will reduce. On the other hand, we don't see bottlenecks in other aspects, such as H_2 supply, H_2 distribution and even regulation is little of a hurdle.

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