DECARBONIZING MARITIME TRANSPORT: A ROADMAP FOR SUSTAINABLE PORTS

Interreg
Baltic Sea Region

Co-funded by
the European Union

BLUE ECONOMY
Blue Supply Chains

Image on cover: Jonas Gunnarsson

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1. THE CHALLENGE: DECARBONIZING MARITIME TRANSPORT

The shipping industry faces an urgent and complex challenge: reducing its dependency on fossil fuels. While other sectors are actively decarbonizing, maritime transport remains a laggard, still relying on conventional fossil fuels for over 99% of its energy consumption. Given that global shipping accounts for nearly **3% of total greenhouse gas (GHG) emissions**, failing to act could significantly hinder international climate goals.

Ports play a **critical role** in enabling this transition. They are not just gateways for goods but potential **hubs for energy transformation**. By facilitating the shift towards alternative fuels and green technologies, ports can support the transition of the entire sector.

What is required for ports to offer alternative fuels and solutions to ships? What actors must be involved to make this transition a reality?

Not all ports can become energy hubs, but those that will soon be able to offer alternative solutions will gain a strategic advantage in the future shipping landscape.

Photo: Lars Lindh

WHY IS SHIPPING BEHIND?

Unlike road transport, where electrification is rapidly expanding, maritime decarbonization is constrained by:

Fuel cost and market dynamics:

there is a lack of incentives to shift from fossil fuels to renewables. The costs are higher, and few customers are willing to pay for a green shipping solution.

Fuel production and infrastructure limitations:

the production capacity of renewable fuels is extremely low considering the great amount of fuel shipping consumes. Few ports are currently equipped for large-scale alternative fuel bunkering or charging.

Long asset lifecycles:

ships are built to last 20-30 years, meaning many in operation today were not designed with alternative fuels in mind.

Safety and regulatory challenges:

new fuels such as ammonia and hydrogen require specialized handling, infrastructure, and global regulatory alignment not in place today.

Despite these challenges, momentum is building. **New EU regulations are reshaping the maritime landscape** and increasing number of companies are setting more concrete climate targets.
The industry is now at a **tipping point**, where the ports that act swiftly will secure a strategic advantage in the future of global shipping.

This report explores the critical role of port authorities in facilitating the transition towards decarbonization of maritime transport, detailing a methodology and specific insights from a Swedish case study: the port of Umeå.

Alternative fuels in the ships on order books: Today, ships consume approximately 280 million tonnes of fuel annually, and more than 99% of the world fleet still runs on fossil-based conventional fuels.

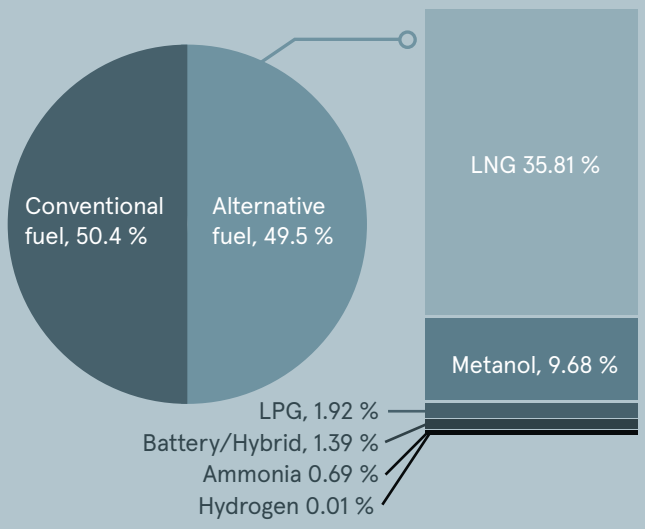


Figure 1. Alternative fuel in the ships on order books (Source: DNV, 2023a).

WHO IS DRIVING THE TRANSITION: Key players and driving forces

KEY PLAYERS

There are **several key players** driving the transition towards decarbonization of maritime transport and ports operations.

Port authorities

Oversee port management, infrastructure and security. Port authorities play a central role in coordinating activities and ensuring that the port operates in accordance with local and international regulations.

Terminal operators

Manage port terminals, handling cargo by themselves or through stevedores, and maintaining equipment and infrastructure.

Shipping companies

Own or operate vessels to transport goods between ports, manage logistics, and negotiate transport contracts.

Cargo owners

Transport buying companies that can affect sustainability and transport mode selection by setting requirements in transport procurement.

Energy providers and grid operators

Supply fuels, propulsion solutions, and innovative port technologies incl. increased electrification (on shore power supply for ships and terminal handling equipment). Essential actors for the establishment of production facilities for renewable fuels.

Regulatory bodies and local authorities

Oversee port governance, set policies, fund projects, and enforce regulations.

Financial institutions

Fund ships, port infrastructure, and maritime projects through loans and investments.

The interactions between these key players are complex, involving both the handling of physical goods flows and the exchange of information. **A key factor in ensuring all players work in sync, especially during the transition to alternative fuels, is following regulations.** These regulations play a crucial role in guiding and enabling strong collaboration, ensuring that all parties align with climate goals and contribute effectively to the process.

Photo: HHM / Peter Glaubitt

DRIVING FORCES

Driving forces to the decarbonization of the maritime sector are the **regulations** in place as well as the **market** influencing corporations engagement and commitment to climate goals.

- **Appropriate regulations in place** such as national, EU and IMO policies (more specifically the EU Fit for 55, including EU ETS, FuelEU Maritime and AFIR) are currently shaping a more sustainable shipping sector.
- **Market aspects and concrete corporate commitment to climate goals** such as the Science-Based Targets Initiatives where committed companies must reduce their emissions to meet the goals of the Paris Agreement, **limiting global warming to 1.5°C above pre-industrial levels.**

There are several challenges preventing the shipping sector from shifting to cleaner alternatives, one **is the cost gap between fossil fuels and renewable fuels**. Traditionally, fossil fuels used in shipping have been tax-exempt and not subject to carbon pricing, while renewable fuels are significant more expensive to produce. This lack of financial pressure has slowed investment in cleaner energy solutions. **However, this is about to change.**

New EU regulations are set to introduce carbon pricing and stricter emissions policies, which will make fossil fuels less economically viable in the future. Another challenge is the present insufficient **renewable fuel production capacity**. Collaboration among several actors is a key to handle the complexity of the task to facilitate and set up production facilities, the large costs and risks involved, and uncertainty of how supply and demand for a specific low-carbon fuel will develop over time.

Fit for 55 - package to reduce EU's total greenhouse emission by 55% by 2030:

The Europen Commission's Fit for 55 package intend to reduce the EU's total greenhouse gas emissions by 55% by 2030, paving the way for full EU decarbonization by 2050.Many of these directives and regulations sets the path towards a more sustainable shipping sector.

This will affect ships calling European port by mainly three new regulations:

- **The EU emission trading system (ETS)**: Shipping has been included in the EU ETS covering ships above 5 000 gross tonnages. In 2024 40% of the emissions will be covered, increasing to 70% in 2025 and then full inclusion from 2026. This policy is expected to provide important incentives to reduce shipping GHG emissions.
- **The FuelEU Maritime Regulation:** The Fuel EU Maritime promote the use of renewable and low-carbon fuels in EU related shipping. The GHG intensity of the energy used on-board of ships is reduced by 2% in 2025 and 6% in 2030, with a gradually decrease over time up to 80% in 2050.
- **The Alternative Fuels Infrastructure Regulation (AFIR)**: which stipulates among other things under which circumstances it is mandatory for ports to offer supply of shore-side electricity to ships (i.e. onshore power supply, OPS).

2. ALTERNATIVES TO FOSSIL FUELS: POTENTIAL AND LIMITATIONS

There are several alternative energy sources that could replace fossil fuels in the maritime sector. The most applicable alternative fuels are: biogas, methanol, hydrogen, ammonia, hydrotreated vegetable oil (HVO), battery-electric propulsion, and wind propulsion.

Key factors to consider when choosing fuels are:

Economic aspects
Investment and production costs, operational expenses and financial viability.

Safety considerations
Handling routines and risks, regulatory compliance.

Technological readiness
The current development stage and practical implementation feasibility.

Environmental considerations
Emissions reduction potential and contamination risks.

Infrastructure and storage
Availability, bunkering and charging requirements. Grid capacity.

Photo: Jonas Gunnarsson

SUMMARY OF FUEL ALTERNATIVES

1. Biogas/LBM

⊕ Compatible with LNG engines, significantly lowers greenhouse gas emissions, and can be produced sustainably in large quantities.
⊖ Limited availability today, dependence on large-scale biogas production, and competition from other sectors for biogas resources.

2. Methanol

⊕ Proven track record in shipping, does not need cryogenic storage, and can be derived from biomass or renewable electricity.
⊖ Sustainable production requires biogenic or non-fossil CO2

3. Hydrogen

⊕ High energy efficiency when used in fuel cells and can be produced from renewable electricity.
⊖ Low volumetric energy density, complex storage requirements (compressed or cryogenic), high infrastructure and transport costs, no large scale renewable production today.

4. Ammonia

⊕ Carbon-free combustion, relatively high energy density compared to hydrogen, and expected to be more cost-competitive than methanol.
⊖ Highly toxic, safety is the strongest limitation as ammonia requires strict safety measures. Lower technological readiness and potential NOx emissions when combusted.

5. Hydrotreated Vegetable Oil (HVO)

⊕ Can be used in existing diesel engines without retrofit, serves as a drop-in biofuel alternative, and has low sulfur emissions.
⊖ Limited production capacity relative to demand, high production costs, and strong competition with other industries for biofuel resources.

6. Battery-Electric Propulsion

⊕ Highly efficient, produces zero local emissions, and is well-suited for short-distance routes and as hybrid solutions to reduce fuel consumption onboard larger vessels.
⊖ Low energy density compared to liquid fuels, high battery weight, long charging times, and dependence on electricity grid capacity.

7. Wind Propulsion

⊕ Can be integrated into hybrid propulsion systems and contributes to fuel reductions.
⊖ Dependent on weather conditions, requires adaptations in ship design, and is best suited for slow-speed operations.

Each alternative fuel presents a unique balance of technological readiness, infrastructure demands, costs, and sustainability potential. Their adoption will depend on regulatory support, advancements in production and storage technologies, and large-scale investments in maritime energy solutions.

A critical consideration for the sector is that **no single solution will dominate in the near future**. Instead, **a combination of alternative fuels and propulsion methods will likely be required to meet fuel demand and operational needs.**

3. THE UMEÅ ROADMAP: EXPLORING GREEN HYDROGEN-BASED FUELS

In Sweden, ports like the port of Umeå are playing a key role in the country's transition to more sustainable maritime transport, supporting the development of alternative fuels, bunkering infrastructure, and low-carbon shipping solutions.

Under the framework of the Blue Supply Chains project, it was developed the so called "Umeå roadmap" which is exploring locally produced green hydrogen-based fuels in the Umeå region, with 2040 as target year.

The Roadmap outlines a structured approach and methodology that can be used for assessing fuel supply and demand, infrastructure development, and decarbonization strategies for ports. This methodology is not just relevant for Umeå but for other ports in the Baltic Sea region as it helps accelerating the adoption of alternative fuels and green port operations.

Blue Supply Chains - a project funded by the Interreg Baltic Sea Region:

https://interreg-baltic.eu/project/bluesupplychains/

The initiative behind Blue Supply Chains is a **broad consortium consisting of actors around the Baltic Sea** who all have a desire to develop fossil-free maritime transport and integrations with land transport via efficient port terminals. The project is coordinated by Hafen Hamburg Marketing in Hamburg (Germany) and is financed by the EU's Interreg Baltic Sea Region.

The Swedish node: within the project, a collaboration on maritime fuels has been established between the IVL Swedish Environmental Research Institute, Closer/Lindholmen Science Park, and several stakeholders in Umeå: Umeå Energy, Umeå Municipality, INAB, Umeå Port, and Kvarken Ports.

WHY UMEÅ?

Umeå was selected for this study due to its active engagement in renewable energy projects, its role as a transport hub and its commitment to environmental sustainability as well as its regional significance.
Umeå is a city in northern Sweden, located along the Ume River near the Gulf of Bothnia. It is the largest city in northern Sweden and the administrative center of the Västerbotten region.

Umeå is particularly suitable for electro-fuel production for several reasons:

- Availability of renewable energy, bio-based carbon dioxide, and clean water
- Opportunity to use the heat by-product in the available district heating system
- Potential regional customers
- Transport hub for export by rail or sea
- Proactive and decisive stakeholder

ROADMAP OF LOCAL GREEN HYDROGEN-BASED FUELS IN THE UMEÅ REGION

The overall **methodology** behind the Umeå roadmap was developed and described in details in the report *"Role of Port Authorities in green energy supply for transport chains"* (Styhre et al., 2024) published under the framework of the Blue Supply Chains project.

The **objective** of the methodology is to create a structure to analyze supply and demand of energy in ports to serve the shipping industry and potentially also other industries, today and in the future.
The idea is to support stakeholders in the shipping industry to move towards low-carbon operations and contribute to the necessary reduction of ship and port emissions.

The Umeå roadmap's methodology consists of **6 steps**:
Step 1. Define objective and timeframe
Step 2. Map the present
Step 3. Assess the future
Step 4. Understand technological developments
Step 5. Explore pathways, actors and measures
Step 6. Plan for realization, follow-up and evaluation

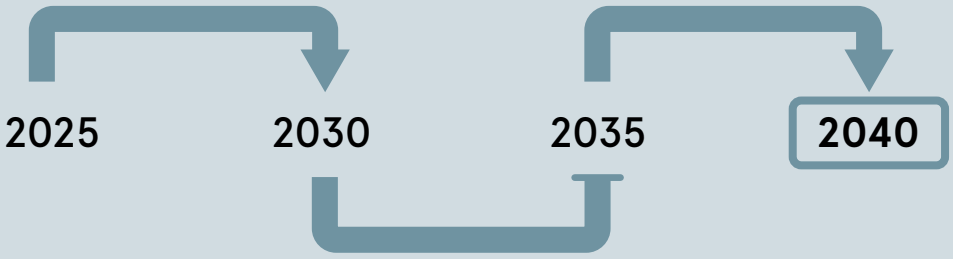
Map of Sweden

Step 1.

Define objective and timeframe

Set the scene by formulating an objective and agreeing on a timeframe of a strategy for the port(s) in a specific country or region.

- Outline: strategic plan for local production of electrofuel in the Umeå Region
- Target year: 2040 – this was set in alignment with key actors like Umeå Municipality, Umeå Energi and the port of Umeå and their energy plans.



Step 2.

Map the present fuel production sites, bunkering and charging facilities

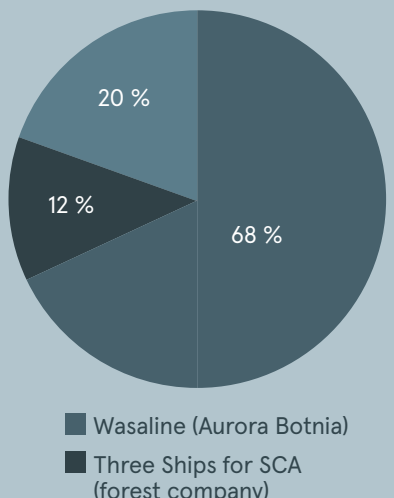
Including investigation of present traffic, transport volumes, ship types, market development, involved actors and energy systems.

- The region's large hydroelectric power production is primarily delivered to the national grid
- Two CHP plants at Dåva provide 80% of Umeå's district heating – rest is coming from individual solutions (heat pumps, biofuel).

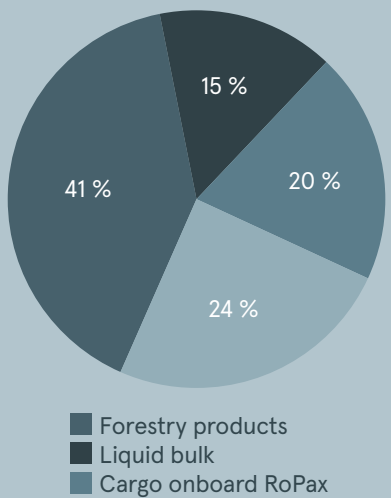
In the port area in Umeå:

- Energy system: OPS and charging of the Wasaline´s Aurora Botnia, No OPS at other berths, No bunkering, No local marine fuel production

- Number of annual port calls: 841 (2022 data)



- Ships have an average of 20 years and 6 800 dwt GT size (general cargos)
- Amount of cargo (tonnes) transported through the port of Umeå in 2019, which steadily increased in the last decades

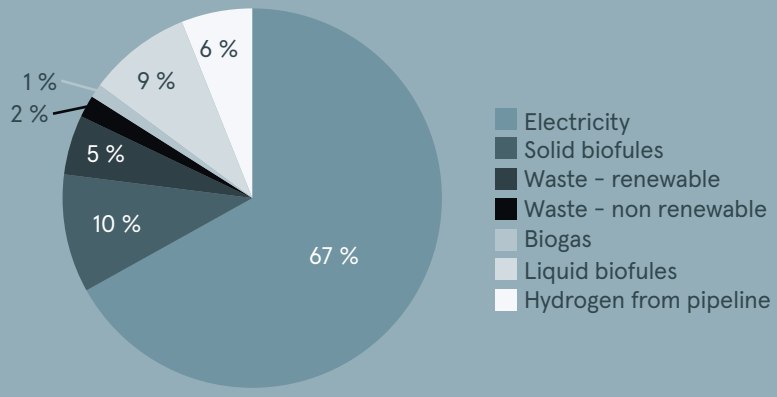


Step 3.

Assess the future demand and supply production sites, bunkering and charging facilities in Umeå

Including investigation of potential future traffic, transport volumes, ship types, market, involved actors and fuel production development sites and charging facilities.

- Umeå signed the *Climate City Contract* with the EU and adopted the *Climate Ambitious Scenario* - outlining its concrete commitments to climate neutrality and future energy plans: fossil fuels to be replaced by electrofuels.
- Future market and actors in Umeå: Liquid wind, Mana, Circle K, Umeå energy, Wasaline, SCA Logistics and other future export markets
- Planned electrofuel production in Dåva: up to 110,000 metric tonnes. (Initially, demand will be lower, allowing Västerbotten to be both self-sufficient and a net exporter of renewable fuels to other parts of Sweden)



Step 4.

Understand technological developments

Understanding maturity, infrastructure, storage needs, and techno-economic, environmental and safety prerequisites of renewable fuels and propulsion options is essential for identifying viable solutions tailored to a country's or region's local conditions.

- Break-down of the costs of methanol, hydrogen and ammonia were addressed (including fuel production costs, transport, storage, bunkering and additional on-board costs, etc).
- A gap analysis to comparing total life-cycle costs of renewable fuel alternatives vs. conventional shipping fuels was made. The analysis cleared out that **further investment is needed** to reduce the gap in life-cycle costs. However, the price gap is expected to decrease shortly as consequence of new EU regulation in place (where ETS, the Fuel EU Maritime Regulation and AFIR are particularly relevant for Umeå)

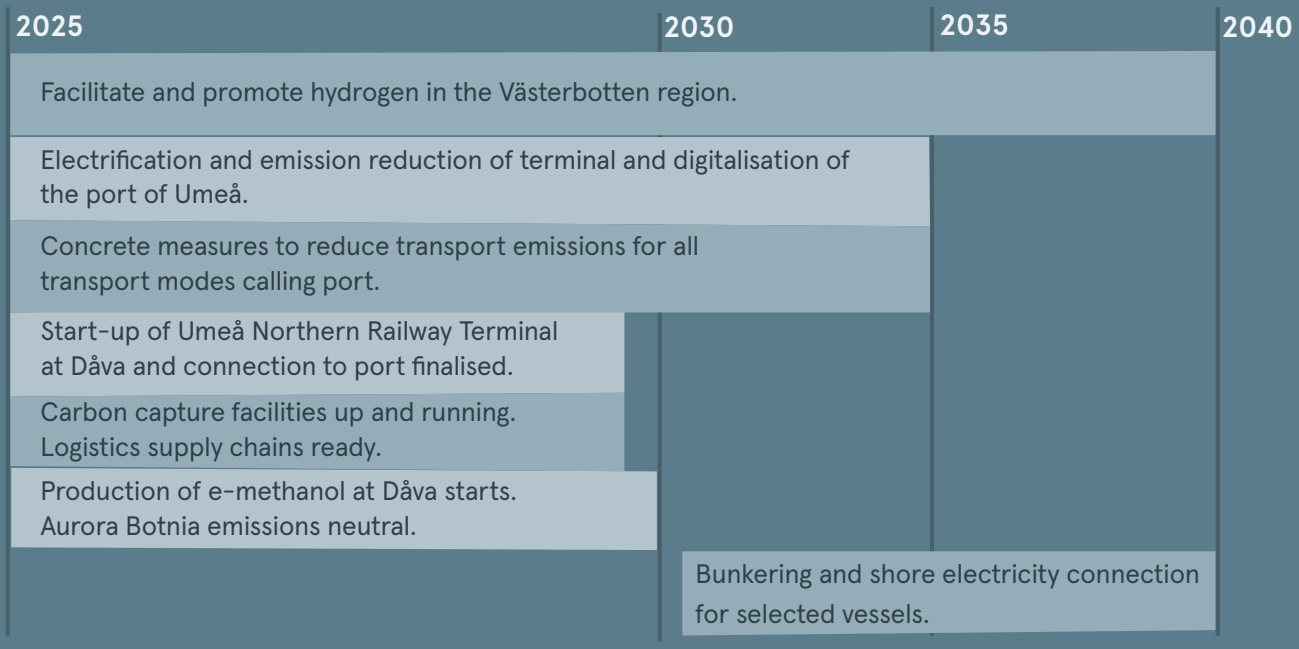
With investment support the cost gap between fossil fuels and alternative fuels can diminish significantly.

Step 5.

Explore pathways, actors and measures

Mapping potential pathways, actors involved, targets or measures needed to realize the roadmap.

- This is an ongoing work for Umeå, regularly updated when as new conditions apply. Those objectives drawn here are leading the pathway towards the target year 2040:



Step 6.

Plan for realization, follow-up and evaluation

Outlining concrete actions, following and evaluating the implementation of the national/regional strategy to be able to move from targets and overall measures to concrete actions.

The plan for realization, follow-up and evaluation is under development in the port of Umeå.

It will be based on the objectives outlined under Step 5 and will be connected to other ongoing work, initiatives and plans. Collaborations among main actors and stakeholders is crucial to make the transition a reality by target year 2040.

CONCLUSIONS FROM THE UMEÅ ROADMAP:

The Blue Supply Chains project made the pathway clearer for the Port of Umeå and get the decision making more confident. The plan is ambitious and includes business development, large investment requirements and long-term efforts among many actors and stakeholders to achieve the goals.

The proposed guidelines for a potential national strategy provide a methodology that can assist Baltic Sea countries in analyzing the fuel and charging needs of the shipping industry and related sectors.

4. CONCLUSIONS AND WAY FORWARD

The methodology to develop a roadmap for sustainable port development provides a structured **approach for assessing present and future fuel and charging needs based on technological development, supporting the transition to low-carbon shipping.** It includes assessment of potential pathways, actors to be involved, the outlining of overall targets or measures, with a concrete plan for realization, follow-up and evaluation. While developed for Sweden, this approach is highly relevant for other Baltic Sea countries and beyond, offering a framework to analyze energy supply and demand, infrastructure requirements, and technological advancements.

To successfully decarbonize, shipping must address key factors: scaling up renewable fuel production, investing in infrastructure, fostering stakeholder collaboration, establishing clear regulatory frameworks, and ensuring economic feasibility.
By taking a proactive approach, ports can reduce emissions, support global climate targets, and position themselves as leaders in the sustainable shipping sector and energy hubs. This transition is underway, and those who act now will shape the future of green maritime transport.

The following conclusions are highlighted:

- Several fuels and solutions will be available in the future and complement each other
- Ships' emissions need to be greatly reduced – and it is urgent!
- Policies and regulations are required and essential for supporting development of renewable fuels and reducing ship emissions.
- Pilot project and financial support is needed to prepare for full scale transformation.
- Costs in all parts of the supply chain need to be reduced for renewable fuels to be competitive.
- Cooperation among many actors is required and increased knowledge to grasp the quick development.

The transition to low-carbon shipping is challenging but necessary today. With the right strategies, investments, and cooperation, ports and the shipping industry can successfully reduce emissions and stay competitive in a sustainable future.

Photo: Jonas Gunnarsson

What are the three main benefits of renewable fuel production in Sweden?

Climate benefits, resilience, and business opportunities. Sweden has excellent conditions for producing renewable fuels thanks to its access to green electricity, biogenic carbon dioxide, clean water, and raw materials for biofuel production. Investing in renewable fuels supports the transport sector's climate transition and enhances resilience as the need for fossil fuel imports decreases. It also creates significant business opportunities for early adopters and strengthens Sweden's position as an export nation.

Linda Styhre
Researcher and senior project manager,
IVL Swedish Environmental Research Institute

Why is broad collaboration between private and public stakeholders crucial for projects like Blue Supply Chains, and why is it especially important for CLOSER at Lindholmen Science Park?

Developing innovative solutions requires a broad approach, integrating diverse stakeholder perspectives, objectives and influence. Many well-intended projects fail by overlooking key aspects. In the shift to fossil-free shipping, collaboration is vital—engaging both those who drive and those affected by change. Policymakers and authorities play a key role, as regulatory shifts often enable new solutions. CLOSER facilitates and orchestrates these crucial discussions.

Kristoffer Skjutare
Programme Manager, Programe development & steering
CLOSER, Lindholmen Science Park

What opportunities and challenges does the transition to e-methanol as fuel present for a port?

The opportunities, of course, include accelerating the transition of the maritime sector, strengthening the port's competitiveness, creating new business opportunities, and developing global trade relations. At the same time, the port must address challenges such as investments, safety risks, logistical complexity, uncertainties regarding regulations and standards, as well as competition with other fuel alternatives.

Mikael Isaksson
CEO, Umeå Hamn AB

What needs to be done to build the infrastructure required to support e-methanol as a fuel for shipping?

Robust logistics arrangements need to be established for renewable fuels, both those produced locally and those that are exported or imported. Ports need to develop cost-effective and secure systems for receiving and distributing the fuel. To supply renewable fuels in sufficient quantities, transport chains between various stakeholders, producers, ports and vessels must function efficiently and without interruptions.

Lina Samuelsson
Urban planer and Sustainability Strategist, INAB

What are the next steps for you (UEAB) to realize e-methanol production in Umeå?

We are in the final phase of making changes to the existing environmental permit to enable e-methanol production at Umeå Eco Industrial Park, where our combined heat and power plants are located. We are also negotiating the scaling up of power capacity from the electricity grid, which is essential to realize these establishment plans.

At the same time, we are working with partners to establish ownership structures and principles ahead of the upcoming investment decision, which is expected to be made in the third quarter of the year. Techno-economic coordination agreements are being developed by Liquid Wind and Umeå Energi to address the interdependencies between our combined heat and power plants and the planned e-methanol facility.

Jan Ridfeldt
Vd & Koncernchef, Umeå Energi AB

What would the realization of a facility for e-methanol production mean/imply for Umeå Municipality?

The realization of a facility for e-methanol production would mark an important milestone in the development of Umeå Eco Industrial Park, serving as a strong example of industrial symbiosis. Utilizing the carbon dioxide generated from combustion at Umeå's combined heat and power plant as a component in the production of electrofuels would enable Umeå to contribute to emission reductions in the shipping industry. In the long run, this could make it possible to operate the new ferry between Umeå and Vaasa on renewable/fossil-free fuels.

Mikael Brändström
Development Director, Umeå Municipality

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LIST OF ABBREVIATIONS

AFIR - Alternative Fuels Infrastructure Regulation
ETS - Emission Trading System
GHG - Greenhouse Gas
HVO - Hydrotreated Vegetable Oil
IMO - International Maritime Organization
LNG - Liquid Natural Gas
LPG - Liquefied Petroleum Gas
NOx - Nitrogen Oxides
OPS - Onshore Power Supply
RoPax - Vessel designed to carry both vehicles (via roll-on/roll-off) and passengers

ACKNOWLEDGMENTS

The project Blue Supply Chains received financial support by the Interreg Baltic Sea Region Programme, the Swedish Transport Administration and the Swedish Institute for Water and Air Pollution Research (SIVL). The Swedish Maritime Administration is thankfully acknowledged for their support with port call statistics for all ships arriving and departing Swedish ports in 2022. The authors thank all companies, organizations and authorities that participated in interviews or shared their data that were included in our calculations or analyses.

Further, we have received valuable contributions to this work and feedback on draft reports from our Blue Supply Chains' partners and associated partners, including Port of Hamburg, Umeå Energy, Umeå municipality, Umeå Port, Kvarken Ports, INAB, Closer Lindholmen Science Park, Swedish Transport Administration and Swedish Maritime Administration.

The Blue Supply Chains project supports port authorities and port operators to decarbonise port operations by advancing electrification, providing alternative fuels strategies and setting up green transport chains.
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