PRE-PILOTING

Intra-Nordic green shipping corridor candidates

Nordic Council of Ministers

Report No.: 2023-0397, Rev. 0
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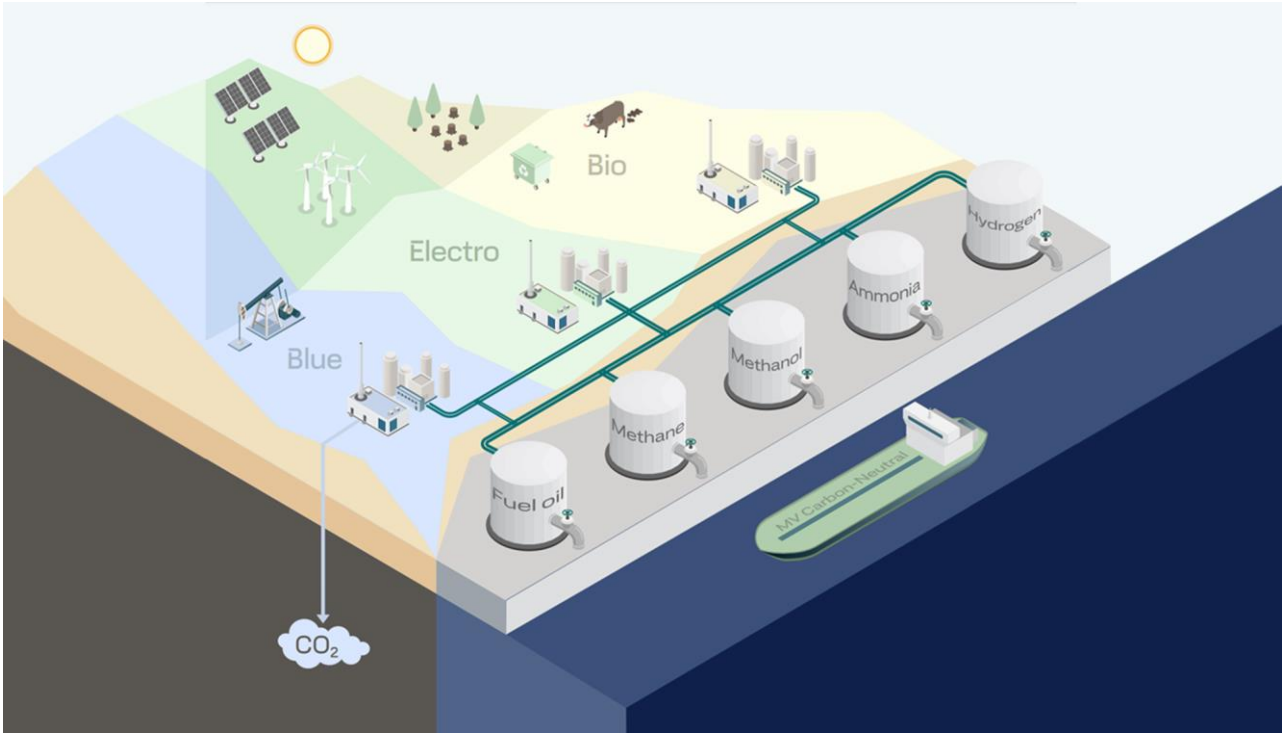

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Objective:

Identifying intra-Nordic ship traffic routes for decarbonization and potential green shipping corridors to be realized in 2025, or towards 2030.

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1 EXECUTIVE SUMMARY

The aim of this pre-pilot project, awarded to DNV by the Nordic Council of Ministers, was to identify specific intra-Nordic shipping routes which have the potential of realizing a green shipping corridor by 2025, or towards 2030 as a follow-up to the Clydebank Declaration launched at COP26.

What we did

A three-step approach was applied to identify specific intra-Nordic shipping routes with the potential of being a "first mover" green shipping corridor. In the first step, 81 intra-Nordic ship traffic routes were identified (longlist). The second step used this longlist and industry dialogues to select six potential intra-Nordic green shipping corridors which potentially could be realized in 2025, or towards 2030. These six corridors all have motivated stakeholders with a strong interest in the specific route. The shortlist of the six corridors includes the following intra-Nordic routes, where the initiator is highlighted in bold:

1. **Viking Line**; Stockholm – Abo (Turku)
2. **Color Line**; Sandefjord – Strömstad
3. **Bornholmslinjen**; Ystad - Rønne
4. **Wasaline**; Umeå – Vasa
5. **ASKO**; Hirtshals – Larvik
6. **Nordic Roadmap (This project)**; an Arctic Green Shipping corridor.

For the screening of the key barriers for three out of the six shortlisted candidates (i.e., candidate 2, 4 and 5 in the above list), a series of workshops were carried out as a third step of the process. These workshops were centered around establishing a coherent view of the value chains of green shipping corridors and were crucial for identifying the partnerships necessary for the realization of such corridors.

What we found

Using a traffic-light screening approach, developed in this project, key barriers were identified for selected corridors and stakeholders. Common key barriers identified in all the workshops were the financial barriers, which could represent a significant showstopper. To overcome financial barriers, certain cost- and risk-sharing measures are necessary to help close the cost gap compared to fossil fuels. The inclusion of shipping into EU ETS and future CO_2 taxation will help decrease the cost gap, but not sufficiently according to involved stakeholders. In addition, discussions with potential green shipping corridor candidates show that green financing and Contracts for Difference (CfD) will be crucial for the first movers.

The workshops also revealed that active involvement of the relevant ports as future energy hubs and stakeholders such as cargo owners and energy suppliers, are important for the green shipping corridor business case. Furthermore, the workshops revealed that realizing a fully decarbonized route by 2025 in one step is challenging, so a green shipping corridor might need to be phased in over several years. In some cases, the operating vessels and the infrastructure in the ports only need minor technical modifications to adapt to new sustainable zero-carbon fuels.

This study concluded with three key barriers that the stakeholders must overcome, in order to realize a green shipping corridor:

a. The **financial** gap between using conventional fuels and zero-emission fuels,
b. The lack of fuel availability and bunkering **infrastructure**, and
c. The lack of safety requirements/**regulations** onboard and onshore for ammonia and hydrogen.

What we recommend

The identified shortlist and other findings from this pre-pilot project will be further developed in the piloting task of the Nordic Roadmap project, where the objective is to execute two to three initial pilot studies on promising intra-Nordic green shipping corridors. It is recommended to continue working on maturing the six shortlisted potential corridors in the Nordic Roadmap project. As seen in Figure 1-1, the maturity of the six shortlisted routes varies, but in general they are all in the planning phase. This means that the process of establishing green shipping corridors in the Nordics will take time – probably several years. Through pilot or feasibility studies, the Nordic Roadmap project could move the candidates towards the right in Figure 1-1. It is also recommended to revisit the longlist for possible pilot candidates, including possible corridor options not yet identified (e.g., new sea routes – moving cargo from land to sea).

The Nordic ministers could play an important role in overcoming the identified financial, regulatory, and infrastructure barriers, enabling the introduction of the first green shipping corridors. Particularly, it is important to provide support on closing the cost gap compared to fossil fuels, considering Contracts for Difference (CfD) and other cost/risk reducing options.

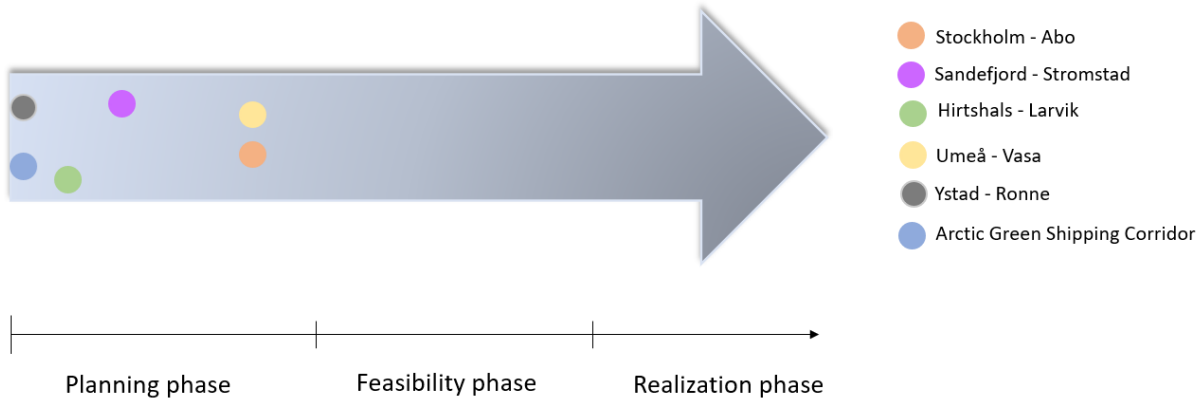

Figure 1-1: Maturity-scale for the shortlisted intra-Nordic routes for decarbonization.

Given the immaturity of hydrogen and ammonia on-board technologies, the Clydebank ambition of establishing at least six green shipping corridors between two (or more) ports by 2025 will have to consider ships fuelled by the more technically ready methanol and LNG (carbon neutral bio or synthetic) or using battery/hybrid solutions.

2 INTRODUCTION

At COP 26, the Nordic countries took part in launching two important initiatives on emission reductions from shipping: the Declaration on Zero Emission Shipping by 2050 and the Clydebank Declaration, where more than 20 countries have committed to develop at least six green shipping corridors between two (or more) ports by 2025 and “many more” by 2030. Green shipping corridors can become key enablers to accelerate the uptake of zero-emission fuels, because they allow for the multitude of barriers hindering the global uptake of zero-emission fuels (such as risks, costs, and supply) to be addressed and resolved on a manageable scale (DNV, 2022a). Already, almost 25 green shipping corridor initiatives have been announced globally, but they are all in the early planning phase (COP27, 2022), (ZESM, 2023). For more information about green shipping corridors, please see the “Knowledge base” developed by the Nordic Roadmap project[1].

Nordic collaboration on green shipping is well situated to follow up concretely on the objective of the Clydebank Declaration. There is currently a significant volume of marine traffic between the Nordic countries, and Nordic waters are home to some of the world’s busiest ferry routes. Conditions are therefore well suited for establishing green shipping corridor projects with intra-Nordic ferry connections and possibly other suitable maritime transport routes. A successful early establishment of the first green shipping corridors will result in routes having potentially zero emissions by 2025 and place the Nordics as a “first mover” region in the fuel transition. These first green shipping corridors must be “low-hanging”, meaning they will apply mature technologies and have motivated stakeholders agreeing on risk- and cost-sharing.

To kick-start the follow-up of the political intention, the Nordic Council of Ministers awarded DNV a pre-pilot project (“Nordisk pilotprosjekt for etablering av nullutslippsruter for sjøtransport i Norden”) which will identify specific intra-Nordic shipping routes for decarbonization, find interested stakeholders and start the establishment of partnerships which can result in green shipping corridor pilot projects.

This report documents the results from the pre-piloting work, carried out in 2022 and 2023. The report is structured as follows: the overall methodology is presented in chapter 3, while chapters 4, 5, and 6 describe in more detail the three steps performed to identify and evaluate potential green shipping corridor partnerships.

The work on identifying specific intra-Nordic shipping routes for decarbonization has been carried out in collaboration with the Nordic Roadmap project[2]. The Nordic Roadmap project has already published 7 deliverables[3] and plans to use the findings from the pre-pilot project in their piloting task[4].

[1] Knowledge Base – Green shipping corridors: https://futurefuelsnordic.com/green-shipping-corridors/

[2] The Nordic Roadmap Project – Future Fuels for Shipping: https://futurefuelsnordic.com/

[3] Knowledge Base – Project deliverables: https://futurefuelsnordic.com/project-deliverables/

[4] Task 3-B: Piloting of selected fuels https://futurefuelsnordic.com/piloting-of-selected-fuels/

3 METHODOLOGY

Figure 3-1 illustrates the 3-step approach used to identify specific intra-Nordic shipping routes for decarbonization:

- **Step 1:** To identify specific intra-Nordic Shipping routes for decarbonization, the longlist of potential green shipping corridors developed in the Nordic Roadmap project has been used (DNV, 2022b). Other studies have been considered, such as the Northern European & Baltic Green Corridor Prefeasibility Study (MMMCZCS, 2022), in addition to industry dialogues with Nordic stakeholders.
- **Step 2:** A high-level screening of the longlist from Step 1 identified potential intra-Nordic green shipping corridor pilots which could be realized in 2025, or towards 2030. Through industry dialogues, DNV's network, and initial meetings with relevant stakeholders, six specific routes from the longlist were extracted to a shortlist.
- **Step 3:** To identify barriers and necessary partnerships to establish intra-Nordic green shipping corridors, workshops were used on three selected corridors from the short list. Using a traffic light screening approach, developed in this project, key barriers were identified for each corridor and main stakeholder. This high-level barrier assessment also identified other stakeholders and partnerships necessary for realization of the selected green shipping corridors.

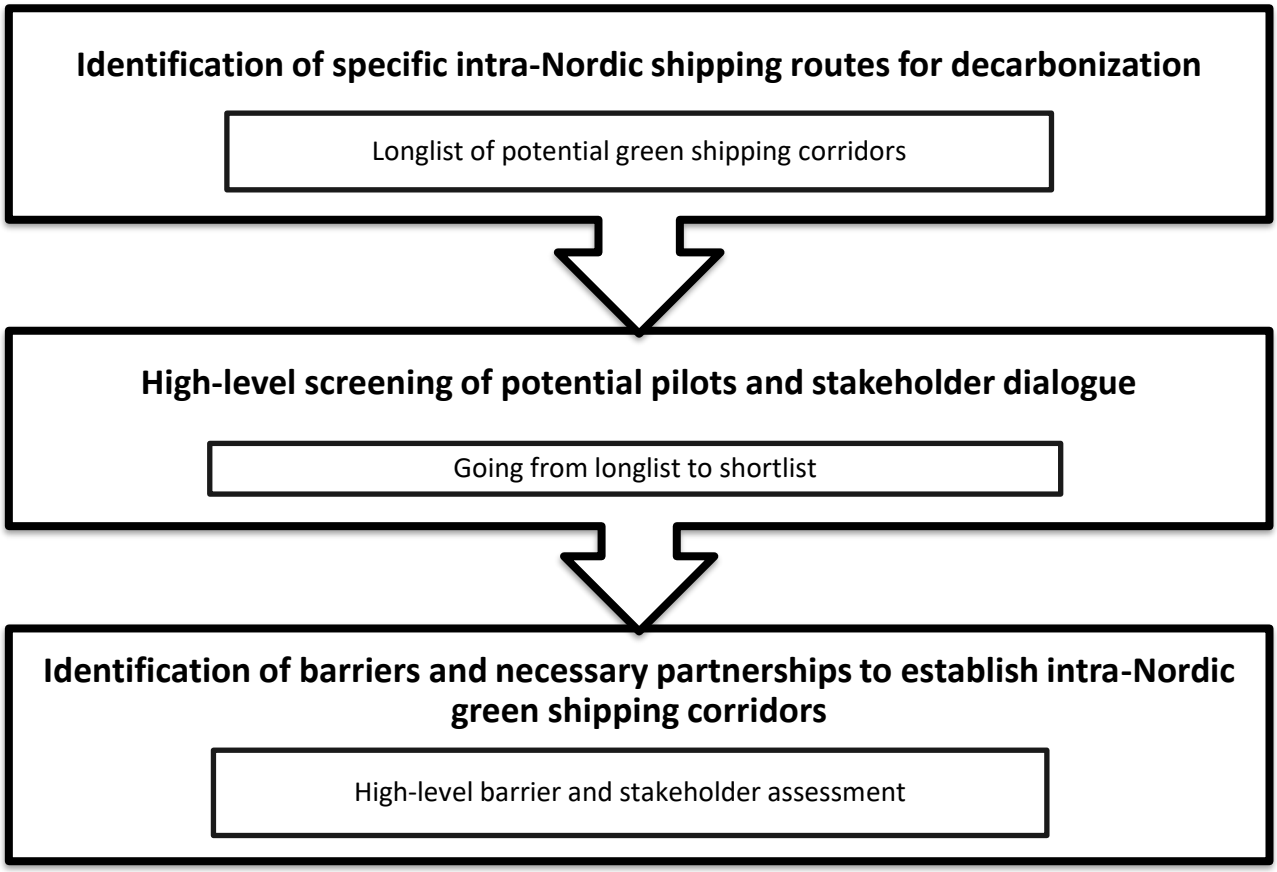

Figure 3-1: The screening approach used to identify and evaluate potential green shipping corridors.

4 IDENTIFICATION OF SPECIFIC INTRA-NORDIC SHIPPING ROUTES

This chapter provides an overview of the long list of potential green shipping corridors, developed in the Nordic Roadmap project based on AIS analysis. In addition, other studies have been considered, such as the Northern European & Baltic Green Corridor Prefeasibility Study (MMMCZCS, 2022).

Based on AIS-modelled energy consumption (fuel consumption) and ship characteristics, the Nordic Roadmap project identified routes between Nordic countries which have a large annual energy consumption for the important ship categories Ro-Pax, cargo, and wet and dry bulk. These routes were labelled potential green shipping corridors and are summarized in Table 1 (DNV, 2022b).

In total, 81 routes were identified in this analysis. These constitute about 17% of the total energy consumption of Nordic ship traffic.

Table 1: Overview of routes selected as potential green shipping corridors in the Nordic Roadmap project (DNV, 2022b).

Route type	No of routes	Potential annual energy demand	
		Mtoe[5]	% of Nordic ship traffic
Intra-Nordic Ro-Pax routes	18	0.38	4.4%
Nordic-international Ro-Pax routes	23	0.70	8.1%
Intra-Nordic/Nordic-international cargo routes	20	0.31	3.6%
Intra-Nordic/Nordic-international wet and dry bulk routes	20	0.07	0.8%
Total	**81**	**1.46**	**17%**

This longlist of 81 corridors was established based on key performance indicators (KPIs) related to the actual ship traffic pattern, regularity on the routes, fuel feasibility, and energy demand extracted from the AIS analysis (explained in more detail in APPENDIX A), and in the Nordic roadmap deliverable - **"**AIS Analysis of Nordic Ship Traffic" (DNV, 2022b).

Figure 4-1 shows the traffic pattern for all passenger vessels in parts of the Nordic region. **For the establishment of initial green shipping corridors, the Nordic Roadmap project recommends that focus is put on the intra-Nordic Ro-Pax routes.** These routes account for 4.4% of the total energy consumption and CO_2 emissions of Nordic ship traffic, involving relatively few ports and relatively few vessels operating on a regular basis (Table 1). The decarbonization of the Ro-Pax segment has already started, primarily through battery electrification of domestic and other short distance Ro-Pax routes.

The challenges and learnings from the decarbonization of intra-Nordic Ro-Pax vessels can easily be transferred to the Nordic-international Ro-Pax routes, which possess many of the same characteristics as the intra-Nordic Ro-Pax routes in terms of ship sizes and sailing distances. These routes have in total more energy consumption than the intra-Nordic Ro-Pax routes, accounting for 8.1% of the total energy consumption and CO_2 emissions of Nordic ship traffic.

Beyond Ro-Pax routes, focus should also be put on the cargo and bulk vessels operating on relatively fixed routes, and routes which involve few individual ports on the round trips. The total annual energy demand for a cargo route can be as high as for an intra-Nordic Ro-Pax route, but fewer annual voyages, less regularity, and several involved ports imply that the barriers are higher for the decarbonization of these routes.

[5] Mtoe – Million tons of oil equivalent

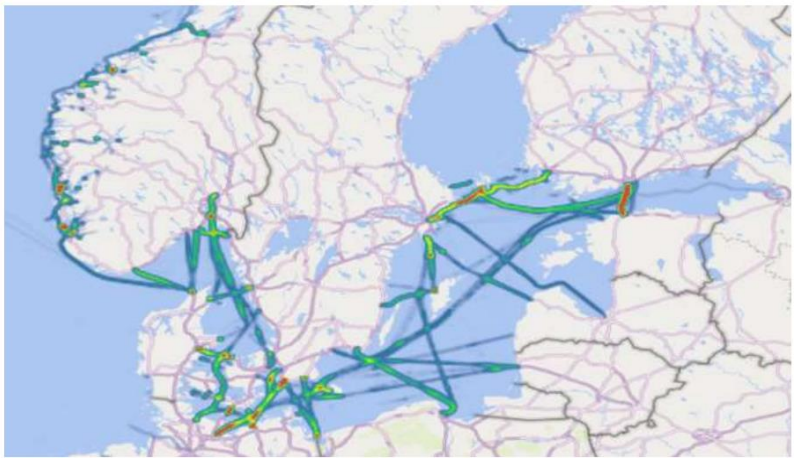

Figure 4-1: Traffic patterns for all passenger vessels in parts of the Nordic region in 2019. Colouring indicates fuel consumption density at the given geographical location (DNV, 2022b).

5 GOING FROM LONGLIST TO SHORTLIST

This chapter describes the approach of going from the longlist to a shortlist of potential intra-Nordic green shipping corridors which can be realized in 2025, or towards 2030.

For a potential green corridor to be realized, a range of different criteria needs to be fulfilled. The criteria include stakeholder engagement, willingness or ability to cover the additional cost of decarbonization and other aspects which cannot be assessed by AIS analysis alone. The selection process for establishing initial green shipping corridors is crucial, to ensure that specific routes are feasible to implement, and capable of generating sustainable operations which can be copied to other routes through diffusion and used as practical learning for development of a green fuel network throughout the Nordic Region.

The longlist from the AIS analysis of Nordic ship traffic routes presented, as mentioned, 81 potential green shipping corridors. A shortlist was developed through industry dialogues and DNV's network with important stakeholders on the routes that scored high on the different KPIs in the longlist. The six intra-Nordic routes making the shortlist are presented in Table 2, along with the corresponding KPIs and the relevant stakeholders who have a high interest in the specific route. Further explanation of the KPIs used in the AIS analysis of Nordic ship traffic routes and presented in Table 2 can be found in APPENDIX A.

Table 2: The shortlist of routes extracted from the longlist, with the assigned KPIs and potential stakeholders. The routes are ranked by the annual total energy consumption (share of total fuel consumption of all intra-Nordic Ro-Pax or cargo routes).

Green Corridor KPIs	Share of total fuel consumption of all intra-Nordic Ro-Pax or cargo routes	Number of ships	Annual number of trips	Fuel feasibility*	Spin-off potential**	Potential stakeholders
Intra-Nordic Ro-Pax routes						
Abo (Turku) - Stockholm	21%	4	2768	Level 2	High	**Viking Line**
Hirtshals - Larvik	6%	2	343	Level 2	High	**ASKO**
Sandefjord – Strömstad	5%	4	1648	Level 1	Low	**Color Line**
Ronne – Ystad	4%	4	2105	Level 2	Low	**Bornholmslinjen**
Holmsund (Umeå) – Vasa	2%	2	765	Level 1	Low	**Wasaline**
Intra-Nordic cargo routes						
Arctic green shipping corridor[6]	5%	2	35	Level 3	Medium	**Royal Arctic Line, Eimskip**

**Fuel feasibility is given by the assessment of which fuels are feasible for the route. This KPI is indicated as Level 1, Level 2 and Level 3 for each route based on which fuel options are feasible. **The Spin-off potential is expressed as Low, Medium or High based on the possible spin-off effects for routes that start, end, or move between potential energy hubs which also have the ability to serve a considerable part of domestic or other traffic (see APPENDIX A for further details).*

The shortlist is well aligned with the recommendation from the Nordic Roadmap project described in chapter 4, since it mainly consists of Ro-Pax routes, but also includes one potential intra-Nordic cargo route. The five potential intra-Nordic green Ro-Pax corridors in the shortlist constitute 38% of the total fuel consumption of all intra-Nordic Ro-Pax routes.

[6] The Arctic green shipping corridor represents the route, rated as number 9, in the longlist of intra-Nordic and Nordic international cargo round trips. The ports in the round trip are overlapping with ports in a potential arctic green shipping corridor.

The Nordic Roadmap project has performed a study on infrastructure and bunkering challenges for zero-carbon fuels (Menon, 2023). The Menon study included an assessment and selection of Nordic ports that have the potential to be a part of green corridors and energy hubs. Based on a set of criteria, the study proposed 37 Nordic ports. The six intra-Nordic corridors selected in this study (Table 2), is also mentioned in Menon's list (their Table 3). Arctic ports, important for an Arctic green shipping corridor, were also listed in this study (e.g., Torshavn, Reykjavik, and Nuuk). The only port not mentioned in Menon's list was Ystad, but Rønne made the list as a "low-hanging fruit".

6 HIGH-LEVEL BARRIER AND STAKEHOLDER STUDY – SELECTED INTRA-NORDIC ROUTES

This chapter describes the results from the high-level barrier and stakeholder assessment of selected potential intra-Nordic green shipping corridors. Three of the routes in the shortlist have been analysed in workshops with the stakeholders where barriers were identified.

Through workshops with the stakeholders operating on selected intra-Nordic routes, barriers and opportunities were identified throughout the complete value chain. Every step of the value chain is assessed based on relevant KPIs, which might be different for the various potential intra-Nordic green shipping corridors. The results from this high-level barrier assessment are presented through scorecards with the traffic-light approach, which is described in more detail in APPENDIX B.

For the corridors assessed, the fuels and technologies discussed were mainly biofuels and battery/electrification, where safety regulations are already in place. If selecting hydrogen or ammonia as fuels, the lack of safety requirements onboard and on shore is a key barrier (DNV, 2022c) (DNV, 2022d).

6.1 Wasaline; Umeå – Vasa

Wasaline is the shipowner operating between Umeå in Sweden and Vasa in Finland. This route has already come a long way in the early planning phase and has a unique collaboration platform between the two ports, the two cities, and the vessel operating on the route. Today, the vessel is using a hybrid propulsion solution with batteries and dual fuel LNG engines. However, this route is not suited for 100% electric operation due to the arctic conditions where ice remains a significant challenge for the peak power demand. Due to the relatively low emissions from this route today, the GHG abatement potential is assessed as intermediate. However, the involved stakeholders are motivated to enable a fully decarbonized green shipping corridor by the end of this decade.

A first step towards a green shipping corridor is likely to phase in bio-LNG, but the long-term goal might be to phase in green methanol. The learning potential for other green shipping corridors is high, both for adoption of green methanol and for utilization of the potential fuel flexibility (where a vessel could rely on a mix of green methanol, bio-MGO, and bio-LNG).

The business case and the financial barrier could be a potential showstopper for this green shipping corridor. The partners will need dedicated cargo owners who are willing to help reduce the financial risk, green financing, or financial support from the government to overcome this barrier. The overall high-level barrier assessment is presented in Figure 6-1.

All the partners in this group (Wasaline, Kvarken Port, INAB, VASEK, Umeå port, Umeå kommunföretag) have signed letters of support to Nordic Roadmap and are tightly linked to this project. This is beneficial for further collaboration in the piloting phase of the Nordic Roadmap project.

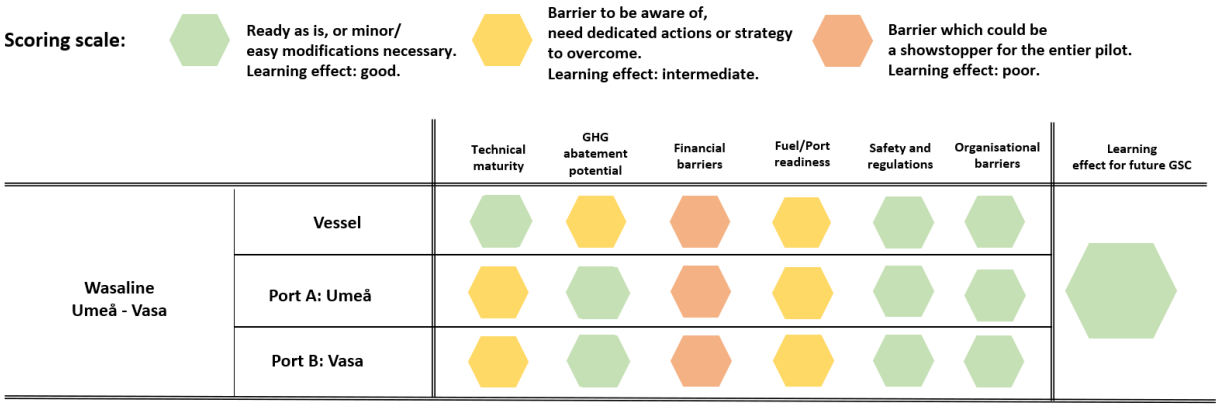

Figure 6-1: High-level barrier assessment for Umeå – Vasa.

6.2 Color Line; Sandefjord – Strömstad

Color Line is a Norwegian shipowner which operates several Ro-Pax vessels from different ports in Norway to Sweden, Denmark, and Germany. Color Line's route between Sandefjord and Strömstad has up to 4 daily crossings of 35 nautical miles. The Ro-Pax vessel operating on the route today has a 5 MWh battery pack installed onboard, which is primarily used in and out of Sandefjord, since charging power is only available in the port of Sandefjord. MGO fuel in addition to battery electric hybrid mode is used when crossing the open sea. Color Line is actively working towards reducing their emissions and a long-term goal would most likely be to fully electrify the crossing. Color Line is working towards realizing this route as a green shipping corridor, where they plan to use additional battery capacity in and out of both ports together with bio-MGO when crossing the open sea.

Through several workshops with Color Line, specific barriers and opportunities were identified. The high-level barrier assessment shows that the vessel has the potential to increase the battery capacity and use biofuel without large technical modifications to the ship. The port of Sandefjord needs to upgrade the shore power capacity if the battery capacity on the ship is to increase, but according to Color Line, this is only a minor barrier. In addition, at least one of the ports will need bunkering infrastructure for biofuel. However, this could initially be done by truck-to-ship refuelling. One of the identified potential showstoppers is the port of Strömstad's lack of shore power infrastructure, which is a crucial element to limit the need for additional bio-MGO. Another potential showstopper for this green corridor is the financial barrier caused by the cost gap between bio-MGO and fossil MGO. It will be necessary to include cargo owners and other stakeholders to share the financial risk posed by the additional OPEX imposed. In addition, financial support from the government or funding, could also help overcome this barrier. See the summary of the conducted barrier assessment in Figure 6-2.

In order for this potential green shipping corridor to be realized, a new way of working together will be necessary. The pre-piloting project has contacted many potential transporters to find potential long-term partners for this purpose. The company ColliCare, who already utilizes the specific route, has shown interest in such a partnership.

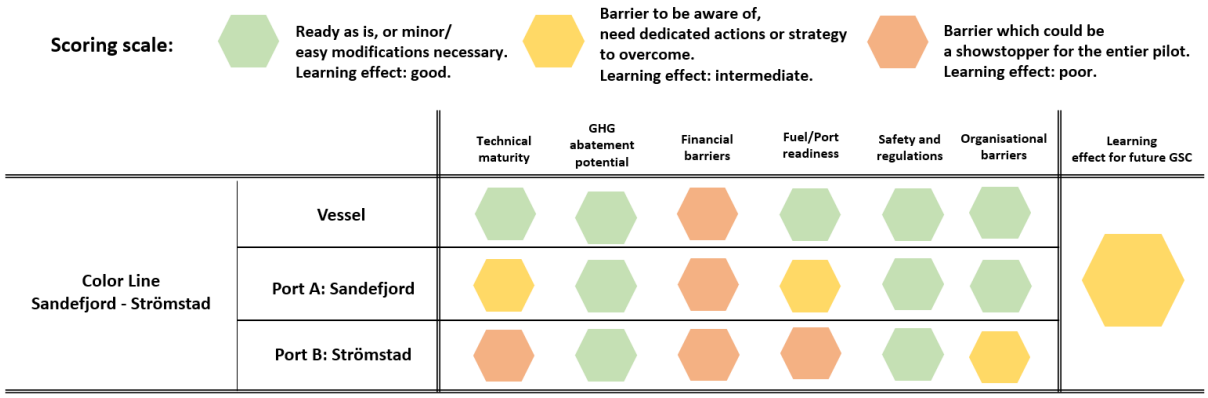

Figure 6-2: High-level barrier assessment for Sandefjord – Strömstad.

6.3 ASKO; Hirtshals – Larvik

This potential Green Shipping Corridor route is different from the two above. The dialogue started with the general transport need between Denmark, Sweden and Norway, since the initiator is a cargo owner, namely ASKO. After workshops with ASKO, together with the shipowner operating in this area, Color Line, and a transportation stakeholder using this route, Frode Laursen, the partners showed interest in making this a potential logistics pilot project for enabling green cargo transport, using Hirtshals – Larvik as the pilot route. The GHG abatement potential was assessed as good, since this route could help transfer goods from road to sea and make the cargo flow more efficient from Denmark to Norway. This pilot would also include the development of infrastructure for electrical road transport from Hirtshals all the way to ASKO's main warehouse in Vestby, also including another local green shipping corridor from Horten to Moss in Norway. The high-level barrier assessment performed focused on the specific route between Hirtshals and Larvik, where Color Line is the main operator as of today.

Color Line has not decided which fuel/technology will be used, but there are several fuel options for this route. While hybrid solutions could be used, the port-stay in Hirtshals is only one hour which would limit the shore charging potential and make fully electric solutions unfeasible. Another important barrier identified is the regularity and frequency of traffic. The vessel sails at fixed hours, which will be a challenge for the volume of cargo transported. However, through good planning and efficient solutions this barrier could be overcome.

ASKO as a cargo owner, Color Line as the operating ship owner, and Frode Laursen as a transportation stakeholder make a strong team, but the port of Hirtshals and the port of Larvik will be crucial stakeholders on this route and must be involved to realize this green shipping corridor. Due to the already identified stakeholders, the financial barrier is solvable, but a strong strategy is nonetheless needed to make this a viable business case. The partners remain in an early planning phase, but initial dialogues and collaboration have started. Figure 6-3 shows the results from the high-level barrier assessment.

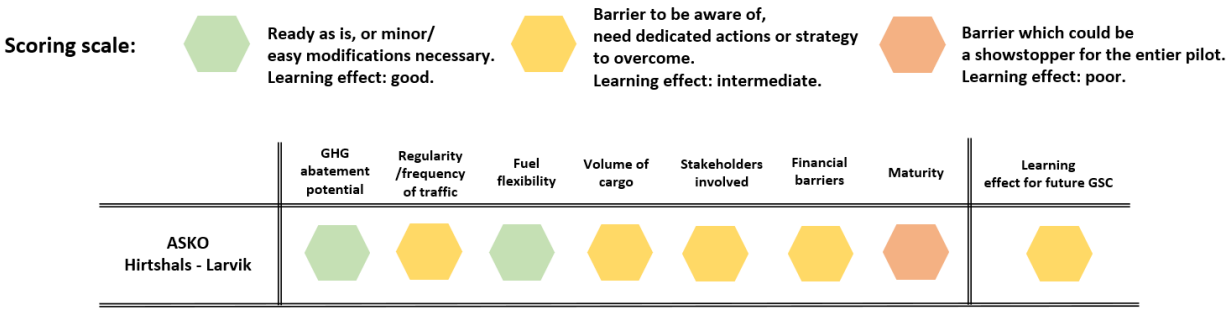

Figure 6-3: High-level barrier assessment for Hirtshals – Larvik *(Please note that this scorecard is different from the two presented in the previous chapters. Due to the high uncertainty of fuel choice, and it was found that these KPIs were more suitable for this corridor)*.

6.4 Other potential green shipping corridors from the shortlist

6.4.1 Viking Line; Stockholm – Turku

Åbo Akademi and PBI Research Institute in Finland are working on the socio-economic benefits arising from green shipping corridors. The pre-pilot project has been involved in meetings with the team in Åbo Akademi, providing input to their project. Further to these meetings, the pre-pilot project has also shared detailed results from the AIS-analysis conducted by the Nordic Roadmap project.

The Stockholm to Turku Ro-Pax route is one of the most trafficked intra-Nordic passenger routes identified in the Nordic Roadmap AIS-analysis. Hence, realizing a green shipping corridor between these ports could greatly impact the overall intra-Nordic shipping emissions.

6.4.2 Bornholmslinjen; Ystad – Rønne

From the long list of passenger routes identified in the Nordic Roadmap AIS analysis, Ystad to Rønne represents a connection where hydrogen-electric operations could be feasible. The pre-pilot project proposes that this potential green shipping corridor between Denmark and Sweden could provide an interesting pilot project in the Nordic Roadmap going forwards. The ferry route will soon enter a new competition round where details about the competition are still unknown to the public. Early discussions have been conducted with the Swedish Green Shipping Corridor Coordinator at Trafikverket.

Potential focus for a pilot project could include feasibility studies of local production of green hydrogen for use as vessel fuel. The green hydrogen could be sourced from the significant offshore wind power potential outside of Bornholm.

6.4.3 Arctic Green Shipping Corridor; Torshavn – Reykjavik – Nuuk

Even though the pre-piloting task has been focused on the potential establishment of green shipping corridors between Nordic countries which could be realised in 2025 or towards 2030, several regions of major shipping activity in the Nordic region remain too remote to easily accommodate a fast transition to zero-emission shipping. Especially the trade networks extending from Scandinavia and out towards Faroe Islands, Iceland, and Greenland are already challenged on cost-effective trade connections with the mainland. Furthermore, the vessels entering Greenland need to be ice-classed, which only compounds the challenge with poorer energy efficiency as compared to non ice-classed vessels.

The pre-pilot project has nonetheless decided to highlight the potential of an “Arctic Green Shipping Corridor” for future pilot studies in the Nordic Roadmap project. Not only is this trade vital for the more remote communities in the Nordics, but the region also has a high potential for green energy production and carbon capture. Focusing on a few commercial stakeholders with invested interest in the region would capture many of the potential energy hubs in the region, which makes the necessary collaborations more easily defined.

Along a possible Arctic green shipping corridor, Iceland will be an important energy hub as it represents the largest shipping activity in the region. There is also a significant potential for local production of sustainable zero-carbon fuels in Iceland, ranging from green methanol utilizing carbon capture, to the increasing focus on wind energy harvesting in the region. Greenland recently broadcasted their interest in the development of additional hydropower, with offtake potential for green shipping fuels in general and ammonia in particular. The Faroe Islands have also identified significant offshore wind potential, which could enable greater electrification and shore power options. Potential shipping companies that could be involved in future studies include Eimskip (Iceland), Royal Arctic Line (Greenland) and Smyril Line (Faroe Islands).

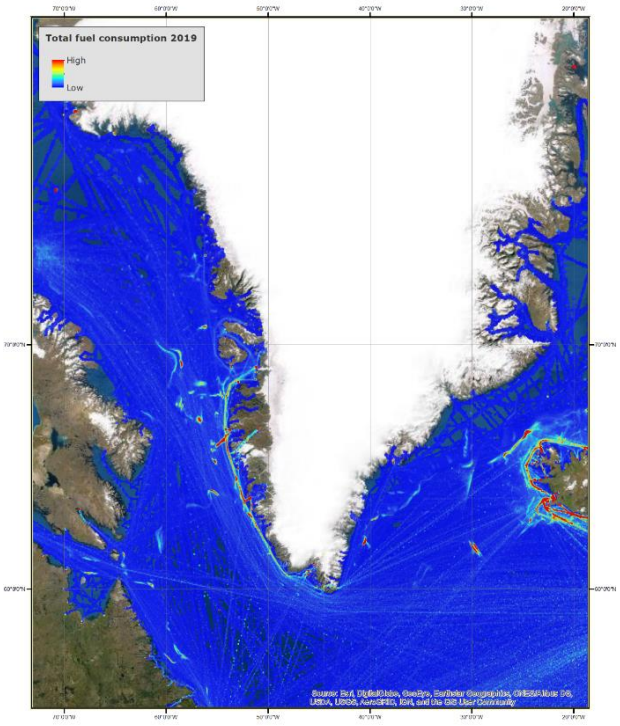

Figure 6-4: AIS analysis of ship traffic around Greenland as shown during the Nordic Energy Research conference in Nuuk, 2022 (DNV, 2022b).

7 SUMMARY AND DISCUSSION

This pre-piloting assessment has used a three-step approach for investigating potential intra-Nordic green shipping corridors. 81 intra-Nordic ship traffic routes were identified, representing the long list. Six corridors were shortlisted from the longlist, and three of these were studied in more detail together with relevant stakeholders, using an in-house developed barrier scorecard.

The two key barriers identified through the workshops are the financial cost gap between zero-emission fuels and conventional fuels, and the lack of fuel availability and bunkering infrastructure. The key barriers are summarized in a scorecard presented in Figure 7-1, using the traffic-light approach for the three potential green corridors where workshops have been performed.

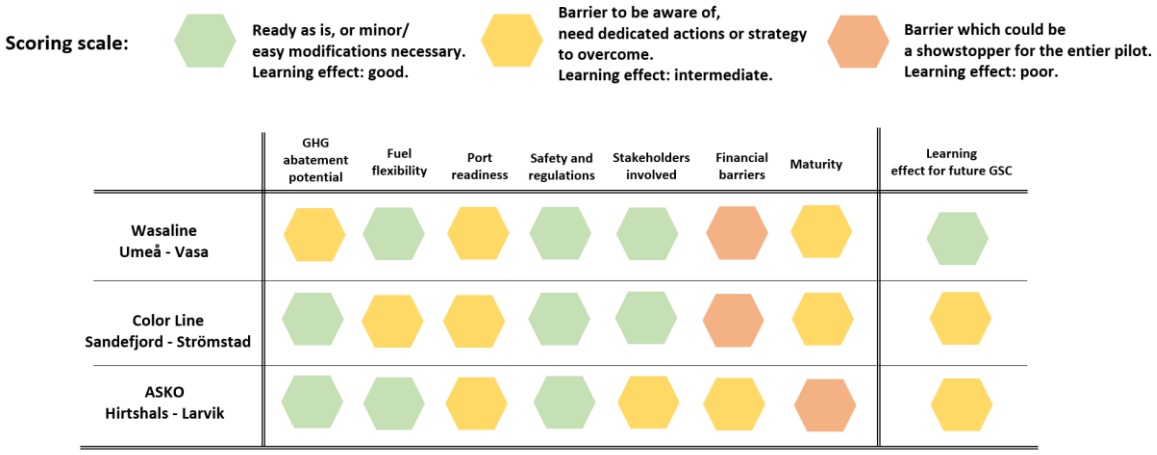

Figure 7-1: Summary of the three potential green shipping corridors from the barrier workshops.

During the workshops, safety and regulations were not in focus because the fuels and technology options mainly discussed (biofuels and battery/electrification) have safety measures and regulations already in place. However, the lack of safety requirements onboard and on shore for ammonia and hydrogen is a key barrier if selecting those fuels. Wider adoption of zero-carbon shipping will require significant progress on bunkering practices and onboard safety standards for all fuel options, including hydrogen and ammonia. Figure 7-1 summarises key barriers identified in the pre-pilot study, as well as learnings from the Nordic Roadmap project. These findings are supported by a recent Nordic Roadmap deliverable, focusing on identifying key barriers for future fuels in a Nordic perspective (Menon, 2022).

A key finding from several workshops performed with the different stakeholder groups is that realizing a green shipping corridor by 2025 in one step is challenging, and the timeframe might have to be stretched to 2030. Figure 7-2 shows the maturity of the six shortlisted routes. This figure indicates that some candidates are more mature than others, but in general they are all in the planning phase. This means that the process of establishing green shipping corridors in the Nordics will take time -probably several years. Through pilot or feasibility studies, the Nordic Roadmap project could move the candidates towards the right in Figure 7-2.

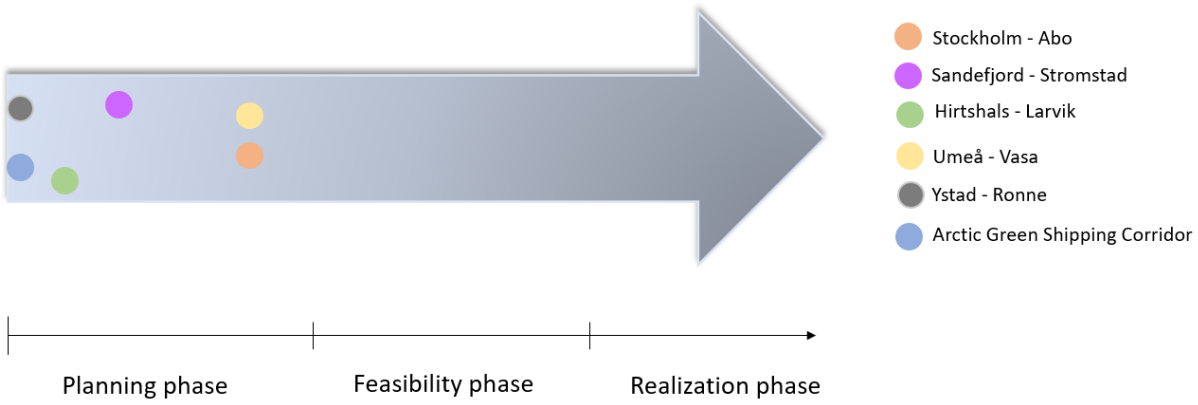

Figure 7-2: Maturity-scale for the shortlisted intra-Nordic routes for decarbonization.

This study concluded with three key barriers the stakeholders must overcome, in order to realize a green shipping corridor (Figure 7-3):

a) The **financial** gap between using conventional fuels and zero-emission fuels,

b) The lack of fuel availability and bunkering **infrastructure**, and

c) The lack of safety requirements/**regulations** onboard and on shore for ammonia and hydrogen.

The Nordic ministers could play an important role in overcoming the identified financial, regulatory and infrastructure barriers, enabling the introduction of the first green shipping corridors. Particularly, it is important to provide support on closing the cost gap compared to fossil fuels, considering Contracts for Difference (CfD) and other risk reducing options.

Creating a common Nordic “playground” with a unified approach to matters relating to alternative maritime fuels may simplify some of the challenges intra-Nordic ship operators will be facing if they choose to explore alternative fuels in the near future (DNV, 2022d). A common understanding among the Nordic administrations on how to manage the alternative design process, and a common acceptance of such ships flying the flag of a Nordic country will reduce the barriers for other stakeholders to engage in the process of decarbonising shipping in the Nordic region. Having a common set of safety regulations relating to bunkering logistics in the Nordics would also ease the process of establishing green corridors and developing them into a network of bunkering locations supporting Nordic green shipping.

Another aspect worth mentioning is that the “green” fuels discussed are considered as zero-emission fuels. Chalmers and IVL has conducted a life cycle assessment on different fuels and how the primary source of the fuel is affecting the well-to-wake emissions (Chalmers/IVL, 2023), which shows that no single fuel option will constitute a truly zero-carbon fuel by 2030. A clear Nordic consensus on green credentials for all fuels will be needed to build trust and confidence amongst green corridor stakeholders and green transport buyers.

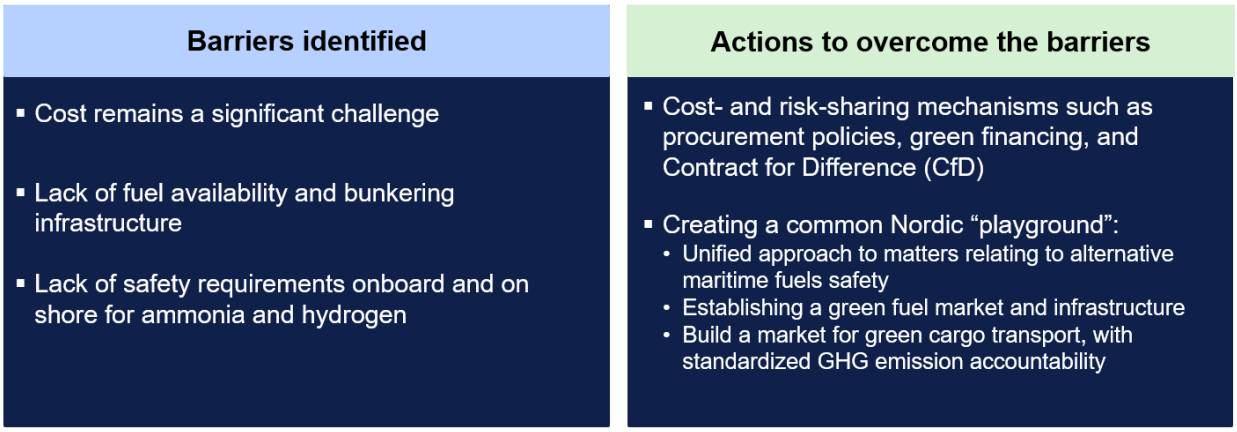

Figure 7-3: Summary of key barriers from the pre-pilot study and suggested actions needed to overcome them. These results also reflect learnings from the Nordic Roadmap project.

Lastly the pre-pilot project has identified the importance of a well-motivated cargo owner or ship owner/shipping company to realize a potential green shipping corridor by 2025 or by the end of this decade.

The findings from this pre-pilot project will be further developed in the piloting task of the Nordic Roadmap project, where the objective is to execute 2-3 initial pilot studies on promising intra-Nordic green shipping corridors.

8 REFERENCES

Chalmers/IVL, 2023. *Life Cycle Assessment of Marine Fuels in the Nordic Region - Task 1C,* s.l.: Nordic Roadmap Publication No.1-C/1/2023, dated 2023-02-09.

COP27, 2022. *Green Shipping Challenge at COP 27.* [Online]
Available at: https://greenshippingchallenge.org/cop27/

DNV, 2022a. *Insight on Green Shipping Corridors,* s.l.: prepared by DNV, dated 2022-11.

DNV, 2022b. *AIS Analysis of Nordic Ship Traffic,* s.l.: Nordic Roadmap Publication No. 2-A/1/2022, dated 2022-10-14.

DNV, 2022c. *Fuel properties and their consequences for safety and operability,* s.l.: Nordic Roadmap Publication No.1-B/2/2022, dated 2022-11-28.

DNV, 2022d. *State of play - status on regulatory developement for zero-carbon fuels,* s.l.: Nordic Roadmap publication No. 1-B/1/2022, dated 2022-11-28.

Menon, 2022. *Task 1A - Screening of Sustainable zero Carbon fuels,* s.l.: Nordic Roadmap Publication No. 1-A/1/2022.

Menon, 2023. *Task 2B- Infrastructure and bunkering challenges for zero-carbon fuels,* s.l.: Nordic Roadmap Publication No. 2-B/1/2022, dated 2023-02.

MMMCZCS, 2022. *Northern European & Baltic Green Corridor Prefeasibility Study,* s.l.: Mærsk Mc-Kinney Møller Center for Zero Carbon Shipping.

ZESM, 2023. *Green Shipping Corridors.* [Online]
Available at: http://mission-innovation.net/missions/shipping/green-shipping-corridors/

APPENDIX A

The longlist in the AIS Analysis of Nordic Ship Traffic (DNV, 2022b) is based on key performance indicators (KPIs) related to the actual ship traffic pattern and energy demand extracted from the AIS analysis. The voyage analysis allows us to identify routes and calculate each of their annual energy consumption as well as to identify other route characteristics. The longlist is ranked by the annual total energy consumption and assigned with the following KPIs:

- **Annual energy consumption:** This reflects the CO_2 emission reduction potential. Large volumes significantly impact GHG emissions, but at the same time can be demanding to initiate as first mover.
- **Regularity:** This is expressed by the number of voyages per year, and number of unique ships sailing the route.
- **Feasibility of fuels:** This is given by the assessment of which fuels are feasible for the route. For a route to be realized as a green corridor within a few years, this is especially critical. In the AIS Analysis of Nordic Ship Traffic, the fuel feasibility screening result is indicated as *Level 1*, *Level 2,* or *Level 3* for each route. *Level 1* indicates all fuel options are feasible, including battery electrification, *Level 2* indicates the potential is limited to compressed hydrogen or higher energy density technologies and *Level 3* denotes that only higher density options (e.g., methanol or ammonia) is feasible.
- **Spin-off potential:** There are possible spin-off effects for routes that start, end, or move between potential energy hubs that also have the ability to serve a considerable part of domestic or other traffic. The indicator for spin-off potential for a given route is based on the total annual (2019) fuel consumption in the ports, excluding the fuel consumption by the given corridor route. The indicator is expressed as low, medium, or high. 'High' spin-off potential indicates that at least one of the ports in the route serves other voyages with an annual fuel consumption higher than 75 000 ton, 'medium' indicates a fuel consumption in the range of 25 000-75 000 ton, while 'low' indicates that all ports in the given route have a total annual fuel consumption lower than 25 000 ton.

APPENDIX B

The scorecards are used to summarize the barriers identified for the intra-Nordic potential green shipping corridors through the workshops. By assessing the different KPIs with the traffic-light approach, using three colours assessing the status of the KPI. It is important to note that different routes may have different KPIs, depending on what is suitable for the specific corridor.

Scorecard KPIs:

- **Technical maturity**: Technical feasibility of zero-emission fuel/technology
- **GHG abatement potential**: Potential reduction in GHG emissions by 2025
- **Financial barrier**: How to finance the Green Shipping Corridor, business case
- **Fuel/Port readiness**: Can the vessel operate on the fuel, can the ports supply this fuel
- **Fuel flexibility**: Fuel availability, how flexible is the choice of fuel
- **Safety and regulations**: Availability of common rules, standards and procedures for bunkering and operating with identified zero-emission solutions
- **Stakeholders involved**: Number of involved stakeholders from the green shipping corridor value chain
- **Organisational/collaboration barriers**: Internal showstoppers
- **Regularity/frequency of traffic:** High, medium or low regularity of ship traffic for individual vessels
- **Volume of Cargo:** Filling rate of vessel
- **Maturity:** Phase of potential green shipping corridor with regards to realization

These KPIs are assessed by using the traffic light method where the three different colours indicate the following;

- **Green**: Ready as is or minor/easy modifications necessary
- **Yellow**: Barrier to be aware of, needs dedicated actions or strategy to overcome
- **Red**: Barrier which could be a potential showstopper for the entire pilot

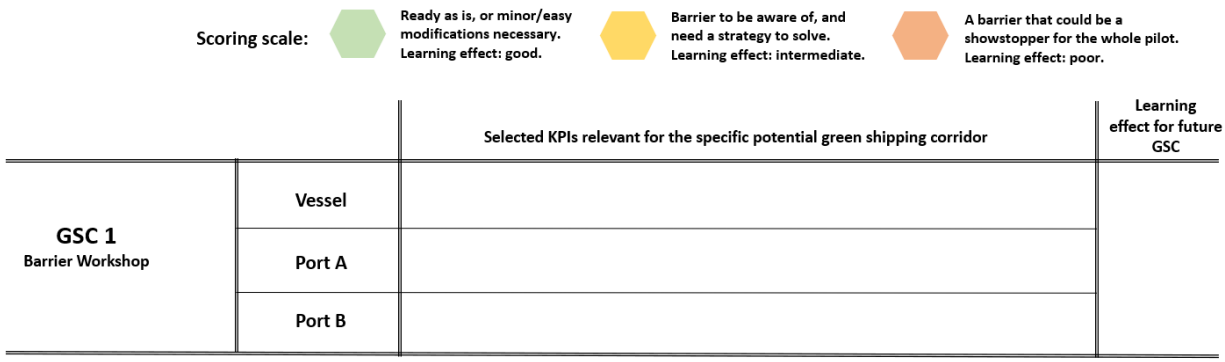

Figure 0-1: Example of scorecard used to identify barriers and opportunities for each potential green shipping corridor

About DNV

DNV is the independent expert in risk management and assurance, operating in more than 100 countries. Through its broad experience and deep expertise DNV advances safety and sustainable performance, sets industry benchmarks, and inspires and invents solutions.

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