European Commission

Global Gateway Green Shipping Corridors

Scoping study for port identification

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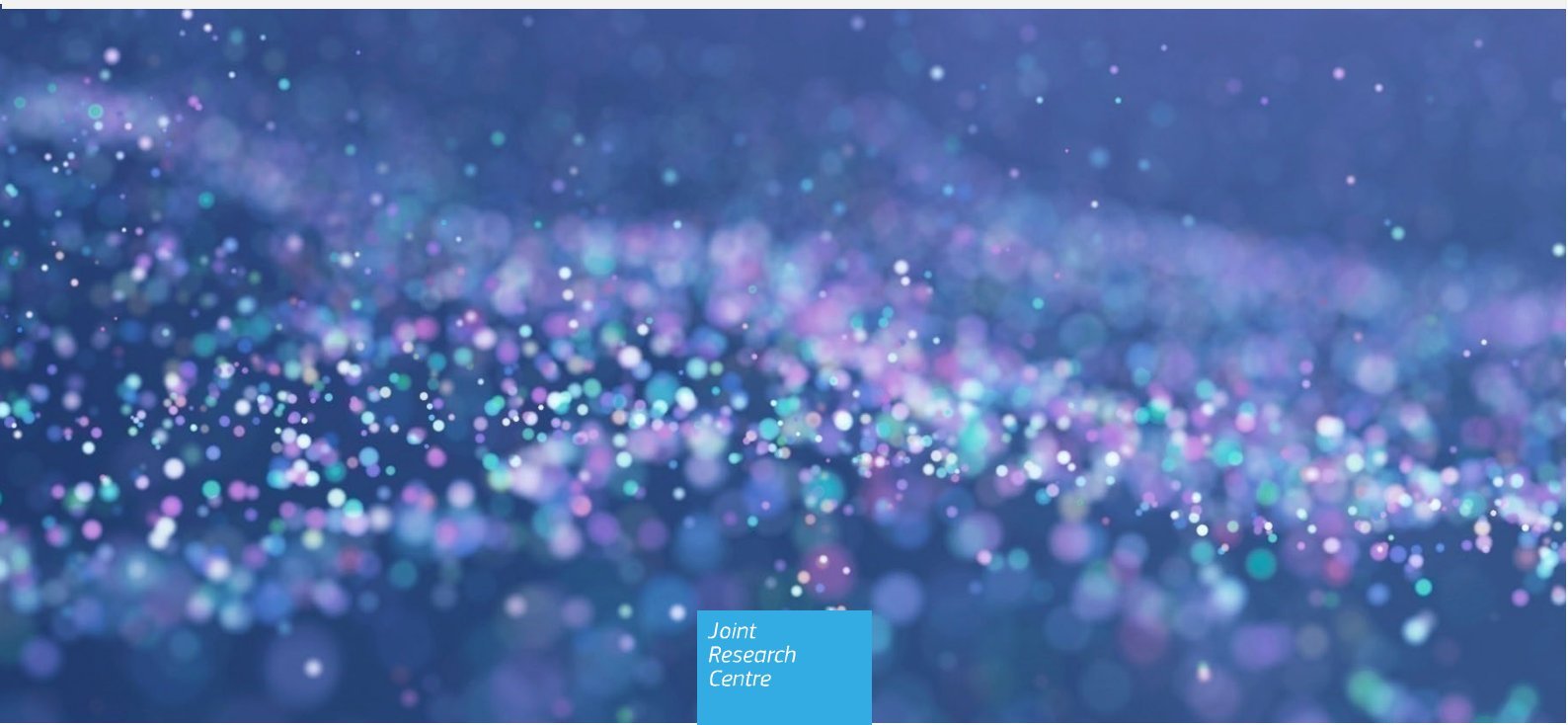

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Contents

Abstract – Objective of this study

The Global Gateway Green Shipping Corridors (GGGSC) is an initiative by the European Commission to facilitate the transition to sustainable renewable and low-carbon fuels for international shipping. This report provides a summary of the data collection and analysis carried out by the JRC in support of the process to identify ports outside Europe that may be supported by the GGGSC. It focuses on the design criteria, main options for sustainable renewable and low-carbon fuels, and the potential implementation options and instruments. The methodology is based on eight overarching priorities that ports possibly included in the GGGSC should address. The potential supply for sustainable renewable and low-carbon fuels (RLCF) and their pathways, impacts, and techno-economic characteristics are also explored. The analysis identifies four main options for sustainable RLCF, including bio-/e- methanol, bio-/ e-ammonia, e-hydrogen, and bio-/e-methane. These options have different technical and economic characteristics, and their selection will depend on various factors, including the specific needs of the shipping industry and the availability of infrastructure. A range of possible actions at port and country level are also discussed.

It is important to emphasize that the criteria, indicators and provisional results are only a data-driven analysis, based on a methodology under development, which may serve as an input to the policy process. The actual definition of the GGGSC will consider additional priorities and inputs from a wider range of stakeholders, in consistency with the Team Europe approach.

Executive summary

This report summarizes the preliminary analysis carried out by the European Commission's Joint Research Centre (JRC) with the aim to provide evidence-based support to the policy making process of the definition and the selection of ports outside Europe that may be supported by the GGGSC. The analysis followed an iterative approach that combined research and technical evaluations that link the stated objectives of the initiative with quantitative indicators that can support the policy design process. While the objective was to reflect policy priorities and discuss how they can shape the initiative, the work presented here is still the technical background on which the European Commission can base the actual design and content of the GGGSC.

The initial exploration of the data on ports and sustainable RLCFs within the scope of the GGGSC suggests that –on one hand- there are several boundary conditions for the design of international shipping corridors that may limit their applicability and impact. On the other hand, there are various possible configurations that can allow the main objectives to be met, depending on the specific policy priorities for each potential corridor. In order to reflect these priorities and to evaluate how the potential inclusion of a port in the GGGSC contributes to them, eight criteria were identified:

- Impact: reduction of GHG emissions of EU and international shipping activities
- Availability: access to RLCF bunkering along the GGGSC corridors for international shipping activities linked to the EU
- Import potential: increase of RLCF production capacity/ surplus that can be potentially imported by the EU
- Development: contribution of GGGSC investments and support to the promotion of local and regional sustainability
- Port interdependencies: safeguarding a level playing field for port operators in the EU and partner countries
- Critical mass: contribution of GGGSC to the development of international markets in sustainable RLCF
- Innovation: acceleration of development and uptake of new technologies in shipbuilding and maritime fuel technologies
- Resilience: development of alternatives to reduce geopolitical risks and instability

In addition, an analysis of the available literature was carried out in order to identify the potential pathways that can produce fuels that meet the target of a 2% reduction of fuel carbon content in 2025, increasing to 6% in 2030, and accelerating from 2035 to reach an 80% reduction by 2050.

The trends in the maritime transport sector suggest that the transition to sustainable RLCF does not have a clear path or a single fuel that is suitable for all uses. Four main families of fuel were identified as having the potential to meet the FuelEU Maritime targets in the 2030- 2050 time horizon, each following a different pathway and timeline, and applicable in different segments of the sector. All four fuel families identified are technologically feasible, yet widely varied when considering production at industrial scale and commercial maturity. Across all four fuel main options, the analysis suggests that two main transition paths, through bio-methanol or bio- ammonia, can be distinguished in the short term (2030), with a shift towards e-methanol or e-ammonia when they become available at industrial level at competitive prices (2040), preparing an eventual (but still uncertain) conversion to hydrogen as a fuel (late 2040s). A smaller niche (10%-15%) may follow the LNG to bio-methane to e-methane to hydrogen with a similar timeline.

For these four families of fuels, the analysis of the current and potential supply of sustainable RLCF was carried out using data collected by the JRC Energy and Industry Geography Lab (https://energy-industry-geolab.jrc.ec.europa.eu/) in combination with Eurostat data and JRC models.

The design of the GGGSC should take into account the demand for sustainable RLCF at various levels, from the global to the local, which for shipping would require the estimation of demand at route and port level. The overall goal was to develop a model of the global markets for the various options of sustainable RLCF, and estimate the impact that each corridor will have on the balance, with particular emphasis on the potential for exports to the EU. In order to prevent lock-in in fossil fuels or unsustainable production processes, the GGGSC should prioritize the production of sustainable RLCFs compliant with the sustainability requirements enforced in the EU and adhering to NDICI legislation provisions on the topic[1]. Several sources can be combined for the estimation of the potential demand for sustainable RLCFs that would correspond to each Green Shipping Corridor.

Most of the regions considered for the GGGSC represent low shares of global demand, with the exception of South East Asia (9.6%) and South America (7.6% Atlantic Coast, 4.9% Pacific Coast). But taken as a whole, the maritime fuel consumption of the main potential corridors taken together would add up to 31.6% of global consumption. In terms of the emissions corresponding to the EU's international shipping activities, the GGGSC candidates would represent 32.6%. This suggests that the GGGSC can have a considerable impact in terms of reducing GHG emissions from maritime transport globally. It also suggests that the GGGSC candidates as a whole have are quite relevant for EU international shipping, while the EU has a higher share of the potential GGGSC partners' shipping activities than the global average. However, the estimated demand for sustainable RLCFs in these areas is expected to exceed 22 Mtoe by 2050, the result of the growing maritime transport activity and the gradually more demanding targets to reduce carbon content in marine fuel. Producing and distributing such quantities of sustainable RLCF can be challenging, especially if the EU's production capacity is not sufficient to cover its own demand. On the positive side, several areas of potential coverage of the GGGSC may offer the advantage of sustainable renewable energy that has been harvested for the production of RLCF at suitable price and quantity to even allow exports to the EU.

Apart from the technical and economic characteristics of sustainable RLCFs and the overall impact of GHG emissions, the design of the GGGSC should also take into account a range of policy priorities that address trade, innovation, port interdependencies, development and strategic aspects.

To support ports in developing countries in preparing for GGGSC and the transition to alternative maritime fuels, various measures can be implemented, depending on the local conditions and needs, as well as the involvement of the relevant stakeholders. A range of possible actions at port and country level can be foreseen, in the following 10 broad categories:

- Infrastructure Development
- Technical and Regulatory Support
- Capacity Building
- Financial Incentives and Investments
- Collaboration and Partnerships
- Research and Innovation
- Policy Alignment
- Environmental Monitoring
- Stakeholder Engagement
- Market Development

[1] Art 29 NDICI regulation

A common denominator across these potential instruments is that the EU's experience and knowledge sharing approach, coupled with regulatory alignment, can significantly accelerate the transition of GGGSC partners to sustainable RLCF in maritime transport. The inclusion of different ports or countries in the GGGSC may combine different instruments, depending on the degree of engagement of the potential partners. Such combinations may involve, for example, a requirement for policy alignment by the partner country if EU financial support and funding are sought. The existence of a scheme that is comparable to ETS or the ratification of the IMO MARPOL Annex VI could be a condition. While the facilitation of the transition to sustainable RLCF globally and the stimulation of international development are both important overarching objectives, the promotion and protection of EU interests should also play a role in the selection of the instruments.

The framework of composite indicators described above allows the quantification of the various criteria of relevance to the GGGSC in a coherent and transparent manner. These indicators can form the basis for the identification of relevant ports and corridors according to specific policy priorities. The GGGSC is an initiative addressing multiple objectives, and analyzing the classification of each port according to different policy perspectives provides additional insights.

One of the main messages of the analysis is that –on purely quantitative terms- larger ports in more developed countries are more relevant in order for the impact of the GGGSC to be maximized in terms of reducing GHG emissions and ensuring the critical mass for sustainable RLCF in maritime transport. This, however, may come into conflict with the main objective of the GGGSC to act as an instrument for the promotion of sustainable development goals in less developed countries which do not currently show sufficient potential as users or suppliers of sustainable RLCF.

Using the data and analysis, a policy scenario can be designed in order to match the overall objectives set out for GGGSC, while also allowing the individual policy perspectives to be reflected. This design splits scenarios in two families, one exploring the impacts on EU industry competitiveness and one on sustainable development goals. The EU industry competitiveness scenarios are further split into 3 scenarios, each addressing shipping, sustainable RLCF production and imports, and ports, respectively.

The rationale of these scenarios can be summarized as follows:

- Supporting EU Shipping Industry Competitiveness: The EU shipping industry faces significant competition from international players. This scenario focuses on enhancing the competitiveness of EU shipping companies by promoting green shipping corridors that reduce operational costs, improve efficiency, and comply with EU environmental, climate and sustainability law. The priorities of this scenario include the reduction of GHG emissions to comply with EU regulatory framework, the increased uptake of sustainable RLCFs in EU shipping operations and the promotion of innovation and R&D to improve shipping efficiency and reduce costs. Apart from the direct benefit for EU stakeholders, additional spill over benefits can be expected from non-EU operators adapting to the transition that the GGGSC will stimulate.

- Supporting sustainable RLCF production and imports: This scenario focuses on promoting the production of sustainable RLCFs in countries participating in the GGGSC and the facilitation of exports of sustainable RLCFs to the EU. By increasing the availability of sustainability RLCFs, the EU and partner countries can reduce their dependence on fossil fuels and decrease GHG emissions, while building the critical mass for the uptake of sustainable RLCF at a global scale. Priorities include the increase of sustainable RLCF production capacity in the non-EU partners and the development infrastructure for sustainable RLCF import and distribution.

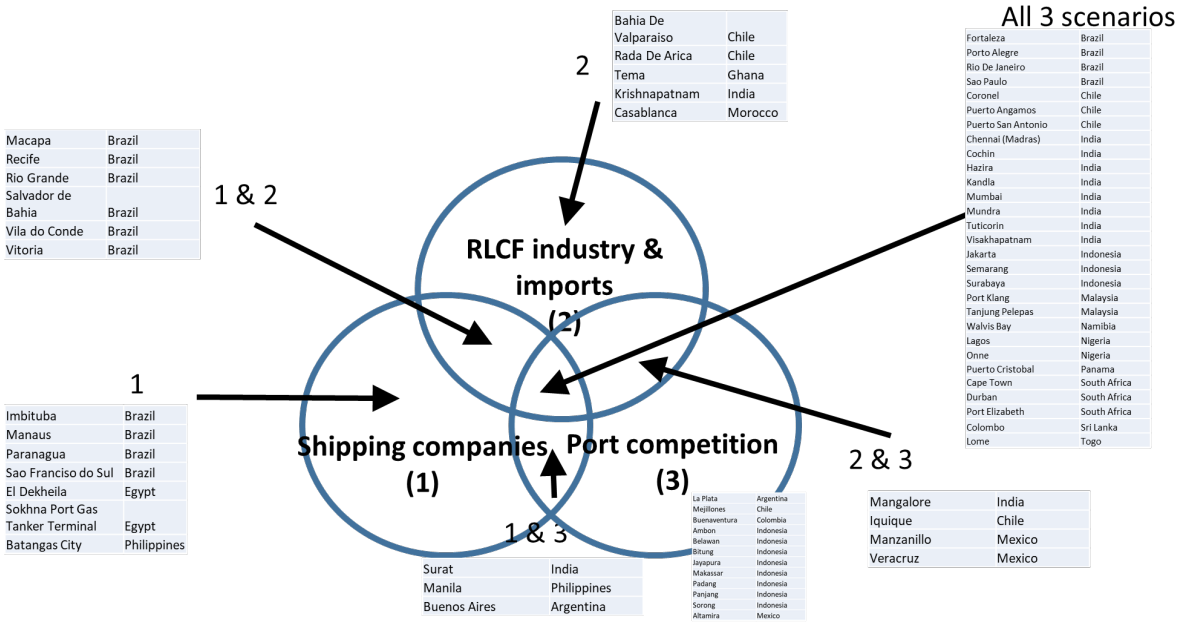
- Ports' interdependencies and management: This scenario focuses on making the best out of port interdependencies and the management of ports to support the transition to sustainable RLCF. By ensuring a level-playing field and the availability of sustainable RLCF across the Green Shipping Corridors, both EU and GGGSC ports can strengthen their position as efficient and attractive nodes in the international shipping networks. Priorities include investments in port infrastructure to support sustainable RLCF bunkering and storage, port management and technologies to reduce costs and emissions, and the encouragement of sustainable practices in port operations. While this scenario aims to ensure that the competitiveness of EU ports is not impacted, the limitations of this study will require further considerations and refinement of the methodology to actually capture the competitiveness dimension and possibly establishing of safeguards may be required before final decision on the possible support to a port is taken. In any case, the study makes already at this stage a reference to the same criteria as the ones used for Regulation (EU) 2023/2297 which lists transhipment ports prone to impact competitiveness. While these ports have been studied, showing indeed their competitiveness vis-a-vis EU ports, they have not been included in the scenarios shown in the report.

- Development Scenario: This scenario focuses on the promotion of sustainable development goals in countries within the scope of the Global Gateway and on narrowing the global investment gap worldwide. In that sense, the GGGSC can be seen as an instrument supporting the EU policies on international development. Priorities include the promotion of sustainable development, the creation of synergies with other Global Gateway initiatives, the support to inclusive growth, the promotion of international agreements and cooperation, and the provision of technical support and knowledge sharing.

Since a different combination of indicators and weights is used in each scenario, the classification of the ports can vary significantly among scenarios. These variations in classification reflect the different role each non-EU port can have from the point of view of shipping operations, RLCF production and import potential or port interdependencies. At the same time, they highlight a trade-off when comparing ports that can contribute to the effectiveness of the GGGSC in terms of reducing GHG emissions with those that can contribute to the international development aspect of the initiative.

From the effectiveness point of view, the Venn diagram of the top-50 ports in terms of the three scenarios under EU industry competitiveness (Figure E.1) suggests that 30 ports are classified as highly relevant in all 3 scenarios. This list of ports can be considered as potentially forming the core of the ports that could be supported by the GGGSC and that can ensure critical mass and availability along the international shipping networks of interest to the EU. This core network can be complemented by other ports considered as important for the development aspect of the GGGSC. Furthermore, this list can be modified according to additional priorities and inputs from a wider range of stakeholders, as well as taking into account the wider range of Political Priorities of the New Commission, in consistency with the Team Europe approach.

Figure E.1: Venn diagram of top-50 ports in the three EU industry competitiveness scenarios (provisional)



The development scenario results in a significantly different classification. As a general observation, the areas where the GGGSC would contribute the most in terms of supporting sustainable development are not classified as highly important in terms of most of the EU competitiveness criteria. This is to be expected to a certain extent, since there is a high correlation between the economic development of a country and the effectiveness of the GGGSC in terms of impact and relevance to the EU industry. To balance the two perspectives, the GGGSC should combine ports that are classified as highly relevant from the competitiveness perspective with ports that would increase the GGGSC impact on development.

The work presented here has obviously several limitations. While it is based on the most objective and reliable data as possible, the wide scope of the analysis did not permit a detailed exploration at specific port level. At the same time, the estimates on supply and demand for sustainable RLCF are focused on the maritime transport sector, assuming that the balance in the other sectors would remain the same. Nevertheless, the sustainable RLCF market that the GGGSC can stimulate will probably interact with the global and local market for specific commodities, especially hydrogen and ammonia. Both of these issues will be addressed in the work to be performed in further work for the definition of the GGGSC, with a more detailed analysis at port level and with improved models on the global markets for RLCF and its EU-compliant sustainable subset.

It is important to emphasize that the criteria, indicators and provisional results are only a data-driven analysis that serves as an input to the policy process. The actual definition of the GGGSC will consider additional priorities and inputs from a wider range of stakeholders, in consistency with the Team Europe approach.

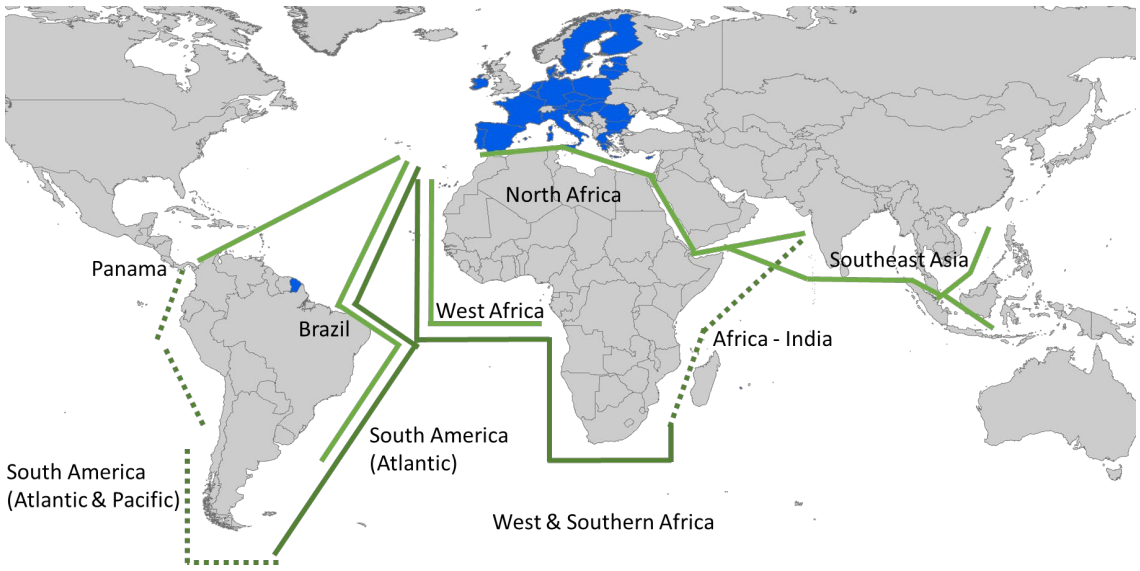
1 Introduction

The Global Gateway Green Shipping Corridor (GGGSC) is an ambitious initiative that aims to facilitate the transition to sustainable Renewable and Low Carbon Fuels (RLCF) for international shipping while contributing to the sustainable development at global level. The GGGSC follows a Team Europe approach, led by the European Commission (EC) and coordinated by is Directorate General for International Partnerships (DG INTPA). The initiative has multiple objectives that address the sustainability of maritime transport, the availability of sustainable RLCF in partner ports, as well as the promotion of EU interests across the globe. Meeting all objectives is challenging, since most ports and countries within the scope of the Global Gateway currently lack the capacity to invest in the required infrastructure, even though they may present a high potential as partners in the transition to sustainable RLCF.

This report summarizes the preliminary analysis carried out by the European Commission's Joint Research Centre (JRC) that provided evidence-based support to the policy making process of the definition and the selection of GGGSC. The analysis followed an iterative approach that combined research and technical evaluations with the extensive feedback from policy stakeholders. This process allowed the refinement of the concepts addressed and the exploration of a wide range of issues. Nevertheless, the work presented here is still the technical background on which further policy analysis can base the design and contents of the GGGSC.

The geographic analysis of the GGGSC covers the full scope of the Global Gateway initiative, with detailed data collected for all countries and ports shown in Figure 1. Data from more than 400 ports across these areas were collected and analysed (the full list of ports is available in Annex 1).

Figure 1: Geographic areas covered by analysis of potential GGGSC.



Source: JRC (2024)

A green shipping corridor can be defined as a shipping route on which commercially operating ships use exclusively sustainable RLCF and other technologies to improve fuel efficiency, in order to reduce the overall environmental footprint of maritime transport. The GGGSC would cover a network of established port connections where vessels can use these alternative fuels and technologies, ensuring fuel availability along the green shipping corridors. The GGGSC should also serve as an initiative to ensure the maritime connectivity of the EU with Global Gateway regions, especially as regards the capacity to import sustainable RLCF and other energy carriers into the EU. In that aspect, the GGGSC should also support the development of production, storage and bunkering capacity for sustainable RLCF fuel for maritime transport, as well as that of other fuels required by other sectors of the economy. The GGGSC can have a strong impact on development in the partner regions through investing and promoting wider sustainability practices. It can be a lever to stimulate innovation in maritime transport globally, while also promoting the commercial and strategic interests of the EU in a changing geopolitical context.

Under the GGGSC initiative, possible technical assistance will be provided to selected partner ports and countries at international level on implementing the shipping fuel standards for pollutant (through the MARPOL convention) and reducing greenhouse gas emissions by implementing regulations based on EU regulatory framework and under MARPOL when possible. Additionally, support could be given to establish the infrastructure and conditions for producing and storing sustainable renewable and low carbon fuels in key ports along international shipping routes. In doing so, the GGGSC is expected to connect Europe to the world through sustainable shipping and provide opportunities for developing countries to establish themselves as hubs for green shipping in the global trade routes.

Infrastructure investments in these countries can help access renewable energy resources (wind, solar, hydro, geo-thermal) and produce sustainable renewable and low-carbon fuels (prioritizing sustainable renewable fuels of non-biological origin (RFNBO)) required for decarbonizing shipping and other hard-to-abate sectors. The development of a sustainable renewable and low-carbon fuels market requires however a significant investment into the fuel supply chain, from the production of bio-LNG, renewable electricity, over green hydrogen from electrolysers, to sourcing biogenic CO2 for producing sustainable renewable and low-carbon fuels.

A clear policy signal can also contribute to preparing the relevant stakeholders (ports, ship operators, ship builders, fuel providers and distributors) and assisting them in maintaining/ increasing their competitiveness at international level. The GGGSC can further bring positive externalities for national economies, enabling the domestic green transition and potentially securing future supply of renewable and low-carbon shipping fuels to European markets (geopolitical dimension). However, this transition is not exempt of challenges, such as the risk of carbon leakage and loss of the trans-shipment business to more polluting ports, which could directly and negatively affect the competitiveness of European ports. To ensure the viability of the GGGSC, subsequent actions following this study must address and mitigate these risks. Criteria such as the impact on ETS and the corresponding conditions for inclusion (300 nautical miles from an EEA port and 65% share of transhipment) should be applied.

With the GGGSC and using a Team Europe approach, the EU can be a leading force in the transformation of the maritime sector, developing green energy infrastructures in emerging economies and strengthening the EU's role as a global partner.

2 Design criteria

The initial exploration of the data on ports and sustainable RLCFs within the scope of the GGGSC suggests that –on one hand- there are several boundary conditions for the design of international shipping corridors that may limit their applicability and impact. On the other hand, there are various possible configurations that can allow the main objectives to be met, depending on the specific policy priorities for each potential corridor.

In order to guide the process of designing the GGGSC, the overall objective of the initiative can be expanded into 8 overarching priorities, as follows (Figure 2):

1. Decrease the environmental footprint of maritime transport between EU and partners: primarily aiming at reducing CO_2/GHG emissions of vessels connecting partner countries to EU ports, but taking the overall environmental performance also into account; depending on the precise formulation of policy priorities, the scope may be potentially extended to the total emissions from maritime transport in the partner countries (i.e. not necessarily limited to emissions corresponding to links with the EU), or even emissions from other sectors not necessarily linked to maritime transport. The importance of each green corridor in this respect can be measured by the potential decrease in its corresponding emissions that the initiative may bring.

2. Ensure the availability of sustainable RLCF for maritime transport internationally: to make sure that the vessels calling at ports belonging to the GGGSC can refuel with RLCF along the whole route between the EU and the partner country/ port. The most important indicator for this criterion is the capacity of each corridor/ port –or the bunkers in the vicinity of the corridor/ port- to provide the quantity/ quality of the RLCF required. The quantity may be higher than that needed to cover the demand generated by the EU-partner country corridor, since vessels serving other routes can be expected to convert to sustainable RLCF. The quantity of each alternative RLCF needs to be estimated based on the specific demand from the industry in each specific case and time horizon.

3. Develop additional capacity for imports of sustainable RLCF to the EU: apart from the availability of sustainable RLCF for the demand generated by the green corridor itself, the potential for additional quantities that can be exported to the EU would be considered as a significant positive impact, since it can increase the security of supply for the EU. In addition to the import potential of sustainable RLCF (which would be necessary assuming that the EU will lack the capacity to produce sufficient quantities at competitive prices), the potential for imports of sustainable RLCF for other sectors would also be a positive impact. In either case, the capacity for production of such fuels in the vicinity of the ports included in the corridor should be considered as criteria for the design of the corridors.

4. Contribute to international development by supporting partners in transition to sustainable RLCF: as part of the Global Gateway strategy, the green corridors should boost smart, clean and secure links in digital, energy and transport sectors and to strengthen health, education and research systems across the world. Investments are to be done in accordance with Global Gateway key principles of democratic values and high standards, good governance and transparency, equal partnerships, green and clean, security-focused and catalysing private sector investments. Green shipping corridors that are relevant to international development cooperation, the European Neighbourhood Policy and the EU External Action can provide multiple synergies among policy priorities. The main criteria for the corridor definition would

be how the local support provided by the GGGSC can contribute to promoting the EU goals for decarbonisation and global development.

5. Ensure a level playing field for ship and port operators in the EU and partner countries: the maritime transport sector is highly competitive and sensitive to policy interventions, with any measure affecting either the EU or the non-EU actors potentially creating a competitive advantage or disadvantage for several participants in the international supply chain. The green shipping corridors should aim at avoiding distortions through the application of comparable conditions and/ or support measures to ports/ vessels from the EU and partner countries, through instruments that avoid providing unbalanced advantages to specific stakeholders. The definition of the corridors should also include the suitable regulation/ monitoring mechanisms that would ensure transparency.
6. Build the critical mass for the development of international markets in sustainable RLCF: most of the options considered for RLCF in maritime transport are still in very early stages as regards their market development, with both the demand and the supply side facing high uncertainty. The GGGSC can contribute to building a critical mass on both sides, by stimulating demand for sustainable RLCF by the vessels and refuelling capacity in the ports.
7. Stimulate innovation in shipbuilding and maritime fuel technologies: the shift to sustainable RLCF can lead to increased funding for R&D in both the public and private sectors and lead to a strong can drive breakthroughs in new materials, propulsion systems (including wind-assisted propulsion or solar panels), energy-efficient designs that reduce the carbon footprint of vessels.
8. Strengthen the resilience of EU and international maritime transport and trade: the collaboration with partner ports and countries

Figure 2: Criteria for inclusion of partners in GGGSC

Note: The numbering of the criteria does not imply any order in priority or importance

Source: JRC (2024)

3 Main options for sustainable RLCF

The starting point for the identification of the options of RLCF that are relevant to the Green Shipping Corridors is the CO_{2eq} emission factor of each marine fuel used as a reference in FuelEU Maritime. An analysis of the available literature was carried out in order to identify the potential pathways that can produce fuels that meet the target of a 2% reduction of fuel carbon content in 2025, increasing to 6% in 2030, and accelerating from 2035 to reach an 80% reduction by 2050 (Figure 3).

The trends in the maritime transport sector suggest that the transition to sustainable RLCF does not have a clear path or a single fuel that is suitable for all uses. Four main families of fuel were identified as having the potential to meet the FuelEU Maritime targets in the 2030- 2050 time horizon, each following a different pathway and timeline, and applicable in different segments of the sector. All four fuel families identified are technologically feasible, yet widely varied when considering production at industrial scale and commercial maturity. Across all four fuel main options, the analysis suggests that two main transition paths, through bio-methanol or bio- ammonia, can be distinguished in the short term (2030), with a shift towards e-methanol or e-ammonia when they become available at industrial level at competitive prices (2040), preparing an eventual (but still uncertain) conversion to hydrogen as a fuel (late 2040s). A smaller niche (10%-15%) may follow the LNG to bio-methane to e-methane to hydrogen with a similar timeline.

As long as the FuelEU Maritime targets are met, the actual selection of fuel is not a factor to be considered in the design of the GGGSC (unless other environmental, safety, etc. issues are involved), which should be in principle technology neutral. Given a clear and foreseeable policy context, the stakeholders involved in the shipping industry (ship operators, ports, fuel distributors, etc.) are best suited for identifying the most suitable choice among these options within the complex context of their activities.

Figure 3: FuelEU targets for reduction of carbon content in maritime transport

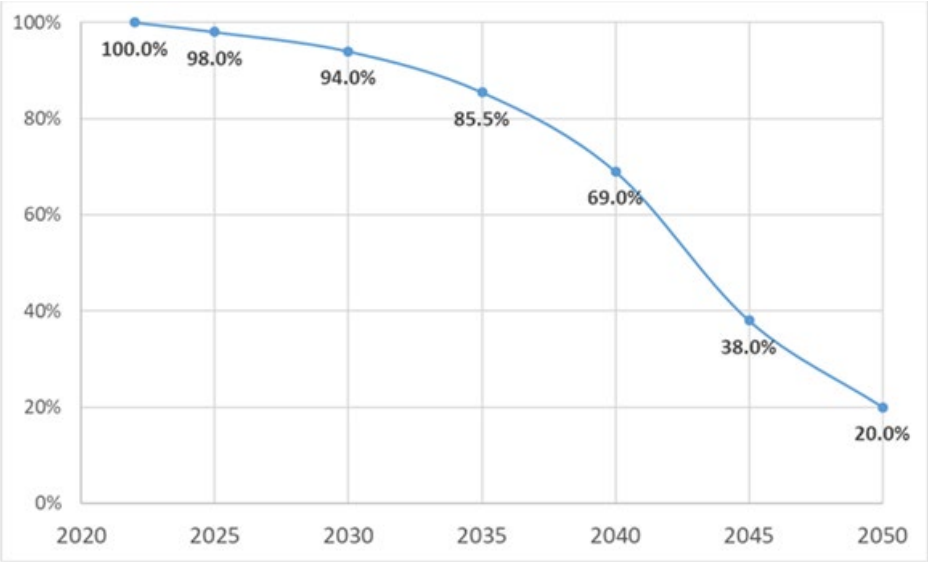
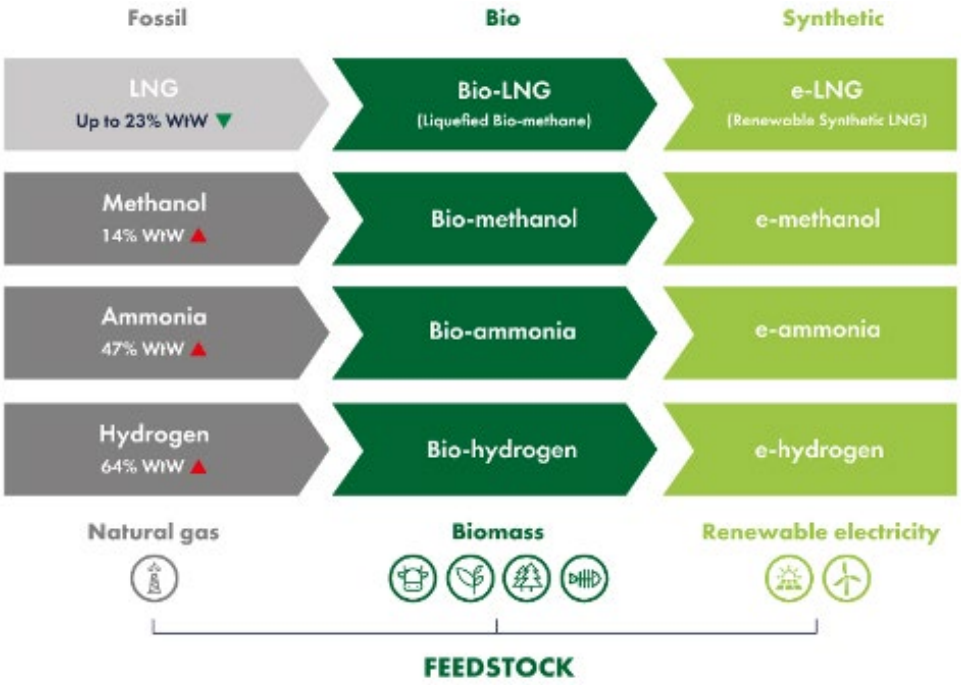


Figure 4: Main RLCF pathways relevant to the GGGSC



Source: https://sea-lng.org/2024/01/lng-leading-maritime-decarbonisation/

Each of the RLCF options considered has different technical and economic characteristics, and differs in terms of maturity (Lloyds Register, Knowledge Hub, 2024). The Technology Readiness Level (TRL) system uses a scale from 1 (basic principles observed) to 9 (actual system proven in operational environment).

- Bio-methanol (TRL 6-8) and e-Methanol (TRL 4-6)

Interest in methanol as a marine fuel is growing, with several projects and vessels already using or planning to use methanol. Stakeholders such as ship owners, fuel producers, and ports are exploring the use of methanol due to its liquid nature and lower emissions profile. Investment in bio-methanol is relatively mature, with production facilities in place and more being developed, but concentrated in the more developed economies (EU, USA, Japan, China). Bio-methanol is produced through the biomass gasification and subsequent methanol synthesis, while e-methanol is produced using green hydrogen (from water electrolysis using renewable energy) and captured carbon dioxide. E-methanol is still in early stages of development and requires significant investment to scale up production facilities and infrastructure. Methanol- regardless of its production pathway- has a lower energy density than conventional maritime fuel, which means more fuel volume or mass is needed for the same energy content. On the positive side, it can be stored as a liquid under ambient temperatures and pressures, which simplifies storage and bunkering infrastructure. Bio-methanol's impact depends on the sustainability of the biomass used. E-methanol's impact is lower if renewable energy sources are used for hydrogen production and if CO_2 is captured from the air or from low-carbon processes.

- Bio-methane (TRL 7-9) and e-Methane (TRL 4-5)

Maritime transport is increasingly adopting LNG -which is primarily methane- as a transition fuel. Conventional LNG cannot, however, lead to the carbon content reductions needed in the longer term. This has paved the way for stakeholders to consider bio-methane and e-methane (synthetic

methane) as viable next steps. Bio-methane is already being produced at scale for other applications, which could be redirected to maritime uses. Bio-methane technologies are relatively well-invested, given their overlap with existing biogas applications. E-methane is less developed and would require investments in green hydrogen production and carbon capture technology, as well as in methanation processes to synthesize methane. Bio-methane is typically produced by anaerobic digestion of organic materials, while e-methane (synthetic methane) is produced by combining green hydrogen with captured CO_2. Methane has a higher energy density than methanol but still lower than conventional marine fuels. It is the main component of natural gas and LNG. It requires cryogenic storage or high-pressure tanks when used as LNG or compressed natural gas (CNG), respectively. Bio-methane's sustainability depends on the feedstock and the production process. E-methane's environmental impact is low if produced using renewable energy and captured CO_2.

- Bio-ammonia (TRL 3-5) and e-Ammonia (TRL 3-5)

Ammonia as a maritime fuel is in the early stages of consideration. There is interest due to its high energy density and potential for carbon-free combustion. However, the technology is not yet mature, and there are significant safety concerns due to ammonia's toxicity and atmospheric emissions. Both bio-ammonia and e-ammonia production are in early development. Investments are being made in pilot projects and research to understand the production, storage, and combustion of ammonia in marine engines. Both versions are produced by combining nitrogen with hydrogen. The hydrogen for bio-ammonia comes from bio-based processes, while for e-ammonia it comes from water electrolysis using renewable electricity. Ammonia has a moderate energy density and can be used as a direct fuel in combustion engines or fuel cells after cracking it back into nitrogen and hydrogen. Ammonia needs to be stored as a liquid at modest pressures or at cryogenic temperatures. Its storage and transport require special precautions due to its toxicity and corrosiveness, raising a challenge for its supply chains and a need for suitable infrastructure and safety protocols. A further challenge to address is the emission of N_2O, a strong greenhouse gas. Technological solutions do exist but increase the cost of using ammonia as a marine fuel.

- Green Hydrogen (TRL 4-6)

Hydrogen is seen as a promising future fuel for a variety of sectors, including maritime transport. However, the maritime industry is still assessing how best to use hydrogen – whether directly in fuel cells or internal combustion engines, or indirectly through conversion to other fuels like methanol or ammonia. Green hydrogen production is currently expensive and at a small scale, but it is receiving considerable attention and investment due to its potential across many sectors. The maritime industry is investing in research and development, as well as piloting projects to test the viability of hydrogen as a marine fuel. Bio-hydrogen is produced from biomass through processes like dark fermentation or bio-photolysis, while e-hydrogen is produced by electrolysis of water using renewable energy sources. Hydrogen has a high energy content per unit mass but a low energy content per unit volume, posing challenges for storage and transportation. It also requires high-pressure tanks or cryogenic storage solutions, both of which are logistically challenging and energy intensive. Bio-hydrogen's impact depends on feedstock and process efficiency, whereas e-hydrogen has near-zero emissions if renewable energy is used for electrolysis.

All four main options of sustainable RLCF in maritime transport require dedicated production facilities, which are capital-intensive and correspond to significant investment. Establishing a reliable supply chain and the necessary bunkering infrastructure at ports is critical and requires further investment and coordination among stakeholders. New regulations and safety protocols must be developed and adopted, particularly for fuels like ammonia and hydrogen, which pose additional risks.

While the technological readiness for a transition of international shipping to RLCF appears to be satisfactory, there is still a high uncertainty as regards the economic feasibility and the potential for market uptake, resulting in a low level of investment. It is not clear which alternative fuel will finally predominate in the sector, with different options potentially covering the requirements of specific business segments. Considering this uncertainty, the European Commission has adopted a technological neutrality approach reflected in the FuelEU Maritime Regulation. An important aspect to highlight is that in line with the Renewable Energy Directive, the use of food and feed crop-based fuels cannot be promoted under the foreseen activities due to sustainability concerns. Similarly, the EU established in its Delegated Regulation (EU) 2023/1184 strict criteria to qualify production for hydrogen (and derivatives) as renewable, including when electricity for this production is supplied from the electricity network and not dedicated plants. In this respect, it should be noted that the definition of sustainability of RLCF used by FuelEU Maritime mirrors the sustainability architecture of the Renewable Energy Directive and differs from the definition agreed at and used by IMO, which continues its work on the implementation of the Life-Cycle Analysis Guidelines.

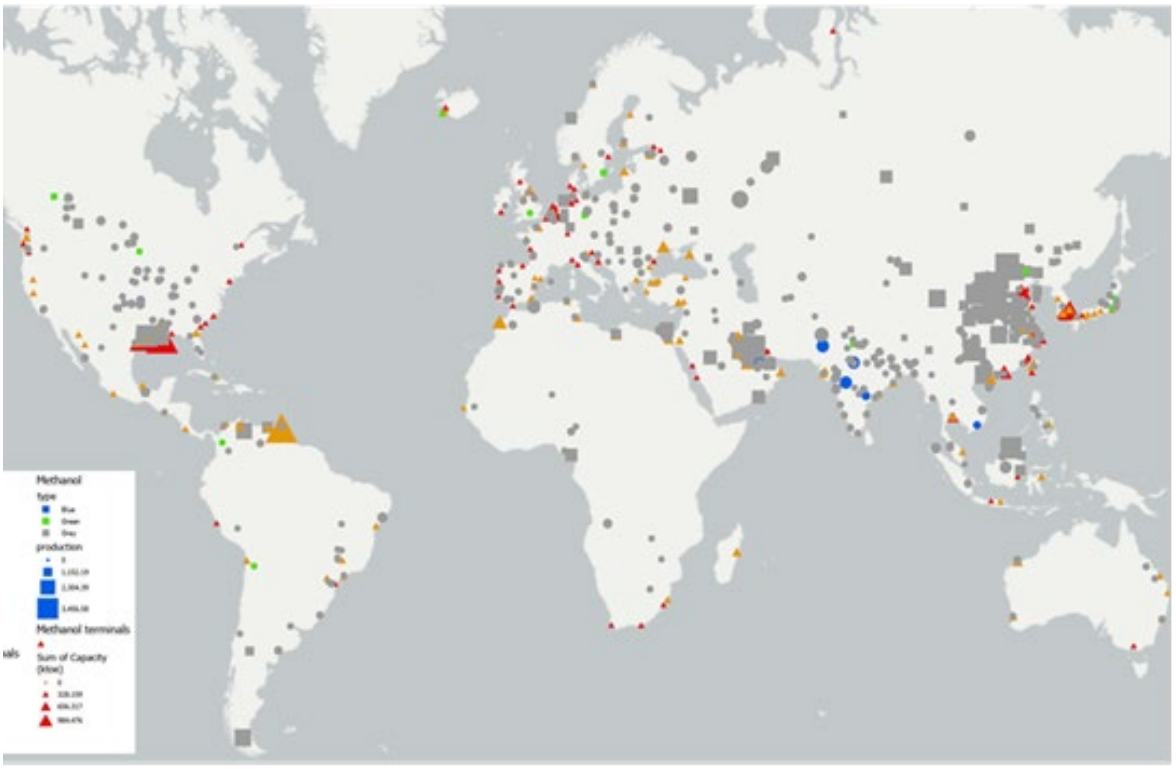
4 Supply of alternative fuels and RLCF for maritime transport

The analysis of the current and potential supply of sustainable RLCF was carried out using data collected by the JRC Energy and Industry Geography Lab (https://energy-industry-geolab.jrc.ec.europa.eu/) in combination with Eurostat data and JRC models.

The energy used for the EU's international shipping activity currently amounts to approximately 45 Mtoe/year, corresponding predominantly to oil and petroleum products, with only about 1% consisting of blended biodiesels. There is no reported consumption of ammonia or methanol in the energy balances. The analysis shows that in the short term, RLCF will be supplied by existing and planned conventional and bio-refineries located within an economically viable distance from each port. In the long term, particularly post-2035, the projected capacities of planned hydrogen, ammonia, and other emerging options will be taken into account. This long-term projection relies on the availability of data on RLCF projects and appropriate energy scenarios at a global level. As of 2023, the EU's annual production of ammonia and methanol stood at 8 384 ktoe and 1 208 ktoe respectively. This combined production represented only 21% of the average amount of energy consumed for maritime transport in the EU during the period 2019-2022. However, it is important to note that these products are used for other purposes and trade outside the fuel/energy markets. The production of these RLCFs was not evenly distributed across the EU. Germany, Poland, Romania, the Netherlands, France and Lithuania accounted for nearly two-thirds of the EU's total ammonia production. In the case of methanol, production was concentrated in Germany, the Netherlands, Romania, Lithuania and Poland. A significant challenge to the development of RLCF for maritime transport is the current production of "grey" ammonia and methanol. The EU's ammonia was virtually all "grey", while the rest of the world produced 92% "grey" and 8% "blue" ammonia. Similarly, the majority of methanol was also "grey" – 97% in the EU and 99% in the rest of the world. With the right policies and investments, the shift from "grey" to "blue" and "green" production could significantly increase the availability of RLCF for maritime transport. Increased production of ammonia and methanol, coupled with advancements in other alternative fuels such as hydrogen, could provide a viable path towards decarbonising the maritime sector. However, achieving this potential will require significant efforts. The geographic concentration of production highlights the need for a cohesive strategy across all EU member states. Additionally, the shift to production not relying on fossil energy sources will require substantial investments in technology and infrastructure.

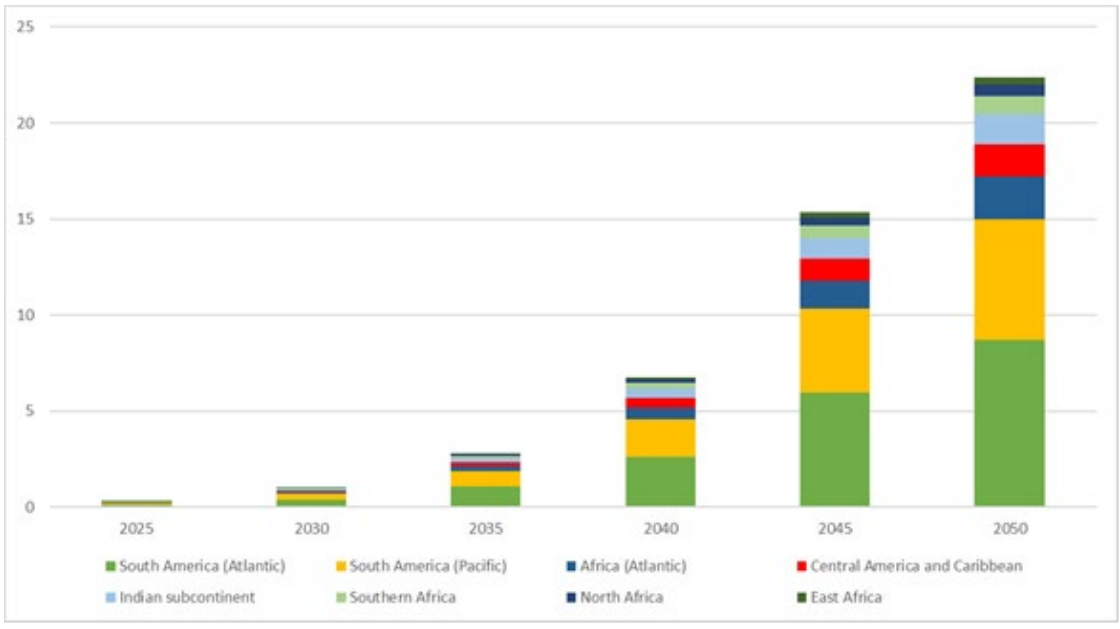
The projected demand for RLCF along the main Global Gateway areas considered for inclusion into the GGGSC are shown in Figure 6. These figures account for the expected increase in maritime transport activity of these regions by 2050 and the gradual replacement of the fuel used to meet the tighter carbon content targets set by Fuel EU Maritime.

Figure 5: Ammonia and methanol production sites, world, 2023



Source: JRC, Energy and Industry Geography Lab, 2024, based on data from (Rystad, 2024)

Figure 6: Projected demand for RLCF by geographic area (Mtoe)



Source: JRC, 2024

The design of the GGGSC should take into account the RLCF supply potential at various levels, from the global to the local, which for shipping would require the estimation of demand at route and port level. The overall goal is to develop a model of the global markets for the various options of RLCF and estimate the impact that each corridor will have on the balance, with particular emphasis on the potential for exports to the EU. Several sources can be combined for the estimation of the potential demand for RLCF that would correspond to each Green Shipping Corridor.

Most of the regions considered for the GGGSC represent low shares of global demand, with the exception of South East Asia (9.6%) and South America (7.6% Atlantic Coast, 4.9% Pacific Coast). But taken as a whole, the maritime fuel consumption of the main potential corridors taken together would add up to 31.6% of global consumption and 32.6% of the EU related one.

Table 1: Share of fuel consumption by bilateral maritime transport activity (in % of global total)

	Africa (Atlantic)	Central America & Caribbean	China	EU 27	East Africa	Gulf	Indian sub-continent	Japan	Middle East	North Africa	North America	Rest of the world	South America (Atlantic)	South America (Pacific)	Southeast Asia	Southern Africa	Total
Africa (Atlantic)	0.0	0.0	0.7	0.2	0.0	0.0	0.1	0.0	0.0	0.0	0.2	0.1	0.0	0.0	0.1	0.0	**1.5**
Central America and Caribbean	0.0	0.0	0.4	0.2	0.0	0.0	0.2	0.0	0.0	0.0	0.1	0.1	0.0	0.0	0.1	0.0	**1.1**
China	0.7	0.4	0.0	0.8	0.1	1.2	0.5	0.3	0.0	0.1	4.6	3.5	2.6	1.6	0.7	0.9	**17.8**
EU 27	0.2	0.2	0.8	0.4	0.0	0.3	0.2	0.3	0.0	0.1	1.9	1.5	0.8	0.6	0.4	0.1	**7.8**
East Africa	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.2**
Gulf	0.0	0.0	1.2	0.3	0.0	0.0	0.2	0.8	0.0	0.1	0.7	0.6	0.3	0.0	0.9	0.0	**5.0**
Indian subcontinent	0.1	0.2	0.5	0.2	0.0	0.2	0.1	0.1	0.1	0.3	0.7	0.6	0.2	0.6	0.4	0.1	**4.3**
Japan	0.0	0.0	0.3	0.3	0.0	0.8	0.1	0.0	0.0	0.0	1.7	1.2	0.8	0.5	0.5	0.2	**6.4**
Middle East	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	**0.3**
North Africa	0.0	0.0	0.1	0.1	0.0	0.1	0.3	0.0	0.0	0.0	0.2	0.1	0.1	0.0	0.0	0.0	**1.0**
North America	0.2	0.1	4.6	1.9	0.0	0.7	0.7	1.7	0.0	0.2	0.7	2.2	0.7	0.3	1.9	0.1	**16.0**
Rest of the world	0.1	0.1	3.5	1.5	0.0	0.6	0.6	1.2	0.0	0.1	2.2	2.4	0.6	0.1	1.7	0.1	**14.9**
South America (Atlantic)	0.0	0.0	2.6	0.8	0.0	0.3	0.2	0.8	0.0	0.1	0.7	0.6	0.0	0.2	1.1	0.0	**7.6**
South America (Pacific)	0.0	0.0	1.6	0.6	0.0	0.0	0.6	0.5	0.0	0.0	0.3	0.1	0.2	0.0	0.9	0.0	**4.9**
Southeast Asia	0.1	0.1	0.7	0.4	0.0	0.9	0.4	0.5	0.0	0.0	1.9	1.7	1.1	0.9	0.7	0.1	**9.6**
Southern Africa	0.0	0.0	0.9	0.1	0.0	0.0	0.1	0.2	0.0	0.0	0.1	0.1	0.0	0.0	0.1	0.0	**1.7**

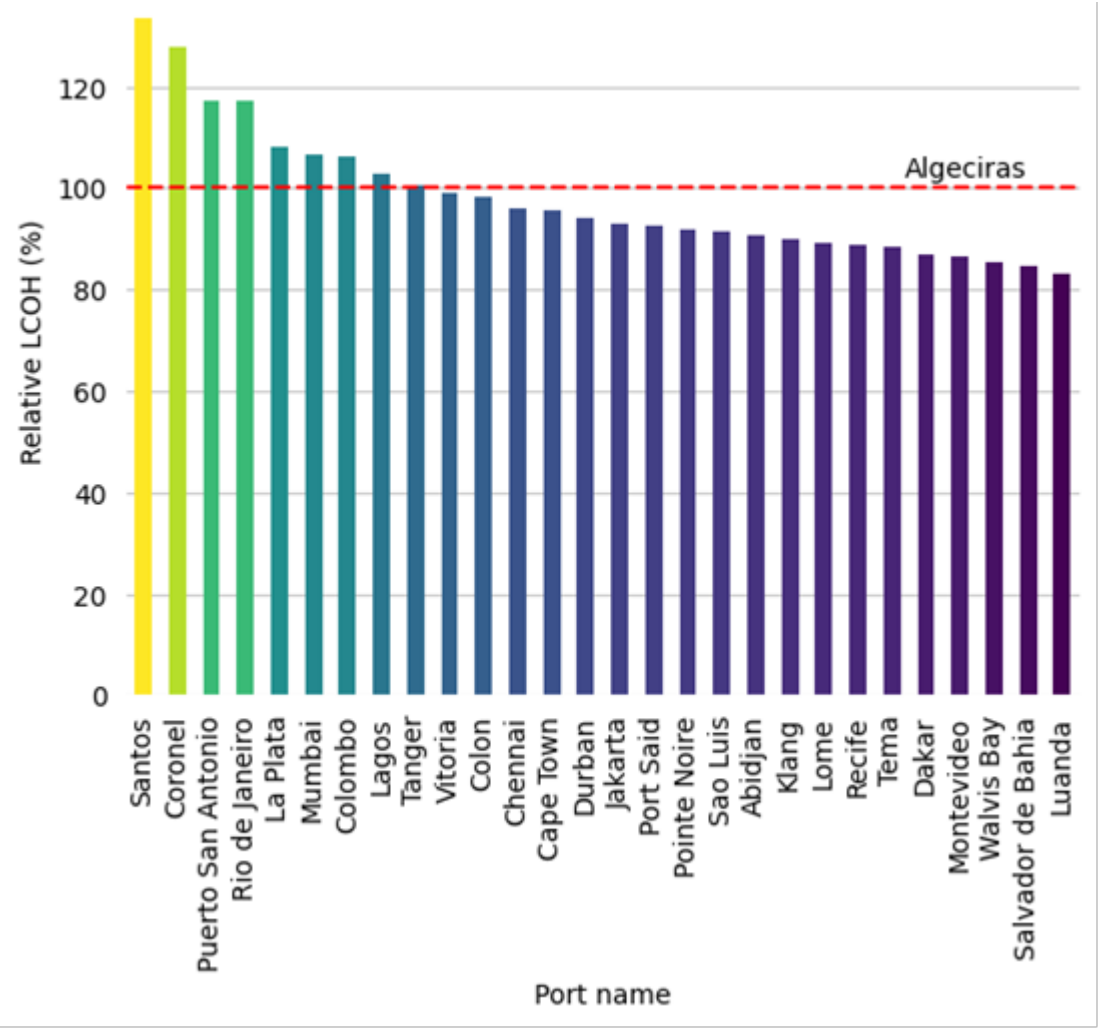
Source: JRC (2024)

In order to estimate the potential cost of production of RLCF in or near each port included in the GGGSC, the JRC study used the cost of production of renewable hydrogen- the basis of production of all RLCF pathways- as a proxy. The starting point was the analysis of solar, wind, hydro and geothermal production capacity to estimate the quantities and costs of producing renewable electricity and hydrogen. On the biomass side, given RED definitions, data on waste from agriculture and forestry was used. The model applied analyzed country-specific investment risks on the levelized costs of green hydrogen production. It used a renewable hydrogen production system model that optimizes hydrogen production on a worldwide 50 km × 50 km grid, considering country-specific investment risks. The following main aspects that affect the levelized costs of hydrogen (LCOH) production and, as a consequence, of sustainable RLCF fuel were taken into account:

- Renewable energy resources: The availability and quality of solar and wind resources signif-icantly impacts the LCOH production. Regions with high full load hours (FLH) for solar and wind have lower LCOH production.
- Country-specific investment risks: The study uses country risk premiums (CRPs) to account for the additional return on investment investors demand when investing in countries with higher risk. CRPs significantly impact the LCOH production, with countries having high CRPs resulting in higher LCOH production.
- Hybrid HPS design: hybrid HPSs consisting of both onshore wind and solar PV as electricity production sources can significantly reduce the LCOH production in comparison to non-hybrid systems.
- Hydrogen storage: hydrogen storage is deployed to balance production and constant hourly demand, while battery storage is not used due to its high costs.

Figure 7 compares the Levelized Costs of Hydrogen (LCOH) assuming a standard installation size, as well as the same investment and labour costs, across a selection of ports considered for inclusion in the GGGSC. Taking solar, wind and other renewable energy potential and cost characteristics into account, the analysis identified ports that can have access to RLCF produced at comparable or lower cost than in Europe (taking Algeciras, in Southern Spain, the point of lowest cost in the EU as the reference). The actual costs for production of RLCF would need to be estimated on a port basis once the design of the GGGSC is finalised. For instance, the 2023 pilot auction of Innovation Fund for Hydrogen produced a result with an average renewable H2 LCOH 5.8-13.5 Eur/kg – revealing the possible cost pf production, under the circumstances in 2023 across the EU. The corridor design affects the size of production installation in each GGGSC port, also depending on the specific RLCF fuel to be produced. Local conditions also affect the capital investment and operational costs in each case. When exports of RLCF are also considered, distance and its impact on transport costs would also be a decisive factor.

Figure 7: Comparison of LCOH across different potential GGGSC ports



Source: JRC (2024)

5 Additional policy criteria

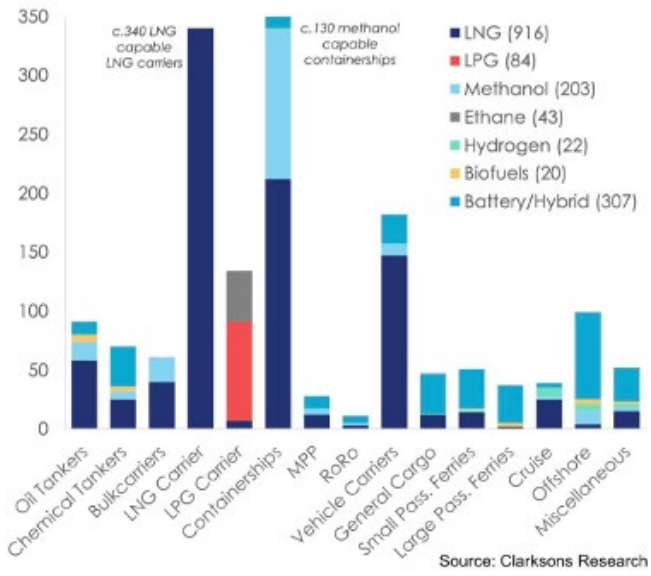
While port traffic and connectivity, fuel supply, including sustainable RLCF potential supply, and demand, sustainable RLCF pathways production costs and emissions are mainly quantifiable techno-economic criteria that can provide an estimate of the potential impact, there is a number of policy relevant criteria that affect the overall design of the GGGSC and require a more qualitative approach.

5.1 Research and innovation dimension

The European shipbuilding industry is a dynamic sector subject to intense international competition. Shipbuilding is important from both an economic and social perspective. It is also linked to other sectors including transport, security, energy, research, and the environment. There are about 150 large shipyards in Europe. Around 40 of them are active in the global market for large seagoing commercial vessels. The European shipbuilding industry is the global leader in the construction of complex vessels, such as cruise ships, ferries, mega-yachts, and dredgers. It also has a strong position in the building of submarines and other naval vessels.

While European ship building is losing market share in the overall market for large containerships, bulk carriers and tankers (due to competition with countries with lower labour costs), the European marine equipment industry is still a world leader for a wide range of higher value-added products ranging from propulsion systems, large diesel engines, environmental, and safety systems, to cargo handling and electronics. The transition to RLCF can be a stimulus for innovation, especially in areas where the EU has a technological lead. The European large marine engine manufacturers (Wartsila and Mann) have already made available engines that allow the use of all main RLCF options, as well as dual fuel engines that can facilitate the transition. The vessel order book at global level also reflects the preparedness of the ship building industry to adapt to the challenge of the transition (Figure 8). The shares of the specific alternative fuels chosen, nevertheless, suggest that the ship owners and operators may be considering different timelines and pathways to reach the future RLCF regulations and targets.

Figure 8: Order book of vessels that use alternative fuels



Research and innovation have a double interest for the GGGSC. On one hand, since most of the potential options for sustainable RLCFs are still far from large-scale commercial production and use, significant research and development work is still required in order to improve the methods and achieve commercially viable alternative fuels. On the other, the commitment of the GGGSC can act as an important trigger for innovation in maritime fuels (and RLCF in general) which -combined with the priorities in other technological areas- can create significant synergies for the EU and the partner countries.

The Transport Research and Innovation Monitoring and Information System (TRIMIS) provides open-access information on transport research and innovation. TRIMIS supports the implementation of transport policies of the European Union and at Member States level. TRIMIS analyses technology trends in the European transport sector and has been used in several analyses of research and innovation (Grosso et al., 2021; Tsakalidis et al., 2021). TRIMIS also participates in the development and monitoring of the Strategic Transport Research and Innovation Agenda (STRIA), which outlines transport R&I priorities to achieve a more sustainable European transport sector.

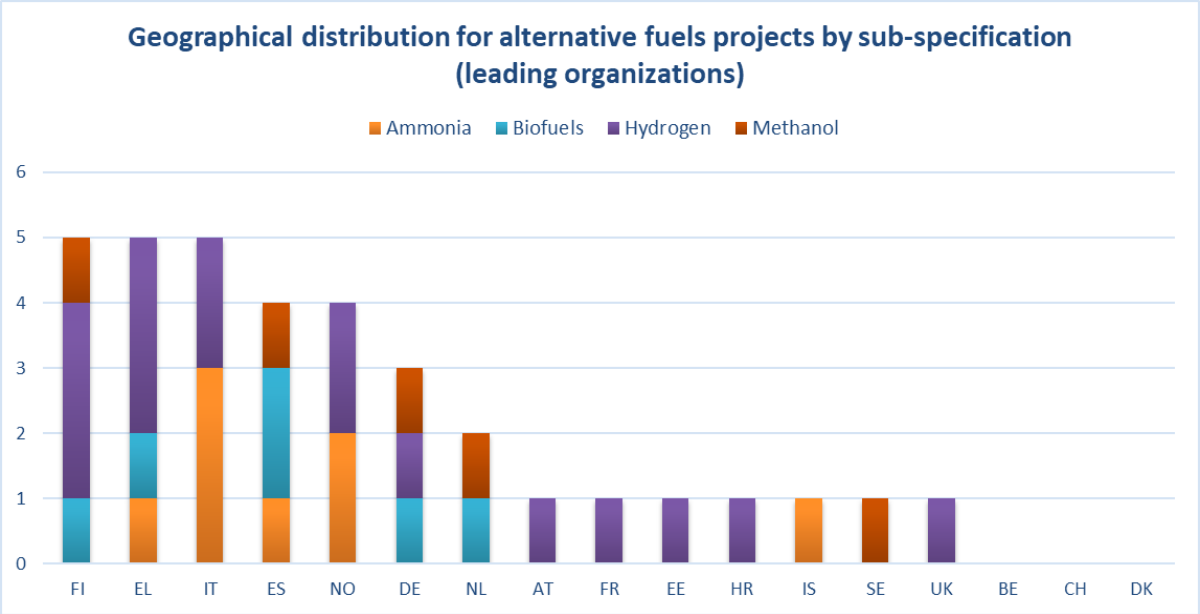
The period considered in this assessment covers 2014-2024, making reference to the H2020 and the Horizon Europe (HE) Framework Programs and to the Innovation Funds.

The project review is presented according to the main topic-research area investigated, addressing namely: ammonia, biofuels, hydrogen, and methanol. It is important to consider that some of these projects are actually covering more than one technology and could be linked to different topics. This review aims to illustrate the technologies investigated and their applications based on the available information, considering that some of these projects are still on going.

The projects selected represent a wide European coverage. When looking at the geographical distribution of lead partners in relation to the different alternative fuels, Finland, Greece and Italy are the countries with higher numbers of projects, with most of them looking at ammonia or hydrogen topics. The participation from Member States (MSs) is relevant when looking at the composition of the project's consortium, as 19 MSs plus Norway, United Kingdom, Switzerland and Iceland participated to the projects development, as presented in the charts below.

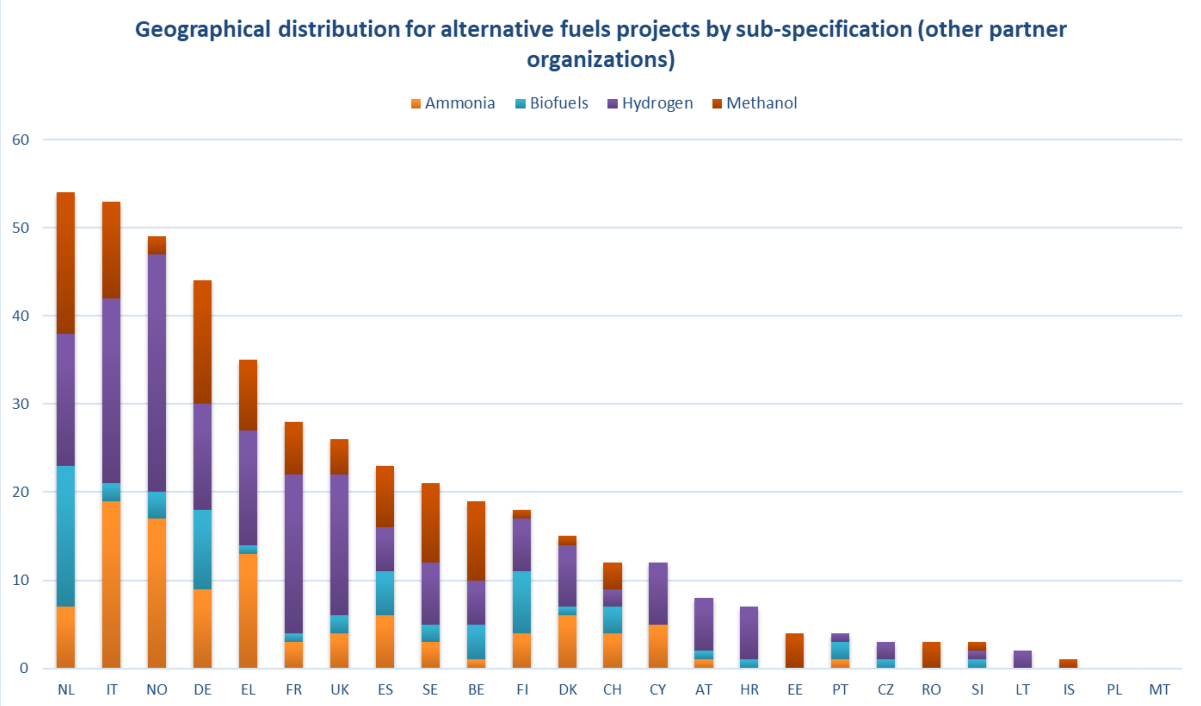
There is currently considerable interest in the waterborne transport sector in future alternative fuels for greening the sector with no clear prioritisation of particular options. Future research of alternative fuels for long-distance maritime shipping, considering the options for scaling up of production as well as their using in ship engines, would be beneficial. Another aspect to take into consideration is the feasibility of developing these technologies both for new built and as retrofit options for existing vessels. The biggest impacts on decarbonisation for the waterborne transport sector are likely to come from the use of alternative fuels, this is because fuels such as electricity from renewable sources or hydrogen from electrolysis, using electricity from renewable sources, can offer a pathway to net zero for the waterborne industry. Therefore, priority for future policy development could have a focus on increasing the uptake of these alternative fuels to help achieve decarbonisation targets of the industry.

Figure 9: Alternative fuels projects and their geographical distribution, based on the project lead organisations



Source: JRC, Trimis database, 2024

Figure 10: Alternative fuels projects and their geographical distribution, based on the project partner organisations



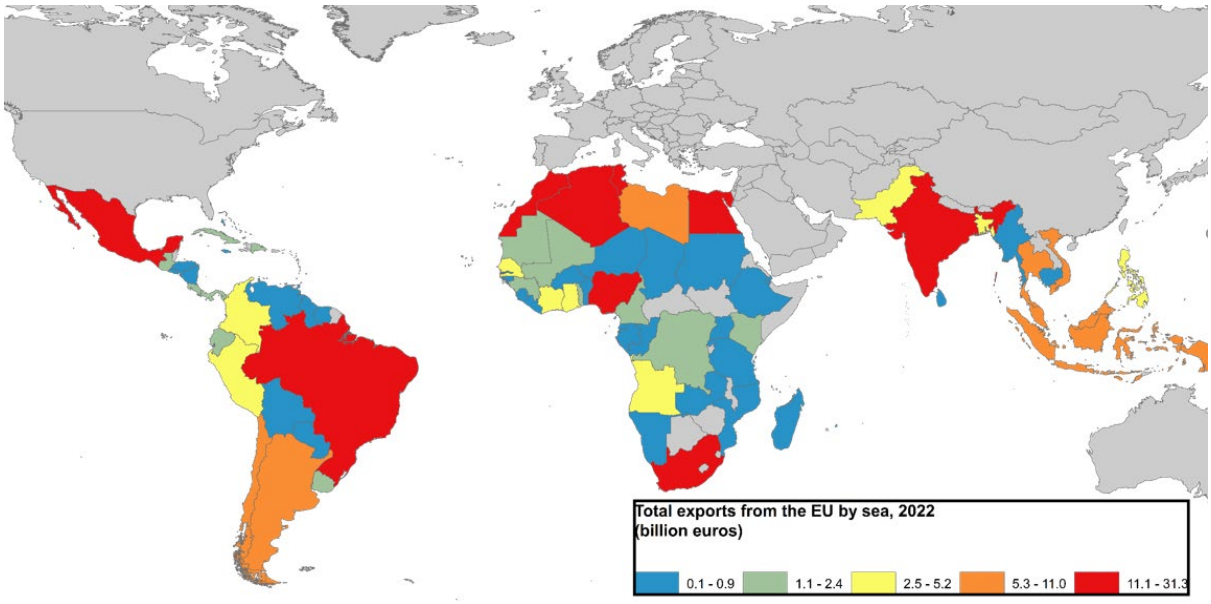
Source: JRC, Trimis database, 2024

5.2 Importance for EU Trade

Figure 11 shows the total value of EU exports and Figure 12 the total value of EU imports for each country in the candidate areas for the Green Shipping Corridors. It is apparent that the larger economies tend to have a higher volume of trade with the EU. For sub-Saharan Africa, Nigeria and South Africa are important markets for EU exports. In terms of imports, the total volume is relatively lower but still Nigeria and Angola (mainly due to imports of petrol products) as well as South Africa appear as the main markets. Brazil is a major trade partner for the EU in the Latin America region, followed by Mexico and Argentina. Most of the other economies in the region are relatively small and represent small shares of the EU's international trade. On the Asian side, India is a major partner for both exports and imports.

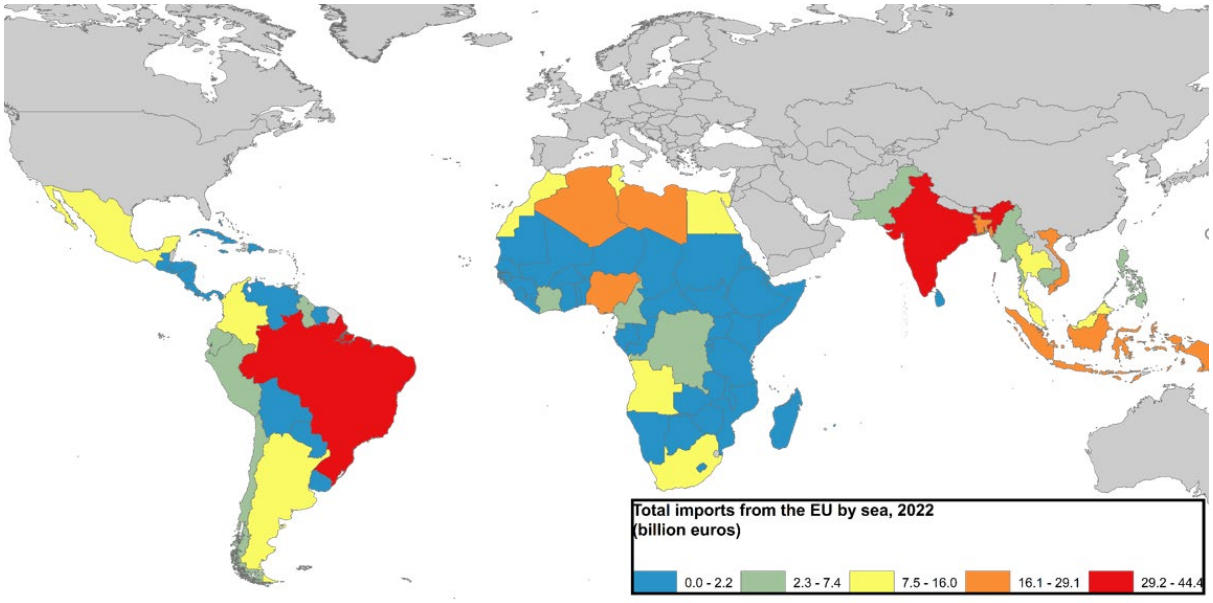
The relevance of each potential partner for the GGGSC in the context of the EU Trade Policy can be assessed through the map of the current state of EU trade agreements (Figure 13). The fact that major countries that have been flagged as potential partners in GGSC, such as Morocco, Egypt, South Africa, Chile, Colombia and Panama have already signed trade agreements with the EU can facilitate the identification of potential instruments and provide a basis for trade in RLCF (or countries for which the adoption/ ratification process is ongoing, such as Argentina, Brazil and Nigeria). For India and SE Asia, collaboration in the GGGSC and trade in sustainable RLCF could be elements to be taken into account in the on-going negotiation of their trade agreements with the EU.

Figure 11: Value of EU exports by sea per partner country, year 2022 (€ billion)



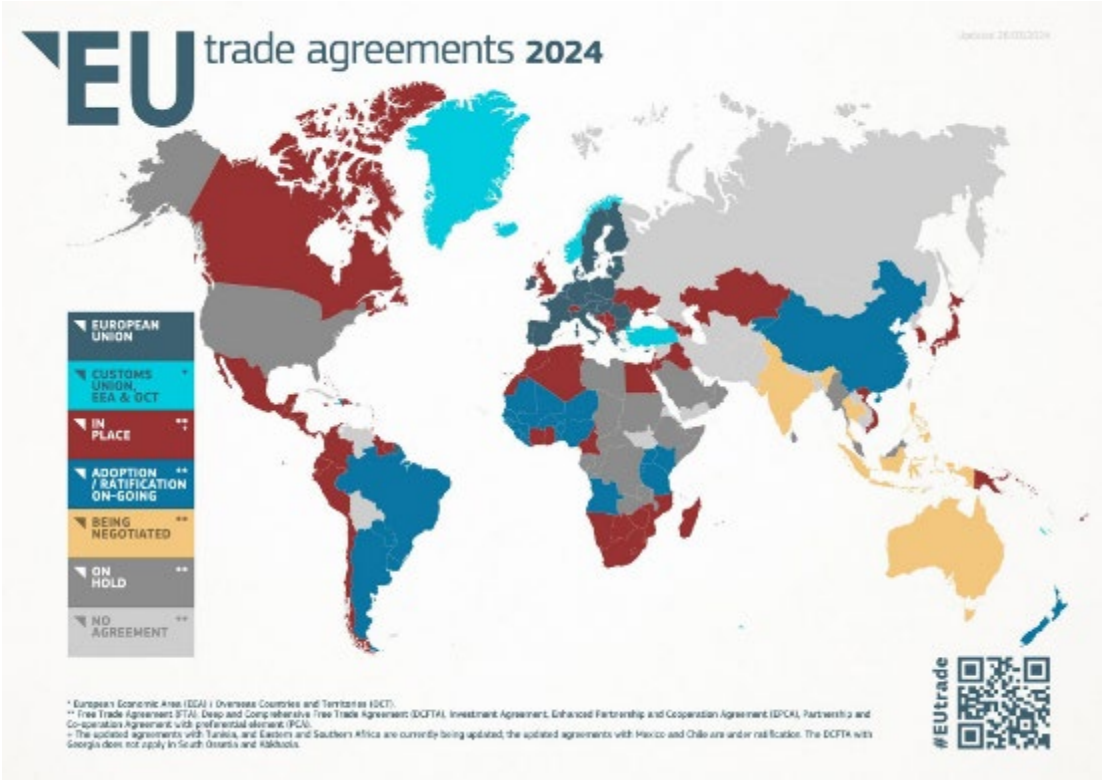
Source: JRC based on (EUROSTAT/ Comext, 2024) data

Figure 12: Value of EU imports by sea per partner country, year 2022 (€ billion)



Source: JRC based on (EUROSTAT/ Comext, 2024) data

Figure 13: EU Trade agreements



Source: European Commission, DG TRADE (https://policy.trade.ec.europa.eu/eu-trade-relationships-country-and-region/negotiations-and-agreements_en)

5.3 Interdependencies with EU ports

The potential impact that including a port in the GGGSC would have on EU ports, as well as the overall impact on competitiveness of EU waterborne sector is a policy issue with high political relevance. It is fundamental that the GGGSC contributes in maintaining a level playing field in both the port and shipping operations market and that the support provided by the GGGSC to partner countries and ports does not have negative repercussions on the competitive position of EU stakeholders. This study contributing to the design of the GGGSC should be neutral and independent of specific EU stakeholder interests and existing or planned choices as regards operations or investments to avoid unfair competition. Additionally, potential distortions in the implementation of other EU policies, such as the Emission Trading System (ETS) or other environmental, safety and security aspects should be avoided.

The competition between EU and non-EU ports for containerized goods, bulk, or liquid cargo is influenced by several key factors related to hinterland, foreland, and transhipment. In order to improve the understanding of the dynamics of this competition, the JRC developed a tailored model to assess the interdependencies between ports, and applied it to describe the relation of EU and non-EU ports (Christodoulou et al., 2019; Ferrari et al., 2023). The model utilizes port connectivity indicators with major markets in Asia, North America, Western Europe, and the Mediterranean. It relies on a dataset comprising port connectivity indicators, which measure the frequency and reliability of shipping services between ports and major markets. These indicators are calculated based on factors such as the number of shipping lines, vessel capacity, and sailing frequencies. The dataset covers ports outside the EU and those within the EU. Additional data on port size, capacity, and geographical location are also collected to help understanding their competitive position. The methodology combines statistical and machine learning techniques. The dataset is first pre-processed to ensure that all variables are normalized and scaled appropriately. A regression analysis was performed to estimate the impact of each model variable on trading routes. The results of the regression analysis are used to develop a predictive model, which can help to understand the level of inter-dependency between ports based on their connectivity indicators, distance, and size.

Any investment in a GGGSC port could alter the shipping costs through that port and affect its relative position in the global logistics chain, this would be relative to the project or actions that could be envisaged. As an example, GGGSC investments in Tangiers could improve the port's competitive position as regards supply of sustainable RLCF in respect with Algeciras, a direct competitor for transhipment, and most major EU ports in the Mediterranean. At the same time though, several EU ports that are linked with Tangiers in routes serving the global market might benefit from sustainable RLCF fuel supply in Tangiers. Such ports can include major EU ports both upstream and downstream in the logistics chain (in this example, both North Sea and East Mediterranean). E.g. Antwerp and Piraeus may be competing with Tangiers (and Algeciras) for transhipment in the EU-Asia market, but may also- at the same time- benefit from any improvements that decrease costs in an Antwerp-Tangiers- Asia, or a Tangiers- Piraeus- Asia connection. Arguably, they would also benefit from improvements that decreases costs in an Antwerp – Algeciras – Asia or an Algeciras – Piraeus – Asia connection.

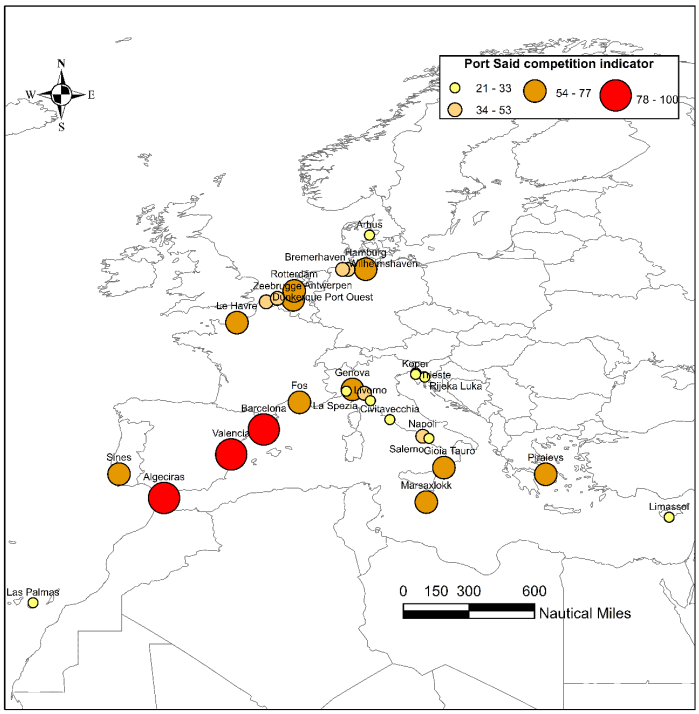
For bulk carries and tankers the situation is simpler, since connections normally involve only the origin (exporting) and destination (importing) ports. In such cases, an investment in the non-EU port would improve the sustainable RLCF fuel supply on a route with the EU port, raising the complementarity between the two ports. The interdependencies between EU ports would be only marginally affected, since the remaining factors affecting port competition (port specialisation, hinterland, infrastructure, capacity, productivity, market share in given product and geographical market etc.) would not be

altered by investments in the non-EU port. This complementarity is under the assumption that investments in 3rd country ports would not lead to a reduction of transhipment volumes or calls to EU ports along the route.

Given the complex nature of international shipping, complementarity and competition between ports cannot be easily measured. In addition, both aspects can be present at the same time. The JRC model on port interdependencies aims to help quantify those two dimensions of port competition, exclusively with the use of detailed data on port calls and port connectivity. These indicators can assist in the prioritization of ports for inclusion in the GGGSC if priority is given to the ports that would complement the activities of EU ports and/or pose lower risks for the EU ports' competitive position. More detailed analyses must be carried out once an initial list of ports that meet EU policy priorities is available.

Specific emphasis will be given to how the selected ports affect EU competitiveness and comply with relevant rules. Figure 14 and Figure 15 give an indication of the extent of potential risk of competition for transhipment between EU ports and the two major North African ports of Port Said and Tangier, respectively. Including them, or other ports in a similar situation, in the GGGSC would require additional safeguards as regards alignment with EU policies and the application of specific rules to avoid distorting competition with EU stakeholders. For example, by applying criteria such as the impact on ETS and the corresponding conditions for inclusion (300 nautical miles from an EEA port and 65% share of transhipment) in the GGGSC[2]. In any case, in case of competition concerns, an analysis of the impact on the EU sector should be undertaken before a final decision is taken.

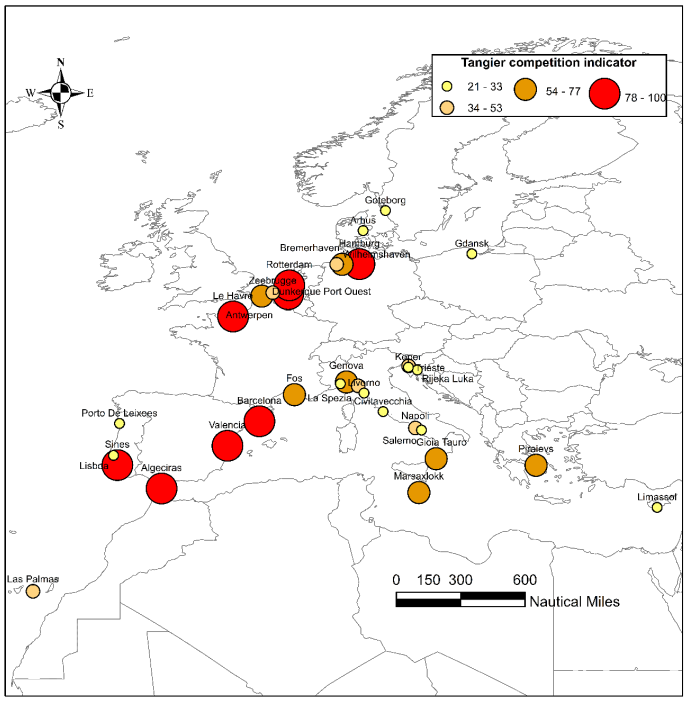
Figure 14: Main EU ports for which Port Said competes in common transhipment markets



Source: JRC (2024)

[2] Regulation (EU) 2023/2297 identifying neighbouring container transhipment ports pursuant to Directive 2003/87/EC of the European Parliament and of the Council

Figure 15: Main EU ports for which Tangier -Med competes in common transhipment markets



Source: JRC (2024)

5.4 Ratification of MARPOL Annex VI

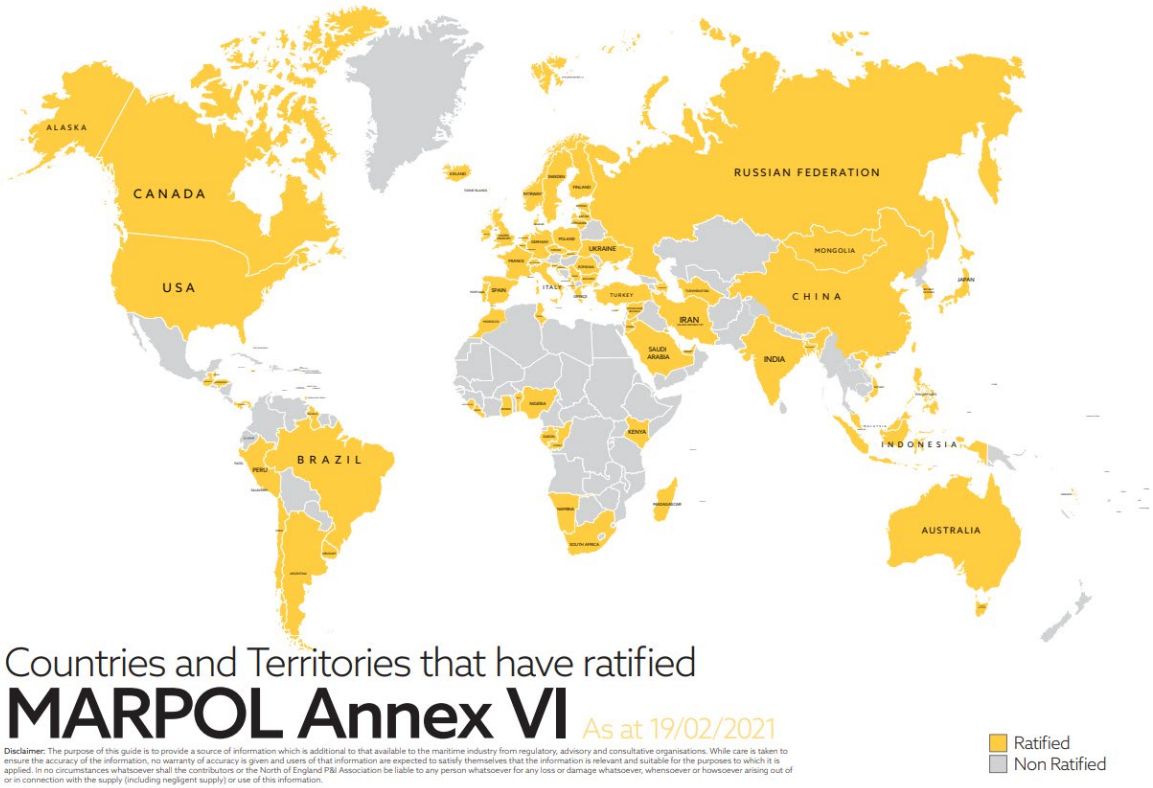
MARPOL, the International Convention for the Prevention of Pollution from Ships, is concerned with preventing marine pollution from ships. Specifically, Annex VI of MARPOL addresses air pollution from ocean-going ships. It provides requirements for the control of emissions from ships such as ozone depleting substances (ODS), nitrogen oxides (NOx), sulphur oxides (SOx) and particulate matter (PM), volatile organic compounds (VOCs), and other pollutants. Following the adoption of the IMO 2023 Revised Strategy on Reduction of GHG Emissions from Ships, currently IMO Member States are negotiating amendments to MARPOL Annex VI including measures that implement the goals of the Strategy.

The ratification of MARPOL Annex VI by a country indicates its commitment to enforcing international standards that limit air pollution from ships. This commitment is an important criterion for the GGGSC since countries that have ratified MARPOL Annex VI are more likely to have the necessary legal and regulatory frameworks in place to enforce the environmental standards that green shipping corridors aim to promote. The implementation of Annex VI may require upgrades to port infrastructure to develop port reception facilities, to ensure the availability of low-sulphur fuels or to develop storage capacity for alternative fuels. Ports in countries that have ratified Annex VI are more likely to have the necessary infrastructure to support green shipping corridors. Ratification is also a signal to the international maritime community that a country is open to collaboration on environmental initiatives. This can encourage partnerships between governments, shipping companies, ports, and technology providers to invest in and develop green corridors. Annex VI also includes provisions for monitoring,

reporting, and verification of emissions from ships, which are all important aspects for the design of the GGGSC.

Figure 16 maps the countries that have ratified Annex VI so far. It is noteworthy that a large number of countries that can be a candidate for the GGGSC has not yet ratified it, especially in Africa. The GGGSC can also have an important role in supporting countries that have not yet ratified Annex VI by providing technical, institutional and financial support to adapt their infrastructure and legislation in accordance to the IMO MARPOL convention and other international agreements. In terms of evaluating the impact of the GGGSC on international development, countries that have not yet ratified Annex VI may be considered as of higher priority.

Figure 16: Ratification of MARPOL Annex VI



source: North Standard, https://www.nepia.com/legislation/

5.5 Synergies with other Global Gateway projects

The Global Gateway strategy is the EU's contribution to narrowing the global investment gap worldwide. It is in line with the commitment of the G7 leaders from June 2021 to launch a values-driven, high-standard and transparent infrastructure partnership to meet global infrastructure development needs. In this respect, it is the EU's contribution to the G7's Partnership for Global Investment and Infrastructure (PGII). The Global Gateway is also fully aligned with the UN's Agenda 2030 and its Sustainable Development Goals, as well as the Paris Agreement.

Between 2021 and 2027, the EU and its Members States will -in a Team Europe approach- mobilise up to €300 billion of investments for sustainable and high-quality projects, taking into account the needs of partner countries and ensuring lasting benefits for local communities while looking at the EU's strategic interest. This will allow EU's partners to develop their societies and economies, but also create opportunities for the EU Member States' private sector to invest and remain competitive, whilst ensuring the highest environmental and labour standards, as well as sound financial management.

An important step in taking forward the Global Gateway strategy was the Africa-Europe Investment Package with approximately €150 billion of investment dedicated to bolstering cooperation with African partners. THE EU has also started implementing Global Gateway in Asia and the Pacific and in Latin America and the Caribbean, where President von der Leyen announced a global investment by EU and its Member States of over €45 billion. The EU and its Member States, working in a Team Europe approach identified 250 Global Gateway flagship projects worldwide across the digital, energy and transport sectors through Global Gateway to strengthen health, education, and research systems globally.

Figure 17: Map of current Global Gateway projects

Source: European Commission, GISCO (2024)

A significant number of Global Gateway flagship projects can be of high relevance to the GGGSC. Such projects include direct investments in port development, renewable energy or energy networks that could facilitate the development of infrastructure to ensure the availability of alternative fuels for maritime transport. Projects that improve land access to the ports or facilitate the availability of alternative fuels for aviation can also be relevant, since they may extend the market for alternative fuels or feedstocks (but would also compete as a sector of high demand).

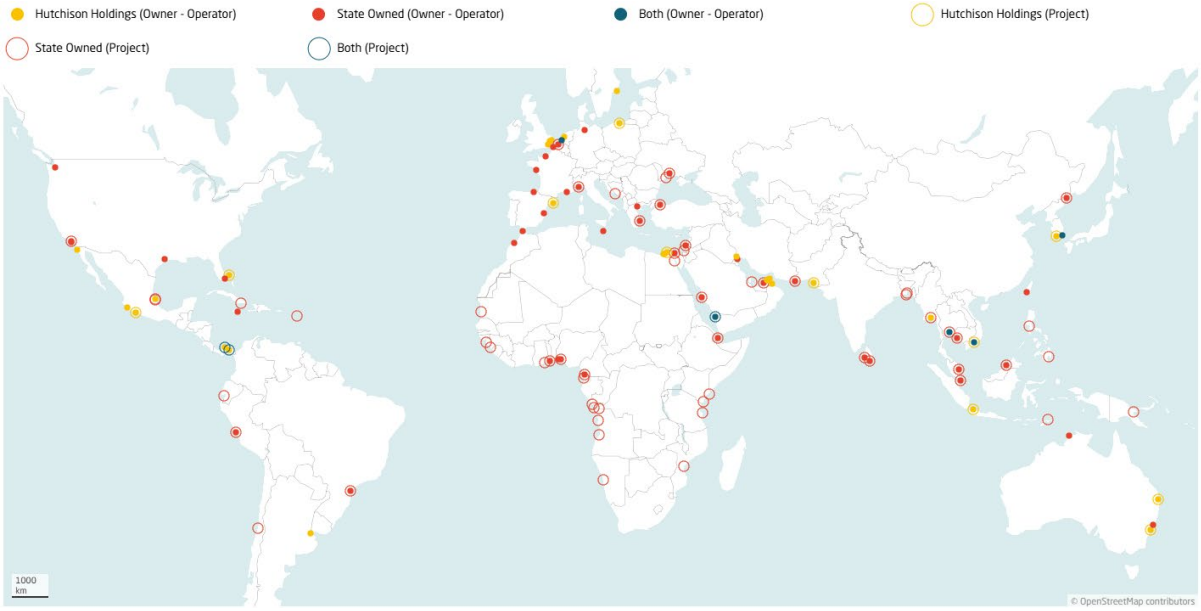
The Global Gateway Projects already include the development of Maritime Technology Cooperation Centres that cover all the regions that are relevant to the GGGSC (Africa, Central and South America, Asia and the Pacific) in order to support countries in these regions in meeting the energy-efficiency and greenhouse-gas targets of the International Maritime Organization. Synergies can be also found with the initiative on Sustainable Aviation Fuel (SAF), which also covers all regions and supports the development, production and use of sustainable aviation fuels globally. In this case, the goal is to contribute to reaching the International Civil Aviation Organization's (ICAO) goal of net-zero emissions from international aviation by 2050.

More specifically, there are currently 50 individual projects that address transport and renewable energy issues relevant to ports and shipping. Two important Flagship Projects are in place in Northern Africa, on hydrogen in Morocco and on bio-methanol in Egypt .In sub-Saharan Africa, 34 projects can be considered as relevant, potentially creating synergies with a Green Shipping Corridor. For South America, the Caribbean and Mexico, 10 projects have been identified as relevant. In Asia and the Pacific there are currently 4 relevant projects.

5.6 Geopolitical aspects to take into account

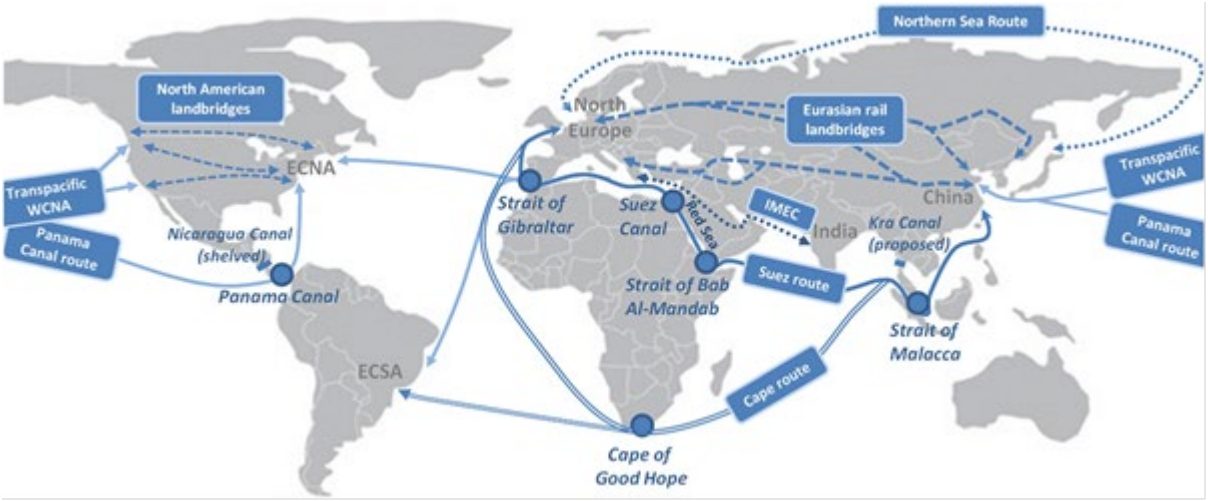
Additional aspects to take into account for the design of the Green Shipping corridors include the investment strategies of other global players, especially China. Figure 18 shows the international ports that China is investing in, mainly through its Belt and Road Initiative (BRI). China's increasing presence in Africa could shift the balance of influence on the continent away from the EU and other traditional Western partners. There is a risk that African countries could become economically dependent on China, potentially aligning more closely with Chinese positions on international matters, which could be not favourable for EU policies and interests. In addition, Chinese investments could raise the competitiveness of certain African ports, resulting in a shift in trade routes and patterns that could potentially divert trade away from European ports. There is also significant concern about the debt sustainability of African countries borrowing from China for large infrastructure projects. Concerns are also often raised as regards the security impacts of Chinese bases and intelligence gathering across Africa. On the positive side, Chinese-funded port infrastructure may improve market access for EU goods into Africa and encourage EU companies to also invest. Investment-wise, the Chinese priorities in areas overlapping with potential Green Shipping Corridors are important in East Africa (primarily Tanzania), but may be of high relevance also in Angola, Ivory Coast and Nigeria. The two largest Chinese port operating companies COSCO (active mainly in Europe) and China Merchants Port Holdings (active mainly in Africa and ASEAN) appear to be following a coordinated strategy to strengthen control over the shipping routes serving the Chinese international trade.

Figure 18: Chinese ownership of ports overseas



source: Mercator Institute for China Studies

Figure 19: Chokepoints and international trade corridors



Source: (Notteboom et al., 2024)

International shipping is highly dependent on 5 nodes that act as a chokepoint due to their geographic position or vessel capacity (Figure 19). They are all critical for EU trade, but in most cases are outside the EU's direct control. The Strait of Gibraltar, at the entrance of the Mediterranean, is a natural point for transhipment for the whole continent. Algeciras (Spain) is an established hub, but is facing strong competition from Tangier Med in Morocco. In either case, capacity may be a limiting factor in the future and updated infrastructure would be necessary for the transition to sustainable RLCF.

The other entrance to the Mediterranean, the Suez Canal, is critical for the trade between the EU and Asia, but faces capacity constraints (vessel size and traffic capacity) and is close to the highly volatile

Middle East. In addition, it is dependent on the Strait of Bab Al Mandab, which makes the whole Suez/ Red Sea area a particularly weak point in terms of the resilience of shipping networks. Especially EU ports in the Eastern Mediterranean are very exposed to the potential risks, with repercussions to the overall economic activity in the area.

The Strait of Malacca, along the main path to China and the ASEAN, has high levels of maritime activity and is facing increasing level of port congestion and vessel traffic, with a potential risk in terms of safety and security. Moreover, the high intra-regional shipping activity and the growing demand for conventional and RLCF for maritime transport (among other sectors) pose the risk of the full potential RLCF supply in the region being absorbed by local and regional demand.

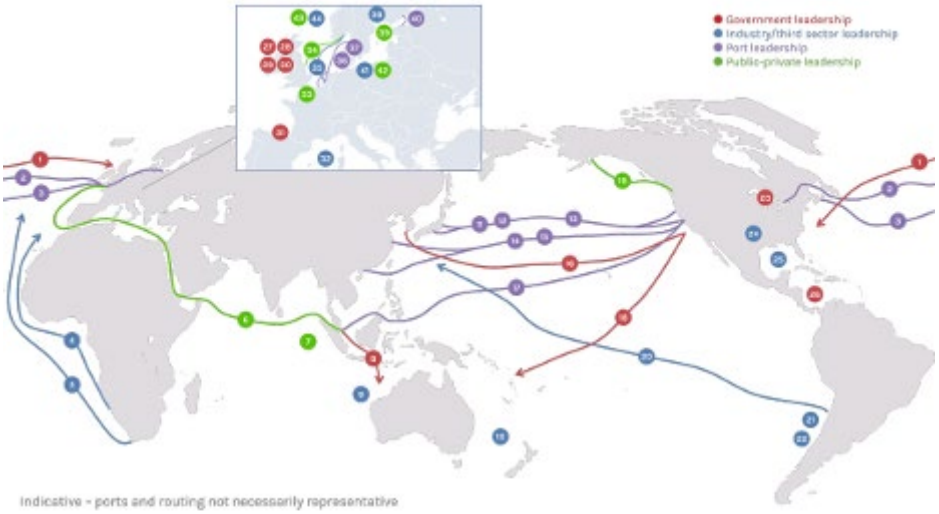
The Panama Canal is strategic for global shipping and plays an important role for several EU trade routes. It faces tighter capacity constraints than the Suez Canal (it can serve smaller vessels at a lower throughput rate) as well as environmental concerns (droughts) but is an important hub for Latin America and parts of North America.

The Cape of Good Hope has been historically a challenge for navigation, but –since these challenges have been overcome- ports such as Durban and Cape Town have become important regional hubs with a growing activity in transhipment. The Cape route is also a main alternative to the Suez Canal, even though using that route may add 10-20 days of additional time at sea for the EU-Asia flows.

The GGGSC can develop alternative networks that avoid such chokepoints and areas that represent high geo-political risk and uncertainty. For example, ensuring sustainable RLCF availability along the West African coast can ensure EU maritime connectivity even if operations through the Suez Canal or the Red Sea are threatened. Developing alternatives for imports of sustainable RLCF from Africa and Latin America can increase the strategic autonomy and the security of energy supply of the EU. It is clear, for example, that if a country would like to export sustainable renewable fuels to the EU, the production of the fuel (including feedstocks, etc.), would necessarily need to meet all relevant EU regulation (i.e., RED, FuelEU Maritime standards, etc.).

Finally, the outlook for the development of green shipping corridors by other countries and stakeholders can be a factor to take into account in the design of the GGGSC. Several corridors are currently at the proposal stage (Figure 20), with different priorities in terms of geographic coverage, levels of ambition and state of progress. It is worth noting that the majority address trans-Pacific operations, and only a few cover EU shipping activities (and mainly limited to specific port-to-port connections). All three major areas of interest to the GGGSC (Africa, Latin America and Southeast Asia) are under-represented, a situation that reinforces the need for the GGGSC to link those areas to the EU. Moreover, GGGSC could seek cooperation with promoters of the major green shipping corridors under development, to jointly connect remote areas that would otherwise remain outside of the corridors e.g. the island states in the Pacific.

Figure 20: Other proposed green shipping corridors worldwide, 2023



1. US-UK Taskforce
2. Antwerp-Montreal
3. Halifax-Hamburg
4. Namibia-EU
5. South Africa - Europe Iron Ore
6. Rotterdam-Singapore
7. The Silk Alliance
8. Singapore-Australia
9. Western Australia-North Asia Iron Ore
10. Australia-New Zealand
11. Oakland-Yokohama
12. LA-Nagoya
13. LA-Yokohama
14. LA-Guangzhou
15. LA-Long Beach-Shanghai
16. Republic of Korea-United States
17. LA/Long Beach-Singapore
18. US-Fiji-Pacific Blue Shipping Partnership
19. Pacific Northwest to Alaska
20. Chile Cu-Concentrate
21. Chile Piscocultura
22. Chile sulfuric acid
23. Canada-US Great Lakes- St Lawrence
24. US Green Bulk
25. Gulf of Mexico
26. US and Panama
27. UK-Belgium
28. UK-Norway
29. UK-Netherlands
30. UK-Denmark
31. Green Corridors Spain
32. La Méridionale
33. Dover-Calais/Dunkirk Ferry
34. H2 powered North Sea crossing
35. Oslo-Rotterdam
36. Gothenburg - Rotterdam
37. Gothenburg - North Sea Port
38. Åland RoPAX
39. Decatrip
40. FIN-EST
41. European GC Network
42. Nordic Roadmap
43. Clean Tyne
44. GREENBOX

source: Global Maritime Forum, Annual progress report on green shipping corridors, Nov. 2023

6 Potential implementation options and instruments

To support ports in developing countries in preparing for GGGSC and the transition to alternative maritime fuels, the EU must establish a decision-making system to which this study will contribute towards. Various measures can be decided and implemented, depending on the local conditions and needs, as well as the involvement of the relevant stakeholders. A range of possible actions at port and country level can be foreseen, in the following 10 broad categories:

- Infrastructure Development
- Technical and Regulatory Support
- Capacity Building
- Financial Incentives and Investments
- Collaboration and Partnerships
- Research and Innovation
- Policy Alignment
- Environmental Monitoring
- Stakeholder Engagement
- Market Development

A common denominator across these potential instruments is that the EU's experience and knowledge sharing approach, coupled with regulatory alignment, can significantly accelerate the transition of GGGSC partners to RLCF in maritime transport.

1. Infrastructure Development:

- Develop or upgrade port infrastructure to handle sustainable RLCF such as methanol, ammonia, bio-methane and hydrogen, with a clear transition path to the low and zero-emissions versions (bio- and e-).
- Install shore power facilities (cold ironing or onshore power supply - OPS) to allow ships to turn off their engines and connect to the electrical grid while at berth, reducing emissions in and around ports.
- Support the use of renewable electricity in ports.
- Promote the development of Port Management Information Systems (PMIS) to improve port efficiency, enhance safety for ship and port operations, and optimize ship fuel consumption.

2. Technical and Regulatory Support:

- Provide technical assistance to help ports understand the requirements of handling and storing new fuels and technologies.
- Develop regulatory frameworks to ensure the safe handling of alternative fuels and to incentivize their use.
- Promote bunkering standards and regulations compatible with those of EU, like safety and security standards for bunkering and handling of the new fuels, wellbeing of crews (no exploitation of work force)

3. Capacity Building:

- Train port staff on the specifics of new technologies and safety procedures related to alternative fuels.
- Engage in knowledge-sharing initiatives with ports that have already started the transition to green technologies.

4. Financial Incentives and Investments:

- Create financial incentives for shipping companies to use low-emission vessels on Green Shipping Corridors.
- Facilitate access to international funding and investment for port modernization projects, including grants, loans, and public-private partnerships.
- Explore options to attract public and private investments using a Team Europe approach.

5. Collaboration and Partnerships:

- Encourage collaboration between ports in developing countries and more advanced ports to share best practices and technologies.
- Form alliances with shipping lines, fuel providers, and technology companies to create an integrated approach to green corridors.

6. Research and Innovation:

- Support research into the development and deployment of new maritime fuels and technologies suitable for the local context.
- Pilot projects to test the feasibility and impact of alternative fuels and green technologies in local conditions.

7. Policy Alignment:

- Align national policies with international maritime regulations, such as those set by the International Maritime Organization (IMO), to ensure compliance and competitiveness. Ensure ratification of IMO MARPOL Annex VI and other international environmental and sustainability measures.
- Application of EU equivalent definitions for sustainability of RLCF, when these include additional criteria to those of IMO.
- Application of an Emission Trading Scheme type of regulation in the country of the corridor to maritime sector, power sector and industrial production sectors.
- Ensure compliance with EU rules concerning port competition, specifically Article 3ga(2) of Directive 2003/87/EC.
- Integrate port development strategies with broader national strategies for sustainable development and climate change mitigation.
- Ensure a regulatory framework in the port that facilitates the handling of vessels equipped with wind propulsion including priority for fuelling with sustainable RLCFs
- Requirement of ships flying the flag of the country benefiting from GGGSC funding to start transition of sustainable RLCF

8. Environmental Monitoring:

- Support the development of local capacity for inspections and fuel quality control
- Implement systems to monitor and report emissions from shipping activities to track progress and make informed decisions on further improvements.

9. Stakeholder Engagement:

- Engage local communities, industry stakeholders, and environmental organizations in the planning and development of green port initiatives to ensure broad support and sustainability

10. Market Development:

- Support the investments if renewable electricity and feedstocks in the region, as well as the capacity to store hydrogen or ammonia as carriers
- Encourage the development of local markets for alternative fuels to ensure their availability and affordability for shipping companies

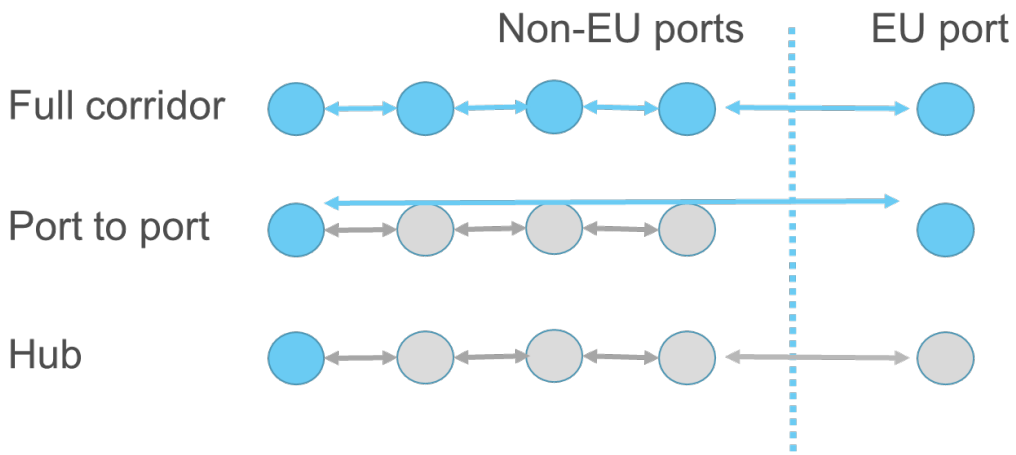
The inclusion of different ports or countries in the GGGSC may combine different instruments, depending on the degree of engagement of the potential partners. Such combinations may involve, for example, a requirement for policy alignment by the partner country if EU financial support and funding are sought. The existence of a scheme that is comparable to ETS or the ratification of the IMO MARPOL Annex VI could be a condition.

As an example of funding programmes in Europe, the EC's Innovation Fund had a budget of €4 billion in 2023 to support the deployment of innovative decarbonisation technologies, funded from the revenues from the EU Emissions Trading System (EU ETS)[3]. Eligible projects could have a budget ranging from €2.5 million for small-scale decarbonisation actions to more than €100 million for large-scale applications. Projects are assessed based on their potential to reduce greenhouse gas emissions, their degree of innovation, maturity, replicability and cost efficiency. The Innovation Fund can cover up to 60% of a project's relevant costs.

In contrast, proposals of carbon pricing measures at IMO which could help to bridge the gap between sustainable RLCFs and other fuels are not decided yet, and a support for a fund to promote the decarbonisation of the maritime sector is still pending. In that sense, support from the GGGSC may be crucial for less developed countries to adapt to the new challenges.

There is no fixed definition of what constitutes a shipping corridor in terms of port connections. Depending on the specific ports selected, their role in shipping networks connecting to the EU, and the GGGSC criteria they meet, three different approaches can be considered as corridors and can potentially co-exist in a framework of GGGSC.

Figure 21: Shipping corridor definition options



Source: JRC (2024)

[3] https://ec.europa.eu/commission/presscorner/detail/en/IP_23_5948

- Full Corridor: A full shipping corridor includes all ports along a specific maritime route between the EU and a non-EU region. This approach would ensure that every port within the corridor adheres to the environmental standards set out by the GGGSC initiative, enabling a consistent level of requirements across the entire route and minimizing the risks for distorting competition (vessel re-routing or change of port call choices). Full corridor implementations allow economies of scale, since they involve multiple ports and vessels and lead to a higher demand for sustainable RLCF, but also increases the complexity of the green corridor implementation, especially when ports along the route have different levels of readiness for a transition to sustainable RLCF. The corridor may also be formed by a combination of a core network of ports that ensure the availability of RLCF along the GGGSC, complemented by partner countries/ ports that are assisted in their transition through tailored support instruments.

- Point-to-Point: A green corridor between a single non-EU port and one or more EU ports. It represents a targeted strategy where specific, high-traffic routes are prioritized for an early adoption of sustainable RLCF. Such corridors can concentrate resources on routes that have the most significant environmental impact or strategic importance and simplify coordination between a limited number of ports and stakeholders, allowing faster implementation. Nevertheless, point-to-point corridors can create competitive disadvantages for ports not included in the green corridor.

- Hub: A single non-EU port as a green hub, which is not necessarily connected to specific EU ports. The hub would serve as a regional centre for sustainable RLCF and could facilitate the adoption of green practices by vessels traveling through the region. Such hubs can serve as a catalyst for a broader transition and provide a scalable model for other ports in the region.

7 Classification of ports

The JRC study collected data and modelling results which were combined into a framework of composite indicators that can support further policy analysis and decision-making in the development of the GGGSC. The aim was to allow the visualisation of the indicators in a transparent manner. The tool can classify ports according to partial indicator and overall scores, using weights that represent the relative importance of each criterion or indicator.

The approach is organized around eight first-level indicators, each representing a main policy criterion. Each first-level indicator is composed of multiple second-level indicators, which are combined using weights that can be manually adjusted to explore different policy priorities (Table 2). The second-level indicators are based on a range of sources, including JRC calculations, model results and external data. The classification of the ports can be based on each first-level indicator, as well as by individual criterion. The classification can be adjusted by changing the weights assigned to each second-level indicator, enabling users to explore different policy priorities and scenarios in an interactive way.

Table 2: Composite indicator framework

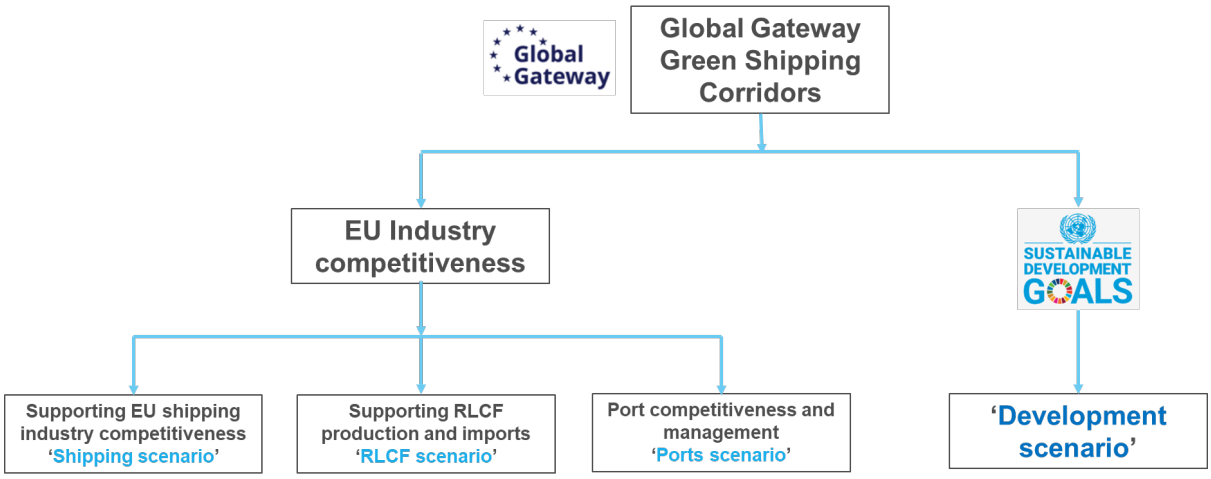
1st level indicator	**2nd level indicators**	**3rd level indicators/ data**
Impact on GHG emissions reduction potential	• share of the country's global maritime fuel consumption • share of that consumption that corresponds to EU shipping • number of port calls at the port.	• JRC calculations • Eurostat/ UNCTAD trade data • EMSA data • AIS data
Availability of sustainable RLCF	• potential capacity at port level • potential capacity at country level	• JRC Energy and Industry Geography Lab estimates
Potential as a source for imports	• available capacity corrected by the distance to EU ports • cost of production of sustainable RLCF	• as above, corrected by maritime distance from EU ports • JRC model
Relevance to Global Development Priorities	• relevance for existing Global Gateway initiatives • four indicators on inclusive growth (UNCTAD) • MARPOL Annex VI ratification • strategic priority indicator	• Data on Global Gateway projects • Underlying indicators used by UNCTAD • Policy priorities
Impact of interdependencies	• port complementarity indicator • port competition indicator • neighbouring transhipment port	• JRC model on port interdependencies
Critical mass for sustainable RLCF uptake	• total number of calls for each port • total maritime fuel consumption of the port's country	• AIS data • EMSA data • JRC calculations

1st level indicator	2nd level indicators	3rd level indicators/ data
Innovation	• share of global maritime transport trade • share of global fleet ownership • share of global shipbuilding activity • share in the supply of global seafarers	• UNCTAD data
Resilience	• the port or country's strategic importance • EU Trade Agreement • Value of maritime trade with EU	• geopolitical risks indicators • trade data • EUROSTAT data

The framework of composite indicators described above allows the quantification of the various criteria of relevance to the GGGSC in a coherent and transparent manner. These indicators can form the basis for the identification of relevant ports and corridors according to specific policy priorities. The GGGSC is an initiative addressing multiple objectives, and analysing the classification of each port according to different policy perspectives provides additional insights. One of the main messages of the analysis is that –on purely quantitative terms- larger ports in more developed countries are more relevant in order for the impact of the GGGSC to be maximized in terms of reducing CO2 emissions and ensuring the critical mass for sustainable RLCF in maritime transport. This, however, may come into conflict with the overarching objective of the GGGSC to act as an instrument for the promotion of sustainable development goals in less developed countries which do not currently show sufficient potential as users or suppliers of sustainable RLCF.

Using the data and analysis presented above, a policy driven scenario can be designed, matching the overall objectives set out for GGGSC, while also allowing the individual policy perspectives to be reflected. The design splits scenarios in two families, one exploring the impacts on EU industry competitiveness and one on sustainable development goals. The EU industry competitiveness scenarios are further split into 3 scenarios, each addressing shipping, RLCF production and imports, and ports, respectively (Figure 22).

Figure 22: Structure of policy scenarios



Source: DG International Partnerships, 2024

The rationale of these scenarios can be summarized as follows:

- Supporting EU Shipping Industry Competitiveness: The EU shipping industry faces significant competition from international players. This scenario focuses on enhancing the competitiveness of EU shipping companies by promoting green shipping corridors that reduce operational costs, improve efficiency, and comply with EU environmental, climate and sustainability law. The priorities of this scenario include the reduction of GHG emissions to comply with EU regulatory framework, the increased uptake of sustainable RLCFs in EU shipping operations and the promotion of innovation and R&D to improve shipping efficiency and reduce costs. Apart from the direct benefit for EU stakeholders, additional spill over benefits can be expected from non-EU operators adapting to the transition that the GGGSC will stimulate.

- Supporting sustainable RLCF production and imports: This scenario focuses on promoting the production of sustainable RLCF in countries participating in the GGGSC and the facilitation of exports of RLCFs to the EU. By increasing the availability of sustainable RLCFs, the EU and partner countries can reduce their dependence on fossil fuels and decrease GHG emissions, while building the critical mass for the uptake of sustainable RLCF at a global scale. Priorities include the increase of sustainable RLCF production capacity in the non-EU partners and the development infrastructure for sustainable RLCF import and distribution.

- Port interdependencies and management: This scenario focuses on making the best out of port interdependencies and the management of ports to support the transition to sustainable RLCF. By ensuring a level-playing field and the availability of sustainable RLCF across the Green Shipping Corridors, both EU and GGGSC ports can strengthen their position as efficient and attractive nodes in the international shipping networks. Priorities include investments in port infrastructure to support sustainable RLCF bunkering and storage, port management and technologies to reduce costs and emissions, and the encouragement of sustainable practices in port operations. While this scenario aims to ensure that the competitiveness of EU ports is not impacted, the limitations of this study will require further considerations and the development of the methodology and possibly establishing safeguards before final decision on the possible support to a port is taken. In any case, the study makes already at this stage a reference to the same criteria as the ones used for Regulation (EU) 2023/2297 which lists Tangier Med and Port Said could have high risk of evasion and therefore prone to impact competitiveness. While these ports have been studied, showing indeed their competitiveness vis-a-vis EU ports, they have not been included in the scenarios shown in the report.

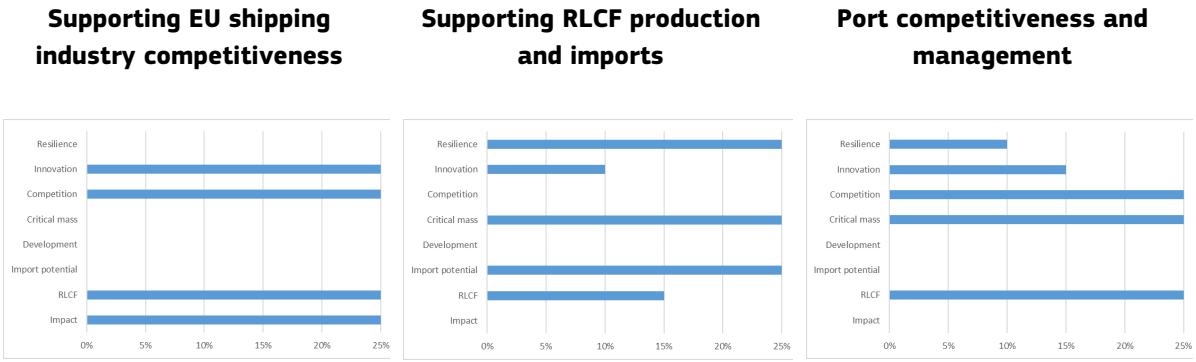
The three scenarios under EU industry competitiveness are quantified using different combinations of the underlying indicators, with individual weights adapted to the priorities of each scenario (Figure 23).

The development scenario is quantified through the already presented development indicator.

- Development Scenario: This scenario focuses on the promotion of sustainable development goals in countries within the scope of the Global Gateway and on narrowing the global investment gap worldwide. In that sense, the GGGSC can be seen as an instrument supporting the EU policies on international development. Priorities include the promotion of sustainable development, the creation of synergies with other Global Gateway initiatives, the support to inclusive growth, the promotion of international agreements and cooperation, and the provision of technical support and knowledge sharing.

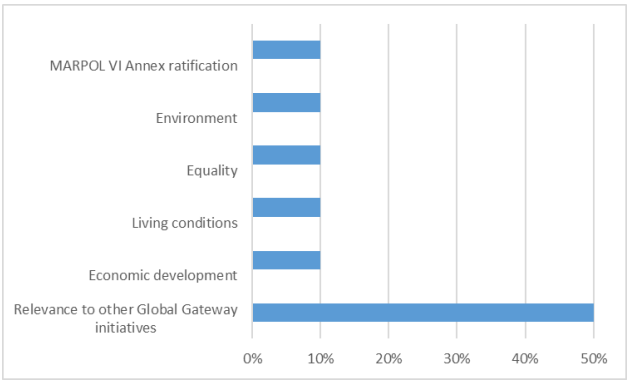
The indicator on development is measured in terms of each port's proximity to other Global Gateway projects, the country's inclusive growth index (split is 4 dimensions: economic, development, living conditions, equality and environment) and the country's situation as regards the ratification of IMO MARPOL Annex VI (Figure 24). Proximity to other Global Gateway projects is considered as a positive aspect. Low inclusive growth indicators, or a country not having ratified Annex VI, are considered as an indication that the candidate country can be supported through the GGGSC to improve the situation. Therefore, such countries are considered as more relevant to the GGGSC.

Figure 23: Indicator weights for policy scenarios



Source: DG INTPA & JRC, 2024

Figure 24: Indicator weights for development scenarios



Source: DG INTPA & JRC, 2024

Since a different combination of indicators and weights is used in each scenario, the classification of the ports can vary significantly among scenarios. These variations in classification reflect the different role each non-EU port can have from the point of view of shipping operations, sustainable RLCF production and import potential or port competitiveness. At the same time, they highlight a mismatch in priorities when comparing ports that can contribute to the effectiveness of the GGGSC in terms of reducing GHG emissions with those that can contribute to the international development aspect of the initiative.

From the effectiveness point of view, the Venn diagram of the top-50 ports in terms of the three scenarios under EU industry competitiveness (Figure 25) suggests that 30 ports are classified as highly relevant in all 3 scenarios. This, still provisional, list of ports can be considered as potentially

forming the core of the ports that could be supported by the GGGSC and that can ensure critical mass and availability along the international shipping networks of interest to the EU, taking into account how EU ports can also be linked in the GGGSC. This core network can be complemented by other ports considered as important for the development aspect of the GGGSC. Furthermore, this list can be adapted according to additional priorities and inputs from a wider range of stakeholders, in consistency with the Team Europe approach. The development scenario results in a significantly different classification. As a general observation, the areas where the GGGSC would contribute the most in terms of supporting sustainable development are not classified as highly important in terms of most of the EU competitiveness criteria. This is to be expected to a certain extent, since there is a high correlation between the economic development of a country and the effectiveness of the GGGSC in terms of impact and relevance to the EU industry. To balance the two perspectives, the GGGSC should combine ports that are classified as highly relevant from the competitiveness perspective with ports that would increase the GGGSC impact on development. The list of ports that are classified as highly relevant from the development point of view is given in Annex 2.

Figure 26 and Figure 27 map the ports that are classified as highly relevant from the competitiveness and development point of view and highlight the need for a policy mix that satisfies both policy priorities.

These figures are -nevertheless- still indicative and should be considered as provisional results. They reflect the classification of ports based on the purely data-driven analysis, which would only be an initial step for the selection of the GGGSC ports that will be made based on a wider range of EU policy priorities.

Figure 25: Venn diagram of top-50 ports in the three EU industry competitiveness scenarios (provisional)

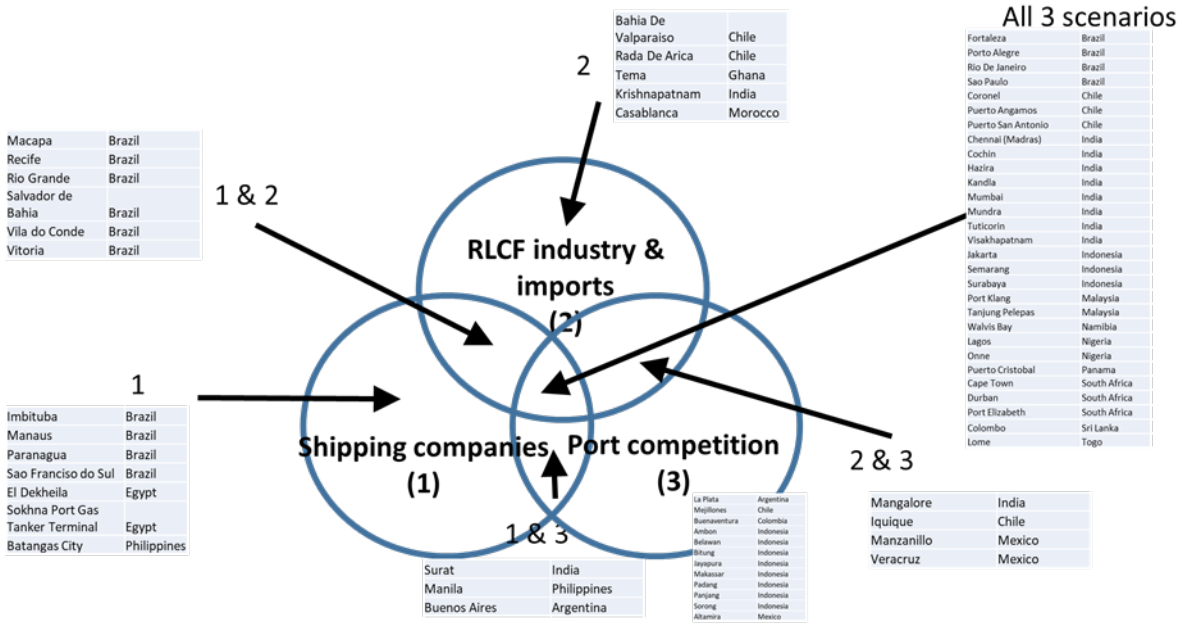
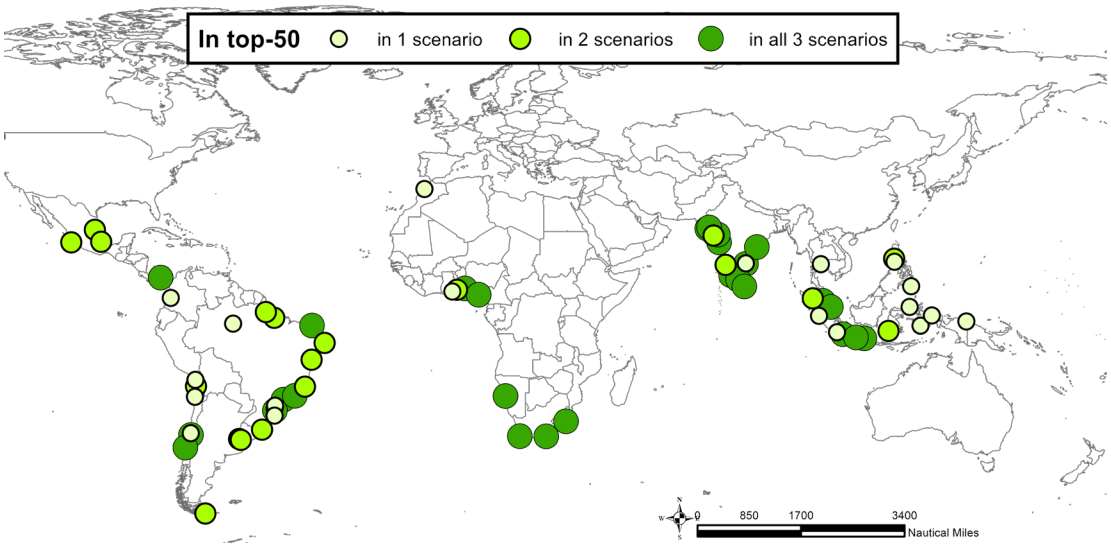
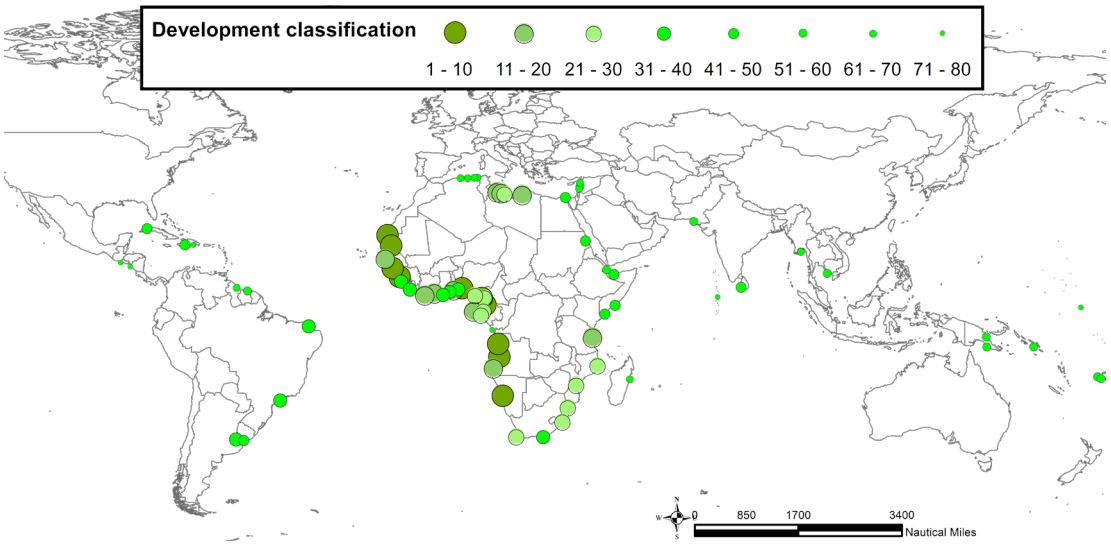


Figure 26: Map of top-50 ports in the three EU industry competitiveness scenarios (provisional)



Source: JRC (2024)

Figure 27: Classification of ports according to the development scenario (provisional)



Source: JRC (2024)

8 Preliminary conclusions

As a general conclusion, the results of this study suggest that the GGGSC initiative has the potential to be a major contributor to reducing greenhouse gas emissions (GHG) from maritime transport, while promoting sustainable development and economic growth in partner countries. The methodology highlights the importance of a multi-dimensional approach, considering various criteria such as environmental impact, availability of sustainable fuels, global development priorities, interdependencies, innovation, and resilience. The analysis of potential corridors and ports identified several regions and countries that could be part of the GGGSC and assessed their potential to contribute to the reduction of GHG emissions, their ability to provide sustainable RLCFs, and their relevance to global development priorities.

The development of GGGSC requires a comprehensive approach that addresses the technical, economic, and social challenges associated with the transition to sustainable RLCF for maritime transport. Further research and development is needed to overcome the technical and economic challenges associated with the use of sustainable RLCF, including the social and economic impacts of the transition to green shipping corridors and the potential impacts on local communities and workers in the maritime sector.

The work presented in this report aimed to provide an evidence base for the design of the Global Gateway Green Shipping Corridors (GGGSC). Eight overarching priorities that can be the basis for the selection of specific corridors are identified, and various approaches and implementation options are discussed. The report explores the major geographic areas within the scope of the GGGSC, and measures the connectivity of ports and countries to the EU, with a focus on Africa, South America, and Asia. The analysis considers the Global Gateway initiative's relevant projects, political stability, and alternative fuel availability in the design of Green Shipping Corridors.

The information provided in the study could contribute to the definition of the overall scope and criteria of the GGGSC. The Global Gateway strategy provides a framework for the EU to support the development of sustainable infrastructure and promote economic growth in partner countries. In order to achieve the goals of the GGGSC, it is essential to involve multiple stakeholders, including governments, private sector companies, and civil society organizations, as well as the development of new policies and regulations that support the transition to sustainable maritime transport. It is also important to identify instruments that monitor and evaluate the progress and the impact of the initiative on greenhouse gas emissions, sustainable development, and economic growth. This will require the collection of data and information from a variety of sources, including governments, private sector companies, and civil society organizations.

The development of the GGGSC is expected to be a gradual process. This study identified the general principles of the design of the GGGSC according to its stated objectives, which include various geographic, economic, technology and geo-political aspects. For the implementation phase, a decision-making system on the choice of specific ports for inclusion in the GGGSC will be set up and will consider the EU policy and political priorities and the willingness of the partner ports and countries to adhere to the GGGSC principles. These ports can be the backbone of an extended network of green shipping corridors in which additional ports with varying levels of commitment and EU support can have a complementary role.

The work presented here has obviously several limitations. While it is based on the most objective and reliable data as possible, the wide scope of the analysis did not permit a detailed exploration at specific port level. At the same time, the estimates on supply and demand for sustainable RLCF are focused on the maritime transport sector, assuming that the balance in the other sectors would

remain the same. Nevertheless, the sustainable RLCF market that the GGGSC can stimulate will interact with the global and local market for specific products, especially hydrogen and ammonia. Both issues should be addressed in the next stages of the definition of the GGGSC, with a more detailed analysis at port level, also covering their role within the global markets for sustainable RLCF.

The data-driven approach followed is based on a snapshot of the situation today. On one hand, this favours ports and countries that currently have a high classification in indicators today and limit the options for those that may become relevant to the GGGSC in the future. On the other hand, ports that are currently small or in development are not represented in most of the data sources available and are –therefore- not included in the composite indicator framework. Such is the case for e.g. the ports of Lobito (Angola) and Lumut (Malaysia), which have been identified as potentially relevant for the Global Gateway based on their development plans, but would be classified very low as a priority using current data. A similar limitation concerns remote and isolated regions such as the Pacific. Even though there may be policy interest in supporting their development, the data available do not justify their inclusion in the analysis.

As a closing remark, it is important to emphasize that the criteria, indicators and provisional results are only a data-driven analysis that serves as an input to the policy process. The actual definition of the GGGSC will consider additional priorities and inputs from a wider range of stakeholders, in consistency with the Team Europe approach.

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List of abbreviations and definitions

Abbreviations	Definitions
AU	African Union
EJ	Exajoule, equal to 23.88 million tonnes of oil equivalent (Mtoe)
EMSA	European Maritime Safety Agency
ETS	Emissions Trading System
IEA	International Energy Agency
IRENA	International Renewable Energy Agency
GGGSC	Global Gateway Green Shipping Corridors
OECS	Organisation of Eastern Caribbean States
RED	Renewable Energy Directive
RLCF	Renewable and Low carbon Fuels
toe	Tons of oil equivalent
TWh	Terawatt hour, equal to 85984.522785899 toe
UNCTAD	United Nations Conference on Trade and Development

List of figures

List of tables

Annex 1: List of ports analysed as potential candidates for the GGGSC

Country	Port	Country	Port	Country	Port	Country	Port
Algeria	Annaba	Brazil	Sepetiba	Chile	Valparaiso	Egypt	El Dekheila
Algeria	Algiers	Brazil	Itapoa	Christmas Island	Flying Fish Cove	Egypt	Port Said
Algeria	Bejaia	Brazil	Itajai	Colombia	San Andres	Egypt	El Sokhna
Algeria	Djen Djen	Brazil	Manaus	Colombia	Barranquilla	El Salvador	Acajutla
Algeria	Ghazaouet	Brazil	Macapa	Colombia	Buenaventura	Equatorial Guinea	Bata
Algeria	Mostaganem	Brazil	Natal	Colombia	Cartagena (CO)	Equatorial Guinea	Malabo
Algeria	Oran	Brazil	Navegantes	Colombia	Leticia	Eritrea	Massawa
Algeria	Skikda	Brazil	Pecem	Colombia	Santa Marta	Fiji	Lautoka
American Samoa	Pago Pago	Brazil	Paranagua	Colombia	Tolu	Fiji	Suva
Angola	Cabinda	Brazil	Rio Grande	Colombia	Turbo	Gabon	Libreville
Angola	Luanda	Brazil	Rio de Janeiro	Comoros	Mutsamudu	Gabon	Port Gentil
Angola	Lobito	Brazil	Sao Luis	Comoros	Moroni	Gambia	Banjul
Angola	Malongo	Brazil	Salvador	Congo	Pointe Noire	Georgia	Batumi
Angola	Namibe	Brazil	Santos	Cook Islands	Aitutaki	Georgia	Poti
Angola	Soyo	Brazil	Suape	Cook Islands	Rarotonga	Ghana	Tema
Antigua and Barb	St John's (AG)	Brazil	Vila do Conde	Costa Rica	Caldera	Ghana	Takoradi
Argentina	Bahia Blanca	Brazil	Vitoria	Costa Rica	Limon	Grenada	St George's
Argentina	Buenos Aires	Brunei Darussalam	Muara	Costa Rica	Moin	Guadeloupe	Gustavia
Argentina	La Plata	Cabo Verde	Mindelo	Cote d'Ivoire	Abidjan	Guadeloupe	Marigot
Argentina	Mar del Plata	Cabo Verde	Palmeira	Cote d'Ivoire	San Pedro (CI)	Guadeloupe	Pointe-a-Pitre
Argentina	Puerto Madryn	Cabo Verde	Porto Praia	Cuba	Mariel	Guam	Apra
Argentina	Puerto Deseado	Cabo Verde	Sal Rei	Cuba	Moa	Guam	Piti
Argentina	Rosario	Cambodia	Sihanoukville	Cuba	Santiago	Guatemala	Puerto Barrios
Argentina	San Antonio Este	Cameroon	Douala	Curacao	Willemstad	Guatemala	Puerto Quetzal
Argentina	Ushuaia	Cameroon	Kribi	Dem. Rep. of the	Banana	Guatemala	Santo Tomas de
Argentina	Zarate	Cayman Islands	George Town	Dem. Rep. of the	Matadi	Guinea	Conakry
Aruba	Barcadera	Chile	Antofagasta	Djibouti	Djibouti	Guinea-Bissau	Bissau
Aruba	Oranjestad	Chile	Arica	Dominica	Roseau	Guyana	Georgetown (GY
Bahamas	Freeport (BS)	Chile	Chacabuco	Dominican Repub	Caucedo	Haiti	Cap Haitien
Bahamas	Nassau	Chile	Coronel	Dominican Repub	Rio Haina	Haiti	Laffiteau
Bangladesh	Chittagong	Chile	Coquimbo	Dominican Repub	Manzanillo (DO)	Haiti	Port-au-Prince
Bangladesh	Mongla	Chile	Iquique	Dominican Repub	Puerto Plata	Honduras	Puerto Castilla
Barbados	Bridgetown	Chile	Lirquen	Ecuador	Guayaquil	Honduras	Puerto Cortes
Belize	Big Creek	Chile	Mejillones	Ecuador	Manta	Honduras	Roatan I
Belize	Belize City	Chile	Puerto Angamos	Ecuador	Puerto Bolivar (E	Honduras	San Lorenzo
Benin	Cotonou	Chile	Puerto Montt	Ecuador	Posorja	India	Mumbai
Bermuda	Hamilton (BM)	Chile	Puerto Natales	Egypt	Adabiya	India	Kolkata (Calcutta
Bonaire	Sint Eustatius an	Chile	Punta Arenas	Egypt	Abu Qir	India	Cochin
Brazil	Fortaleza	Chile	San Antonio (CL	Egypt	Alexandria	India	Ennore
Brazil	Imbituba	Chile	San Vicente	Egypt	Damietta	India	Haldia

Country	Port	Country	Port	Country	Port	Country	Port
India	Hazira	Indonesia	Pekanbaru	Malaysia	Sibu	Myanmar	Rangoon
India	Mangalore	Indonesia	Palembang	Malaysia	Sandakan	Myanmar	Thilawa
India	Kandla	Indonesia	Panjang	Malaysia	Tanjung Pelepas	Namibia	Luderitz
India	Port Blair	Indonesia	Pontianak	Malaysia	Tawau	Namibia	Walvis Bay
India	Krishnapatnam	Indonesia	Pantoloan	Maldives	Addu	New Caledonia	Baie de Prony
India	Kattupalli	Indonesia	Sibolga	Maldives	Koodoo	New Caledonia	Noumea
India	Chennai	Indonesia	Sorong	Maldives	Male	New Caledonia	Prony
India	Mormugao	Indonesia	Semarang	Marshall Islands	Kwajalein	Nicaragua	Corinto
India	Mundra	Indonesia	Samarinda	Marshall Islands	Majuro	Nicaragua	Rama (Arlen Siu
India	New Mangalore	Indonesia	Surabaya	Martinique	Fort de France	Nigeria	Apapa
India	Nhava Sheva	Indonesia	Tolitoli	Mauritania	Nouadhibou	Nigeria	Lekki
India	Pipavav	Indonesia	Timika	Mauritania	Nouakchott	Nigeria	Lagos
India	Paradip	Indonesia	Tarakan	Mauritius	Port Louis	Nigeria	Onne
India	Tuticorin	Indonesia	Ternate	Mauritius	Port Mathurin	Nigeria	Port Harcourt
India	Visakhapatnam	Jamaica	Kingston (JM)	Mayotte	Longoni	Nigeria	Tin Can Island
Indonesia	Ambon	Jamaica	Montego Bay	Mexico	Altamira	Niue	Alofi
Indonesia	Banjarmasin	Jordan	Aqaba	Mexico	Coatzacoalcos	Norfolk Island	Norfolk I
Indonesia	Benete Bay	Kenya	Mombasa	Mexico	Ensenada	Northern Mariana	Saipan Island
Indonesia	Biak	Kiribati	Betio	Mexico	Guaymas	Pakistan	Gwadar
Indonesia	Bitung	Lebanon	Beirut	Mexico	Lazaro Cardenas	Pakistan	Karachi
Indonesia	Bengkulu	Lebanon	Tripoli (LB)	Mexico	Mazatlan	Pakistan	Port Qasim
Indonesia	Belawan	Liberia	Monrovia	Mexico	Puerto Chiapas	Palau	Koror
Indonesia	Balikpapan	Libya	Benghazi	Mexico	Puerto Morelos	Panama	Balboa
Indonesia	Batam Island	Libya	Khoms	Mexico	Progreso	Panama	Coco Solo
Indonesia	Batu Ampar	Libya	Misurata	Mexico	Tampico	Panama	Cristobal
Indonesia	Jayapura	Libya	Tripoli (LY)	Mexico	Tuxpan	Panama	Manzanillo (PA)
Indonesia	Gorontalo	Madagascar	Antsiranana	Mexico	Veracruz	Panama	Colon
Indonesia	Jakarta	Madagascar	Ehoala	Mexico	Manzanillo (MX)	Panama	Almirante
Indonesia	Kendari	Madagascar	Mahajanga	Micronesia (Fede	Kosrae	Panama	Panama
Indonesia	Kupang	Madagascar	Nosy Be	Micronesia (Fede	Pohnpei	Panama	Rodman
Indonesia	Kumai	Madagascar	Toliary	Micronesia (Fede	Truk	Papua New Guine	Buka
Indonesia	Lembar	Madagascar	Toamasina	Micronesia (Fede	Yap	Papua New Guine	Alotau
Indonesia	Luwuk	Malaysia	Kota Kinabalu	Morocco	Agadir	Papua New Guine	Kimbe
Indonesia	Makassar	Malaysia	Bintulu	Morocco	Casablanca	Papua New Guine	Lae
Indonesia	Medan	Malaysia	Kuching	Morocco	Nador	Papua New Guine	Lihir Is
Indonesia	Merauke	Malaysia	Kuantan	Morocco	Tanger Med	Papua New Guine	Madang
Indonesia	Manokwari	Malaysia	Labuan	Mozambique	Beira	Papua New Guine	Motukea Island
Indonesia	Maumere	Malaysia	Penang	Mozambique	Nacala	Papua New Guine	Port Moresby
Indonesia	Padang	Malaysia	Pasir Gudang	Mozambique	Maputo	Papua New Guine	Rabaul
Indonesia	Perawang	Malaysia	Port Klang	Mozambique	Pemba	Papua New Guine	Oro Bay

Country	Port	Country	Port	Country	Port	Country	Port
Papua New Guine	Wewak	Solomon Islands	Noro	Vanuatu	Santo		
Paraguay	Asuncion	Somalia	Berbera	Vanuatu	Port Vila		
Peru	Callao	Somalia	Kismayu	Venezuela (Boliva	Guaranao Bay		
Peru	Ilo	Somalia	Mogadiscio	Venezuela (Boliva	Guanta		
Peru	Iquitos	South Africa	Cape Town	Venezuela (Boliva	La Guaira		
Peru	Matarani	South Africa	Durban	Venezuela (Boliva	Maracaibo		
Peru	Paita	South Africa	East London	Venezuela (Boliva	Puerto Cabello		
Peru	Pisco	South Africa	Port Elizabeth	Venezuela (Boliva	Palua		
Peru	Salaverry	South Africa	Richards Bay	Viet Nam	Chu Lai		
Philippines	Bacolod	South Africa	Coega	Viet Nam	Cai Lan		
Philippines	Batangas	Sri Lanka	Colombo	Viet Nam	Chan May		
Philippines	Cotabato	Sudan	Port Sudan	Viet Nam	Da Nang		
Philippines	Cebu	Suriname	Paramaribo	Viet Nam	Haiphong		
Philippines	Cagayan de Oro	Syrian Arab Repu	Latakia	Viet Nam	Nghi Son		
Philippines	Dumaguete	Syrian Arab Repu	Tartous	Viet Nam	Ho Chi Minh City		
Philippines	Davao	Thailand	Bangkok	Viet Nam	Qui Nhon		
Philippines	Dadiangas	Thailand	Phuket	Viet Nam	Can Tho		
Philippines	Iloilo	Thailand	Laem Chabang	Viet Nam	Vung Tau		
Philippines	Manila	Thailand	Sahathai	Wallis and Futuna	Futuna		
Philippines	Nasipit	Thailand	Songkhla	Yemen	Aden		
Philippines	Ozamiz	Thailand	Sriracha	Yemen	Hodeidah		
Philippines	Polloc	Timor-Leste	Dili	Yemen	Mukalla		
Philippines	Puerto Princesa	Togo	Lome				
Philippines	Roxas	Tonga	Nukualofa				
Philippines	Subic Bay	Tonga	Vavau				
Philippines	Surigao	Trinidad and Tob	Port of Spain				
Philippines	Tagbilaran	Trinidad and Tob	Point Lisas				
Philippines	Mindanao Termi	Tunisia	Bizerta				
Philippines	Zamboanga	Tunisia	Rades				
Saint Helena	Rupert's Bay	Tunisia	Sfax				
Saint Kitts and Ne	Basseterre	Tunisia	Sousse				
Saint Lucia	Port Castries	Tunisia	Tunis				
Saint Vincent and	Campden Park	Turks and Caicos	Grand Turk				
Saint Vincent and	Kingstown	Tuvalu	Port Funafuti				
Samoa	Apia	United Republic c	Dar es Salaam				
Sao Tome and Pr	Sao Tome	United Republic c	Mtwara				
Senegal	Dakar	United Republic c	Zanzibar				
Seychelles	Port Victoria	Uruguay	Montevideo				
Sierra Leone	Freetown	Uruguay	Punta Pereyra				
Solomon Islands	Honiara	Vanuatu	Luganville				

Annex 2: Ports classified as of high relevance for the development criterion

Port	Country
Lobito	Angola
Lagos	Nigeria
Conakry	Guinea
Bata	Equatorial Guinea
Malabo	Equatorial Guinea
Bissau	Guinea-Bissau
Walvis Bay	Namibia
Nouadhibou	Mauritania
Nouakchott	Mauritania
Luanda	Angola
Lome	Togo
Abidjan	Cote D'Ivoire
San Pedro	Cote D'Ivoire
Tripoli	Libya
Namibe	Angola
Dakar	Senegal
Banghazi	Libya
Khoms	Libya
Sao Tome	Sao Tome and Principe
Dar es Salaam	Tanzania
Misurata	Libya
Beira	Mozambique
Nacala	Mozambique
Maputo	Mozambique
Douala	Cameroon
Libreville	Gabon
Port Gentil	Gabon
Cape Town	South Africa
Durban	South Africa
Onne	Nigeria
Freetown	Sierra Leone
Cotonou	Benin
Monrovia	Liberia
Buenos Aires / La Plata	Argentina
Tema	Ghana
Takoradi	Ghana
Port Elizabeth	South Africa
Tangier-Mediterranean	Morocco
Fortaleza	Brazil
Santos	Brazil
Montevideo	Uruguay
Alexandria	Egypt

Port Au Prince	Haiti
Berbera	Somalia
Kismaayo	Somalia
Mogadishu	Somalia
Colombo	Sri Lanka
Port Sudan	Sudan
Mariel	Cuba
Lautoka Harbor	Fiji
Suva Harbor	Fiji
Karachi	Pakistan
Kampong Saom	Cambodia
Tarabulus	Lebanon
Lae	Papua New Guinea
Port Moresby	Papua New Guinea
Honiara	Solomon Islands
Paramaribo	Suriname
Djibouti	Djibouti
Toamasina	Madagascar
Georgetown	Guyana
Beirut	Lebanon
Latakia	Syria
Annaba	Algeria
Alger	Algeria
Bejaia	Algeria
Skikda	Algeria
Rangoon	Myanmar
Thilawa	Myanmar
Pointe Noire	D.R. Congo
Tarawa Atoll	Kiribati
Caucedo	Dominican Republic
Rio Haina	Dominican Republic
Acajutla	El Salvador
Corinto	Nicaragua
Male	Maldives

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