State-of-the-art sustainable energy efficiency technologies roadmap for waterborne transport towards the fit-for-55 guidance compliance

Project 101192661— FLEETfor55

Deliverable D3.2– Definition and data requirements for the use cases

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Acronyms and Abbreviations	Meaning
A/E	Auxiliary Engine
ALS	Air Lubrication System
BP	Between Perpendiculars
CCS	Carbon Capture System
CEMT	European Conference of Ministers of Transport
CII	Carbon Intensity Indicator
CO2	Cardon Dioxide
CPP	Controllable Pitch Propeller
DC	Direct Current
DF	Dual-Fuel Engine
DWT	Deadweight
EEDI	Energy Efficiency Design Index
EET	Energy Efficient Technology
EEXI	Energy Efficiency Existing Ship Index
E/R	Engine Room
ESD	Energy Saving Device
ESS	Energy Storage System
FAME	Fatty Acid Methyl Esters
FC	Fuel Cell
H2	Hydrogen
HVAC	Heating, Ventilation, and Air Conditioning
HVO	Hydrotreated Vegetable Oil
ICE	Internal Combustion Engine
IMO	International Maritime Organization
LNG	Liquified Natural Gas
LPG	Liquified Petroleum Gas
MCR	Maximum Continuous Rate
M/E	Main Engine
NB	New Build
NH3	Ammonia
NCR	Nominal Continuous Rating
OA	Overall
OPS	Onshore Power Supply
PBCF	Propeller Boss Cap Fins
PEM	Proton Exchange Membrane
PTI	Power Take-In

Acronyms and Abbreviations	Meaning
PTO	Power Take-Out
RFB	Redox Flow Batteries
RT	Retrofit
SFOC	Specific Fuel Oil Consumption
SG	Shaft Generator
SOFC	Solid Oxide Fuel Cell
TEU	Twenty-foot Equivalent Unit
TRL	Technology Readiness Level
UC	Use Case
WAPS	Wind Assisted Propulsion
WED	Wake Equalizing Ducts
WHRS	Waste Heat Recovery System
WP	Work Package

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Executive Summary

Task 3.2 is an essential step in FLEETfor55 activities, focusing on the definition of specific use cases (UCs) for the application of the most appropriate Energy Efficiency Technologies (EETs) on the selected vessels, either as retrofits or new designs, towards decarbonization of marine transport.

D3.2 is based upon the results of WP2, which initially delivered a consolidated catalogue of 68 EETs in D2.1, mapping the suitability and maturity of each technology to the three vessel segments – ocean-going (OG), short-sea shipping (SSS), and inland waterway transport (IWT). It is recalled that D2.4 provides a preliminary technical evaluation through structured filtering and feasibility checks, reducing the broad catalogue of technologies to a shortlist of the most promising options.

This D3.2 ensures continuity with the earlier WP2 analyses and provides targeted inputs for the subsequent feasibility and integration work. More specifically, D3.2 was the first step of defining the UCs by establishing the technical boundaries, data requirements, and operational conditions under which EETs can be realistically deployed. Particular attention was paid to ensure short/ mid-term uptake of the EETs, in line with the expectations of the EUs “Fit for 55” legislative package.

Two workshops were conducted during task 3.2 in order to perform an engineering assessment of the vessel cases and the potential EETs, one with the engineering/design experts of the consortium and one with the end users. A diverse set of vessel types was examined, each representing different operational patterns, design constraints, and opportunities for the integration of EETs. For each vessel type, consideration was given to the opportunity of implementing the EETs on new ships or retrofitting existing vessels – taking as reference baseline designs from 2008. A wide range of technologies was screened, considering the most relevant options for possible combinations and integration. Data concerning various operating scenarios have been collected to preliminary evaluate the UCs. Overall, 11 use cases were identified for further investigation, 5 retrofits and 6 new builds. Overall, this task focused on potential combinations of EETs and established the foundation for the evaluation to be carried out in T3.4 and T3.5 in order to define the UCs. Finally, T3.2 provides the necessary input for the detailed engineering development in WP4.

1 Introduction to the desktop studies

1.1 Definitions

In this deliverable the following definitions are used:

A case study ship is the ship whose data are provided by ship operators / ship owners / shipyards, playing the role of end users in the project;

A use case is the combination of the selected EETs for each vessel type. It should be noted that this is a preliminary assessment and the final combination of EETs per vessel case will take place at T3.5.

1.2 Data collection for the case study ships

The first step to define the use case ships is the identification of the data required for the assessment, followed by the collection from project partners. A data template was prepared in collaboration of the partners in WP3 and WP4 (see Annex A), which was then circulated to the relevant end users.

The necessary data collected for all vessels considered in the analysis include:

- **Ship identification information:** IMO number, flag administration, classification society, etc.
- **Design and operational characteristics:** dimensions, payload, current fuels, service and actual average speed, time at port vs. time at sea, EEDI/ EEXI values, etc.
- **Existing machinery / power generating sets:** Main Engine(s) (M/E) and Auxiliary Engine (A/E) type, Specific Fuel Oil Consumption (SFOC), Engine Room (E/R) arrangement, energy saving devices, etc.
- **Fuel handling and storage:** Fuel tank capacity, changeover procedures, auxiliary systems, etc.
- **Technical documentation and drawings:** Arrangement drawings, piping diagrams, hull structure and frame drawings, general arrangement plan, capacity plan, etc.
- **Operational data:** sea trials data, trim and stability booklet, noon reports, CII values, etc.

1.3 Ships selected for the use cases

This section presents the key data collected for the ships that will be investigated. The available drawings, the ship particulars, the operational profile as well as the pictures of each sample ship are included.

CONTAINERSHIP

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Figure 1: Profile image of the container ship

Table 1: Container ship particulars

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GENERAL CARGO SHIP

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Table 2: General Cargo ship particulars

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Ro-Pax Passenger Ship

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Table 3: Large sized Ro-Pax ferry particulars

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Ro-Pax Passenger Ship

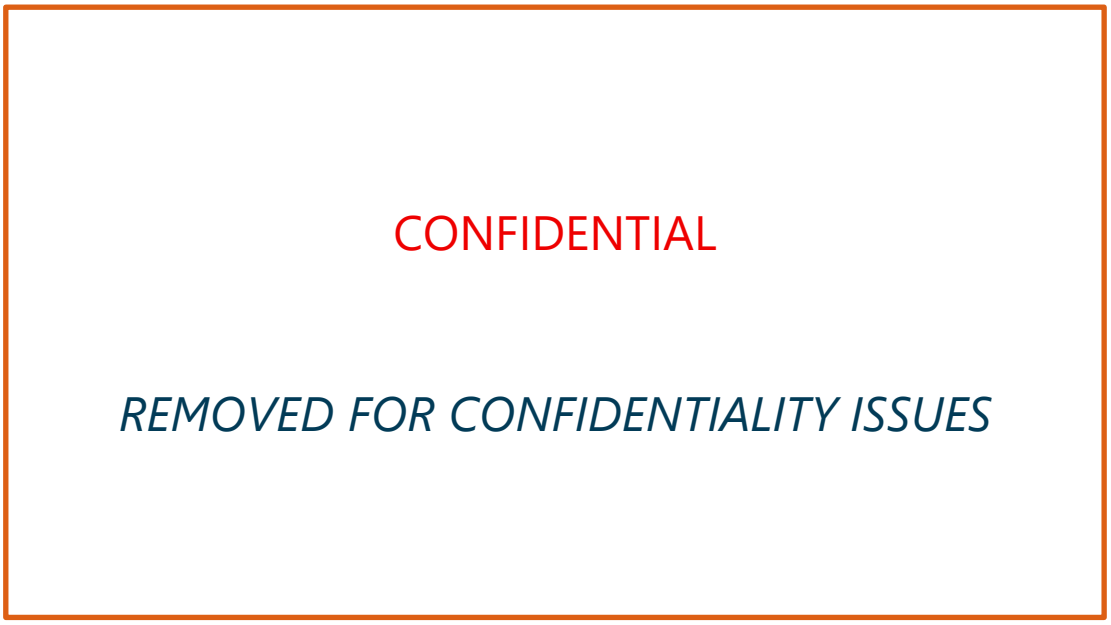
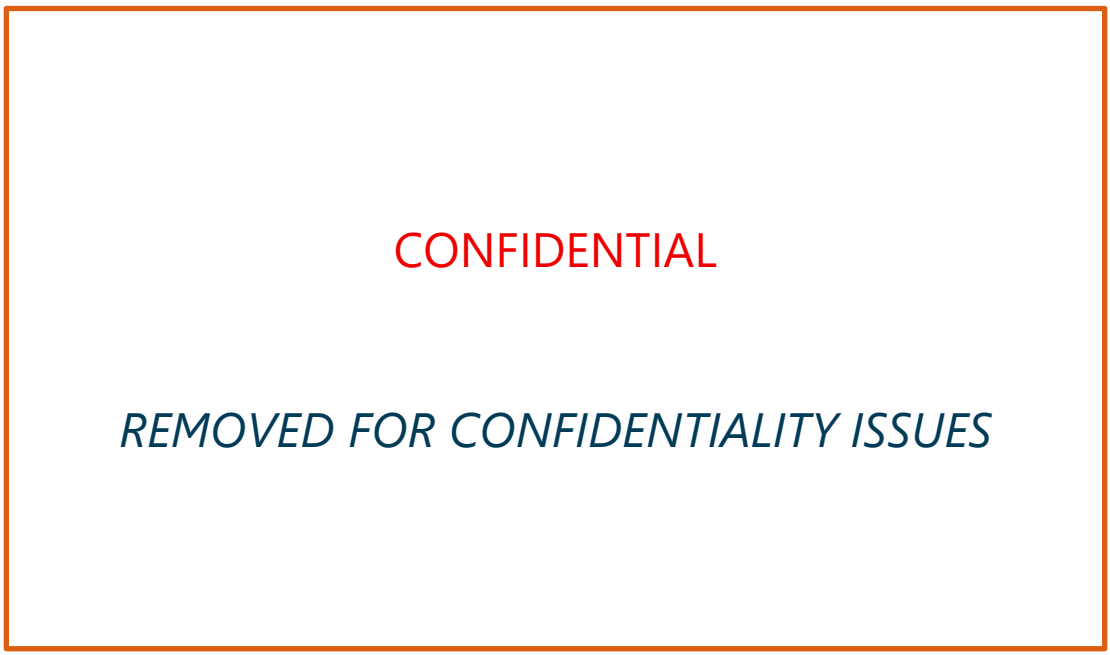


Figure 4: Small sized Ro-Pax ferry side image

Table 4: Small sized Ro-Pax ferry particulars



Ro-Pax Passenger Ship

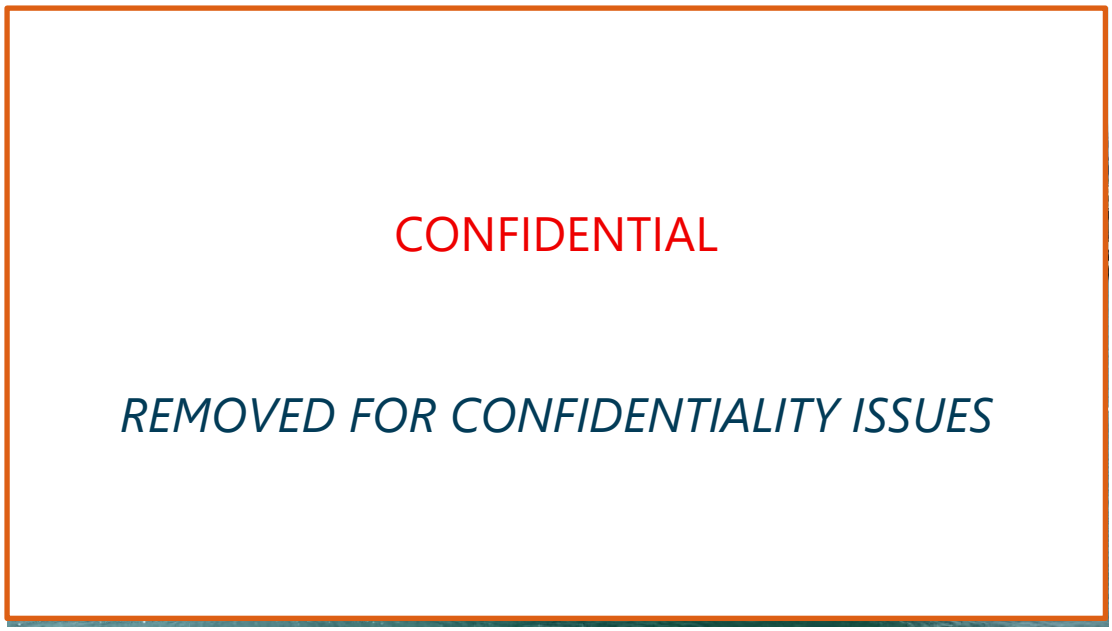


Figure 5: Medium sized Ro-Pax ferry side image

Table 5: Medium sized Ro-Pax ferry particulars

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Crude Oil Tanker

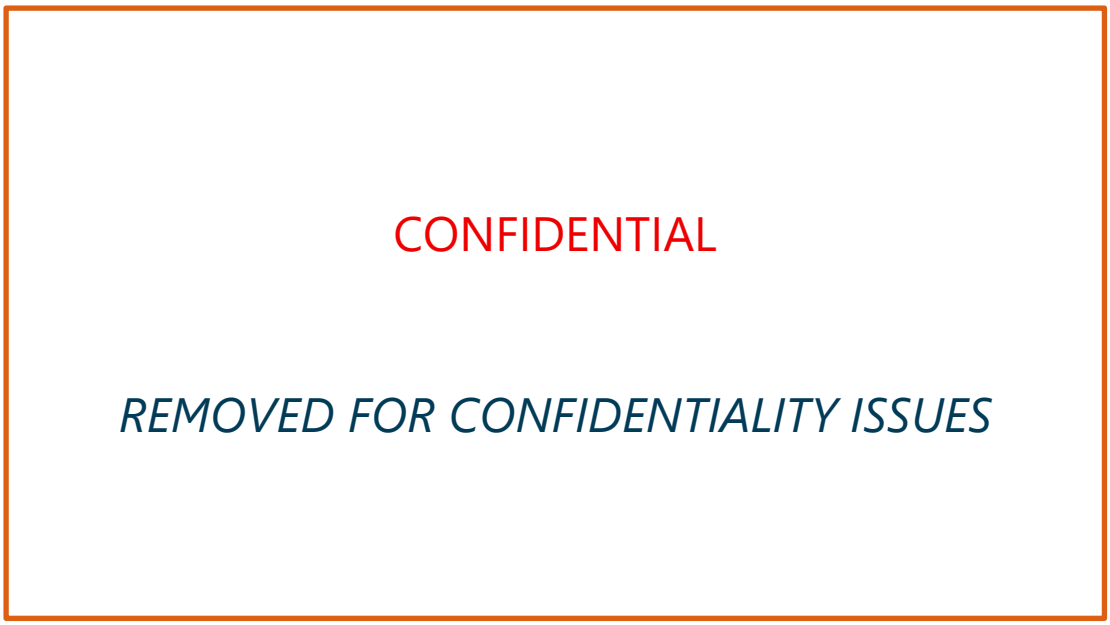
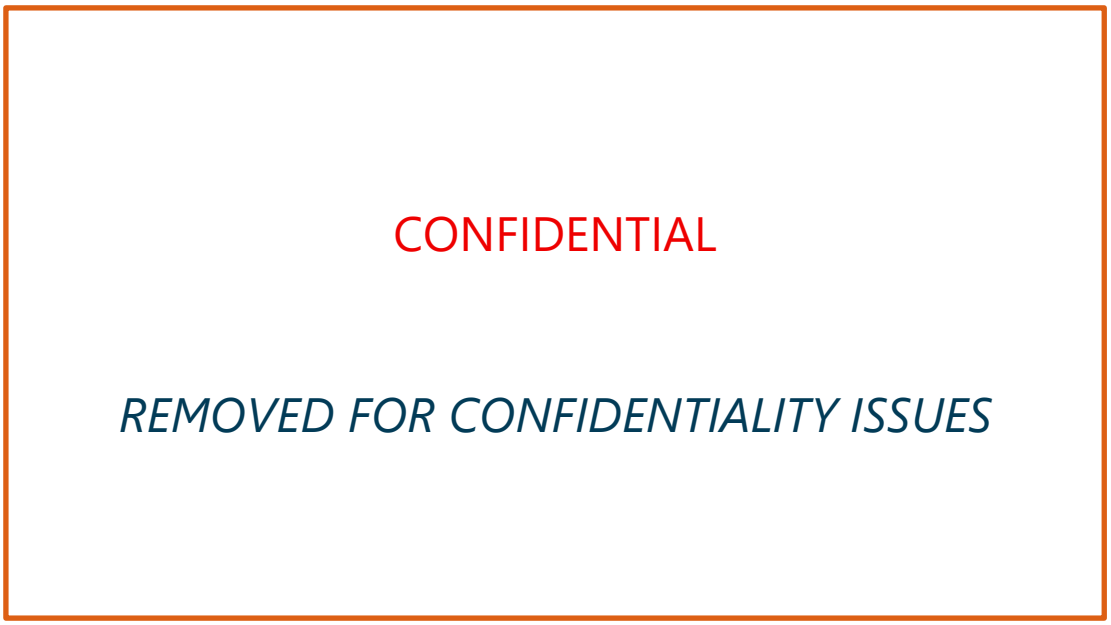


Figure 6: Side Image of the retrofit tanker.

Table 6: Retrofit tanker particulars



Crude Oil Tanker

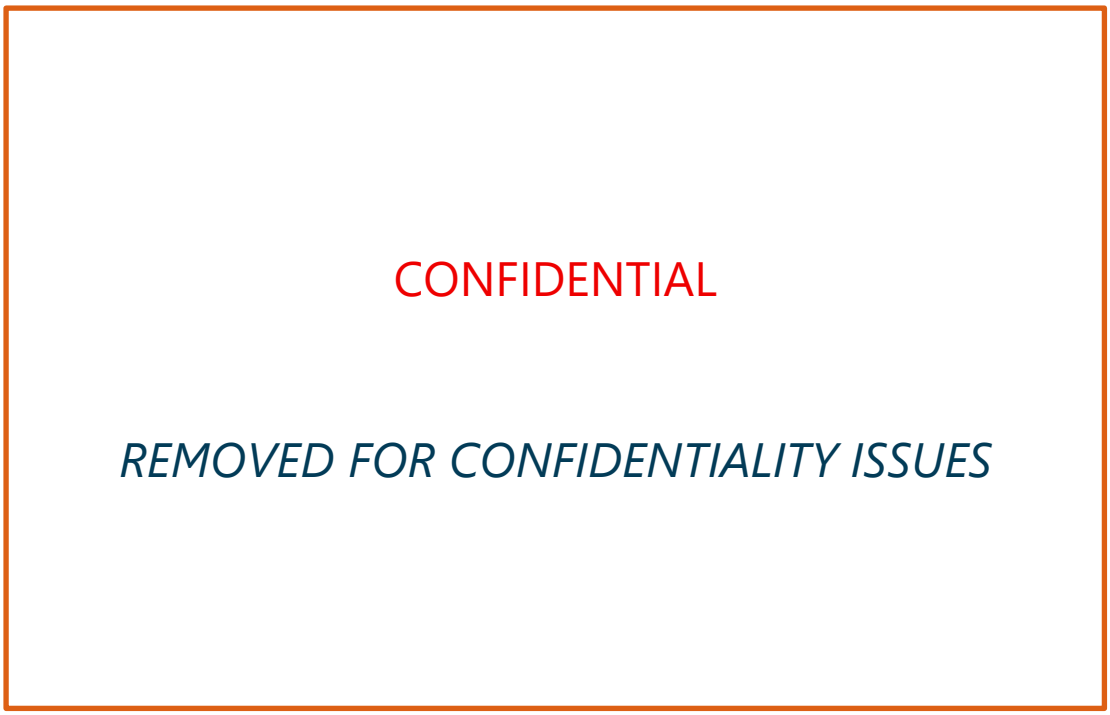
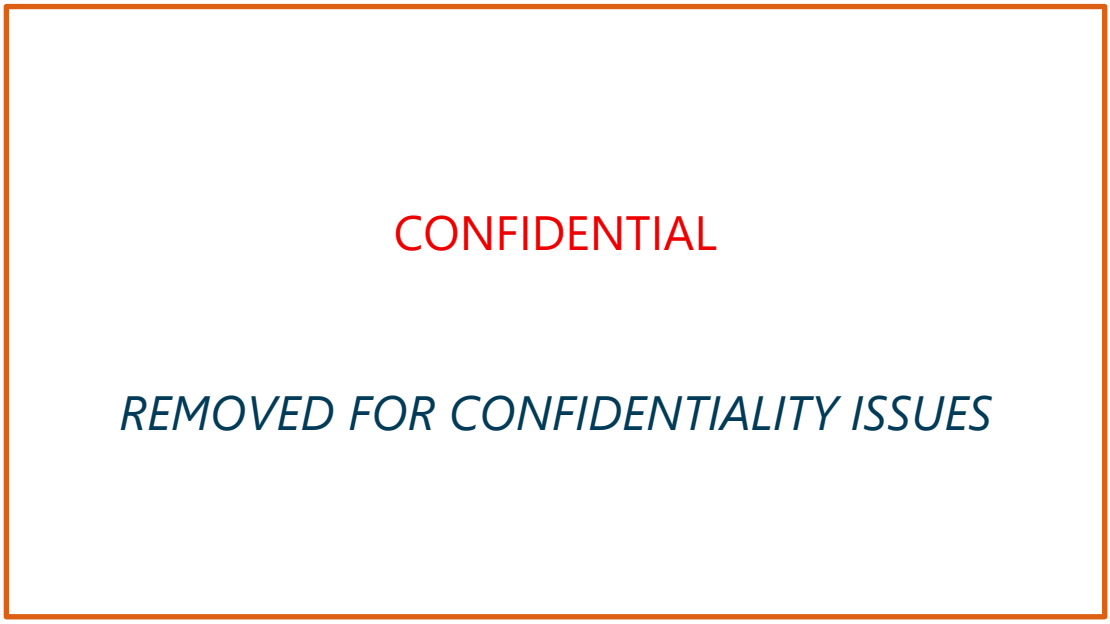


Figure 7: Side Image of the new build tanker.

Table 7: New build tanker particulars



BULK CARRIER

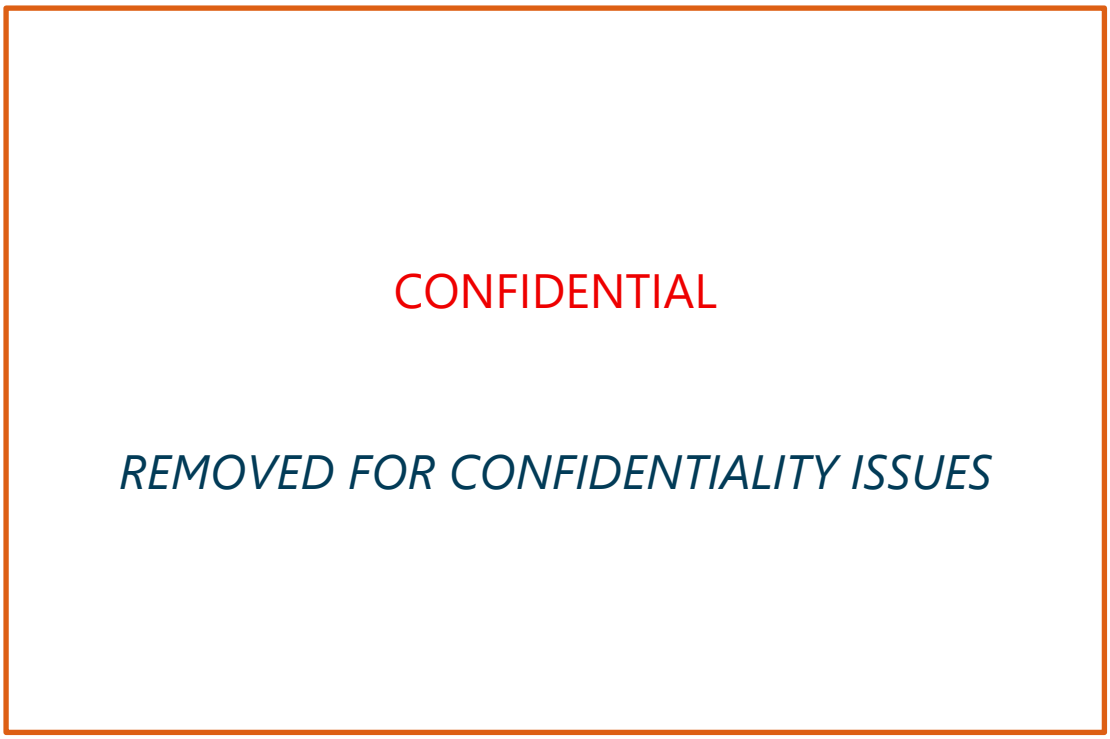
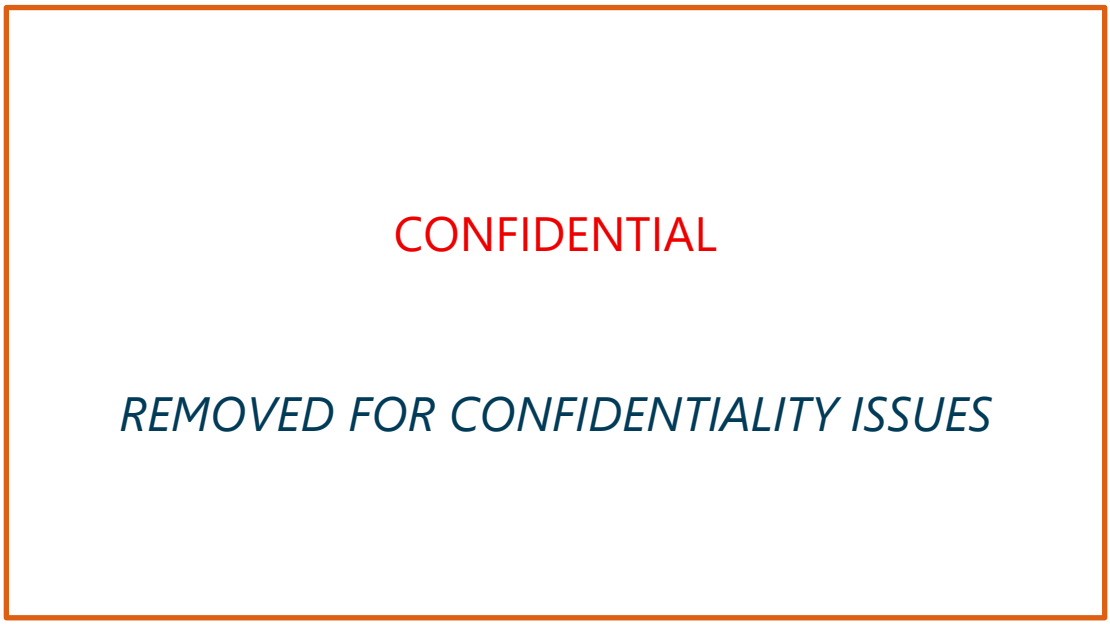


Figure 8: Bulk carrier front image

Table 8: Bulk carrier particulars



LPG TANKER

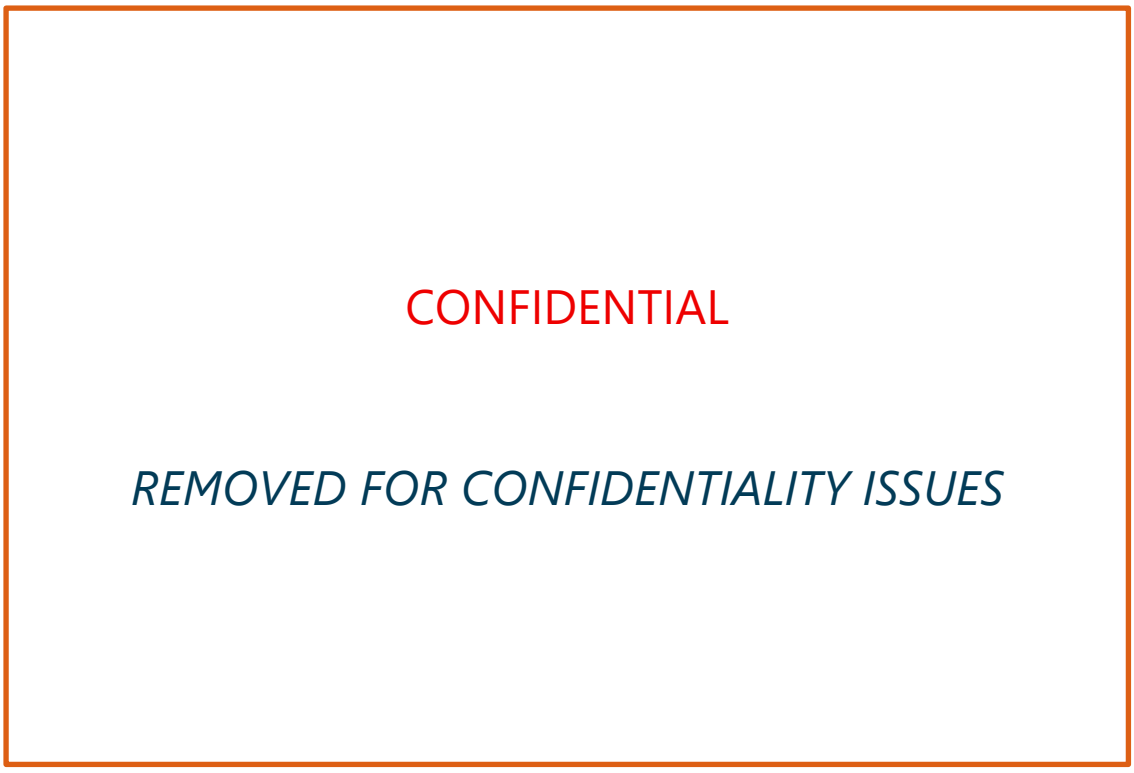


Figure 9: LPG Tanker front Image

Table 9: LPG Tanker particulars

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Inland Chemical Tanker

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Figure 10: Inland tanker side image

Table 10: Inland tanker particulars

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1.4 Operational profile of case study ships

As part of the work on vessel operational assessment, detailed noon-report datasets were collected from each shipowner participating in the study. These datasets, collected daily for each ship and accumulated over a year, report actual vessel operations, capturing parameters such as position, speed, fuel consumption, loading conditions, and machinery load. The objective of the analysis was to derive a realistic operational profile for each vessel type, forming the foundation for assessing the applicability and the impact of EETs.

Each participating company provided performance datasets extracted from their respective databases. While the overall data structure was comparable, data availability varied across companies:

- In some datasets, parameters such as sailing speed, mean draught and main engine power consumption were directly available.
- In other datasets, some elements were missing, and derived indicators were computed using available data fields.

For example, when the sailing speed of the vessel was not explicitly recorded, it was calculated as the distance travelled in nautical miles over the hours spent underway (Table 11). Similarly, missing engine load values were inferred from known relationships between specific fuel consumption and Maximum Continuous Rating (MCR) of the main engine. This approach ensured that all operational profiles contained a complete and consistent set of key performance indicators suitable for the evaluation of EETs. It should be noted that the average speed and the standard deviation are calculated based on the operational data provided, whereas the service speed is the nominal one shown in the design data (e.g. GA) and it corresponds to a specific draught and % MCR for each vessel.

Table 11: Speed profiles of used cases.

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Each dataset was segmented into distinct operational phases (e.g. “At Sea”, “In Port”) based on log entries (Table 12). Contiguous “At Sea” segments were treated as voyages, while port-related periods were grouped to estimate time in port and idle durations. This allowed calculation of key operational statistics such as:

- Average sailing speeds per voyage
- Distribution of power and fuel use across operational phases
- Typical voyage durations

Table 12: Time spent at sea and in port for use cases.

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To complement the analysis before selecting the most appropriate EETs for investigation, the typical operating range, bunkering intervals and route patterns of each vessel were explored (Table 13). For some vessels, the information was provided but in the case of data absence this was achieved by mapping the sequence of port calls and identifying the duration of typical voyages.

Table 13: Operational ranges of use cases.

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These routes were overlaid with wind yearly availability profiles derived from an online application, MARIN Blue Route[1], combining the most visited route schedule and average sailing speed of the vessel, we assessed the magnitude of prevailing beneficial wind conditions encountered along the route (Table 14). These data, although not fully detailed in terms of exact wind direction, were used to estimate where WAPS could provide meaningful thrust assistance.

[1] https://blueroute.application.marin.nl/

Table 14: Wind profile of use cases.

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1.4.1 Operational profile of inland vessel use case(s)

The selected Inland vessel is a typical chemical tanker belonging to the CEMT class Va (vessel length between 110 m and 135 m). Inland tankers in this category are the fastest growing fleet family of inland cargo vessels in Western Europe: over 650 new vessels have been added to the fleet in the first two decades of the 21st century. Nevertheless, the very fact that they can carry a variety of cargos – from conventional fuels (diesel, gasoline) to biofuels (HVO, FAME) to a range of chemicals used in industry and agriculture – makes their operational profiles rather varied. Tankers that normally carry (conventional) fuels will sail laden upstream, supplying the fuel loaded in one of the ports in ARA (Amsterdam-Rotterdam-Antwerp) region to the communities in the Netherlands, Belgium, Germany, France, and Switzerland, and unladen downstream. On the contrary, the tankers which carry chemicals produced e.g. in the Middle Rhine to the large seaports, will sail laden downstream, and unladen upstream. Even though their size and engine power may be the same, the operational profiles of such vessels would be completely different.

Further complexity in operation of inland vessels in general is the effect of seasonality, that is, the low water level periods (characterized by shallow water effects) and high-water level periods (characterized by strong currents) which both affect the power demand of vessels. Irregularity of such periods, exacerbated by climate change effects, with more extreme and prolonged phenomena taking place more frequently, contributes to variability of operational profiles. Finally, the time spent in large seaports, as well as time spent in locks or waiting for locking operations may significantly vary.

Last but not least, the “noon reports” which are customary in seagoing shipping are not a standard in inland navigation in Europe. It is rather summarized reports on completed voyages that may be obtained; those only reflect the described complexities, but do not provide data sufficient for analysis of operational profiles and for isolation of individual effects. The information herein provided is based on such reports which cover almost one full calendar year, from the 6th of November 2024 to the 22nd of October 2025. Details of the operational profile of this vessel are reported in Annex C of this deliverable.

To conclude, the lack of a standardized daily reporting on relevant parameters, and the environmental and logistical complexities typical for inland shipping, make it difficult to create representative operational profiles. Such a task has to be performed on a case-by-case basis and would require either continuous measurements over a representative period, or simulations which would complement the existing data. However, based on the previous research (e.g. in the Horizon Europe project SYNERGETICS) it is known which EETs could be the most feasible candidates at least in the retrofit use case. This does not exhaust the work that has to be done within the FLEETfor55 project, but it does form a sound basis for it.

2 Methodology for use cases selection

2.1 General methodology

The methodology presented in Figure 11 was followed for the preliminary assessment of the use cases and for outlining the boundaries. Two diverse approaches were followed for the two groups of EETs - globally and non-globally applied - as they were defined in T2.4. Globally applied are considered the technologies that can be theoretically implemented with minimal engineering modifications, whereas the non-globally applied technologies are required to undergo a deeper technical review.

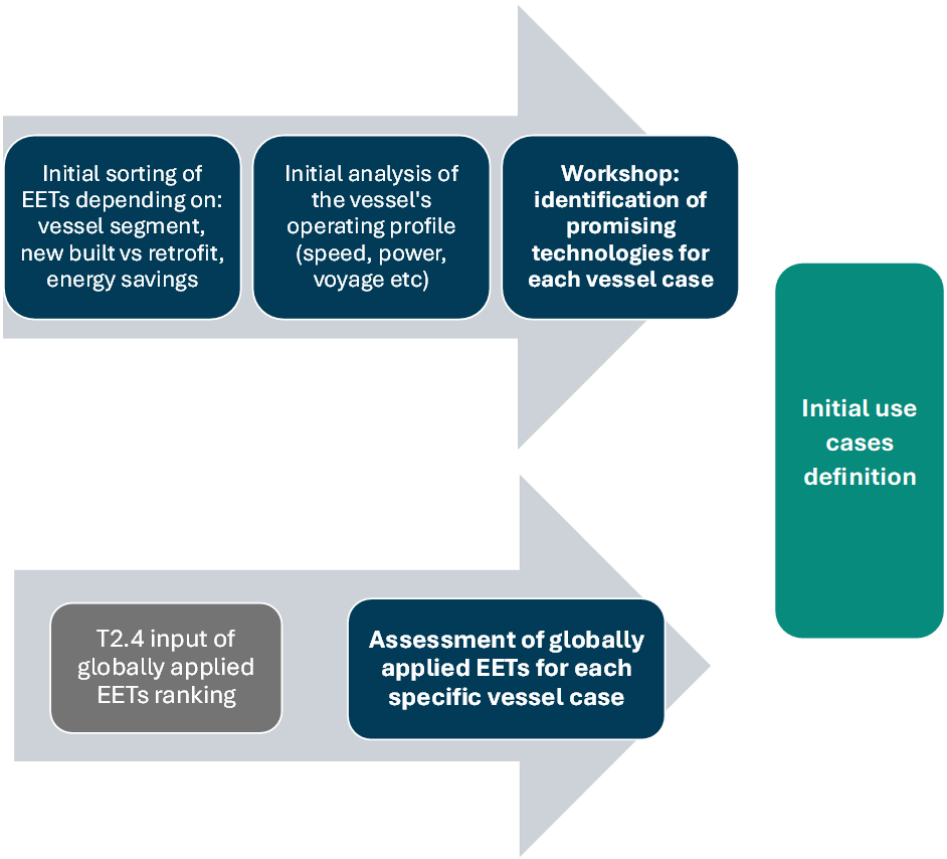

Figure 11: Methodology for initial use cases definition

Non-globally applied EETs were initially sorted, as shown in Annex B. This sorting was based on the level of appropriateness of each technology on the vessel type (tanker, containership etc.) and the vessel status (retrofit or newbuild).

Vessels already in operation, with an established machinery arrangement and limited flexibility in their layout and arrangement, were classified as retrofit cases. For these ships, only technologies that can be feasibly installed during scheduled dry-dockings or operational maintenance windows were considered, favouring solutions with moderate integration complexity.

In contrast, vessels labelled as newbuild cases were treated as if they could be taken back to the design stage, while retaining their baseline hull form from the reference design. This allows a much broader range of technologies to be explored, because these can be planned from the outset and integrated into the design without the limitations imposed by an existing vessel. This approach ensures that each vessel is evaluated within a realistic engineering envelope, while still enabling ambitious configurations to be explored for newbuilds and more pragmatic solutions for retrofits.

Table 15: Desktop cases retrofit or new build status.

#	Vessel Name	Vessel Type	RT vs NB
1	CONFIDENTIAL *REMOVED FOR CONFIDENTIALITY ISSUES*	Containership	NB
2		General Cargo	RT
3		Ro-Pax	RT
4		Ro-Pax	RT
5		Ro-Pax	NB
6		Tanker	RT
7		Tanker	NB
8		Bulk Carrier	RT
9		LPG Tanker	RT
10 & 11		Inland Chemical Tanker	RT & NB

In addition, information such as the TRL and the energy savings of the EETs per ship type, safety and risk assessment information per EETs were included. The inputs for this table were provided by the DNV report [2]and Task 2.4. Furthermore, a preliminary evaluation of compatibility issues between the EETs was performed (Table 16).

As a second stage, a workshop was organised, and the table of Annex B was utilised as a guideline to identify the most promising technologies for each vessel type with the specific operating requirements as they were presented in Section 1. More information regarding the workshop is provided in the following section. For the globally applied EETs, an assessment focused on each specific vessel case was performed based on the input received by T2.4. More details of this assessment are given in Section 4.

[2] Energy efficiency measures and technologies, DNV, 2025

Table 16: Technologies limitations.

EETs		Conflict type	Detailed Technical Reasons
26 Alternative Fuelled 2-S ICEs (e.g. hydrogen, ammonia, methanol)	29. PEM fuel cells 30. SOFC fuel cells 31. Other type of fuel cells	Integration challenge	Two-stroke ICEs provide direct mechanical propulsion, making integration with fuel cells impractical. Fuel cells produce steady electrical output, suited for auxiliary power or hybrid-electric architectures rather than direct shaft drive. Furthermore, hydrogen or ammonia ICEs and FCs require independent fuel conditioning and control systems, increasing complexity and safety management requirements.
26 Alternative Fuelled 2-S ICEs (e.g. hydrogen, ammonia) 27 Alternative Fuelled 4-S ICEs/Gensets (e.g. hydrogen, ammonia) 29. PEM fuel cells	1. Onboard Carbon Capture and Storage (CCS) Systems	Redundant carbon management	Hydrogen and ammonia are carbon-free fuels; CCS provides no added benefit. The additional weight, volume, and parasitic load of CCS reduce ship efficiency with no emission advantage. CCS only benefits carbonaceous fuels (e.g., LNG, methanol, biofuels). For hydrogen/ammonia systems, CO_2 is not produced, making CCS unnecessary and adding cost, space, and maintenance burden.
62 Ammonia	66. Hydrogen	Fuel handling incompatibility	Different storage temperatures/pressures (NH_3: –33 °C @ 1 bar, H_2: –253 °C @ 1 bar). Dual-fuel integration increases risk of cross-contamination and explosion hazards. Simultaneous handling violates IGF Code segregation requirements.
25 Full Electric Propulsion Concepts (e.g. dynafin, Superconducting electric motors)	36 Shaft Generator PTI, PTO, PTI/PTO	System architecture conflict	Shaft generators rely on mechanical propulsion lines, while full-electric systems use DC buses or power electronic converters with independent electric motors. Combined installation is redundant and causes efficiency loss due to multiple energy conversions.

2.2 Workshop details

The 1st Technical Workshop, two days in person meeting 11th-12th November hosted by RINA in their headquarter in Genoa, was followed by a virtual meeting on 17th November. The key member of the consortium that participated thanks to their engineering/design expertise were the following:

- Hydrus: Astrinos Papadakis, Dimitris Vlachos, Spyros Pappas
- DST: Igor Backalov
- NTUA: George Charvalos, Nikos Themelis (online), Dora Tsiourva (online), Zoe Chatzaki (online)
- DNV: Thomas Papacharizanos
- RINA: Alessandro Maccari, Dionysios Melissinos, Nikoletta Trivyza

The scope of the workshop was to screen EETs to evaluate those which would better fit onboard each vessel case and propose the solutions that would be advanced for further assessment in the following tasks and WPs.

In the beginning of each session, the operating requirements of each vessel were presented (Section 1). Then each EET discussed, assessing its technical feasibility on each specific ship case. In addition to the technical feasibility, the technologies were matched against the remaining life of each vessel case and the consequent need to comply with short-, mid- and long-term regulatory targets. The approach followed for the selection of the EETs per vessel case is shown in Figure 12.

The technologies were grouped into three categories, marked with distinctive colors: red, green, and orange. **Green technologies** are technically viable and operationally relevant for the vessel type. Their integration is consistent with common maritime practices on retrofit or newbuild cases. **Orange technologies** are potentially feasible but subject to vessel-specific constraints and case by case compatibility with other technologies. **Red technologies** were excluded because they are technically non-feasible. This is consistent with standard maritime practices, using engineering judgement to assess and filter the compatibility of different options. The first two categories were promoted to be better evaluated in the following Tasks and Work Packages. The selection was made according to the technical expertise of the workshop members.

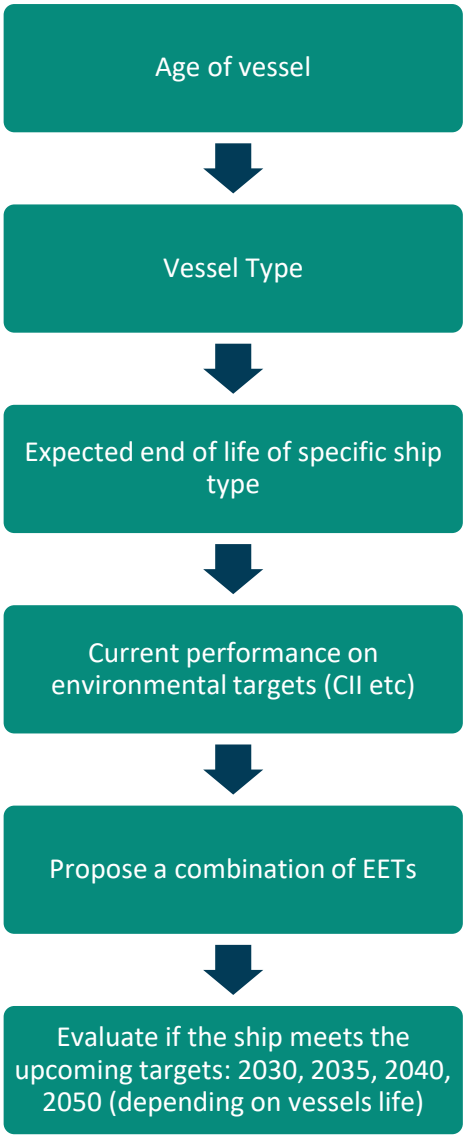

Figure 12: Workshop selection approach

The assumptions on each vessel's average life have been based on the following:

- Ship study/desing practice.
- Feedback from the end-user partners.
- Exploitation of available data, obtained from "S&P Global – SeaWeb-ships" database.

The following graphs present the number of vessels, for each of the relevant fleet segments:

1. Bulk Carriers, currently in service, built between 1995 and 2025.
2. Double hull Crude Oil Tankers and Chemical/Product Tankers, currently in service, built between 1995 and 2025.
3. Containerships, currently in service, built between 1995 and 2025.
4. LPG tankers, currently in service, built between 1995 and 2025.
5. General Cargo, vessels, currently in service, built between 1995 and 2025.
6. ROPAX vessels, currently in service, built between 1980 and 2025.

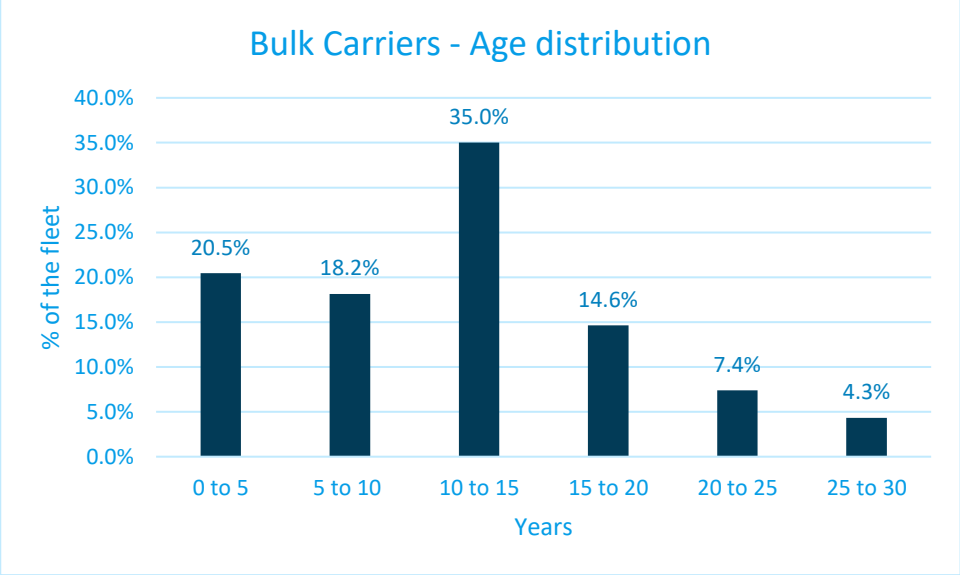

Figure 13: Bulk carriers age distribution

From Figure 13, it is evident that most of the Bulk Carrier fleet (~50%) has a current life between 10 and 20 years, whereas a small portion of the fleet has exceeded the 25 years life span.

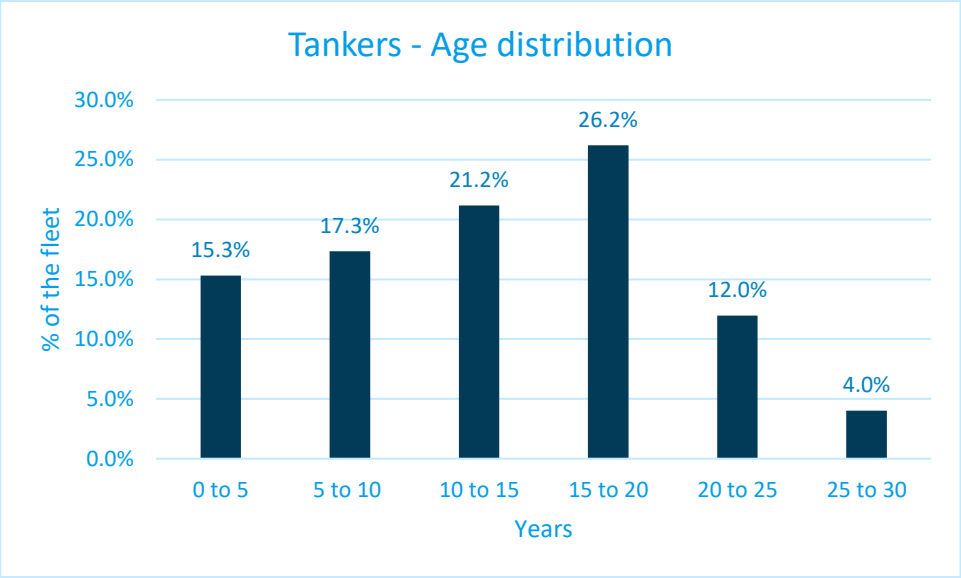

Figure 14: Tankers age distribution

For the tanker segment (Figure 14), 32.6% of the ships have been built the past decade, 47.4% between 2005 and 2015, while the age for the remaining significant portion (16%), has exceeded 20 years.

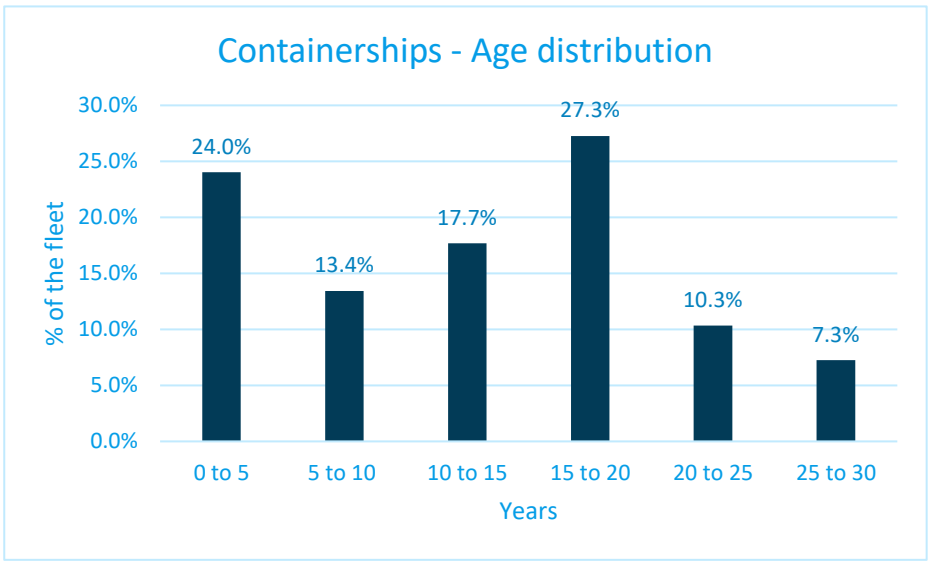

Figure 15: Containership age distribution

For the containerships (Figure 15), 37.4% of the fleet has been built the past decade, 45% of the fleet age lies between 10 and 20 years and a significant portion 17.6% has exceeded 20 years of life.

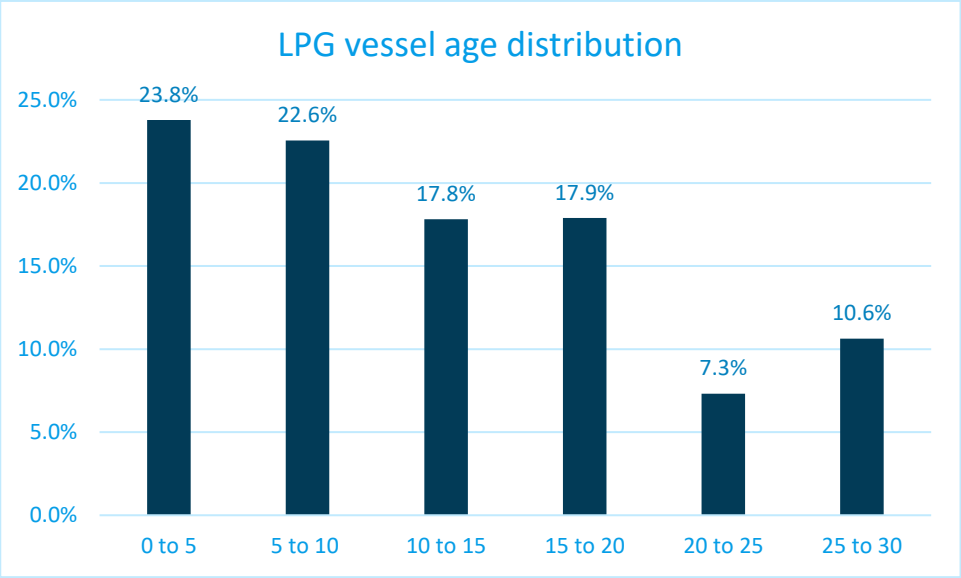

Figure 16: LPG age distribution

The LPG (Figure 16) fleet segment exhibits the largest portion of new build vessels, with 46.4% being build the past decade. 35.7% of the fleet has been operating from 10 to 20 years and the remaining 17.9% is over 20 years old.

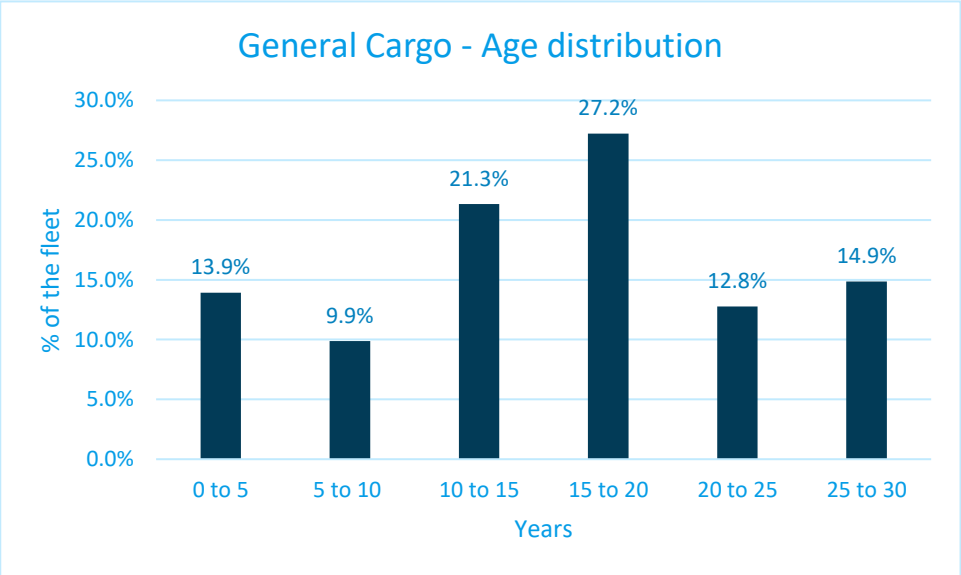

Figure 17: General Cargo age distribution

The General Cargo (Figure 17) fleet is older than the other segments, with 48.5% of the vessels being 10 to 20 years old and 27.7% having exceeded 20 years of life.

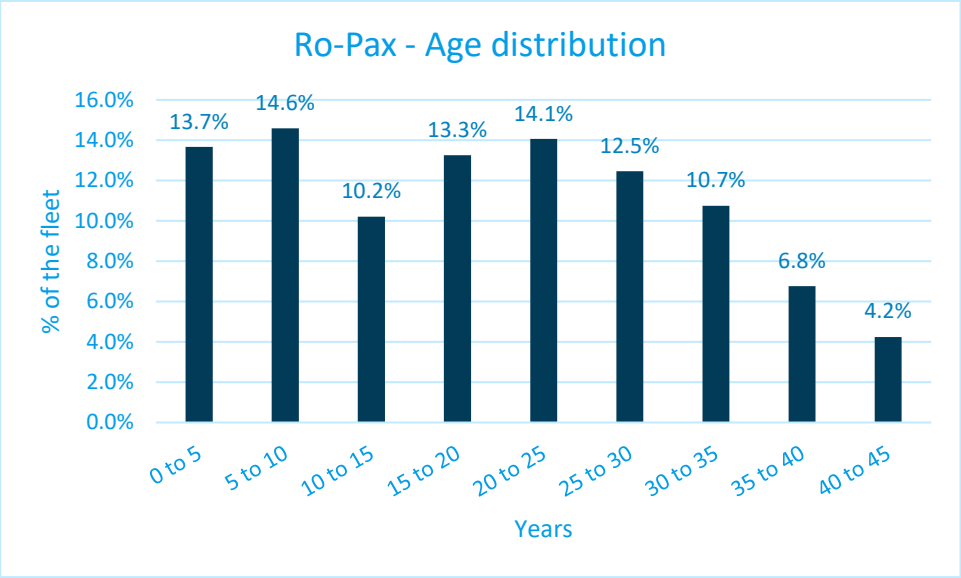

Figure 18: Ro-Pax age distribution

A ROPX (Figure 18) vessel life is longer than the expected life of a non-passenger commercial vessel. 48.3% of the vessels have exceeded a life of 20 years, 26.6% of the vessels exhibit a life of 20 to 30 years, 23.5% are aged between 10 and 20 years.

2.3 General assumptions

The following general assumptions reflect the consensus reached during the workshop:

- At this stage the market availability of the EETs was not considered, as it was the object of study of D2.2. The selection process proceeded on the long-term expectation that technologies will have matured by 2035 and 2040. Therefore, the choice of a ship equipped with a measure having a low TRL is justified by the technology's potential to satisfy the ship's operational requirements. In the next tasks, the outputs of this report will be combined with previous tasks accounting for the technology's availability.
- For retrofit use cases, the classification of EETs explicitly reflected their sensitivity to the vessel's operational profile, design and equipment, combining technical features with the vessel's real-world operation to get meaningful performance gains.
- During a new build use case, the vessel is not re-designed. The hull form/shape remain unchanged (unless dictated by a specific measure) and the enclosed spaces are rearranged to accommodate the selected EETs.
- At this stage, multiple EET set are promoted for the definition of the use cases, satisfying both ship technical and operational requirements. In a later stage of the project, the proposed EETs will be further evaluated, and the exact combination will be finalised. It is highlighted that not all the EETs promoted for evaluation will be implemented

simultaneously. Compatibility issues between the technologies have not yet been addressed, as simulation models are required.

- For newbuilds the same operating requirements are maintained, although ship optimisation – e.g. ship lengthening, modification of machinery and possible interference with cargo and payload - may be considered, since they might affect the ship's achieved/required service speed. In general, solutions such as re-engining and WAPS are mostly preferred for NB due to the major modifications required.

2.4 General comments on EETs

The analysis was carried out for each ship case, and the findings are presented in detail in Section 4. In this section, some general comments are given for each EET, derived from the discussion made during the workshop – see also Table 17.

Table 17: Case specific EETs comments

EETs	General comment
Advanced HVAC & cooling systems	For passenger vessels that have extensive cooling requirements
Air lubrication systems (ALS)	ALS systems reduce the frictional component of ship resistance. Vessels with slow speeds, high block coefficient values, U-shaped hulls and extended flat bottom surfaces are the most suitable candidates as frictional resistance prevails, and these systems can be effective. Efficiency improvements may also be obtained in ships with moderate speeds (since at high speeds the wave making resistance component is dominant and ALS targets friction resistance). ALS performance depends on the draught of the vessel, in ballast or full load conditions. The main requirement is not to disrupt the continuous flow of bubbles by the ship wake field. Installation in slender vessels is not ideal. Trade-off between the energy to create the bubbles and the energy saved must be considered.
Alternative fuels	DF engine can be considered for possible power conversion to extend ship's compliance with the different short-, mid- and long-term targets. A full conversion to an alternative fuel is not always necessary, and blending fuel to an appropriate quantity can be selected to comply with the specific targets. Engine room conventional auxiliaries could also use a percentage of alternative fuel (e.g. 20% hydrogen) and operate to meet the 2030 targets.
Batteries	Batteries could be considered as secondary power conversion, coupled with the PTI/PTO, WAPS, OPS, or used to replace a GenSet for power peak saving. In case of fuel cell installation, batteries may be required to store potential excess of energy, or energy surplus at partial loads of operation.

EETs	General comment
Bulbous Bow optimisation	This option will be evaluated for retrofit vessels that have a bulbous bow highly affected by a change of the operation profile or average speed reduction. For ferries operating close to the design speed, assuming that their initial hull shape was well optimised for this speed, this option will not be considered, as the benefits would be marginal. The combined effect with other hydrodynamic measures (e.g. ALS) and interaction with WAPS should be further investigated.
CCS	CCS requires space for the carbon capture units and liquefaction/storage of captured CO_2, and scrubber installation. This option is challenging for long ocean-going voyages with no frequent port calls offering the possibility of unloading the captured CO2. CCS is promising for new tankers and retrofits with scrubbers (in the case that they are compatible with the CCS). It could be a potential solution also for retrofit non-bulk cargo (general cargo, containerships because they already have the infrastructure to install swappable containers for CO2 storage. It is a more challenging solution for ships having very high energy consumption, which may require towers higher than 14m and storage tanks up to 150m^2. The capacity of the tanks depends on the capture rate and the engine load.
FCs	FCs are more promising for short sea shipping vessels or ferries. In some retrofit cases, they could also be considered, mainly for auxiliaries or part of the propulsion with PTO or PTI.
HVO & biodiesel	These are standard solutions that could be easily implemented to the majority of ships. The focus will be on retrofits in combination of other EETs to meet the short-term targets.

EETs	General comment
Hydrodynamics	Hydrodynamic measures focus on either reducing a resistance component (e.g. frictional resistance which can be up to 85% of the total resistance for slow speed U-hull shaped vessels), or recover energy due to pressure losses in the ship's wake field or propeller-rudder area. Vessel waterline area, draught and speed are key parameters affecting such options. The actual effect of such measures should be examined through models. The combined effect with other technologies (e.g. WAPS, ALS) should be investigated. Moreover, for ships operating very close to the service / design speed, potential hydrodynamic gains will be minimal, as the initial hull form had already been optimized for those conditions. For inland vessels, aft-hull optimisation is particularly relevant, as changes in hull–bottom interactions in shallow waterways can significantly influence resistance and yield meaningful hydrodynamic benefits.
Lengthening of hull	This option is a common practice for inland vessels retrofit, as well as for Ro-Pax retrofits to allocate the additional space for batteries, FCs or other space-consuming equipment and increase the ship's payload. In case of lengthening all the hydrodynamic parameters, hull optimisation and ESD propeller options should be reconsidered. Propulsion power margin and maximum speed capability must be examined against the lengthening.
Methanol	Methanol is more promising for retrofits to meet short term regulatory targets. It may be coupled with CCS.

EETs	General comment
OPS	OPS will be mandatory from 2030 only for cruise ships, Ro-Pax, containerships. Containerships are the most promising and are required to have the cable handling system on board (they do not receive it from the port). For other vessels, like bulk carriers, it is not promising, not having high energy requirements and spending long time at anchorage and not at berth. Safety concerns arise for LPG carriers and similar vessels, due to simultaneous operation of charging during loading and unloading in an ATEX zone.
Propeller ESD	Such technologies aim at recovering energy losses induced by rotation of the propeller. They are easy to retrofit (requiring limited modification) and have a positive impact on the efficiency of the vessel, especially when optimised. However, their implementation is to be decided for each case study. Some EETs of this category are a “must have” with the WAPS (such as gate rudder). A nozzle is more promising when the vessel has a limited draught. CFD studies are required to evaluate them.
SG PTI, PTI/PTO	For long vessels (like containerships) this option could be considered since there is more space available. In general, it is a very efficient solution that could provide benefits in the majority of cases. It will be implemented on all the newbuilds. Bulk carriers are also promising due to the high-power demand and fuel consumption. Increased duration at constant engine loads is crucial for the operation of a SG. These systems can be combined with other electrification solutions (batteries, etc.). Furthermore, for ships operating at low main engine loads, PTOs may offer a way to achieve an optimal engine loading condition.

EETs	General comment
Steam/heat plant improvement/optimisation	This option is recommended for vessels with increased steam production, like tankers, that need to generate steam for cargo heating. Upgrades of such a system may include the boiler combustion, insulation of piping, installing VFDs at the attached auxiliaries. The combined effect with waste heat recovery options should be investigated.
WAPS	WAPS are more appropriate on vessels that do not have cranes and have space on the deck (Ro-Pax, bulk carrier, tankers). They are not feasible for IWV due to weather and bridge limitations. WAPS are more promising for newbuilds, but will also be investigated for retrofits. WAPS performance depends significantly on the vessel's operating profile, specifically on its routes and the prevailing weather conditions. When adopted, they can be combined with potential propeller improvements to enhance overall efficiency.
WHR	Must be combined with FCs and CCS solutions. Potentially it could be considered for all vessels, either for high temperature or low temperature applications. It should also be examined in combination with steam generation (e.g. installing a waste heat boiler downstream of the auxiliary engines).

3 Global EETs selection

In chapter 4 of D2.4 an extended analysis of globally applied EETs was presented. This section outlined specific technical and engineering characteristics of these EETs, explaining why they were considered to be theoretically applicable to all ship types from an engineering and generally technical standpoint. In particular, these EETs, do not require the installation of additional components or complex systems that could influence ship design or interfere with the integration of existing systems and technologies on board. The globally applied EETs, as described in deliverable D2.4, were sorted following the technical assessment of each one, or combined with each other, as appropriate, depending on cumulative benefits or operational and performance characteristics.

It is important to note that in D2.4 the analysis was focused on the technologies themselves, independent of the ship type or the operation profile. At this stage and for the purposes of D3.2, a more detailed approach was adopted. While globally applied EETs can be considered practically applicable to all ship types, the selection of the most suitable technology for adoption on a specific vessel fundamentally depends on the operational profile of each case. In Section 4 (Table 2), the list of globally applied EETs is provided as proposed in D2.4.

Among the ten (10) globally recognized EETs:

- three (3) are focused on optimizing operations, specifically targeting time spent in ports or during anchoring.
- one (1) pertains to electrification, with a focus on optimizing ship lighting systems.
- one (1) addresses the use of alternative fuels as a sustainable solution.
- three (3) aim to improve hydrodynamic efficiency by reducing hull resistance.
- two (2) optimize energy systems, specifically for the ship's piping system and main engine.

Based on the key technical findings of D2.4 regarding the globally applied EETs, as well as the operational profile of desktop cases, a summary table (

Table 18) presenting the specific desktop cases and the applicability level of each EET is presented below, as described in Chapter 2.

Table 18 provides some of the main thoughts and engineering approaches which are used to establish the final rank in Table 19.Table 19

Table 18: Case specific Globally Applied EETs comments

EETs	General comment
Variable Frequency Drive (VFD) for speed control (e.g. pumps, fans)	Most impactful when multiple pumps are available (e.g. tankers, LPG carriers), as they allow for precise speed control and energy optimization across different pumps. In simpler systems with fewer pumps, the effect is still positive but less significant.
Main Engine Tuning & Optimization	Not typically assessed in NB since the engine is selected from scratch during the design process. However, in retrofits, it becomes most impactful when a large number of engines are running at normal operational levels, or when the vessel is older and potentially experiencing performance degradation
Hull Surface Coatings & Low-Drag Paints	The impact depends on the hull surface. Larger surfaces benefit more from these coatings and paints due to the greater reduction in friction and drag
Trim & draught optimization	Evidence to date suggests the strongest gains are in container ships, with less consistent impacts across other vessel types (i.e. passenger vessels).
Lightweight shipbuilding materials (composites, aluminium)	Primarily an option for new builds, providing weight reduction benefits during the design stage, which in turn enhance fuel efficiency and overall performance
LED lights application	Passenger vessels typically have higher lighting loads due to greater illumination requirements. For other vessel types, the impact is positive but less significant.
Biodiesel	Same level of impact given that it affects proportionally the total fuel consumed.
Weather routing systems for voyage speed/fuel optimization	Primarily applicable to ocean-going ships as these vessels typically operate on long-duration, oceanic routes where weather conditions can significantly impact fuel consumption and travel times.
Just-in-time (JIT) arrival strategies	Not applicable to passenger vessels due to fixed schedules and time-sensitive operations. More impactful in containerships, enhancing the optimization of arrival times and reduction of idle waiting time at ports.
Cargo Load Factor Optimization	Not applicable to passenger vessels, as their capacity and load are generally fixed. In containerships, the impact is less significant, as the cargo load factor is often optimized by the nature of containerization and scheduling, but there's still some potential for efficiency gains through better planning and load distribution.

Table 19: Suitability ranking for globally applied EETs

High level category	NAME OF EET	General Cargo (RT)	Container ship (NB)	RO-PAX (NB)	RO-PAX (RT)	RO-PAX (RT)	Crude oil tanker (RT)	Crude oil tanker (NB)	Bulk carrier (RT)	LPG Tanker (RT)	IWT Chemical Tanker (NB)	IWT Chemical Tanker (RT)
Optimised energy systems	Variable Frequency Drive (VFD) for speed control (e.g. pumps, fans)											
	Main Engine Tuning & Optimization											
Hydrodynamics	Hull Surface Coatings & Low-Drag Paints											
	Trim & draught optimization											
	Lightweight shipbuilding materials (composites, aluminium)											

High level category	NAME OF EET	General Cargo (RT)	Container ship (NB)	RO-PAX (NB)	RO-PAX (RT)	RO-PAX (RT)	Crude oil tanker (RT)	Crude oil tanker (NB)	Bulk carrier (RT)	LPG Tanker (RT)	IWT Chemical Tanker (NB)	IWT Chemical Tanker (RT)
Electrification	LED lights application											
Sustainable, Climate-Neutral & Low-Emission Fuels	Biodiesel											
Operation & Digital Optimization	Weather routing systems for voyage speed / fuel optimization											
	Just-in-time (JIT) arrival strategies)											
	Cargo Load Factor Optimization											

4 Summary of case studies

This section provides a summary of the use cases form each case study, presenting first the outcomes of the Technical Workshop held in Genoa, followed by the input from the end users during a subsequent workshop, and concluding with a consolidated overview of the use cases.

4.1 Technical Workshop output

In Table 20 the EETs that were advanced for each use case are presented with the appropriate colour coding. The criteria used for the EETs selection per use case were discussed in Section 2.4, and in few cases specific comments are added on the table. It should be noted that this is an initial sorting of the technologies focused only on their applicability, and further detailed evaluation will be done in the following Tasks and WPs.

During the workshop in Genoa, it was proposed to consider one more retrofit use case for the Ro-Pax vessels on top of the two use cases (1 retrofit & 1 newbuild) that were proposed during the proposal stage. Given the substantial number of existing Ro-Pax vessels with extended operational lifespan, further investigation into retrofit options would provide significant value to the project. Therefore, for the ferry cases the consortium is proposing two retrofit cases, one for a bigger and one for a smaller Ro-Pax, as follows:

- Option A) Lengthening to accommodate large equipment and alternative fuel storage tanks: this would enable installation of alternative fuels and extensive electrification. Lengthening is proposed to add a compartment with batteries/FCs and at the same time increase the payload capacity (add cabins and garage lane meters) and improve the stability. A new propulsion arrangement will be proposed while keeping the same operating requirements.
- Option B) The ship is not lengthened but ‘smart’ solutions are investigated to improve the vessel’s efficiency without installing equipment needing much space. It is considered to keep the conservative fuel but install CCS.
- WAPS will also be investigated for both retrofits.

The newbuild case will require a complete restructuring of the vessel (re-engining and alternative fuel). Two options will be investigated: a) green fuel b) diesel electric (offering an optimal use of multiple engines and greater flexibility, as commonly adopted on cruise ships). In the latter case, a CCS will be included.

Table 20: EETs selection per use case

High level category	NAME OF EET	General cargo (RT)	Containers hip (NB)	RO-PAX (RT)	RO-PAX (RT)	RO-PAX (NB)	Crude oil tanker (RT)	Crude oil tanker (NB)	Bulk carrier (RT)	LPG tanker (RT)	IWT Chemical Tanker (NB)	IWT Chemical Tanker (RT)
CCS	Onboard Carbon Capture and Storage (CCS) Systems		(for methanol)			(if we do not select a green fuel)						
Electrification	Heaving Oscillating Systems											
	Full Electric Propulsion Concepts (e.g. dynafin, Superconducting electric motors)							(not justified by the operational profile)				
	Energy storage systems (ESS) – lithium-ion batteries	(in the case that PTO is effective)							(as a secondary / only if there is SG or WAPS)	(as seconda ry/ with WAPS)		
	Energy storage systems (ESS) – redox flow batteries (RFB)	(in the case that PTO is effective)							(as a secondary / only if there is SG or WAPS)	(as seconda ry/ with WAPS)		
	Onshore Power Supply (OPS)											
	Hydrofoil-Based Wave Energy Converters											

High level category	NAME OF EET	General cargo (RT)	Containers hip (NB)	RO-PAX (RT)	RO-PAX (RT)	RO-PAX (NB)	Crude oil tanker (RT)	Crude oil tanker (NB)	Bulk carrier (RT)	LPG tanker (RT)	IWT Chemical Tanker (NB)	IWT Chemical Tanker (RT)
	DC Grid technologies											
Fuels	Fuel Reforming/Cracking											
	Methanol											
	Biomethane											
	Ammonia			(complexity of retrofit)	(complexity of retrofit)					(ammonia as cargo ready)		
	Hydrogen											
Hydrodynamics	Hull Form Optimization (Streamlined Design for Efficiency)		(wind shields)									
	Air lubrication systems (ALS)			(minimum benefit /not for so high speeds)	(minimum benefit /not for so high speeds)							
	Bulbous Bow Optimization			(if we consider lengthening)	(if we consider lengthening)							

High level category	NAME OF EET	General cargo (RT)	Containers hip (NB)	RO-PAX (RT)	RO-PAX (RT)	RO-PAX (NB)	Crude oil tanker (RT)	Crude oil tanker (NB)	Bulk carrier (RT)	LPG tanker (RT)	IWT Chemical Tanker (NB)	IWT Chemical Tanker (RT)
	Hull Openings and Skeg Shape Optimization											
	Variaton of block coefficient/lengthening											
Optimised energy (heat) systems	Steam/heat plant improvements/optimization											
	Advanced HVAC & cooling systems											
	Waste heat recovery systems (WHRS)		(for CCS)	(with FCs)	(with FCs)				(with CCS)	(with CCS)		
Power conversion	Alternative Fuelled 2-S ICEs (e.g. hydrogen, ammonia, methanol)											
	Alternative Fuelled 4-S ICEs/Gensets (e.g. hydrogen, ammonia, methanol, biofuels)			(consider blending of fuels)	(consider blending of fuels)							
	PEM fuel cells											
	SOFC fuel cells											
	Shaft Generator PTI, PTO, PTI/PTO											

High level category	NAME OF EET	General cargo (RT)	Containership (NB)	RO-PAX (RT)	RO-PAX (RT)	RO-PAX (NB)	Crude oil tanker (RT)	Crude oil tanker (NB)	Bulk carrier (RT)	LPG tanker (RT)	IWT Chemical Tanker (NB)	IWT Chemical Tanker (RT)
Propeller ESD	Post-swirl ESD Contra-rotating propellers (CRP)			(condition of lengthening)	(condition of lengthening)							
	Pre-swirl ESD Wake Equalizing Ducts (WEDs)			(condition of lengthening)	(condition of lengthening)							
	Pre-swirl ESD Fins			(condition of lengthening)	(condition of lengthening)							
	Manoeuvring devices (e.g. Gate rudder)			(condition of lengthening)	(condition of lengthening)				(with WAPS)			
	Propeller Nozzle (e.g. Kort)											
	Post-swirl ESD PBCF (Propeller Boss Cap Fins)											
	Post-swirl ESD Grim Vane Wheel			(condition of lengthening)	(condition of lengthening)							
	Propeller-Retrofitting Advanced propeller Blade Sections (e.g. Winglets/kappel)			(condition of lengthening)	(condition of lengthening)							

High level category	NAME OF EET	General cargo (RT)	Containership (NB)	RO-PAX (RT)	RO-PAX (RT)	RO-PAX (NB)	Crude oil tanker (RT)	Crude oil tanker (NB)	Bulk carrier (RT)	LPG tanker (RT)	IWT Chemical Tanker (NB)	IWT Chemical Tanker (RT)
Renewables	WAPS - Soft Sails			(consider complexity of retrofit)	(consider complexity of retrofit)						(conflict with bridges)	(conflict with bridges)
	WAPS - Flettner Rotors (Magnus Effect Rotors)			(consider complexity of retrofit)	(consider complexity of retrofit)						(conflict with bridges)	(conflict with bridges)
	WAPS - Rigid Wing Sails			(consider complexity of retrofit)	(consider complexity of retrofit)						(conflict with bridges)	(conflict with bridges)
	WAPS - Kite Propulsion Systems			(consider complexity of retrofit)	(consider complexity of retrofit)						(conflict with bridges)	(conflict with bridges)
	WAPS - Suction Wings (Ventifoils)			(consider complexity of retrofit)	(consider complexity of retrofit)						(conflict with bridges)	(conflict with bridges)

4.2 Input from end users

A follow-up workshop was held on 28th November in Athens, hosted by Hydrus, to further discuss the findings from the Technical Workshop in Genoa with the end users. The focus was on the ocean-going vessels and not on the Inland water vessels. This is due to the fact that during the 1st technical workshop the IWV end users were present, therefore their input was already considered when defining the use cases.

Participants from all end users were present (online or hybrid) and each use case was discussed separately. The end users shared their experience, preference, technical challenges according to their expertise and the findings are reported in this section. The most promising combinations derived from the end users' input is summarised in Table 21. Accordingly, the initial matrix with the EETs selection for each use case was revised and presented in Table 22. The IWV use cases were not discussed during the 2nd workshop, thus they are not included in the updated Table 22 - the use cases remain those defined in Table 20.

In addition, it was decided to proceed with three Ro-Pax use cases, one newbuild and two retrofits.

Table 21: Promising combinations for use cases (End users input)

Use case	Promising combinations
Containership (NB)	• OPS (mandatory for containers) • Interest in investigating the SG, PTI/PTO. • High interest in investigating potential propeller ESD solutions: PBCF (PBCF + WED improve wake alignment and propeller efficiency) • Pre-swirl Wake Equalizing Duct (WED) • Windshield for forward container stacks (Windshield reduces aerodynamic drag, especially at service speeds >13kts) • Alternative fuels possibility: ammonia (ISO tanks) or hydrogen (swappable tanks). It has the possibility to lengthen and add a bay for fuel tanks.
General cargo ship (RT)	• Energy Storage System (ESS) – Li-ion batteries (hotel load support, peak shaving, load smoothing). There is space in the engine room that would allow the batteries to be installed. • Shaft Generator PTO (Batteries are charged ~50% from shaft generator (PTO)) • DC Grid Technologies (Smoother engine loading) • Hydrodynamics optimization (Bulbous bow) • ALS: could also be investigated since the vessel operates on an appropriate speed and the majority of the operation is in loaded condition. • ESDs: Post swirl ESDs to be investigated as per the end user suggestion.

Use case	Promising combinations
RO-PAX (RT)	• Lengthening to accommodate demanding space equipment and alternative fuel tanks: Enable alternative fuels (focus on methanol) and extensive electrification. Lengthening to add a compartment with batteries) and at the same time increase the payload capacity (add cabins and cargo lanes) and improve stability and hull resistance coefficients. • DF M/E retrofit (methanol) • WAPS to be investigated • High interest in investigating ALS. • OPS for port operation and peak savings and to charge the batteries during the extensive stay at port.
RO-PAX (NB)	• A) Green alternative fuel (hydrogen) + FCs & batteries for electricity production (either to cover the D/E engines, or the aux. loads of the ship) • B) Diesel electric (offers an optimal use of the engines when there are multiple engines, offering flexibility) & CCS & pod propulsion • SG & PTO/PTI (investigated only in option A) • WAPS to be investigated
RO-PAX (RT)	• Investigate 'smart' solutions (ESDs, globally applied etc.) to improve the vessel's efficiency without adding large equipment. Keep the conservative fuel with possible CCS. • Already equipped with SG, intention to apply the PTI approach as well, with batteries (charging at berth) as source of power. Possibility to investigate batteries on the higher deck, if stability margins allow it. • WAPS to be investigated. • Very interested in investigating the ALS. • M/E operation optimization/tuning • OPS for port operation. • Possibility to consider FCs with methanol and reformer.
Crude oil tanker (RT)	• DF M/E with alternative fuel (ammonia given that the vessel is ammonia-ready designed). • Partial CCS for conventional fuel. • WHRS. • Possibility to employ steam turbine for electricity downstream of the M/E (to take advantage of the unused excess steam). • ALS (to be investigated, it is attractive for a wide, relatively flat-bottomed tanker hull, more promising for newbuild). • Conventional ESDs: PBCF + pre-swirl device (duct or fins). • Existing steam pumps to be switched to electric (VFD) ones.

Use case	Promising combinations
Crude oil tanker (NB)	• WAPS (depending on deck layout, foldable or other geometries of WAPS will be investigated that could increase the ROI). • Green methanol. • DC grid + Shaft generator PTI/PTO. (Newbuild freedom). • ALS (to be investigated, it is attractive for a wide, relatively flat-bottomed tanker hull).
Bulk carrier (RT)	• Alternative-fuel ICE conversion (DF methanol). • WAPS (Bulk carriers usually have large unobstructed deck areas & positive to investigate due to wind profile). • ALS: could be an option given the ship's characteristics, but the end user would prefer avoid focusing on technologies that are dependent on cruising speed. • Shaft generator PTI/PTO. (M/E kept in reduced power while the shaft generator exports excess power to the batteries), it is a promising solution. • Small to medium ESS (Li-ion) used as: (buffer for load smoothing and peak shaving). • Pre-swirl ESD (ESDs provide robust "baseline" savings) • Post-swirl ESD (PBCF). The solution is very promising from the end user's side, due to effectiveness and easy implementation. • Promising for hull coating. • Promising for VFDs.
LPG tanker (RT)	• There is available space on the upper deck (currently two Type-C tanks – potential for expansion) that can be used for CO2 storage and/or bio-LPG fuel storage. • End user is very interested to investigate the possibility to burn the LPG boil off. • Onboard CCS system, possibly a partial CCS. The LPG reliquefaction system could be modified to be used also for the CO_2 refrigeration. • ALS: very promising and highly promoted by the end user given the "low impact" application and the proper speed that the vessel operates at. • DF M/E retrofit to use bio-LPG. • Possibility to investigate WAPS because there is space on the deck. • Major hydrodynamic modifications will not be considered since it is a very young vessel and operates very close to the design speed. • The drydock will take place in the next 2-3 years, so the end user's focus is in easy to implement in short term solutions.

Table 22: EETs selection per desktop case (after end users input, IWV excluded)

High level category	NAME OF EET	General cargo (RT)	Containership (NB)	RO-PAX (NB)	RO-PAX (R)	RO-PAX (R)	Crude oil tanker (RT)	Crude oil tanker (NB)	Bulk carrier (RT)	LPG tanker (RT)
CCS	Onboard Carbon Capture and Storage (CCS) Systems		(for methanol)	(if we do not select a green fuel)						
Electrification	Heaving Oscillating Systems									
	Full Electric Propulsion Concepts (e.g. dynafin, Superconducting electric motors)							(not justified by the operational profile)		
	Energy storage systems (ESS) – lithium-ion batteries	(in the case that PTO is effective)							(as a secondary / only if there is SG or WAPS)	(as secondary/ with WAPS)
	Energy storage systems (ESS) – redox flow batteries (RFB)	(in the case that PTO is effective)							(as a secondary / only if there is SG or WAPS)	(as secondary/ with WAPS)
	Onshore Power Supply (OPS)									
	Hydrofoil-Based Wave Energy Converters									

High level category	NAME OF EET	General cargo (RT)	Containership (NB)	RO-PAX (NB)	RO-PAX (R)	RO-PAX (R)	Crude oil tanker (RT)	Crude oil tanker (NB)	Bulk carrier (RT)	LPG tanker (RT)
	DC Grid technologies									
Fuels	Fuel Reforming/Cracking									
	Methanol									
	Biomethane									
	Ammonia				(complexity of retrofit)	(complexity of retrofit)				(ammonia as cargo ready) or bio LPG
	Hydrogen									
Hydrodynamics	Hull Form Optimization (Streamlined Design for Efficiency)		(wind shields)							
	Air lubrication systems (ALS)									
	Bulbous Bow Optimization				(if we consider lengthening)	(if we consider lengthening)				
	Hull Openings and Skeg Shape Optimization									
	Variaton of block coefficient/lengthening									

High level category	NAME OF EET	General cargo (RT)	Containership (NB)	RO-PAX (NB)	RO-PAX (R)	RO-PAX (R)	Crude oil tanker (RT)	Crude oil tanker (NB)	Bulk carrier (RT)	LPG tanker (RT)
Optimised energy (heat) systems	Steam/heat plant improvements/optimization									
	Advanced HVAC & cooling systems									
	Waste heat recovery systems (WHRS)		(for CCS)		(with FCs)	(with FCs)			(with CCS)	(with CCS)
Power conversion	Alternative Fuelled 2-S ICEs (e.g. hydrogen, ammonia, methanol)									
	Alternative Fuelled 4-S ICEs/Gensets (e.g. hydrogen, ammonia, methanol, biofuels)				(consider blending of fuels)	(consider blending of fuels)				
	PEM fuel cells									
	SOFC fuel cells									
	Shaft Generator PTI, PTO, PTI/PTO									

High level category	NAME OF EET	General cargo (RT)	Containership (NB)	RO-PAX (NB)	RO-PAX (R)	RO-PAX (R)	Crude oil tanker (RT)	Crude oil tanker (NB)	Bulk carrier (RT)	LPG tanker (RT)
Propeller ESD	Post-swirl ESD Contra-rotating propellers (CRP)				(condition of lengthening)	(condition of lengthening)				
	Pre-swirl ESD Wake Equalizing Ducts (WEDs)				(condition of lengthening)	(condition of lengthening)				
	Pre-swirl ESDFins				(condition of lengthening)	(condition of lengthening)				
	Manoeuvring devices (e.g. Gate rudder)				(condition of lengthening)	(condition of lengthening)			(with WAPS)	
	Propeller Nozzle (e.g. Kort)									
	Post-swirl ESD PBCF (Propeller Boss Cap Fins)									
	Post-swirl ESD Grim Vane Wheel				(condition of lengthening)	(condition of lengthening)				
	Propeller-Retrofitting Advanced propeller Blade Sections (e.g. Winglets/kappel)				(condition of lengthening)	(condition of lengthening)				

High level category	NAME OF EET	General cargo (RT)	Containership (NB)	RO-PAX (NB)	RO-PAX (R)	RO-PAX (R)	Crude oil tanker (RT)	Crude oil tanker (NB)	Bulk carrier (RT)	LPG tanker (RT)
Renewables	WAPS - Soft Sails				(consider complexity of retrofit)	(consider complexity of retrofit)				
	WAPS - Flettner Rotors (Magnus Effect Rotors)				(consider complexity of retrofit)	(consider complexity of retrofit)				
	WAPS - Rigid Wing Sails				(consider complexity of retrofit)	(consider complexity of retrofit)				
	WAPS - Kite Propulsion Systems				(consider complexity of retrofit)	(consider complexity of retrofit)				
	WAPS - Suction Wings (Ventifoils)				(consider complexity of retrofit)	(consider complexity of retrofit)				

4.3 General disclaimer for desktop cases selection

It should be noted that some differences exist compared to the desktop cases proposed at the project proposal stage. These changes reflect data availability, input from end users, and the need to improve overall fleet representation. As a result, one additional retrofit case has been included among the investigated use cases.

All desktop cases were selected to ensure comprehensive coverage of the global fleet and, consequently, to enhance the project's impact in developing a decarbonisation roadmap for the shipping sector by focusing on the largest vessel groups.

5 Conclusions

The main conclusions of this deliverable are the following:

- A data template was prepared identifying the data required (Annex A) for the use cases definition and evaluation - the majority of data have been collected.
- The specific vessels of the desktop studies were defined, and a preliminary analysis of their operating profile was performed.
- An initial sorting of the EETs according to literature sources was performed considering the different vessel types, suitability for newbuild or retrofit, and savings. A matrix (Annex B) was utilised as a guideline to define the use cases.
- A technical workshop was performed with engineering/design experts from the consortium to perform an initial screening of EETs to evaluate which would fit onboard each vessel case and propose the solutions that would be advanced for further assessment of the next tasks and WPs. Each EET was discussed following the actual operational behaviour of each ship, which allowed to move beyond a purely theoretical feasibility exercise. In addition, the technologies were considered depending on the remaining life of each vessel case and thus the need to comply with short-, mid- and long-term regulatory targets, in line with the expectations of the EUs “Fit for 55” legislative package.
- A sorting of the globally applied EETs took place, since not all globally EETs are relevant for each vessel case, thus the selection of the most suitable globally applied EETs for adoption on a specific vessel depending on the operational profile of each desktop case was performed.
- A second workshop was conducted to present the proposed EET selections to the vessel providers and collect their preferences regarding suitable technology combinations for their ships. The feedback received from the end users closely aligned with the initial sorting performed during the technical workshop, confirming the robustness of the proposed combinations.
- Finally, 11 preliminary use cases were defined: 5 retrofits and 6 newbuilds.
- Overall, the activities in T3.2 established the foundation for the evaluation to be carried out in T3.4 and T3.5, providing the necessary input for the detailed engineering development in WP4.

As a next step, input from the Technology Innovation Network (TIN), which brings together the relevant technology providers, will be required. Their contribution will support the subsequent tasks by supplying detailed technical data and integration insights, enabling a deeper review of the proposed EET combinations and helping to confirm their suitability for onboard implementation.

Annex A: Data template

General Info					
#	Category	Data			
1	Vessel name				
2	Vessel type (eg. Bulk, Tanker)				
3	Year of built				
4	IMO number				
5	Flag administration				
6	Hull number				
7	Shipyard				
8	Classification Society				
9	Vessel's Notations (from "Certificate of Class")				
10	DWT or TEUs (for Containers)		[ton] or [TEU]		
11	Gross Tonnage		[ton]		
12	LBP (length btw perpendiculars)		[m]		
13	Breadth		[m]		
14	Design (cruising) range		[nm]		
15	Operational (actual) range		[nm or max fare days or bunkering schedule]		
16	Service speed		[knots]		
17	Current Fuel(s) in use				
18	M/E model/type				
19	MCR (Maximum Continuous Rate) @ XXX rpm		[kW]		[rpm]
20	NCR (Nominal Continuous Rating) @ XXX rpm		[kW]		[rpm]
21	M/E SFOC (Specific Fuel Oil Consumption)		[g/kWh]		Fuel:
22	FO Consumption (M/E)		[MT/day]		
23	A/E model/type				
24	A/E output		[kW]		[rpm]
25	A/E SFOC (Specific Fuel Oil Consumption)		[g/kWh]		Fuel:
26	Number of A/Es installed				
27	MDO Consumption (A/E)		[MT/day]		
28	Exhaust gas boiler / Composite boiler type and capacity		Type		[kg/h]

General Info						
#	Category	Data				
29	Auxiliary boiler number and capacity		Number		[kg/h]	
30	Capacity of existing fuel storage tanks		[m3]		[m3]	
			[m3]		[m3]	
			[m3]		[m3]	
31	Exhaust Gas Scrubber existence		Y or N			
32	Shaft Generator Existence		Y or N			
33	Shaft Generator (if exists) rated output		[kW]		[rpm]	
34	ESDs fitted ? (if affirmative, brief description of items) [including EEXI compliance devices]					

Supporting Drawings/Documents	
35	Hull Particulars/Ship's Particulars/Pocket Plans
36	Particulars of Machinery Part
37	General Arrangement (GA)
38	E/R Arrangement
39	Arrangement of manholes in Upper Deck
40	Capacity Plan
41	Structural Drawings (Midship, Transversal, Longitudinal sections, Shell expansion)
42	Piping Diagrams (Hull, E/R)
43	Trim and Stability Booklet
44	Propulsion drawings (Propeller)
45	M/E Product Guide for the specific fitted engine(s) - if available
46	A/E Product Guide for the specific fitted engine(s) - if available
47	Sea Trials - Hull Part (Speed power curves/Speed consumption tables/M/E SFOC curves/Speed RPM curves/Model Tank tests results)
48	Sea Trials - Machinery Part
49	A/E Shop Tests

General Info		
#	Category	Data
50	Electrical Load Analysis (updated - including any modification i.e. BWTS installation)	
51	Steam Balance Tables (steam production)	
52	Aux. Boiler Manual (including composite boiler if applicable)	
53	Shaft Generator Data/PTO curves (if applicable)	
54	Noon Reports for 1 year or IMO DCS Table for 2023 (If EETs have been applied noon reports (at least) for a period before and after their application required)	
55	Biofouling reports	
Carbon profile		
56	MRV Technical File	
57	EEXI Technical File	
58	EEDI Technical File	
59	CII rating	
60	IWT relevant indexes	
Additional Info (Optional)		
61	Fuel Oil Change over procedure	

Annex B: General classification Matrix

Due to limited data availability, some information is not provided for certain technologies.

High-level category	NAME OF EET	TRL	Segment	Savings (%)	Savings (L/M/H)	Suitability	Age	Applicability
CCS	Onboard Carbon Capture and Storage (CCS) Systems	7	Bulk carrier		Medium	Medium	Up to 10	Both
CCS	Onboard Carbon Capture and Storage (CCS) Systems	7	Tanker		Medium	High	Up to 10	Both
CCS	Onboard Carbon Capture and Storage (CCS) Systems	7	Gas carrier		Medium	High	Up to 10	Both
CCS	Onboard Carbon Capture and Storage (CCS) Systems	7	RO-RO/RO-PAX		Medium	Medium	Up to 10	Both
CCS	Onboard Carbon Capture and Storage (CCS) Systems	7	Containerships		Medium	Medium	Up to 10	Both
Optimised energy (heat) systems	Steam/heat plant improvements/optimization	9	Bulk carrier	0.5-1.5%		Low	Up to 20	Both
Optimised energy (heat) systems	Steam/heat plant improvements/optimization	9	Tanker	0.5-1.5%		High	Up to 20	Both

High-level category	NAME OF EET	TRL	Segment	Savings (%)	Savings (L/M/H)	Suitability	Age	Applicability
Optimised energy (heat) systems	Steam/heat plant improvements/optimization	9	Gas carrier	0.5-1.5%		Low	Up to 20	Both
Optimised energy (heat) systems	Steam/heat plant improvements/optimization	9	RO-RO/RO-PAX	0.5-1.5%		Low	Up to 20	Both
Optimised energy (heat) systems	Steam/heat plant improvements/optimization	9	Containerships	0.5-1.5%		Low	Up to 20	Both
Optimised energy (heat) systems	Advanced HVAC & cooling systems		Bulk carrier	0.5-1.5%				
Optimised energy (heat) systems	Advanced HVAC & cooling systems		Tanker	0.5-1.5%				
Optimised energy (heat) systems	Advanced HVAC & cooling systems		Gas carrier	0.5-1.5%				
Optimised energy (heat) systems	Advanced HVAC & cooling systems		RO-RO/RO-PAX	0.5-1.5%				
Optimised energy (heat) systems	Advanced HVAC & cooling systems		Containerships	0.5-1.5%				

High-level category	NAME OF EET	TRL	Segment	Savings (%)	Savings (L/M/H)	Suitability	Age	Applicability
Hydrodynamics	Hull Form Optimization (Streamlined Design for Efficiency)	9	Bulk carrier	3.5-7%		High		NB
Hydrodynamics	Hull Form Optimization (Streamlined Design for Efficiency)	9	Tanker	3.5-5.75%		High		NB
Hydrodynamics	Hull Form Optimization (Streamlined Design for Efficiency)	9	Gas carrier	2.5-10%		High		NB
Hydrodynamics	Hull Form Optimization (Streamlined Design for Efficiency)	9	RO-RO/RO-PAX	6-8%		High		NB
Hydrodynamics	Hull Form Optimization (Streamlined Design for Efficiency)	9	Containerships	2-10%		High		NB
Hydrodynamics	Hull Form Optimization (Streamlined Design for Efficiency)		Inland	17-24%				
Hydrodynamics	Air lubrication systems (ALS)	9	Bulk carrier	6.9-19.5%		Medium	Up to 15	Retrofit
Hydrodynamics	Air lubrication systems (ALS)	9	Tanker	5-25%		Medium	Up to 15	Retrofit

High-level category	NAME OF EET	TRL	Segment	Savings (%)	Savings (L/M/H)	Suitability	Age	Applicability
Hydrodynamics	Air lubrication systems (ALS)	9	Gas carrier	4-5%		High	Up to 15	Retrofit
Hydrodynamics	Air lubrication systems (ALS)	9	RO-RO/RO-PAX	2-6%		Low	Up to 15	Retrofit
Hydrodynamics	Air lubrication systems (ALS)	9	Containerships	3.2-5%		High	Up to 15	Retrofit
Hydrodynamics	Air lubrication systems (ALS)		Inland	11-34%				
Hydrodynamics	Bulbous Bow Optimization	9	Bulk carrier	5-9%		None		
Hydrodynamics	Bulbous Bow Optimization	9	Tanker	11.5-13%		None		
Hydrodynamics	Bulbous Bow Optimization	9	Gas carrier	1.6-15%		Medium	Up to 20	Retrofit
Hydrodynamics	Bulbous Bow Optimization	9	RO-RO/RO-PAX	1.6-8%		Medium	Up to 20	Retrofit

High-level category	NAME OF EET	TRL	Segment	Savings (%)	Savings (L/M/H)	Suitability	Age	Applicability
Hydrodynamics	Bulbous Bow Optimization	9	Containerships	1.4-2.6%		High	Up to 20	Retrofit
Hydrodynamics	Bulbous Bow Optimization		Inland	16-36%				
Hydrodynamics	Hull Openings and Skeg Shape Optimization		Bulk carrier	1-6.7%%				
Hydrodynamics	Hull Openings and Skeg Shape Optimization		Tanker	1-8%				
Hydrodynamics	Hull Openings and Skeg Shape Optimization		Gas carrier	2-8%				
Hydrodynamics	Hull Openings and Skeg Shape Optimization		RO-RO/RO-PAX	1.2-4%%				
Hydrodynamics	Hull Openings and Skeg Shape Optimization		Containerships	2.9-5%				
Hydrodynamics	Hull Openings and Skeg Shape Optimization		Inland	1-7%	Low			

High-level category	NAME OF EET	TRL	Segment	Savings (%)	Savings (L/M/H)	Suitability	Age	Applicability
Hydrodynamics	Variation of block coefficient/lengthening		Bulk carrier					Retrofit
Hydrodynamics	Variation of block coefficient/lengthening		Tanker					Retrofit
Hydrodynamics	Variation of block coefficient/lengthening		Gas carrier					Retrofit
Hydrodynamics	Variation of block coefficient/lengthening		RO-RO/RO-PAX					Retrofit
Hydrodynamics	Variation of block coefficient/lengthening		Containerships					Retrofit
Hydrodynamics	Variation of block coefficient/lengthening		Inland	1-6%				Retrofit
Electrification	Heaving Oscillating Systems		Bulk carrier	10-40%				
Electrification	Heaving Oscillating Systems		Tanker	10-40%				

High-level category	NAME OF EET	TRL	Segment	Savings (%)	Savings (L/M/H)	Suitability	Age	Applicability
Electrification	Heaving Oscillating Systems		Gas carrier	10-40%				
Electrification	Heaving Oscillating Systems		RO-RO/RO-PAX	10-40%				
Electrification	Heaving Oscillating Systems		Containerships	10-40%				
Electrification	Full Electric Propulsion Concepts (e.g. dynafin, Superconducting electric motors)		Bulk carrier	10-25%				
Electrification	Full Electric Propulsion Concepts (e.g. dynafin, Superconducting electric motors)		Tanker	10-25%				
Electrification	Full Electric Propulsion Concepts (e.g. dynafin, Superconducting electric motors)		Gas carrier	10-25%				
Electrification	Full Electric Propulsion Concepts (e.g. dynafin, Superconducting electric motors)		RO-RO/RO-PAX	10-25%				
Electrification	Full Electric Propulsion Concepts (e.g. dynafin, Superconducting electric motors)		Containerships	10-25%				

High-level category	NAME OF EET	TRL	Segment	Savings (%)	Savings (L/M/H)	Suitability	Age	Applicability
Power conversion	Alternative Fuelled 2-S ICEs (e.g. hydrogen, ammonia, methanol)		Bulk carrier		Medium			
Power conversion	Alternative Fuelled 2-S ICEs (e.g. hydrogen, ammonia, methanol)		Tanker		Medium			
Power conversion	Alternative Fuelled 2-S ICEs (e.g. hydrogen, ammonia, methanol)		Gas carrier		Medium			
Power conversion	Alternative Fuelled 2-S ICEs (e.g. hydrogen, ammonia, methanol)		RO-RO/RO-PAX		Medium			
Power conversion	Alternative Fuelled 2-S ICEs (e.g. hydrogen, ammonia, methanol)		Containerships		Medium			
Power conversion	Alternative Fuelled 4-S ICEs/Gensets (e.g. hydrogen, ammonia, methanol, biofuels)		Bulk carrier		Medium			
Power conversion	Alternative Fuelled 4-S ICEs/Gensets (e.g. hydrogen, ammonia, methanol, biofuels)		Tanker		Medium			
Power conversion	Alternative Fuelled 4-S ICEs/Gensets (e.g. hydrogen, ammonia, methanol, biofuels)		Gas carrier		Medium			

High-level category	NAME OF EET	TRL	Segment	Savings (%)	Savings (L/M/H)	Suitability	Age	Applicability
Power conversion	Alternative Fuelled 4-S ICEs/Gensets (e.g. hydrogen, ammonia, methanol, biofuels)		RO-RO/RO-PAX		Medium			
Power conversion	Alternative Fuelled 4-S ICEs/Gensets (e.g. hydrogen, ammonia, methanol, biofuels)		Containerships		Medium			
Optimised energy (heat) systems	Waste heat recovery systems (WHRS)	9	Bulk carrier	5-12%		Medium	Up to 10	Both
Optimised energy (heat) systems	Waste heat recovery systems (WHRS)	9	Tanker	5-12%		Medium	Up to 10	Both
Optimised energy (heat) systems	Waste heat recovery systems (WHRS)	9	Gas carrier	5-12%		Low	Up to 10	Both
Optimised energy (heat) systems	Waste heat recovery systems (WHRS)	9	RO-RO/RO-PAX	5-12%		Medium	Up to 10	Both
Optimised energy (heat) systems	Waste heat recovery systems (WHRS)	9	Containerships	5-12%		High	Up to 10	Both
Power conversion	PEM fuel cells		Bulk carrier		Medium	Medium		

High-level category	NAME OF EET	TRL	Segment	Savings (%)	Savings (L/M/H)	Suitability	Age	Applicability
Power conversion	PEM fuel cells		Tanker		Medium	High		
Power conversion	PEM fuel cells		Gas carrier		Medium	High		
Power conversion	PEM fuel cells		RO-RO/RO-PAX		Medium	High		
Power conversion	PEM fuel cells		Containerships		Medium	Medium		
Power conversion	SOFC fuel cells	7	Bulk carrier		Medium	Medium	Up to 10	Both
Power conversion	SOFC fuel cells	7	Tanker		Medium	High	Up to 10	Both
Power conversion	SOFC fuel cells	7	Gas carrier		Medium	High	Up to 10	Both
Power conversion	SOFC fuel cells	7	RO-RO/RO-PAX		Medium	High	Up to 10	Both

High-level category	NAME OF EET	TRL	Segment	Savings (%)	Savings (L/M/H)	Suitability	Age	Applicability
Power conversion	SOFC fuel cells	7	Containerships		Medium	Medium	Up to 10	Both
Electrification	Energy storage systems (ESS) – lithium-ion batteries	9	Bulk carrier	0-30%		Medium	Up to 20	Both
Electrification	Energy storage systems (ESS) – lithium-ion batteries	9	Tanker	0-14%		Medium	Up to 20	Both
Electrification	Energy storage systems (ESS) – lithium-ion batteries	9	Gas carrier	0-14%		Medium	Up to 20	Both
Electrification	Energy storage systems (ESS) – lithium-ion batteries	9	RO-RO/RO-PAX	0-14%		Medium	Up to 20	Both
Electrification	Energy storage systems (ESS) – lithium-ion batteries	9	Containerships	0-30%		Medium	Up to 20	Both
Electrification	Energy storage systems (ESS) – redox flow batteries (RFB)	9	Bulk carrier	0-30%		Medium	Up to 20	Both
Electrification	Energy storage systems (ESS) – redox flow batteries (RFB)	9	Tanker	0-14%		Medium	Up to 20	Both

High-level category	NAME OF EET	TRL	Segment	Savings (%)	Savings (L/M/H)	Suitability	Age	Applicability
Electrification	Energy storage systems (ESS) – redox flow batteries (RFB)	9	Gas carrier	0-14%		Medium	Up to 20	Both
Electrification	Energy storage systems (ESS) – redox flow batteries (RFB)	9	RO-RO/RO-PAX	0-14%		Medium	Up to 20	Both
Electrification	Energy storage systems (ESS) – redox flow batteries (RFB)	9	Containerships	0-30%		Medium	Up to 20	Both
Electrification	Onshore Power Supply (OPS)	8	Bulk carrier	25-50%		Medium	Up to 20	Both
Electrification	Onshore Power Supply (OPS)	8	Tanker	25-50%		Medium	Up to 20	Both
Electrification	Onshore Power Supply (OPS)	8	Gas carrier	25-50%		Medium	Up to 20	Both
Electrification	Onshore Power Supply (OPS)	8	RO-RO/RO-PAX	25-50%		High	Up to 20	Both
Electrification	Onshore Power Supply (OPS)	8	Containerships	25-50%		High	Up to 20	Both

High-level category	NAME OF EET	TRL	Segment	Savings (%)	Savings (L/M/H)	Suitability	Age	Applicability
Power conversion	Shaft Generator PTI, PTO, PTI/PTO	9	Bulk carrier	2-10%		High	Up to 15	Both
Power conversion	Shaft Generator PTI, PTO, PTI/PTO	9	Tanker	2-10%		High	Up to 15	Both
Power conversion	Shaft Generator PTI, PTO, PTI/PTO	9	Gas carrier	2-10%		High	Up to 15	Both
Power conversion	Shaft Generator PTI, PTO, PTI/PTO	9	RO-RO/RO-PAX	2-10%		High	Up to 15	Both
Power conversion	Shaft Generator PTI, PTO, PTI/PTO	9	Containerships	2-10%		High	Up to 15	Both
Electrification	Hydrofoil-Based Wave Energy Converters		Bulk carrier	10-20%				
Electrification	Hydrofoil-Based Wave Energy Converters		Tanker	10-20%				
Electrification	Hydrofoil-Based Wave Energy Converters		Gas carrier	10-20%				

High-level category	NAME OF EET	TRL	Segment	Savings (%)	Savings (L/M/H)	Suitability	Age	Applicability
Electrification	Hydrofoil-Based Wave Energy Converters		RO-RO/RO-PAX	10-20%				
Electrification	Hydrofoil-Based Wave Energy Converters		Containerships	10-20%				
Electrification	DC Grid technologies		Bulk carrier	15%				
Electrification	DC Grid technologies		Tanker	15%				
Electrification	DC Grid technologies		Gas carrier	15%				
Electrification	DC Grid technologies		RO-RO/RO-PAX	15%				
Electrification	DC Grid technologies		Containerships	15%				
Propeller ESD	Post-swirl ESD Contra-rotating propellers (CRP)		Bulk carrier	10%				

High-level category	NAME OF EET	TRL	Segment	Savings (%)	Savings (L/M/H)	Suitability	Age	Applicability
Propeller ESD	Post-swirl ESD Contra-rotating propellers (CRP)		Tanker	10%				
Propeller ESD	Post-swirl ESD Contra-rotating propellers (CRP)		Gas carrier	10%				
Propeller ESD	Post-swirl ESD Contra-rotating propellers (CRP)		RO-RO/RO-PAX	10%				
Propeller ESD	Post-swirl ESD Contra-rotating propellers (CRP)		Containerships	10%				
Propeller ESD	Pre-swirl ESD Wake Equalizing Ducts (WEDs)	9	Bulk carrier	5-7%		High	Up to 20	Both
Propeller ESD	Pre-swirl ESD Wake Equalizing Ducts (WEDs)	9	Tanker	5-7%		High	Up to 20	Both
Propeller ESD	Pre-swirl ESD Wake Equalizing Ducts (WEDs)	9	Gas carrier	5-7%		Low	Up to 20	Both
Propeller ESD	Pre-swirl ESD Wake Equalizing Ducts (WEDs)	9	RO-RO/RO-PAX	5-7%		Low	Up to 20	Both

High-level category	NAME OF EET	TRL	Segment	Savings (%)	Savings (L/M/H)	Suitability	Age	Applicability
Propeller ESD	Pre-swirl ESD Wake Equalizing Ducts (WEDs)	9	Containerships	5-7%		Medium	Up to 20	Both
Propeller ESD	Pre-swirl ESD Fins	9	Bulk carrier	2-4%		High	Up to 20	Both
Propeller ESD	Pre-swirl ESD Fins	9	Tanker	2-4%		High	Up to 20	Both
Propeller ESD	Pre-swirl ESD Fins	9	Gas carrier	2-4%		Low	Up to 20	Both
Propeller ESD	Pre-swirl ESD Fins	9	RO-RO/RO-PAX	2-4%		Low	Up to 20	Both
Propeller ESD	Pre-swirl ESD Fins	9	Containerships	2-4%		Medium	Up to 20	Both
Propeller ESD	Manoeuvring devices (e.g. Gate rudder)		Bulk carrier	10-15%				
Propeller ESD	Manoeuvring devices (e.g. Gate rudder)		Tanker	10-15%				

High-level category	NAME OF EET	TRL	Segment	Savings (%)	Savings (L/M/H)	Suitability	Age	Applicability
Propeller ESD	Manoeuvring devices (e.g. Gate rudder)		Gas carrier	10-15%				
Propeller ESD	Manoeuvring devices (e.g. Gate rudder)		RO-RO/RO-PAX	10-15%				
Propeller ESD	Manoeuvring devices (e.g. Gate rudder)		Containerships	10-15%				
Propeller ESD	Manoeuvring devices (e.g. Gate rudder)		Inland	50%				
Propeller ESD	Propeller Nozzle (e.g. Kort)		Bulk carrier	10%				
Propeller ESD	Propeller Nozzle (e.g. Kort)		Tanker	10%				
Propeller ESD	Propeller Nozzle (e.g. Kort)		Gas carrier	10%				
Propeller ESD	Propeller Nozzle (e.g. Kort)		RO-RO/RO-PAX	10%				

High-level category	NAME OF EET	TRL	Segment	Savings (%)	Savings (L/M/H)	Suitability	Age	Applicability
Propeller ESD	Propeller Nozzle (e.g. Kort)		Containerships	10%				
Propeller ESD	Propeller Nozzle (e.g. Kort)		Inland	10-20%				
Propeller ESD	Post-swirl ESD PBCF (Propeller Boss Cap Fins)	9	Bulk carrier	1-2%		High	Up to 20	Both
Propeller ESD	Post-swirl ESD PBCF (Propeller Boss Cap Fins)	9	Tanker	1-2%		High	Up to 20	Both
Propeller ESD	Post-swirl ESD PBCF (Propeller Boss Cap Fins)	9	Gas carrier	1-2%		High	Up to 20	Both
Propeller ESD	Post-swirl ESD PBCF (Propeller Boss Cap Fins)	9	RO-RO/RO-PAX	1-2%		High	Up to 20	Both
Propeller ESD	Post-swirl ESD PBCF (Propeller Boss Cap Fins)	9	Containerships	1-2%		High	Up to 20	Both
Propeller ESD	Post-swirl ESD PBCF (Propeller Boss Cap Fins)		Inland	up to 3%				

High-level category	NAME OF EET	TRL	Segment	Savings (%)	Savings (L/M/H)	Suitability	Age	Applicability
Propeller ESD	Post-swirl ESD Grim Vane Wheel		Bulk carrier	4-7%				
Propeller ESD	Post-swirl ESD Grim Vane Wheel		Tanker	4-7%				
Propeller ESD	Post-swirl ESD Grim Vane Wheel		Gas carrier	4-7%				
Propeller ESD	Post-swirl ESD Grim Vane Wheel		RO-RO/RO-PAX	4-7%				
Propeller ESD	Post-swirl ESD Grim Vane Wheel		Containerships	4-7%				
Propeller ESD	Post-swirl ESD Grim Vane Wheel		Inland	up to 10%				
Propeller ESD	Propeller-Retrofitting Advanced propeller Blade Sections (e.g. Winglets/kappel)		Bulk carrier	2-4%				
Propeller ESD	Propeller-Retrofitting Advanced propeller Blade Sections (e.g. Winglets/kappel)		Tanker	2-4%				

High-level category	NAME OF EET	TRL	Segment	Savings (%)	Savings (L/M/H)	Suitability	Age	Applicability
Propeller ESD	Propeller-Retrofitting Advanced propeller Blade Sections (e.g. Winglets/kappel)		Gas carrier	2-4%				
Propeller ESD	Propeller-Retrofitting Advanced propeller Blade Sections (e.g. Winglets/kappel)		RO-RO/RO-PAX	2-4%				
Propeller ESD	Propeller-Retrofitting Advanced propeller Blade Sections (e.g. Winglets/kappel)		Containerships	2-4%		Low		
Renewables	WAPS - Soft Sails		Bulk carrier	5-35% route dependent				Both
Renewables	WAPS - Soft Sails		Tanker	5-35% route dependent				Both
Renewables	WAPS - Soft Sails		Gas carrier	5-35% route dependent				Both
Renewables	WAPS - Soft Sails		RO-RO/RO-PAX	5-35% route dependent				Both
Renewables	WAPS - Soft Sails		Containerships	5-35% route dependent		Low		Both

High-level category	NAME OF EET	TRL	Segment	Savings (%)	Savings (L/M/H)	Suitability	Age	Applicability
Renewables	WAPS - Flettner Rotors (Magnus Effect Rotors)		Bulk carrier	0-40% route dependent				Both
Renewables	WAPS - Flettner Rotors (Magnus Effect Rotors)		Tanker	0-40% route dependent				Both
Renewables	WAPS - Flettner Rotors (Magnus Effect Rotors)		Gas carrier	0-40% route dependent				Both
Renewables	WAPS - Flettner Rotors (Magnus Effect Rotors)		RO-RO/RO-PAX	0-40% route dependent				Both
Renewables	WAPS - Flettner Rotors (Magnus Effect Rotors)		Containerships	0-40% route dependent		Low		Both
Renewables	WAPS - Rigid Wing Sails		Bulk carrier	10-20%				Both
Renewables	WAPS - Rigid Wing Sails		Tanker	10-20%				Both
Renewables	WAPS - Rigid Wing Sails		Gas carrier	10-20%				Both

High-level category	NAME OF EET	TRL	Segment	Savings (%)	Savings (L/M/H)	Suitability	Age	Applicability
Renewables	WAPS - Rigid Wing Sails		RO-RO/RO-PAX	10-20%				Both
Renewables	WAPS - Rigid Wing Sails		Containerships	10-20%		Low		Both
Renewables	WAPS - Kite Propulsion Systems		Bulk carrier	1-40% route dependent				Both
Renewables	WAPS - Kite Propulsion Systems		Tanker	1-40% route dependent				Both
Renewables	WAPS - Kite Propulsion Systems		Gas carrier	1-40% route dependent				Both
Renewables	WAPS - Kite Propulsion Systems		RO-RO/RO-PAX	1-40% route dependent				Both
Renewables	WAPS - Kite Propulsion Systems		Containerships	1-40% route dependent		Low		Both
Renewables	WAPS - Suction Wings (Ventifoils)		Bulk carrier	5-20%				Both

High-level category	NAME OF EET	TRL	Segment	Savings (%)	Savings (L/M/H)	Suitability	Age	Applicability
Renewables	WAPS - Suction Wings (Ventifoils)		Tanker	5-20%				Both
Renewables	WAPS - Suction Wings (Ventifoils)		Gas carrier	5-20%				Both
Renewables	WAPS - Suction Wings (Ventifoils)		RO-RO/RO-PAX	5-20%				Both
Renewables	WAPS - Suction Wings (Ventifoils)		Containerships	5-20%		Low		Both
Fuels	Fuel Reforming/Cracking		Bulk carrier	depends on fuel				
Fuels	Fuel Reforming/Cracking		Tanker	depends on fuel				
Fuels	Fuel Reforming/Cracking		Gas carrier	depends on fuel				
Fuels	Fuel Reforming/Cracking		RO-RO/RO-PAX	depends on fuel				

High-level category	NAME OF EET	TRL	Segment	Savings (%)	Savings (L/M/H)	Suitability	Age	Applicability
Fuels	Fuel Reforming/Cracking		Containerships	depends on fuel				
Fuels	Methanol		Bulk carrier		Medium			
Fuels	Methanol		Tanker		Medium			
Fuels	Methanol		Gas carrier		Medium			
Fuels	Methanol		RO-RO/RO-PAX		Medium			
Fuels	Methanol		Containerships		Medium			
Fuels	Biomethane		Bulk carrier		Low			
Fuels	Biomethane		Tanker		Low			

High-level category	NAME OF EET	TRL	Segment	Savings (%)	Savings (L/M/H)	Suitability	Age	Applicability
Fuels	Biomethane		Gas carrier		Low			
Fuels	Biomethane		RO-RO/RO-PAX		Low			
Fuels	Biomethane		Containerships		Low			
Fuels	Ammonia		Bulk carrier		High			
Fuels	Ammonia		Tanker		High			
Fuels	Ammonia		Gas carrier		High			
Fuels	Ammonia		RO-RO/RO-PAX		High	Low		
Fuels	Ammonia		Containerships		High			

High-level category	NAME OF EET	TRL	Segment	Savings (%)	Savings (L/M/H)	Suitability	Age	Applicability
Fuels	Hydrogen		Bulk carrier		High	Medium		
Fuels	Hydrogen		Tanker		High	Medium		
Fuels	Hydrogen		Gas carrier		High			
Fuels	Hydrogen		RO-RO/RO-PAX		High			
Fuels	Hydrogen		Containerships		High	Medium		

Annex C: Operational profile of the inland vessel case study

The information herein provided is based on reports which cover almost one full calendar year, from the 6th of November 2024 to the 22nd of October 2025.

In that period, the use case vessel has completed 52 "full" voyages (i.e. vessel laden) and as much "empty voyages" (i.e. ballast). The vessel sails in "B regime", that is, it may operate 24 h a day. It transported around 115000 t of cargo (diesel, gasoline, HVO, FAME, heating oil) and consumed around 410 t of fuel. The vessel called 25 different ports in France, Germany, Belgium, and the Netherlands, while sailing on the rivers Rhine, Main, Moselle, Meuse, Scheldt, and the canals network in Belgium and the Netherlands (see **Figure 19**). However, when it comes to full journeys, the points of origin narrow down to seven ports only (see **Figure 20**). As much as 80% full journeys started in the ARA region. Thus, in most of the available voyages, the use case vessel sailed full upstream, and empty downstream, at least in the observed period.

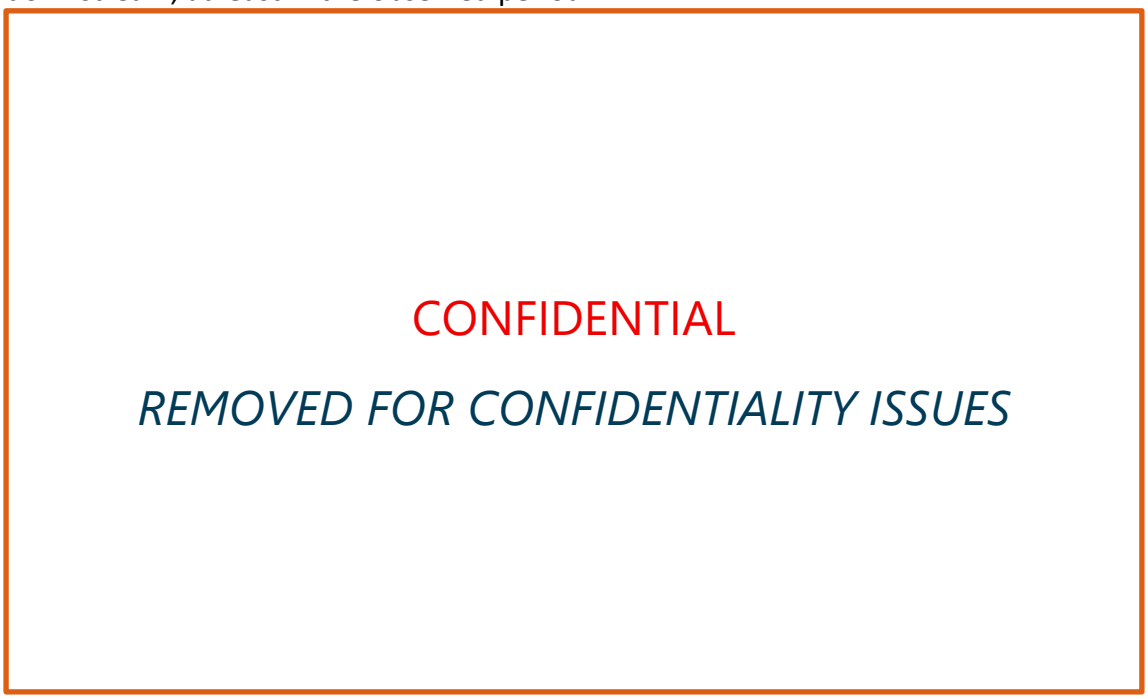

Figure 19: Ports of call of the use case inland tanker in period November 2024-October 2025

Figure 20: Ports of origin of full journeys of the use case inland tanker in period November 2024-October 2025

In the following, two most frequent routes in the observed period are analysed based on the information available from the reports on completed journeys. These two routes are

Antwerp-Trier (seven completed journeys) and Rotterdam-Ghent (three completed journeys), see Figure 21. The Antwerp-Trier route is 644 km long and includes 11 locks (nine on the river Moselle). The Rotterdam-Ghent route is 174.5 km long and includes four locks. The very fact that two most frequent routes comprise less than 20% of full journeys reflects the variety of operational profiles of the use case vessel.

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Figure 21: Two most frequent routes of the use case inland tanker in period November 2024-October 2025

Fuel consumption as a function of cargo carried on the Antwerp-Trier voyages is shown in Figure 22. It may be observed that there is no correlation between the data: with almost the same amount of cargo, the differences in fuel consumption may be up to 30%. Moreover, the fuel consumption in case when vessel carried 900 t was 14.1 t, whereas in case when vessel carried 2350 t of cargo, the fuel consumption was 13.3 t. These differences may have come as a consequence of a number of previously indicated reasons, whereby the most prominent source of discrepancies could be the hydrodynamic effects in low water levels. In Figure 23, fuel consumption on the same journeys is shown as a function of sailing time. Again, it may be observed that there is no correlation between the two quantities; moreover, the sailing time may be between 70 and 150 hours. For the sake of comparison, online route planner used in inland navigation blueroadmap.nl estimates the duration of the voyage of the vessel of the same type and size to 70.5 h. Significant differences between the journeys may be observed with respect to the time spent sailing vs. the time spent in port, as well (Figure 24 and Figure 25). The time spent in port may take less than 10% of time for the entire voyage (as was the case in voyage No. 4, see Figure 17), but it may also amount to 45% of the entire journey (as was the case in voyage No. 7, see Figure 17). It may also be observed that in some cases, the total time spent in port may comprise significant waiting times, as was the case in the journey No. 7 given in Figure 16. Furthermore, based on the available data it cannot be

concluded how much “sailing” time has been spent in actual sailing, and how much in e.g. passing through 11 locks on the route.

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Figure 22 : Fuel consumption vs. cargo carried during voyages on the most frequent route of the use case inland tanker

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Figure 23: Fuel consumption vs. sailing time during voyages on the most frequent route of the use case inland tanker.

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Figure 24: Duration of different phases during voyages on the most frequent route of the use case inland tanker; "Total time loading/unloading" is the subset of the "Total time in port".

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Figure 25: Share of different phases during voyages on the most frequent route of the use case inland tanker

Similar conclusions may be derived from the reports concerning the second most frequent route (Rotterdam-Ghent) in the observed period. Even though the loading case was almost the same in each of the three voyages, the fuel consumption in one of the

voyages was as much as twice the fuel consumption in other voyages (Figure 26). Moreover, the fuel consumption was the highest during the shortest voyage (Figure 27).

Figure 26: Fuel consumption vs. cargo carried during voyages on the second most frequent route of the use case inland tanker

Figure 27: Fuel consumption vs. sailing time during voyages on the second most frequent route of the use case inland tanker