Needs

The NEEDS project has received funding from Horizon Europe research and innovation programme under grant agreement No 101056938

Needs

Dynamic Techno - Economical Scenario Simulation Model for Sustainable Waterborne Activities and Transport

D 4.2 Transposition roadmaps

Document information	
Short description	The Deliverable focuses on the identification of barriers and challenges for both NEEDS cases and proposed measures to overcome them to shape the transition to cleaner practices. The Technology Readiness Levels (TRL) of promising technologies is determined and translated into transposition roadmaps.
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Executive summary

The Deliverable focuses on the identification of barriers and challenges for both NEEDS cases and proposed measures to overcome them to shape the transition to cleaner practices. The Technology Readiness Levels (TRL) of promising technologies is determined, offering a snapshot of their preparedness for real-world application.

Taking a strategic approach, our discussion has emphasized the translation of these promising technologies into actionable plans through Transposition Roadmaps. These roadmaps serve as dynamic guides, outlining the pathways that facilitate the seamless integration of innovation into practical, sustainable solutions.

In essence, the Deliverable provides a better understanding of the pathway ahead for zero-emission waterborne transport. By addressing challenges, assessing technology readiness, and charting strategic roadmaps, we pave the way for a future where environmental sustainability and new technologies are fostering a cleaner and more efficient water transport.

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List of abbreviations

BAU	Business As Usual
CAPEX	Capital Expenditures
CO2	Carbon Dioxide
CO2e	CO2 equivalent emissions (also known as CO2eq)
ECA	Emission Control Area
GHG	Greenhouse gases
H2	Hydrogen
HFO	Heavy Fuel Oil
HVO	Hydrotreated Vegetable Oil
ICE	Internal Combustion Engine
LNG	Liquified Natural Gas
LPP	Length between perpendiculars
MDO	Marine Diesel Oil
MGO	Marine Gas Oil
MWh	Megawatt hours
NOx	Nitrogen Oxides
OPEX	Operational Expenditures
OPS	Onshore Power Supply
PM	Particulate Matter
RES	Renewable Energy Sources
SO_2	Sulfur Dioxide
SRIA	Strategic Research and Innovation Agenda
TRL	Technology Readiness Level
WTW	Well-to-Wake

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1. Introduction

Waterborne transport pursuits zero-emission solutions are a pivotal challenge and opportunity. In this Deliverable, the exploration into the identification of enablers, challenges and barriers within this dynamic landscape is documented for the Rhine and the Greek case and categorised into technological, business, environmental, societal and political factors.

Therewith, the Technology Readiness Levels (TRL) for potential technologies to achieve these overall goals is assessed and transferred to the concept of Transposition Roadmaps, offering strategic pathways for the transference of innovation into practical and sustainable implementations.

2. The Inland waterway transport case

2.1 Readiness levels of solutions to each emission reduction

In the simulation model for the WP3 NEEDS IWT case two types of readiness levels have been distinguished:

- Technology Readiness Levels
- Social Acceptance Level

In addition also the availability of the energy carrier in the ports was used as an element in the simulation.
The business readiness level was derived from the model results. Initially the business readiness level assessment is was executed based on model settings to select the solution with the lowest costs of ownership (scenario's 1, 2 and 3). In addition, for scenario's 4 and 5 also the Social Acceptance Level was introduced to simulate a much stronger focus on emission reduction from the business point of view. The latter resulted in selection of solutions which provided the highest CO2 reduction per euro of costs (Total Costs of Ownership). The results have been presented in the scenario's 4 and 5 in the Deliverable 3.3. The scenarios 4 and 5 therefore present the business readiness level taking into account full implementation of upcoming legal obligations from the Corporate Sustainability Reporting Directive (CSRD).
The following tables present the TRL for the different scenarios with reference to the Deliverable 3.3.

Table 1 Acceptance multiplier BAU scenario (also known as scenario setting "AVERAGE")

	Estimated value (1-9 scale)								
	2023			2035			2050		
Technology	**TRL**	**Acceptance level**	**Availability in ports**	**TRL**	**Acceptance level**	**Availability in ports**	**TRL**	**Acceptance level**	**Availability in ports**
Fossil diesel + Stage V ICE	9	9	9	9	8	9	9	7	9
Hydrotreated Vegetable Oil (HVO) + Stage V ICE	9	9	7	9	9	9	9	9	9
Liquefied Natural Gas (LNG) + Stage V ICE	9	3	4	9	2	4	9	1	4
Liquid Biomethane (LBM)+ Stage V ICE	9	6	4	9	7	4	9	8	5
Battery/electricity	8	7	2	9	8	6	9	9	8
Hydrogen Fuel Cell (H2 FC)	7	6	1	9	7	5	9	8	7
Hydrogen Internal Combustion Engine (H2 ICE)	5	5	1	9	6	5	9	7	7
Methanol Fuel Cell (MeOH FC)	7	5	1	9	6	4	9	7	6
Methanol Internal Combustion Engine (MeOH ICE)	5	4	1	9	5	4	9	6	6

Table 2 Acceptance multiplier conservative scenario (also known as scenario setting "CONSERVATIVE")

	Estimated value (1-9 scale)								
	2023			2035			2050		
Technology/energy	**TRL**	**Acceptance level**	**Availability in ports**	**TRL**	**Acceptance level**	**Availability in ports**	**TRL**	**Acceptance level**	**Availability in ports**
Fossil diesel + Stage V ICE	9	9	9	9	8	8	9	7	7
Hydrotreated Vegetable Oil (HVO) + Stage V ICE	9	9	7	9	9	9	9	9	9
Liquefied Natural Gas (LNG) + Stage V ICE	9	3	4	9	2	4	9	1	4
Liquid Biomethane (LBM)+ Stage V ICE	9	6	4	9	8	6	9	9	7
Battery/electricity	8	7	2	9	8	6	9	8	6
Hydrogen Fuel Cell (H2 FC)	7	6	1	9	7	5	9	7	5
Hydrogen Internal Combustion Engine (H2 ICE)	5	5	1	9	6	5	9	6	5
Methanol Fuel Cell (MeOH FC)	7	5	1	9	6	4	9	6	4
Methanol Internal Combustion Engine (MeOH ICE)	5	4	1	9	5	4	9	5	4
Share of frontrunners/share of social responsible operators	2%			35%			90%		

Note: the last row only applies in the conservative early adopter scenario

Table 3 Acceptance multiplier innovative scenario (also known as scenario setting "INNOVATIVE")

	Estimated value (1-9 scale)								
	2023			2035			2050		
Technology/energy	**TRL**	**Acceptance level**	**Availability in ports**	**TRL**	**Acceptance level**	**Availability in ports**	**TRL**	**Acceptance level**	**Availability in ports**
Fossil diesel + Stage V ICE	9	9	9	9	7	8	9	6	7
Hydrotreated Vegetable Oil (HVO) + Stage V ICE	9	9	7	9	8	8	9	7	7
Liquefied Natural Gas (LNG) + Stage V ICE	9	3	4	9	2	3	9	1	2
Liquid Biomethane (LBM)+ Stage V ICE	9	6	4	9	6	3	9	5	2
Battery/electricity	8	7	2	9	8	8	9	9	9
Hydrogen Fuel Cell (H2 FC)	7	6	1	9	7	7	9	8	8
Hydrogen Internal Combustion Engine (H2 ICE)	5	5	1	9	7	7	9	8	8
Methanol Fuel Cell (MeOH FC)	7	5	1	9	6	6	9	7	7
Methanol Internal Combustion Engine (MeOH ICE)	5	4	1	9	6	6	9	7	7
Share of frontrunners/share of social responsible operators	2%			35%			90%		

Note: the last row only applies in the innovative early adopter scenario

2.2 Barriers and opportunities

2.2.1 Financial and economic elements

As was concluded in the D3.3, the main barrier for the emission reduction is the **lack of a business case** for the vessel owner operator to make investments in cleaner technologies and to use energy with a lower carbon intensity. Using fuels with a zero- or low carbon intensity is **much more expensive**.

Furthermore, there is no obligation to replace diesel engines or to use energy with a lower carbon intensity. As a result, without intervention, the vessel owners do select the propulsion system and the type of energy based on the lowest total costs of ownership.

The Business As Usual scenario clearly showed a dominance of fossil diesel, resulting in hardly any GHG emission reduction. However, also the conservative and innovative scenario (scenario's 2 and 3 in the D3.3) do not show a significant reduction of GHG emissions. This was a bit surprising, because the prices of hardware and energy were already changed in favour of the low/zero carbon intensity solutions. It turned out that much more significant price changes are needed to make the business case.

In the CCNR studies[1] and in the PLATINA3 deliverable[2] D2.5 a significant in depth assessment was made on the financial gaps which need to be closed to achieve an emission reduction of at least 90% in year 2050 compared to 2015.

The key takeaways from the PLATINA3 Deliverable 2.5 were summarised as follows:

- Enabling the energy transition requires addressing economic, financial, technical and regulatory obstacles to the deployment of relevant technologies.

[1] See for more information https://ccr-zkr.org/12080000-en.html

[2] See for more information https://platina3.eu/d2.5/

- Many funding and financing opportunities are available but are not all considered adequate to support the energy transition of the inland waterway transport (IWT) sector. There is room to make best use of existing funding and financing opportunities.
- The setting-up of a European financial instrument could be an appropriate solution to finance the energy transition of the inland navigation sector. The implementation of such an instrument could follow a two-phase approach, following the rhythm of the Multiannual financial framework.
- In order to move on with the implementation of such an instrument, all actors need to come forward with their intentions
- One centralised instrument combining, EU, national and sectoral contributions as part of a common pool of money would not be realistic.
  A more realistic concept for a European instrument would therefore be decentralised with:
    - national contact points and national co-funding
    - in addition to resources managed at European level coming from the EU budget (i.e. new or adapted funding programmes) and a sector contribution.
- The current framework does not enable to trigger the energy transition at the level of the individual vessel owner. In addition, no mechanism currently exists to ensure that those who invest today in emission reduction technologies and take a financial risk in doing so are not put at disadvantage compared to those who decide to invest at a later stage. The setting-up of a sector contribution is therefore not seen as a goal in itself but mainly as a tool to address those two issues is therefore necessary. Different options for a sector contribution remain available. Should support for the setting-up of such a contribution be lacking, it is likely that regulatory evolutions will need to take place to stimulate the switch on the side of vessel owners.

- Even if a decentralised approach is promoted, the energy transition remains a European challenge that requires a European solution and proper European coordination:
    - to ensure sufficient financial resources are available to enable the transition and at same conditions
    - the assess whether the burden set on different actors is fairly distributed
    - to mitigate risk of different national co-funding schemes in parallel which may disturb level playing field
    - to avoid that some vessel owners are side-lined

- A clear European strategy between the EU, national governments and IWT sector representatives regarding the funding and financing of the energy transition towards 2050 is therefore required, as well as a clear action plan to overcome the related financial challenge.

Regarding the economic and financial bottlenecks, existing studies point to the limited business case for vessel owners to invest in technologies which fit within the transition pathway to reach zero-emission in 2050. In addition, the costs of the transition are too high to be borne by the private parties in the inland waterway transport sector alone. The financial gap to be bridged (or total cost of ownership ("TCO") gap) to achieve the emission reduction objectives at international level is expected to reach several billion euros (ranging between 2,5 and 10 billion euros depending on transition pathways and price scenario assumptions). This is a major bottleneck for driving the transition towards zero-emission and it is urgent to find solutions to close this TCO gap for the IWT to realise its transition.
In addition, the relatively small size of the European inland waterway vessel market implies that technological solutions designed specifically for the inland navigation sector alone are not commercially viable. It is therefore unlikely that a technological solution will be developed for the inland waterway transport sector alone. To overcome these economic and financial bottlenecks, synergies should be found with technologies developed for seagoing vessels and for non-marine applications whether in Europe or in other parts of the world.
It is important to remind that regulatory and technical solutions must also be found to enable the transition. From a regulatory perspective, such measures could for instance play an important role in improving the business case for cleaner technologies, from a technical perspective, uncertainties remain concerning especially the development, the cost, the level of maturity and the availability of the technologies contributing to the transition towards a zero-emission inland navigation sector.
For some fleet families, zero tailpipe emission technologies and fuels are not yet widely available for roll-out. This is for instance the case of large push boats with their high energy demand, 24/7 operation and high engine utilisation which are for now expected to continue relying on internal combustion engines (ICE) (according to the latest standards) which can achieve near zero-emission performance from well-to-wake perspective (e.g. with green methanol as fuel or HVO). On the other hand, for some vessels categories such zero tailpipe emission solutions exist, this is the case for instance of ferries and daytrip vessels which are expected to use batteries. In general, vessels operating locally (especially in densely populated areas) with a limited energy demand and a fixed route may benefit from low energy costs for electricity from the grid used.
To enable this transition, vessel owners and operators also need certainty that their investment in low/zero emission vessels will pay-off and a well-to wake perspective is essential to remain technology neutral and goal oriented. For this purpose, developing a shared vision of the energy transition, the possible transition pathways for the fleet (new and existing vessels) and the concomitant challenges within the inland navigation sector is

essential. The roadmap for reducing inland navigation emission adopted by the CCNR in December 2021 is a reference document in developing this shared vision.[3]
As regards the funding instruments it is concluded that working towards better coordination between national programmes and providing transparent information about them would be of added value. At EU level, another bottleneck lies in possible restrictive eligibility criteria and funding priorities. A major bottleneck remains the accessibility of such funding opportunities, hence the need for more technical support available to possible applicants. Given the key role played by public funding at national level alongside other EU funding opportunities the possibility for state aid measures to support solutions enabling to reduce emissions, even if they are not zero tailpipe emissions, should remain intact.

[3] https://www.ccr-zkr.org/files/documents/Roadmap/Roadmap_en.pdf

Developing a European financial instrument to support the energy transition

Building on existing studies, the need to develop new financial instruments but also the European Parliament's proposal to set up a new inland waterway fund, the PLATINA3 report D2.5 outlines a proposal for a new European financial instrument dedicated to IWT, based on mixed sources (public and private), including a sector contribution.

Such an instrument should be **focused primarily on providing grants to vessel owners**. Next to public contributions, a contribution by the sector is envisaged to support its energy transition. Indeed, it is unrealistic to expect that the public sector will provide the full volume of resources needed to close the TCO gap by means of providing grants. Specific and detailed proposals for the development of such as sector contribution are presented in the report.

Given that the setting up a sector contribution might seem at odds with the conclusion that in general, limited investment capacity is available on the side of the sector to invest in low/zero-emission technologies, the rationale behind the development of such a contribution is also explained in-depth. **The current framework does not enable to trigger the energy transition at the level of the individual vessel owner**. In addition, **no mechanism currently exists to ensure that those who invest today in emission reduction technologies and take a financial risk in doing so are not put at disadvantage compared to those who decide to invest at a later stage**.

Reflections on the setting up of a sector contribution were driven by the **need to create an incentive for vessel owners to invest in emission reduction technologies and to use clean and low/zero carbon fuels (what is currently lacking), but also to ensure that such a contribution be earmarked to support the private sector and be invested in their projects to adapt the fleet of inland vessels for the energy transition of the sector**.

The setting-up of a sector contribution has therefore never been seen as a goal in itself. At the same time, in anticipation of expected legislative developments that would require the sector to contribute financially to the energy transition in ways which might not be the most appropriate (general tax, integration into Emission Trading Schemes…), this idea of a sector contribution also aimed at generating a large-scale discussion on what could be the most appropriate way for the sector to contribute to this transition and being in the driving seat to develop the parameters for such a contribution (bottom-up approach) instead of such parameters being imposed on the sector (top-down approach such as an ETS for IWT) with possibly a very high cost impact but without having certainty on an earmarked use of the resources.

This is why an important implication of the sector is expected, as well as its support, with regards to the further development of a sector contribution. It is also important to mention that the first reflections regarding the need for the sector to contribute to the energy transition challenge in the form of a sector contribution started before the COVID-19 crisis, before the proposals from the European Commission in the context of the "Fit for 55" package and before the Russian war of aggression against Ukraine. The form which such a sector contribution and its viability will also depend on such developments. Should such support for the setting-up of such a contribution be lacking, it is likely that regulatory evolutions will need to take place to stimulate the switch on the side of vessel owners.

At the level of the EU, it was made clear that financial commitments (public side) to feed a new instrument supporting the IWT fleet and which could come on top of a sector contribution, would not be possible under the current MFF (2021-2027). At the level of national governments, some financial commitments to support the IWT fleet have already been made in some countries, but not in others. Such financial commitments are limited in time. In addition, it is not always possible to dedicate financial means for the coming years "at will", usually such financial means are negotiated in a law defining the budget and spending on a yearly/pluriannual basis.

Given the ambitious emission reduction objective set at international level, including for the IWT sector, it is quite urgent to develop an appropriate financial solution to enable the transition or to take other regulatory measures to force the energy transition and emission reduction.

The need to develop a solution at European level was also highlighted on several occasions to ensure a level playing field. Indeed, should the financial solutions be developed only in parallel (EU, national/regional level) without a proper European coordination or strategy, it is to be expected that some vessel owners will not obtain the necessary support to make their transition.

<u>Developing a roadmap to financially support the IWT sector in realising its energy transition</u>

The report D2.5 describes a roadmap to improve the funding and financing of the energy transition and to develop a European financial instrument. It is important to note that the reflections regarding the development of such a new instrument started before the COVID-19 crisis, the latest proposals from the EC in the context of the "Fit for 55" package and the Russian invasion in Ukraine. These are factors which can influence the decision making on the sector contribution and the development of a European instrument. Despite that it is unclear how Fit for 55 proposals will unfold into legislation, the PLATINA3 consortium is convinced that there are already clear actions to be done to improve the overall financing framework. In parallel the preparation of a dedicated European funding instrument (or at least at corridor level) to support the energy transition of the IWT sector should continue. An important role is foreseen for the IWT sector itself. In fact, it was made clear that without sufficient support from the IWT sector, the steps towards the setting up of a sector contribution will probably not be taken. In the context of such reflections, keeping the momentum and involving all possible parties involved in the setting up of the envisaged instrument is recommended.

The different actions outlined in the action plan are classified according to priority I and priority II actions. The actions are described in detail. The date by when such actions should be performed as well as by whom is presented in the action plan. The actions relate in particular to:

1. Making best use of the existing funding and financing programmes at national and European level.

2. The role of customers and intermediaries in the greening challenge. Indeed, they are key players to enable the energy transition. The demand for low-zero emission vessels and transport services from customers (i.e. shippers and brokers or tourists) can be a huge push factor for ship owners/operators to invest in greening technologies and to use sustainable alternative fuels. This should be an additional topic in future work. A key action in that regard relates to enquiring about the

willingness, barriers and opportunities of cargo owners to contract low/zero-emission vessels, even if this implies additional costs, and whether arrangements, standards and commitments could be made in that regard, taking into account level playing field issues as well as competition law.

3. The setting up of a European financial instrument. This will require addressing questions of political nature the latest by 2024 taking into account the impact of Fit-for-55 implementation. This in view of reaching a common understanding on the meaning and the goals of a European financial instrument to support the inland navigation energy transition as well as evaluating the willingness of public and private parties to contribute to the European instrument dedicated to inland vessels. Further analyses and discussions regarding the setting up of a sector contribution should also be dealt with as a matter of priority. Other actions regarding the parameters of a European instrument or its governance can be dealt with as a subsequent matter and therefore second priority as such actions are relevant only if the willingness to develop a European instrument is confirmed.
4. Monitor and report on the progress made. To ensure that the work undertaken in PLATINA3 receives a proper follow-up, it will be essential to keep track on the progress and execution of the actions listed and organise periodic meetings where the overall progress regarding the setting up of a European financial instrument.

2.2.2 Regulatory and standardisation elements

Besides this economic barrier, there are other barriers as well. In the field of the technical regulations, the PLATINA3 Deliverable[4] D2.7 presents the overview of the barriers and also a vast set of recommendations to overcome the barriers.
Regulations and standards belong to the group of obvious policy instruments to support the transition to zero emissions for the IWT fleet. In fact, the legal certainty associated with regulations and standards significantly influences the ability to invest in new technologies (energy carriers / converters). Appropriate regulations and standards allow to:

- reduce risks for ship owners willing to invest (and help companies plan their investments),
- reduce operating costs (initial investment, running costs and insurance costs),
- facilitate the acceptance of new technologies by mitigating safety and environmental risks, and
- stimulate market structuring and enable a wider adoption of technologies and clean forms of energy (it reinforces market potential for technology suppliers and may result in economies of scale).

[4] See for more information https://platina3.eu/towards-zero-emission-fleet/

More generally, regulations and standards influence the costs and duration of the transition process to zero emissions for the IWT fleet. In synergy with financial support, a consistent and effective regulatory framework is needed to level out the operational advantages of conventional fossil fuels and related technologies over renewable fuels and thereby improve the business case for cleaner solutions for the fleet.

The purpose of the PLATINA3 report D2.7 was to identify the regulations and standards related to vessels and technologies (energy carriers / converters) which are missing nowadays to effectively support the transition towards a zero-emission IWT fleet in Europe. The scope of this report is limited to fleet-related regulations and standards: vessel design, including energy converters, energy used, and vessel operations including bunkering, charging and swapping. It covers regulations and standards enacted by the EU, but also those of the River Commissions (such as CCNR or DC) and UNECE which co-exist alongside EU law. In terms of technologies considered (energy carriers / converters), this PLATINA3 report takes into account the study published by the CCNR on the energy transition towards a zero-emission inland navigation sector as well as the roadmap for reducing inland navigation emissions adopted in December 2021.

In terms of methodology, a desk study of existing regulations and standards was initially conducted to clarify the general impact on the IWT fleet, the specific gaps for new energy sources as well as gaps in terms of missing regulations for effective emission reduction policies. Then, interviews and discussions (with policy makers, classification societies, technology and energy suppliers, shipyards, IWT sector) allowed to improve the analysis further and prepare recommendations. In particular, the findings of this report were also examined during the third (10-11 February 2022) and sixth (23-24 March 2023) PLATINA3 stage events to ensure acceptance and support by the main impacted stakeholders. This report was elaborated with guidance from the PLATINA3 Advisory Board, as well as representatives of the European Commission’s DG MOVE.
This report includes 42 recommendations to effectively support the transition towards zero emissions for the fleet. In this respect, the recommendations are summarised in table format on the following pages. They include:

- 21 recommendations for the vessel regulations,
- 11 recommendations for fuel regulations and
- 10 recommendations for the operational regulations.

no V=vessel, F=fuel, P=operation/police	Who	What	When	Priority
V1	EC, CCNR, DC, Moselle Commission, Sava Commission, National administrations	facilitate the financing and commissioning of pilot vessels using alternative technologies, subject to the sharing of the experience collected for the regulatory work	Continuous	I
V2	CESNI, EC, CCNR	investigate the opportunity to introduce efficiency and greenhouse gas emission	2023-2025	I

		limits, possibly both for existing vessels and newly built vessels, in line with emission reduction target		
V3	CESNI and EUROMOT	update regularly their FAQ document on NRMM and ES-TRIN	Continuous	I
V4	EC	review opportunity to further reduce exhaust emission limits for inland navigation vessels, taking account of existing related Union and international standards and propose any necessary legal changes	2025	II
V5	EC, CCNR, CESNI	consider introducing a phasing out of existing engines in ES-TRIN to achieve minimum air pollutant emission standards	2030	II
V6,8	EC, engine manufacturers classification societies	facilitate the use of marinized engines (clarify the accepted inducement strategies and possible use on board vessels transporting dangerous goods)	Continuous	II
V7	EC	review the extent to which the engine emissions measured during type-approval tests using corresponding test cycles reflect engine emissions in real operating conditions and propose any necessary changes.	2025	II
V9	EC	evaluate the need to lower the factor A of emission limits for gas engine in NRMM to increase the climate performance of LNG propulsion systems	2025	II
V10	CESNI	evaluate the requirements for lithium-ion batteries after several years	2024-2025	II
V11	CESNI/CCNR	develop provisions to allow the swappable battery containers for the considering the risks involved	2023	I
V12	CESNI	monitor the development in the use of batteries for propulsion and anticipate the spreading of type of batteries other than LIB.	Continuous	II
V13	CESNI	collect experience regarding the approval of the hydrogen tanks and the relevant standards	2023	I
V14	CESNI	finalise the requirements for the compressed and liquefied storage of hydrogen	2023-2025	I
V15	EUROMOT/CESNI	develop guidelines for the implementation of Articles 34 and 35 of NRMM for engines using hydrogen as fuel (pending a revision of NRMM).	2023	I

V16	CESNI	start the development of safety requirements for hydrogen in internal combustion engine	2024	II
V17	ADN SC (UNECE-CCNR)	confirm that hydrogen is accepted for propulsion of vessels carrying dangerous goods	2024-2025	II
V18	CESNI	monitor the development in the hydrogen carriers	2025	II
V19	CESNI	finalise the requirements for the storage of methanol and its use in internal combustion engines (ES-TRIN 2025)	2023	I
V20	EUROMOT/CESNI	develop guidelines for the implementation of Articles 34 and 35 of NRMM for engines using methanol as fuel (pending a revision of NRMM).	2023	I
V21	ADN SC (UNECE-CCNR)	confirm that methanol is accepted for propulsion of vessels carrying dangerous goods	2024-2025	II

F1	Member States, CCNR, DC, Moselle Commission, Sava Commission, EC	coordinate on implementation of REDII revision and FQD as regards obligations for energy suppliers to inland vessels (preferably this coordination takes place at River Commissions level in relation with IWT fleet modernisation issues or even on EU level).	2023-2024	I
F2	EC	start policy research/development and impact assessment study for a proposal of “FuelEU IWT” based on the FuelEU Maritime proposal in Fit for 55, aligned with EU Taxonomy technical screening criteria and methodology	2024-2025	I
F3	EC	start policy research/development and impact assessment study for a proposal about IWT to be included in ETS (based the approach for road transport in ETS)	2024-2025	I
F4, F5	Member States / EC	limit the share of EN590 and fossil LNG in fuel supply, e.g. by means of limits on carbon intensity levels and/or ETS on EU level.	2030	I
F6, F9, F10, F11	Member States / EC	promote the share of fuels (HVO or biofuels/e-fuels, hydrogen and methanol) as well as electricity from renewal sources in fuel supply, e.g. by means of limits on carbon intensity levels and/or ETS on EU level	2030	I
F7	CEN	investigate need for more strict fuel quality standards for FAME and their blends as well	2025	II

		as quality checks in the supply chains of these fuels and enforcement.		
F8	EBU / ESO / national shipowner associations / IVR	launch awareness campaigns on the usage of biodiesel to be aware of possible technical risks and mitigation measures to prevent problems (e.g. as regards filter blockage, water separation)	2024	I

P1	CCNR, DC, Moselle Commission, UNECE	examine the need of operational requirements to ensure safety in case of thermal runaway of batteries	2023	I
P2	National authorities	facilitate the exchange of good practices between the fire brigades involved in fires with LIB, especially on-board inland vessels	2023-2024	I
P3	CEN, CENELEC	develop standards for shore-side battery recharging and battery swapping, taking into account the experience gained in inland navigation and the difference with the maritime sector.	2026	I
P4	CCNR, DC, Moselle Commission, UNECE	examine the need of operational requirements to ensure safety of hydrogen	2023-2024	I
P5	CEN, CENELEC	develop standards for swapping of racks/containers of compressed hydrogen, taking into account the experience gained in inland navigation and the existing industrial standards	2026	I
P6	CEN, CENELEC	develop standards for bunkering of liquefied hydrogen	2028	II
P7, P10	National authorities	collect and share the experience gained with the first pilot vessels to feed in the regulatory work	Continuous	I
P8	CCNR, DC, Moselle Commission, UNECE	examine the need of operational requirements to ensure safety of methanol	2023	I
P9	CEN, CENELEC	develop standards for bunkering of methanol, taking into account the experience gained in inland navigation and the existing industrial standards	2024	I

2.2.3 The infrastructure elements

Another important element for the energy transition is the energy bunkering and charging infrastructure. This is in particular the case for the energy types which can not be seen as ‘drop-in’ solutions for existing diesel based internal combustion engines. Examples of drop-in solutions are HVO and FAME, which can basically use the same bunkering facilities, tanks and fuel systems. However, for alternative energy types such as electricity, hydrogen and methanol new infrastructure will be needed. In particular for battery-electric applications, this will require a vast network of terminals where exchangeable battery containers can be

swapped. Currently, this network does not exist. An opportunity here is to make use of the facilities of existing container terminals in seaports and inland ports. In case of vessels with fixed batteries, infrastructure will be needed to quickly recharge the batteries on board. Such infrastructure with high capacity (e.g. 250kWh - 1MWh) does not yet exists for inland waterway transport. Possibly, synergies can be made here in terms of technology developed for full battery electric trucks (e.g. using the same type of standards, protocols and interfaces).
The PLATINA3 Deliverable D4.2 studied the topic of energy infrastructure development along inland waterways and in ports. It was concluded that there are differences in the details of the vision and approaches for the future clean energy infrastructure and the gaps and challenges that lie on the path. Especially at the level of European IWT countries, it will be crucial to develop and align national and regional strategies for the development of the clean energy infrastructure. The TEN-T corridor programs and European Coordinators of the corridors should coordinate and assist Member States in the creation of joint policy frameworks and strategies.

Need for clean energy infrastructure for IWT to be triggered by demand
At the moment, the greatest challenge for the clean energy infrastructure for IWT has an economic nature and concerns the currently minimal demand from vessel operators for clean energy. Demand and supply should develop in a balanced way. Policies and incentives (i.e. grants) should stimulate combined projects that will ensure a first critical mass of demand for clean energy, considering a corridor approach. This will help ensuring an initial consumption of alternative clean energy which is large enough for suppliers of clean energy to invest in the required energy infrastructure. When the right market conditions are met, clean energy suppliers can move relatively easily given their financial capacity, as compared to small individual vessel owners, and invest in infrastructure once there is a prospect of a market.

Need for synergies and economies of scale
It should be considered though that the IWT is seen as a small and fragmented market for energy suppliers, and hence would only support a limited number forms of clean energy. Otherwise, the infrastructure becomes too costly with potentially a negative impact on factors such as price and availability of the supplied energy. This should be well thought out and synergies should be created wherever possible with other industries and transport modes for the supply of clean energy, e.g. with clean energy hubs.

Clean energy needs to be competitive compared to fossil fuels
The current status of bunkering fossil diesel is one of high availability on short notice, high service, flexibility and low prices. It will, especially in its initial phase, be difficult for the alternative clean energy infrastructure to compete with. Laws and regulations should therefore be facilitative in terms of the realization and operation of the clean energy infrastructure for IWT. The right framework conditions should apply so that clean energy infrastructure operators can compete with the infrastructure for fossil fuels. The same line of reasoning applies for operators of clean energy vessels. The right framework conditions should also be in place for the operators of the vessels, which naturally strengthens the

realization of the clean energy infrastructure.

Important to address regulations and permits
There are also economic challenges with regulatory/legal causes, such as cumbersome permitting procedures and rules for the construction and operation of clean energy infrastructure, driving up costs for companies investing in the infrastructure. Experiences were gained with the construction and operation of the LNG bunkering station in Cologne and LNG truck-to-ship deliveries, lessons should be learned from this and rules and procedures could be eased where possible. Rules and procedures can be very different between countries and even at the local level. However, for a clean energy provider, it would help if the rules and procedures were aligned. Overall, laws and regulations should be facilitative as much as possible for the development of the clean energy infrastructure. Learning from the LNG bunkering infrastructure for IWT is also possible in other areas. This especially concerns the operation of the bunkering infrastructure, i.e. with operating the bunkering station in Cologne, bunkering pontoons and the truck-to-ship supplies.

How to use the existing bunkering infrastructure?
On the technical front, the challenge is to utilize the existing bunker infrastructure to store and deliver clean energy to vessels. Existing bunkering stations and bunker boats are not necessarily technically suitable for this, depending on the energy carrier to be dealt with; there are also legal bottlenecks here due to safety rules and permits. I.e. existing bunker boats are not allowed to carry H2 stacks. It would help to map the details here to understand if and how the existing bunker infrastructure can be utilized for the storage and delivery of clean energy to inland vessels. This allows the use of an existing and proven infrastructure and avoids stranded assets.

On shore power supply to be uniform and scalable in capacity for charging batteries
For Onshore Power Supply (OPS) it is important to have the necessary electricity infrastructure in place. The grid should reach the quay side (in an effective manner), meet the demand (also from inland cruise vessels) and there should be a uniform concept for the operation of the shoreside power connections and a commonly accepted payment method. Looking to the future, it is also essential to set up OPS points in such a way that they can also be utilized for (rapid) charging of batteries on board used for propulsion of the vessel. However, it does appear that this is technically very complex and requires a lot of infrastructural modifications to make a regular OPS point ready to serve as a charging point to charge batteries on board of vessels used for the propulsion of the vessel.

Future of exchangeable energy storage concepts using existing container terminals
With containerized energy storage for e.g. batteries and hydrogen (and possibly also other forms of clean energy), there are technical challenges both on the vessel and ashore. Not all (existing) vessels will be suited to carry containers and large parts of the sector never visit container terminals. Furthermore, a lot of inland terminals are still operated by one crane only and may not be able to take on the additional handling of alternative-fuel/energy-containers. However, swapping locations could also be at shore-side locations along

waterways and not necessarily at container terminals. The feasibility of this would need to be mapped.

Build up the new infrastructure step-by-step on corridor level
For suppliers of alternative clean energy it will be technically challenging to provide (full) geographic coverage for their customers. Since a large proportion of vessels operate on the spot market and will have varying sailing trajectories and may not be able to bunker and charge clean energy always on the same place. This will imply, especially in the deployment phase, a development of the clean energy infrastructure for specific cases and dedicated routes (e.g. container vessels, ferries, etc.) on limited parts of a corridor. Resources from European programmes such as Connecting Europe Facility as well as resources from national public resources and from the private sector need to be combined to deploy the clean energy hub network along the TEN-T corridors.

Mind shift needed in usage of new energy carriers
Furthermore, clean alternative forms of energy such as H2 are not the same as fossil diesel and require a significant mind shift in the supply and bunkering of the fuel as well as the operations of the vessel. The stakeholders who are going to be affected should become aware of this need for a mind shift in a timely manner.

Will there be sufficient supply of clean energy at competitive prices?
An overarching technical challenge is whether there will be enough supply of clean energy in all European IWT countries to meet the 55% GHG reduction targets by 2030. This is not yet entirely clear and is also going to depend on demand from other modes of transportation and industries. This should be monitored closely and it should be made clear what the prospects are for IWT in the various European countries and regions.

Work to do to develop a facilitating legal framework and procedures
On the legal front, there are many standalone challenges and gaps. In addition, technical and, to a lesser extent, economic challenges can also have a legal basis and/or could be solved by legal measures. Legal bottlenecks that suppliers of clean energy (will) encounter in practice are in the field of supplying/taking alternative clean energy on board of the vessel and the construction and operation of the clean energy infrastructure. This relates e.g. to port bye-laws and legislation at a higher level that need to include provisions for bunkering/charging/swapping alternative clean energy, harmonised bunkering checklists and procedures that are lacking, complex permits and procedures for building the infrastructure and for bunkering alternative clean fuels through truck-to-ship at reserved quays. Complex permits and procedures can also form a bottleneck for supplying alternative forms of energy at existing bunkering stations and for providing multiple forms of clean energy next to each other at the same location.

Gaps to be addressed by policy makers, mainly to develop the demand for clean energy
For policymakers, it is of great interest to adequately assess the identified gaps and challenges that lie on the path and take advantage of them for policies and incentives related to the clean energy infrastructure development for IWT. The biggest challenge is

seen in developing the demand for clean energy carriers, meaning vessel owners/operators demanding clean energy because they can make a business case or to have a 'licence to operate'.

2.2.4 Enablers

Much can be expected from the European and national policies addressing the climate goals. In this respect we can mention the following regulatory developments:

- Corporate Sustainability Reporting Directive (CSRD), making it mandatory for many clients of IWT to report on the GHG and air pollutant emissions and make plans to reduce emission levels, including the 'scope 3' concerning the contracted transport operations which includes IWT operations

- CountEmissionsEU proposal which makes it obligatory for transport service providers (including IWT) to present data on the CO2 intensity of the transport operations (grams per tonkilometre)

- Expansion of the Emission Trading Scheme, notably the opt-in other sectors such as inland waterway transport in the ETS-2 which is expected to increase the price of fossil fuels (around 15 cents per litre during the first year)

- Revision of the Renewable Energy Directive (RED 3) which requires a CO2 intensity reduction of 14.5% on the fuels used in transport in 2030 compared to 2015.

- Revision of the Energy Taxation Directive, proposing the abolishment of the exemptions for inland waterway transport to have excise duties on the fuels and imposing a minimum tax level for fuel supplied to IWT

- Dutch national policy aiming for a 70% reduction of GHG reduction in IWT by 2030, with measures planned to be implemented in The Netherlands such as:

    - RED3 implementation with specific sector goals for IWT to reduce the carbon intensity of fuels (aiming for around 11 PJ of renewable energy in the mix by 2030)
    - Inclusion of IWT under the ETS-2 scope from year 2027 onwards
    - Introducing a legal obligation to have an emission label for each vessel active in inland waterway transport
    - Possibly setting mandatory emission limits for vessels based on the emission label scheme, possibly in a differentiated way, to make sure that the 70% GHG reduction will be reached
    - Large subsidy schemes for:

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- converting existing vessels to Stage V performance and after treatment for existing vessels using internal combustion engines
- creating a breakthrough for a network for swappable batteries to be applied by inland container vessels on pay-per-use basis
- supporting development projects focussing Fuel Cell Hydrogen as technology with exchangeable hydrogen ‘tanktainers’ with a pay-per-use model

3. The maritime case in the Greek region

3.1 Readiness level of emission reduction technologies

There are a number of different technologies in discussion to achieve the transition towards zero-emission waterborne transport. In order to evaluate the potential transposition of these technologies with an associated timeline in a roadmap, the TRL of energy converters, energy production facilities, emission reduction measures like CCS or wind-assisted propulsion and regulation need to be considered.
In WP 2, project partners analyzed the promising clean technologies and energy carriers (see Deliverable D 2.2) based on existing studies, like the Maritime Forecast to 2050 by DNV. Figure 1 provides an overview of TRL development and timelines for energy converters, onboard CCS technologies and corresponding safety regulations.

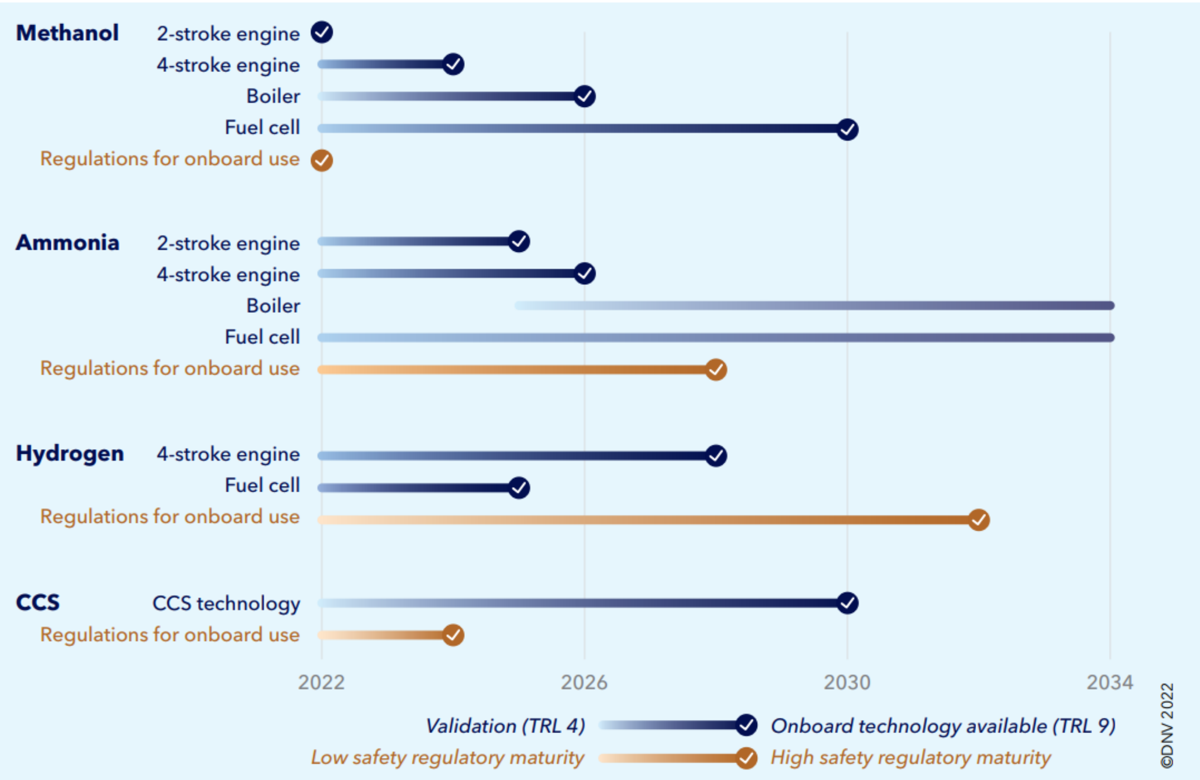

Figure 1: Estimated maturation timelines for energy converters onboard CCS technologies and corresponding safety regulations (DNV 2022)

The comparison underlines the high maturity of Methanol with available ICE and existing regulations, while the TRL of Ammonia and Hydrogen energy converts is estimated to take at least until 2025 to reach TRL 9 and the need for regulation development.

3.2 Enablers, challenges and barriers

For the maritime case in the Greek region, the following Enablers, barriers and challenges have been identified.

SC5	Technological	Business	Environmental	Societal	Political
Enablers	Lower maintenance costs for LNG engines	Aged fleet (increasing maintenance costs) – renewal will be required shortly	Significant expected reductions in GHG emissions and other pollutants	Reduced impact on public health of port-city residents	Requirement to comply with the GHG emission reduction targets set in EU regulations
	Technical know-how already in place (considering the share of LNG-fuelled vessels in world fleet)	LNG bunkering facilities currently being planned or starting operations at major hub ports in Greece	Enhanced air quality at ports of call (and nearby cities)	New job opportunities to be created along the whole value chain	Political will, at national level, to green the coastal shipping network
		Improved quality of service (i.e. reduced emissions, noise, vibration, etc.) that can contribute into further increasing demand		New knowledge, skills and competences will be required – existing educational and training programs to be reformed and new ones to be introduced (multiple EQF levels)	Shoreside Electricity (SSE) facilities to be made mandatory in European ports (according to FuelEU Maritime) by 2030
		Favourable characteristics of selected business case (national scale, fixed routes and services, etc.)			Availability of funding mechanisms that can be exploited (e.g. Green Fund)
		Constantly growing demand – customers (passengers) pressure for greener operations			
		Competition between operators for greening their			

SC5	Technological	Business	Environmental	Societal	Political
		fleet considering the relevant pressure excessed by customers (passengers)			
		Competition between ports for providing infrastructure that will support the aforementioned greening of the fleet			
		Marine fuel cost structures to change in the future to the detriment of fossil fuels			
		Ongoing privatization of Greek ports with large-scale investments (also for greening facilities) included in the relevant contracts (within a certain time horizon)			
		Large-scale investments on shipyards are currently undertaken – can uptake part of the expected demand on retrofit and newbuilds			
Barriers	Electric grid will need to be upgraded for being able to handle additional (large) loads	Relevant port infrastructure (i.e. bunkering facilities, charging areas, etc.) currently not in place. No bunkering network can thus be formed	Depending on production source, BioLNG may not be carbon neutral	Lack of experienced personnel (crew, port staff, etc.)	External costs of existing fleet not internalized

SC5	Technological	Business	Environmental	Societal	Political
	Long-time currently needed for constructing the new vessels considering shipyards' capacity, orderbook and existing backlog	Heavy capital investments required for existing players (shipowners, port authorities, RES producers, etc.) as well as new players interested to enter the market – challenging especially for small-scale companies		Relevant educational and training programs are currently very limited	Lack of a clear greening policy for the Greek coastal shipping sector
		Economic uncertainty due to crises and geopolitical tensions, enlarging the financial risks to be taken			Lack of relevant financial incentives to be provided to ship owners (e.g. tax reductions, etc.)
		Existing and planned RES capacities cannot fully fulfil energy requirements. Additional investments should be undertaken and new projects should be constructed			Lack of a national Maritime Spatial Plan that can unlock investments on offshore RES projects
		Cost of service likely to increase for compensating part of the investment			
		Lower level of profitability to be considered and addressed, resulting from reduced transport capacity, longer stay times at ports, etc.			
Challenges	Power delivery from the local	Seasonality of demand,	Climate change impacts on	Ensure that fleet changes	Devise and maintain, in

SC5	Technological	Business	Environmental	Societal	Political
	grid to charge batteries on the shore	prolonging ROI period	infrastructure (ports, energy production facilities, etc.)	do not have a negative impact on the level of connectivity of Greek islands to the mainland (capacities, frequencies, etc.)	the long-term, a clear energy transition policy for the coastal shipping sector
		Organic feedstock availability for ensuring stable rates of BioLNG production			
		Ongoing energy crisis affecting marine fuel prices			
		Uncertainties in fossil fuel cost development			
		Competition faced from other transport modes (i.e. air transport)			
		RES production to increase considerably for meeting projected needs			
		Shipbuilding capacities in Greece still quite limited for accommodating expected demand			
		Availability of land space area at ports for accommodating bunkering / charging activities (very challenging for ports at Greek islands)			

Table 1: Enables, Challenges and barriers in the Greek case

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4. Conclusion

In conclusion, the exploration into waterborne transport's transition toward zero-emission solutions has fostered a deeper understanding of the identification of barriers and challenges. The Transposition Roadmaps discussed act as guides. Facing challenges head-on, practical measures to overcome them are suggested. The journey toward cleaner transport is a collective effort, requiring teamwork and a commitment to a greener future. By understanding the challenges and proposing solutions, we pave the way for a more sustainable and eco-friendlier era in water transport.

In the Rhine case, the assessment of technology readiness levels (TRLs) is a crucial aspect for various low-emission technologies across three distinct scenarios outlined in Deliverable 3.3. This evaluation not only investigates the current state of these technologies but also projects their development trajectory leading up to the year 2050.

Moving beyond technology assessment, a comprehensive analysis is undertaken to identify and understand the barriers hindering the green transition. These barriers are then thoroughly discussed, highlighting the challenges that need to be addressed. In response to these challenges, a set of measures is introduced, aiming to overcome the identified barriers and pave the way for a successful transition towards environmentally friendly practices in the Rhine region.

The Greek case the transition to liquefied natural gas (LNG) in the coastal shipping sector presents several promising factors. Technologically, lower maintenance costs for LNG engines and existing technical expertise in LNG-fueled vessels contribute to its viability. The business landscape is favorable, with planned LNG bunkering facilities at major ports in Greece, a growing demand for greener operations, and healthy competition among operators. Environmentally, the transition promises significant reductions in greenhouse gas emissions, improved air quality at ports, and heightened service quality. Societal benefits include the creation of new job opportunities and the need for enhanced knowledge and skills, prompting educational reforms. Political support is evident at the national level, with a commitment to comply with EU regulations on emission reduction targets. Despite these enablers, various barriers and challenges exist.

Barriers include the need for electric grid upgrades, absent port infrastructure, potential non-carbon neutrality of BioLNG, and a lack of experienced personnel. Challenges encompass power delivery logistics, the seasonality of demand affecting return on investment, climate change impacts on infrastructure, and the necessity to maintain connectivity for Greek islands during fleet changes. Additionally, clear long-term energy transition policies are crucial. Despite these obstacles, the overall outlook for the coastal shipping sector's transition to LNG appears promising.

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