HØST PTX ESBJERG

LITEHAUZ MARITIME ENVIRONMENTAL CONSULTANCY

Nordic Roadmap
Future Fuels for Shipping

Ammonia as a transition fuel- barriers and solutions

Pilot study report

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Executive summary

Ammonia is a well-known cargo, but new as fuel for propulsion of vessels. It is attractive for the green transition in shipping, as it does not lead to CO_2 emissions, considering only the "Tank-to-Wake" perspective, as the fuel itself contains no carbon, and it can be produced sustainably from water, air, and electricity. The HØST Power-to-X (PtX) project is a flagship initiative considered by Copenhagen Infrastructure Partners (CIP) and situated in Esbjerg, Denmark. The proposed plant will ensure efficient use of the electricity being fed into the Danish energy system from the planned 10 GW offshore wind build-out in the North Sea. The annual outcome of the CO_2-free production process would be 100,000 tonnes green hydrogen, and one possible end-product is 600,000 tonnes green ammonia via the Haber-Bosch process.

One offtaker for green ammonia is the maritime transport hub in Esbjerg, specifically the Esbjerg-Immingham Ro-Ro route operated by DFDS. This Nordic Roadmap pilot study on ammonia was initiated in 2023 as an early-stage pilot related to the HØST PtX project. Based on interviews with public and private stakeholders and commercial actors in an ammonia supply chain, a mapping of the stakeholder concerns and the encountered barriers was developed. Key actors were HØST PtX, DFDS, Port of Esbjerg, Monjasa, and Unifeeder, with LITEHAUZ as pilot facilitator and author of this report.

As per early 2025, HØST PtX is still in the feasibility and pre-investment stage without reaching final investment decision and is now focusing on hydrogen as end-product. While this is obviously a setback for this ammonia pilot study, it is emphasized that several other potential pilot projects exist in Denmark and the Nordic countries with Danish lead partners. The main offtaker, DFDS, has yet to select an alternative fuel for the UK route from Esbjerg, although both ammonia and hydrogen remain possibilities. DFDS is also investigating ammonia as a fuel for their route between Sweden and Belgium (PortSEurope 2024).

The deselection of ammonia is a consequence of the assessment of the market. Currently, the investment needed is considered too risk-prone when offtakers are available for hydrogen. The following recommendations are given for barriers and solutions:

- Ensure financial planning capacity via access to sufficient green power, for example through affordable long-term Power Purchase Agreements (PPAs) and predictable management of grid tariffs. This requires a significant expansion of renewable energy sources in Denmark supported by state incentives, policies, and regulatory frameworks.
- Support is needed through addressing regulatory frameworks and providing incentives for first-movers in a nascent market. While CAPEX investments need to be supported the technical issues are not considered major barriers to execution of ammonia production.
- It is reported very important to establish funding mechanisms for green corridor projects that aim to ensure a price gap on OPEX can be covered for a reasonable duration.
- Governments and organisations should ensure competitive conditions and a level playing field for green transition projects in Nordics/Europe to retain investments.
- Standardization is ongoing and that cross-border solutions should be supported actively e.g. in IMO or other international organisations.
- A green corridor is a very suitable framework, but funding should remain agnostic as to the transition fuel of choice from a consortium tendering for a project

These solutions aim at getting the stakeholders and partners on the same page at the same time. Sharing risks and liabilities, promoting a shared framework, and rewarding and safeguarding first-

movers. The barriers mentioned here are not exclusive to this pilot study and are reflected in the Nordic Roadmap's recommendations to the Nordic Council of Ministers.

Participants

Pilot study owner

Pilot study participant

Pilot study participant

HØST PtX project owner

Pilot study participant

Pilot study participant

Extended pilot participant

Extended pilot participant

Extended pilot participant

Extended pilot participant

Extended pilot participant

1. Introduction

A primary objective of the Nordic Roadmap project is to facilitate green corridor pilot studies, advancing the implementation of zero-emission fuels. The HØST Power-to-X (PtX) project is a flagship initiative in the supply chain for green hydrogen and ammonia, critical components in the maritime fuel transition. Copenhagen Infrastructure Partners (CIP) is behind the project HØST PtX, which aims to produce hydrogen and potentially ammonia from purely renewable energy in Esbjerg Municipality, on the southwestern coast of Denmark. Located in the Måde Industrial Area near the Port of Esbjerg, the facility will cover approximately 30 hectares and produce around 100,000 tonnes of green hydrogen annually, which can be converted into 600,000 tonnes of green ammonia (HØST PtX 2023). The project has a permitting envelope of up to 1GW installed electrolyser capacity, which will be build-out over two phases (approx. 500MW per phase). With a total capital investment exceeding 2 billion EUR, HØST PtX Esbjerg is poised to become one of Europe's largest PtX facilities.

The production of hydrogen by direct current electrolysis of water splits two H_2O molecules into hydrogen (2 H_2) and oxygen (O_2). When the power for the electrolysis is produced in a sustainable manner, e.g. by wind, solar, or hydroelectric power, the result is green hydrogen, which may be used directly in combustion processes. The hydrogen may also be a starting point for further production e.g. of ammonia (NH_3), through the Haber-Bosch process, which captures and converts atmospheric nitrogen into a usable form for ammonia production (Figure 1).

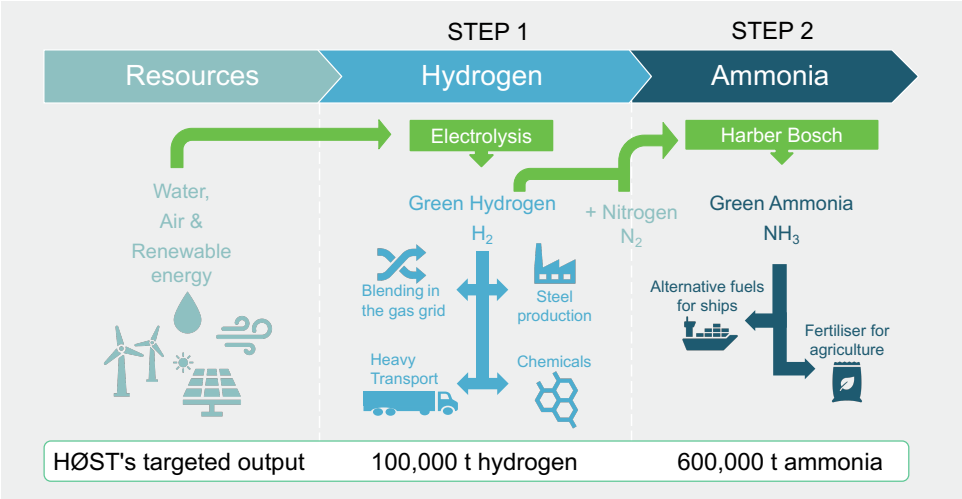


Figure 1: Schematic of the stepwise production of hydrogen through electrolysis and the electrified Haber-Bosch ammonia production for the offtakers in food, commodities, energy, and transport sectors. (HØST PtX 2023a)

By harnessing wind power, the project aims to use advanced electrolysis to convert 4-6 GW excess electricity into hydrogen and potentially ammonia by 2030, aiming to provide decarbonization to industrial sectors and maritime transportation. The project is shown considerable interest from the German hydrogen offtake market as well as from the Danish market leaders in agriculture and shipping, as green ammonia can be used both as a CO_2-free fertiliser and as a CO_2-free fuel. The HØST PtX project in Esbjerg agreed to become a Nordic Roadmap pilot study in mid-2023. During the pilot stage, the HØST PtX project is expected to progress through detailed planning, design work, and regulatory approvals phases toward Final Investment Decision (FID) in 2026.

Thus, while other Nordic Roadmap pilot studies address more mature technologies in a more advanced planning stage, the HØST PtX project is for the duration of the pilot study still in relatively

sensitive stages regarding business case, technology choices, and partnering. While the facilitator was given permission to access documents and to interview CIP and various partners, the confidentiality level has been relatively high and sharing of detailed hard facts and numbers of the proposed development with the public is not possible. The focus has therefore been on identification of the driving forces of the process and, in particular, the barriers encountered.

The HØST PtX project faces not only the technical challenges of green ammonia production, but also the complex task of establishing a robust supply chain. Its success hinges on addressing numerous interconnected factors both with respect to the demand side and the supply chain. The report outlines the methodology for collection and sharing of information in the sensitive environment (Chapter 2) and continues to describe the four main workstreams: Stakeholder supply chain mapping (Chapter 3); Mapping stakeholder concerns in establishing a supply chain (Chapter 4); HØST PtX project timeline;(Chapter 5); and Context of solutions and measures in the Nordics (Chapter 6).

During the work with this pilot study, it has been presented and discussed at several public events, incl. the High-Level Conference on Green Shipping arranged within the Nordic Roadmap project in Copenhagen in December 2024. The work carried out in this pilot has also been used as input to the Fuel Transition Roadmap for Nordic Shipping.

Aim of the pilot study

This pilot focuses on reporting on the barriers and solutions identified by CIP since the launch of the HØST PtX project, as well as those of the other stakeholders in the pilot. The HØST PtX project faces not only the technical and safety challenges of green ammonia production, but also the complex task of establishing a robust supply chain and demand scenario. Its success hinges on addressing numerous interconnected factors.

The aim of this study is to identify barriers to developing a green shipping corridor value chain, covering the entire process from production to bunkering and operating with green ammonia on ships. As illustrated in Figure 23, the pilot study involved interviewing relevant stakeholders and reviewing materials to create a comprehensive overview of these challenges and requirements, including the mapping of stakeholder concerns and barriers.

Figure 2: Main activities of the pilot study.

2. Methodology

This chapter gives a brief description of the methodology used to collect the information for the pilot study. This includes details about the pilot study design, the selection of participants, the data collection process, and the methods of analysis. The methodology emphasizes the use of shared materials and interviews with key stakeholders involved in the HØST PtX project in Esbjerg. The key participants, and in particular the pilot owner, were throughout the study actively engaged and adamant that confidentiality was paramount, as the sensitivity of business positions was high. The facilitator has agreed to limit the presentation to non-sensitive information. This report is a representation of the work provided by LITEHAUZ ApS as facilitator on the ammonia pilot project in Denmark, and it is authored by the facilitator.

Pilot study design

The study is rooted in the HØST PtX project in Esbjerg as described briefly below, and it is based on the analyses and findings of the stakeholders involved. This study makes particular use of semi-structured interviews and volunteered material to gain in-depth insights from participants. This approach was chosen for its flexibility and its ability to comprehensively explore participants' perspectives. The timeline and activities of the pilot study is illustrated in Figure 34.

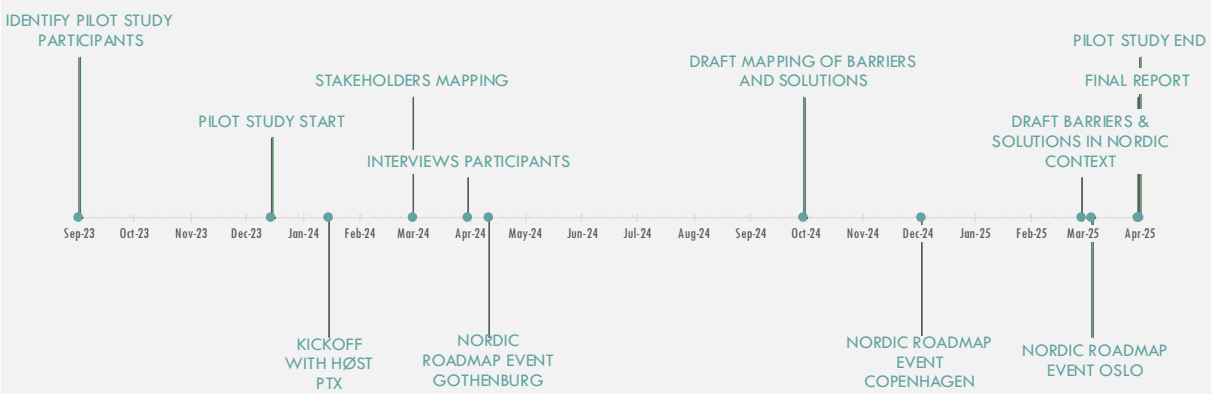


Figure 3: Timeline and activities of the pilot study.

Participants in the pilot

The participants were identified based on their role in HØST's supply chain of green ammonia as a marine fuel, upstream as well as downstream (Figure 45). The stakeholders' main contacts included project managers and team members from different parts of the value chain.

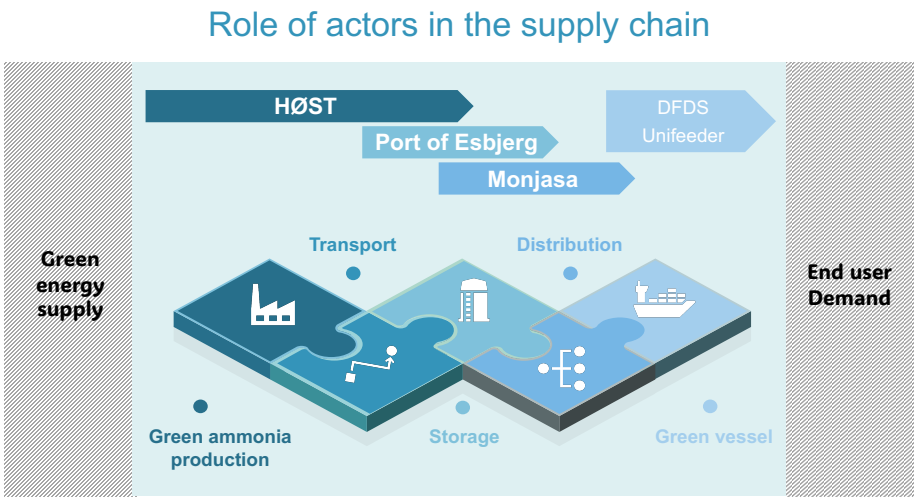


Figure 4: Supply chain actors of the pilot study.

The selection criteria ensured a diverse range of perspectives. The participants are shown below.

- Potential Danish ammonia manufacturer (the HØST PtX project by CIP)
- Danish shipowner and short-sea Ro-Ro operator (DFDS)
- Short-sea container feederline operator (Unifeeder)
- Danish port (Port of Esbjerg)
- Bunkering company (Monjasa)

In addition to the key actors above, a number of other Nordic Roadmap partners volunteered to be included in the pilot study at the level of receiving and sharing information:

- Yara
- Danish Maritime Authority
- MAN Energy Solutions
- Birr Consulting
- Port of Gothenburg

In Denmark, the pilot study also had dialogue with national and local entities involved in the broader value chain of the fuel transition:

- Agencies and authorities (Danish Maritime Authority, Danish Energy Agency)
- Utilities (DIN Forsyning Esbjerg)
- Organisations involved in guidelines and standards (Danish Institute of Fire and Security, DBI)
- Industry organisations (Danish Maritime, Danish Shipping, Danish Ports, Danske Shipping- og Havnevirksomheder)

Data collection
Semi-structured interviews were conducted to allow flexibility in probing deeper into specific topics. An interview guide was developed to cover topics such as barriers and solutions to the introduction of green ammonia as a fuel. Where it made sense, questionnaires were used as a basis for the interviews and to deepen knowledge on selected issues. The interviews were conducted in on-site

meetings or by video call and lasted up to 60 minutes each. Further questions were addressed by e-mail, in telephone conversations, or by video call. In addition, relevant material received from stakeholders, such as presentations or reports, was reviewed and used for the assessment.

Ethical considerations
Informed consent was obtained from all participants, who were assured of the confidentiality of data and data management. Data was securely stored, accessible only to the team.

Data analysis
Notes from the interviews were taken and analysed thematically. The background reports and presentations received from the stakeholders were used to summarise the findings, and numerical data are typically shown in an aggregated or rounded form.

Validity and reliability
For validation, the interview data was compared with pilot documents and meeting notes. Internal team meetings were held regularly to ensure reliability.

3. Stakeholder supply chain mapping: HØST PtX Esbjerg

Summary

The supply chain mapping includes regulatory entities such as government agencies and regional authorities, but the main actors on the actual demand and supply side are found in the private and utility sectors. These include investors, water and energy suppliers, technology holders, and a range of site owners and managers.

Objective of the workstream

The objective of this workstream is to contact or interview supply chain participants and other stakeholders regarding responsibilities and positions, in order to identify timing issues and organisational coverage.

Methodology

The stakeholder mapping of HØST PtX in Esbjerg is included in Figure 67. Since HØST PtX was in the process of addressing the business case and mechanisms for elevating certain stakeholders to potential business partners, it was not considered conducive for the pilot study to get ahead of the business case. Those contacted were initially invited to provide general comments on the fuel transition, the PtX project(s), and the specific relevance to shipping. More in-depth dialogue was reserved for the interviewees after consultation with HØST PtX.

Results and discussion

Main stakeholders
Figure 56 illustrates the production services that HØST PtX could offer and the various applications of its green products. This provides an overview when identifying potential stakeholders for setting up a supply chain.

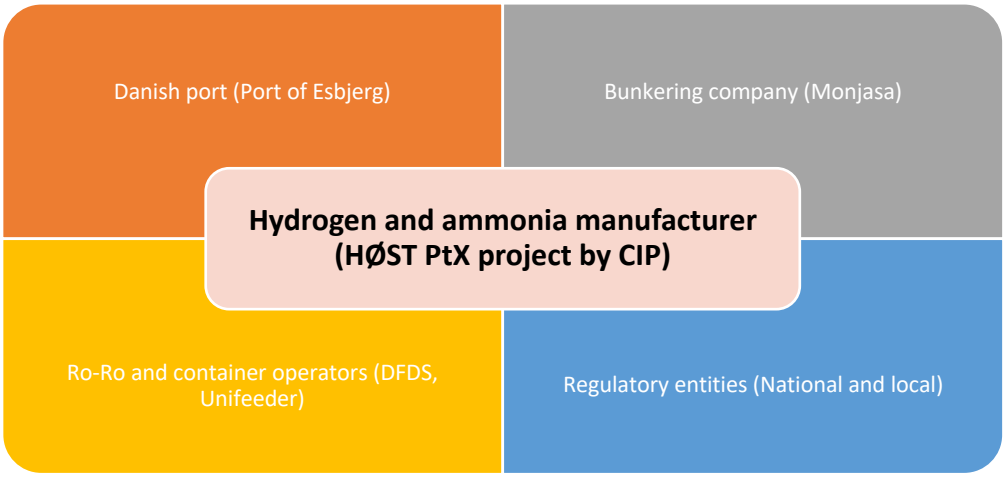


Figure 5: Main stakeholders in the HØST PtX Esbjerg project.

Potential Danish ammonia manufacturer (the HØST PtX project owned by CIP)

- Copenhagen Infrastructure Partners (CIP) is a Danish investment firm specializing in renewable energy projects. CIP is actively involved in developing sustainable energy infrastructure, and as part of their initiatives, HØST PtX Esbjerg, focuses on producing and utilizing green hydrogen and potentially other e-fuels like ammonia. HØST PtX may play a vital role in creating the necessary infrastructure for the Immingham-Esbjerg green corridor and provide a leading example of sustainable maritime transport.

Danish shipowner and short-sea Ro-Ro operator (DFDS)

- The DFDS Immingham-Esbjerg route is a freight and logistics service that connects the UK (Immingham) and Denmark (Esbjerg). DFDS (Det Forenede Dampskibs-Selskab), a Danish shipping and logistics company, operates this route to facilitate the transportation of goods, vehicles, and containers across the North Sea. This route plays a key role in enabling trade between the UK and mainland Europe, offering efficient and reliable shipping solutions for businesses in both regions. The service is part of DFDS's extensive network of ferry routes that support European logistics and supply chains.

Short-sea container feederline operator (Unifeeder)

- Unifeeder is a leading Danish shipowner and operator specializing in short-sea container feeder services. As a key player in the logistics industry, Unifeeder connects major ports across Europe, facilitating the efficient movement of containerized goods. In Denmark, Unifeeder plays a crucial role in supporting regional trade by linking smaller ports to larger global shipping routes. The company is also at the forefront of sustainable shipping practices, exploring the use of ammonia as an alternative fuel to reduce carbon emissions and enhance environmental performance in maritime transport.

Danish port (Port of Esbjerg)

- The Port of Esbjerg plays a pivotal role in the green shipping corridor between Immingham and Esbjerg, serving as a key hub for the decarbonization of maritime transport on this route. As a major North Sea port, it supports the transition to sustainable shipping by facilitating the production, storage, and distribution of green fuels such as hydrogen and ammonia. The port is central to the infrastructure development necessary for the corridor, enabling the

adoption of alternative fuels and fostering greener logistics and shipping practices between Denmark and the UK.

Bunkering company (Monjasa)

- Monjasa is a leading Danish energy and marine fuel supplier, specializing in the delivery of marine fuels and lubricants worldwide. Headquartered in Denmark, Monjasa provides a range of services, including bunker fuel supply, logistics, and procurement, to support global shipping operations. The company is recognized for its commitment to safety, reliability, and sustainability in the marine fuel industry. Monjasa is actively involved in exploring and integrating alternative fuels to support the maritime sector's transition to greener and more sustainable practices.

Extended project stakeholders

The extended stakeholders' community in the HØST PtX project is illustrated in Figure 67. In addition to the main stakeholders described above, other stakeholders were contacted during the pilot study:

- Nordic Marine Oil, Bunker One, Dan-Bunkering
- Danish Maritime Authority, Danish Energy Agency
- Energinet, Dansk Brandteknisk Institut (DBI)
- Esbjerg municipality
- Danish Shipping, Danish Maritime, Danish Ports

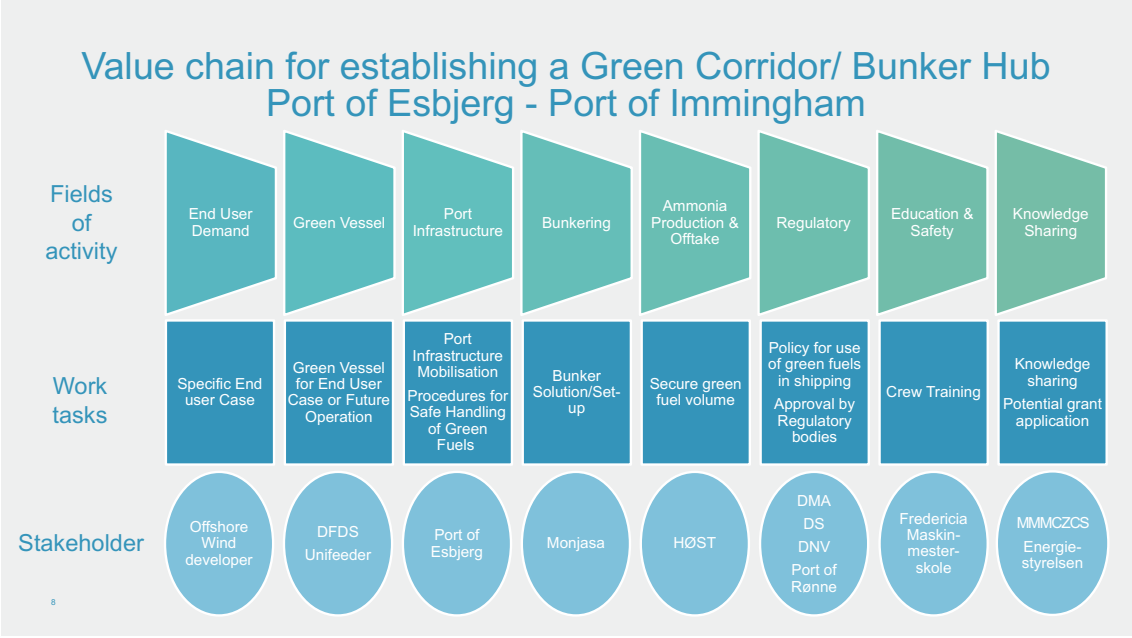


Figure 6: Extended stakeholders' community in the HØST PtX Esbjerg project. (HØST PTX 2024a)

As an example of the complexities of the stakeholder ecosystem and the possible interactions, the Danish Maritime Agency has mapped the parties to be consulted regarding safety issues of handling alternative fuels in the ports or in Danish waters (Figure 78).

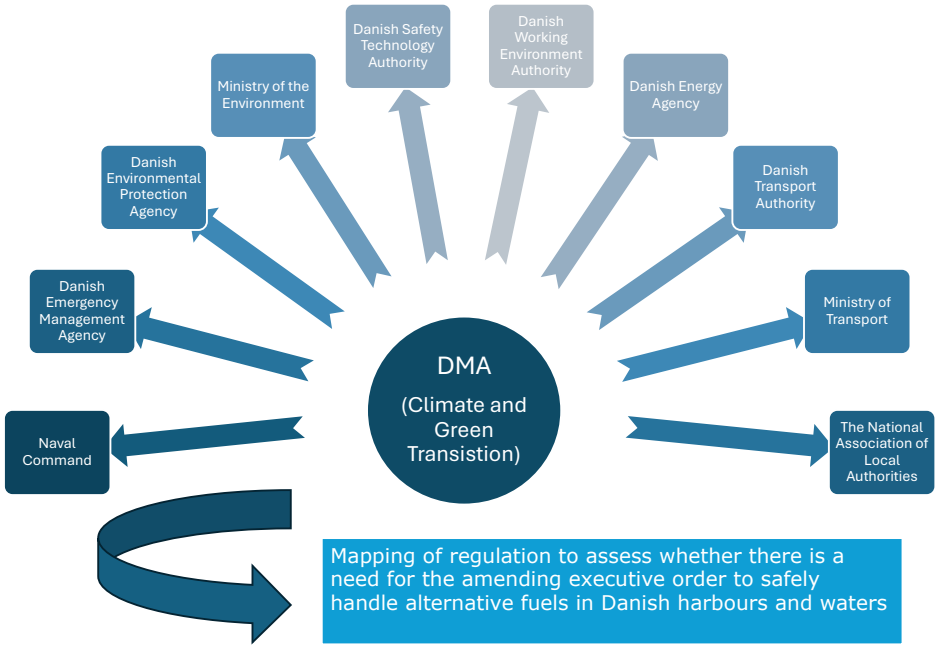


Figure 7: Deep dive into regulator stakeholders regarding safe fuel management in the supply chain in the HØST PtX Esbjerg project (Danish Maritime Authority 2024).

4. Mapping stakeholder concerns in establishing a supply chain

Summary

Interviews with each stakeholder of the mapped supply chain revealed that while some concerns are shared across all participants, others are specific to individual stakeholders. A key observation from the discussions is that alignment and timing present significant barriers to the adoption of new fuels. The lack of synchronization between different actors in the supply chain poses challenges to investment decisions, infrastructure development, and fuel availability.

Objective of the workstream

The objective of this workstream is to engage supply chain participants and other relevant stakeholders to assess their concerns and perspectives regarding the adoption of ammonia as a transition fuel. Through consultations and interviews, the workstream aims to identify key barriers and timing challenges associated with the introduction of ammonia, ensuring a clearer understanding of the factors influencing the implementation in the maritime sector.

Methodology

This workstream employed an in-depth dialogue approach to gather insights from key stakeholders involved in the pilot study. The objective was to map out concerns and perspectives from each stakeholder within the identified supply chain for ammonia as a maritime fuel. Through structured discussions, stakeholders provided firsthand knowledge of challenges, opportunities, and key considerations for the fuel transition.

Additionally, partners from the Nordic Roadmap project, recognized for their expertise in fuel transition and PtX projects, were invited to contribute. Their input focused on both general

perspectives regarding the fuel transition and topics of specific relevance to the shipping sector. By incorporating their expert opinions, this methodology ensured a comprehensive assessment of the viability, challenges, and potential pathways for ammonia adoption in maritime applications.

Results and discussion

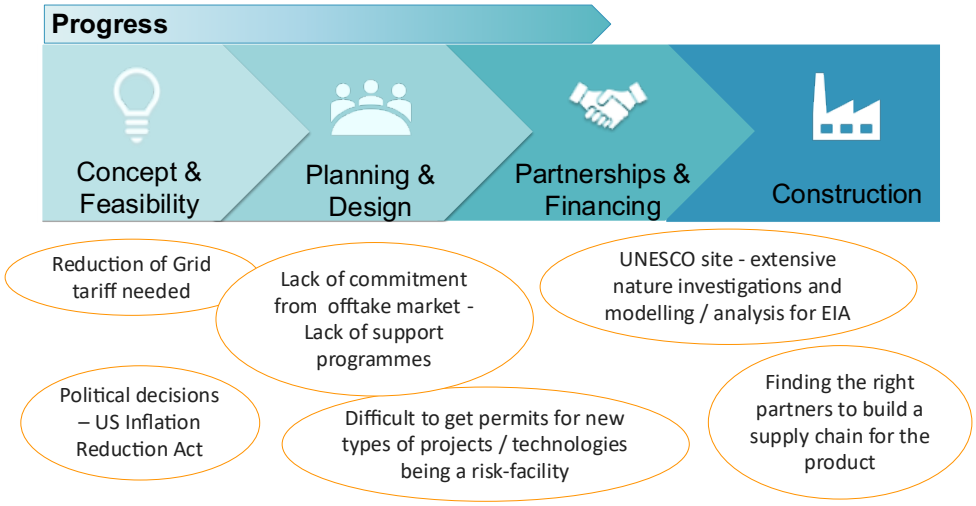
In the framework of the HØST PtX project, the main actors and obstacles for the mobilisation of the value chain and the development of the Port of Esbjerg and the Port of Immingham as green fuels bunker hubs and green shipping corridor were investigated. The following table provides a brief summary of the preliminary findings, highlighting the main concerns and challenges faced by different stakeholders in the supply chain (HØST PtX 2024b).

Stakeholder	Barriers
Green power (offshore and solar)	Financing of green energy production
HØST PtX	• Resource availability • End user case • Technical maturity • Infrastructure
Port of Esbjerg	• Port readiness • Noise • Traffic
Bunker company (Monjasa)	• End user case
DFDS, Unifeeder	• Lack of fuel availability • Safety on board • Bunkering procedures
Danish Maritime Agency **Esbjerg municipality**	• Regulation • Licences and approvals

The stakeholder interviews revealed that while some concerns are shared across all participants, others are specific to individual stakeholders. A key observation from these discussions is that alignment and timing in the transition to new fuels represent significant barriers in themselves. Differences in readiness, investment strategies, and regulatory expectations contribute to these challenges, making coordinated action essential.

The following illustrations address the specific concerns and perceived barriers of each main stakeholder: HØST PtX, DFDS and Unifeeder, Port of Esbjerg, and Monjasa, highlighting their unique perspectives and challenges in the transition to ammonia. The progress bar at the top of the graphics illustrate where each stakeholder is in their own organization's process, from concept to construction. It does not represent the progress of the ammonia pilot study.

HØST PtX Esbjerg



Energy cost/competitive pricing:

- The main cost driver for green ammonia production is the cost of renewable electricity. Given this, securing affordable power, for example through Power Purchase Agreements (PPAs),) and managing grid tariffs is crucial for HØST PtX. If energy prices are too high, these factors become significant barriers to cost-competitive production.
- If grid tariffs remain high or access to low-cost renewable energy is limited due to transmission constraints or regulatory barriers, the overall cost of green ammonia will increase and become less competitive on a global scale.

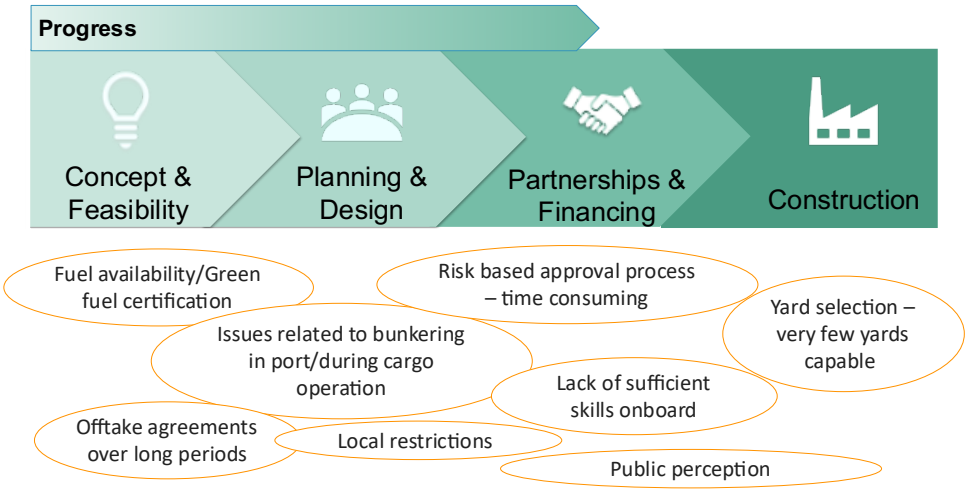
Political decisions:

- The US Inflation Reduction Act (IRA) has an indirect impact on the HØST PtX project in Denmark. By offering substantial subsidies for clean energy projects, the IRA has made the US an attractive location for global investors in clean ammonia and hydrogen. This increased competition has caused concern in Europe, as companies may be tempted to relocate projects to the US to take advantage of IRA subsidies.
- For HØST PtX, this could lead to problems in securing financing or investment, as investors may favour markets with better financial incentives. It also puts pressure on European policy makers to offer competitive subsidies to maintain clean energy projects.

Multiple stakeholder involvement:

- Coordinating among various stakeholders, including government bodies, local authorities, utility companies, and industry partners, is essential for project success. This requires effective communication and alignment of interests, and it would also involve a multistakeholder approach in public processes, such as Environmental Impact Assessments (EIA).

DFDS/Unifeeder



Technical maturity:

- Technological and commercial maturity of the technology in general. DFDS points out that ammonia engines are still in the early stages of development and have not been widely tested in real-world maritime applications. Unlike conventional fuels, ammonia poses unique challenges such as toxicity and the need for specialized storage and handling systems. (DFDS' plan: All ammonia engines are dual fuel by default as they need pilot fuel to operate. The share of pilot fuel could be increased up to 100%.)
- Finding a shipyard capable of designing and constructing vessels equipped with ammonia engines is challenging. Many shipyards are not yet prepared to work with ammonia-related technologies, which require advanced safety measures and new engineering solutions. This limited availability can delay projects and inflate costs.

Green fuel:

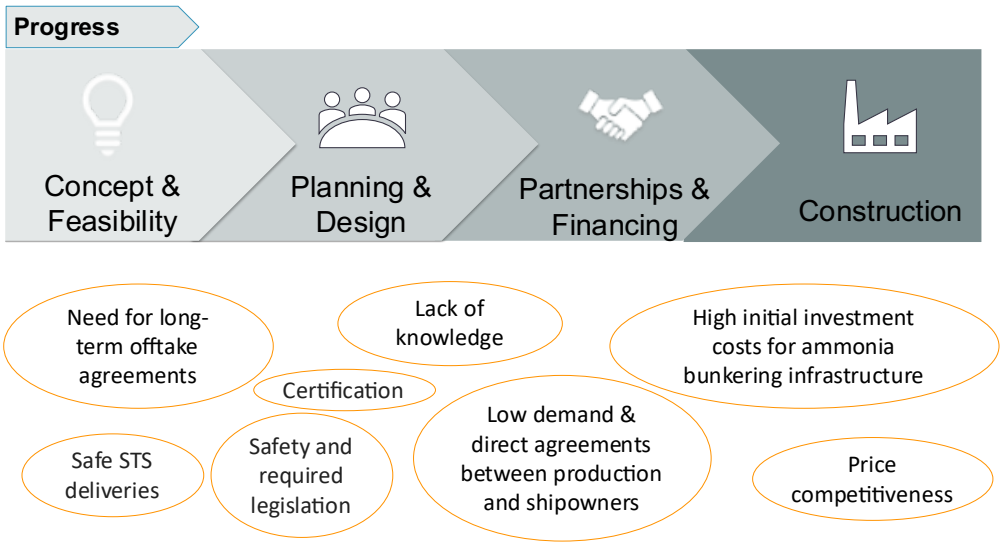
- Willingness to pay for green fuel is limited – Cargo owners are often cost-sensitive, requiring competitive pricing for green fuels. A clear certification system is needed to verify sustainability claims and justify potential cost premiums.

Port of Esbjerg

Infrastructure investment in the Port of Esbjerg:

- The Port of Esbjerg have identified suitable sites in the port area for possible installation of physical infrastructure but awaits specific details regard type of fuel, safety concerns, and other conditions.
- The Port of Esbjerg has not identified or investigated safety requirements and distance regulations for ammonia infrastructure. An ongoing Environmental Impact Assessment (EIA) will provide information to further address infrastructure safety issues.
- The Port of Esbjerg does not intend to further address the infrastructure needs until a demand is demonstrated from the market or an implementation framework exists, such as a green corridor project.

Monjasa



The bunkering of ammonia and other green fuels in ports or at sea are considered technically challenging but not seen as unsurmountable:

- Monjasa's role in the green ammonia supply chain is currently limited due to low demand. This demand level means that they cannot contract large quantities from producers, which is necessary for financially viable operations. As a result, ship owners in this early development stage often bypass the fuel broker and purchase ammonia directly from producer, thus preventing the brokers to develop the mechanisms to act as an effective intermediary in the supply chain,
- The safety concerns regarding bunkering ammonia on vessels are only just being considered by IMO and further assessment of (technical and financial) consequences await the organisation's decisions and the emerging standards and guidelines.

As a broker of fuels for shipping the initial investments (CAPEX) in bunker tankers and/or landbased infrastructure are large. As mentioned above, for Monjasa to play a greater role the demand needs to increase sufficiently to justify infrastructure investments and bulk purchases. This process may be assisted by a green corridor project in advance of the sheer market forces.

Summary of barriers identified

The transition to ammonia as a maritime fuel in Esbjerg is presented with several key barriers that can be broadly categorized into 1) Demand and cost (financial viability), 2) Technology and safety (technological maturity), and 3) Fuel availability (summing up risks). These uncertainties linked to entering an uncharted industry generates a high risk of misalignment of stakeholders (Figure 89).

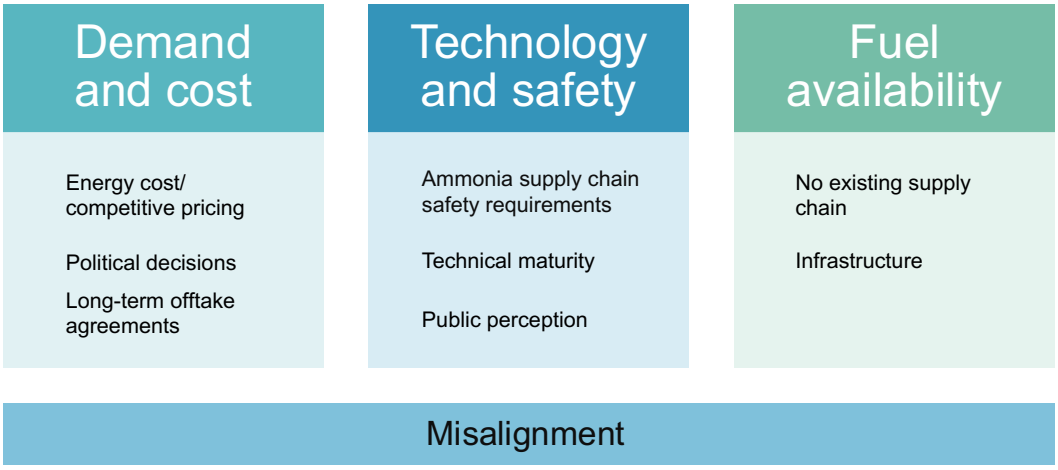


Figure 8: The key barriers identified across stakeholders in the HØST PtX Esbjerg project.

A major concern is financial viability—stakeholders need clarity on costs, potential returns, and whether the political and economic landscape will remain stable enough to justify long-term investments. Additionally, securing commitment from shipowners and fuel suppliers remains uncertain, adding to the financial risk.

In terms of technological maturity, while there are challenges, it is important to highlight that these are not perceived as insurmountable obstacles. Rather, they represent areas requiring further development and testing to ensure safe and efficient implementation.

Beyond financial and technological aspects, the industry is navigating uncharted territory, with little prior experience to guide decision-making. This inherent uncertainty increases hesitation among stakeholders.

A fundamental issue underlying all these barriers is the lack of synchronization between different parts of the value chain. Financial, technical, and operational elements are not yet aligned, making coordination difficult. Without this alignment, progress remains fragmented, slowing down the adoption of ammonia as a maritime fuel.

This is where political leadership plays a crucial role. A clear and stable strategy, backed by consistent policies and incentives, is essential for driving progress. Governments and regulatory bodies must provide both incentives and regulations ("carrots and sticks") to ensure that all stakeholders move forward in a coordinated manner, creating the necessary conditions for a successful fuel transition.

Addressing these barriers requires a concerted effort from all involved parties, innovative solutions, and supportive policies to pave the way for the successful implementation of a green corridor with ammonia.

5. HØST PtX project timeline

Objective of the workstream

The objective of this workstream is to establish a timeline, which is key in large infrastructure projects to identify, understand and avoid barriers during the process.

Methodology

In this workstream, interviews were carried out with the stakeholders of the project and information on the various inputs and commitments was obtained.

Results and discussion

The original timeline for the HØST PtX project is shown in Figure 910 with an 8-year implementation period (10, if including the Concept development & Feasibility study phase, which is not shown here). This timeline reflects the complexity of developing large-scale green hydrogen and ammonia infrastructure, including regulatory processes, investment decisions, and construction phases.

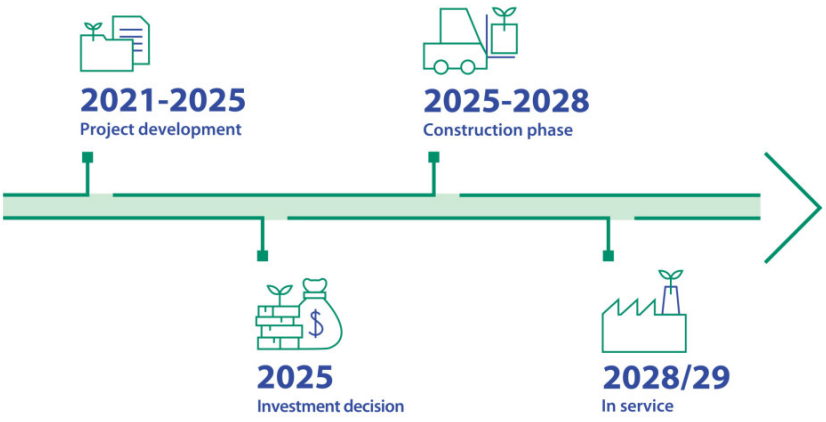


Figure 9: Timeline as envisioned in 2019 for the HØST PtX Esbjerg project. (HØST PtX 2023b)

While the ammonia fuel production was relying on commitment from the shipping industry, the developments leading to the change of course are provided here. The pilot study interviewed all major stakeholders and was in close liaison with HØST PtX and CIP throughout nearly 18 months. In the course of the ammonia pilot study, the timeline for the HØST PtX Esbjerg project has been adjusted as outlined for each phase below. Each phase includes the original and actual timelines, key tasks, and the reasons for schedule changes.

Original timeline: 2019-2021
Actual timeline: 2019-2021 (Completed on schedule)

Tasks in phase 1:

- Initial discussions on the potential of large-scale PtX production in Denmark.
- Feasibility studies to assess site selection, technology readiness, and market demand for green hydrogen and ammonia.
- Early stakeholder engagement, including CIP, governmental bodies, and industrial partners.

Reasons for the adjustment:

⇒ Initial feasibility studies, site selection, and early stakeholder engagement proceeded as planned.

Original timeline: 2021-2023
Actual timeline: 2021-2024 (Extended by 1 year)

Tasks in Phase 2:

- Selection of Esbjerg as the project location due to its strong renewable energy infrastructure and port access.
- Initial design and engineering work for the facility.
- Environmental Impact Assessment (EIA) and regulatory approval processes initiated.
- Engagement with potential offtakers in agriculture, shipping, and industrial sectors.
- Partnerships established with Danish and international stakeholders.

Reasons for the adjustment:

⇒ The extended process of obtaining environmental permits from the Danish Environmental Protection Agency has resulted in the postponement of front-end engineering design (FEED) and other technical studies.

⇒ Partnerships with Uniper and other stakeholders were established in 2024, indicating continued progress despite delays.

⇒ The detailed project design, including engineering and procurement planning, is still ongoing, supported by newly secured DEVEX funding in February 2025.

Original timeline: 2023-2025
Actual timeline: 2023-2026 (Extended by 1 year)

Tasks in Phase 3:

- Environmental approvals secured from the Danish Environmental Agency
- Detailed project design finalized, including engineering and procurement planning.
- Ongoing discussions with investors and financial institutions.
- Final Investment Decision (FID) expected in 2025, determining whether the project proceeds to construction.

Reasons for the adjustment:

⇒ The project secured primary environmental approvals from the Danish Environmental Agency in December 2024, slightly later than anticipated.
⇒ The FID was initially expected in 2025 but has now been pushed to 2026.
⇒ In February 2025, the European Climate, Infrastructure and Environment Executive Agency (CINEA) awarded the project up to €13 million in DEVEX funding. This grant supports FEED and other technical studies leading up to the FID.
⇒ Ongoing discussions with investors and financial institutions are still in progress, impacting the project's ability to move into the construction phase.

Original timeline: 2025-2028/2029
Actual timeline: 2026-2030/2031 (Expected delay of 1-2 years)

Reasons for the adjustment:

- With FID expected in 2026, the construction phase is likely to begin later than planned, pushing the first production of green hydrogen to around 2030 or 2031. First Production is heavily dependent on availability of State-owned hydrogen infrastructure as well as having secured sufficient offtake from end-customers.

6. Context of solutions and measures in the Nordics

The ammonia pilot study

Three green fuels were chosen for the pilot studies in the Nordic Roadmap project: methanol, hydrogen, and ammonia. The fuels are on different maturity levels when it comes to fuel technology in ships, with methanol being the most developed with respect to technology, fuel safety, and supply chain availability.

- The Danish pilot study was chosen to be on ammonia. The potential stakeholders included a strong global actor on ship combustion engines in MAN Energy Solutions in Copenhagen holding a vested interest in the development of an ammonia-fuelled engine, a handful of early-stage PtX projects on e-fuels including one on ammonia, and a large Pan-European Ro-Ro operator.

The Nordic Roadmap project longlisted 81 intra-Nordic green shipping corridor candidates and short-listed six, but few routes between the Nordic countries fit the longer deep-sea voyages typically seen in shipping as the optimal ammonia-fuelled option. The few longer green corridor options to Faroe Islands, Iceland, and Greenland from Denmark were ruled out at an early stage for reasons associated with fuel logistics, infrastructure maturity, and a preference to avoid passenger vessels in ammonia pilot studies.

- The HØST PtX project in Esbjerg agreed to become the pilot owner.

Fortunately, a PtX project called HØST converting North Sea wind energy into hydrogen had been initiated near Esbjerg, and the project owner CIP had already flashed the shipping industry as a potential costumer to a further conversion to green ammonia with the agriculture sector being another potential customer. The HØST PtX project agreed to become the pilot owner in mid-2023 although stressing that they had no intention of designing vessels or becoming a ship owner. CIP's aim is to identify feasible investments in the green energy sector and CIP investigated collaboration across multiple workstreams to mobilize the value chain and establish the Port of Esbjerg - Port of Immingham nexus as a green fuels bunker hub and green corridor.

- The main stakeholders of this pilot study include HØST PtX Esbjerg, the Ro-Ro operator DFDS, Port of Esbjerg, the bunker supplier Monjasa, and the regional container operator Unifeeder. A number of important partners were in the pilot study's extended information loop.

In a flashback to 2021-2023, it is reminded that a considerable number of sustainable energy projects were then presented globally by all major energy sector players, including the Danish energy sector (Energinet & Dansk Energi 2020). The Danish Energy Agency (2022) estimated in a positive scenario that 25-35 GW of wind energy could be harvested in the Danish exclusive economic zone (EEZ) by 2050. In 2025, macroeconomics and geopolitics have changed, and a toxic mix of supply chain issues, inflation, borrowing costs, geopolitical unrest, and new strategic and political priorities have set in and led to the termination or at a minimum the serious reconsideration of many of these projects in Denmark, in the Nordics, and globally. This has also affected this pilot study.

The beauty of the PtX route to ammonia from an investor's point of view is that the process leads to hydrogen in the first step, since you basically add power to water and generate oxygen and hydrogen. And, if customers are in the market for ammonia, a process line may be added to allow production of ammonia via the Haber-Bosch process.

- The HØST PtX project's original goal was to produce 100,000 tonnes of hydrogen or 600,000 tonnes ammonia using purely from renewable energy (HØST PtX 2023).

At the end of the pilot study and the Nordic Roadmap project in 2025, the situation is that HØST PtX has decided to continue their studies to reach FID based on production of hydrogen as a final product, having concluded that the ammonia business case is too uncertain and that a reliable demand case for shipping is still not identified.

- While it is positive that FID is pursued for a PtX project that will produce green hydrogen to meet a demand, the ammonia fuel for shipping angle is currently not considered viable in Esbjerg – why?

The main influence on the decision to postpone ammonia production was an opportunity for the production, transport, and marketing of green hydrogen from the HØST PtX Esbjerg project to Germany and further develop a model to bring up to 140,000 tonnes of green hydrogen to German industry consumers annually (CIP & Uniper, 2024).

- The planned hydrogen pipeline connecting Denmark to Germany is a major factor in this decision. This demand has much higher degree of certainty/less risk and may be the factor on which an FID will be based.

The early-stage barriers

The following barriers were identified in the Esbjerg HØST project (Figure 1011). The barriers mentioned here are not exclusive to this pilot study and are also reflected in the Nordic Roadmap's recommendations to the Nordic Council of Ministers. The uncertainties on the development and construction of facilities to produce and distribute green energy carriers are reduced dramatically in these years despite areas of low readiness level. Also, the first ammonia driven ship engines have been built and tested, and the design of actual newbuilds are completed and approved by the class. Thus, many of the uncertainties related to CAPEX are addressed and while the technical, regulatory and financial data may not be complete, the associated risks are considered acceptable, and not far from "decision-ready".

The barriers are mainly found in the uncertainties regarding the future energy price point. The main cost driver for green ammonia production is that of renewable offshore electricity and the main revenue driver is the acceptable market price for shipping's green fuel. Both of these markets are infused with uncertainty and stakeholders demonstrate little enthusiasm to commit to pricing for a 5- or 10-year horizon.

For the vessel operators, key factors in their considerations of abatement costs, apart from the cost of the fuel, are the capacity of the route and the implementation of regulation. Since IMO has yet to come out with its proposed GHG levy and fuel standard, routes that operate 100% within the EU and are covered by EU ETS and FuelEU Maritime will always present a better business case for the adoption of alternative fuels than routes operating outside or partly outside the EU. Given the FuelEU Maritime pooling mechanism, where a certain percentage of fuel used in an entire network or pool of vessels determines compliance, vessel operators will seek to introduce green transition fuels (low GHG fuels) on routes that make the highest contribution, percentage-wise, to the fuel used

in the entire network. Longer routes, with bigger vessels, sailing entirely in the EU will be those with the best overall business case for transition.

The specific Esbjerg – Immingham route itself is challenged on three main factors: 1. the size and age of the vessels operating the route; 2. that only half of the route is in the EU, and UK does not yet have ETS for maritime nor a fuel regulation; and 3. the pooling mechanism of FuelEU Maritime works to favour longer routes in EU waters.

Figure 10: Barriers identified for the HØST PtX Esbjerg project.

Currently, the development is therefore locked in a chicken-and-egg conundrum. Reducing financial uncertainty on energy pricing may be one of the key mechanisms to entice investors.

Solutions to the barriers are summarised in the table below. At the early stage of the ammonia scene, the market forces driven business case is may be broken only by a risk reduction mechanism such as a green corridor project or other frameworks, that address in particular price gaps on OPEX, i.e. energy cost upstream and downstream.

Barriers	Solutions
Uncertainty on future energy cost – The main cost driver for green ammonia production is the cost of renewable offshore electricity.	Secure affordable and predictable conditions by managing grid tariffs and ensuring a significant build-out of renewable energy sources in Denmark.
Overarching political decisions make or break markets – Examples include the Denmark-Germany pipeline agreement, which "makes" the market, while the US Inflation Reduction Act has "broken" some projects by increasing global competition.	Governments and organizations should act decisively in Nordics/Europe to retain capital and investments.
Technological readiness level – Safety and technical solutions for ammonia management across the supply chain are still maturing.	Support ongoing standardization efforts and promote cross-border solutions through international organizations.
Misalignment – Companies prioritize individual objectives without incentives for early commitment, leading to sequential rather than parallel actions. Example: HØST PtX needs a long-term offtake agreement for FID, while DFDS is keeping its fuel options open.	Green corridor projects should provide flexibility in funding terms, allowing consortia to decide on partnerships and fuel choices.
Market-driven business cases are stalled as no party wants to invest first. Ports and bunker providers wait for upstream and downstream commitments before developing infrastructure.	Green corridor tenders should identify and address root causes of barriers in the feasibility phase to reduce risk and unlock investments.
Lack of commitment from the offtake market – Uncertainty in future ammonia prices and low technological readiness create an expectation that prices will improve, delaying commitments.	Funding mechanisms should cover the price gap in operational costs for a reasonable duration to encourage early adoption.

Late-stage developments during the pilot study

While the HØST PtX Esbjerg project remains largely on track in terms of design development, the regulatory approvals and financial structuring have taken longer than initially expected. The final FID delay has subsequently pushed the construction and operational timelines by approximately 1-2 years. In February 2025, HØST PtX secured funding from Connecting Europe Facility (CEF) of up to 13 MEUR toward progressing the FID work and is further engaged in strengthening of partnerships (HØST PtX 2025).

It is also noted that in December 2024, the Danish Environmental Agency granted the HØST PtX Esbjerg project the primary environmental approvals (EIA approval of the project and Environmental approval of the facility). For the HØST PtX project, this represents a key milestone project that will allow the development of installing up to 1 GW of electrolyser capacity in Esbjerg to generate sustainable green fuels, such as hydrogen (HØST PtX 2024b).

It is emphasised that the scope of this pilot study was an ammonia-based green shipping corridor between Esbjerg and Immingham, and hence other fuels or possible routes were not addressed. Other activities of the involved parties and in this area include:

- **Green transport DK-UK:** In June 2023, the food sector heavyweights Arla and Danish Crown teamed up with DFDS and DSV to develop a new green transport corridor to achieve climate-neutral food transports from Denmark to the UK (net zero) by 2030 (DFDS 2023) While this is

directed at greening the entire supply chain primarily addressing electric trucks, refrigeration, and infrastructure, the climate neutrality of the maritime transport DK-UK is also a key element, albeit not necessarily ammonia-driven.

- **Hydrogen fuelled vessel Esbjerg-Immingham:** H2 Energy and DFDS in December 2023 completed a technical and operational feasibility study of hydrogen propulsion systems by analysing the main aspects of a complete hydrogen ecosystem using the DFDS cargo (Ro-Ro) vessel *Magnolia Seaways* on the Esbjerg-Immingham-Esbjerg route as the focal point of the study (H2Energy and DFDS 2023). However, DFDS is keeping its alternative fuel options open.
- **DFDS ammonia driven route:** The Sweden-Belgium green corridor is initiated by DFDS and the ports of Gothenburg, Antwerp-Bruges, and North Sea Port. The aim is to have at least two DFDS ammonia-fuelled vessels in operation on the corridor from 2030 (Port of Antwerp-Bruges 2024) but this will be relying on funding mechanisms available.
- **Ammonia fuelled-fuelled vessels:** CIP, through its Energy Transition Fund, has signed Memorandums of Understanding with Færder Tankers and BW Epic Kosan, to develop ammonia-fuelled carriers. Additionally, CIP is in advanced discussions with other major shipping operators to develop Very Large Ammonia Carriers (VLACs), designed for large-scale deep-sea ammonia transportation (CIP 2024).
- **Ammonia engine:** Last but not least, MAN Energy Solutions began full-scale engine testing in November 2024 and operated their engine on ammonia from 25–100% load. MAN Energy Solutions states that its proprietary SCR (Selective Catalytic Reduction) was operational at all test loads to treat exhaust gases, and that all supply and safety systems worked as intended. The next phase of testing will focus on performance and emission optimisation, including injection and SCR systems, as well as control strategies (MAN ES 2025).

7. Conclusion

The ammonia pilot study is a study on a Power-to-X project near Esbjerg investigating to convert North Sea wind energy into 100,000 t hydrogen or 600,000 t ammonia potentially for shipping to provide ammonia for the Port of Esbjerg - Port of Immingham Green Corridor and an ammonia bunker hub. During the course of the ammonia pilot study 2023-2025 macroeconomics and stakeholder objectives have changed, and in the case of HØST PtX in Esbjerg, the green focus is now to pursue only hydrogen production in Esbjerg, and in consequence the project reports the recommendations regarding barriers and solutions for the postponed ammonia production below.

- Ensure financial planning capacity via access to sufficient green power, for example through affordable long-term Power Purchase Agreements (PPAs) and predictable management of grid tariffs. This requires a significant expansion of renewable energy sources in Denmark supported by state incentives, policies, and regulatory frameworks.
- Support is needed through addressing regulatory frameworks and providing incentives for first-movers in a nascent market. While CAPEX investments need to be supported the technical issues are not considered major barriers to execution of ammonia production.
- It is reported very important to establish funding mechanisms for green corridor projects that aim to ensure a price gap on OPEX can be covered for a reasonable duration.
- Governments and organisations should ensure competitive conditions and a level playing field for green transition projects in Nordics/Europe to retain investments.
- Standardization is ongoing and that cross-border solutions should be supported actively e.g. in IMO or other international organisations.
- A green corridor is a very suitable framework, but funding should remain agnostic as to the transition fuel of choice from a consortium tendering for a project

While a cancelled ammonia production is a setback for the pilot study, it is emphasized that several other potential pilot projects exist in Denmark and the Nordic countries with Danish lead partners, e.g. the involved vessel operator, DFDS, have also investigated a hydrogen powered vessel on the Esbjerg - Immingham route, and is still keeping its fuel options open.

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9. Appendices

Technical description of green ammonia production

Ammonia (NH_3) is an essential chemical compound used primarily in the production of fertilizers, but it also has various industrial applications, e.g. as an intermediary compound in the production of sodium bicarbonate, explosives, nylon, synthetic fibres, plastics, and polymers. It functions as a constituent in paints, hair dyes, and household cleaners, while also playing roles as a refrigerant, solvent, and whitener in the paper industry, etc. Apart from its extensive utilisation, in recent years more attention has been paid to its potential as an energy carrier. Specifically, the growing appeal of green ammonia, derived from renewable resources, is notable both as an energy storage medium and as a carbon-free fuel in the shipping industry.

The production of ammonia involves the Haber-Bosch process, a well-established and widely used method developed in the early 20th century, illustrated in Figure 1112.

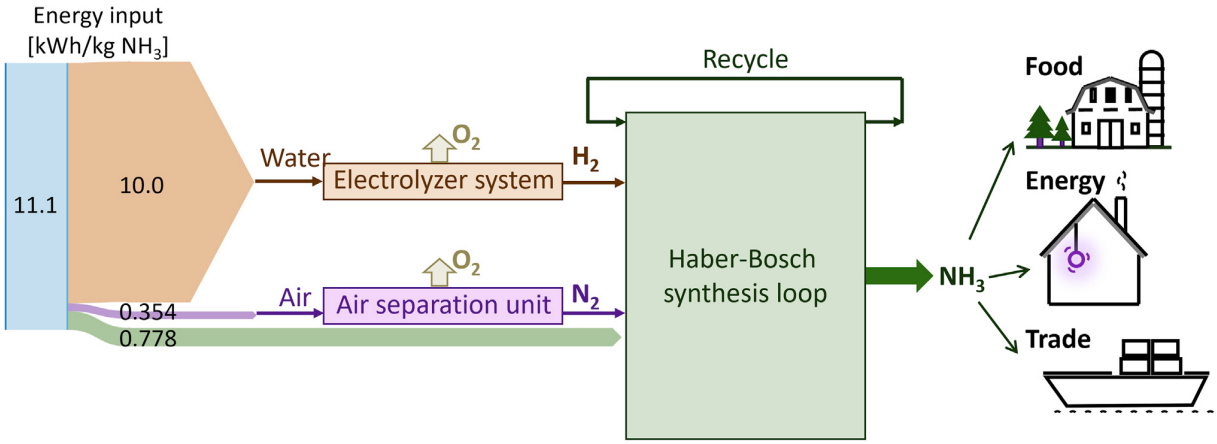

Figure 11: Schematic of the electrified Haber-Bosch ammonia production for the food, energy, and trade sectors (Source: Milind et al. 2022).

Feedstocks

a. Nitrogen

Nitrogen is obtained from the air, which consists of approximately 78% nitrogen gas (N_2). The Haber-Bosch process captures and converts atmospheric nitrogen into a usable form for ammonia production.

b. Hydrogen

Hydrogen is the other key feedstock, usually derived from natural gas (methane) through a process called steam methane reforming (SMR), or from other hydrocarbons. Alternatively, hydrogen can be obtained through water electrolysis, which is an environmentally friendly option using renewable energy sources.

Synthesis Gas (Ammonia Precursor) production

The next step is to produce a mixture of nitrogen and hydrogen, known as synthesis gas (syngas). This is typically achieved through the following steps:

a. Steam Methane Reforming (SMR)

- Methane reacts with steam to produce hydrogen and carbon monoxide.
- $CH_4 + H_2O \rightarrow CO + 3H_2$

b. Water-Gas Shift reaction

- Carbon monoxide reacts with water to produce carbon dioxide and more hydrogen.
- $CO + H_2O \rightarrow CO_2 + H_2$

Ammonia synthesis

The actual synthesis of ammonia occurs through the Haber-Bosch process, which takes place at high pressure and temperature using iron-based catalysts. (Figure 1213)

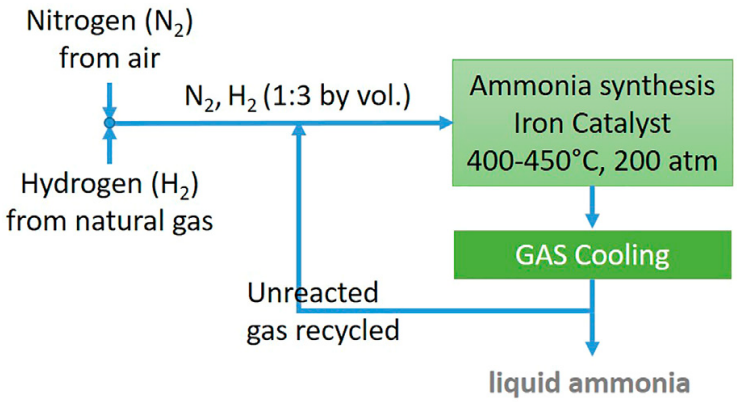

Figure 12: Scheme of a typical Haber–Bosch process (Source: Tornatore et al. 2022).

a. Reaction

- $N_2 + 3H_2 \rightleftharpoons 2NH_3$
- The reaction is reversible, and the equilibrium constant is influenced by temperature and pressure.

b. Conditions

- High pressure: Typically in the range of 100 to 300 atmospheres.
- High temperature: Usually between 400 to 500 degrees Celsius.
- Iron catalyst: Finely divided iron catalysts are used to enhance the reaction rate.

Separation and purification

After synthesis, the ammonia must be separated and purified from the unreacted nitrogen and hydrogen, as well as any inert gases present. This is typically done through a combination of compression, cooling, and absorption processes.

Ammonia storage and distribution

Once separated and purified, the ammonia can be stored and distributed for various industrial applications.

Environmental considerations

The Haber-Bosch process is energy-intensive, and the production of hydrogen, particularly through steam methane reforming, can contribute to carbon emissions. Ongoing research is focused on

developing more sustainable methods for ammonia production, including green hydrogen production using renewable energy sources and alternative catalysts for the synthesis process.

The Haber-Bosch process is a well-established method for ammonia production, but traditionally, it has been associated with significant energy consumption and carbon emissions. Green ammonia production aims to mitigate these environmental impacts by utilizing renewable energy sources and adopting more sustainable technologies.

Ammonia properties

- Liquid under -33°C @ atmospheric pressure or @ standard room temperature @ around 10 bar pressure.
- The required ammonia volume is 1.6-2.3 times higher than conventional fuel marine oil (MGO).

Green shipping corridor basis in Esbjerg

Background

Denmark stands uniquely poised to exploit the offshore wind potential in the North Sea, thanks to a combination of favourable factors such as wind speed, water depth, seabed conditions, and environmental considerations. These elements collectively ensure the high feasibility and profitability of offshore wind projects. In support of this, Denmark has issued tenders to establish Energy Islands on its west coast, aiming for a capacity of 5 GW by 2030, with the potential to expand to 10 GW by 2040. This ambitious initiative is backed by strong national and European support, driving the development of renewable energy capacities to meet climate targets and bolster Power-to-X production and export. While the planned rapid acceleration of renewable energy expansion in the North Sea has suffered a setback in late 2024, due to a lack of confidence in the business case from the private sector, Denmark is still set to maintain its position as a competitive and strategic prize zone in the realm of renewable energy.

Despite ammonia as a fuel for shipping still has considerable ground to cover, it was chosen for the pilot study due to the combined interests of a strong global actor on ship combustion engines, MAN Energy Solutions in Copenhagen, which holds vested interest in the development of an ammonia-fuelled engine, the PtX projects on e-fuels including HØST, and a large Ro-Ro operator, DFDS, with routes long enough to make ammonia relevant.

Demand side

Although the ammonia pilot study is early stage and primarily engaged in the feasibility of the supply side, the basis for a demand side of a future green corridor between Esbjerg and Immingham is described here, based on the feasibility study performed by H2Energy AG and DFDS A/S (H2Energy and DFDS 2023) and information on Esvagt activities.

DFDS operates two vessels, Magnolia Seaways and Ark Germania, on the Esbjerg-Immingham route, which is 330 nm (610 km) long, and the ports are serviced daily 6 days a week. One or both converted vessel(s) would make DFDS a main purchaser of ammonia for maritime transport purposes in Esbjerg. The feasibility study by DFDS and H2Energy on a green corridor based on hydrogen uses the Magnolia Seaways as a base vessel and its main specifications are given in Table 1.

Table 1 Main specifications of DFDS vessel Magnolia Seaways.

Magnolia Seaways	Value
Built year	2003
Length	199.8 m
Breadth	26.5 m
Dead weight	10,400 t
Gross tonnage	32,500 t
Lane length	3,800 m
Capacity	258 trailers, 300 cars
Propulsion power	20 MW

Table 2 shows approximate data for annual fuel consumption on the Esbjerg-Immingham route and the longer route Gothenburg-Ghent for comparison.

Table 2 Annual fuel consumption and number of voyages for the routes Esbjerg-Immingham and Gothenburg-Ghent.

Route	Fuel consumption at sea (t)	Annual no. voyages	No. vessels on route
Esbjerg – Immingham	25,000	600	2
Gothenburg – Ghent	45,000	600	3

The other main offtaker in Esbjerg are service vessels for the offshore energy sector in the North Sea, notably the company Esvagt A/S. The company are developing low- or zero-emission fuel concepts for their different vessel types focusing on batteries, bio- and e-fuel. The total annual fossil energy consumption by Esvagt vessels exceed 40,000 MWh in 2022 and 2023, although this is not all supplied in Esbjerg, and the emissions from vessels have hovered around 100,000 tonnes of CO_2 in the last five years corresponding to approximately 32,000 t fuel.

Motivation and stakeholders in Esbjerg

The HØST PtX project was initially driven by a number of key factors that collectively underpinned the initiation of the project in Esbjerg, with a view to positioning it as a key player in the transition to a sustainable and low-carbon energy future.

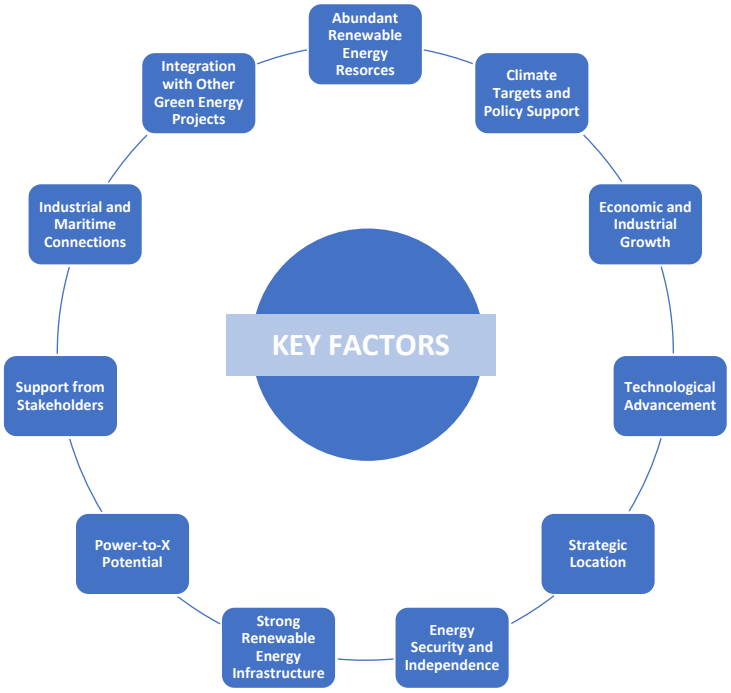

Figure 13: Key factors in identifying Esbjerg as a HØST facility location.

1. **Abundant renewable energy resources**: Esbjerg is ideally located to leverage the substantial offshore wind energy resources available in the North Sea. This provides a reliable and sustainable source of electricity, which is crucial for the production of green hydrogen and other PtX products.
2. **Climate targets and policy support**: There is strong national and European commitment to reducing carbon emissions and meeting ambitious climate targets. The HØST PtX project aligns with these goals by promoting the production of green hydrogen and other renewable energy carriers, contributing to the overall reduction of greenhouse gases.
3. **Economic and industrial growth**: The project is expected to stimulate economic growth and create jobs in the region. By positioning Esbjerg as a hub for green energy production and innovation, the project attracts investments and fosters the development of related industries.
4. **Technological advancements**: Advances in electrolyser technology and other related technologies have made large-scale PtX projects more viable and cost-effective. These technological improvements are key enablers for the HØST PtX project.
5. **Strategic location**: Esbjerg's proximity to major industrial centres and its well-developed infrastructure, including ports and logistics facilities, makes it an ideal location for the HØST PtX project. This strategic location facilitates the distribution and export of green hydrogen and other PtX products.
6. **Energy security and independence**: By developing its own green energy production capabilities, Denmark enhances its energy security and reduces dependence on fossil fuel imports. This is particularly important in the context of global energy market fluctuations and geopolitical tensions.
7. **Strong renewable energy infrastructure**: Esbjerg is a major hub for offshore wind energy in Denmark, making it an ideal location for a PtX facility that relies on renewable electricity to

produce green hydrogen and ammonia. The region has access to a vast supply of wind power, ensuring a stable and sustainable energy source for large-scale electrolysis.

8. **Power-to-X potential**: The PtX concept allows for the conversion of surplus renewable electricity into various energy carriers such as hydrogen, ammonia, and synthetic fuels. This flexibility provides multiple pathways for integrating renewable energy into different sectors, including transportation, industry, and heating.
9. **Support from stakeholders**: The project has garnered support from various stakeholders, including governmental bodies, private companies, and research institutions. This collaborative approach ensures a comprehensive and robust framework for the successful implementation of the HØST PtX project.
10. **Industrial and maritime connections**: Esbjerg has a well-established industrial base and is home to Denmark's largest port on the North Sea. This location is crucial for the transportation and export of green ammonia, particularly for use as a sustainable fuel in the maritime sector. The port's infrastructure facilitates easy distribution to shipping companies and international markets.
11. **Integration with other green energy projects**: The project aligns with other green energy initiatives in the region, creating synergies with existing infrastructure and planned developments. This integration enhances the overall efficiency and effectiveness of Denmark's renewable energy strategy.

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