
MAGPIE
SMART GREEN PORTS

Grant Agreement No.	101036594
Start date of Project	1 October 2021
Duration of the Project	60 months
Deliverable Number	D7.1
Deliverable Leader	TNO
Dissemination Level	PU
Status	V1.0
Submission Date	31-03-2022
Author	Bergsma, Jurrit TNO Jurrit.bergsma@tno.nl; van Son, Liam, EUR UPT vanson@ese.eur.nl

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 101036594

Modification Control

Version #	Date	Author	Organisation
V0.1	22-03-2022	Bergsma, J.M., van Son, Liam	TNO, EUR UPT
V0.5	08-03-2022	Bergsma, J.M., van Son, Liam	TNO, EUR UPT
V0.8	16-03-2022	Bergsma, J.M., van Son, Liam	TNO, EUR UPT
V1.0	31-03-2022	Bergsma, J.M., van Son, Liam	TNO, EUR UPT

Release Approval

Name	Role	Date
L.M. van der Lugt	WP Leader	28-03-2022
J. Veira Silva	Peer reviewer	18-03-2022
C. Verciglio	Peer reviewer	28-03-2022
M.B. Flikkema	Scientific Coordinator	31-03-2022
A.J. Polman	Project Coordinator	31-03-2022

History of Changes

Section, page number	Change made	Date
x	x	x

Table of Contents

Executive Summary

The aim of this report is to gather and structure the barriers related to the implementation of zero-emission solutions. A barrier is defined as a factor 'limiting the ability to perform the innovation process, due to the absence or lacking capability of one of the stakeholders, institutions, infrastructure or interactions.' This is done by reviewing academic and industrial literature complemented by port ecosystem stakeholders' interviewees. The resulting barriers will be used to decide which eight non-tech innovations need to be developed to overcome these barriers as part of the MAGPIE project.

The research scope was limited to a subset of 50 academic and industrial literary sources on barriers in innovation processes in the context of sustainability in ports. Furthermore, the sample size of the interviewees was limited to 28, due to time restraints.

The resulting barriers were coupled to road, rail, inland and seagoing transport in the port context:

- Two strong barriers to innovation were identified for **road** transport that hamper the adoption of zero emission trucks in the port context, both of which are ***economic*** in nature. First and foremost, interviewees identified a ***high Total Cost of Ownership of new, relatively untested zero emission trucks.*** Second, interviewees noted ***a lack of demand*** for zero emission trucks. The latter ***economic barrier*** is a culmination of ***infrastructural***, ***knowledge*** and ***regulatory*** barriers that erode confidence in prospective buyers and users of zero emission trucks.
- Barriers identified in the interviews for **rail transport** were predominantly ***economic***, ***infrastructural***, and ***interaction-based***. The key element of innovation barriers could be ground down to ***high capital costs*** that contribute to a high Total Cost of Ownership. The ***purchase of state-of-the-art e-locomotives is prohibitively expensive*** (see ***'Economic'***), thus presenting a serious limitation and investment risk for rail operators.
- For **inland shipping**, barriers were predominantly ***economic***, ***interaction and directionality based.*** On the economics, ***the supply and demand side have difficulty to meet in a mutually sustainable business case*** to develop and operate solutions. On the interaction, the major challenge is the ***complexity to organize, inform and align all stakeholders*** to create informed perspective. However, due to ***a lack of harmonization of policy for inland shipping*** (e.g., NOx regulation in the Netherlands vs EU) the clarity of the direction and expected regulatory boundaries results in uncertainty.
- The innovation barriers identified for **seagoing shipping** were predominantly ***economic and interaction based, where the interaction is closely linked to the process of shaping standards and policy.*** The principal barrier is the lack of ***feasibility of a sustainable business case beyond niche operators***.

Summarizing, the lack of a business case for commercial actors in line with the emission reduction goals is considered critical and affects all stakeholders in the value chain. The main approach indicated is to increase the system level insight, and the capacity or process to enable an authority to act in an accelerated manner in line with the societal urgency. However, all barriers and their stakeholder impact differ significantly dependent on the specific context. So, when looking at the solutions, it is critical to understand the detailed circumstances of the barrier to solve.

1. Introduction

1.1 From WP7 to subtask 7.1.1

The goal of WP7 within the MAGPIE project is to develop and demonstrate non-technological innovations that enable and accelerate the implementation of low or zero-emission technological and logistical solutions. The key results, target audience, channel, and key performance criteria are shown in Table 1. See for full details on the scope of WP7 also Annex 3.

Table 1: Main elements of WP7

Project Title	Target audience	Channel	Project Output	Criteria for success
Non-technological innovations (WP 7)	Truck, train, barge and ship owners, operators, port authorities, IMO, European River Committee regulators, governments, and policy groups.	MAGPIE stakeholder groups, project website, conferences, and peer reviewed publications. .	Developed and tested non-tech innovations, such as incentives, regulations to stimulate green transport	Adoption of non-technological innovations (I.e., incentives, policy, etc) by target audience, for example, European port authorities.

The first task of WP7, Task 7.1 represents problem-analysis and concept creation. This report focuses on the first subtask within Task 7.1, subtask 7.1.1. This subtask defines barriers that innovations in the context of the energy transition face in scaling up from a mid-TRL to commercialization. The target output of this report is to deliver a thoroughly analysed state of affairs leading to a complete set of barriers. The barriers identified in this report are thus the main issues that the non-technological innovations will seek to address. As such, these barriers serve as the guidance and reference points for the non-technological innovations and will be used in preparation for the forthcoming deliverables.

To ensure that the description of the state of affairs remains an accurate reflection of the context, this report will adopt a dynamic approach. That is to say that this report will not be updated, but further reports for the next deliverables will incorporate new developments that may emerge through the dynamic approach, as elaborated below. The final report of D7.1 for the Master Plan will thus incorporate any developments that may have emerged since the completion of this report.

This dynamic approach will consist of bi-monthly informal reviews and consultations of relevant literature on barriers and non-technological measures between Work Package 7 members. The dynamic approach will ensure that future developments concerning barriers will be incorporated into the process of identifying and developing effective non-technological innovations. Such an approach allows for a flexible recalibration of efforts to accommodate new contexts and challenges. In so doing, the results of this report will be continuously evaluated to make certain that the non-technological innovations do indeed target the various barriers of this report sufficiently, and that any additional barriers are addressed if, and wherever, they appear.

Specific activities of 7.1.1 are described in Table 2.

Table 2: Description of main activities in D7.1.1

Activity	Next step	Output
1. Structure	Develop based upon socio-technical transition pathways and Mission Oriented Innovation Systems a context to gather barriers (and where possible) non-technical solutions	Methodological context for structuring and identifying barriers
2. Broad scope, barriers & data acquisition approach	Develop methodology framework for prioritized barriers based upon literature; List literature-based barriers; Develop interview set-up;	Framework for analysis /prioritized set of structured barriers (see Annex 2A).
3. Modality based differentiation	Perform semi-structured interview with MAGPIE partners (potentially external) for completeness of the modality specific barriers	Modality differentiated and prioritized list of barriers; Final report 7.1.1 (EU Deliverable)

2. Methodology

Considering that the goal of the deliverable is to characterize and analyse the innovation barriers, the first step seeks to determine the areas of innovation that merit research. Following consultations with all WP7 members, the research team began with a broad scope that covers innovation systems related to the various modalities active in the port context – shipping, road, and rail. This broad-to-narrow approach supports the exploratory nature of the initial stages of the research and offers a diverse range of avenues and key words to be explored in the following steps.

2.1 Introduction

While innovation processes in transport and ports are widely documented, discussions remain on which non-tech innovations itself are most effective to counteract the barriers described in port research. The aim of this study is to gather and structure the barriers present in academic and industrial literature complemented by port ecosystem stakeholders' interviewees. This in preparation for further analysis in subtask 7.1.2 on the definition of non-technological innovations themselves.

The research scope was limited to a subset of 50 academic and industrial literary sources (see Annex 1A and 1B) on barriers in innovation processes in the context of sustainability in ports. A barrier is defined as a factor 'limiting the ability to perform the innovation process, due to the absence or lacking capability of one of the stakeholders, institutions, infrastructure or interactions. The term is rooted in academic literature on innovation systems, which form key components of large and complex 'socio-technical' transitions like the Energy Transition.[1] An example of such a barrier could be, for instance, the absence of funding to invest in sustainable infrastructure.

Within the literature, the scope is grouped considering different modalities (road, rail, Inland Waterway and maritime). Furthermore, the sample size of the interviewees was limited to 28 due to time constraints. Additional information was only considered as environmental elements (e.g., global politics) when required to understand the port related innovation processes. Other information was excluded.

The approach for the barrier analysis in 7.1.1. is shown in Figure 1. This will be clarified step by step in the following paragraphs.

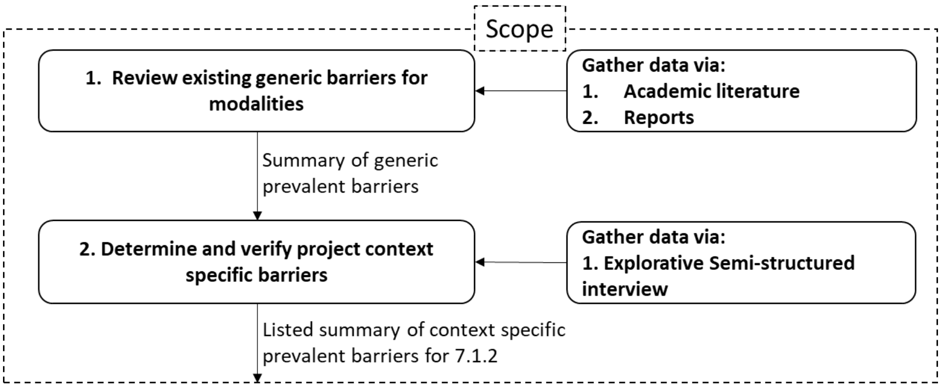

Figure 1: Approach barrier analysis

2.1.1 Step 1: Review existing generic barriers for modalities in literature

Firstly, we apply a systematic review in which we 'bring together as many studies as possible relevant to the research, irrespective of their published location, or even disciplinary background' (Thorpe et al, 2005). A broad search was performed aimed at barriers in relation to the implementation of sustainable solutions in the context of port activities. The keywords used for searching Google Scholar are: Sustainable AND Barrier AND Port, or "Inland Shipping", or IWT, or Maritime, or Trucking, or Rail. In Figure 2, we illustrate the various steps involved to come to literature input.

[1] Hekkert et al. (2020). Mission-oriented innovation systems. *Environmental Innovation and Societal Transitions (34).*; Geels and Schot (2007). Typology of sociotechnical transition pathways. *Research Policy (36),* 399-417.

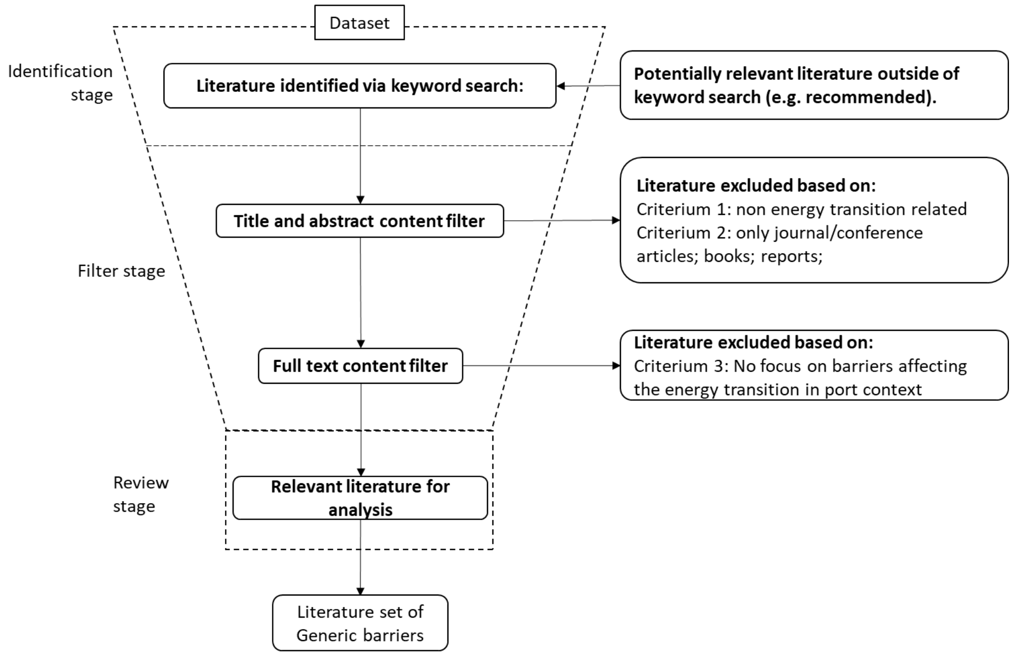

Figure 2: Step 1 literature analysis filter.

Output of the initial keyword search was filtered towards a final subset for analysis. This was done by excluding literature which does not align with the scope based upon the title, abstract and full text as shown in Figure 2. In total, 40 studies were consulted, half of which covered inland and maritime shipping while the other half covered land transport modalities. The port interface was covered by both sets. For academic rigour, the set consisted of 20 peer-reviewed journal articles and 20 reports or industrial studies.

In the review stage, the subset of literature was reviewed for analysis. Barriers mentioned in line with the scope were extracted as quotes and grouped as barriers. For example, see Figure 3, where two exemplary quotes are grouped to the generic barrier "Lack of business case".

Barrier	Quote	Source
Lack of business case	*"Lack of business case will affect policy makers' considerations in EMDE countries considerably."*	Tob-Ogu et al. 2018
	"Business case structure of corporate decision making prioritizes short term profitability"	Notteboom et al 2020

Figure 3: Example of quote extraction from literature sources.

The barriers identified in the literature review are listed in Annex 1A '*Generic Barriers for Shipping and Ports in the Literature*', 1B '*Generic Barriers for Land Transport and Ports in the Literature*', and 2A '*Tally of Generic Barriers Identified in the Literature Review*'. These generic barriers provide a reference for step 2.

2.1.2 Step 2: Determine and verify context specific barriers

To ascertain whether all barriers are covered, and to create sufficient context to understand the practical consequences and relevance of the barriers, a series of semi-structured interviews are to be held. It is important to note that the emphasis of the literature review on certain barriers will be considered throughout the interview process. However, these barriers should not eclipse the explorative nature of the interview process, and thus the interviewers will use caution. This to facilitate discussion of other barriers.

The interviews process was organized and managed in line Article 5 of the GDPR concerning the lawful processing of personal data. The interviews were recorded, and these recordings have been processed with due consideration for lawfulness, fairness, and transparency. The recordings were collected for a specified, explicit and legitimate purpose, as communicated to the prospective interviewees. The recordings will be processed, kept, and protected by the trusted researchers for a predetermined amount of time. No personal data will be shared, made public, or reused for any other purpose than for the specified research. The recordings wll be transcribed and fully anonymized before the analysis commences. Upon their completed transcription and analysis, the recordings will be deleted. These protocols were communicated to the interviewees before recording, and recording did not begin unless explicitly agreed to.

The semi-structured interview is an explorative approach based upon a series of open yet contextualized questions, which provide the possibility for the interviewee to share their insights linked to their daily operations. The interviewees represent all relevant types of stakeholders in the scope of the research, at innovation role varying from executives to leading researchers in their field. The subset of questions can be seen in Table 3.

Table 3: Semi-structured interview questions

Questions
What kind of organization do you represent and what is your role?
What are the goals of your organization towards emission reduction/energy transition?
How are you trying to achieve these goals?
Who are your primary partner organizations in achieving these goals?
Which barriers do you come across in achieving these goals?
Do you think the barrier …. plays a role? (Only if barriers from literature are not mentioned)
Do you have any other additions?

The selection process for the interviewees will prioritise expediency due to the time constraints. As such, the interviewees are to be selected primarily from the MAGPIE consortium, though further suggestions and referrals to relevant external stakeholders will be pursued where possible. The target number of interviews stands at 30, though this will be dependent on the number of responses. In total, 38 interview invitations have been sent via email to entities spanning the land and maritime transport value chains, the vast majority of which are members of the MAGPIE consortium. A breakdown of the interviews follows in Table 4.

Based on the responses, a total of 28 interviews will be conducted, just two interviews short of the target. A deliberate choice is made to cover all 'types' of stakeholders to create a complete as possible insight. To this end, suppliers, end-users, logistical companies, research institutes, etc. will be interviewed. It is worth mentioning that not all of the target stakeholder types are represented in the interviews. Notably, none of the policy makers contacted were available for interview. This leaves a gap in the primary research that must be addressed by complementary desk research and further consultations with policy makers where possible. This gap in the research is addressed in the Recommendations (see Section 5).

Table 4: Stakeholder types of interviews

Stakeholder type	**# Invitations**	**# Responses**
Landside (Road & Rail)	12	11
Shipping (IWT & Seagoing)	12	9
Port Authorities	4	4
Policy makers	5	0
Academia	2	2
Energy [2]	3	2
Total	**38**	**28**

[2] Various parties: Port gas & power strategy representative, R&D Centre, Biofuel retailer/supplier.

The interviews will be recorded via ‘Microsoft Teams’, then transcribed with ‘Amberscript’ (see GDPR concerns above). These transcriptions are then checked by the researchers, and thereafter provided for confirmation by the interviewees. Finally, the resulting transcriptions are analyzed in a similar manner to the literature (Step 1: Review existing generic barriers for modalities in literature), by extracting the quotes which describe the barriers that the stakeholder comes across in the daily operations. This results in a further completion of the listed barriers and, additionally, the use case context in which these barriers can be placed. The different modality is shortly discussed covering the resulting output of the literature and interview analysis.

Note, during the interviews non-tech innovations were occasionally mentioned. These remarks are denoted as recommendations input for 7.1.2.

3. Results

3.1 Introduction

The following section presents and analyses the modality specific barriers identified over the course of the literature scan and the semi-structured interviews.

3.1.1 Scope of the research: Getting to zero

The results of the research are situated in the broader context of various institutional programs striving for zero emission transport, most notably those under the EU Green Deal umbrella and the IMO Strategy. The port ecosystem represents a cluster of emissions-producing activities of which transport and energy production are the most significant polluters. Though most of the transport related emissions occur outside the bounds of ports, ports themselves constitute a key nexus where emission-reduction initiatives can be implemented in coordination with a large variety of stakeholders. [3]

The MAGPIE objective addresses the reduction of the transport related emissions by aiming to facilitate the supply and use of green energy at the port nexus[4] In doing so, the contributions of the MAGPIE project will be in line with several EU policy packages supporting the uptake of renewable and low-carbon fuels in maritime transport,[5] and the deployment of alternative fuels infrastructure for vehicles and vessels.[6] Furthermore, research will seek to contribute to the IMO's ambitions of phasing out emissions in shipping, which recent reports suggest will rise by at least 50 percent by 2050.[7]

As the following research will show, a key concern of the initiatives alluded to above is the economic viability of the technological innovations put forward. In other words, establishing Green Ports as primary nodes in a resource-efficient transport network will ultimately have to include the use of economic instruments to alleviate risk/cost burdens for the various stakeholders.

3.1.2 Structure of results

For a thorough analysis of the results, this section will be structured as follows. First, the barriers to emerge are presented in lists categorized by modality, allowing the barriers to be discussed within a relevant context. Within the modality segmentation, the long list of specific barriers is grouped together by theme, such as 'Economic' or 'Technological' barriers. These groupings constitute *general barriers* (see Table 5) that are common for all modalities. The reasoning behind said categorization is to establish a set of parameters whereby context-specific barriers can be described and adequately grouped across modalities. In essence, this will allow the research to establish the use cases by defining the requirements of each modal system and identifying which interactions within that system inadequately serve the goal of innovation.

[3] Alamoush et al (2021). Port greenhouse gas emission reduction: Port and public authorities' implementation schemes. *Research in Transport Business & Management, x(x),* 2.; International Transport Forum (2018). Reducing Shipping Greenhouse Gas Emissions. *OECD,* 9; International Transport Forum (2014). Shipping Emissions in Ports. *OECD,* 17.

[4] European Commission (2020). Horizon 2020: sMArt Green Ports as Integrated Efficient multimodal hubs. https://cordis.europa.eu/project/id/101036594

[5] Council of the European Union (2021). Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on the use of renewable and low-carbon fuels in maritime transport and amending Directive 2009/16/EC. https://data.consilium.europa.eu/doc/document/ST-13897-2021-INIT/en/pdf

[6] Council of the European Union (2021). Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on the deployment of alternative fuels infrastructure, and repealing Directive 2014/94/EU of the European Parliament and of the Council. https://data.consilium.europa.eu/doc/document/ST-13896-2021-INIT/en/pdf

[7] Baresic, D., Rojon, I., Shaw, A., Rehmatulla, N. (2022) Closing the Gap: An Overview of the Policy Options to Close the Competitiveness Gap and Enable an Equitable Zero-Emission Fuel Transition in Shipping. Prepared by UMAS, January 2022, London.

Table 5: Type of barriers

#	Type	Barrier example
1	Economic	Lack business case
2	Knowledge	Lack of adequate models describing the multimodal dependencies
3	Standards & Regulation	Lack of non-fossil fuel standards
4	Interaction	Lack of trust between stakeholders
5	Directionality	Lack of clear emission reduction goals
6	Technology	Immature technology
7	Infrastructure	Absence of sustainable energy infrastructure

Second, the Discussion subsection (3.3) will further analyse the general and context-specific barriers by situating them in a theoretical framework titled 'Mission-driven Innovation Systems theory' (MIS) (see Table 6). The framework offered by the MIS theory is crucial for holistically evaluating weaknesses in innovation regimes, such as the EU's 'Horizon Europe'. The framework evaluates key innovation processes within the innovation regime in order to adequately design appropriate intervention strategies.[8] Table 6 describes the innovation process elements that provide the basis for the system level, and modality specific discussions.

For clarity's sake, these innovation processes refer to functions that are generally required for an innovation regime to successfully accommodate change. In essence, the analysis done by this framework outlines which functions are inadequate or are simply missing from the system. Therefore, if a given innovation process is overrepresented in the barriers, the function it serves is likely inadequately performed. This suggests that the eventual non-technological solutions address this function and the barriers that have derailed it.

Table 6: Sub-scope description of innovation barriers (based on Mission driven Innovation Systems theory (Wesseling, 2022).

#	Innovation process	Description	Example barriers
1	Directionality (Developing strategy & policy)	Encompasses complexity and quality of interaction between stakeholders to set a joined course	Lacking clear emission reduction policy goal, with sufficient support.
2	Entrepreneurship & Market formation (Developing economic legitimacy)	Encompasses the (societal) and commercial legitimacy for stakeholders to act based on costs, risk, and availability of finance	No investment willingness by technology solution providers to develop new technologies due to sunken cost in LNG.
3	Resource allocation (Acquiring resources)	Mobilization of human, financial and material resources to enable all other system functions.	Lack of sustainable energy sources for e-fuels
4	Knowledge (Development & diffusion of insights)	Encompasses the development and dissemination of knowledge, information and expertise	New training required for ammonia bunkering procedures.

As mentioned in the methodology, the barriers of the different modalities are shortly discussed covering the resulting output of the literature and interview analysis.

3.2 Presentation of results

The barriers that affect implementation of low or zero-emission solutions are clarified below based upon the literature research (see Annex 1A, and 1B), and the interviews (see Annex 2B and 2C for examples). Note, the results are not exhaustive as the context rapidly changes (e.g., geo-political stability).

The modality barrier results are presented and discussed, starting with road, followed by rail, then inland shipping, and lastly seagoing shipping.

[8] Hekkert et al. (2020). Mission-oriented innovation systems. *Environmental Innovation and Societal Transitions (34),* 77.

3.2.1 Road Transport

Road transport refers to freight traffic carried by light and heavy-duty vehicles. In the general port context, this mode serves as the dominant mode of hinterland transport and contributes significantly to congestion issues and emissions in the port and in surrounding urban areas. Heavy duty trucks in particular are responsible for a quarter of CO_2 emissions in the road transport sector, and approximately 6 percent of total EU emissions.[9]

Notable operational and technological innovations addressing the reduction of road transport pollution consist of modal shift initiatives, traffic-spreading initiatives, the phase-out of fossil fuels, and the electrification of the fleet. With a view to relating the information to DEMO 9 'Green Connected Trucking', the focus of the interviews was on the development of a battery-electric heavy-duty trucks and supporting infrastructure. Included in the interviews were Original Equipment Manufacturers (OEM), component manufacturers, terminal operators, and freight forwarders. Each approached the identification of barriers from a unique perspective in the supply chain.

As DEMO 10 'Spreading Road Traffic' had not officially kicked-off at the time of the interviews, the researchers noted less interest among potential interviewees to discuss the topic. However, information concerning innovation barriers in traffic management was accrued both directly in one interview with a representative from the Rotterdam Port Authority, and indirectly in interviews with other parties not specifically tied to DEMO 10.

Table 7: Listed barriers linked to the road transport sector in general (see for more detail Annex 2B).

#	Type (*General Barrier*)	Barrier
1	**Economic**	High Total Cost of Ownership (TCO) of zero emission trucks for consumers
		High investment risk in scaling up to high TRL
		Uncertainty over customer demands (transport companies) as there is currently no 1-size-fits-all solution with current battery technology.
		Market not yet mature, so demand for zero emission trucks is inadequate
		Fierce competition disincentivizes necessary data sharing for road traffic management in and around ports
2	**Knowledge**	Lack of historical technical performance indicators for medium/heavy duty zero emission trucks due to the low technical maturity of the concept
		Customers unaware about current zero emission truck capabilities
		Lack of system level oversight hampers *operational* innovation (i.e., new transport practices and traffic management)
3	**Standards & Regulation**	Lack of supply chain wide CO_2 emission regulation
		Lack of common safety regulations and standards
		Long standardization process
	Standards & Regulation	Lack of regulation and enforcement mechanisms to facilitate data sharing
4	**Interaction between stakeholders**	Complex stakeholder system for developing useable charging infrastructure with sufficient grid capacity
		Lack of integration of traffic management jurisdictions and practices
		Unaligned stakeholder interests and strategic priorities between disparate traffic management entities hampers innovation

[9] Kotowska and Kubowicz (2018). The role of ports in reduction of road transport pollution in port Cities. *Transportation Research Procedia (39)*, 212–220

#	Type (*General Barrier*)	Barrier
		Lack of trust between commercial parties disincentivizes data sharing
5	**Directionality (Cohesive policy direction)**	Slow & inefficient incentive programs kill business case
		Varying quality of incentive programs for OEMs per country
6	**Technology**	Inadequate operational range and long charge times with current generation of zero emission medium/heavy-duty trucks limit long distance transport operation options
7	**Infrastructure**	Lack of grid connection and network capacity for increasing electricity demand
		Lack of batteries and battery-swapping infrastructure
		Insufficient sustainable energy to accommodate the demand from the electricity grid (Scope 2 emissions)
8	**Other**	Lack of human capital (E.g., truck driver shortage and civil servants in traffic management)
		(Un)Known Unknowns: unpredictable barriers will emerge

The interviews clarified the presence of strong barriers that hamper the adoption of zero emission trucks and the development of congestion-reducing innovations in the port context (see Table 7). First and foremost, based on importance conveyed by the interviewees, the interviewees identified the ***economic barriers*** in the form of a ***high Total Cost of Ownership of new, relatively untested zero emission trucks*** and ***a lack of demand,*** partly due to other factors. Factors impacting demand amount to a ***lack of awareness among costumers*** of the current performance of e-trucks for specific transport practices (see ***'Knowledge'***), slow and ***inefficient incentive programs*** for truck manufacturers (see ***'Directionality'***), and inadequate infrastructure – specifically a ***lack of charging ports***, and ***inadequate power network capacity*** to facilitate growing demand (see ***'Infrastructure'***). A final observation from the OEM pointed to a ***lack of emissions regulations directed at transport companies*** (see ***'Standards & Regulation'***), which additionally quells demand among customers of OEMs for the relatively expensive zero emission truck models. Combined, these factors hamstring the scale-up and adoption of battery-electric freight vehicles in the road transport sector.

Barriers in traffic management innovation were **economic, interaction, and regulation-*based***. The issue, which straddles all three general barriers, is primarily that of data sharing. First, the road transport sector's ***fierce competition*** and low margins disincentivize data sharing, due to the competitive advantage that intransparency gives vertical integrators of a given supply chain like freight forwarders (see ***'Economic'***). The lack of economic incentive is currently ***not addressed by regulation*** or enforcement mechanisms that can compel (open) data sharing between parties (see ***'Standards & Regulation'***). This leads to distrust of data sharing between commercial parties (see ***'Interaction'***). However, the ***lack of institutionalized interaction between the entities*** that manage traffic is also a factor that ***causes unaligned strategic priorities*** to the detriment of innovation. To illustrate this further, a mismatch between an entity that prioritizes throughput about all else and another entity that prioritizes safety could lead to conflicting, or even competing, innovation initiatives along the same stretch of road infrastructure.

3.2.2 Rail Transport

Rail transport refers to the carriage of freight over railway. It is already a sustainable mode of freight transport, comparing favourably in CO_2 emissions per freight tonne-kilometre to both barge and road transport.[10] With a modal share of 8.5 percent, rail transport (including passenger transport) disproportionately contributes 1.5 percent of total transport emissions.[11] In fact, freight transport by rail is 77.4 percent less polluting and consumes 43.5 percent less fuel compared to road.[12] For this reason, the modal shift to rail freight operations is viewed as a viable strategy for emissions reduction in the transport sector.

[10] Climate Chance (2018). Greenhouse gas emissions: a decisive asset for rail?. *Climate Chance,* 218.
[11] Ibid., 218
[12] Kumar and Anbanandam (2020). Evaluating the interrelationships among inhibitors to intermodal railroad freight transport in emerging economies: A multistakeholder Perspective. *Transportation Research Part A 134,* 559-581.

In fact, the Sustainable and Smart Mobility Strategy of December 2020 stipulates the ambition to increase rail freight transport traffic by 50 percent by 2030 and to double it by 2050[13].

Rail's efficiency and comparably low emissions are due, in part, to the electrification of much of Europe's rail networks. In the Netherlands, high-traffic freight corridors such as the Betuweroute are more than 85 percent electrified. Despite this, diesel propulsion makes up a significant proportion of rail freight operations, particularly for international transport and port drayage operations. DEMO 8 of the MAGPIE project seeks to electrify the latter. The focus of the interviews was on the development of battery-electric shunting locomotives and supporting charging infrastructure for use in the port context. Several types of stakeholders were approached for interview, including a national railway infrastructure manager, port authority, freight forwarder, and the locomotive owner and operator.

Table 8: Listed barriers linked to rail transport (see for more detail Annex 2B).

#	Type	Barrier
1	**Economic**	Price barrier between fossil fuel and alternative fuel
		High capital costs
		High operational costs
		Unlevel playing field for independent rail transport companies
		Context specific: Small national markets
2	**Knowledge**	Training new workforce for new technological and safety standards
		Lack of verifiable and cohesive emissions data across international rail system
3	**Standards & Regulation**	Strict safety standards limit access and raise costs for new e-shunting locomotives
		Complex homologation process may hamper investment
		Lack of European electrification standard
4	**Interaction**	Power imbalance between public and private stakeholders
		High level of communication between infrastructure provider, manufacturer, and locomotive operator required
		Unaligned interests in (international) traffic management
		Financiers demand unfavourable terms: high interest rates or equity stake
5	**Directionality**	Lack of clear 'green' vision from rail infrastructure managers
		Lack of incentive schemes for green track use
6	**Technology**	Proof of concept required for e-locomotive
7	**Infrastructure**	Lack of, or inadequate, grid connection for e-locomotives in the port
		High capital costs for modernizing rail infrastructure

[13] European Commission (2020). Sustainable and Smart Mobility Strategy – putting European transport on track for the future. https://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A52020DC0789.

The innovation barriers identified in the interviews were predominantly ***economic***, ***infrastructural***, and ***interaction-based*** (see Table 8). The key element of innovation barriers could be ground down to ***high capital costs*** that contribute to a high Total Cost of Ownership. The ***purchase of state-of-the-art e-locomotives is prohibitively expensive*** (see ***'Economic'***), thus presenting a serious limitation and investment risk for rail operators. This limitation is further complicated by the level of risk that financial instruments are prepared to take, ***leading investors to demand unfavourable terms, such as high interest rates or a high equity stake***, that SMEs are not willing to comply to (see ***'Interaction'***). ***Power imbalances between public and private actors*** in the rail sector add to the complexity of interaction. The ***interests of infrastructure managers and users are misaligned***, with examples including a ***lack of an incentive program for low-emission track use***. Furthermore, infrastructural limitations in the port include ***a lack of grid connection and charging ports*** for e-locomotives, which are crucial for electrification in the absence of overlines in, and between, terminals (see ***'Infrastructure'***). ***Concerns over grid capacity*** were echoed as well.

3.2.3 Inland Shipping

Inland shipping covers inland waterborne transport activities. It is considered clean in respect to GHG emissions compared to road due to its energy efficiency based on scale. Inland shipping is seen as a highly important option in the multimodal transport chain. It links the hinterland for dry and liquid bulk and containerized goods. It is often mentioned as a modal shift option to mitigate congestion in rail and road, and to reduce emissions. However, inland shipping is part of ongoing discussions considering other non-GHG emissions like PM, NOx. Therefore, inland shipping companies are actively analysing and pursuing possibilities for implementing emission reduction solutions. It is important to note that inland shipping operations often cross international borders and that the majority of the shipping companies are SMEs.

Within the innovation process, emission reduction goals are set on various policy levels. E.g., national Green Deal for inland, seagoing and ports in the Netherlands, and the EU fit for 55 policies. During the innovation process to meet these goals, all inland shipping stakeholders encounter barriers. These barriers are derived from literature and the various interviewee stakeholders. The focus of the interview was on the role of the interviewee organization and the barriers they came across. The interviewees consisted of inland ports, inland shipping companies, knowledge institutes, energy suppliers, and technology suppliers.

Table 9: Listed barriers linked to inland shipping (see for more detail Annex 2C).

#	Type (*General Barrier*)	Barrier
1	**Economic**	Lack of business case for solution suppliers due to small numbers of inland vessels of the market in comparison to the automotive or maritime shipping market (both in total number of vessels and the number of vessels per market segment).
		Risk of (economic) lock-in with new technology with long term assets
		Short term contract (sport-market) is predominant, causing lack of perspective
		Little investment capacity due to limited funds, especially for small scale operators which constitute a majority of the market.
2	**Knowledge**	Lack of capacity to build expertise for stakeholders in comparison to the complexity of the (technical, operational, regulatory) changes
		Lack of system level insight (e.g., data, decision models) for policy makers
3	**Standards & Regulation**	Standard complexity too high for inland (e.g., due to leaning in seagoing)
4	**Interaction between stakeholders**	Innovation averse mindset
		Short term commercial relationships (spot market)
		Quality of organized interaction and representation (also multimodal)
5	**Directionality**	Inland shipping seen as niche (e.g., embedded in other policy)
		Harmonization of policy on European level (e.g., NOx or emission reduction goals)
6	**Technology**	Too many new (immature) technologies
		Lifecycle of technology (lock in)
7	**Infrastructure**	Uncertainty linked to infrastructure required to support new technology

The innovation barriers identified in the literature and interviews were predominantly ***economic***, ***interaction and directionality based*** (see Table 9)**.** On the economics, ***the supply and demand side have difficulty to meet in a mutually sustainable business case*** to develop and operate solutions.

The supplier market is relatively small (several hundred systems are sold annually in the EU) compared to, for example, trucking. SMEs furthermore have limited funds available for large investments. The relatively short-term focus of inland shipping market based upon a spot market, and the risk of technology lock-in when purchasing, for example, a hydrogen-based system, creates a too significant risk for the SME's.

On the interaction, the major challenge is the ***complexity to organize, inform and align all stakeholders*** to create informed perspective. Many inland shipping companies are too small to be able to handle the technology and regulatory changes, while maintaining daily operations as performed over the past decades. The resulting effect is innovation averse mindset as it's not perceived as a business opportunity, but a forced and sometimes overwhelming change. This is strengthened as mentioned before with the more short-term focus based upon spot-market dynamics. A few of the larger operators are capable to mitigate this, but the overall interaction and sectoral organization is not sufficient.

This increases the importance of directionality for inland shipping. However, due to ***a lack of harmonization of policy for inland shipping*** (e.g., NO_x regulation in the Netherlands vs EU) the clarity of the direction and expected regulatory boundaries results in uncertainty. Efforts are ongoing at an EU level to align this, yet it is still perceived as "bits and bytes, here and there"[14]. The complexity of the interaction in the sector in combination with a lack of data, makes it also complex to create a system level insight. Especially when considering the interaction with the other modalities. This combined with complexity of the standards, the upcoming technologies and infrastructure, and the above create the overarching barrier to shape a sustainable business case.

3.2.4 Seagoing Shipping

Seagoing shipping covers the seagoing waterborne transport activities. Similar to inland shipping, seagoing shipping is considered clean in respect to GHG emissions compared to road and rail due to its energy efficiency based on scale. 90% of all goods are shipped by seagoing waterborne transport, which adds up to roughly 3% of the global GHG emissions[15]. It's seen as essential in the global transport system, with little alternative for the volumes which are transported. The seagoing maritime domain is an ancient global domain with equally longstanding rules, regulations and bodies providing the interaction, such as the International Maritime Organization. As stated by Bergsma et Al: "the global shipping industry is characterized by regulatory compliance. Its global nature has led to fierce competition, inertia, and the rigidity of existing structures (e.g., infrastructure, institutions, interaction)"[16]. It's important to note that seagoing shipping often operates within several layers of regulatory frameworks. The regulatory requirements are affected by the leading influence and type of requirements. For example, the location of the vessel in ports, territorial sea, the exclusive economic zone, or international waters affect regulatory requirements, and the flag state affects the vessels requirement.

Within WP7 of MAGPIE, we consider the innovation process for implementing emission reduction solutions. These are linked to the emission reduction aims which are set on various policy goals which coalesce with the operational area of the ship. E.g., national Green Deal for inland, seagoing and ports in the Netherlands, the EU fit for 55 policies, and the global IMO GHG strategy. During the innovation process to meet these goals, all seagoing shipping stakeholders encounter barriers. These barriers are derived from literature and the various interviewee stakeholders. The focus of the interview was on the role of the interviewee organization and the barriers they came across. The interviewees consisted of ports, marine contractors, shipping companies, knowledge institutes, energy suppliers, and technology suppliers.

Table 10: Listed barriers linked to seagoing shipping (see for more detail Annex 2C).

#	Type (*General Barrier*)	Barrier
1	**Economic**	Uncertainty on emission pricing / energy carrier subsidies
		Risk of (economic) lock-in with new technology with long term assets
		Absence of a level playing field
		Lack of, or uncertain, customer willingness to pay for sustainable innovations
2	**Knowledge**	Lack of capacity to build expertise for actors in comparison to the complexity of the (technical, operational, regulatory) changes
		Lack of system level insight (e.g., data, decision models) for policy makers
		Lack of, or inadequate, non fossil based fuel standards
		Limited (onboard and regulatory) standardization

[14] EICB interview dated 2022-02-14

[15] International Maritime Organization (2020). Reduction of GHG Emissions of Shipping – 4th IMO GHG Study – Final Report. *IMO.*

[16] Bergsma et al (2021). A Literature Evaluation of Systemic Challenges Affecting the European Maritime Energy Transition. *Sustainability (13*),715.

3	**Standards & Regulation**	Lack of integrated and sufficiently flexible standards (e.g., unintended mistakes fit for 55)
		Permit uncertainty
4	**Interaction between stakeholders**	Difficulty to align, externally and internally to the wide variety and scale of stakeholders
		Global political and strategic interests in shipping
		Lacking unity or rallying for leading stakeholder(s)
		Difficulty for small stakeholders to align with major initiatives
5	**Directionality (Cohesive policy direction)**	Potential negative business impact due to unbalanced directives (e.g., fuel directives)
		Harmonization of policy on National, European and where possible global level
6	**Technology**	Too many new (immature) technologies options
		Lifecycle of technology (lock in)
7	**Infrastructure**	Uncertainty about the presence of new infrastructure and impact of stranded assets

The innovation barriers identified in the interviews were predominantly ***economic and interaction based, where the interaction is closely linked to the process of shaping standards and policy*** (see Table 10)**.** The principal barrier is the lack of feasibility of sustainable business case beyond niche operators. There is an uncertainty on mid to long term emission pricing (e.g., carbon taxation or ETS) and sustainable energy carrier subsidies when bunkering. Then the risk of a potentially costly technology lock-in based upon a 'wrong' choice on the energy carrier on ship or even system level adds to the uncertainty. Furthermore, there is an ongoing discussion on the level playing field globally considering state owned and independent enterprises. This makes it complex to determine the cost, which needs to be offset to a willing customer base that appreciates the added value of reduced transport emissions. This customer base is still perceived as niche-markets where sustainability directly adds value. For the majority the uneconomic gap is not yet solved.

Mitigating this requires advanced interaction between all stakeholders which ***lacks an adequate consensus building process for the supportive policies and standards that aligns with the timeframe to act to achieve the policy aims***. This is affected by the complexity of a wide variety and large number of stakeholders involved in these processes. These stakeholders have different backgrounds and interests yet need to speak the 'same language'. The high political and strategic stakes involved add pressure to these processes, where also the level of influence of the various stakeholders (e.g., voting rights and relative weight in at the IMO) is not perse aligned with global interests. A leading (group of) stakeholder(s) can overcome this impasse, on which many efforts are placed in various contexts (e.g., Getting to zero coalition, and fit for 55 EU policy). On the other end of the spectrum, a key risk is observed when policies are not sufficiently balanced or based on insight. Balanced in this context means, considering the full system perspective instead of e.g., mono-fuel policy. In addition, on technical standards more detailed barriers occur. A clear example is ***the quality of standards for non-fossil-based fuels such as bio.*** This strongly affects the uncertainty in deciding the direction for all stakeholders involved, and thereby the legitimacy to act. However, the presence of this barrier is not limited by e.g., expertise or resource, but is considered ***due to the lack of coordination between all actors*** in order to define the standards.

Overall, without the possibility to analyze, track and adjust the standards and policies, a large-scale unintended lock-in could occur with significant system damage. The ***knowledge gap of system level insight*** is therefore a significant barrier, also observed in other modalities. This also affects the capacity to understand which technologies are of interest and of least risk for lock in and the required sustainable energy infrastructure.

3.3 Discussion

To discuss the topic, we describe the innovation process. Though many of the identified barriers constrain innovation in one or more of the relevant modalities, how they do so, and which stakeholders are affected, may differ. To illustrate this, consider that road, rail and shipping all require significant investment in physical infrastructure to facilitate the uptake of innovative technologies, but the type of infrastructure and the responsible stakeholders differ, thus posing unique challenges. Similarly, challenges faced in the design, production, and operationalization of new fixed-assets – like vessels or vehicles – differ per modality despite being widely noted in the literature and interviews.

As such, to further understand the context of the barrier. We discuss the barriers in the context of the innovation process that occurs at a system level, and for the different modalities. This renders a more cohesive picture of how various barriers impact innovation processes in the transport sector. It is important to note that the barriers are often interdependent. Table 11 describes the innovation process elements that provide the basis for the system level, and modality specific discussions.

Table 11: Discussion on the four consequential process steps within Innovation process[17].

#	Innovation process	Description
1	Directionality (Developing strategy & policy)	The directionality given by the policies and analysis under development seem to align with the sustainable goals (see Figure 4), however the timeframe and support towards implementation is currently perceived as non-realistic. This is due *to the lacking agreement between global, European, and national actors on both the type of (economic) instruments, and the timeframe as part of an extremely complex mix of political and strategic interests.*
2	Entrepreneurship & Market formation (Developing economic legitimacy)	To ensure the required entrepreneurial activities to develop and implement sustainable solutions, the actors in the value chain require an overarching and actor specific business case. For niche/first-mover actors, this perspective is already in place to facilitate pilots. However, the scale up phase is dependent on a stable long term financial outlook.
3	Resource allocation (Acquiring resources)	The overall challenge in successfully allocating the right resources, whether financial, material, or human capital-based, to the right places is seen as a secondary barrier, as successful allocation will follow the development of the business case.
4	Knowledge (Development & diffusion of insights)	The knowledge development and dissemination of technical zero-emission solutions is seen as a less critical barrier.

A barrier that is often mentioned as important is the ***lack of a business case for commercial actors in line with the emission reduction goals.*** To clarify, this barrier is seen as the sum of most, if not all barriers. The societally driven energy transition requires economic instruments *(standards & regulation, policy)* to align the societal needs with the commercial interests. However, the insufficient or lacking sustainable economic instruments limit the feasibility of the scale-up phase for non-first movers. This topic is widely accepted as the most critical to address, however comprises of all barriers such as: ***fierce global competition; lacking capacity of actors to shape policy; due to inertia resulting from globally required alignment; lacking policy for long term emission pricing by (governmental) authorities aligned with the investment timeframe of actors; insurance for mitigating 'hindsight wrong technology' choices for end-users; visibility of sustainability of products combined with the willingness and capacity of customer to act;*** *etc. (see also Annex 1A and 1B).* All barriers affect either indirectly by increasing the uncertainty, or by directly affecting the business case.

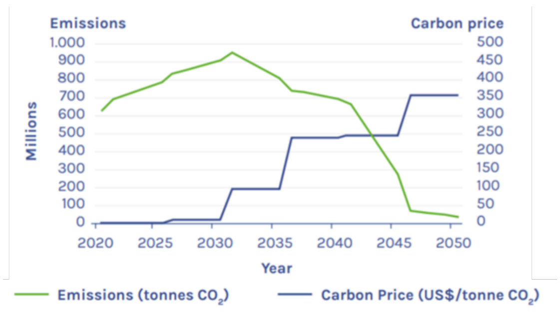

Figure 4: Carbon price trajectory for deep sea shipping (Global Maritime Forum, 2022)

In conclusion, the lack of a business case for commercial actors in line with the emission reduction goals is considered critical and affects all stakeholders in the value chain. The main approach indicated is to increase the system level insight, and the capacity or process to enable an authority to act in an accelerated manner in line with the societal urgency. However, all barriers and their impact on stakeholders differ significantly dependent on the specific context. So, when looking at the solutions, it is critical to understand the detailed circumstances of the barrier to solve.

[17] Adjusted from "Developing and applying the Mission-oriented Innovation Systems (MIS) approach' by (Wesseling et al, 2022)

4. Conclusion

The aim of this study is to present and discuss innovation barriers as experienced by stakeholders in the transport sector in port contexts. As such, this report forms the problem-analysis phase, which seeks to define barriers that hamper the implementation and scaling up of new technologies driving the energy transition. In the context of this report, barriers are defined as factors 'limiting the ability to perform the innovation process, due to the absence or lacking capability of one of the stakeholders, institutions, infrastructure or interactions. The report thus establishes an important foundation for the eventual identification and development of a set of non-technological innovations that can enable and accelerate the implementation of low or zero-emission technological and logistical solutions.

The research followed an exploratory approach based on an initial literature review, which sought to identify a broad array of potential issues and inadequacies in the innovation processes related to the port context. Having set a broad focus, the literature review was followed by a series of 28 interviews. These interviews were designed to ascertain and establish specific, context-bound barriers by order of modality. The primary data that the interviews produced should be regarded as expert insights covering various aspects of the different transport value chains.

Based upon the research, the following key barriers have been identified and analysed with a view to determining which areas of the innovation process require potential intervention. In brief, the main barriers as experienced in the **road transport sector** were economic in nature. Of particular concern was the ***high total cost of ownership of the new, relatively untested zero emission trucks***, and thus a resulting lack of demand. Other knowledge-based and infrastructural barriers merit mention. A given ***lack of historical performance data***, ***lack of awareness among customers*** about available battery-electric trucks, and a lack of charging ports all affect demand for zero emission trucks. In addition, the existence of ***incentive programs for OEMs is constrained by inefficiencies***, which hamper both R&D and the scale-up of production.

The main barriers affecting innovation in the **rail sector** are equally economic. ***High capital costs affect rail infrastructure managers and rail operators alike***. For SMEs the purchase of state-of-the-art e-locomotives is prohibitively expensive without significant co-investment. Furthermore, ***interaction between public and private players is marked by a significant power imbalance*** that leads to a lack of clear avenues for emission reduction initiatives, as concerns between lobby groups and public entities are inadequately addressed. This leads to a ***lack of incentive schemes for green track use***. A final barrier, though less pronounced than with other modalities, is the ***availability of charging ports and adequate grid capacity*** for e-locomotives performing shunting and drayage operations in the port.

Inland shipping predominantly faces barriers related economics, interaction, and 'directionality,' whereby directionality refers to the cohesiveness of the strategic direction among the relevant stakeholders. On the economics, ***the supply and demand side have difficulty to meet in a mutually sustainable business case*** to develop and implement sustainable solutions. On the interaction, the major challenge is the ***complexity to organize, inform and align all stakeholders*** to create informed perspective, largely due to the overrepresentation of SMEs in the domain. Additionally, ***a lack of harmonization of policy for inland shipping*** (e.g., NOx regulation in the Netherlands vs EU) limits the strategic direction perspective.

The innovation barriers identified for **seagoing shipping** were predominantly ***economic and interaction based, where the interaction is closely linked to the process of shaping standards and policy.*** The principal barrier is the lack of feasibility of sustainable business case beyond niche operators. This is for example closely linked to the uncertainty on mid to long term policy on emission pricing (e.g., carbon taxation or ETS) and sustainable energy carrier subsidies when bunkering.

In summary, the most prominent set of barriers for each of the modalities is economic. The research suggests that the lack of a business case for commercial actors in line with the emission reduction goals is critical and affects all stakeholders in the value chain.

By comparing and analysing the contextualized barriers by modality, the research was able situate these barriers within a relevant innovation process. In doing so, the report puts forth key aspects of the innovation process that require feasible intervention. The targeted innovation processes are listed as follows:

1) The development of strategy and policy
2) The development of economic legitimacy

The main approach indicated is to increase the system level insight, and the capacity or process to enable an authority to act in an accelerated manner in line with the societal urgency. Looking towards the next deliverable, the non-technological innovations should primarily address these processes. However, sufficient focus on the specific context barrier via stakeholder consultation is considered invaluable.

5. Recommendations

This report puts forward three key recommendations both for a further analysis of relevant innovation barriers and for setting foundations in preparation for the next deliverables.

Firstly, the report recommends the development of a quantifiable scale of importance to classify, categorize, and prioritize the identified innovation barriers. Such a quantifiable scale of importance could further establish the attributions of importance indicated in the research above. This is a critical parameter when deciding which non-tech solutions will be addressed throughout WP7 of MAGPIE. Said prioritization could be conducted by way of a Best-Worst Method analysis, which allows for the relative scoring of the barriers to determine their perceived importance. In this method, a set of stakeholders from the various modality supply chains are asked to complete a 'questionnaire' to determine the weight of a given innovation barrier in their daily operations or strategy.

Secondly, further desk research and consultations are advised to fill research gaps identified in subsection 2.1.2. Specifically, this report recommends contacting members of the policy making community for insights into innovation barriers and potential solutions as they arise in the governance of the energy transition.

Thirdly, it is recommended to analyse the validity and set-up of the following non-technological solutions (see Table 12). The table below presents a non-exhaustive list of non-technological innovations mentioned by the interviewees in the interview process. This list is by no means a thorough set of solutions, but merely a first glance at prospective avenues that might warrant further research. Some of the solutions listed are less specific than others or seem broader in scope, but are nonetheless included to reflect some of the innovation pathways currently being discussed by the respective industries represented by the interviewees.

Table 12: non-tech solutions mentioned by interviewees for analysis in 7.1.2

Modality	Solution
General	Digital twin of complete value chain
	Tooling for consensus building in prioritizing issues for complex stakeholders
	Increase efficiency through logistical optimization
	Sustainable fuel stock exchange
Road	Emission regulation for transport companies to stimulate demand
	Recalibrate driving routes for drivers, segmenting long distance routes by 2 or more legs.
	Stronger marketing of current e-truck generation for specific short distance economic operation
Rail	Discounts for green track use
Inland	Green Labels for inland shipping
	Service based investment solutions
	Market consolidation
	Validity KPI whether the collaboration supports the required processes
Seagoing	Development of Green Corridors

Annex 1A: Generic Barriers for Shipping and Ports in the Literature

Barrier	Context	Reference(s)									
Lacking capabilities of key actors	Port innovation research	Arduino, et al.,									
Missing business case, due to lack of market formation	Limitations in realizing the Dutch Green Deal towards sustainable shipping	Wesseling, et al, 2021									
Missing business case, due to lack of solution directionality	Limitations in realizing the Dutch Green Deal towards sustainable shipping	Wesseling, et al, 2021									
Presence of many unaligned actors	Various	Shell International	de Langen, 2002	Dewan, et al., 2018	European Commission,	Hekkenberg, et al., 2007	Pallis, 2007	Viederyte, 2013	Hyvättinen & Hildén, 2004)	Arduino, et al., 2013	Chintoan-Uta & Ramos Silva,
Limited capabilities towards regulation formulation	Various	Dewan, et al., 2018	Parker, 2003	Roe, 2013	Makkonen, 2017	Wiegmans, 2010	Wijnolst, 2008	Karahalios, 2017	Topali, 2019		
Presence of traditional cultural norms	Various	Jenssen & Randoy, 2006	Arduino, et al., 2013	Makkonen, et al., 2013	Blanco, et al., 2010	EC, 2010	Jenssen, 2002				
Insufficient lobbying power	Various	Pallis, 2007;	Hyvättinen & Hildén, 2004)								
Insufficient public awareness & negative perception of the sector	Various	Shell International B.V., 2020	Wijnolst & Wergeland, 200	Salvador, 2014	Waterborne, 2020)	European Commission, 2010					
Absence of a business case	Various	Psarros & Mestl, 2015	Shell International B.V., 2020	Wijnolst & Wergeland, 2008	Dewan, et al., 2018						
Absence of a level playing field	Various	Wijnolst & Wergeland, 2008	European Commission, 2010	de Langen, 2002	U.S. Congress, 2006	Kalouptsidi, 2018					
Limited regulatory drivers	Various	DNV-GL, 2020	Arduino, et al., 2013	Psarros, 2015	Hyvättinen & Hildén, 2004						
Limited availability of risk-reducing funds	Various	Psarros & Mestl, 2015	Arduino, et al., 2013	European Commission,	Dewan, et al., 2018		Waterborne, 2020;	Poseidon Principles, 2019)			
Fierce global competition	Various	(Psarros & Mestl, 2015	Shell International B.V., 2020;	Arduino, et al., 2013;		Solesvik, 2018)	de Langen, 200				
Presence and quality of resource providing actors	Various	(de Langen, 2002	; Wijnolst & Wergeland, 2008;	Arduino, et al., 2013;	Dewan, et al., 2018	; Doloreux, 2017)					
Limited (onboard and regulatory) standardization	Various	Hengst, 1999;	Hoppe, 2005)	Psarros, 2015	Notteboom & Rodrigue, 2008)						
Limited availability of educated staff	Various	(Dewan, et al., 2018;	Cogliolo, 2015)	European Commission,	; Wijnolst & Wergeland,						
Lacking physical infrastructure	Various		Waterborne, 2020;	Shell International	DNV-GL, 2020;	Lloyd's Register | UMAS, 2017)	(Psarros & Mestl, 2015				
Quality of interaction with resource providers	Various	(Wijnolst & Wergeland,	de Langen, 2002	Benito, et al., 2003)	Shell International						
Presence and quality of (maritime) knowledge organizations	Various	(Benito, et al., 2003;	Cogliolo, 2015)	Waterborne, 2020;							
Heterogeneity of the relevant actors	Various	(de Langen, 2002;	Blanco, et al., 2010;	Benito, et al., 2003;	Blonk, 2015;	Wijnolst & Wergeland,	Pagoropoulos, 2016				
Insufficient embedding of knowledge	Various	(Dewan, et al., 2018;	van Bruinessen, 2014)	(Wijnolst & Wergeland, 2008;	Jenssen, 2002						
Knowledge infrastructure irrespective of economic trends	Various	(Psarros & Mestl, 2015;	Arduino, et al., 2013;	Dewan, et al., 2018)	European Commission,						
Complexity of knowledge development	Various	(Psarros & Mestl, 2015;	Wijnolst & Wergeland, 2008;	Hengst, 1999;	Bruinessen, 2014						
Limited (cross-)sectoral interaction	Various	(de Langen, 2002;	(Arduino, et al., 2013;	Monteiro, et al., 2013)	(Shell International	(Jenssen & Randoy, 2006)	Chen, 2016	Monteiro, 2013			

Annex 1B: Generic Barriers for Land Transport in the Literature

Barrier	Context	References											
Heterogeneity of actors	Various	Tob-Ogu et al. 2018	Gonzalez-Aregall et al 2021	Bergvist and Egels-Zanden 2012	Gonzalez-Aregall et al 2018	Lange et al 2017	TNO & Buck Consultants International (Topsector Logistiek) 2017						
Quality of interaction and coordination between actors	Various	Tob-Ogu et al. 2018	Bergvist and Egels-Zanden 2012	Colicchia et al 2017	Notteboom et al 2020	FREVEU 2017c							
Current knowledge gaps (in strategic implementation of innovations)	Various	Tob-Ogu et al. 2018	Gozalez-Aregall et al 2018	Lam and Gu 2013	Colicchia et al 2017	Bask and Rajahonka 2017	Chen et al 2019	Lange et al 2017					
Lack of, or poor quality of, physical infrastructure (including EFV production and catalogue range)	mobilization of resources, creating demand/legitimacy	Tob-Ogu et al. 2018	Gonzalez-Aregall et al 2021	Dai and Yang 2020	Colicchia et al 2017	Klumpp 2016	FREVEU 2017a	FREVEU 2017b	FREVEU 2017c	Transport & Environment 2020	Transport & Environment 2021	ZEV Transition Council 2021b	Bucks Consultants International (Topsector Logistiek) 2016
Complexity of knowlegde creation/development	Developing and disseminating knowledge, designing policy	Tob-Ogu et al. 2018	Gozalez-Aregall et al 2018	TNO & Buck Consultants International (Topsector Logistiek) 2017									
Lack of interaction between sectors and geographical areas	Developing and disseminating knowledge	Tob-Ogu et al. 2018											
Lack of business case	various	Tob-Ogu et al. 2018	Bergvist and Egels-Zanden 2012	Notteboom et al 2020	Kl [Son, Liam van(TNOPartners): "business Case" structure of coroporate decisionmaking prioritizes short term profitability -]	FREVEU 2017a	FREVEU 2017b	FREVEU 2017c	Transport & Environment 2020	Transport & Environment 2021	ZEV Transition Council 2021a	TNO & Buck Consultants International (Topsector Logistiek) 2017	Bucks Consultants International (Topsector Logistiek) 2016
Lack of regulatory/legislative driver	Various	Gonzalez-Aregall et al 2021	Gonzalez-Aregall et al 2018	Colicchia et al 2017	Notteboom et al 2020	Klumpp 2016	FREVEU 2017a	FREVEU 2017b	Transport & Environment 2020	Transport & Environment 2021	ZEV Transition Council 2021a	ZEV Transition Council 2021b	
presence of complex, inhibitive, or overcomplicated legislation/regulation/administration	Creating legitimacy	Alamoush et al 2022 (IN PRESS)	Bucks Consultants International (Topsector Logistiek) 2016										
Lack of information and data (e.g. emissions data, performance indicators of tech)	Various	Alamoush et al 2022 (IN PRESS)	Gonzalez-Aregall et al 2018	FREVEU 2017b	TNO & Buck Consultants International (Topsector Logistiek) 2017								
Uncertainty of future demand for service, product, or technology	Various (designing policy, and creating legitimacy)	Dai and Yang 2020	Colicchia et al 2017	Notteboom et al 2020	Klumpp 2016	FREVEU 2017a	ZEV Transition Council 2021b	Bucks Consultants International (Topsector Logistiek) 2016					
System lock-in/path dependency	Changing practices	Bergvist and Egels-Zanden 2012	Klumpp 2016										
Lack of information sharing within sector	developing strategy	Gonzalez Aregal et al 2018											
Lack of standardization of technology and infrastructure	developing strategy	Gonzalez Aregal et al 2018	FREVEU 2017b	Lange et al 2017	Bucks Consultants International (Topsector Logistiek) 2016								
Lack of reliability/flexibility of service (poor value proposition)	Creating legitimacy	Gonzalez Aregal et al 2018	Colicchia et al 2017										
Perceived urgency of emissions reduction	Designing policy, developing strategy	Gonzalez Aregal et al 2018											
Insufficient stakeholder participation	designing policy, developing strategy	Gonzalez Aregal et al 2018	FREVEU 2017b										
Fierce competition	creating legitimacy	Bergvist and Egels-Zanden 2012	Colicchia et al 2017										
Non suitability of product or service for modal shift	mobilizing resources. actor problem: asset incompatibility	Colicchia et al 2017											
presence of culture/mindset	various	Colicchia et al 2017	Notteboom et al 2020	Bask and Rajahonka 2017	TNO & Buck Consultants International (Topsector Logistiek) 2017								
Negative perceptions in sector	creating legitimacy	Colicchia et al 2017											
Limited availability of financial infrastructure or risk-reducing funds	Various	colicchia et al 2017	FREVEU 2017a	FREVEU 2017b	FREVEU 2017c	Transport & Environment 2020	Transport & Environment 2021	ZEV Transition Council 2021a					
Incapability of government to form effective policy	Designing policy, developin	Klumpp 2016											
Lack of public awareness	Dissemination	FREVEU 2017b	FREVEU 2017c	ZEV Transition Council 2021a									

Annex 2A: Tally of Generic Barriers Identified in the Literature Review

Land Transport				**Shipping**		
#	**Barrier name**	**Tally**		#	**Barrier name**	**Tally**
1	Lack of, or poor quality of, physical infrastructure (including EFV production and catalogue range)	**12**		1	Presence of many unaligned actors	**10**
2	Lack of business case	**12**		2	Limited capabilities towards regulation formulation	**8**
3	Lack of regulatory/legislative driver	**11**		3	Limited (cross-)sectoral interaction	**7**
4	Current knowledge gaps (in strategic implementation of innovations)	**7**		4	Presence of traditional cultural norms	**6**
5	Uncertainty of future demand for service, product, or technology	**7**		5	Limited availability of risk-reducing funds	**6**
6	Limited availability of financial infrastructure or risk-reducing funds	**7**		6	Heterogeneity of the relevant actors	**6**
7	Heterogeneneity of actors	**6**		7	Insufficient public awareness & negative perception of the sector	**5**
8	Quality of interaction and coordination between actors	**5**		8	Absence of a level playing field	**5**
9	Lack of information and data (e.g. emissions data, performance indicators of tech)	**4**		9	Fierce global competition	**5**
10	Lack of standardization of technology and infrastructure	**4**		10	Presence and quality of resource providing actors	**5**
11	presence of culture/mindset	**4**		11	Lacking physical infrastructure	**5**
12	Complexity of knowlegde creation/development	**3**		12	Absence of a business case	**4**
13	Lack of public awareness	**3**		13	Limited regulatory drivers	**4**
14	presence of complex, inhibitive, or overcomplicated legislation/regulation/administration	**2**		14	Limited (onboard and regulatory) standardization	**4**
15	System lock-in/path dependency	**2**		15	Limited availability of educated staff	**4**
16	Lack of reliability/flexibility of service (poor value proposition)	**2**		16	Quality of interaction with resource providers	**4**
17	Insufficient stakeholder participation	**2**		17	Insufficient embedding of knowledge	**4**
18	Fierce competition	**2**		18	Knowledge infrastructure irrespective of economic trends	**4**
19	Lack of interaction between sectors and geographical areas	**1**		19	Complexity of knowledge development	**4**
20	Lack of information sharing within sector	**1**		20	Presence and quality of (maritime) knowledge organizations	**3**
21	Perceived urgency of emissions reduction	**1**		21	Insufficient lobbying power	**2**
22	Non suitability of product or service for modal shift	**1**		22	Lacking capabilities of key actors	**1**
23	Negative perceptions in sector	**1**		23	Missing business case, due to lack of market formation	**1**
24	Incapability of government to form effective policy	**1**		24	Missing business case, due to lack of solution directionality	**1**

Annex 2B: Interview results (example general/land)

		Interview						
		General			Land			
					Rail		Road	
	Actor type=>	Knowledge institute	Knowledge institute	Energy Supplier (biofuels)	Rail SME	Rail#2	Road#1	Road#2
Type	**Sub type barrier↓**	**Interview 1 (TNO)**	**Interview 6 (RSM)**	**Interview 2 (goodfuels)**	**Interview 3 (RIG)**	**ProRail (rail Infra manager)**	**DAF (OEM)**	**VDL (Machine components/charging ports)**
Economic (Lack of business case)		Sustainability via less transport creates a perceived risk of business reduction in logistics	Lack or complexity of business case in supplying data	price barrier alt fuels + (onboard) infra	price barrier fossil fuel	High capital costs	Cost gap zero emission vehicles and fossil fuel	high investment risk scaling up to high TRL
	Lack of finance			not enough grants/PPP	high capex, no proof of concept = high interest rates or equity stake	low profit margins for goods traffic	TCO impacted by long charging time	
	Lack of effective incentive schemes	Uncertainty about the willingness of goverment to guarantee/mitigate financial risk for 10-20 years.		no accountability for int'l emissions	no discount on track use for green locs	Dutch market quite small	Uncertainty over customer demands as there is currently no 1-size fits all solution	
	No level playing field	Multimodal competition based on emission performance			competition with public companies			
Knowledge (Lack of system level insight)	**Lack of system level oversight**	Lack of insight in rebound effects		no global intergration of carbon market			No operational innovation among customers (transporters) because of lack of system level view. Customers seek 1-1 replacement of diesel truck with E-truck with same capabilities, rather than changing their transport operations	
	lack of knowledge/expertise	Lack of insight or focus on system level resulting in local optimum from knowledge perspective		consumers uncertain which to alt fuel to pay for and how to structure business	finding/training new workforce		customers unaware about current e-truck capabilities	
	lack of data				no emissions data		lack of historical performance indicators	
Standards & Regulation (Lack of adequate standards)	**Lack of adequate standards**		Lacking technical standards for sharing data	ISO standards. Measuring standards	strict safety standards = higher costs less access	lack of European safety system	CO2 targets not supplychain-wide, which prevents maturation of market	lack of common safety regulations and standards
						lack of pan-european electrification standard		standardization could take a long time
						complex homologation process may hamper investment		
Interaction (Lack of trust and aligned interests)	**Lack of interaction**	Lack of willingness to share data	Lacking cultural mindset to share data (trust)	no stakeholder engagement for standards	power imbalance between public-private players	issues cultivating the will to make (very) expensive infrastructural changes		Public opinion impedes renewable energy supply
		Lack of insight or focus on system level resulting in local optimum from cultural perspective				communication between infra provider, manufacturer and loc operator is crucial		
	Perception problems			Hesitancy and lack of urgency		unaligned interests in traffic management		
Directionality (Lack of unambigious and supported policy)	**Lobbying prohibitive**	Lack of impact based choices	Asymmetry in interests of public (reduce emissions) and commercial actors (increase gain)	Lobbying leads to tech lock-in			Slow & inefficient incentive programs kills business	
		Single companies cannot handle the complexity					varying quality of incentive programs per country	
Technology (only inland shipping issue)		Uncertainty about dominant technological solution for inland shipping				low TRL e-loc	Current battery performance requires significant operational change	
		Limited scale of inland shipping limits technology development and adoption						
Infrastructure (Lack of available sustainable energy)	**Lack of physical infra**	Lack of electric charging infrastructure for road transport			no overlines or charging stations	Aging fleet of diesel locs	lack of grid connection and grid capacity	inadequate energy storage and transport capacity
		Lack of available sustainable energy				lack of European safety system	availability of green energy	
	Lack of sustainable energy					expensive to change/modernize rail infrastructure	Lack of batteries and swapping infra	
						grid capacity		
						inflexibility of rail in logistics and planning		

Annex 2C: Interview results (example shipping)

	Shipping			
	Maritime		Inland	
	Port	Maritime#2	Knowledge Institute	
Type	Interview 4 (PoR - Mollema)	Linked to other interviews	Interview 5 (EICB)	ZES
Economic (Lack of business case)	Sufficient, yet not complete certainty for investing actors		Lack of business case for suppliers due to small numbers	Chartering vessels for testing is highly uneconomical
	Lack of business case due to regulatory uncertainty	Uncertainty on emission pricing	Risk of lock-in with new technology	Cost gap prototype
	Potential negative business impact due to unbalanced directives (e.g. fuel directives)		Short term contract	high capital costs
				high competition with FF valuechain
Knowledge (Lack of system level insight)				lack of expertise on hydrogen
	Lack of expertise and appropriate proces with governing bodies			
Standards & Regulation (Lack of adequate standards)	Lack of integrated and sufficiently flexible standards		Standard complexity too high for inland (on all technical and operational aspects)	Lack of hydrogen safety standards
	Risk of creating unintended mistakes fit for 55			
	Handling safety issues in operation of new technologies in port context			
	Permit uncertainty			
Interaction (Lack of trust and aligned interests)	Difficulty to align, externally and internally		Innovation averse mindset	Trust of captain and ship owner
			Short term relationships	
			Level of interaction vs. required level of interaction	
Directionality (Lack of unambigious and supported policy)			Inland shipping seen as niche and trial area	
	Difficulty for small stakeholders to align with major initiatives		Harmonization on European level also on type of modality	
Technology (only inland shipping issue)			Too many new (immature) technologies	TRL of connection box for versatile electrical drive
			Lifecycle of technology	Tech specifications of pressurized hydrogen
				(Un)known unknowns with regard to tech hurdles
Infrastructure (Lack of available sustainable energy)	Uncertainty about the occurance and impact of stranded assets			chicken and egg problem charging/loading infrastructure
				lack of renewable energy mix

Annex 3: WP7 project description

WP Number	7			Lead Beneficiaty:		EUR				
Work Package Title	**Non-technological Innovations**									
Participant number	1	2	3	4	5	6	7	8	9	17	40
Short name of participant	POR	HAROPA	DTP	APS	TNO	EUR	TUD	INESC	EDP	EWI	GFLS
PMs per participant	20	2	3	8,5	17	44	40	8,7	8,5	15,1	8,5
Start Month	**1**					**End Month**	**54**				

Objectives

WP7 will develop and assess the necessary non-technological conditions for enabling and accelerating the implementation of low or zero-emission technological, digital, and logistical solutions, which to a large extent will be the ones that are developed (as demos) within the MAGPIE project. Non-technological innovations should go hand in hand with the set of technological and logistical solutions needed to accelerate the transition of the whole value chain towards zero-emission. The introduction and scaling-up of new forms of energy, smart data-driven energy saving solutions and modal shift in most cases bring issues like initial investment risks, initial price/cost gaps between existing and new solutions, competition risks and trust-related behavioural issues. To overcome this and to get all the actors aligned, committed, and actively involved, asks for setting the right conditions, i.e., the introduction of new market mechanisms, new financial arrangements, new organizational structures and/or new regulatory and legislative frameworks. Implementing such innovations must support first movers but should also facilitate general use leading towards the desired upscaling of the necessary innovations in the market. The target output of this task will be a set of detailed, designed and evaluated scalable non-technological innovations generating the highest impact in the context of this projects' Roadmap and Master Plan that led to a transition towards Green Ports.

Description of work

In this WP we go beyond identification and description of non-tech measures by taking a selected set of most impacting and most promising non-tech innovations to a high level of 'readiness for implementation'. Taking a value chain perspective and actively involving chain partners in the development and the impact assessments are key in realising this goal. This WP will strongly integrate with WP3 and WP4 and with the demo-work in the other work packages. Setting the level for implementation, whether it will be port level or rather national or EU level and the confrontation of the identified promising innovations with existing frameworks will be guiding the concrete approach. Innovations/measures can be aimed for local, national or EU, even global level, depending on its nature. Measures that should be taken at national or EU level will require a slightly different approach, as local development and testing may not be effective. Here, in-depth assessment and simulations will be applied together with a confrontation with existing frameworks to design the interventions in the most effective way.

The work will be broken down into three main tasks:

Task 7.1: Identification and selection of most impacting and promising non-tech innovations (M1-M12)

The objective of task 7.1 is to select a set of high-impact and promising non-tech innovations that will be worked out in detail as use cases in a living-lab setting. Potential innovations for development that we already identify:

Related to WP3 and its demos:
- price differentiation schemes towards maritime and inland shipping for enhancing zero-emission shipping,
- end-customer oriented blockchain based services for accelerating the use of new fuels
- pay-for-use principles for low and zero-emission fuel systems,
- specific new legislation around operations and use of new energy carriers

Related to WP 4 and its demos:
- new governance structures for digital energy-saving solutions like digital twin platforms
- new business models for digital platforms
- specific new legislation around operations and use of data and digital platforms

Related to WP5, WP6
- new market structures for sustainable last-mile transport,

More general:
- regulatory incentives,
- new legislation enabling transitions needed,
- specific start-up subsidies.

Important is to select those innovations that are most promising achieving the overall goal of greening transport. To come to this final set of most relevant non-tech innovations that we develop as use cases, the project's demos will be primary input in combination with a broader assessment of the lighthouse ports' and fellow ports' needs and opportunities.

Subtask 7.1.1 Context characterization. Do an overarching assessment of the most important issues that have to be 'cracked' / conditions that can be created by non-tech innovations to accelerate reaching the next level of TRL for different low or zero-emission solutions. This will be strongly aligned to the solutions that are developed in other WPs (WP3 to WP7), in addition a broader assessment will be done at port level. Alignment with fellow ports will be part of this.

Subtask 7.1.2 Selection of non-tech innovations. Identify a set of valuable innovations (long list), establish requirements for these innovations in each key area and rank them based upon impact and suitability in the context of this project's lighthouse ports' and fellow ports' issues and opportunities. Select the eight most promising non-tech innovations for further assessment and development (shortlist).

Subtask 7.1.3 Requirements and level of implementation assessment. For each innovation in the selected set specific requirements for further development will be assessed in combination with an assessment of the level at which the innovation should be implemented: port, city/region, national, EU, global (IMO).

Task 7.2: Detailed design and assessment of non-technological innovations: eight use cases (M6-M48)

Task 7.2 aims at the detailed development of a selected set of eight non-tech innovations which will be further worked out. The ambition is to bring solutions – as use cases in the overall living-lab setting of the project- to the level of 'readiness for implementation', if possible, including testing in a small-scale setting in the lighthouse port.

The design of the innovations goes hand in hand with an impact assessment and confrontation with existing and developing frameworks at national and EU level, in an iterative way, as to develop the solutions at hand in the best way. Investigative design, applying serious gaming tools and simulation will be brought into the use cases. Translation to fellow ports will be taken up during development.

Subtask 7.2.1 Innovation development process. Create a development, assessment, and feedback tool for the validation of the innovations. Aspects that should be part of this tool are:

- design of the relevant value chain,
- the set of relevant actors to involve in the design and assessment work, covering the relevant value chain,
- preliminary set-up,
- interim assessment and feedback including translation to other ports
- detailed design,
- further assessment (modelling, serious gaming), stakeholder assessment
- if possible - depending on the nature and level of implementation of the innovation - small-scale testing,
- alignment with existing policy frameworks

Depending on the level at which the innovation must be implemented the development tool will differ.

Subtask 7.2.2 Development of use cases. Develop the eight use cases using the above-described tool of task 7.2.1., involving all relevant actors, with iterative loops. Close alignment with the demos and their actors as well as the external context, e.g., new external developments, new regulations, will at a regular pace bring new input into the development work.

Task 7.3: Synthesis and policy recommendations (M42-M54)

The objective of this task is to provide policy recommendations on a regular basis for action and implementation of the non-tech innovations in relation to the foreseen technological and logistical low-emission innovations. This includes an implementation timeline with preparation steps and requirements towards the adoption of new innovations and policies. Furthermore, a toolset will be developed to effectively monitor ongoing developments in implementation but also its earlier steps and requirements, as to better steer implementation. This tool will be brought into the Handbook that will be developed in WP9.

Subtasks 7.3.1 Assessment of conditions for the implementation and upscaling of new non-tech innovations: Assess dependencies with the technological and logistical solutions, with the existing non-tech frameworks and impact on the level playing field issues

Subtask 7.3.2. Timeline creation. Create an implementation timeline with preparation steps and requirements and confront with the IMO 2030 and 2050 transition goals as well as the Paris Climate Agreement goals and related more specific agreements at different governance levels

Subtask 7.3.3 Create of implementation monitoring tool. Create a tool that supports guiding the implementation of the developed innovations and policies.

Deliverables
D7.1.1 Overview of non-technological issues/barriers (M6)
D7.1.2 Long list of potential non-tech innovations, described, categorised and ranked (M9)
D7.1.3 Selected set of non-tech innovations including requirements for the developments (M12)
D7.2.1 Development, assessment, and feedback system for non-tech innovations (M12)
D7.2.2 Eight detailed developed and assessed non-tech innovations, where appropriate with readiness for wider implementation in the lighthouse and translated to fellow ports (M48)
D7.3.1 Policy recommendations for introduction and upscaling of new non-tech innovations including a timeline (M54)
D7.3.2 Implementation monitoring tool (M54)