Hydrogen HOPE for the Nordics: Shipping as a frontrunner

Julia Hansson, IVL Swedish Environmental Research Institute
Erik Fridell, IVL Swedish Environmental Research Institute
Johan Burgren, PowerCell Sweden AB
Brynhildur Davíðsdóttir, University of Iceland
Mattias Goldmann, Swedish 2030-secretariat
Karl Jivén, IVL Swedish Environmental Research Institute
Kevin Koosup Yum, SINTEF Ocean, Norway
Mauricio Latapí, University of Iceland
Helena Lundström, IVL Swedish Environmental Research Institute
Rasmus Parsmo, IVL Swedish Environmental Research Institute
Dag Stenersen, SINTEF Ocean, Norway
Per Wimby, Stena Rederi AB, Sweden
David Cook, University of Iceland

Background

Maritime transportation is one of the key remaining sectors to be decarbonized in the Nordics, with other industry having largely moved out of the fossil fuel-era or designed concrete strategies for this, and cars, buses and trucks switching to renewable fuels and electricity at a high pace – Norway, Iceland and Sweden all being world-leaders in this. The Nordic region is to become the most sustainable and integrated region in the world by 2030 (1). There is also the aim for a carbon-neutral Nordic region (2). Being open, export-oriented economies with a large share of the trade done by maritime transport, a low-carbon and competitive shipping sector is highly relevant for the Nordics. Furthermore, key connections between the people of the Nordics are done through waterways, including Finland-Sweden, Denmark-Norway, and Denmark-Sweden.

In this context, the introduction of alternative low-carbon fuels is a necessary complement to energy efficiency improvements for reducing greenhouse gas (GHG) emissions (as well as other harmful emissions), as other measures are not sufficient. There are several maritime fuel options, with varying technological readiness level but some with large potential as they can represent zero carbon fuels. Thus, it is important to learn more about the possibilities and impacts of hydrogen-based solutions for shipping in the Nordic region as they are not yet introduced in large-scale.

With this, as well as the Clydebank Declaration for Green Shipping Corridors (3), as a background, the Ministers of Environment and Climate from Denmark, Finland, Iceland, Norway, Sweden, Faroe Islands, Greenland, and Åland in May 2022 signed a joint declaration for the creation of zero-emission ferry routes between the Nordic countries (4). The overall aim of the declaration is to help the Nordic shipping industry accelerate its transition towards new fuels and propulsion technologies that have low emissions throughout their value chain, from production to end use. The Ministers agreed to focus on the ferry segment and to promote the creation of zero-emission ferry routes between Nordic countries. This would allow key stakeholders to gain experience and test new fuels and technologies in pilot projects involving short ferry routes.

The HOPE project

The research project HOPE (Hydrogen fuel cells solutions in shipping in relation to other low carbon options – a Nordic perspective) has addressed how regional shipping in the Nordic region can transition to become fossil-free (https://www.nordicenergy.org/project/hope/). The project partners are IVL Swedish Environmental Research Institute, SINTEF Ocean AS, University of Iceland, Stena Rederi AB, PowerCell Sweden AB and – for communication – the Swedish 2030-secretariat.

The project aimed at clarifying the potential role of hydrogen based marine solutions in reducing the Nordic GHG emissions. It has been centered around a typical ROPAX-vessel (a ferry transporting passengers and goods) with an operating distance of around 100 nautical miles, for which a conceptual design for operation with hydrogen as fuel and fuel cells for propulsion has been outlined (Figure 1). The conditions include technical design and costs of fuel systems, handling, and powertrains in relation to other fuels options such as ammonia, methanol, and batteries (5, 6) as well as an analysis of barriers and drivers for the realization of such ships (7, 8). Strategies and the potential of producing these fuels in the Nordic region were reviewed from a shipping perspective (5). A potential uptake of these technologies/fuels by Nordic shipping was assessed and the emissions of climate gases and air pollutants were calculated.

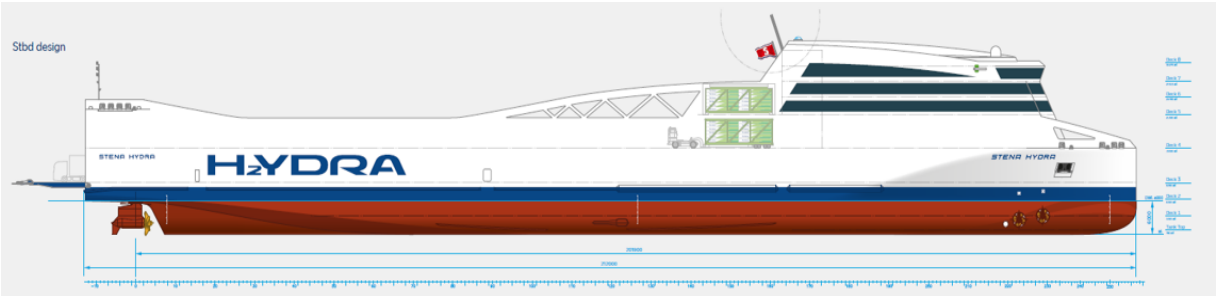

Figure 1. Illustration of the concept design for the studied vessel (Stena Teknik).

Insights

The HOPE project has gained several insights, including:

- Hydrogen in some form (liquefied, compressed, ammonia, or electro-fuels), may be an interesting solution for long-term reduction of shipping's GHG emissions. However, we expect a limited introduction of hydrogen and associated fuels in the next ten years, even though there are some initiatives to introduce hydrogen for shipping, mainly in Norway.
- For regional shipping in the form of ROPAX vessels between the Nordic countries, hydrogen could be an interesting future solution, but electrification has advantages on certain routes though often with electrical power challenges. Case-route-specific assessments are needed.
- Using hydrogen for a regional ROPAX vessel, between the Nordic countries is found to be technically feasible. A concept design has been developed focusing on fuel cells for propulsion, and storage of hydrogen in compressed or liquefied form. Fuel cell systems in the megawatt range are needed.
- Hydrogen-based solutions for regional shipping may not be the lowest cost option at present and will require increase in electricity production but considerable cost reductions are expected in the future. There are also uncertainties linked to the cost for other options such as renewable methanol or electricity.

- Barriers for the introduction of hydrogen in shipping include economic, technological, organizational, and behavioral aspects. Economic barriers are currently regarded the most challenging but also lack of infrastructure, green hydrogen supply, and regulations/standards have been lifted. Further, uncertainties about costs and high risks are hindering the development in the Nordic region.
- There is a general global lack of knowledge of hydrogen as energy carrier, shipowners and ship operators are unaccustomed to operate the technology, and there are questions to solve about the safety for maritime applications. However, hydrogen solutions for shipping must be tested in parallel with the development of rules and regulations and cannot wait for them to be finally adopted first.
- Even with significant plans for hydrogen production in the Nordics, it is uncertain what amount of hydrogen that will be available for shipping. Relatively few of the Nordic projects for hydrogen production clearly address the possible use in shipping, and the expansion of bunkering infrastructure for hydrogen in different forms is an extensive task.
- It is possible to substantially reduce the GHG emission from Nordic shipping by introducing hydrogen-based marine fuel options by 2030-2050. Further, other emissions such as nitrogen oxides (NOx) and particles would decrease significantly.
- Drivers for hydrogen in Nordic shipping include EU and national policy proposals for the transition of the shipping sector, the hydrogen economy in general and a willingness from shipping companies to decarbonize their operations. Thus, there is a growing interest in sustainable marine fuels in the Nordics, including green hydrogen.
- Policies are crucial for the shipping sector's transition. Details in the policy design can be crucial for the prerequisites for various options not the least for hydrogen-fuel cell solutions.

Policy recommendations

The project delivers several policy conclusions on how to fast track to Vision 2030 and specifically how to deliver on the declaration on zero-emission ferry routes between the Nordic countries:

- Zero-emission ferry routes between the Nordic countries should be prioritized due to the potential to replace fossil-fuel powered ferries, and the climate benefits this would lead to.
- Sufficient public economic support is needed to bridge the cost difference between fossil solutions and renewable ones for Nordic shipping actors. There is a need for pilot projects to promote technical maturity and reduce costs. The high costs and risks for first mover shipping actors need to be shared by the society.
- Regional and clearly coordinated policies are needed for a wider adoption of hydrogen and fuel cells in the Nordics. Coordination of polices for the energy and shipping sector is also important.
- Green hydrogen and green hydrogen-based fuels should be a prioritized energy carrier, as it would help position the Nordic countries as a center of excellence within the nascent hydrogen economy, and since it is well-suited to the increased fluctuations of the Nordic electricity production due to an increased share of wind and solar. Policy interventions would be needed to facilitate the adoption of hydrogen and to address the barriers associated with their use, including the high costs, lack of supply, lack of infrastructure and the uncertainty and high risks for early adopters.

- The price of fossil fuels in shipping needs to increase; the current price of heavy fuel oil, marine gas and diesel oil, and liquified natural gas does not incorporate all the external costs to society from their production and consumption. Whilst the scope in HOPE has been the Nordics, addressing this issue through the EU Emissions Trading System (ETS) is seen as a key policy instrument to help achieve this. Part of the incomes in the ETS system should be used to help fund investments by early adopters in alternative fuel and propulsion systems for regional shipping.
- The Nordic countries will gain from jointly pushing the development of policies for decarbonizing shipping in the EU and in the International Maritime Organization (IMO).

Further research

Bearing in mind how immature the subject of hydrogen for shipping is, it comes as no surprise that several areas are not yet at the level of policy recommendations, but need more insights gained from additional research and early field trials. This includes:

- *What economic incentives are the most efficient for sustainable shipping based on hydrogen in the Nordics and at the EU level?* How can these best be introduced at national level in the Nordics and be the next steps of the already decided policies in the EU?
- *How can sustainable energy best be used in shipping*; a what-goes-where is urgently asked for by shipowners and policy makers alike, including what ships should use which fuel and to what extent drop-in of fuel and hybrid solutions are needed.
- *What is the point of entry for hydrogen in shipping?* Would it, for instance, be relevant to support hydrogen solutions for small scale vessels (not covered by proposed policy initiatives in the EU) or auxiliary systems to gain insights which can be used when hydrogen is later introduced in more large-scale vessels? Development of rules and regulations to meet safety challenges linked to hydrogen as fuel for ships is also needed.
- *How can the cost of hydrogen in shipping be brought down*? Subjects for further research include the mixing of hydrogen with methane (natural gas or biogas), to reduce the need for specific adaptations, use the already existing fleet of gas driven ships and reduce the need for space on the ships.
- *How to increase the production of hydrogen and to expand the distribution and infrastructure for hydrogen?* What is the potential role of ports as hydrogen hubs?
- *To what extent can hydrogen for shipping and land transport be combined?* With the new alternative fuels infrastructure regulation (AFIR) directive from the EU, a green hydrogen infrastructure for land transport must be established at pre-determined intervals. If this can be shared with the shipping, using the ports that are relevant for both transport modes, costs will be shared, and initial demand might increase.
- *Definition of green hydrogen (and ammonia).* The EU has hitherto failed to reach consensus on what constitutes green hydrogen. Potentially, the well-to-wheel GHG emissions (also including methane and nitrous oxides) can be the deciding criteria. The actual climate and environmental performance of hydrogen based marine fuels is however still uncertain due to the lack of knowledge on real emissions. Other environmental impacts linked to various alternative fuels also need to be further assessed.

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