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D2.1 BlueBARGE use cases, technical specification and requirements

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Acronyms and Abbreviations	
Acronym/Abbreviation	**Meaning**
GHG	Greenhouse Gas
SSE	Shore Side Electricity
OPS	On Shore Power Supply
BESS	Battery Electricity Storage System
ROI	Return on Investment
DWT	Deadweight Tonnage
TEN-T	Trans-European Transport Network
AFIR	Alternative Fuels Infrastructure Regulation
RES	Renewable Energy Sources
ESPO	The European Sea Ports Organization
DR	Demand Response
PDS	Power Demand Smoothing
ECA	Environmentally Critical Areas
PSSA	Particularly Sensitive Sea Area
MPA	Marine Protected Area
IWT	Inland Waterway Transportation
ZEMars	Zero Emission Marinas
OECS	Offshore Electric Charging Station
BESS	Battery Energy Storage Systems
LNG	Liquefied Natural Gas
PM	Particulate Matter
MW	Megawatts
PAS	Publicly Available Specifications
LVSC	Low Voltage Shore Connection
HVSC	High Voltage Shore Connection
EMSA	European Maritime Safety Agency
MGO	Marine Gas Oil
MDO	Marine Diesel Oil
CI	Cold Ironing
HFO	Heavy Fuel Oil
VLSFO	Very Low Sulphur Fuel Oil
SFOC	Specific Fuel Oil Consumption
SPC	Shore Power Connection
ACBs	Air Circuit Brakers
MCCB	Molded Case Circuit Breaker
PMS	Power Management System
BMS	Battery Management System
AIS	Automatic Identification System
ISO	International Organization for Standardization
IEEE	Institute of Electrical and Electronics Engineers
ABS	American Bureau of Shipping
DNV GL	Det Norske Veritas – Germanischer Lloyd
PLC	Programmable Logic Controller
EMS	Energy Management System
LNG	Liquified Natural Gas
UC	Use Case

Table of Contents

List of Figures

List of Tables

1 - Executive Summary

This document presents a thorough analysis of the potential use cases, technical requirements, and user expectations related to power barge applications. At the core of this study lies the opportunity for power barges to provide practical solutions that enhance the lives of end users and offer alternative options across various sectors.

The use cases detailed in this document are as follows. However, these applications are not limited to these cases. There may be additional use cases that the authors have not identified. Reviewers are therefore encouraged to contribute their insights.

List of Use Cases:

1. Anchored Vessels
2. Moored Vessels
3. Isolated Inhabited Areas
4. Environmentally Critical Areas (Marine Protected Areas)
5. Charging of Small Transportation Vessels (Inland Waterway Transport)
6. Powering Leisure Boats Along the Coast
7. Powering Offshore Platforms - Oil Rigs
8. Charging from Offshore Power Plants and Wind Farms
9. Providing Power to Land After Natural Disasters
10. Charging BlueBARGE from Outer Anchored Vessels

Although these use cases are individually categorized for clarity, they can often be combined to enhance the field of applications and efficiency. Based on operational similarities, they are grouped into three main categories (umbrella cases):

1. Charging anchored ships and recharging the barge from offshore power sources (Use Cases: 1, 4, 5, 6, 8, 10)
2. Utilizing power barges as onshore power systems for moored vessels (Use Case: 2)
3. Supplying power from the barge to land and offshore structures (Use Cases: 3, 7, 9)

For each use case, power requirements were estimated using data from existing literature and from the experiences of project partners and stakeholders. This information serves as a foundation for business and technology developers, to support them in the assessment of capacity needs during product development and feasibility studies.

Recent research and analogous applications were examined with a needs-based approach, and ongoing projects with similar goals were reviewed. The industry appears to be exploring opportunities for power barges in various contexts, with a particular focus on offshore charging and providing power to isolated areas. Wherever possible, references to completed or ongoing Horizon projects are included to strengthen the connection between these projects.

As readers may already know, a consortium was formed among ongoing European maritime projects under the EUWT-SE (European Waterborne Transport Synergies Ecosystem) network, where BlueBARGE team also takes part in. The primary objectives are to adopt best practices, broaden the dissemination of results, and harmonize efforts across projects.

Consequently, significant efforts were made to establish connections to these projects. Reviewers are encouraged to contact the BlueBARGE project team if they identify any missing information that could benefit the ecosystem.

Given the comprehensive nature of these projects, project efficiency is crucial. As such, partners have taken great care to minimize duplication of efforts across similar projects. For instance, when a recently completed project (such as Ealing.eu) had already conducted research on existing regulations, the BlueBARGE consortium focused on verifying any updates or revisions rather than duplicating the work. If no updates were necessary, the relevant project was referenced without repetition of the same information.

It is also worth noting that participants have also gone through the documents and results of various national and international projects, not limited to Horizon but also including Interreg, CEF, and other applicable programs.

A survey was conducted to gather feedback from identified stakeholders. The survey questions are included in Appendix 1. The results were analyzed to understand expectations and validate the use cases. Additionally, several unstructured interviews were conducted with potential users, partners, and advisory board members to assess the initial feasibility of the use cases.

Understanding both barriers and enablers is essential to providing feedback to regulatory bodies and public authorities. The main challenges for maritime decarbonization are detailed. The responses for ocean-going and inland waterway stakeholders differed slightly. Results were shared under Chapter 5, Gap Analysis. The results related to shore power applications are briefly as follows;

1. Lack of economic or business viability,
2. Lack of knowledge,
3. Risks of technology lock-in,
4. Communication and standardization challenges.

Considering this context, a stakeholder mapping was completed for each use case, down to the persona level.

Initial evaluations suggest that instead of increasing the technical and financial risks associated with a universal barge, it may be more practical to group applications based on power and voltage requirements, resulting in 3-4 barge types to cover different ship categories. These questions will be addressed in detail in the project's later phases.

As previously noted, this project includes a demonstration with a 1.5MWh battery capacity (Li-Ion + Redox flow) to provide shore power to a tanker ship. The demo case, however, should be at least 500 kW. Tanker OPS applications face unique challenges due to safety concerns, necessitating a detailed risk assessment. Some initial findings are shared in this document, with particular attention to ATEX requirements in the design process.

Survey results show that about 90% of respondents believe that BlueBARGE can be a viable business case and a promising solution, and out of the listed use cases, following are the most promising:

1. UC4 - Environmentally critical areas (30 people answered “Very High”)
2. UC1 - Anchored vessels (27 people answered “Very High”)
3. UC9 - Providing power to land after natural disasters (26 people answered “Very High”)
4. UC2 - Moored Vessels (26 people answered “High”)

A technical requirements document has been prepared to gather and consolidate user needs, identifying approximately 30 key requirements. A summary of the results from the technical requirements document was shared under Chapter 5- Use requirement Elicitation. These technical specifications documents will remain a living document updated throughout the project's duration as new specifications emerge and are validated. An updated version of the requirements will be provided in later deliverable, on which the design and verification of the system will be based.

Power requirement levels are gathered under Chapter 4 with the data available from various resources, supporting the calculation of the capacity planning for the power barges. This case only includes moored or anchored vessels. For the rest of the use cases, a detailed analysis is required since the targets may vary to a great extent depending on the individual case.

The chapter regarding requirement elicitation (Chapter 5), as well as the missing Concept of Operations are linked to upcoming deliverables, within the context of WP2 tasks.

This deliverable is focused on establishing the overall objectives for the project and guiding it in the right direction to address industry concerns and actual industry needs.

2 - Introduction

The BlueBARGE project brings together a multidisciplinary consortium that includes ship owners, operators, ports, technology providers, integrators, classification societies and academia, aiming to design, develop and demonstrate a power-barge solution. The goal of this power barge is to provide Shore Side Electricity (SSE) for moored and anchored vessels, while also supporting other use cases (UCs). Mounted onboard a barge, the various containerized power supply modules, will provide offshore electricity based on an optimized power system that includes as a basis an innovative hybrid concept battery storage system of conventional lithium (Li-ion) batteries and the more innovative vanadium redox flow batteries (VRFB).

14 project partners coordinated by the American Bureau of Shipping will collaborate on a flexible concept for containerized power supply modules to provide green energy to vessels. This effort will address challenges related to electrical integration, interfacing with ships at offshore locations, ports, and local networks, as well as operational safety and regulatory compliance aspects. The project will explore various technical alternatives and configurations.

The fully integrated system developed through the BlueBARGE project seeks to contribute to the maritime industry's transition toward electrification and decarbonization at both EU and international levels.

Deliverable D2.1 is a part of WP2 which focuses on the following tasks:

- Further elaborate on and expand the identified BlueBARGE use cases by considering real-case scenarios from the wide spectrum of maritime industry and beyond and define them in detail.
- Specify power demands for the BlueBARGE use cases, by considering all necessary variables.
- Identify all technical, operational and safety requirements for setting up the basis for the design and development of the power barge solution, by also considering all relevant regulations and standards.
- Address all technical safety issues for all individual BlueBARGE modules towards their integration.
- Develop guidelines for covering all technical and operational safety aspects for offshore power supply, including training material for relevant personnel, to support the commercialization of BlueBARGE.

2.1 – Purpose and scope of the document

The aim of the deliverable document is to define the objectives for the BlueBARGE project, develop use cases, and identify the technical and operational requirements associated with these cases. It is essential to ensure that these objectives are aligned with industry expectations by utilizing the knowledge and experience of project partners and stakeholders.

This document also focuses on identifying the barriers, risks, and opportunities linked to the proposed use cases, while exploring the most effective operational strategies. A structured framework for decision-making will be developed for each use case, along with designing the concept of operations for both the demonstration phase and a broader application. Additionally, the document seeks to connect ongoing industrial and academic projects with the BlueBARGE initiative.

The requirements outlined in this deliverable will direct the subsequent work packages. As the project progresses, further details will be provided in the following chapters. This deliverable, therefore, serves as the foundation for the BlueBARGE project.

2.2 – Deliverable structure

The deliverable is structured into seven (7) sections, following the project and deliverable details, the table of contents and tables for abbreviations, document tables and figures:

Section 1 includes the executive summary of the deliverable.

Section 2 includes a short introduction to the deliverables' purpose, scope and structure.

Section 3 refers to the most crucial aspect of the deliverable which elaborates on the BlueBARGE use cases, including real-life scenarios and end-user aspects.

Section 4 focuses on the technical specifications referring to energy and power demand.

Section 5 includes the requirements elicitation process for the proposed power-barge system.

Section 6 includes the concluding remarks of the document, by focusing on the most important findings and aspects, as well as highlighting the next steps.

The document also includes a set of references used for its development, necessary appendix as references to the deliverable's main structure and finally a project disclaimer.

3 – BlueBARGE Use Cases

This chapter comprehensively investigates the actors, and the potential areas of application related to power barges. Subsections 3.1, 3.2 and 3.3 focus on these actors and stakeholders whereas subsection 3.4 provides an overview of the use cases. Finally. subsection 3.5 collects all the uses cases under 3 branches depending on the similarity of application.

3.1 – Stakeholder analysis

A stakeholder, according to the Project Management Body of Knowledge (PMBOK) Guide is defined as "an individual, group or organization that might affect, be affected by or perceive itself as affected by a decision, activity or outcome of a project or activity". Based on the project's contributors, a stakeholder can be either internal or external to the project. In the case of the BlueBARGE project, internal stakeholders refer to consortium members. The rest are identified as external stakeholders. The Advisory Board members, as it is set up within the context of T1.5 of the project, are considered as external stakeholders due to the consulting nature of their role and not a direct involvement in the project. The identification of stakeholders that are relevant to the entire life cycle of the proposed power-barge solution, i.e., the BlueBARGE system, is useful for understanding their expectations and projections on the future trajectories.

A list of stakeholders is shared below.

1. Regulation bodies & Public Authorities
2. Accreditation & Certification Organizations, Classification Societies
3. Shipping Companies/Ship Owners/Ship Operators and Managers
4. Ports and Port Operators
5. Companies Specialized in Risk Assessment & Environmental Monitoring
6. Power Systems & Equipment Manufacturers, s/w and h/w SMEs
7. Financiers & Investors focusing on Power and Water Technologies
8. Research Institutes and Universities.
9. Citizens - Social Organizations, Port-City Committees, National and World Climate Change Societies, Environmental Protection Agencies or Other Organizations Active in Environment & Health
10. Other

3.1.1 – Primary Stakeholders

For the BlueBARGE project, the *primary stakeholders* are defined as all direct beneficiaries, mainly the operators and the end-users who are or could be involved in the day-to-day system operation. Stakeholders are grouped in relation to their responsibilities to the operation.

Considering the identification of the barge operation; barge operators, tugboat owners and operators, port authorities and operators, as well as the parties responsible for the ship operation constitute the primary stakeholder list. Each identified stakeholder group is described in detail regarding the BlueBARGE innovation.

Bunkering Services and Barge Operators

Description: Bunkering service providers are responsible for the ship's marine fuel supply. This group of stakeholders shall have close contact with other parties such as the vessel and the terminal for smooth bunkering planning and proper alignment of other port activities. The bunkering service providers follow a specific protocol with bunkering standards covering documentation, fuel quality valuation, and other procedures.

Relevance: Since the bunkering companies are experienced in meeting the power needs of the vessels, they may take the responsibility and ownership of the BlueBARGE operation. They are experienced in aligning the whole process and communicating the protocols with the ship and the port side. Depending on the use cases, this responsibility is not limited to large ports but can also include inland waterways (IWT) and Emission Controlled Areas (ECAs).

Ports and Port Authorities

Description: The International Maritime Organization (IMO) and the Fit for 55 targets directly affect the ports and port authorities. Ports are expected to invest in SSE and take necessary actions. It may be important to consider the ports as public and private ports as their reactions may be slightly different.

Relevance: Ports are expected to act until 2030. Especially the ones on the Ten-T have higher urgency. However, there are several challenges to be solved such as infrastructure requirements, power availability, experience in electrification, congestion etc. Therefore, the ports are in the center of the transition and should participate in developing novel methods to achieve the targets.

Port and Terminal Operators

Description: Terminal operators are part of the ports which face the vessel owners and manage the operation and the logistics at the ports. So loading, unloading operations, efficient use of the areas are all under their responsibility.

Relevance: Depending on the vessel type, terminal operators carry different responsibilities. For example, in the case of a container ship, the services provided may differ from a bulk carrier. Especially in the case of inland waterways and moored vessel operations, the BlueBARGE integration to the process should be planned with terminal operators' foresight.

Ship Owners

Description: This stakeholder group refers to the owners of merchant ships. They shall be individuals or companies owning the assets (ships) and equip and exploit these for shipping cargo at an agreed freight rate. Most commonly, the ship owners are organized through a company, but it is usual for people or investment funds to be considered as ship owners too. The technical management of their fleet shall be performed in-house be the ship owners or it can be performed outsourced. Ship owners' primary ambition is to increase their profits by dealing with the trends of the market and proceeding with investments such as building new vessels or purchasing a specific type of existing vessel.

Relevance: Ship owners, through the ship operators are involved in the planning of meeting the regulations. As stated, the trend of the market will determine profitability through the rental prices. In case, if the ship operation becomes burdensome due to the fines related to carbon emissions, the business may be affected. In summary, both parties should consider the pros and cons of the upcoming regulations to run a successful business.

Ship Operators & Crew

Description: Ship Operators are in charge of a series of daily matters on the ship. The day-to-day responsibilities include voyage planning, monitoring of vessel's movements, voyage calculations (e.g. demurrage), cargo handling, insurance and other legal matters accompanied by administrative and financial routine procedures. The group of Ship Crew personnel reflect to the on-board essential team accountable for vessel's operations and maintenance during sailing or other port activities (i.e. berthing, cargo operations). Each crew member has a distinct role on board and collaborates with the rest of the team to ensure smooth ship's operation, safety of the crew and environment and security of the cargo. It is common practice; ship operators and crew have daily communication with each other for the day-to-day operational matters.

Relevance: Ship operators and the crew are the main actors in planning for decarbonization measures. For example, if the ship is going to wait in anchorage for couple of days (Use Case 1) due to any reason, they should plan for an offshore power service. Or as in Use Case 10, they can plan for Emission Trading System (ETS) and benefit from selling out excess capacity to the barges. Along with these macro responsibilities, the crew is also responsible for handling the cables and connecting them to the ship's switchbox. They should plan the whole process and make sure the safety and other regulatory guidelines are met. Communication for the whole process is also a part of the responsibility.

Tugboat Owners

Description: Tugboats are a requisite part of the marine industry, as they collaborate with vessels and barges to maneuver them safely and efficiently through challenging waterways or restricted waters. Tugboats are utilized in harbors, rivers, or shipyard areas. Individuals, shipping companies, independent marine towing companies or port authorities could be the owners of the tugboats.

Relevance: In the case of non-propelled barges, navigation relies on the tugboats. So, tugboats are part of the operation and the ownership of such an operation can be handled by tugboat owners. They can also share the ownership with barge owners or operators.

Tugboat Operators & Crew

Description: This stakeholder group refers to onshore personnel who arrange daily the planning and execution of tugboat's scheduled trips. Tugboat operators should have leadership, analytical and mathematical skills giving attention to details. Usually, the ownership and the operation of a tugboat are separated in the maritime industry. Tugboat crew offshore personnel is a highly skilled profession combining sea-going experience and other soft skills. This stakeholder group shall be diligent in safety matters for smooth maneuvering activities.

Relevance: In the non-propelled power barge case, as in the BlueBARGE case, tugboat operators are responsible for the operation. The tugboat crew will ensure that the connections are made on the shore and ship side. They will monitor the process, take necessary actions to achieve the correct connection depending on the ship type. Assuming there are no extra personnel on the barge, they own the process.

Traffic Management Services

Description: Traffic management services are a part of the port process. They are responsible for managing the congestion, minimizing delays and improving process efficiency. These responsibilities can be considered also by port authorities, or the responsibilities may be carried out by a third party.

Relevance: Being part of the planning process and managing the port congestion and traffic, the information provided by the services decides the length of stay at anchorage or at berth. So, the decisions taken by this team have a big effect on the planning and scheduling activities of the BlueBARGE.

3.1.2 – Secondary Stakeholders

For the power-barge concept, i.e., the BlueBARGE system, secondary stakeholder groups are defined as stakeholders that indirectly influence or are affected by the project and its outcomes. In effect, the term 'secondary stakeholders' refers to the stakeholder groups whose relationships with primary stakeholders are affected as a result of the project's outcomes. In this paragraph, each identified stakeholder group is described focusing on the relevance to the BlueBARGE innovation.

Regulatory and Standardization Bodies

Description: Regulatory and Standardization bodies ensure that the operations are safely conducted by enforcing regulations. Some of the important bodies for the maritime industry are the International Maritime Organization (IMO), International Organization for Standardization (ISO), Institute of Electrical and Electronics Engineers (IEEE) etc.

Relevance: In the BlueBARGE case, a power transfer as an SSE application will be a novel demonstration. Therefore, available regulations will be considered when possible. However, during the application, if gaps are observed between the regulations and the operation itself, these will be reported.

Public Authorities

Description: Public authorities are a range of governmental and semi-governmental institutions. Like regulatory bodies, they ensure operations are safely completed in the ports and maritime industry. In the case of public ports, port authorities take this function. European Maritime Safety Agency (EMSA) can be considered as one of the agencies and coast guards.

Relevance: Depending on the port management type, the public authority can be a primary stakeholder. In other cases, the relevant actors are indirectly involved in the process through guidelines, best practice guides or safety measures.

Classification Societies

Description: Classification societies are responsible for preparing the technical specifications for the construction and operation of ships and offshore structures. They provide feedback for the development of standards, oversee the projects by onsite inspections, risk assessment and checking for compliance to the existing standards. Some examples are American Bureau of Shipping (ABS), Det Norske Veritas – Germanischer Lloyd (DNV GL), RINA Services S.p.A. (RINA).

Relevance: In BlueBARGE project, ABS is one of the partners. Since there are several novelties involved in the system level components and the application, ABS will make sure that the solution adheres to the applicable standards. In case if the standards do not cover such as application, then new ones will be developed.

Shipyards and Designers

Description: Shipyards and designers take part in the design and manufacturing of newbuilds or retrofits. Depending on the project type, shipyards may take the responsibility of choosing the electrical system integrator for the project and even choose the component level manufacturers such as a Cable Management System (CMS) supplier for a specific project. Since these applications require shore and ship side modifications, designers who are used to working with the sockets of a supplier may prefer to proceed with these ones in the prospective projects.

Relevance: For power barge applications, depending on the user requirements and system level components, the design of the barge may change. After the completion of the design phase, manufacturing should be handled by a shipyard.

Power Systems and Electrical Equipment Manufacturers

Description: Power products range covers propulsion systems, generators, switchboards, panels, batteries, fuel cells, alternative fuel systems, HVAC and cooling systems, and onboard machinery. So, it is a very wide product range corresponding to a wide supplier base, including also electrical equipment manufacturing, such as cabling, sockets, plugs, panels and other products related to the electrical system of a vessel.

Relevance: BlueBARGE product is an integration of several systems and subsystems including the various power systems that could be considered for the BlueBARGE solution and the respective electrical equipment. Not only onboard equipment but also onshore equipment is also a part of this group.

Automation and Control Systems Manufacturers

Description: Management of power and energy units rely on automation system components. These may include programmable logic controller (PLC), relays etc. Software development including Power Management System (PMS) and Energy Management System (EMS) is usually handled by electrical system integrators.

Relevance: The hardware suppliers can be considered a secondary stakeholder if the class regulations are met. However, the software part of the control system is one of the most important features of a power barge unit.

Energy Providers

Description: Energy providers are public or private companies which are one of the enablers for such applications. In a port case, the energy provider should deliver the required power capacity at a designated area and then the port is responsible for adjusting the voltages and currents depending on the applications.

Relevance: For the BlueBARGE case, charging of batteries can be at the ports through shore power connection systems or at designated locations where the capacity is available. For alternative fuels, the same is valid. However, for example if Liquified Natural Gas (LNG) is used, a truck to ship application may be of relevance, in this case, the LNG service company replaces the infrastructure company.

Research Institutes and Academia

Description: Research institutes and academia take part in fundamental research activities and enable technology development.

Relevance: In BlueBARGE project and other EU projects as well, research institutes and universities participate and take various roles. In this project, universities participate in understanding the power requirements, establishing a framework for universal design of power systems and providing technical expertise.

Financiers & Investors

Description: Financing of infrastructure related projects is another important enabler for meeting the targets. There are already several applicable methods available such as credits, subsidies, grants and investments.

Relevance: BlueBARGE or – in general – power barge operations can be highly scalable with financial support.

The Public & Citizen Organizations

Description: Along with public authorities, public and citizen organizations are the main force behind the realization of decarbonization projects. Since the citizens are directly affected by the emissions, the issues elevate to public health and management level. Therefore, the pressure of the organizations is important for the whole ecosystem.

Relevance: Several of the use cases are related to public health, such as powering islands, supporting the infrastructure after natural disasters and powering leisure boats the ECAs and along the coastlines.

3.1.3 – The BlueBARGE stakeholders

The above analysis shows that the identified stakeholder groups include a wide range of actors, referring to different multi-disciplinary backgrounds, and focusing on different perspectives, i.e., operational, design, manufacturing, certification, and wider environment.

In the Table 3.1-1 below, the identified BlueBARGE stakeholders are further classified as follows:

- The operational area
- The containing business area
- The wider environment

Table 3.1-1: Stakeholder groups from BlueBARGE.

	Stakeholder Analysis	Operational Area	Containing Business Area	Wider Environment
Primary Stakeholders	Bunkering Services	X		
	Barge Operators	X		
	Ports and Port Authorities		X	
	Port and Terminal Operators		X	
	Ship Owners			X
	Ship Operators & Crew	X		
	Tugboat Owners			X

	Stakeholder Analysis	Operational Area	Containing Business Area	Wider Environment
	Tugboat Operators & Crew	X		
	Traffic Management Services	X		
Secondary Stakeholders	Regulatory and Standardization Bodies			X
	Public Authorities		X	
	Classification Societies			X
	Shipyards and Designers		X	
	Power Systems/Products Manufacturers		X	
	Electrical Equipment Manufacturers		X	
	Automation and Control Systems Manufacturers		X	
	Energy Providers		X	
	Research Institutes and Academia		X	
	Financiers & Investors		X	
	The Public & Citizen Organizations			X

3.2 – Stakeholder Engagement –Online Survey

In this first phase of the BlueBARGE project, it was essential to engage industry stakeholders to provide early input on the concept, potential use cases, and challenges. In more detail, stakeholders were engaged through an online survey (questionnaire), in order to support the process of Use Cases identification and verification, with respect to the power-barge concept, and therefore, the BlueBARGE solution. The questionnaire was structured and delivered in Google Forms, which is relatively easy to access and use, and can be found in Appendix I. The goals of the survey were to:

1. Assess the BlueBARGE concept and gather feedback from stakeholders
2. The review identified use cases and assessed the potential impact of BlueBARGE
3. Identify additional use cases
4. Provide real-life examples/scenarios related to the use cases
5. Identify early business enablers, business models, and value propositions

3.2.1 – Survey Structure

The survey comprised a preamble, which included a short description of the project and a disclaimer, followed by the main body divided into three segments, designed for respondents to complete within 10 minutes. It consisted of multiple-choice and a few open-ended questions to assess respondents' intuition. Here is a brief overview of each part of the questionnaire:

1. The first contains demographic questions to identify organizational details and their relevance to the project.
2. The second covers potential UCs, verifies and ranks them in importance, and provides the opportunity to identify additional ones. This section also provides real-life scenarios and examples to support the UCs.
3. The third focuses on the general requirements of the BlueBARGE system. Stakeholders are asked to assess and rank the importance of identified user (and system) requirements.

Participants were instructed to complete the questionnaire after submitting their identification and profile information. Stakeholders evaluated the concept of BlueBARGE and each UC using a Likert-type scale to quantify their level of agreement/disagreement or perceived importance, respectively. The concept was assessed using a five-item Likert-type scale ranging from "Strongly Disagree" to "Strongly Agree," while questions regarding the significance of the need, expected impact, and industry perspective priority for each UC were rated on a scale from "Very Low" to "Very High," with "Low," "Normal," and "High" falling in between. Furthermore, throughout the survey, the user could navigate back and forth to the instructions page anytime while answering the questionnaire. The option to skip a specific question generally and return later to answer it was also available.

3.2.2 – Dissemination Channels

This survey was distributed via email on July 22, 2024. The recipients were individuals from consortium partners' network contacts (Stakeholder Mapping list) who had opted to receive information regarding maritime-related projects such as BlueBARGE. The primary goal was to engage with these contacts using a two-pronged approach. While increasing awareness about BlueBARGE, the stakeholders were encouraged to subscribe to the project newsletter and follow its channels on LinkedIn and X and to forward it to other relevant stakeholders. Stakeholder participation in the survey was essential for defining the UCs and materializing them by creating energy and power demand specifications. Also, partners were encouraged to complete the study and urge members of their organizations to do the same to enhance input for WP2. The survey was open for responses until the end of July 2024.

3.2.3 – Analysis of Results

The survey questions are presented in detail in Appendix I (Survey for the BlueBARGE UCs). In this section the results (charts) will be presented followed by some remarks. The total number of participants in the survey was 62 persons, from across the industry, as presented below.

The chart shown in Figure 3.2-1 illustrates the percentage of people who are members of the BlueBARGE project or not. Approximately 84% of the people who completed the survey are not members of the project. Furthermore, Figure 3.2-2 illustrates the percentages of the stakeholder groups. The most prominent stakeholder groups participating in the survey are the "Port/Port Operators" with 50% and the "Port/Port Authorities" group with 12.9 %. Figure 3.2-3 illustrates the percentage distribution of survey respondents per their role within their organization, for a complete picture of the participants.

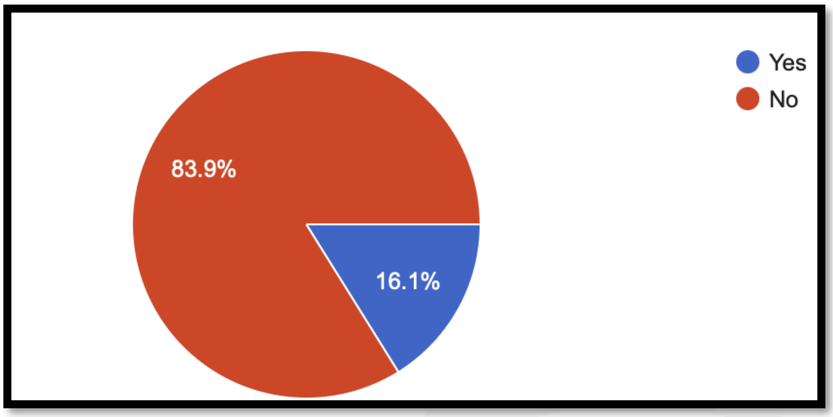

Figure 3.2-1: Chart illustrating whether the person completing the survey is a BlueBARGE member or not

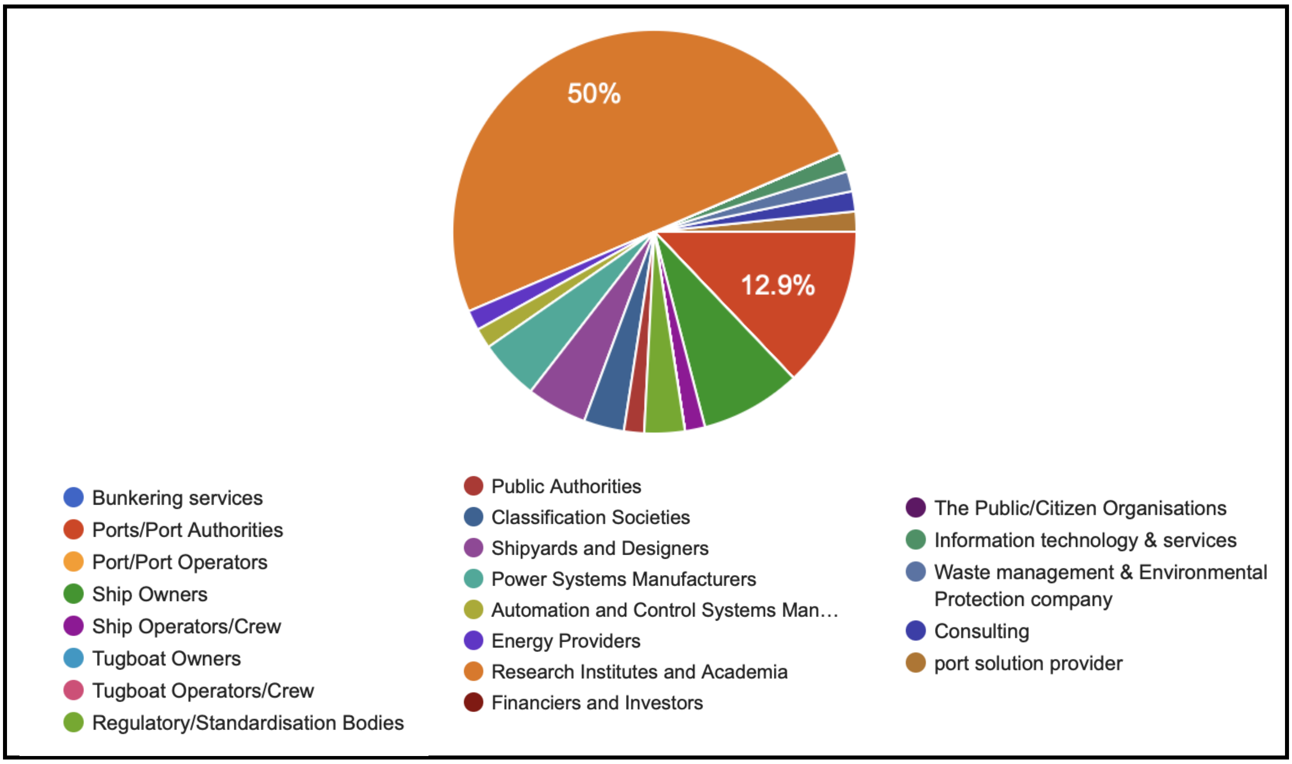

Figure 3.2-2: Percentage distribution of survey respondents per stakeholder group

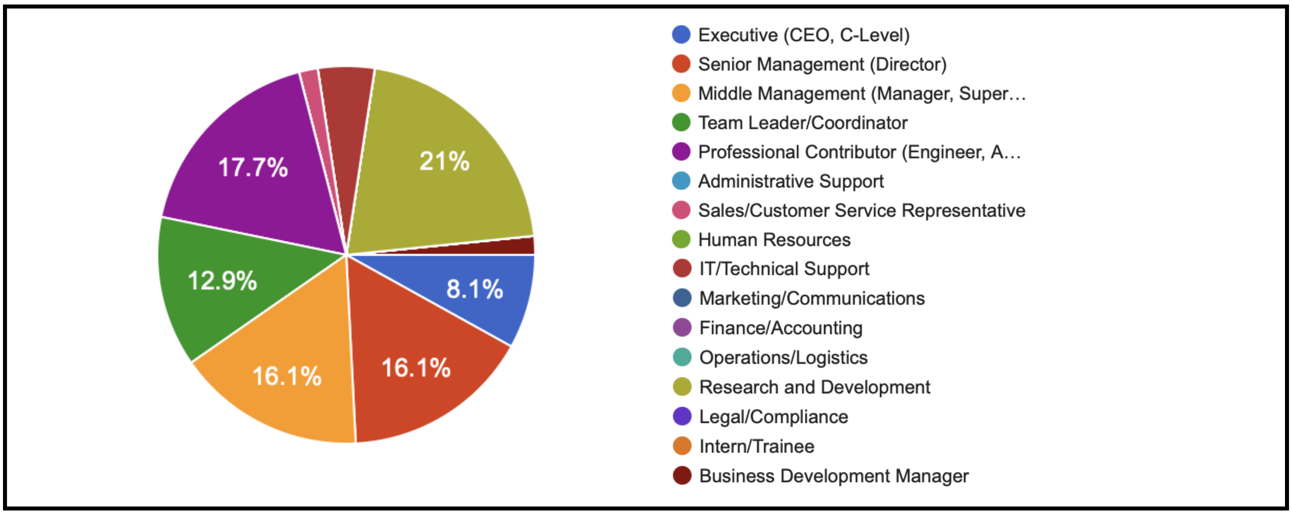

Figure 3.2-3: Percentage distribution of survey respondents per role within their organization.

With respect to the BlueBARGE concept, Figure 3.2-4 illustrates the percentage of people who strongly agree - 41.9 %, agree - 48.4% and are not sure -9.7% if the BlueBARGE concept for offshore power supply can be a promising electrification solution, leading to emission reductions and complementing SSE where needed. Results demonstrate with a high vote of about 90.3% of the people who completed the survey believe that the BlueBARGE concept is a promising solution. Furthermore, Figure 3.2-5 illustrates the percentage distribution the received answers to the question regarding most prominent difficulties for the implementation of the BlueBARGE. The most popular answers include reaching the energy capacity and the increased cost for designing and developing the power barge, including probably also operational costs.

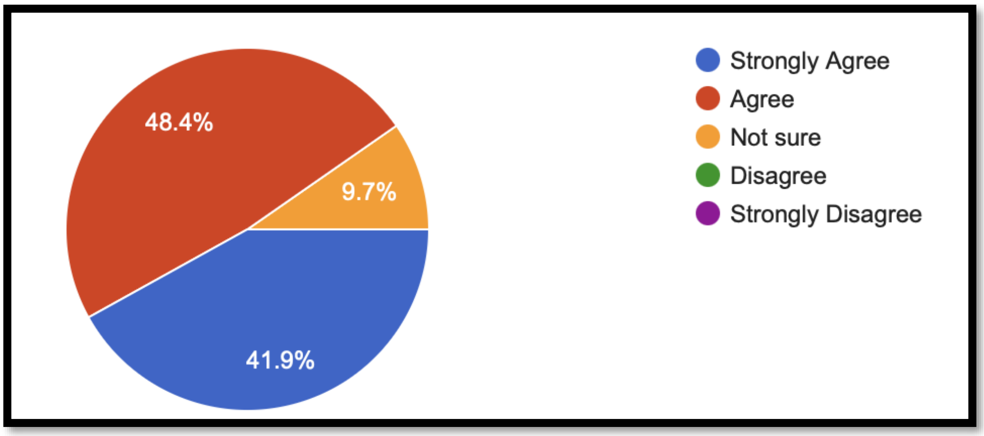

Figure 3.2-4: Percentage distribution of the answers to the question whether the BlueBARGE concept for offshore power supply can be a promising electrification solution or not.

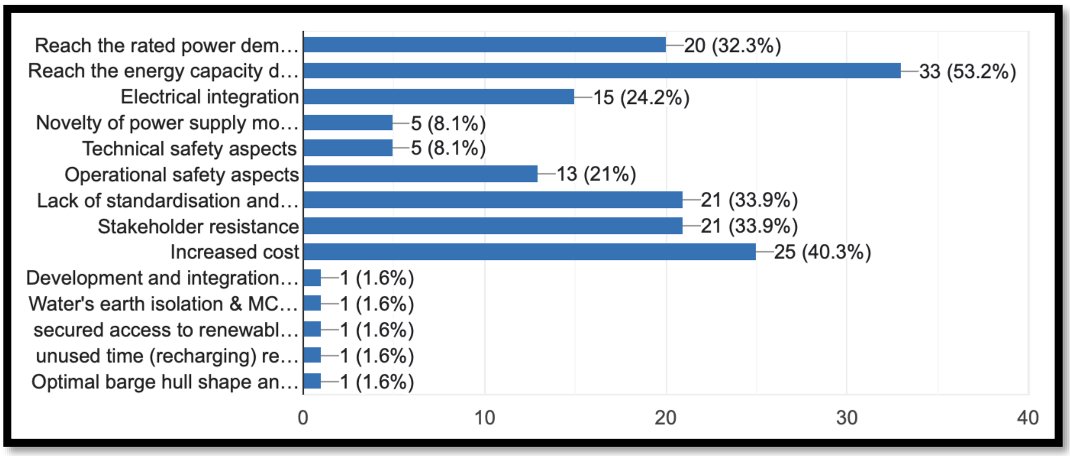

Figure 3.2-5: Percentage distribution of the most prominent difficulties for the implementation of the BlueBARGE project.

Figure 3.2-6 illustrates the percentage distribution of the received answers to the question "What could be the most promising solutions as power supply modules for the BlueBARGE concept, if we consider 2030 as the year to be available in the market?". The most popular answers are the hybrid battery systems and combination of batteries (43.5%), followed by fuel cells running on alternative fuels (38.7%) and gen sets running on other alternative fuels (33.9%).

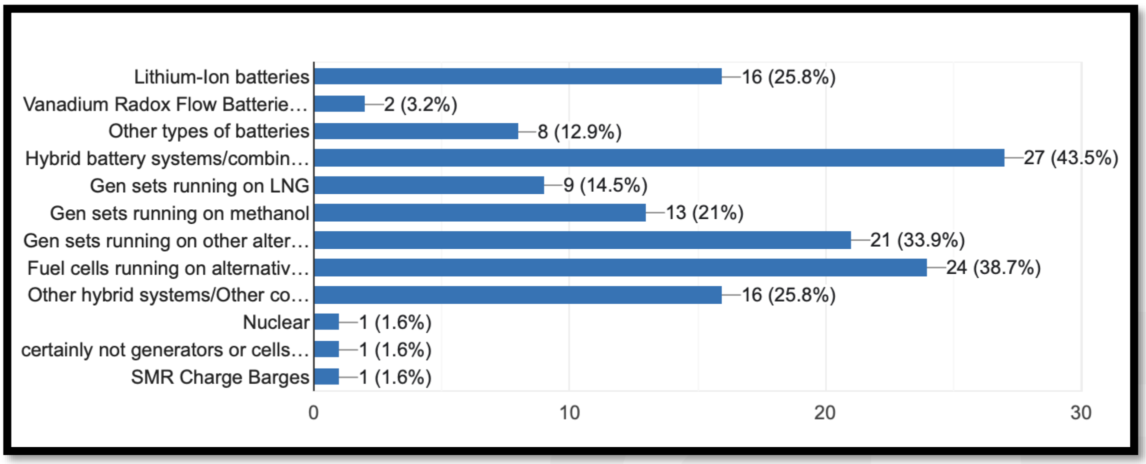

Figure 3.2-6: Percentage distribution of the most promising solutions as power modules for the BlueBARGE concept.

In addition, Figure 3.2-7 illustrates the percentage distribution of the answers to the question whether a self-propelled solution or a tugboat supported design (in order to reduce the complexity in the design) is more suitable. 38.7% of the people opted for the self-propelled solution, while 33.9% preferred tugboat supported design, and 27.4% of the people where not sure which option would be the best. Survey participants were asked through **Q2.05** to provide some additional comments for their choice.

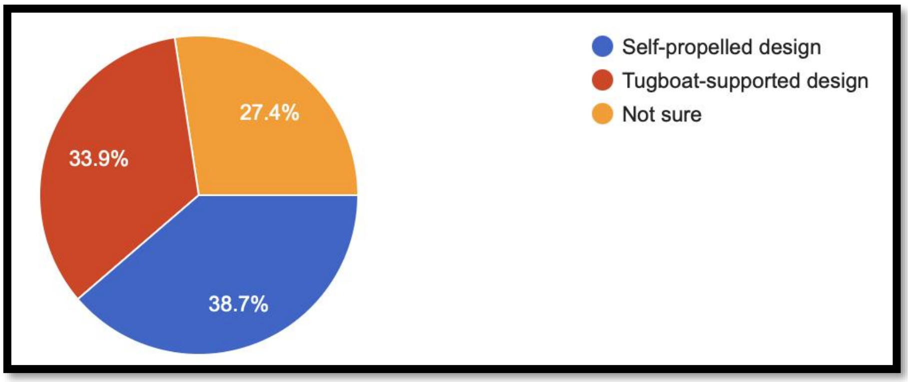

Figure 3.2-7: Percentage distribution of the answers to the question "Do you think that a self-propelled solution is more suitable, or a tugboat supported design should be more suitable to reduce complexity in the design?"

Regarding the Use Cases, a graph illustrating the distribution of the answers regarding the significance of the need of coverage for each Use Case is presented in Figure 3.2-8. As per the respondents answers the Use Case with the highest significance of coverage are UC4 - Environmentally critical areas (30 people answered "Very High"), UC1 - Anchored vessels (27 people answered "Very High"), UC9 - Providing power to land after natural disasters (26 people answered "Very High") and UC2 - Moored Vessels (26 people answered "High").

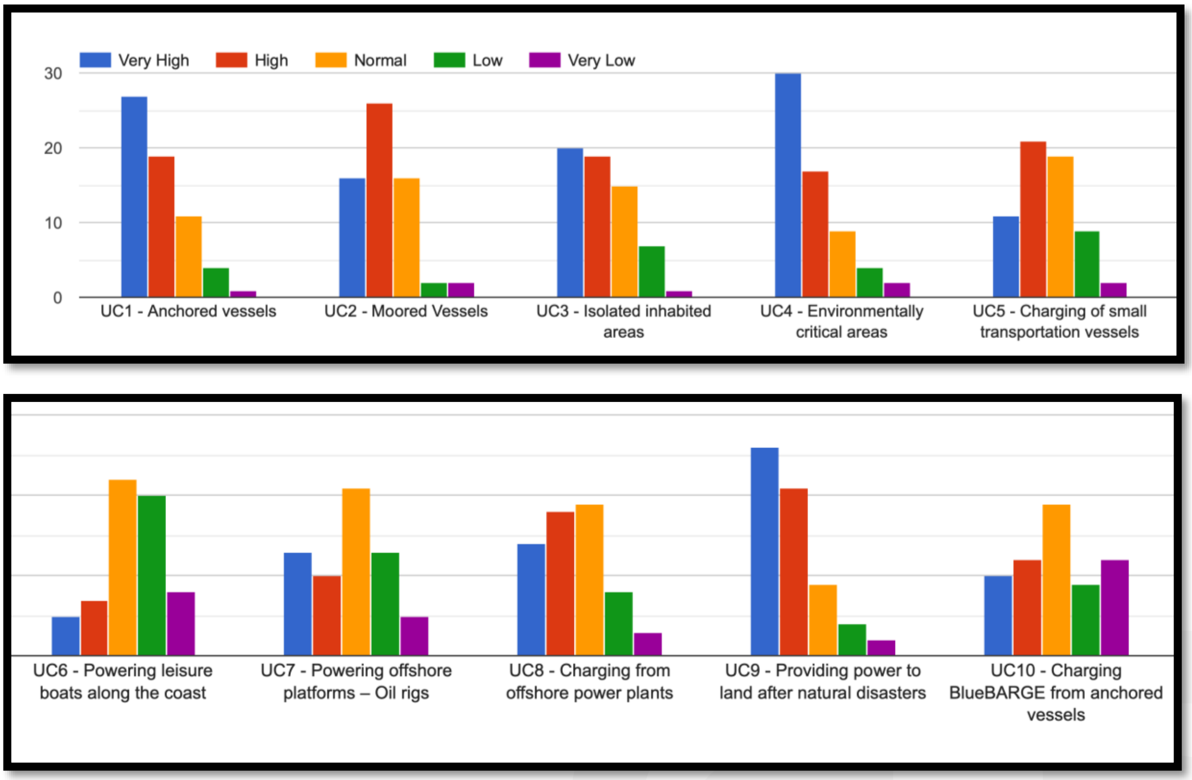

Figure 3.2-8: Ranking of the coverage significance per Use Case

Furthermore, a graph illustrating the distribution of the answers regarding the expected impact that the BlueBARGE concept will have per Use Case is presented in Figure 3.2-9. The Use Cases on which the BlueBARGE concept is believed that will have a higher impact are UC4 - Environmentally critical areas (27 people answered, “Very High” and 21 “High”), UC9 - Providing power to land after natural disasters (27 people answered, “Very High” and 18 “High”), UC1 - Anchored vessels (24 people answered, “Very High” and 25 “High”), UC2 - Moored Vessels (17 people answered, “Very High” and 26 “High”) and UC3 - Isolated inhabited areas (21 people answered, “Very High” and 18 “High”). Finally, in terms of Use Cases, Figure 3.2-10 illustrates the answers distribution considering the priority from an industry perspective per Use Case. The Use Cases ranked with the highest priority are UC1 - Anchored vessels (25 people answered, “Very High” and 25 “High”), UC2 - Moored Vessels (18 people answered, “Very High” and 25 “High”), UC4 - Environmentally critical areas (22 people answered, “Very High” and 19 “High”), UC9 - Providing power to land after natural disasters (18 people answered, “Very High” and 20 “High”) and UC3 - Isolated inhabited areas (19 people answered, “Very High” and 14 “High”).

It is crucial to comment on the results regarding the Use Cases, as they signify – and verify – the importance of the most highlighted by the project, through its Grant Agreement, use cases. These are the support of anchored vessels, the main use case of the project, the support in cases of environmental critical areas, the support of land areas after natural disasters, the support of isolated inhabited areas (as power barges were meant support) and the case of moored vessels, either in berthing dolphins or ports, especially in the case of the absence of cold ironing.

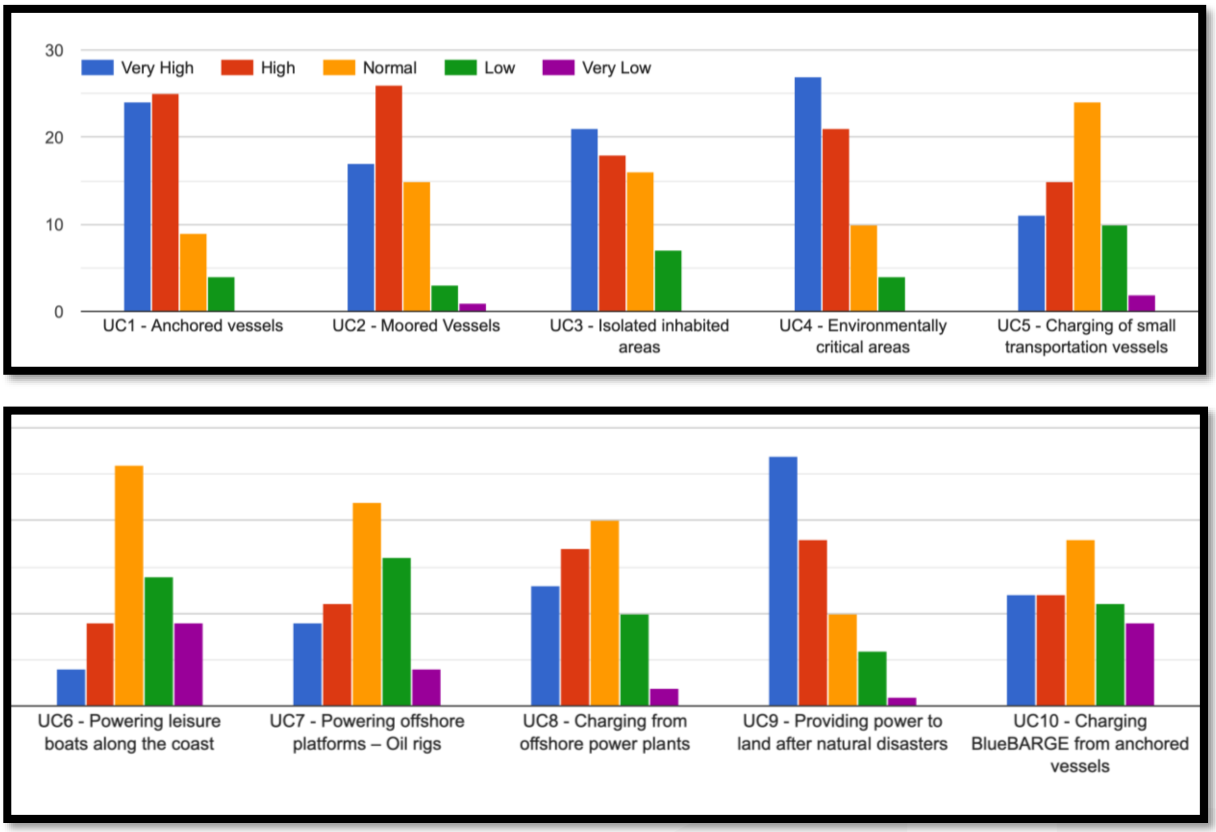

Figure 3.2-9: Ranking of the impact that the BlueBARGE concept would have per Use Case

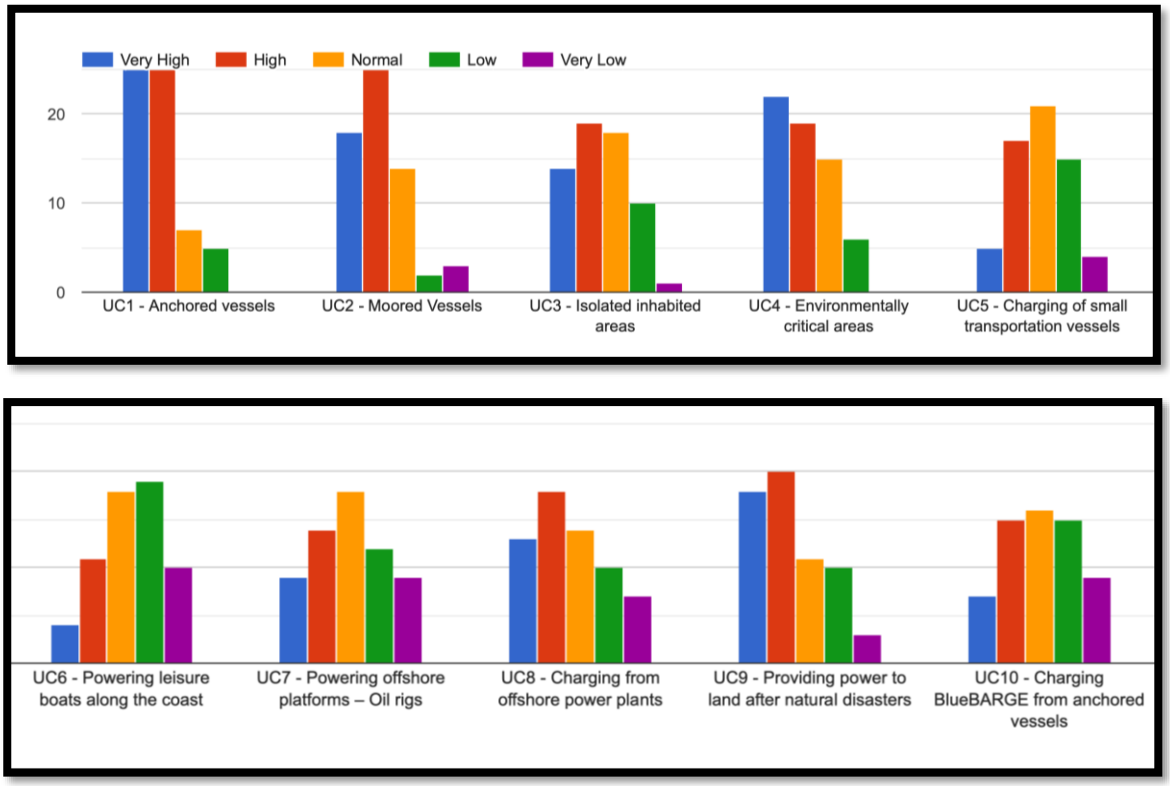

Figure 3.2-10: Priority ranking from an industry perspective per Use Case.

Survey participants were also asked to identify real-life scenarios/examples (e.g., specific port or anchorage area, island or inland or smaller port to support moored vessels, isolated inhabited areas that may need support, environmentally critical areas that require zero-emission compliance, etc.) where the BlueBARGE could be employed, with respect to any of the Use Cases. The provided answers included several ports, such as port of Copenhagen, Singapore, various Greek islands especially in Cyclades (e.g. Santorini) and the Port of Limassol, which are all considered in the analysis of Use Cases below, as well as in Section 4, for the analysis regarding power and energy demand.

Additionally, Figure 3.2-11 illustrates the answers regarding the specification of the reason behind increased waiting time at anchorage (in relation to UC1). Based on the received feedback the reasons affecting the most the waiting hours are Terminal unavailability, Cargo operations, Bunkering operation, Technical reasons/repairs, Audits and surveys and Detentions/regulatory compliance.

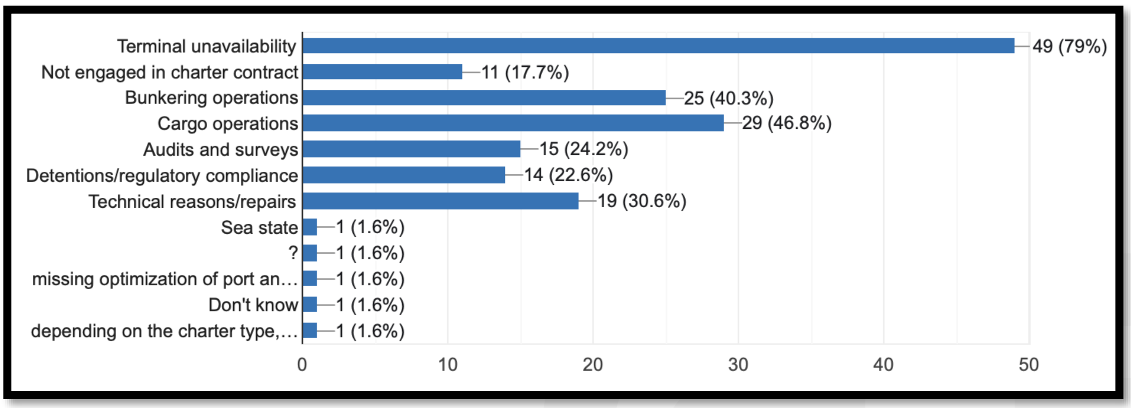

Figure 3.2-11: The root causes of increased waiting time at anchorage.

Following, Figure 3.2-12 illustrates which Use Cases the respondents believe are more realistic and promising. Specifically, the Use Cases that were selected as more realistic and promising are: UC1 - Anchored vessels, UC2 - Moored Vessels, UC4 - Environmentally critical areas, UC9 - Providing power to land after natural disasters and UC3 - Isolated inhabited areas. Finally, the survey participants were asked to identify additional Use Cases for the BlueBARGE concept. They provided interesting input and ideas, which are already covered by existing Use Cases.

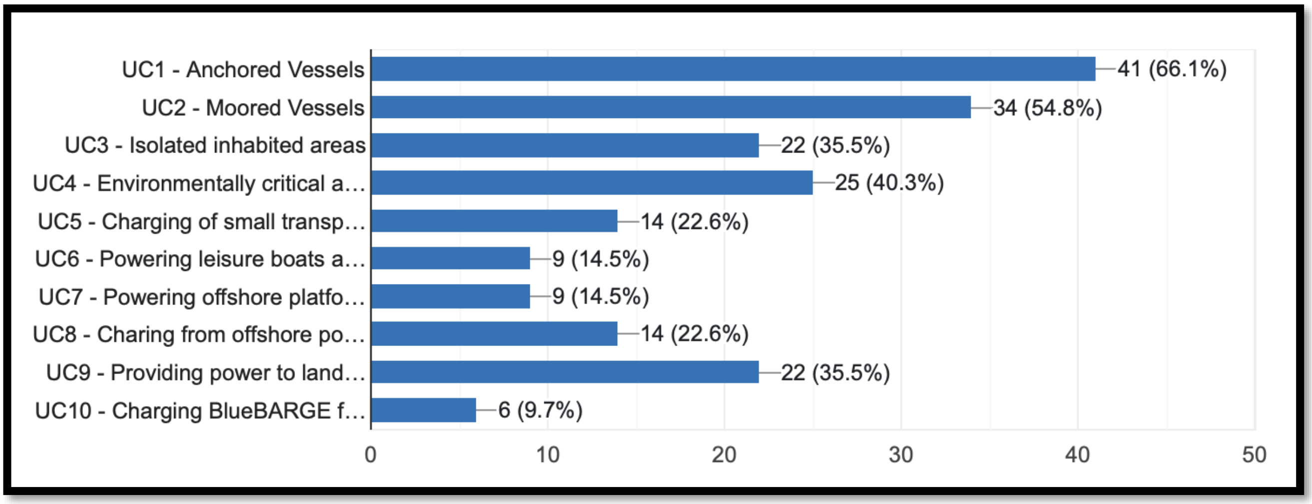

Figure 3.2-12: The most realistic and promising Use Cases.

3.3 – Identification of BlueBARGE personas

BlueBARGE will address the needs of different stakeholders being involved within its concept. The following table (Table 3.3-1) provides an overview of the main stakeholder groups (as identified in Chapter 3.1.1), which are categorized into two groups: primary and secondary [3.3-1]. The intention, besides the description of the stakeholder groups' individual points of interest for the BlueBARGE project in general, is to briefly describe the main benefits arising from the foreseen BlueBARGE operations and developed technologies per stakeholder group, in order to facilitate the personas identification process.

Table 3.3-1: Benefits of the identified stakeholder groups from BlueBARGE services and technologies.

Stakeholder Group		Benefits from BlueBARGE services/technologies
Primary Stakeholders	Bunkering Services and Barge Operators	Bunkering services: BlueBARGE solution and successful application is a new business opportunity for bunkering services. Barge operators: New technologies when integrated with available infrastructure providing a new business model may help extend the operational range and reduce idle time.
	Ports and Port Authorities	When a barge (or a greater number of barges) is in any port, it must occupy one (or more) secured places in it. This will result in a constant increased revenue for the port coming from the barge owner, since the specific position will never remain empty, as it would possibly be if the barge(s) were not there. Another indirect benefit for the ports will be that when actions such the ones proposed through the BlueBARGE research project spread, competent bodies will possibly proceed with greater ease in the upgrading of the port networks, thus upgrading them in general. An offshore charging application will partially take the responsibility from the ports and help them align investment priorities

		accordingly. There is a big potential in removing the urgency for ports.
	Port and Terminal Operators	The integration of the new proposed solution and technologies of the BlueBARGE project into the already existing systems of the ports, will ensure a smoother operation, a more efficient functioning and a better distributed workload of all the port and terminal operations that need to be performed. The possible increase in the number of ships that the port will be able to serve may also lead to an increase in the port's staff.
	Ship Owners	Shipowners are the main stakeholder who will benefit from the BlueBARGE technologies and services. Initially through the provided services they will comply with the relevant imposed regulations and limitations considering local polluting emissions and global GHG footprint, while at the same time they will reduce the BlueBARGE solution will be more cost-effective than installing batteries or non-polluting power supply modules onboard the ships, providing a significant economic advantage. With the help of ETS, they may exchange carbon points by charging barges with excess power.
	Ship Operators & Crew	Ship operators and crew will benefit from the fact that the incorporation of the BlueBARGE services will result in a smoother, more consistent, efficient and well-structured schedule, due to reduced waiting times to OPS because BlueBARGE will be an additional source of power.
	Tugboat owners	Tugboat owners will benefit from incorporation of the BlueBARGE concept as the need for tugboats will increase dramatically. Simply put, the workload of the tugboats will greatly increase, as they will be needed constantly to move the BlueBARGE, and the implementation of the concept will also create the need of the construction of new tugboats generating in this way new market opportunities. Furthermore, in a hypothetical scenario where electric tugboats will be developed to a sufficient extent and spread in the market in the future, they will be able to be charged from the BlueBARGE by making some needed modifications to the existing concept.
	Tugboat operators & Crew	The great increase in the workload and number of tugboats needed will eventually create new market opportunities, as the number of tugboat operators and crew will also need to be increased accordingly.
	Traffic management services	Traffic management operators will benefit from the fact that the incorporation of the BlueBARGE services will result in a smoother, more consistent, efficient and well-structured schedule in terms of coordinating vessel movements, monitoring traffic and managing congestion, due to reduced waiting times that are a norm without its implementation.
Secondary Stakeholders	Regulatory and Standardization bodies	There are several novelties involved within the project. As mentioned previously, the certification process will rely on the available regulations. However, whenever there are gaps or opportunities, the recommendations will be shared with the policy makers. T2.4 focuses on this aspect. With the growing number of applications in the field, more feedback will be provided to the authorities so that the regulation can be fine-tuned.
	Public Authorities	Alternative means of power supply will help support the increase in decarbonization efforts in the maritime industry, resulting in meeting local and international targets for public authorities.
	Classification Societies	The benefits are similar to those in Regulatory and Standardization bodies.
	Shipyards and Designers	Shipyards and designers will benefit from the implementation of the BlueBARGE concept in the maritime domain as they will need to undertake the construction of a number of barges and tugboats to satisfy the newly created market needs.

	Power systems manufacturers	Power system manufactures will benefit from the implementation of the BlueBARGE concept in the maritime domain as they will need to undertake the construction of a number of needed power system for the ports and the barges in order to satisfy the new created market needs.
	Electrical equipment manufacturers	Electrical equipment manufacturers will benefit from the implementation of the BlueBARGE concept in the maritime domain as they will need to undertake the construction of various electrical equipment to satisfy the newly created market needs.
	Automation and control systems manufacturers	Automation and control systems manufacturers will benefit from the implementation of the BlueBARGE concept in the maritime domain as they will need to undertake the construction various automation and control systems to satisfy the new created market needs.
	Energy providers	Energy providers will benefit from the application of the BlueBARGE concept in the maritime sector as they work hand to hand with ports for infrastructure investments. Interim solutions such as the BlueBARGE will allow time for the allocation of resources and decrease the time pressure.
	Research Institutes and Academia	The implementation of the BlueBARGE's concept services and technologies will create a strong technological and operational momentum towards achieving the targets set by Regulatory bodies. Eventually, setting the tone by developing a sufficient technology towards the goal of facilitating the transition to a sustainable future, and complying with all the strategies to reduce greenhouse gas emissions from shipping, will create for new topics and subjects to be studied and further explored by students and research engineers.
	Financiers & Investors	Financiers and investors will benefit from the implementation of the BlueBARGE services and technologies by exploiting new market opportunities and the more attractive prospect of being both a barge owner and a shipowner. Furthermore, companies that serve as technology providers, constructing power systems, electrical equipment, automation and control systems will also possibly draw the attention of financiers and investors seeking new opportunities in the maritime domain.
	The public & citizen organizations	The public and citizen organizations (Citizens - Social organizations, port-city committees, national and world climate change societies, environmental protection agencies or other organizations active in Environment & Health) will benefit from the results of implementing the BlueBARGE concept services which are climate-neutral along with a sustainable economy in Europe. By reducing local emissions, these services will also contribute to improved public health near port areas.

The above-mentioned stakeholders' groups and their correlation with the main benefits arising from the foreseen BlueBARGE services and technologies were used as an intermediate step facilitating the personas identification process. As stakeholder groups tend to be large audiences with numerous persons in different working positions having various responsibilities and dealing with different challenges, their correlation with the potential BlueBARGE benefits, is an important step of the process towards properly identifying right personas.

A persona is presented as a description of an individual person, even though the persona actually represents a group of users with similar characteristics. Specifically, they are formed using characteristics of people who present similar objectives and behaviors. The BlueBARGE services and technologies shall be designed by having the satisfaction and facilitation of the end users and decision makers. This is one of the top priorities, and the personas identification will assist this procedure.

Different personas were identified and are presented in the following tables based on their operational profiles and considering their fundamental interaction with BlueBARGE services and technologies. The tables contain a brief analysis and elaboration on their main role and activities, as well as on the challenges they regularly have to deal with. Different uses case may require different roles and activities and challenges. Therefore, the tables are populated assuming the most common use of the BlueBARGE.

Persona 1: Bunkering service operator – Barge operator
Main role and activities: Bunker service operators should communicate with the tug operator, the port authority and the ship operator for offshore charging.
Challenges: Effectiveness of communication and the delivery of the barge to the ship is very important for the whole operation. Congestion and the availability of tugs or other services on call may be hard to handle.
Persona 2: Barge crew member
Main role and activities: The barge crew members are responsible for the safe operation of the BlueBARGE in general and for ensuring a safe mooring to the port from their side and a safe connection with the ship to be charged.
Challenges: The mooring and connection with the ship to be charged can be challenging and dangerous depending on the weather conditions and time pressure.

Persona 3: Barge captain (self-propelled case)
Main role and activities: The barge captain (in the self-propelled BlueBARGE concept) is responsible for finding the most proper route and for ensuring the safe navigation of the barge towards its target. He/she is also responsible for communicating with the ship or point to be charged.
Challenges: The safe navigation of the barge can be a very challenging process, taking into account the barge's size and traffic conditions in the port. Bad weather conditions, which should be monitored by the captain though the relevant tools, could also make any challenging situation even more difficult to deal with. The barge captain must also be aware of all the relevant regulations and keep the barge's operation in line with them.

Persona 4: Member of the port management staff
Main role and activities: The efficient use of the port facilities and resources and crucial for the smooth operation of the port functions in general. The port's management staff are the general technical activities within the port, such as the development of defined efficient procedures for the port's technical processes and operations.
Challenges: Compliance with all available and implemented regulations and processes to be followed, taking into account the time limitations, creates a very challenging workflow. Considering the changes that are coming due to the regulations aiming for significant emission reduction until 2030 and then neutrality until 2050, the compliance with the updated regulations and limitations and familiarization with all the new technologies are consisting of a new challenge for the port management staff.

Persona 5: The shipper/ freight forwarder
Main role and activities: The shipper is responsible for the efficient transportation of goods and commodities. He/she must deal with all the necessary administrative procedures to complete the transportation and ensure no issues occur during the cargo-sending process. His/her responsibilities also include transport booking and communication with the relevant ports.
Challenges: One of the main challenges a shipper usually must deal with is that he/she must be aware of the various shipping options that are available. This also involves choosing the most appropriate shipping rates and transit times, which can be a very time-intensive process. The changes to the typical waiting times will assist the shipping companies and the maritime domain in general, but probably shippers will need some time to adapt to the new norm, compared to the processes that have been followed until now.
Persona 6: The ship's captain
Main role and activities: The role of the ship's captain is to navigate the ship along the safest route to its port of call. He/she must be aware and comply with all the relevant regulations and oversee the pilotage area and the bridge crew members. He/she also must cooperate with the bridge crew members regarding the overlook of the

loading and offloading operations, as well as of the risk assessment of ship key operations that could possibly have an impact on crucial decisions to be made.
Challenges: The ship's captain has to deal with a very high workload. Some very challenging aspects to deal with are the evaluation of environmental conditions, the effective communication with numerous partners in order to reassure an effective and accurate transfer of information that needs to be exchanged for a smooth operation.

Persona 7: A ship crew member
Main role and activities: The ship crew member, besides the usual predefined operations (including within others the operations and maintenance of various equipment, performing safety checks and emergency drills, maintenance and repairs, assisting docking operations etc.) has to reassure a safe connection of the ship with the BlueBARGE.
Challenges: The safe connection of the ship with the BlueBARGE can be proved a very challenging operation, highly depending on the weather conditions. The ship crew members will have to be in constant communication efficiently with the barge crew members.

Persona 8: The moorer
Main role and activities: The main role of the moorer is to undertake the ship mooring process, at the quays, by handling the ship's mooring lines, when leaving and arriving at the berth.
Challenges: Mooring operations are considered some of the most complex and dangerous tasks on ships. Mooring operations are -in most cases- a routine, but when things go wrong, their cascading effects can cause very damaging and sometimes tragic circumstances [UC3.3-2].

Persona 9: The tugboat captain
Main role and activities: The tugboat captain is the person who communicates with the barge operator and ensures the timely, smooth and safe movement of the barge towards its point of call. He/she is responsible for steering the tugboat to push or pull the barge to the desired destination and to communicate with the barge captain and the captain of the rest of the tugboats (if any).
Challenges: The tugboat captain's role is highly challenging as the safety of all on-board personnel must be ensured and the vessel's technical/mechanical systems must be under control. Also, the navigation constitutes a great challenge as every decision taken, depends on the unpredictable weather conditions, on traffic in the port area that can be heavy and to the smooth communication and cooperation with other tugboat captains when needed.

All the identified personas do not have a specific role within all the defined use cases. The correlation of the identified personas with the BlueBARGE uses cases is presented in Table 3.3-2.

Table 3.3-2: Matrix of the identified personas with the defined BlueBARGE use cases.

Personas		Use cases									
No	Persona's title	1	2	3	4	5	6	7	8	9	10
1	Bunkering service operator – Barge operator	x	x	x	x	x	x	x	x	x	x
2	Barge crew member	x	x	x	x	x	x	x	x	x	x
3	Barge captain	x	x	x	x	x	x	x	x	x	x
4	Member of port management staff	x	x								x
5	Shipper/freight forwarder	x	x								x
6	Ship's captain	x	x								x

7	Ship crew member	x	x								x
8	Moorer		x								
9	Tugboat captain	x	x	x	x	x	x	x	x	x	x

3.4 – Use Cases and Real-life Scenarios

This section digs deeper into the 10 main use cases and 3 umbrella use cases which were identified after several discussions and debates with the project partners and stakeholder. Even though there are 10 uses cases identified in the BlueBARGE project, the number of cases can be expanded, and other applications can be derived. This is the reason why a comprehensive survey is designed and shared with the stakeholders.

Under each use case, the description, rationale and potential applications in real life scenarios have been shared. The goal of the detailed examples is to help the reader have a better understanding of the potential case and provide pros and cons of the proposed operation. Please remember that, in some use cases, the authors may overlook important details such as risks or regulations. In such cases, readers are encouraged to provide feedback and share their know-how as much as possible. All information gathered will help the BlueBARGE consortium to improve the working model of the unit in a more beneficial context. This benefit is expected to be shared amongst the stakeholders.

However, it is important to keep in mind that all the uses cases are somehow interrelated, and it is not easy to imagine each case in isolation. So, preferably for efficiency it may be wise to address more than one use case with the help of a power barge. In order to explain a bit further, UC-4 Environmentally Critical Areas are highly related to UC-6 Powering Leasure Boats. With the help of the coinciding operations, a single barge may serve several purposes if the compatibility is satisfied.

Another critical subject to address is the effort by the authors to reference previous and ongoing Horizon EU projects whenever possible. It is of utmost importance for different projects to exchange information to enhance the quality of the work and progress towards achieving results. Reports from different authorities, associations, class societies and companies have been reviewed as much as possible and related content was integrated into this document.

For each use case, business models are also defined whenever possible. For some cases, the commercial solutions are already available in the market with alternative means, and these are identified and shared. In other cases, the commercial market is still not addressed, presenting opportunities for new solutions to support innovative business models.

An overview is shared for each use case in the following table (Table 3.4-1). The table summarizes the foreseen power levels, ease of application, distances to source and the sink, urgency and scalability potential. The overall evaluation of each parameter will affect the decision makers to select the use case and take necessary actions. In this document, the so called ‘umbrella uses’ cases have been identified depending on the urgency, ease of application and power requirements.

Table 3.4-1: An overview of Uses Cases.

Use Case Description	Power Requirement	Ease of Application	Est. Distance to the Power Source	Est. Distance to the Sink	Urgency	Scalability Potential	Comments
UC1: Anchored Vessels	Medium	Medium	Short	Short	Medium	High	Requires regular but moderate power.
UC2: Moored Vessels	Medium	Medium	Short	Short	Medium	High	Similar to anchored vessels, needs stable power.
UC3: Isolated inhabited areas	High	Low	Long	Short	High	Medium	Critical for sustaining life and basic amenities.
UC4: Environmentally critical areas	High	Low	Medium	Medium	High	Low	Essential to prevent ecological damage.
UC5: Charging of small transportation vessels (inland waterways)	Low	High	Short	Short	Low	Medium	Typically requires lower power for short durations.
UC6: Powering leisure boats along the coast	Low	High	Short	Short	Low	Medium	Mostly for non-essential, recreational use.
UC7: Powering offshore platforms – oil rigs	High	Low	Long	Medium	High	Low	Crucial for operations and safety of the rigs.
UC8: Charging from offshore power plants	Medium	Medium	Medium	Medium	Medium	High	Dependent on the power plant capacity and output.
UC9: Providing power to land after natural disaster events	High	Low	Long	Short	High	Medium	Essential for recovery and relief operations.
UC10: Charging BlueBARGE from anchored vessels	Medium	Medium	Short	Short	Medium	High	Facilitates other operations by ensuring BlueBARGE is powered.

3.4.1 – UC1: Anchored Vessels

Currently, shore power or SSE is only accessible when a ship is docked during cargo operations or passenger transfers. Ships anchored in and around ports, waiting for their turn, do not have access to shore power [UC1-1]. Even though the number of SSE systems in port areas are continuously increasing, the anchored vessels, including all ship types and sizes, cannot be supported by these infrastructures due to the increase in power demand. Since the transition takes time due to infrastructure investment, conventional use of diesel generators results in locally concentrated GHG and other emissions, such as noise and vibration. Underwater radiated noise is also a critical concern.

Some of the potential solutions for providing shore power to anchored ships are using submerged cables, [UC1-2] or charging from offshore facilities. However, these approaches are costly to implement and maintain, with a limited-service range, which has resulted in minimal interest so far [UC1-1].

This gap could be effectively addressed by using power barges. Unlike submerged cables, the power barge concept can play a pivotal role in the busiest and biggest ports as it can offer an interim or permanent solution for shore power, extending the concept of SSE to the wider port area. Power barges are not subject to range restrictions and do not require underwater infrastructure.

As a result, power barges offer a practical solution to provide the same functionality without the associated infrastructural limitations and challenges. The application results in reduction of GHG and other emissions such as underwater noise at the anchorage.

European ports are vital gateways, linking its transport corridors to the other continents and countries as these ports handle most goods importing or exporting Europe by sea [UC1-3]. Rotterdam port, pioneer of the European hub due to its size and its advanced equipment, reigns supreme with 439 million tons of cargo in 2023 [UC1-4]. As it is the largest port in Europe, the number of vessels approaching the port reflects its size. More specifically, around 150 vessels arrive in the port area daily with most of them waiting in anchorage, before their cargo operations, for approximately two days [UC1-5, UC1-6].

It is worth taking into consideration that in recent years port congestion has been constantly increasing due to the increasing volume of cargo and the limited port capacity, leading to delays in docking of the vessels and then to cargo operations [UC1-7]. As a result, some vessels need to wait at the anchorage until a terminal can accept the ship for cargo operation.

Antwerp is the second largest European port handling over 231 million tons of international cargo. In total, 26 terminals are in this port-region ready to contribute to cargo operations [UC1-8]. It is estimated that approximately 39 vessels enter and leave the port on a daily basis [UC1-9]. Based on the latest data collected after a 3-years investigation ended in December 2020, on average gas carriers and tanker vessels need to wait above 30 and 19 hours respectively before their berthing [UC1-10].

Moreover, other foreseeable reasons that may lead to vessels berthing delays and congestion in ports are the geographical location of the ports and further logistic connection from the port to hinterland and vice versa, or the inclement weather conditions. Apart from the bad weather, a recent phenomenon due to climate change and the drought which affects riverways congestion is the low water level at big river canals. For example, the port of Hamburg faces congestion challenges despite being one of the most important and busiest ports in Europe. In 2023, the port of Hamburg handled 114.3 million tons; that has decreased by 4.7 per cent since 2022 [UC1-11]. It was observed that the delays in the port of Hamburg have increased over the last few months when in some cases the waiting times reached 74 hours or above. One of the most important reasons for the continuous congestion and series of delays impacting Hamburg is climate change/ impact, as major waterways are becoming unpassable due to low water levels. Because of such drought, several vessels are waiting to berth more than fifteen times the normal/common waiting time during the summer season [UC1-12] (Figure UC-1.1 and Figure UC-1.2).

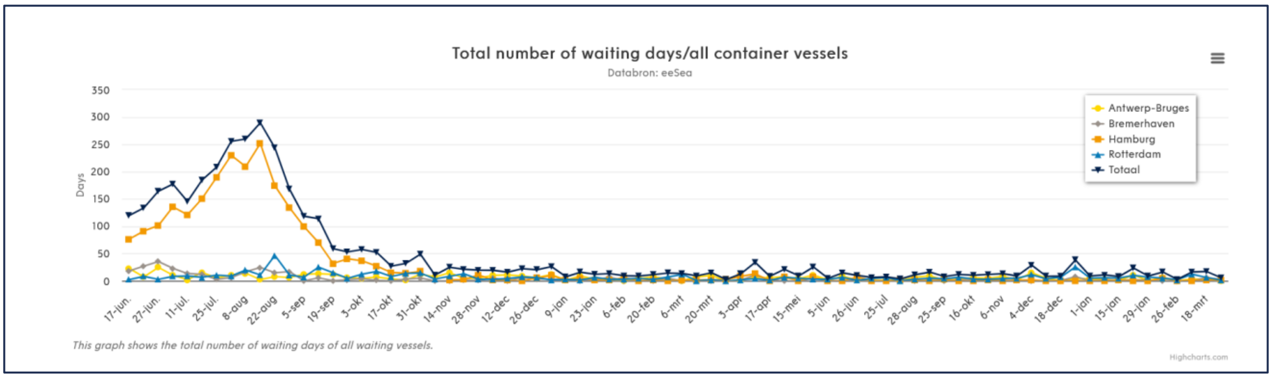

Figure UC1-1: Total number of waiting days/all container vessels [UC1-13].

Additional unpredicted or unconventional factors may cause additional port congestion, such as a pandemic (i.e. Covid-19 lockdown) which has led to massive cyber-ordering and has resulted in an increase in maritime logistics. In addition, an incident of war or suspected regions for territory attacks lead to consecutive disruptions of the global supply chain as delays occur due to the amendments in inland freight modes of transports and rerouting the seaways to safely deliver the goods.

For instance, since December of 2023 maritime across the Red Sea faces a crisis due to the Houthi attacks. Therefore, vessels operating on the Asia-Europe trade need to change their route via the Cape of Good Hope, instead of passing by Suez waterway. This deviation leads to a steep increase in congestion in Algeciras and the nearby Mediterranean ports, this is an additional factor that increases even more the existing average waiting time of the vessels at Algeciras anchorage [UC1-14].

Maintenance or intentional purposes to stay at the anchorage may also be considered as the reasons for extended stay.

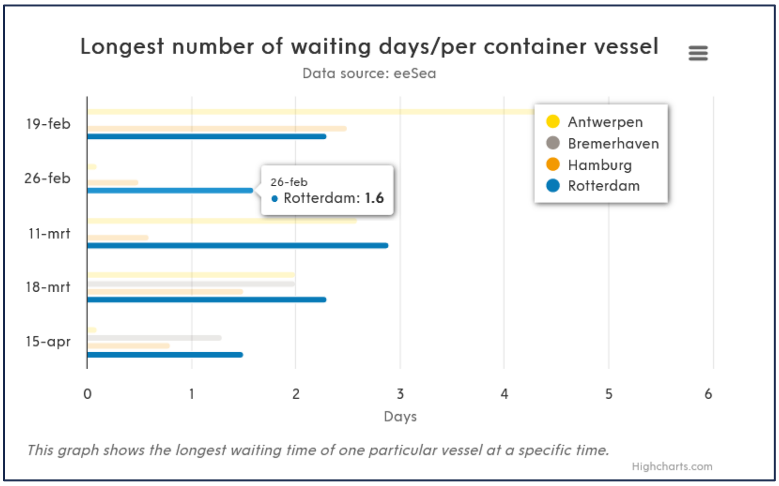

Figure UC1-2: Longest number of waiting days/per container vessel [UC1-13].

Two of the major and busiest ports in Europe are in Spain, Valencia and Algeciras. They handle a big volume of cargo, specifically 4.80 and 4.73 million TEU in 2023 respectively, according to the Euro Mediterranean container map [UC1-15] and link the Atlantic and Mediterranean routes. However, both, Valencia and Algeciras, are facing port congestion due to the continuous increase in cargo volume, limited ports' infrastructures and temporal availability of manpower [UC1-16]. That causes a vessel's delay of approximately one day for container ships at the port of Valencia and about 3.5 (median) days for bulk carriers at the port of Algeciras [UC1-17, UC1-18].

The port of Piraeus is one of the most important ports due to its strategic position in Eastern Europe and the Mediterranean Sea. In recent years, the waiting time in Piraeus anchorage has increased. Trading and shipping companies choose the port of Piraeus for cargo transshipment rather than other ports in Northen Europe to avoid this excessive congestion [UC1-19]. Sometimes, the number of vessels at the terminals for cargo operations was equal to those waiting at the anchorage [UC1-20].

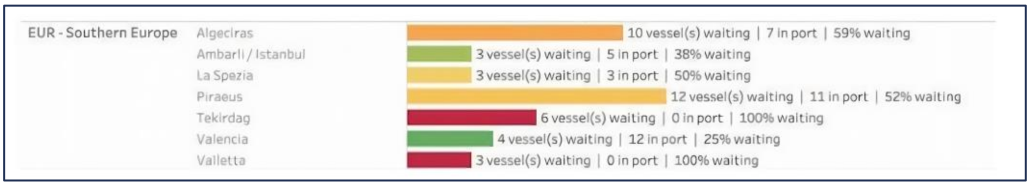

Figure UC1-3: Total number of waiting days at various EU ports [UC1-20].

On the other side of the Atlantic Ocean, the port of Houston plays a vital role in the international trade in the United States as it is one of the busiest ports in U.S with more than 150 terminals. The Houston Ship Channel is considered the biggest container hub in the U.S. Gulf South [UC1-21] and it has a high inflow of crude oil, LPG, petrochemical and oil tanker vessels. The maximum median waiting time for a vessel at Houston anchorage is three days [UC1-22]. Seasonal weather conditions are capable to impact berthing processes, causing congestion at Houston anchorage. More specifically, for the long-winter season (from the month of October until March) resulting in a period of acute fog may drive to Houston Ship Channel embargo for days at the time. This specific phenomenon can delay the normal operation of the port for many hours. In 2015, it has been recorded that the port remained closed for 680 hours and in 2018 for 537 hours due to the fog [UC1-23]. In February of 2019, at the peak of the winter fog phenomenon, 57 vessels were waiting to go into the Channel and 16 waiting to get out.

Asian ports are also of particular importance in global trade and transport infrastructures as this continent moved above the 40 percent of the global goods before the pandemic but remains in the first place handling the 36% of the world's goods for 2023 [UC1-24]. It is important to mention that Shanghai port manages approximately 25% of global shipping [UC1-25]. Annually, Shanghai and Qingdao ports which are from the busiest ports in China, handle approximately 700,000 kilotons of cargo. Despite the important growth and modernization to support the continuous increase of global trade, Chinese ports face other challenges resulting in delays in vessel's berthing and supply chain. Chinese ports faced a crisis during the pandemic (Covid-19) such as berthing delays which had been reported due to the measures and restrictions against Covid-19. For instance, during the pandemic, the waiting time at Qingdao anchorage has increased fourfold compared to non-Covid period [UC1-26]. After the pandemic, other challenging issues interrupted the port operations. During the winter, the major Asian port faces berthing delays due to the bad weather. More specifically, in Shanghai, weather conditions caused a delay of about three-days in January 2024. In addition, after the commencement of crisis in Red Sea due to Houthi attacks, as mentioned above, since late December 2023, vessels have been obliged to change their route travelling around southern Africa. This plight results in a 10- to 14-day delay causing congestion in the anchorages. All the reasons acting together cause delays such as a 'domino effect'. For instance, if a container vessel needs to reach two or three Chinese ports to unload its cargo the delay from the first to the last port will cumulatively increase [UC1-27].

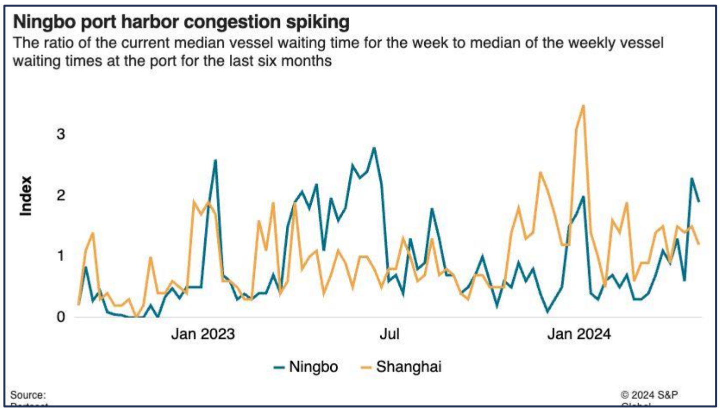

Figure UC1-4: Total number of waiting days in Ningbo and Shanghai [UC1-27].

A typical real-life application can be as follows:

The barge-to-ship power system use case for ships anchored offshore covers the process of providing electricity to the ships. In this use case, the main actors are the ship captain, the barge and tug operator, the maintenance crew and the electricity supplier [UC1-28]. The process begins with the support request from the captain after determining the power requirement. The operation can easily be supported by port tugboats. The tug operator docks the power barge to the ship then the competent personnel connect the cables [UC1-29]. Power transfer starts after the connection confirmation, system constantly monitors the energy/power flow, either physically or remotely [UC1-30]. The crew constantly checks that the system is working properly and that there are no malfunctions and carries out maintenance and repairs when necessary [UC1-31]. Once the energy/power need is completed, the captain requests the termination of the energy supply. The barge operator shuts down the energy flow and safely separates the connecting cables. The barge moves away from the support ship and takes its position [UC1-32]. This process reduces the emissions while increasing its operational efficiency [UC1-33].

If an emergency occurs during barge-to-ship power supply, the barge operator shuts down the energy flow and urgently initiates emergency procedures [UC1-34]. All these processes are carried out in accordance with the emission and safety standards set by MARPOL and IMO and the local regulations applicable in the offshore region [UC1-35]. The step-by-step description of the provision of electricity to offshore anchored support vessels via a barge-to-ship power system, is described in Chapter 6.

3.4.2 – UC2: Moored Vessels

Onshore power supply emerges as a pivotal solution to mitigate GHG emissions, and other emissions such as noise [UC2-1]. Long-term solutions involving SSE applications, also known as cold-ironing, are increasingly integral to future port requirements [UC2-2]. For instance, a case study analyzing a Ro-Ro vessel between France and Spain demonstrated that electrification through onshore power supply and onboard batteries significantly reduced fuel consumption and associated emissions [UC2-3]. Another study suggests that even combining OPS with LNG generation has the potential to reduce emissions by 40% [UC2-4].

However, it is also important to note how high the power requirements are, regarding different types of vessels. This power demand could necessitate improvements in the electricity grid to avoid grid congestion as the number of vessels requiring SSE is scaling up. For example, Eastern EU ports' grid capacity is not found adequate to fulfill the maximum power demands of the vessels arriving, posing risks against the stability of the electricity network [UC2-1, UC2-5]. Considering that renewable electricity will be a prominent part of the electricity grid, intermittent generation could also pose risks against the continuity of supply. At this point, the necessity of an energy storage system emerges as it can provide an integration ground for renewable generation. For example, by using a Battery Electricity Storage System (BESS), surplus of generated electricity could be stored to be used when there is a deficit. So that, the battery could act as a buffer to smooth out the intermittency of electricity generation, balance the discrepancies in supply and demand coming from the OPS and fast charging applications, and decouple the charging load from the main grid to avoid congestion. Therefore, a storage source is an essential part of such a power system. It is also anticipated that a floating energy storage [UC2-6, UC2-7] and a plug-in power system [UC2-8] could be an advantageous configuration to supply energy to the ships during their stay at berths [UC2-1]. At this point, a power barge seems a notable solution to facilitate this process providing elasticity to the grid, thanks to a BESS. This allows the energy demand of ships to be met without necessitating costly upgrades to the grid and infrastructure.

Even though, assuming that the power supply is enough for the OPS operation for a specific port, electricity pricing may vary depending on the used capacity and the hours. Especially, in case if a port exceeds the assumed capacity causing a peak on the grid, this may be additionally fined. During a survey conducted by the British Port Authority [UC2-9], the results showed that the port operators hesitate to invest in OPS and infrastructure. The primary reason is because the operations which ports can make money out of are not directly related to supplying shore power. In most of the operations, providing shore power is the responsibility of the ship charterer. Considering the costs associated with infrastructure investment, maintenance, technical personnel required to control the complex nature of power applications, the interest of ports to spend resources in shore application diminishes.

Ports evaluate their investment strategies for decarbonization in different scopes; Scope-1 being the direct operations such as vessels, cranes and other equipment used at the berth operations. Scope-2 being the indirect ones and Scope-3 involves the other indirect ones which covers the shore power solutions. So, as in a usual business case, ports tend to evaluate the Return on Invesment (ROI) and go for the best options when selecting in between the potential projects. Therefore, most of the shore power installations turn out to be publicly funded to date.

Another distinction is to be made between the public and private ports. Depending on the country, the ownership of ports may vary. Public ports may have different targets than private ports considering the energy transition urgency. For private port owners, shore power applications are considered as a `stranded asset` which means, the system will not fulfil its lifetime.

In case, if during a shore power supply, a black-out occurs. Who will carry the responsibility? This is one of the questions considering the operational and financial risk. The owner of the system also carries the financial risk of the service. And when the service is not profitable enough (selling electricity etc.) then the risk may not be taken by the ports.

Considering all these legitimate business concerns, power barge applications show a great potential for the success of transition. The solution is flexible in many aspects such as balancing the load on the port side as discussed above, controlling the demand, eliminating the time to wait for all the investment decisions to occur etc. Therefore, in general barge to ship shore power solutions constitute a good alternative removing many of the concerns identified during the port surveys.

One of the alternatives proposed was mooring dolphins. As the number of moored vessels in a port is steadily increasing, the concept of mooring dolphin is introduced to expand the existing port infrastructure and increase the berthing capacity of a port [UC2-10]. Mooring dolphins are structures to provide extra mooring spots in the port, close to the shore. In this way, the port cannot only accommodate a bigger number of moored vessels but also longer or greater vessels than the ones that shore docks are capable of. In addition, these structures can also elongate the number of berths by forming lines between the vessels and the dolphin's pier [UC2-11]. Mooring dolphins are located near the shore but usually do not have the same advantages as those on the shore. A mooring dolphin pier is not interconnected with the coastal infrastructures of a port. For instance, 'Motor Oil Hellas SA', located in Corinth, Greece, is one of the biggest petroleum companies affiliated with oil refining and trading. The 'Motor Oil' refinery can accommodate more than 3,000 vessels on an annual basis [UC2-12]. Moreover, it is equipped with 'Multi Buoy' Mooring Dolphins that serve to supply crude oil supply to tanker vessels up to 300,000 Tonnes deadweight (DWT), as shown in Figure UC2-1. The power-barge concept can easily be connected to the mooring dolphin interface and supply moored vessels with offshore electricity while loading their cargo. A three hundred thousand tons DWT crude oil tanker vessel typically takes a day or more to fully load. Considering that in the same mooring dolphin, more than one vessel can be moored at the same time, this can justify the usage of a power barge which will operate continuously and provide electrification to a moored vessel instead of running its diesel generators.

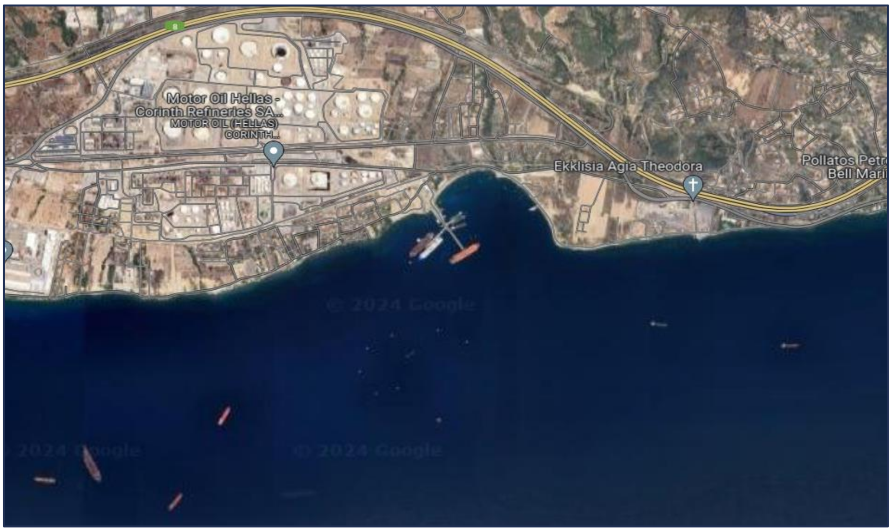

Figure UC2-1: Mooring Dolphins for Crude Oil Supply [UC2-12].

Apart from the Mooring Dolphins being considered offshore structures in the sea, berthing dolphins practically extend the berthing surface in a port. The berthing dolphin is usually connected to a shore through a jetty approach [UC2-13] and is basically associated with fuel or other liquid supply or discharging from shore to a vessel and vice versa. This structure is equipped with a transfer piping system that initiates from the shore and ends up charging or discharging arms closest to the sea. The berthing dolphin provides more safety for the vessels and the ports as it controls the sideways movement of the moored ship and protects the latter from contact with the port or the dock [UC2-14]. As the berthing structure are not capable for providing direct electrification to the moored vessels, then the power-barge option may be useful to support the moored vessels with electricity during their operation instead of utilizing the auxiliary engines. This will lead to the elimination of local polluting emissions and the ones related to shipping pollution, and a cleaner and healthier environment. The power-barge concept can easily connect to the mooring dolphin interface and supply the vessels in berth with offshore electricity while loading their cargo.

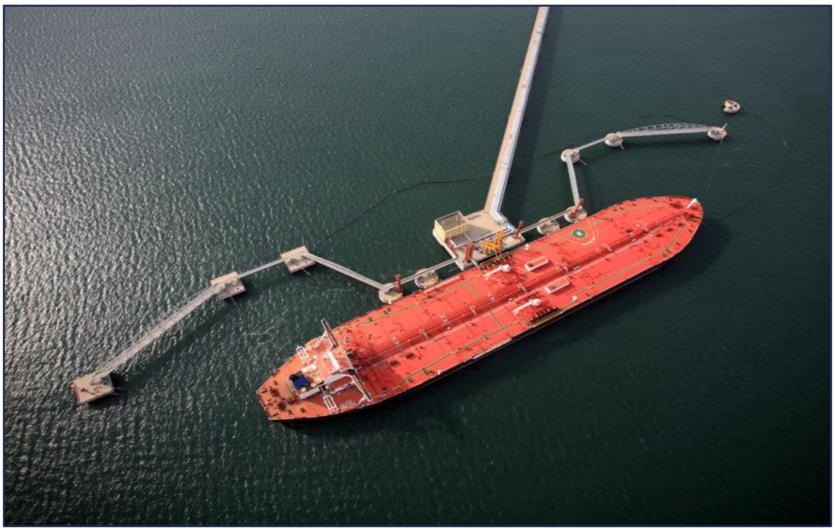

Figure UC2-2: Offshore Mooring Dolphins [UC2-15].

For the BlueBARGE project, the demo application will be conducted on a tanker in Cyprus. Cyprus is one of the island countries in Europe and the eastern Mediterranean Sea. Limassol and Larnaca ports, the two biggest ports in Cyprus, are listed in the EU Trans-European Transport Network (TEN-T) ports. Both ports are excluded by recent Alternative Fuels Infrastructure Regulation (AFIR) and Directive EU 2016/1629 [UC2-16, UC2-17] as they are located on an island country with no electricity cable connection with the mainland.

Therefore, SSE will not be mandatory by 2030. It should be highlighted that Cyprus currently possesses the fifth lowest position in Europe in electricity consumption because much of its electricity is generated from non-renewable fuels, based on Renewable Energy Sources (RES) shared data.

However, on the other hand another important update from The European Sea Ports Organization (ESPO) which strongly supports the co-legislators' decision to include energy ports in TEN-T [UC2-18]. So, ports which tend to contribute to the energy transition will be in a more advantageous position.

The application of a floating power barge may prevent heavy investments for islands which are on the TEN-T network and have high priority to supply shore power. So, instead of a potentially heavy infrastructure investment, smart bi-directional charging schemes may be used to manage the island SSE applications.

Specifically, Cyprus is heavily dependent on imported oil products, with the highest percentage coming from Israel, and the remaining from Greece and Italy [UC2-19]. Consequently, the RES share in electricity consumption in 2022 was about 17% which is significantly below the European average [UC2-20]. Therefore, the past year, the energy system in Cyprus has been making efforts to gain a competitive advantage in the electricity market. More specifically, by mid-2023 the Ministry of Energy, Commerce and Industry of Cyprus has set the goal of meeting 40% of the country's energy needs through solar power by 2030 [UC2-21]. Moreover, Cyprus aims to expand its inland power storage system as it faces economic losses due to the unused surplus green energy production [UC2-22]. It must be taken into consideration that generating electricity from RES is challenging for Cyprus, given its small market size and isolation due to its geographical position [UC2-23]. Limassol and Larnaca ports lie on Cyprus' southern coast and can accept all types of vessels such as container vessels, bulk carriers and Passenger/ Ro-Ro Cargo Ships [UC2-24]. These ports are approximately 38 nautical miles apart. Due to country's isolation and the lack of green power storage infrastructures, the power-barge concept can significantly support the moored vessels which are berthed in mentioned ports. In addition, the excess generated renewable energy can be easily stored in the battery modules and further supplied to moored vessels.

A very recent feasibility study where DNV and Port of Rotterdam participated in investigated the OPS application for tankers [UC2-25]. As BlueBARGE demo case will cover an offshore shore power application for a tanker, the details are discussed under Chapter 6.

3.4.3 – UC3: Isolated inhabited areas

There are numerous seaside regions or islands where their local power grid has not recently developed to cover their inhabitants' power needs. This use case refers to isolated areas or islands with no underwater power supply cabling (non-interconnected) or limited connection. This may result in a lack of power due to transient demand increase and limited supply. In `Islands and Energy Islands in the EU Energy System` report [UC3-1], 447 islands from 8 countries have been identified as either non-connected or connected with limited capacity to the mainland. Further investigation revealed that most of these islands are in the Mediterranean Sea. However, there are several challenges with these islands to become 100% self-sufficient. Some of the main challenges can be summarized as; lack of economies of scale which hinders the development of large-scale projects, lack of fuel supplies which results in 2 to 10 times higher energy costs and limited available space.

In such cases, the adaptability and the flexibility of the power barge solution allow easy mobilization and bidirectional shore power connection to support the specific area. This is achieved by connecting to the microgrid when additional power is required, and this is considered as Scenario 1 case for the potential applications.

The Canary Islands consist of eight main islands and many other smaller islands and inlets. They are a Spanish autonomous community in the Atlantic Ocean. All these islands are equipped with renewable energy systems such as wind farms and solar or hydro parks, but most of them cannot suffice their power needs. Power demand during the summer season is estimated at approximately 1,300 MW per day. The power is derived from green energy sources, and delivers approximately 350MW in total, while emissions deriving from conventional energy sources, such as fossil fuel, are estimated to be approximately 5.5 tons CO2 eq/MWh [UC3-2]. In more detail, La Gomera island, with 23,000 inhabitants, satisfies 85% (or above depending on the season) of its power demand by utilizing diesel engines and only 15% (1,3 MW during the winter period) derived from wind energy [UC3-3]. El Hiero, which also belongs to the Canary Islands complex, is the first island to achieve energy self-sufficiency, significantly limiting – in total – the energy generated by diesel engines, and consequently the generated pollutant emissions. El Hiero can store excessive green energy and supply other Canary Islands, based on their demand. Based on the above, the power-barge concept can collect and store the excessive renewable energy generated in El Hiero. Then, due to the power-barge flexibility, it can be mobilized to another island which belongs to the same island complex and faces lack of power. For instance, the power barge commencing from El Hierro needs to sail approximately 43 nautical miles to reach La Gomera island (Figure UC3-1). This means that the barge needs less that 4 hours to approach La Gomera; depending on the exact location of the island's energy station.

WiseGRID project [UC3-5], deliverable 8.1 'Analysis of the electric transportation sector' goes through the potential application of OPS with a combination of smart grid. Basically, since the shore power systems are integrated with power converters, transformers, meters and other smart devices, it may be useful for smart grid applications in islands such as El Hiero case in Canary Islands to reduce their equipment and

IT investment costs (Figure UC4-1). With the help of BlueBARGE, which is an ESS with the whole OPS infrastructure availability, demand response (DR) and power demand smoothing (PDS) can be managed. Even further, there may be a potential for making profit from electricity balancing markets. So, in summary, the whole BlueBARGE system can be visualized as an embedded smart grid system on its own, which has the capability to connect (with bidirectionality) to the land side providing smart management solutions. This property can even be used to control current harmonics and prevent high harmonic content. This may be termed as an "on-demand smart grid management system".

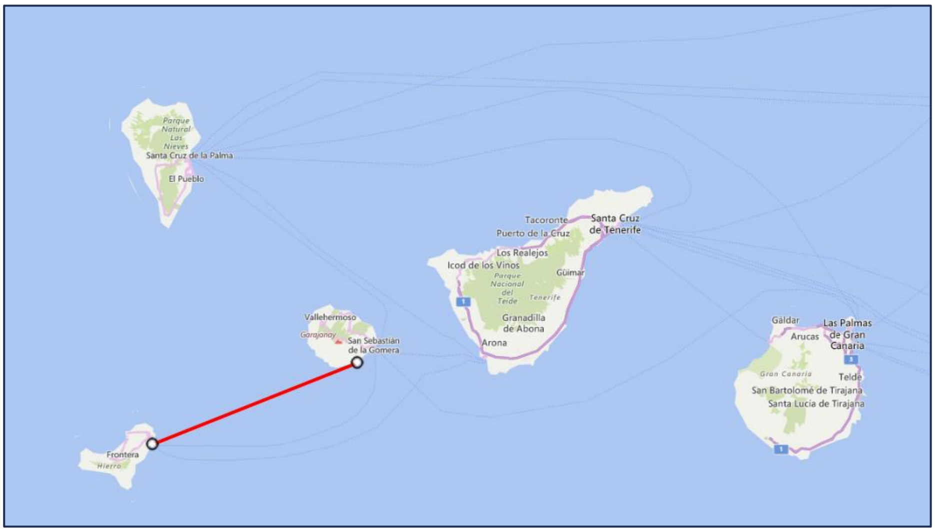

Figure UC3-1: Distance Measurement in Canary Islands [UC3-4].

In the case of interconnected islands, in case if they experience seasonal demand changes or try to continue with islanded mode (with self-sufficient RES infrastructure) then the BlueBARGE can still serve as a part of the instantaneous balancing. Especially for smaller islands with limited financial resources, the application may be designed to generate a better business case [UC3-6].

In case of Scenario 2, with the increasing electrification and upcoming regulations (as stated in the updated revisions of AFIR and Directive in UC2) at ports, isolated inhabited areas may struggle to meet the growing power demands of modern ships, ferries, and other electrical loads. This challenge is exacerbated where the microgrid is unsupported, making it difficult to accommodate the high-power demands expected from OPS stations without exceeding the supply capacity. To address this issue, power barges can support these ports by providing OPS to berthed ships [UC3-7].

A case study focuses on the Åland Islands which is an isolated autonomous territory in Finland with a fragile electricity grid. The island is expected to face high demand from electric ferries and the locals explore potential solutions. The study highlights significant opportunities for local renewable energy generation on the Åland Islands, with plans to integrate wind and photovoltaic sources by 2030. However, integrating renewables introduces power fluctuations due to their intermittent nature. Therefore, the study recommends deploying storage systems, such as a power barge, to stabilize the microgrid, integrate renewable generation, support electric ferry charging and OPS [UC3-8].

The need for storage to accommodate high-power charging loads in remote locations underscores the potential utility of power barges. BlueBARGE offers flexibility, independently managing charging demands and swiftly connecting to the microgrid when needed. This approach allows managing the strain caused by electric ferries and OPS. Furthermore, it also ensures that local demand can be met when necessary while optimizing the size and cost of passive components such as transformers and transmission lines.

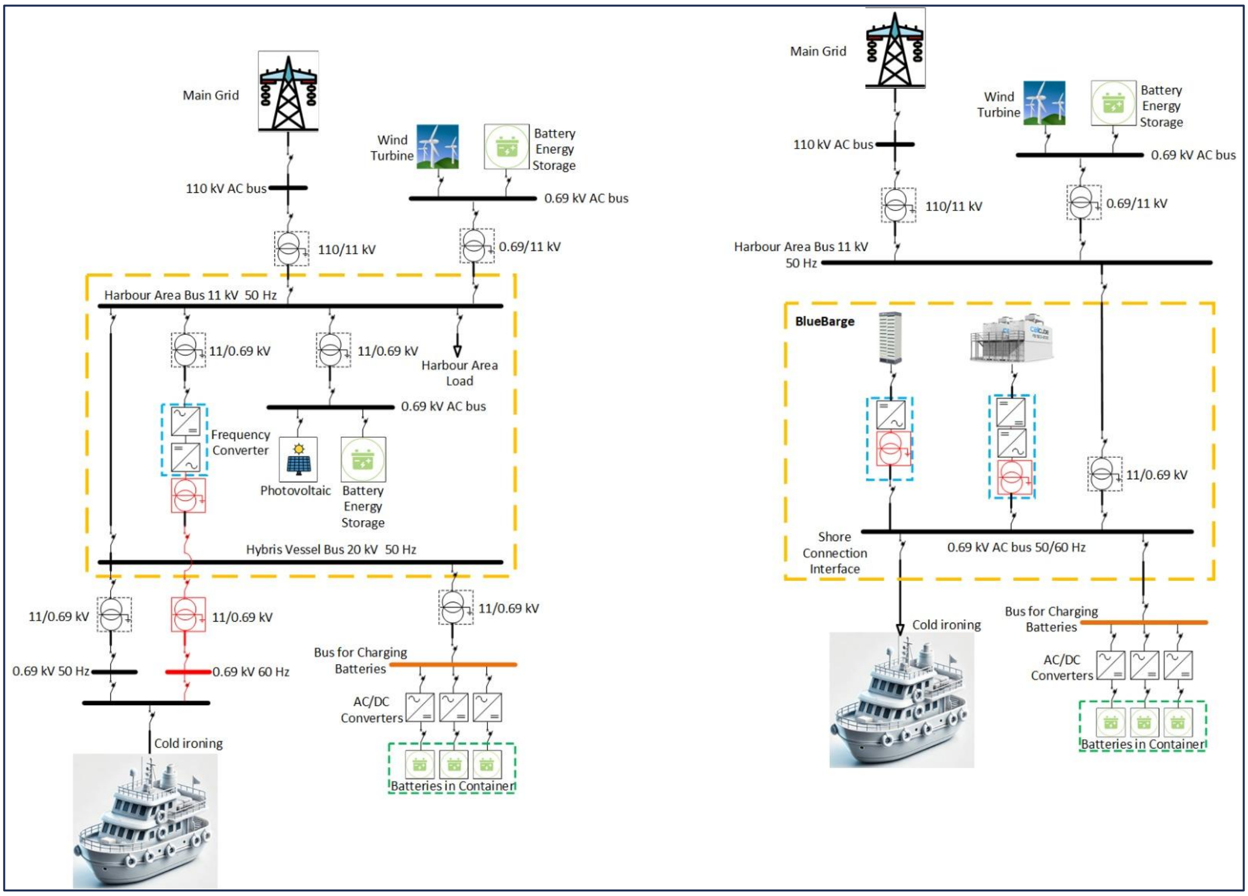

Figure UC3-2: Illustration of Power Barge as a Smart Grid Tool.

3.4.4 – UC4: Environmentally critical areas (Marine Protected Areas (MPAs))

In the last decades, the destruction suffered by the environment and other natural landscapes worldwide due to exhaust gases and other pollutant emissions such as GHG emissions, is more regrettable than ever. An additional concern reflects to those areas with a significant environmental value or the ones with sensitive ecosystems, including natural heritage priority sites, national parks, large areas rich in flora and fauna or upland forest [UC4-1], wildlife preserves or whale migration routes, areas frequently affected by natural disasters and areas or coasts with coral reefs. Moreover, aesthetic value tourist areas or cities, and areas of unique historic interest are also considered environmentally critical areas [UC4-2]. In such places, which are rich in biodiversity and critical to maintaining ecological balance, the zero-emission goal or a cleaner and healthier environment has been set for succeeding soon.

The power-barge concept can be considered as a measure that can be involved, among others, as a solution to lead to zero-emission or air and sea pollution extinction or mitigation. Marine Protected Areas (MPAs) define the areas which require special attention for protection. There are several types of MPAs used in shipping which include,

1) Particularly Sensitive Sea Areas (PSSAs)
2) Emission Control Area Designation (ECA)
3) Special Area Designations (SADs)
4) Areas to be Avoided
5) No Anchoring Areas
6) Mandatory Ship Reporting Systems

Figure UC4-1 shows the status in MPAs. This figure identifies the level of protection in various parts of the EU. A more interesting view occurs when the areas under assessment are highlighted on the existing figure (Figure UC4-2). Obviously, the number of MPAs will increase in time and considering the strict targets set for 2030, the areas under assessment will turn into MPAs.

In these areas, special mechanical and electrical solutions need to be developed to establish such a power connection. Therefore, it is of great importance to make such power or alternative fuel connections in accordance with environmental protection standards, together with technological innovations and effective operating strategies. Constituting one of the most important uses cases, providing barge-to-ship power connection in these so called protective or sensitive areas, may help speed up the transition and immediately prevent further risks [UC4-4].

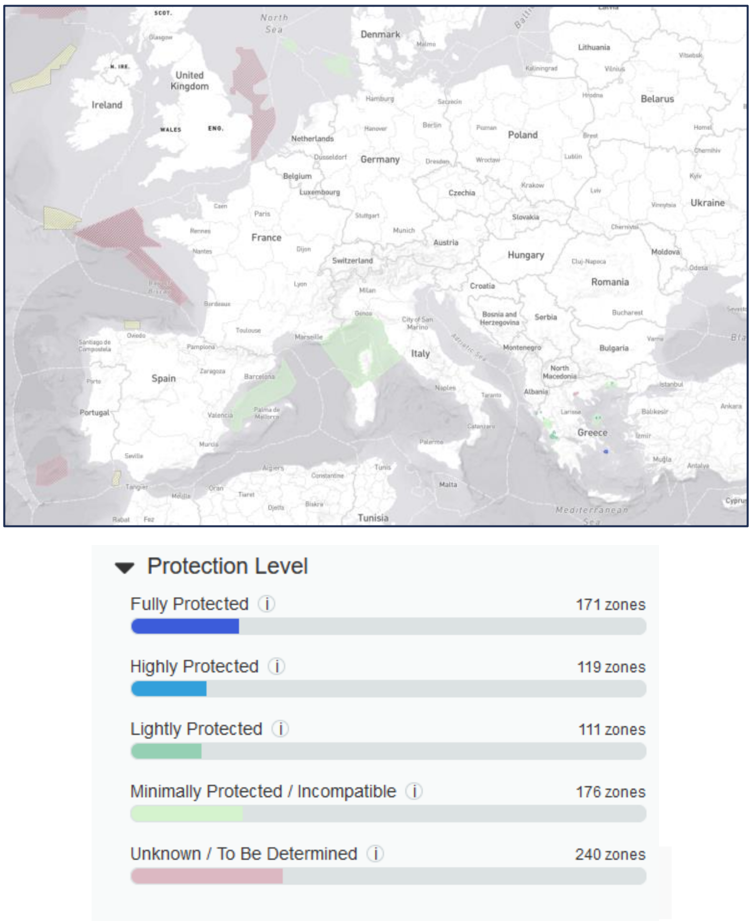

Figure UC4-1: Marine Protected Areas in EU [UC4-3].

Some of the potential areas for such a case; the Great Barrier Reef in Australia is the largest coral reef in the world [UC4-5]. In addition, the Red Sea Coral Reefs are well known for their corals that are resistant to warm waters [UC4-6]. The Galápagos Islands, which are among the marine protected areas, are protected as a world heritage site with different marine species and ecosystems [UC4-7]. Moreover, Monterey Bay is an important habitat for rich biodiversity and marine mammals [UC4-8]. The Arctic and Antarctic regions are among the most important examples of ecosystems threatened by the melting of glaciers due to global warming [UC4-9]. The Arctic Ocean and Antarctic Peninsula are important for scientific research and have sensitive marine life [UC4-10]. The Port of Hamburg implements strict environmental regulations to protect the fragile marine ecosystem [UC4-11]. In addition, the Port of Singapore is one of the important ports with environmental sustainability targets despite the heavy ship traffic in Singapore [UC4-12]. Among whale and dolphin sanctuaries, the Hawaiian Islands are breeding grounds for humpback whales and the Azores are important habitat for sperm whales and other marine mammals [UC4-13].

Figure UC4-2: Marine Protected Areas under assessment in EU [UC4-3].

Venice became an important maritime power in the 10th century and has been considered a semi-structured habitat listed in the UNESCO World Heritage Convention since 1987. Venice has become vulnerable due to the impact of large cruise ships, natural and climate changes and mass tourism. Urgent action is needed to safeguard the ecosystem of Venice's islands, its fishing villages and rice fields [UC4-14]. In 2023, Venice faced the imminent risk of being delisted from the UNESCO World Heritage List due to the above factors. In the same sense, it avoided being included in the list of sites at risk in 2021, as the government of Rome banned the passage of large cruise ships past St. Mark's Square and through the Guidecca canal [UC4-15]. Venice has managed to decrease the emissions over the past year. Despite the reduction and measures taken, 7 million kg of CO2, 116.000 tons of NOx, and a significant magnitude of fine particulates ($PM_{2.5}$) have been reported due to cruise ships by the end of 2022 [UC4-16]. Venice's road transport sector accounts for 8.4% of the GHG emissions in the city. Pollutants such as $PM_{2.5}$ and NO_2 cause a great risk to citizens' health and a serious number of premature deaths are associated with high levels of $PM_{2.5}$ [UC4-17]. Venice is a tourist destination that receives many cruise vessels in its outer port every day, but also many small yachts and tourist boats sail in its canal. Therefore, the power-barge concept can assist in providing renewable electricity mainly to yachts and tourist boats and to cruise vessels. By using the power-barge solution in the canals, this will contribute to the depletion of air pollution in the city of Venice and then, this UNESCO World Heritage listed city to improve its environment for citizens and achieve zero emissions within next years.

The Maldives is an independent island country which is in the Indian Ocean and composed of approximately 1,200 coral islands [UC4-18]. Over the recent decades, the economy of the Maldives has flourished rapidly in various sectors such as infrastructures, boatbuilding, health, education, and fisheries sectors. Since the 1970s and after, extreme growth has been introduced to the tourism sector and the related industry. This rapid growth has significantly affected its natural capital and especially its ocean, coral reef, and coastal ecosystems. The Maldives has started facing the challenges of climate change, which affects its unique picturesque coral environment. This environmental deterioration gradually led to a tourist and fishing economic drop [UC4-19]. The nation has adopted a series of new policies to promote renewable energy techniques and become carbon neutral by introducing solar power installations, wind farms, and energy storage solutions. The ambition of its government is to reduce the insertion of fossil fuels and to limit the emissions [UC4-20]. This is considered a major challenge as by the end of 2021, 94% of generated electricity came from non-renewable sources [UC4-21].

Therefore, the Maldives was seeking effective solutions of how to limit GHG emissions and fuels import and provided recommendation for a more sustainable economy. The Maldives can rely on the production of solar energy with an average of approximately 290 sunny days per year and a global horizontal irradiance approximately 2,000KWh per m2 and year [UC4-22] Based on this fact and the numerus solar power farms which are located in these islands, the power-barge concept could be used for collecting electricity or excess electricity separately from each island, storing and further supplying it to the less green energy-independent country's islands or feeding the leisure crafts and boats achieve. On this way, the power-barge solution may contribute to the elimination of the diesel consumption of generators aiming to a much cleaner local environment.

This is a very similar application to Canary Islands discussed in UC3- Isolated Inhabitant Areas, except that the target is not only providing electricity to the islands which are not self-sufficient but also providing shore power.

3.4.5 – UC5: Charging of small transportation vessels (Inland Waterway Transport)

This use case covers the OPS applications of small transportation vessels, and the vessels used in inland waterway transportation (IWT).

The number of offshore infrastructures is increasing worldwide such as offshore oil rigs for oil extraction and offshore power plants for clean energy collection. Respectively, the number of small boats participating in routine procedures is increasing and transportation is more frequent to cover the needs. Usually, tugboats apart from the conventional towing and anchor handling functions are utilized for rig towage as the rigs and floating production storage and offloading (FPSOs) often need to change their location and be transferred to a new one [UC5-1, UC5-2]. Most tugboats generate more than 6,000 horsepower and their auxiliary systems such as auxiliary engines can support the generated power. However, electric tugs have recently shown up which can reach the same power as the conventional ones [UC5-3]. In an offshore complex, apart from the tugboats, other small boats are frequently used in assisting with the planned maintenance works and for transferring the personnel. The power-barge concept can be used in both cases consisting of offshore infrastructures and supply sustainable energy to these smaller types of vessels, tugboats, or launch boats. The power barge can collect renewable energy from the offshore power farms and further supply it to the small transportation boats when they are anchored or moored. Moreover, with the implementation of the power-barge concept in such areas, the zero-emission target is significantly empowered.

Providing OPS to inland waterways is another important challenge. Several projects are addressing (especially Interreg) the issues related to inland waterway transport (IWT) because most of the good transportation (about 70%) in the EU is carried out by IWT.

A recent study [UC5-4] focused on the literature review about the sustainable development of the IWT. Out of the 51 papers reviewed, only 3 papers had a clear addressing to the definition. The IWT fleet's structure turned out to be a combination of self-propelled vessels and convoys of barges. However, due to the high congestion at the ports, the total distance travelled decreased from almost 400 km to 60 km. Also, the investments in IWT infrastructure are well below road infrastructure.

There are several characteristics related to the sustainability of inland waterways (IWT). Some indicative examples are listed below [UC5-5]:

a. Resilience to climatic change (flood protection)
b. Preserve biodiversity
c. Protect ecosystems
d. Ecological conservation and restoration
e. Socio economic challenges such as appropriate infrastructure and maintenance, efficient and effective operations on terminals and many more.

Since, in the TEN-T network there are in total 173 comprehensive inland ports and 69 core inland ports with 15 hybrid comprehensive ports (sea and inland) and 26 hybrid core ports (sea and inland) [UC5-6], then to meet 2030 targets, solutions should be proposed and taken into action.

Horizon Platina 3 [UC5-7] project addresses these challenges and has detailed reports on the pros and cons for alternative options.

For the IWT, energy infrastructure mainly consists of bunkering facilities [UC5-8]. It was stated that the bunkering applications are not suitable and new solutions are required. To have a better understanding of the expectations of the shareholders, a survey was conducted on the contacts in European IWT countries. Most of the respondents believe that the batteries will be the leading solution (Figure UC5-1).

Another important result was the fact that OPS applications are essential to meet the targets in decarbonizing the IWT. However, the transition is limited to the reach and capacity of the existing electric grids. Also, some ports have limited space and equipment (for example number of cranes for battery swapping). Therefore, this gap may be filled with power barge applications. Since the load demand may change along the corridor, mobility of the barges will provide flexibility.

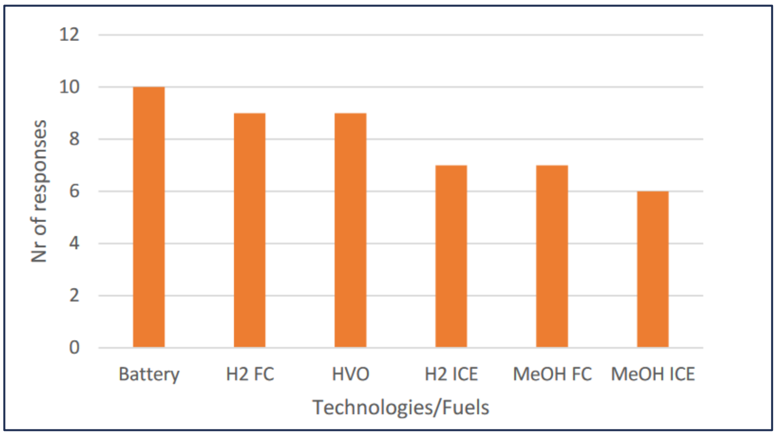

Figure UC5-1: Platina 3 Survey Results 1 [UC5-7].

Another remarkable survey result is shared in the document, regarding the charging solution (Figure UC5-2). Most of the participants agree that containerized batteries are required as one strong solution for IWT.

Figure UC5-2: Platina 3 Survey Results 2 [UC5-7].

Interestingly, for IWT, there is a challenging situation as described in a report by the IW-Net report [UC5-8]; stating that the European Federation of Inland Ports (EFIP) estimates that only "*20% or less of all berths in Europe*" allow to use shore power. Main challenge seems to be the infrastructure and the stakeholders. On the other hand, there is an increasing pressure for shore power installations.

As a matter of fact, GHG emissions for IWT are approximately 40% lower than road transport [UC5-9]. The main reason is due to the total volume transported with one marine vessel against tens of trucks. Therefore, at some point in time, to meet the overall CO_2 target, governments may start investing in greener alternatives [UC5-10].

Synergetics [UC5-11] project is also underway, and the goal is to make use of alternative fuel powered engines and electrification. In general, hybrid applications are the main target with the help of battery swapping solutions. A power barge with fast charging capability can provide the flexibility to reduce the battery weight on the ships while also reducing the equipment to be used in ports for swapping operation. As already discussed, limited space is already one of the main challenges of the ports. There are also specific challenges related to the operation of inland ports during OPS which will be discussed in gaps and challenges section (Chapter 5.4).

Platina4Action recently started [UC5-12] to address policy guidance along with targets such as establishing a labelling system for IWT vessels and a RD&I roadmap for technologies which help remove the barriers for zero-emission shipping.

In summary, IWT ports and ship operators face different challenges, and the potential of power barges migrate the problem from being an infrastructure problem to an operational opportunity which is believed to speed up and help the transition.

3.4.6 – UC6: Powering leisure boats along the coast

Leisure boating holds an extremely important place in terms of the European Blue Economy [UC6-1]. It shall be highlighted that in Europe, the Mediterranean Sea is one of the most famous nautical tourist destinations such as Italy, Spain and France due to its climate. They are also capable of accommodating various types of leisure boats in their coastal areas and marinas. Over the last years, an excess in the maritime tourist industry to the Mediterranean coasts has been observed. This results in multiple environmental challenges. About 87% of the leisure boats with varying lengths from 2.5 to 24m are motorboats [UC6-2] which have an ecological impact on freshwater and marine ecosystems. The main reasons being motor noise disturbance – termed as underwater radiated noise (URN), GHG emissions, fuel and oil leakages or spills.

All these have a particular impact on the marine environment as they contribute to local air and water pollution, and ocean acidification [UC6-2].

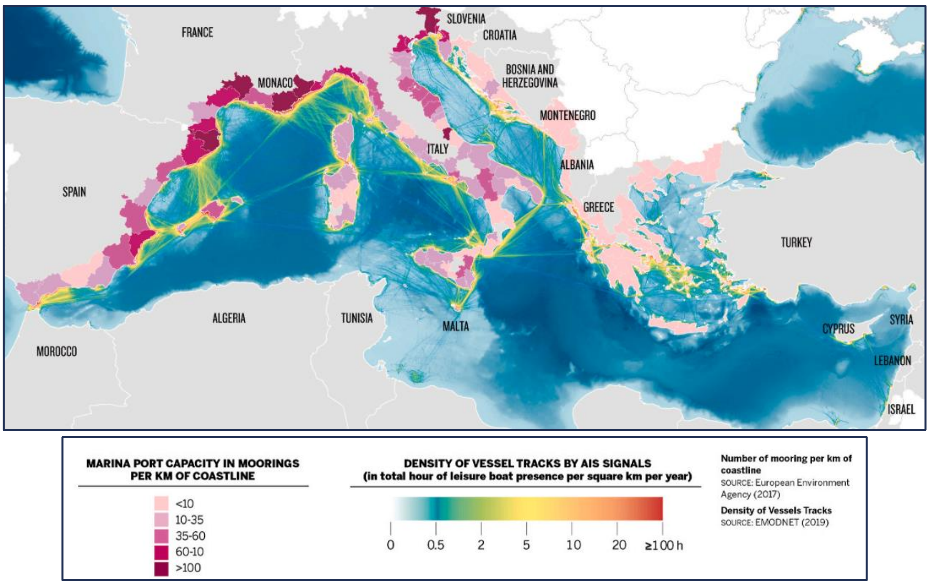

Figure UC6-1: Marina port capacities in number of moorings per km of coastline in EU counties and sailing and pleasure craft routes [UC6-3].

The power-barge solution offers the opportunity to provide renewable power to the coastal areas and bays, and further distribute it for leisure boats electrification during their stay at marinas.


Figure UC6-2: Leisure boats at the bays (Google Images).

Usually, leisure boats, when anchored, turn on their generators for about 2-3 hours before night causing noise and emission. Later, they shut their system down.

In busy areas, there may be more than 10-15 boats anchored next to each other. This concentration causes high levels of oil which may be spilling through the cooling water at populated areas along with noise causing Posidonia meadows to be lost and dolphins to leave their natural habitats [UC6-2].

Depending on the size of the boat, energy transition may take place at different paces. For example, in Germany, small boats do not rely on charging infrastructure with the possibility of battery exchange. However, larger boats require to be charged from the port which depends on the investment decisions to take place [UC6-4]. So, power barges can act as an interim solution speeding up the process for the transition of larger boats.

Considering that the global nautical fleet has over 33 million pleasure crafts, only 13% are docked in equipped marinas. Therefore, it is crucial for new marinas to invest in becoming Zero Emission Marinas (ZEMars). Unlike conventional marinas, ZEMars are designed to provide rapid recharging with the help of solar and wind power, and additional services with ESS [UC6-5].

As future marinas move towards zero emissions and are powered by renewable energy sources and battery energy storage, power barges could become essential components to meet the increasing energy demand. Since local grids are generally not well-developed enough to handle the ever-increasing charging loads resulting from this electrification trend, power barges can manage the charging tasks independently of the local grid.

The number of yachts and leisure boats visiting the Monaco port is steadily increasing resulting int the construction of new two jetties by 2025 [UC6-6]. This expansion will help reinforce the existing leisure ports and increase the capacity of moored yachts in the district. The Yacht Club in Monaco supports the greener yachting industry, and its marina has been equipped with fast chargers since 2019 to promote electric propulsion in leisure boats [UC6-7]. Currently, the electricity which is produced by renewable energy sources in Monaco reaches 23% [UC6-8] and the biggest percentage of renewable energy is derived from solar and wind [UC6-9]. However, Monaco has set the goal to decrease its local greenhouse gas emissions by 55% by 2030. Therefore, additional strategic planning shall be applied to succeed in that goal. The power-barge concept can effectively be used to supply several vessels with slow and fast charging. Due to barge's adaptability and flexibility, it can be easily moved to different marinas along Monaco's coastline and further distribute the stored electricity to the numerous leisure boats that are moored and in marinas.

The Port of Amsterdam has developed a mobile power storage solution (on shore) to resolve the challenge of low grid capacity during peak river cruise seasons. With energy suppliers, it applies a container-based large battery that is charged by wind, solar, or biomass, hence providing electricity to vessels or boats while at berth. The initiative furthers the port's ambition to be emission-free by 2050 and adheres to Amsterdam's zero-emission legislation regarding canal cruise and leisure boats by 2025. The floating battery also services electric boats during the high-demand tourist seasons [UC6-10].

The floating battery services leisure boats (electric or diesel) during the high-demand tourist seasons. With the BlueBARGE solution, this floating service can be provided on land without any investment, space or extra equipment.

3.4.7 – UC7: Powering offshore platforms – oil rigs

Even though offshore structures play a pivotal role in distilling non-renewable energy such as fossil fuel, several measures and actions shall be taken to eliminate their usage. Environmental crisis and its impact are apparent. Therefore, based on the Net Zero Scenario and the legislation aiming for a clean energy transition in all sectors, efforts for the oil and gas industry are focusing on limiting emissions from all its activities. There is a target for a 60% reduction in emissions from oil and gas operations up until 2030 [UC7-1]. Thus, electrification solutions are potentially attractive compared to other solutions for limiting carbon and greenhouse gas emissions [UC7-2].

Offshore rigs require a significant amount of energy to support their operations, and the demand depends on the rig's operation, type, location, and the respective environment. Offshore rigs commonly utilize diesel engines which consume 20 to 45 cubic meters of diesel fuel daily [UC7-3].

Offshore oil and gas platforms exceed 9,000 worldwide [UC7-4], which causes a big amount of fuel consumption and emissions production. Therefore, it is necessary to investigate alternatives for more sustainable electrification manners and expunge the usage of the typical diesel generators or cables connection to the grid [UC7-5]. Gas turbines have traditionally been used for power in offshore oil and gas facilities, in addition to being non-eco-friendly machines. These days, this sector of the economy appears to be shifting towards employing electricity that is generated from onshore sources and transmitted via undersea cables, an approach that leads to superior fuel consumption rates and minimized greenhouse gas discharges. In this way, by using electricity from on the coast Norway's Johan Sverdrup field helps to reduce its CO2 emissions by about 460, 000 Tonnes per year. On the other hand, it lowers operational expenditure. Tapping shore power for offshore oil and gas facilities UC7-6].

The power-barge concept can be applied and provide the needful electrification to the power-demanding offshore platforms. A barge can be allocated close to the offshore oil rig complex and through a barge-to-ship power connection, can provide renewable electrification contributing to the reduction of conventional power usage as fuel supply will be eliminated. Due to the power barge's flexibility and ease of maneuverability, the power connection might alternate and support the specific oil rigs depending on their power needs. That results in minimizing the local polluting emissions from a life cycle perspective.

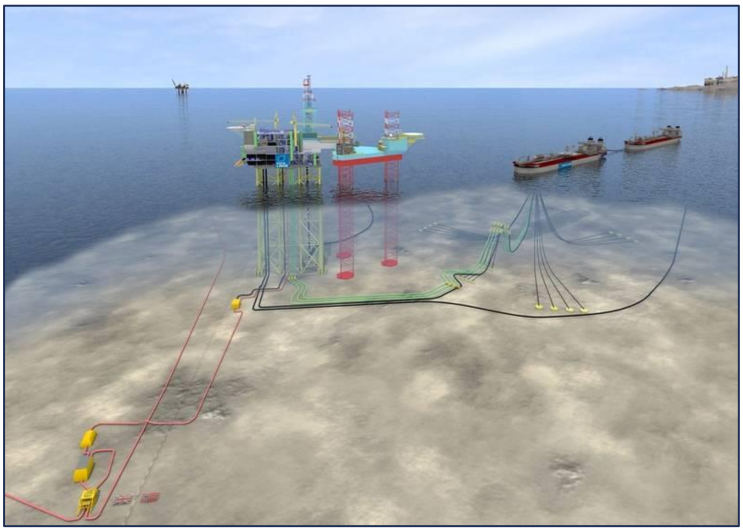

Figure UC7-1: Oil facilities and shore connection concept (Image: *Siemens*)

To succeed in this energy/power transfer, it is necessary to first determine the energy need and select the barge-to-ship infrastructure suitable for the offshore platform. This includes a detailed analysis of energy demand and environmental impact assessment. Then, the appropriate barge-to-ship system that will provide energy to the platforms must be designed. This stage should include technical details such as the capacity of the energy barge, the design of the cable management system and connection sockets, and suitability for marine conditions. The compliance of the region where the project will be carried out with the marine and environmental laws must be investigated and the necessary permits must be obtained. In the next step, operations on how the cable management system will be transferred after the construction, transportation, and installation of the energy barge should be determined. It is important to carry out regular maintenance and monitoring activities after the barge-to-ship power transfer system is first commissioned to ensure that the energy supply is continuous and uninterrupted when there is a demand for energy in emergencies. These steps ensure the successful and safe implementation of barge-to-ship power connections and provide sustainable uninterrupted energy.

Currently, approximately 5% of the world's offshore oil and gas production is dedicated to powering production platforms, consuming 16 terawatt-hours of electricity annually — more than the entire consumption of Croatia. This is a substantial contribution to the carbon burden, and based on, for example, a $40 per ton base price, would lead to an $8 billion yearly carbon tax on the industry's 200 million tons of CO_2 emissions. Changing to renewables will cut such operational costs as well as lower emissions, hence their support for sustainability. Some examples are onshore renewables through existing offshore wind farms, further supported by new dedicated projects like Equinor's Hywind Tampen, showing costs and environmental savings of significance [UC7-7].

Wärtsilä suggests creating a floating energy hub for offshore oil and gas operations using floating wind turbines and hybrid batteries, which could reduce their carbon emissions by 100% or more. It could have multiple installations, thus resulting in a 50% to 90% reduction in emissions without the cost of power cables. It clusters offshore assets by using technologies, such as power barges, or floating production storage and offloading (FPSO) vessels, together with sustainable, flexible, and reliable power generation that contributes highly to actions of decarbonization [UC7-8].

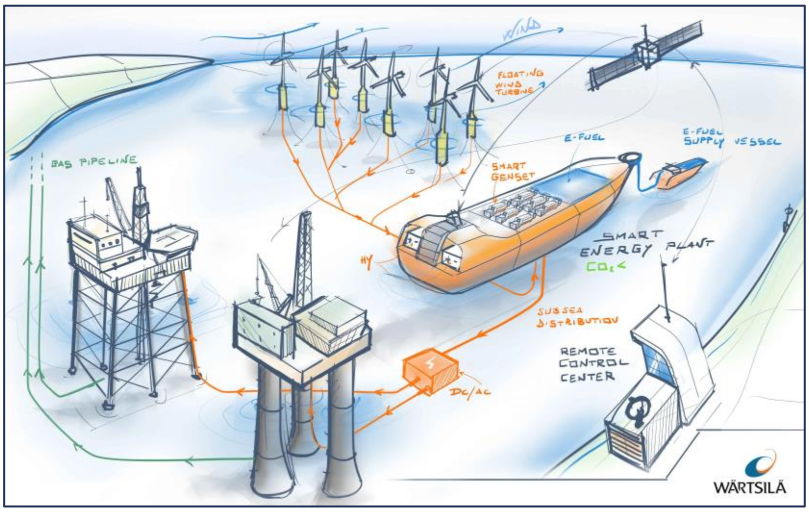

Figure UC7-2: Floating energy hub for offshore oil and gas operations [UC7-8].

The successful implementation of barge-to-ship power connection reduces operational costs by potential carbon emission related fines and energy efficiency. Another successful application is the project carried out by Karpowership in Ghana, which contributes to the country's energy security and supports environmental sustainability [UC7-9].

3.4.8 - UC8: Charging from offshore power plants and wind farms

One of the questions recently raised is making use of the power generated at the offshore wind power stations by delivering to hybrid or full electric vessels on route. Another option is delivering power using power barges. One application is Japan Power X [UC8-1] company where barges are used to transport the power generated in batterised containers.

The main advantage of making use of the power generated at offshore power plants (especially from the wind or solar installations) is the green source. Especially with the increasing number of floating power plants, for example wind farms can be moved to deeper regions in the ocean, behaving as energy hubs. Assuming that these hubs are away from the shipping corridors, power can be transferred with barges to supply power to the ships.

Recently, there are some applications and feasibility studies to use buoys as charging stations. However, most of the time, they don’t have additional battery capacity and make use of the power generated from the wind farms and transfer it to the ships [UC8-2, UC8-3]. With the support of a power barge, the use cases designed in these applications can be expanded such as powering barges during idle time slots, using power barges to reach out to distant locations (charging at a specific distance due to safety), balancing the loads etc.

All these features will be beneficial to the ship builders because increasing the number of charging locations will help reduce battery sizes. A quick analysis will provide more insight about the potential:

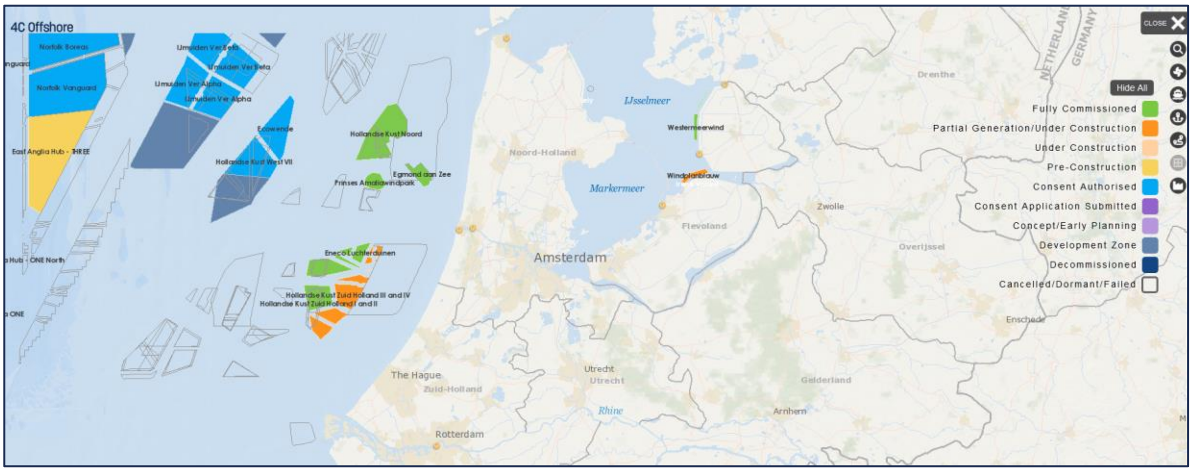

Figure UC8-1: Windfarm locations around the West Coast of the Netherlands [UC8-4].

In Figure UC8-2, a snapshot of the vessel traffic around the same region is given.

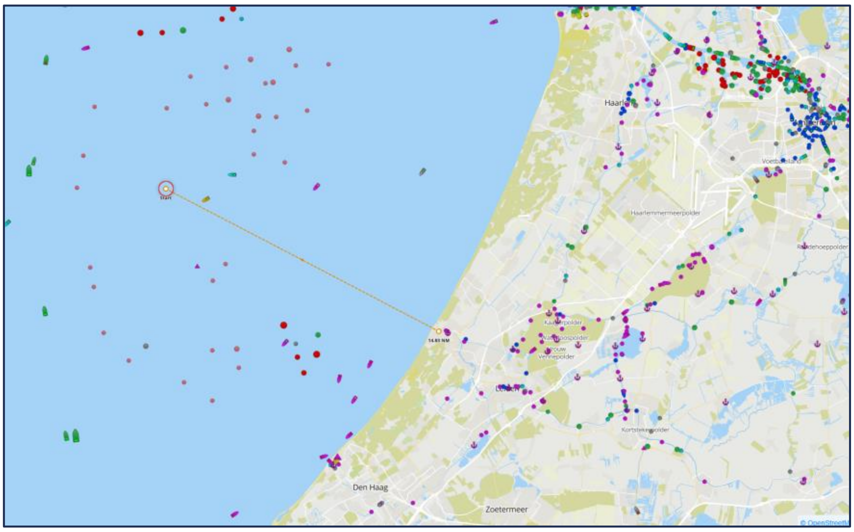

Figure UC8-2: Marine Traffic Around the Farm Region [UC8-5].

As stated in the previous paragraphs, a group of power barges recharged from a buoy and/or from offshore wind farms can provide ship to ship power for vessels at anchorage.

Another advantage which should be considered is reduced distance to the target vessels. In this case, a barge can be charged from a buoy in the proximity of the highlighted tanker (Figure UC8-3) and start supplying power without the need for travelling and adhering to safety rules.

Considering the ambitious target of 65 GW of offshore wind power installation by 2030 in Esbjerg and Dublin Declaration (2022), it is reasonable to make use of this capacity within alternative methods [UC8-6].

Also, another advantage of power barges is to provide flexibility to the mainland grid. For example, congestion is becoming a concern and requires grid expansion [UC8-7]. For example, again considering Netherlands, there is a well-known supply problem (Figure UC8-4).

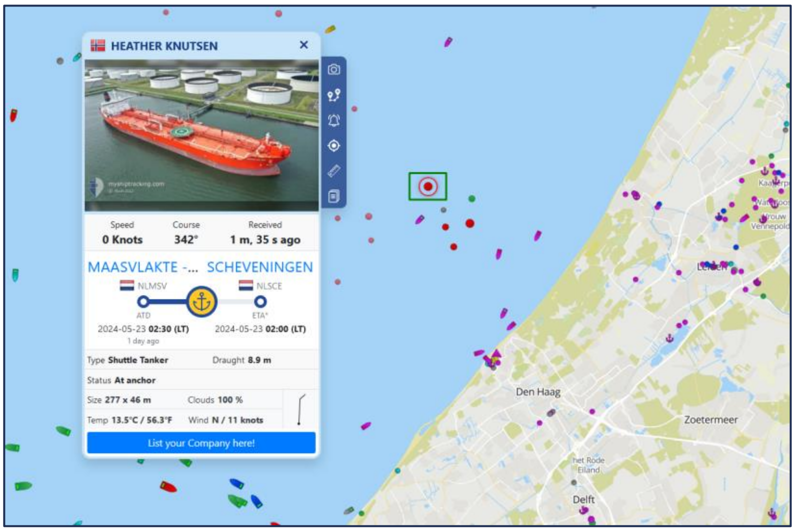

Figure UC8-3: Tanker at anchorage [UC8-5].

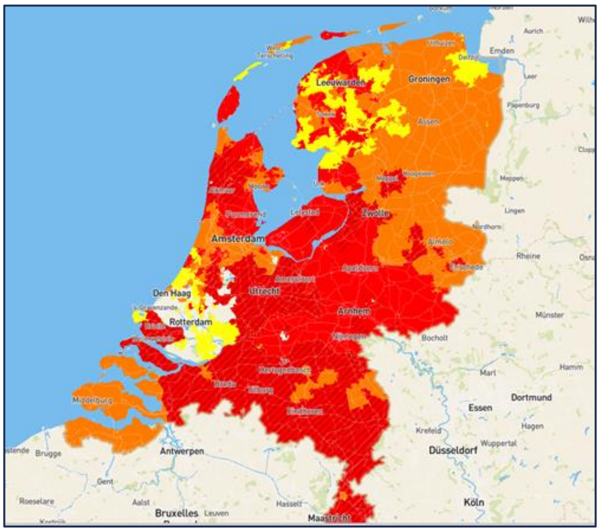

Figure UC8-4: Netherlands Power Supply Map [UC8-8].

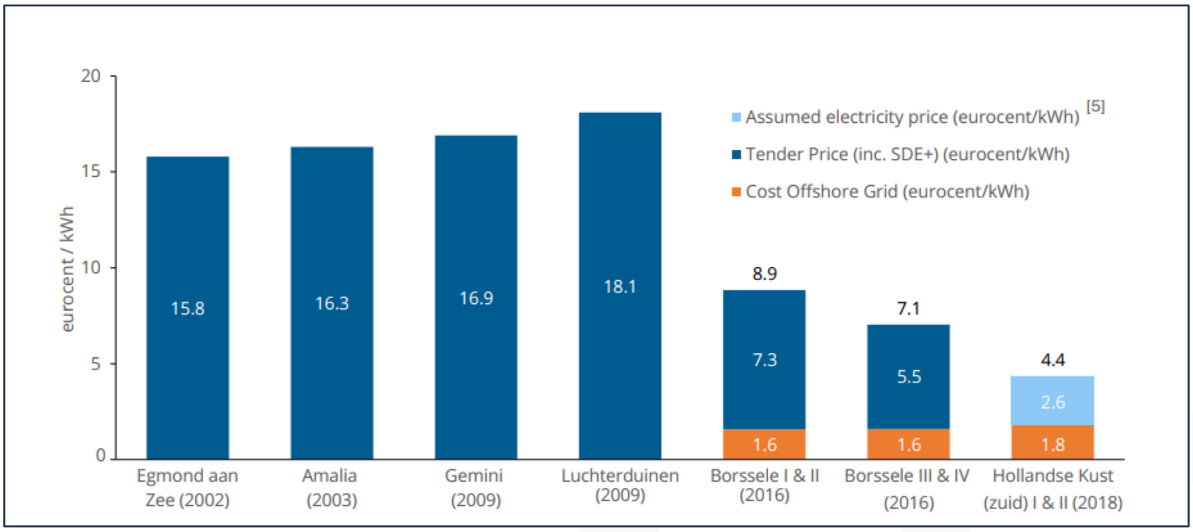

Figure UC8-5: Cost of offshore wind farms from Egmond aan Zee until Hollandse Kust (zuid) I & II [UC8-9].

So, considering the supply challenges and the target prices, there seems to be a good opportunity for offshore charging applications. Land line electricity prices is around 0.077 Euro/kWh for the Netherlands [UC8-10]. Since the port dues will be removed, barge case seems to be a good application.

A study investigating the feasibility of offshore charging stations evaluates three different floating power generation options: a 100 MWe capacity PV field planned in the North Sea [UC8-11], a 588 MWe wind farm operational off the coast of Wick in Scotland [UC8-12] and a nuclear power plant [UC8-13]. The study concludes that offshore charging stations are financially competitive even without carbon taxation, suggesting a promising business case for maritime electrification and potential cost reductions [UC8-14].

A novel approach proposes the world's first zero-emission Offshore Electric Charging Station (OECS) to overcome the limitations of shore-based charging along coastal routes [UC8-15]. This concept aims to install OECS in deep waters along major shipping routes, enabling large ocean-going vessels with significant battery installations to recharge and extend their travel range [UC8-16].

Acting as an integration platform between offshore renewable generation and electrified vessels, power barges can facilitate charging tasks offshore. This allows ships to perform these charging operations more flexibly and at strategic locations, thereby reducing delays and consequently lowering costs. Since a considerable portion of generated energy is lost during transmission from offshore power plants, power barges could enable more efficient use of harvested offshore energy by minimizing transmission losses [UC8-17].

A very recent project which was funded by the The Clean Maritime Demonstration Competition (CMDC) demonstrates a direct charging from an offshore wind power station (Figure UC8-6) [UC8-18].

This use case can be analyzed from a diversified perspective. One perspective is based on the need of recharging the batteries of hybrid ships during operation, where the barge is a safe and secure solution for transferring energy generated in offshore platforms to ships. Another perspective is related to supplying power to berthed ships that do not have onboard energy storage systems. The barge, as its batteries are charged from the mentioned offshore platforms in non-operation periods, can easily supply the required power to these types of vessels. In this case, among various offshore power platforms that we will report, floating solar plants and wind farms are considered as the offshore power platform which then barge charge its batteries from them and navigates to ships so supplying them with needed power while berthed and it cause ensuring significant emission and fuel reduction during slow steaming.

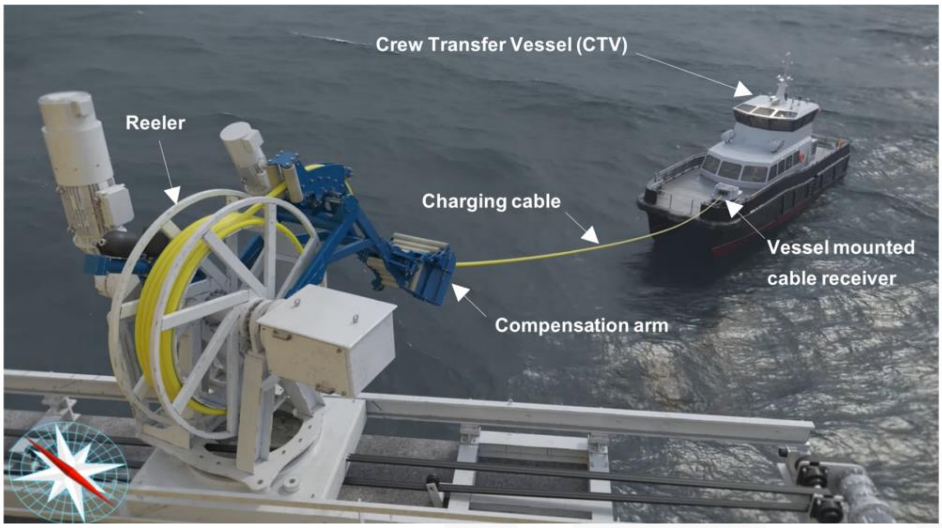

Figure UC8-6: Charging from an offshore windfarm [UC8-18].

Figure UC8-7: Charging from an offshore windfarm [UC8-19].

As of December 2018, worldwide capacity of floating photovoltaic (FPV) systems exceeded 1.3 GWp and it has grown rapidly since 2017 [UC8-21]. However, most of the floating solar plants are deployed in inland waters and therefore for offshore application in the context of this use case, offshore wind farms should be considered.

For ships passing through the Turkish Straits, the transit state is defined according to Turkish regulation "A vessel is considered 'in transit' if it is not bound for a Turkish port or does not have an anchorage duration exceeding 168 hours except waiting times stemming from impediments" [UC8-21]. This regulation ensures that hybrid vessel with ESS transiting through Çanakkale and Bosphorus Straits has enough time to recharge its batteries without jeopardizing transit status. Fig UC8-9 presents real-time marine traffic in Bosphorus Strait dated 29.07.2024 where dots represent stationary vessels which are berthed due to various reasons. On the other hand, Fig UC8-10 (source: World Bank Data Catalog) indicates locations along Aegean Sea and Marmara Sea where offshore wind farms are feasible (in purple).

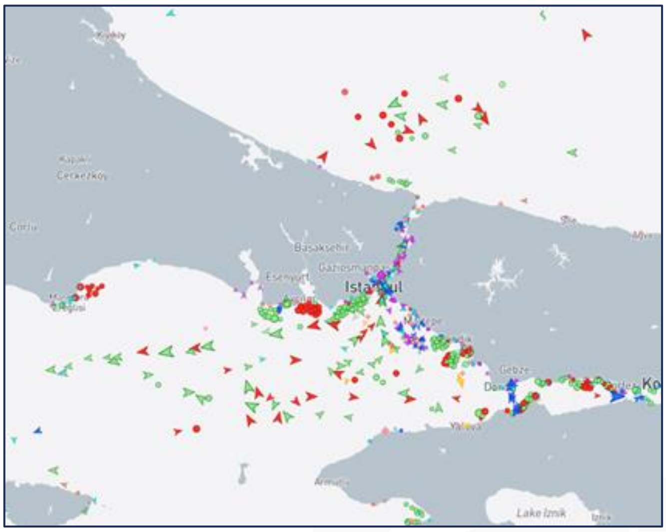

Figure UC8-8: Marine Traffic at Bosphorus Strait.

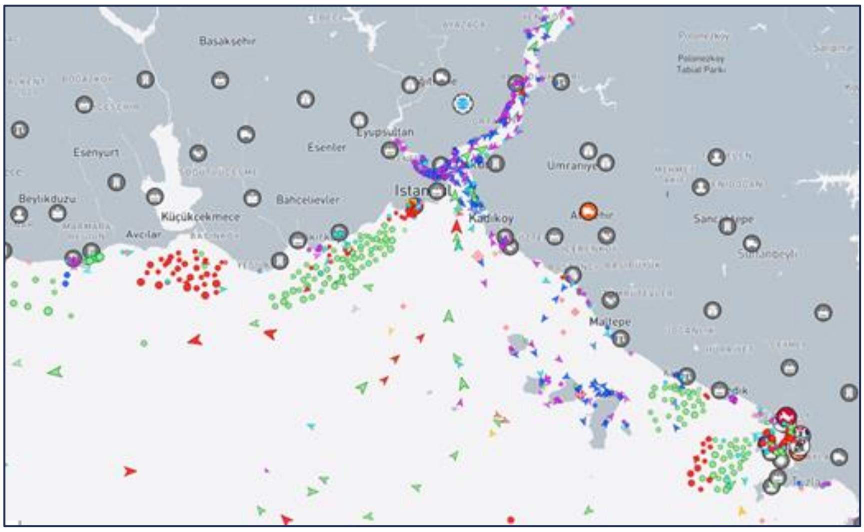

Figure UC8-9: Detailed Image of Marine Traffic at Bosphorus Strait.

Figure UC8-10: Feasible Zones for Offshore Wind Turbines.

Including UC8, integration of offshore wind farms in indicated location can significantly improve BlueBARGE operation by powering vessels berthed within Marmara and Aegean Seas. High density of marine traffic in this region indicates also how important is utilizing barge solution to transfer energy generated by wind farms to vessels. The design product offshore wind energy project areas of Türkiye match well with the mentality of utilizing offshore renewable energy to support BlueBARGE through Bosphorus and Çanakkale Strait. In fact, the largest area design is 1,111 square kilometers off the coast of Bandırma in the Marmara Sea followed by 410 square kilometers, Karabiga, and 75.6 square kilometers from Gelibolu. The Aegean Sea also acquires a significant portion which is 299 square kilometers from Bozcaada Island. When considering only Marmara Sea has an offshore wind energy potential of 19.2 GW for floating installations and 2.8 GW for fixed-based installations [UC8-22].

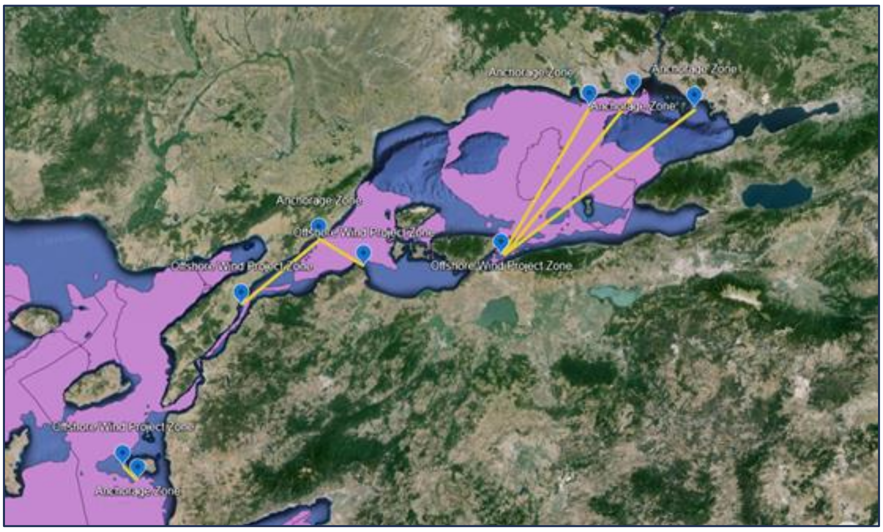

Figure UC8-11: Map of Offshore Wind Project Zones and Anchorage Zones.

These images identify and map where most of the vessels dock, as well as sites being developed for new offshore wind farms. The distance from Bozcaada Island neighborhood offshore wind farm to the anchorage area next to it is around 5 miles. The alternative is from the Bandırma shores to the Istanbul coasts (approx. 50 NM). This proximity indicates a great deal of potential for effectively using offshore wind energy to power conventional ships without ESS or to recharge the batteries of berthed or transiting vessels, improving the operational efficiency and sustainability of BlueBARGE solutions in these areas.

3.4.9 – UC9: Providing power to land after natural disaster events

Natural disasters (earthquakes, tsunamis, tornadoes, or hurricanes etc.) cause unforeseen consequences to communities, resulting in loss of life and significant damage. In addition to the immediate damage, infrastructure recovery often takes time, slowing down search and rescue efforts.

Some unforeseen obstacles may arise or occur after an obvious natural disaster, such as gas leaks and power outages. Earthquakes and floods can damage power grids and transmission lines. Often, it can take months for power to be restored after an earthquake. However, in most cases, this phenomenon lasts 2 to 4 days [UC9-1].

In the event of a flood, recovery can take up to 3 to 5 weeks. The first and second days are the most important days for the rescue team to continue their search and rescue efforts. It is also important that logistics teams organize the planning and distribution of necessary supplies and other equipment. The estimated time for repair is shown in the following table [Table UC9-1]:

Table UC9-1: Estimated repair duration due to earthquake damage [UC9-1].

Component	Repair strategy	Repair time
Transmission Tower	Replacement	10 days
	Erect temporary tower	1-2 days
Large Power Transformer	Inspect, reset and re-energize	14-20 hours
	Refill oil, onsite	2 days
	Minor repair, onsite	1-2 weeks
	Change windings, onsite	3 months
	Replace (no existing spare)	1 year or more
	Replace with spare	5 days

It is estimated that it will take at least two days to restore normal operations around the affected area. Usually, portable generators are used to provide electricity during this period. However, it is not always possible to supply the necessary fuel to keep the generators running. For larger generators which need to be transported by trucks, road blockages make the deliveries very difficult.

Over the past decade, 12 cities around the Mediterranean have experienced earthquakes larger than 6.5 on the Richter scale (Figure UC9-1). Most of them occurred on islands or very close to the Mediterranean coasts.

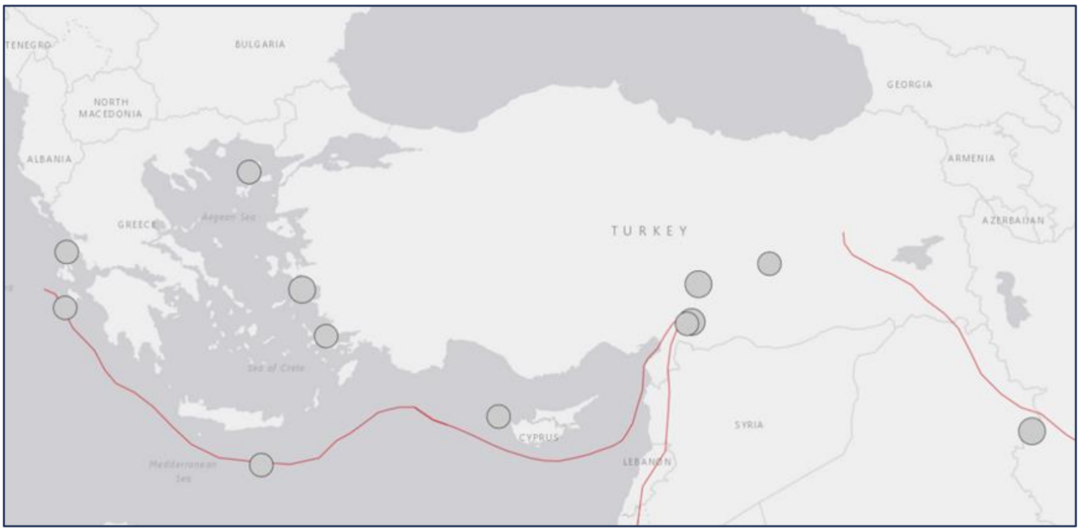

Figure UC9-1: Earthquake locations around the Eastern Mediterranean with 6.5+ scale in between 2014-2024 [UC9-2].

Examining earthquake sites across the globe reveals a similar occurrence (Figure UC9-2). It appears that earthquakes are more likely to occur near coasts and islands than in interior regions.

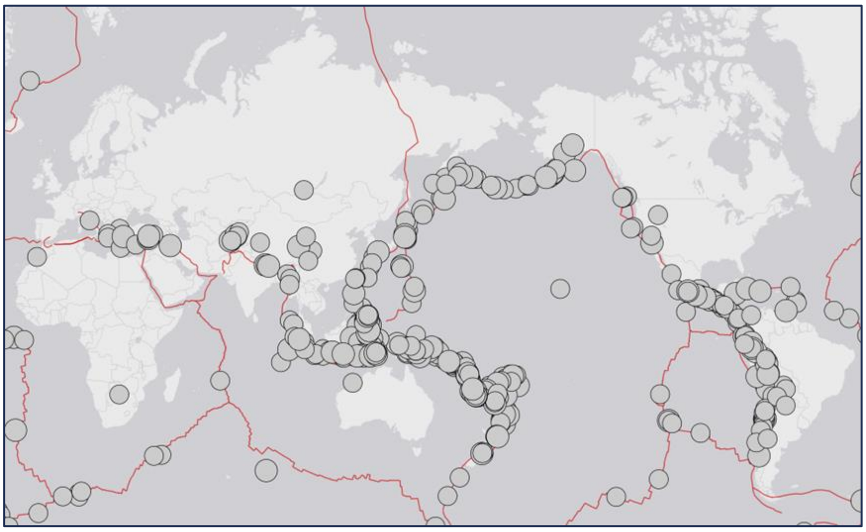

Figure UC9-2: Earthquake locations around the globe with 6.5+ scale in between 2014-2024 [UC9-2].

<u>A case of Gaziantep, Turkey:</u>

On February 6, 2023, a strong 7.7-magnitude earthquake impacted southern and central Turkey near Gaziantep. Eleven provinces in all, including Mersin, Adana, and Hatay, located along the Mediterranean coast, have been impacted. A blackout occurred because of the damage to the power transmission lines, energy infrastructure, and substations. In situations such as these, the rescue operations and other lifelines (such as communications and the provision of water and electricity) depend heavily on the uninterrupted flow of electric power.

The power barge can quickly assist these afflicted districts, which are near the coast or on islands, saving valuable time. With a shore connection, it is possible to support numerous critical operations until the main line is restored.

However, it should be noted that in some circumstances, the ports may have been demolished or are inaccessible. In this case, it is critical to have a system in which the power barge can still transmit electricity to the port or shore side. One of the proposals would be to place shore connection boxes at strategic spots along the shoreline. This application will also be very helpful for connecting multiple barges to the shore.

If there is an issue with the transmission lines or towers that prevents power from being transported from the shore to the center, temporary towers (also known as emergency restoration towers/systems) or external cables can be used to temporarily deliver the power. As a result, the shore connection boxes should be outfitted with redundant cables to increase system robustness.

<u>Fukushima, Japan in 2011:</u>

When a disaster event occurs, the blackout in an urban city may be very devastating to people and key infrastructures. In the Fukushima earthquake of 2011, the event caused damage to the nuclear power plant; only ships at sea survived the tsunami. They proposed an emergency power supply strategy using EVs for ships at sea to transfer electricity into the land to hospitals and shelters [3,4].

3.4.10 – UC10: Charging BlueBARGE from outer anchored vessels

This use case involves transferring electricity from anchored vessels to a barge. It's similar to how power ships operate [UC10-1], but on a smaller scale. Vessels in anchorage utilizing generators for the necessary electrical loads, especially when powered by alternative fuels such as LNG, Methanol, or Ammonia, may be used as a source of power. This application is similar to the V2V application in road vehicles. So, the case is another application of bi-directional charging. Recent data from DNV alternative fuels statistics indicates that almost 15% of new builds are powered with alternative fuels (Figure UC10-1).

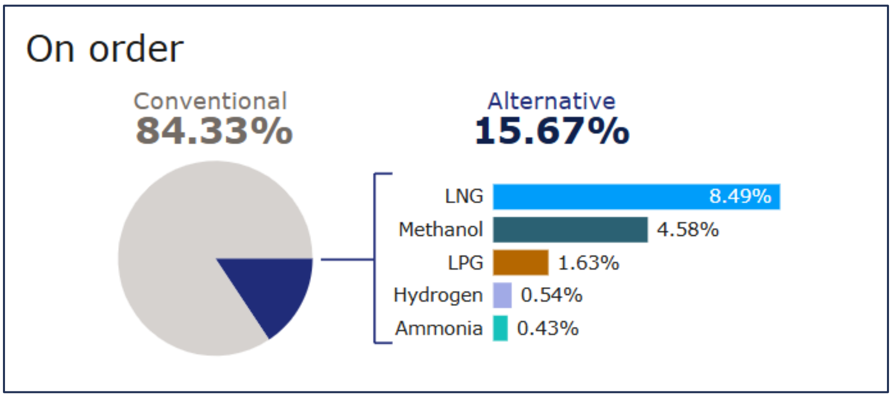

Figure UC10-1: Distribution of new orders [UC10-2].

The barge can be charged from these vessels which may constitute a totally new business case. Technically there are some important factors to be considered such as the operating voltage and current compatibility. A universal barge is decorated with various equipment to address this part. For example, it can carry transformers to respond to low or high voltage.

A typical concept of operations for this use case is summarized below:

In this use case, the main actors are the ship's captain, the barge crew member and the ship crew member onboard the barge and the ship. The process begins with the ship's captain determining the energy surplus that can be provided to the barge operator. The barge operator secures the BlueBARGE alongside the ship and competent barge and ship crew check and securely connect the connection cables. During the charging process, safety protocols and procedures for the shore power system - available on most vessels by design - must be followed to prevent electrical hazards. The ship then supplies the necessary electricity to the barge. The system automatically monitors the energy transfer and in case of an issue, the system reacts based on the predefined action routine. Once the energy transfer is completed, the ship's captain requests the termination of the connection. This data should be sent through the communication protocol and the control system shuts the transfer down. The competent crew safely separate the connecting cables. The barge moves away from the ship and takes its stand-by position within port limits. This process leverages the capability of the auxiliary engines/gensets to provide optimum energy conversion at highest efficiency from a compliant fuel to electricity, while observing onshore electricity and compliant fuel prices, emission regulations and geographical operational concerns.

For a merchant vessel to be considered as energy supplier for the BlueBARGE, several conditions must apply:

1. The electricity cost at berth (if available) should be higher than the electricity produced onboard, when compliant fuel is used during outer anchorage.

2. The merchant vessel should have both the Shore Power Connection (SPC) and the crew onboard, prepared for the BlueBARGE energy transfer.
3. The environmental conditions should allow for safe BlueBARGE recharging. The GHG emissions allowance and environmental regulations are observed for the geographical area of the port, including outer port limits and off-port limits anchoring areas.
4. The anchorage time should be long enough to charge the BlueBARGE.

To have a better understanding of the conditions, each are explained in detail:

CONDITION 1: Electricity Prices at Cost and Onboard

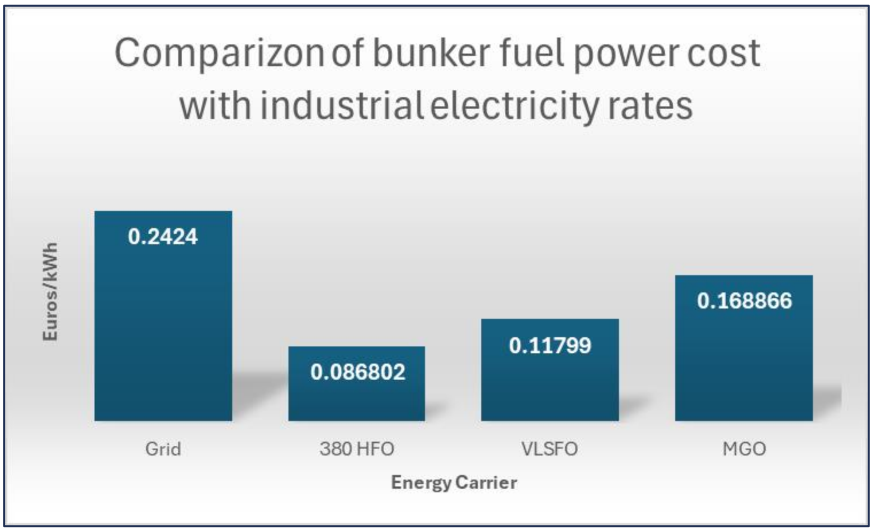

Figure UC10-2: Comparison of Prices [UC10-2].

The national and international economics of OPS or Cold Ironing (CI) has been an integral part of academic literature with most publications emphasizing the importance of prices per kWh [UC10-3, UC10-4]. To elaborate on the impacts of electricity prices, the above figure (Figure UC10-2) compares the cost of electricity between onboard electric production (depicting 2023 European averages prices for fuel types: 380 HFO 1% sulphur, for usage with onboard scrubbers; VLSFO 0.5% sulphur, for usage in non-ECA zones; and MGO 0.1% sulphur, for usage in all remaining cases) and the average industrial electricity rate of European Union (27 countries) for 2023-S2 (this is reported in half-year averages in Eurostat, including all applicable taxes). The assumptions used for Figure UC10-2 rely on a USD to Euros conversion rate of 0.92 and the auxiliary engine SFOC of 200g/kWh at 40% average load. As the above results are based on historical averages, a more accurate cost-benefit forecast per ship would be necessary for operational decisions concerning BlueBARGE energy bunkering.

The operational decisions of when, where, and for how long a BlueBARGE can be charged from a ship should be considered the overall decarbonization strategy of the shipping company. Notwithstanding auxiliary engine(s) used for hotel loads during anchorage provide for minimum GHG emissions, the excess CO_2 emitted should be carefully planned. With the EU Trading Scheme, the ability to pool is not limited to single fleets: if a shipowner has surplus compliance after pooling within its own fleet, it can sell that surplus to other shipowners through the pooling system.

Alternatively, the shipowner can ‘bank’ the surplus ‘credits’ and use them in subsequent years as the mandated GHG intensity reduces further. The profit of gCO_2/kWh offered to the BlueBARGE versus the projected profit of emissions trading or "banking", is an important element of the final operational decision.

CONDITION 2: Shore Power Connection and Experienced Personnel

The SPC is a different system than the one required for HVCI or SSE, as it is demonstrated by EMSA [UC10-5]. Referring to Figure UC10-3, which demonstrates one of the potential cases for SSE, the shore power connection can be considered as case J reversed, with the *E. Berth OPS Module* installed onboard the BlueBARGE.

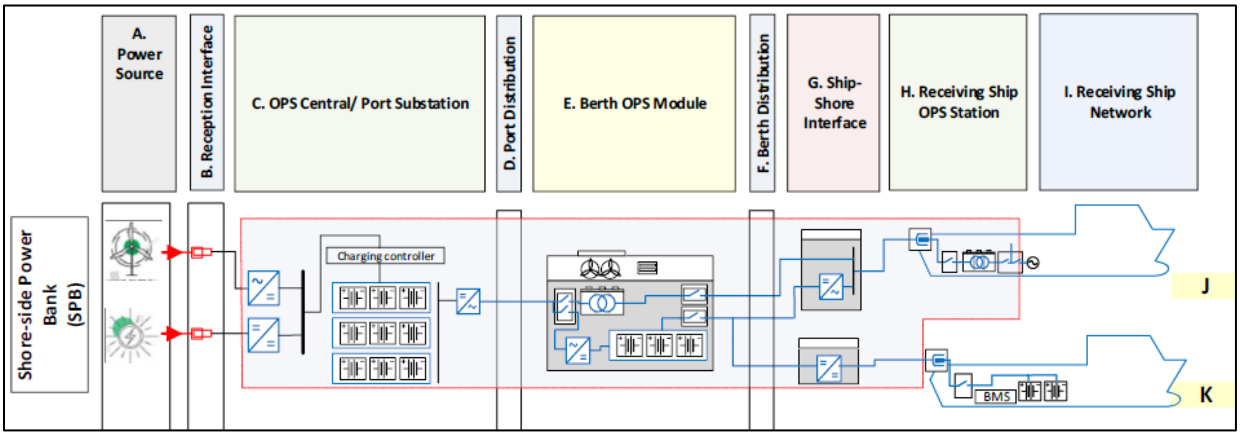

Figure UC10-3: SSE Types – Arrangements for SSE configuration "J" to "P" [UC10-5].

Currently, the SPC takes place in case of dry or retrofit docking for most vessels. The SPC cables enter the side panel of the emergency generator switchboard through a door installed in the base of that panel. The connection to the power from shore is made via a Moulded Case Circuit Breaker (MCCB) to the bus tie line that connects the primary and secondary circuit breakers in the emergency switchboard. The system includes Air Circuit Brakers (ACBs), a trip device used to provide overcurrent and short circuit protection for electric circuits over 800 Amps and up to 10kAmps. The usual application of ACBs is meant for low voltage applications (below 480 V), which is the case for several ships. The ACB at the main switchboard at the end of the bus tie line does not have undervoltage trips installed, and therefore, it is mandatory to remain closed, while SPC procedures are being performed. When the ship is supplied by shore power, the emergency switchboard can be supplied as normal through the main/emergency switchboard bus tie circuit-breakers.

There is a special interlocking mechanism for the shore source however and cannot be operated in parallel with any of the ship's generators (main or emergency). This means that it is not possible for the generators to operate when the shore's supply ACB is closed, and the shore supply is not allowed to operate when any of the generators' ACBs are closed.

Even though it is not anticipated currently by the SPC procedures, an upgrade to the Power Management System (PMS) and the interlocking mechanism could allow the charging of the BlueBARGE. Also, this upgrade can serve as a connection to the off-board Battery Management System (BMS), effectively supervising the optimum charging of the BlueBARGE batteries through the ship's generator(s).

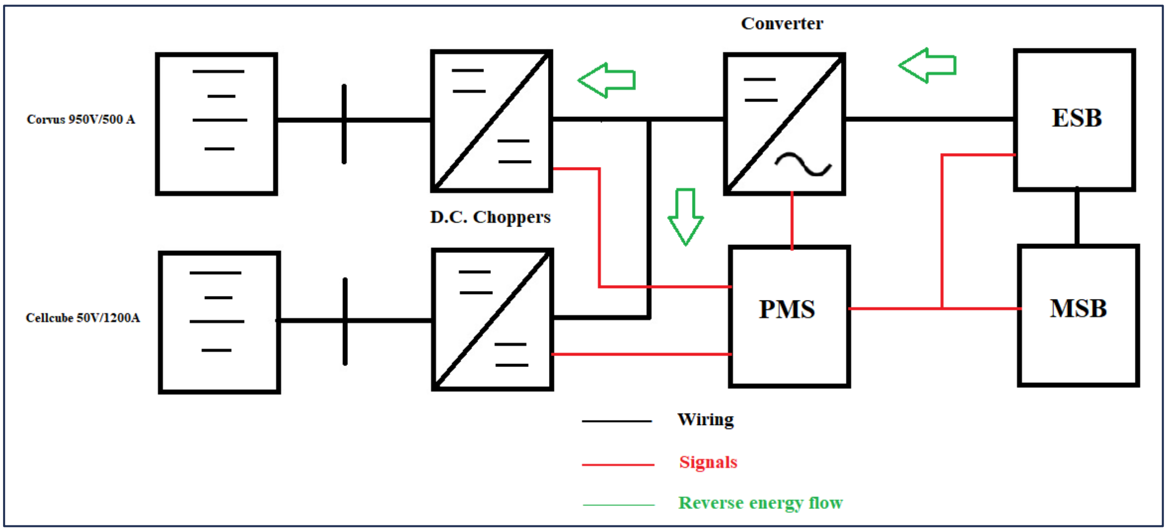

Figure UC10-4: Single wiring diagram of BlueBARGE and Ship's Emergency and Main Switch Boards. Application of PMS system.

CONDITION 3: ECA and Related Regulations

Referring to Use Case 4, ECAs include the current and future ECAs, commonly known as ECA zones. ECAs are sea areas that limit SOx and NOx emissions 0.10% [m/m] fuel for SOx and Tier III for NOx (pending vessel age).

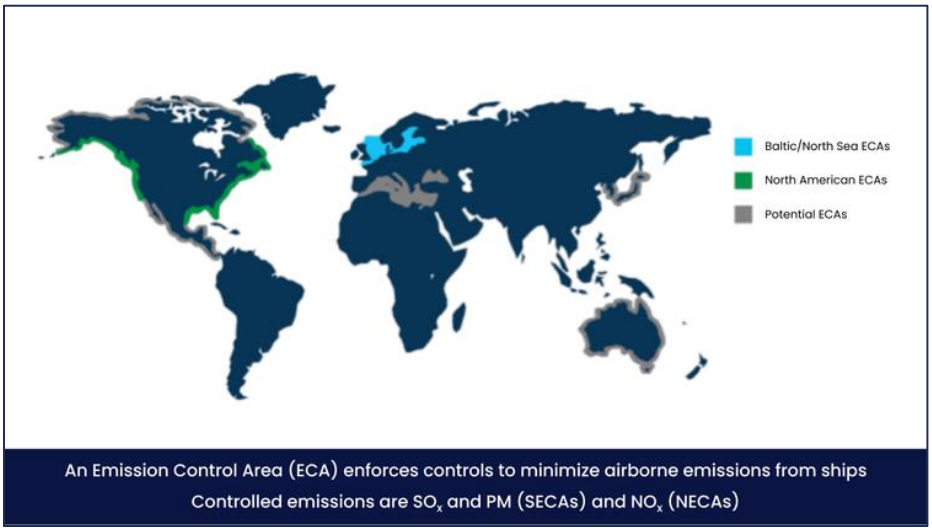

Figure UC10-5: Current ECAs around the world. Note that the Mediterranean ECA comes into effect as per 1 May 2025. Others are not yet official [UC10-6].

If not operating with scrubbers, a vessel should change over to a compliant fuel while operating within an ECA zone which includes also all ports within its limits. For ports not within an ECA zone, local regulations may apply for emissions controls. Several online sites [UC10-7] provide a comprehensive list, covering also the provisions of scrubber's usage. According to Bryan et. Al. [UC10-8], if a ship is operating outside of an ECA, the scrubber flow rate may be adjusted down to allow SO_2 emissions that would correspond to 0.50% sulfur fuel, thus reducing the load of the auxiliary engine in operation. This reduced load or the above suggested can also be used for charging the BlueBARGE.

Table UC10-1: Relative emissions change after the scrubber when using HFO (2.6% S) compared with other fuels [UC10-8].

Comparison: 2.6% S HFO + scrubber versus…	SO_2	CO_2	PM_{10}	$PM_{2.5}$	NO_x	CO	BC (SSD)	BC (MSD)
HFO (2.6% S)	-98%	+2%	-79%	-79%	0%	-11%	-9%	-11%
VLSFO (0.50% S)	-90%	+4%	-59%	-59%	0%	-11%	unknown	unknown
MGO (0.10% S)	-52%	+4%	+61%	+61%	0%	-11%	+353%	+81%
MGO (0.07% S)	-31%	+4%	+69%	+69%	0%	-11%	+353%	+81%

Noting that CO_2 emissions are not controlled by ECA zones regulations, other local, national and international regulations (e.g., FuelEU) should also be followed for CO_2 emissions. According to *REGULATION (EU) 2023/1805 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL* of 13 September 2023 on the use of renewable and low-carbon fuels in maritime transport, and amending Directive 2009/16/EC, it is provided that:

Table UC10-2: General Requirements for Zero Emission Technologies, Annex III [UC10-9].

ANNEX III

General requirements for zero-emission technologies

The following non-exhaustive table identifies types of technologies as well as general requirements for their operation to be considered as zero-emission technologies within the meaning of Article 3, point (7).

Types of technology	General requirements for operation
Fuel cells	Power supplied by onboard fuel cells with a fuel or a system ensuring that, when used to provide energy, it does not release any emissions referred to in Article 3, point (7), into the atmosphere
On-board electrical energy storage	Power supplied by on-board electrical energy storage systems previously charged via: — onboard power generation at sea — shore side battery charging — battery swapping
On-board power generation from wind and solar energy	Power supplied by on-board renewable energy sources, either directly supplying to the ship grid or via charging of on-board intermediate electrical energy storage

According to Table UC10-2, power supplied by on-board electrical energy storage systems, previously charged via onboard power generation at sea, are considered zero-emission technologies. The regulation does not specify any limitations regarding the type of fuel used to charge the on-board electrical energy storage system. Also, the above table is non-exhaustive and can be extended to off-board electrical energy storage systems, by virtue of systems' integration and boundaries.

CONDITION 4: Anchorage Durations

KPI 1.4 of BlueBARGE project states that a set of power supply modules for marine environments for a minimum of 3MW discharge and 35MWh power capacity is required. Assuming a charging rate of 1 C and a battery container of 500A/950V, demanding 475 kW charging power from an assumed 3000 kW Generator Set, then the demand of the BlueBARGE container from the Generator set could be 513 kW, including all potential energy losses, as it is shown in line 1 of Table UC 10-3. This is approximately 17% of the GenSet's capacity, resulting in a total GenSet loading factor of 60%, considering that around 40% of one GenSet capacity is used for hotel loads during anchorage. The charging time for each battery container is considered 1h according to charging rate, therefore assuming a total BlueBARGE of 35MWh the total charging time is 68,2 h which translates in 2.8 days. Other cases for batteries with a marine certificate and different charging/discharging rates were also considered, as derived from Table 6 of D3.1. The relevant calculations and figures are summarized in Table 1.

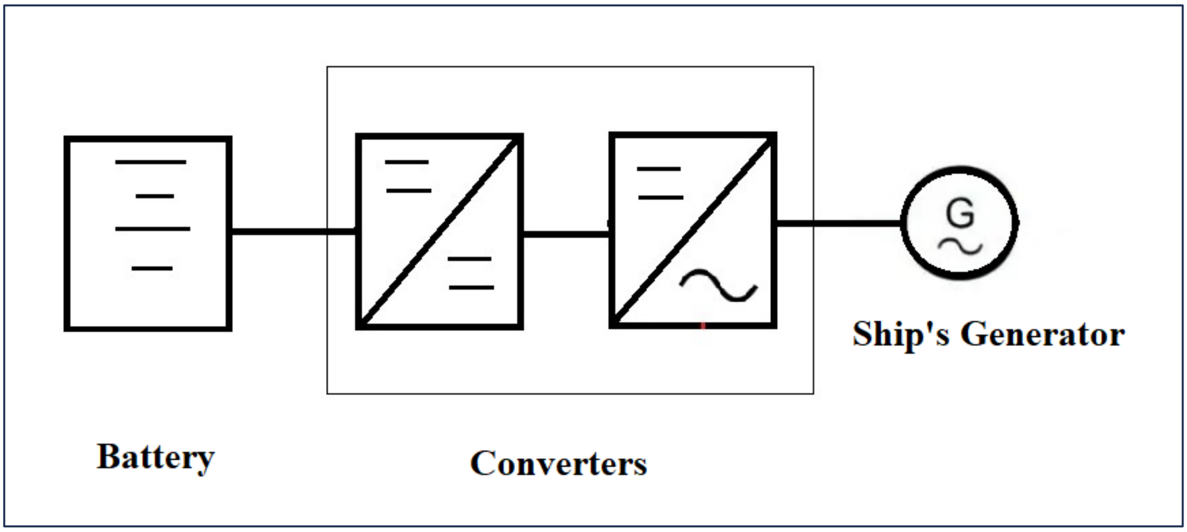

Figure UC10-6: Simplified diagram of the battery charging procedure.

Table UC10-3: Figures of the battery charging scenario by a ship's generator set.

Demanded Battery power	Converter Losses	Power demanded by ship's generator (3MW Rating)	Generator's demanded current at 460 V (assuming p.f.=1)	Generator's demanded current at 690 V (assuming p.f.=1)	Hours demanded for charging
475 kW(1C) =500 A×950 V	10%	513 kW	643.889A	429.259 A	35÷0.513=68.2
1.5 MW (1C) =1579 A×950V	10%	1.65MW	2.07kA	1.3806kA	35:1.65=21.21
0.5 MW (0.5C) =263.1A×950V	10%	275kW	345.165 A	230.11 A	35:0.275=127.272
50 kW (0.17C) =8.947A×950V	10%	9.349kW	11.4617	7.823 A	35:0.009349=3473

Analysis of global Automatic Identification System (AIS) data undertaken by Marine Traffic [UC-10] shows that ships, on average and depending on the ship type, spend up to 9% of their time waiting at an anchorage (Figure UC10-7). Data used for this analysis was filtered to remove any ships that, after waiting at an anchorage, did not call at the immediate port, i.e. ships that spent time at anchorage for other reasons (such as waiting for the next orders). The waiting time therefore represents only the actual time ships wait at anchorage before getting into berth, which is a subset of all vessels at anchorage, for all possible reasons [UC-11].

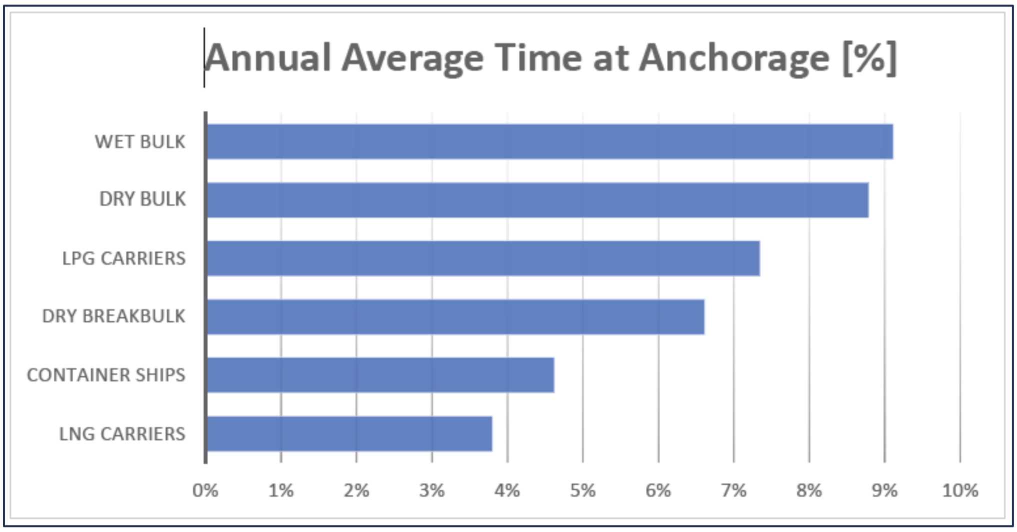

Figure UC10-7: Annual Average Time at Anchorage/ Ship Type [UC10-10].

3.5 – Use cases categorization – umbrella use cases

Umbrella cases are basically a condensed version of the use cases described above. A quick overview is given in the following Figure (Figure 3.5-1).

For all cases, single line diagrams have been developed and shared in the following Figure 3.5-2 to Figure 3.5-7 (Green arrows show power direction.). When the process can be unified, a power barge can serve more than one use case, with small modifications with the assumption that all other requirements are met. Integration of BlueBARGE have been identified with blue-dashed lines or explained in wording. For figures 3.5-3, 3.5-4 and 3.5-5, left hand diagrams exhibit the conventional application of OPS whereas on the right-hand side updated operation with BlueBARGE support can be seen. These single line diagrams are indicative and depending on the application, they can be updated.

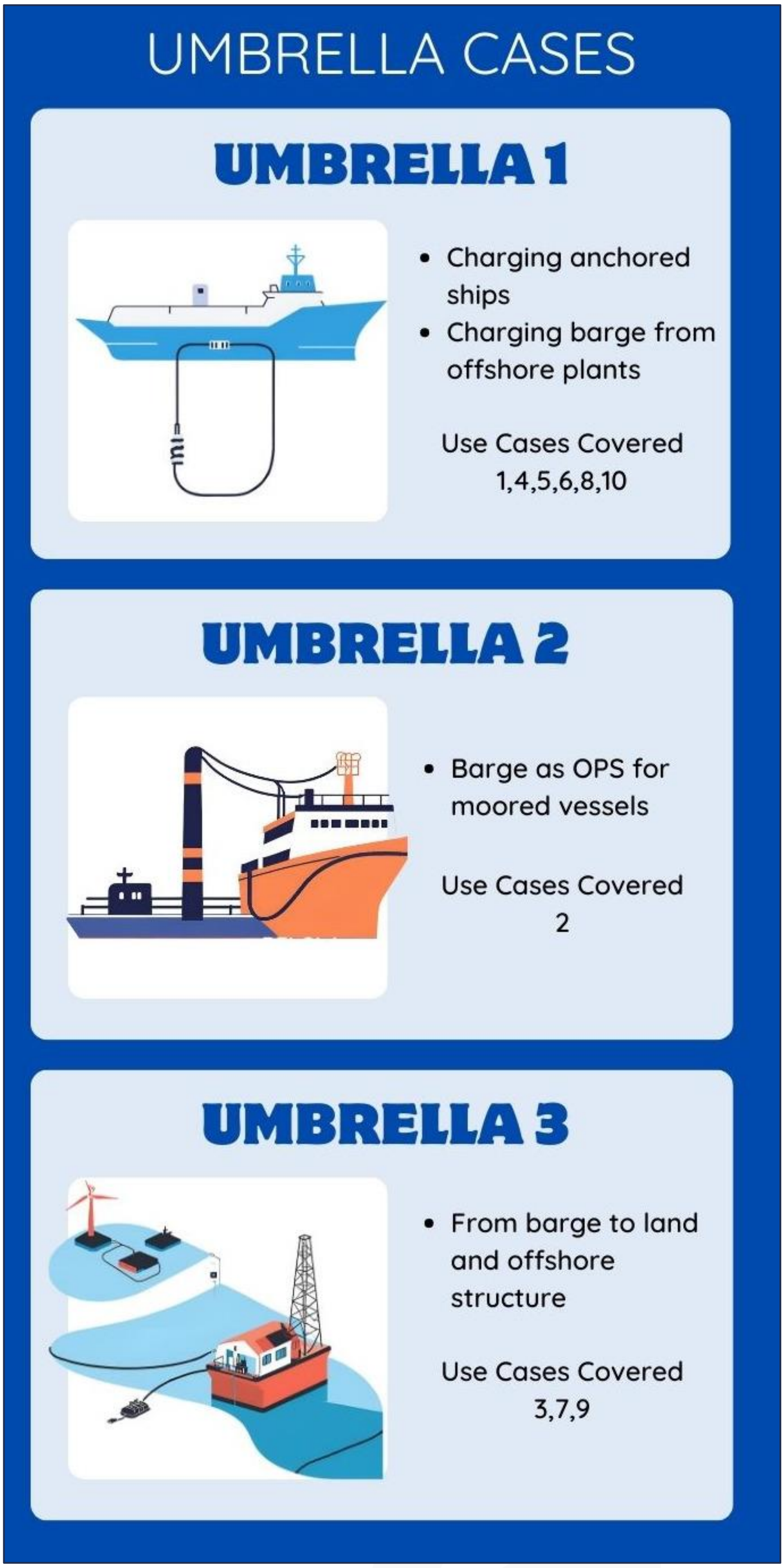

Figure 3.5-1: A review of umbrella uses cases.

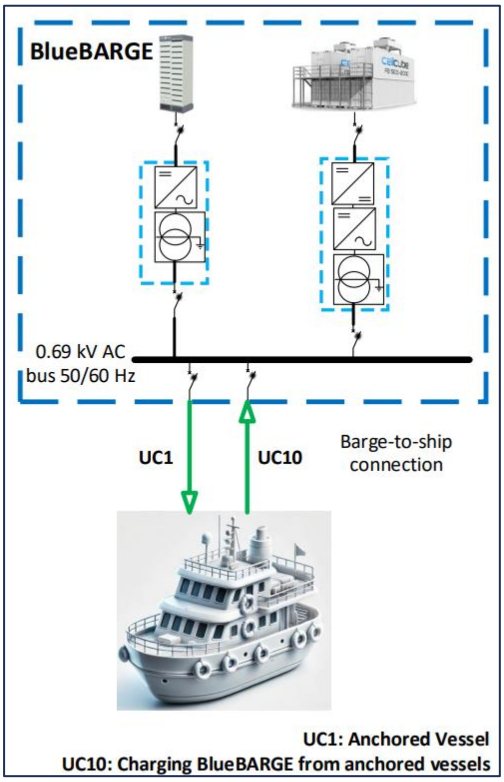

Figure 3.5-2: Uses cases 1 and 10.

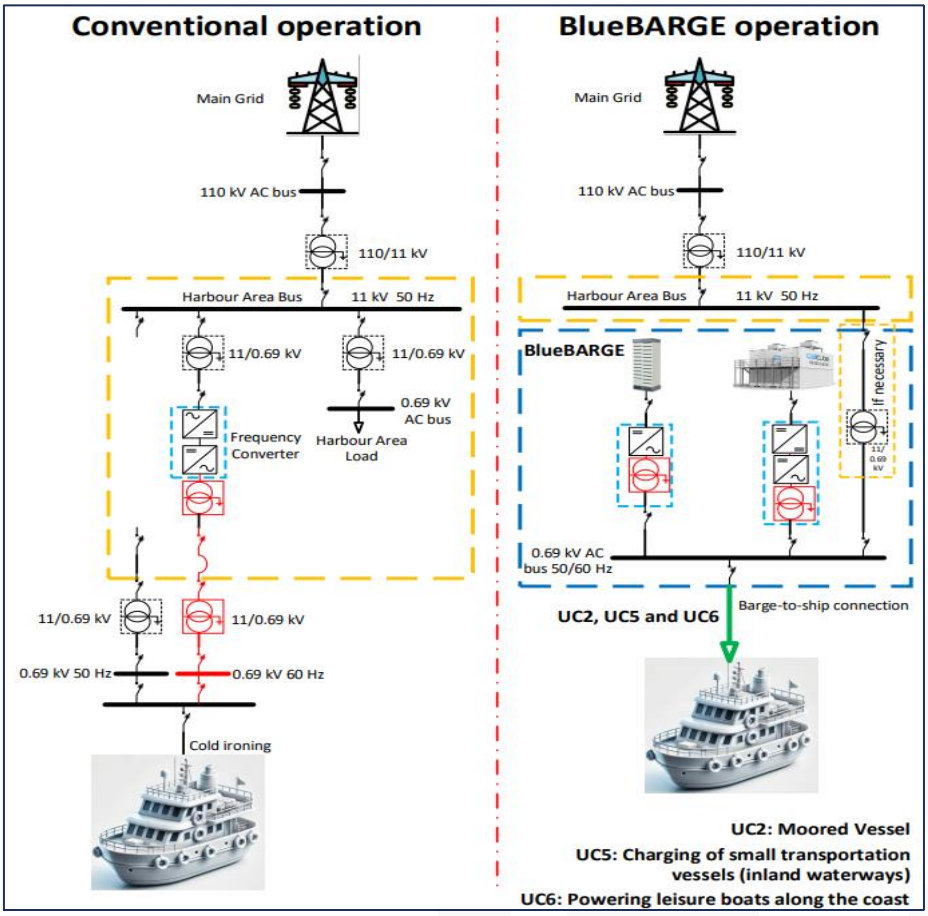

Figure 3.5-3: Uses cases 2, 5 and 6.

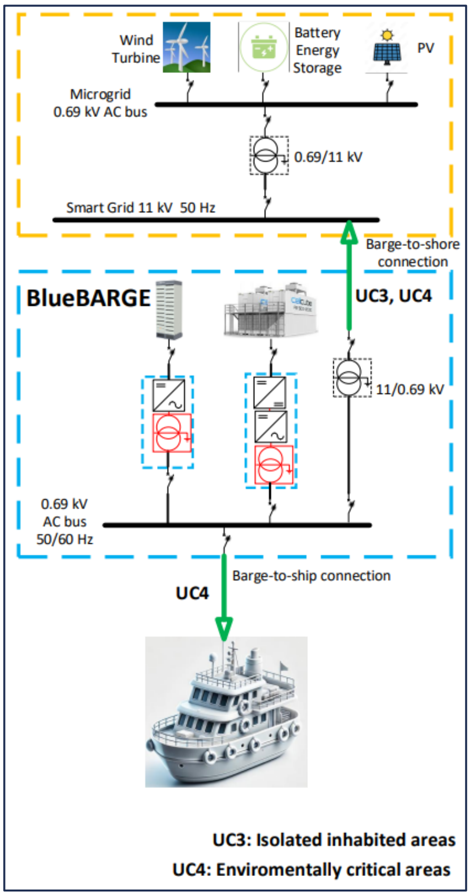

Figure 3.5-4: Uses cases 3 and 4.

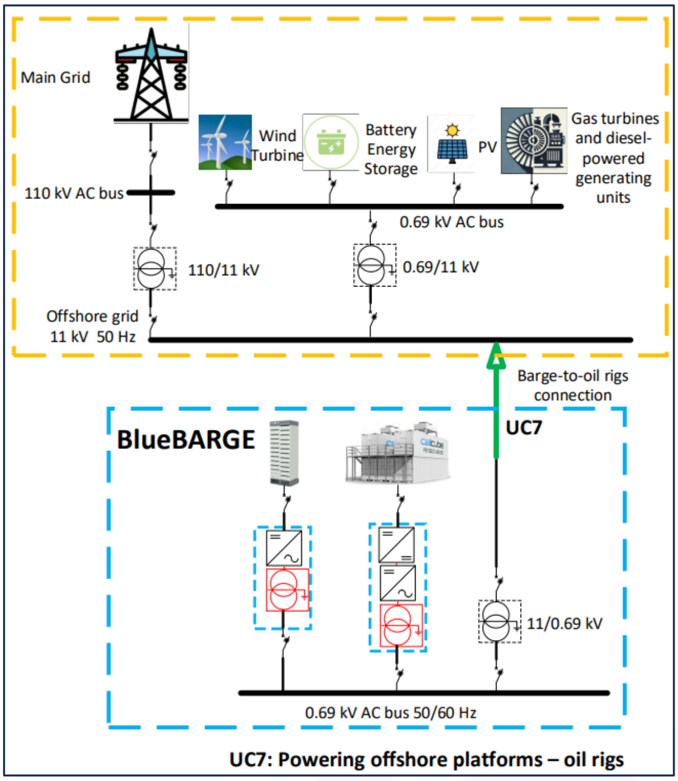

Figure 3.5-5: Uses cases 7

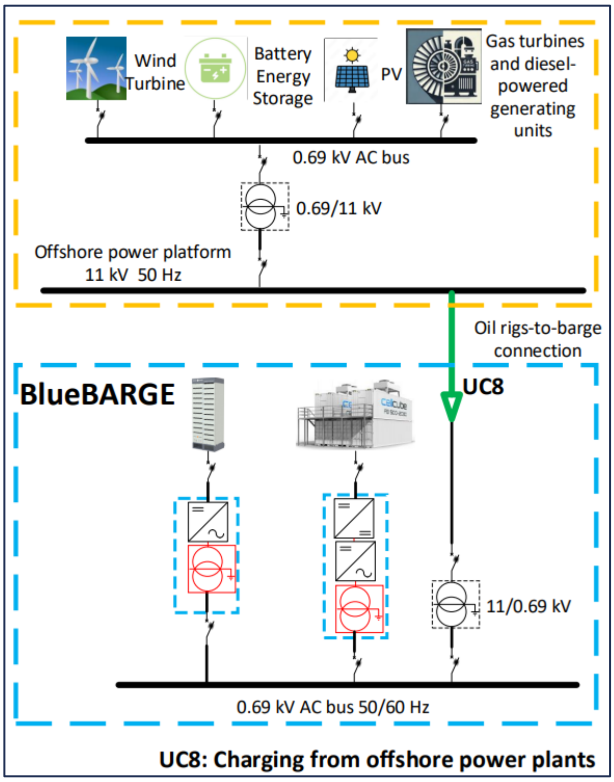

Figure 3.5-6: Uses cases 8.

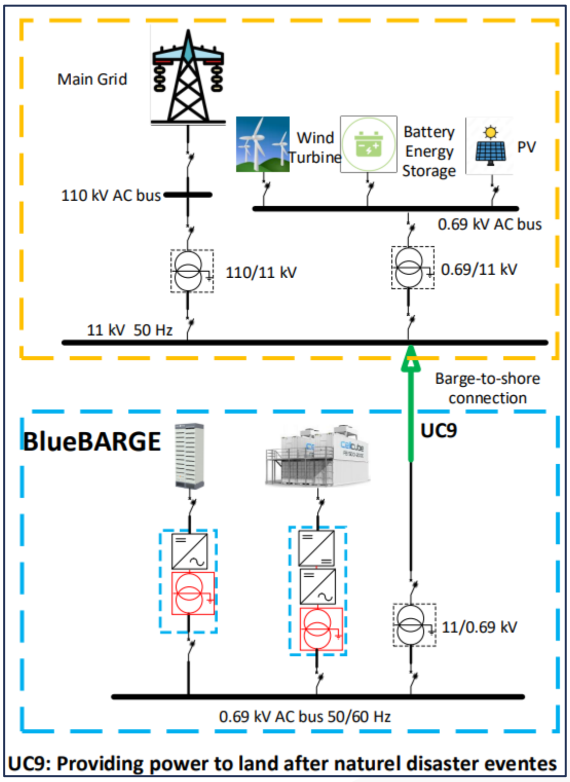

Figure 3.5-7: Uses cases 9.

4 – Energy and power demand specifications

This section refers to one of the most crucial parts of the project in its early steps; the definition of energy and power demands specifications, namely the technical performance in terms of power output (MW) and energy capacity (MWh) to be met from the BlueBARGE solutions. The approach is based on the analysis of data of waiting time at anchorage of ships in various ports and the data for their power demand, based on previous studies and assumptions, enhanced by limited but actual industry data. The adopted methodology is presented below, along with the data requirements, the data collection process and pre-processing. Finally, the data analysis and the overall results are presented, followed by a short summary. Appendix II complements the analysis below, with additional figures and tables.

4.1 – Methodology for defining specifications

The aim of this section in the deliverable, as part of Task 2.1, is focusing on defining the overall context for the technical performance of the BlueBARGE solution, namely the power output (in MW) and energy capacity (in MWh) ranges to be covered by the power barge. These specifications can be defined based on the anchorage port calls and the respective waiting time for a variety of ports and ship types, as well as on the auxiliary engines power output for the ships under analysis.

Thus, within the context of Task 2.1, data were explored regarding the time at anchorage, based on the port call data as provided by relevant databases. Their analysis establishes a basis for the time that vessels remain at anchorage, for all ports and ship types under consideration, while the results will be used for the calculation of energy demand. Only a certain duration range at anchorage could be considered, excluding logical but extremely high values, which will later be analyzed. Furthermore, for the power demand, which will also be used to calculate the energy demand, actual data regarding the loading operation profile of the installed auxiliary system for ships can provide an ideal estimation. Thus, shipping companies were asked to accumulate and provide such data. However, these data were scarce, and could not feed the entire analysis – instead, they were used only for verification purposes. Therefore, the data used to estimate the power demand were obtained from the literature. This data mostly included specifications over the power output of auxiliary systems for ships, provided by both IMO and EMSA, but also loading factors for auxiliary engines for various ship types, as provided by multiple references.

Table 4.1-1: Auxiliary engine power output by ship type size and operational mode, adapted from IMO [4-1].

Ship Type	Size	Unit	Auxiliary Engine Power Output (kW)			
			At berth	Anchored	Manoeuvring	Sea
Bulk Carrier	0-9.999	DWT	110	180	500	190
Bulk Carrier	10.000-34.999	DWT	110	180	500	190
Bulk Carrier	35.000-59.999	DWT	150	250	680	260
Bulk Carrier	60.000-99.999	DWT	240	400	1100	410
Bulk Carrier	100.000-199.999	DWT	240	400	1100	410
Bulk Carrier	200.000+	DWT	240	400	1100	410
Chemical Tanker	0-4.999	DWT	110	170	190	200
Chemical Tanker	5.000-9.999	DWT	330	490	560	580
Chemical Tanker	10.000-19.999	DWT	330	490	560	580
Chemical Tanker	20.000-39.999	DWT	790	550	900	660

Ship Type	Size	Unit	Auxiliary Engine Power Output (kW)			
			At berth	Anchored	Manoeuvring	Sea
Chemical Tanker	40.000+	DWT	790	550	900	660
Container	0-999	TEU	370	450	790	410
Container	1.000-1.999	TEU	820	910	1750	900
Container	2.000-2.999	TEU	610	910	1900	920
Container	3.000-4.999	TEU	1100	1350	2500	1400
Container	5.000-7.999	TEU	1100	1400	2800	1450
Container	8.000-11.999	TEU	1150	1600	2900	1800
Container	12.000-14.499	TEU	1300	1800	3250	2050
Container	14.500-19.999	TEU	1400	1950	3600	2300
Container	20.000+	TEU	1400	1950	3600	2300
General Cargo	0-4.999	DWT	90	50	180	60
General Cargo	5.000-9.999	DWT	240	130	490	180
General Cargo	10.000-19.999	DWT	720	370	1450	520
General Cargo	20.000+	DWT	720	370	1450	520
Liquefied Gas Tanker	0-49.999	CBM	240	240	360	240
Liquefied Gas Tanker	50.000-99.999	CBM	1700	1700	2600	1700
Liquefied Gas Tanker	100.000-199.999	CBM	2500	2000	2300	2650
Liquefied Gas Tanker	200.000+	CBM	6750	7200	7200	6750
Oil Tanker	0-4.999	DWT	250	250	375	250
Oil Tanker	5.000-9.999	DWT	375	375	560	375
Oil Tanker	10.000-19.999	DWT	690	500	580	490
Oil Tanker	20.000-59.999	DWT	720	520	600	510
Oil Tanker	60.000-79.999	DWT	620	490	770	560
Oil Tanker	80.000-119.999	DWT	800	640	910	690
Oil Tanker	120.000-199.999	DWT	2500	770	1300	860
Oil Tanker	200.000+	DWT	2500	770	1300	860
Other liquids tankers	0-999	DWT	500	500	750	500
Other liquids tankers	1.000+	DWT	500	500	750	500
Cruise	0-1.999	GT	450	450	580	450
Cruise	2.000-9.999	GT	450	450	580	450
Cruise	10.000-59.999	GT	3500	3500	5500	3500
Cruise	60.000-99.999	GT	11500	11500	14900	11500
Cruise	100.000-149.999	GT	11500	11500	14900	11500
Cruise	150.000+	GT	11500	11500	14900	11500
Ferry-RoPax	0-1.999	GT	105	105	105	105
Ferry-RoPax	2.000-4.999	GT	330	330	330	330
Ferry-RoPax	5.000-9.999	GT	670	670	670	670
Ferry-RoPax	10.000-19.999	GT	1100	1100	1100	1100
Ferry-RoPax	20.000+	GT	1950	1950	1950	1950
Refrigerated Bulk	0-1.999	DWT	520	570	560	570

Ship Type	Size	Unit	Auxiliary Engine Power Output (kW)			
			At berth	Anchored	Manoeuvring	Sea
Refrigerated Bulk	2.000-5.999	DWT	1100	1200	1150	1200
Refrigerated Bulk	6.000-9.999	DWT	1500	1650	1600	1650
Refrigerated Bulk	10.000+	DWT	2850	3100	3000	3100
Ro-Ro	0-4.999	DWT	750	430	1300	430
Ro-Ro	5.000-9.999	DWT	1100	680	2100	680
Ro-Ro	10.000-14.999	DWT	1200	950	2700	950
Ro-Ro	15.000+	DWT	1200	950	2700	950
Miscellaneous - Fishing	0+	GT	200	200	200	200
Offshore	0+	GT	320	320	320	320

More specifically, in the fourth IMO GHG study [4-1], there are detailed specifications for the power output of auxiliary systems including ship type, size and mode of operation. These were used in the study's context for estimating emissions from auxiliary systems. These specifications are presented in Table 4.1-1. The fourth IMO GHG study, apart from capitalizing on the third IMO GHG study [4-2], used also the following for establishing the auxiliary engine power output specifications; the Starcrest's VBP reports from 2012 to 2018, auxiliary engine and boiler fuel consumption data provided by ClassNK, auxiliary engine fuel consumption provided by continuous monitoring data at the time, and expertise/professional judgement from experts on the field. In addition, EMSA, in its guidelines for SSE design and development, provides analytic data for power demand (mean and peak); these may be significantly different from the needs in anchorage, but can be used as a reference for the estimations to be made. These are presented in Table 4.1.-2. Finally, there are various publications [4-4 – 4.10] that are trying to define load factors for the auxiliary engine systems of ships, which in combination with data regarding the total installed auxiliary power onboard, can provide an approximation of the power demand. These load factors are presented in Table 4.1-3.

Table 4.1-2: Average power, peak power and voltage for SSE specifications and design, adapted from EMSA [4-3]

Ship type	GT	Voltage [kV]	Average Power [MW]	Peak Power [MW]
Oil Tankers	<5.000	0.4/0.44/0.69	4	6
Oil Tankers	<10.000	0.69/6.6/11	6	8
Oil Tankers	>10.000	0.69/6.6/11	8	10
Chemical/Product Tankers	<5.000	0.4/0.44/0.69	6	9
Chemical/Product Tankers	<10.000	6.6/11	9	12
Chemical/Product Tankers	>10.000	6.6/11	10	20
Gas Tankers	<5.000	0.4/0.44/0.69	5	8
Gas Tankers	>5.000	6.6/11	9	12
Bulk Carriers	<50.000	0.4/0.44/0.69	0.5	0.7
Bulk Carriers	>50.000	0.69/6.6/11	2	2.8
General Cargo	<25.000	0.4/0.44/0.69	1.5	3
General Cargo	>25.000	0.69/6.6/11	3	5
Container Ships	<10.000	0.4/0.44/0.69	1.5	2
Container Ships	<50.000	0.69/6.6/11	2	5

Ship type	GT	Voltage [kV]	Average Power [MW]	Peak Power [MW]
Container Ships	>50.000	6.6/11	4	6
Ro-Pax Ships	<20.000	0.4/0.44/0.69	2	4
Ro-Pax Ships	>20.000	0.69/6.6/11	5	6.5
Cruise Ships	<50.000	0.4/0.44/0.69	4	4.5
Cruise Ships	<100.000	0.69/6.6/11	9	12
Cruise Ships	>100.000	6.6/11	18	20
Offshore Supply Vessels	<5.000	0.4/0.44/0.69	1	1.5
Offshore Supply Vessels	>5.000	6.6/11	2	3
Fishing Vessels	<5.000	0.4/0.44/0.69	0.5	0.7
Fishing Vessels	>5.000	6.6/11	2	3

In summary, the methodology outline includes the use of available port call data for defining time at anchorage, which will be combined with power demand data to provide the energy demand. The power demand will be defined by the combination of available literature and methodologies, i.e., IMO auxiliary power output specifications, EMSA power demand estimates and load factors), with the actual data that have been provided by shipping companies.

Table *4.1*-3: Load Factors for auxiliary power system per mode of operation [4-4].

Ship-Type	Cruise	RSZ	Maneuver	Hotel
Auto Carrier	0.13	0.3	0.67	0.24
Bulk Carrier	0.17	0.27	0.45	0.22
Container Ship	0.13	0.25	0.5	0.17
Cruise / Passenger Ship	0.8	0.8	0.8	0.64
General Cargo	0.17	0.27	0.45	0.22
Miscellaneous	0.17	0.27	0.45	0.22
Ocean Going Tugs (Offshore)	0.17	0.27	0.45	0.22
RORO	0.15	0.3	0.45	0.3
Reefer	0.2	0.34	0.67	0.34
Tanker	0.13	0.27	0.45	0.67

4.2 – Data requirements and specifications

Apart from the presented information/data regarding the IMO, EMSA and load factor approaches for the power demand estimation, as part of the methodology, the most important datasets are the following:

1. Port specifications
2. Port call and time at anchorage
3. Ship specifications

The port specifications data are the first to be defined, as they will be used – a specific list of ports – for accumulating port call and time at anchorage data. The reference period for collecting port call data was the entire 2023 year, in order to include also seasonal variations, while also covering a large period to collect enough data, but not too many for the analysis and the study's limitations. Consequently, based on the identified ships from the port call data, the ship specifications data will be extracted accordingly, by including all (available) relevant information to be used in the analysis. Thus, the list of ports was the first to be finalized; all ports are shown in Figures 4.3-3 and 4.3-4 in the next sub-section, along with additional information and data. The list was produced by partners with relevant expertise in similar studies (e.g., EALING project) and/or with experience from the industry.

After defining the list of ports, relevant data were sought out, based on the specifications that are shown in Table 4.2-1. Furthermore, based on the identified ports, data regarding the port calls and anchorage time could be sought out, following the data specifications shown in Table 4.2-2. Finally, for the ships (and relevant IMO numbers) that are considered in the port calls identified, data regarding the ships under consideration were explored. Their specifications are presented in Table 4.2-3. Based on the data collection process and data processing, as analysed in the next sub-section, the datasets were enhanced with additional data and refined accordingly in order to be used for the analysis and for providing results.

Table 4.2-1: Ports data specifications

Attribute	Description	Type
Port name	The name of the port, as commonly referred to.	String
World port number	A distinct identification number for the port, as defined at an international level.	String
Port ID	A distinct identification number for the port in various databases.	Integer
UNLOCODE	A distinct identification number for the port; UNLOCODE is a geographic coding scheme developed and maintained by United Nations Economic Commission for Europe (UNECE).	String
Country	The country that the port belongs to.	String
Latitude	The latitude of the port location.	Geometry
Longitude	The longitude of the port location.	Geometry
TEN_T	Whether a specific port is considered within the TEN-T network or not, and whether it is in the core or comprehensive network.	String
Region 1	A primary categorisation for the area the port belongs; this corresponds to the continent.	String
Region 2	A secondary categorisation for the area the port belongs; this corresponds to the sea basin.	String
OPS	Whether a specific port supports Onshore Power Supply.	Boolean
OPS berths	The number of berths that a specific port supports through relevant Onshore Power Supply infrastructure.	Integer

Table 4.2-2: Port call and anchorage time specifications

Attribute	Description	Type
IMO number	The 9-digit unique identification code for a vessel.	Integer
Arrival date	The date of the arrival at the port of call.	Date
Arrival time	The time of the arrival at the port of call.	Time
Cargo change	The change in cargo, in tons, at the port of call.	Integer
Arrival draught	The draught of the ship when arrived at the port of call.	Float
Departure draught	The draught of the ship when departed from the port of call.	Float
Hours in port	The time (hours) that the ship remained at the port of call; considering the anchorage areas, the time that the ship remained at the anchorage, at the port of call	Integer
Port	The name of the port of call.	String

Attribute	Description	Type
Port zone	The zone of the port of call, that the ship called; the scope of the dataset referred only to anchorage zones/areas.	String
Previous port	The name of the previous port, before the port of call.	String
Previous sailed date	The date of the departure from the previous port.	Date
Previous sailed time	The time of the departure from the previous port.	Time
Voyage hours	The time (hours) that the voyage from the previous port to the port of call lasted.	Integer

Table 4.2-3: Ship data specifications

Attribute	Description	Type
IMO number	The 9-digit unique identification code for a vessel.	Integer
Ship name	The name of the ship, as given by its company.	String
Ship type	The ship type/category as defined by the relevant databases.	String
Ship type group	A group type/category for the ship, as defined by relevant databases.	String
Statcode 5	The respective identification code from the relevant coding system, which refers to the categorisation of ships by type.	String
Deadweight	The deadweight of the ship, as a measure of its size and capacities.	Integer
Gross Tonnage	The gross tonnage of the ship, as a measure of its size and capacities.	Integer
TEU	The number of TEU that can be carried by the ship, as a measure of its size and capacities; applicable only for container ships.	Integer
Total ME power	The total power in kW (MCR) of the main engine.	Float
Total AE power	The total power in kW of the auxiliary power system, including all engines (generators), but excluding the emergency generator.	Float
Number of AEs	The number of auxiliary engines.	Integer
AE builder	The builder/manufacturer of the auxiliary engines.	String
AE model	The model of the auxiliary engines.	String
Displacement	The design displacement, in tons, of the vessel.	Integer
Crew	The rated number of crew onboard the vessel.	Integer
Passenger	The rated number of passengers (if applicable).	Integer
Class	The classification society that the ship is registered.	String
Speed	The design speed of the ship.	Float
Length	The design length (overall) of the ship	Float
Draught	The design draught of the ship.	Float
Flag	The flag state that the ship belongs to.	String
Year built	The year that the ship was built.	Integer

4.3 – Data collection and pre-processing

Based on the aforementioned data specifications, a specific database has been identified for data collection and extraction, considering all three datasets, namely port data, port call and anchorage time data, and ships specifications data, driving also the definition of the data specifications to a large extend.

This is the Maritime Sea-web Online Ship Register[1], as accessed through relevant subscription by consortium partners. The database includes modules relevant to all datasets, facilitating the data collection process. The following paragraphs, along with a number of figures, present key details of the data collected, as well as the processing that was conducted.

First of all, the final list of ports consists of 37 ports, as presented below, in Figures 4.3-3 and 4.3-4. Based on this list, the port data were collected, as presented in the dataset specifications, allowing for the visualisation in Figure 4.3-2, along with other information. The port dataset was enhanced with the information regarding the inclusion in the TEN-T network[2], the regions (continent, sea basin) that each port belongs to, and the OPS availability and berths, as provided by the European Alternative Fuels Observatory (EAFO)[3]. Furthermore, the dataset of the port calls was extracted from the database, resulting in a total of 302,538 records. These are port calls, when ships calling the anchorage of the port, providing also the waiting time at anchorage, namely the anchorage time periods for each port call. An appropriate processing was needed for formatting the records in the dataset. Based on the IMO number field of the port call dataset, the ship dataset (ship characteristics) was extracted from the database, resulting in a total of 23,157 ships. An appropriate processing was needed here as well for formatting the record in the dataset. The fleet composition regarding ship types is shown in Figure 4.3-1, while Figures 4.3-3 and 4.3-4 show the average anchorage time and total port calls per port.

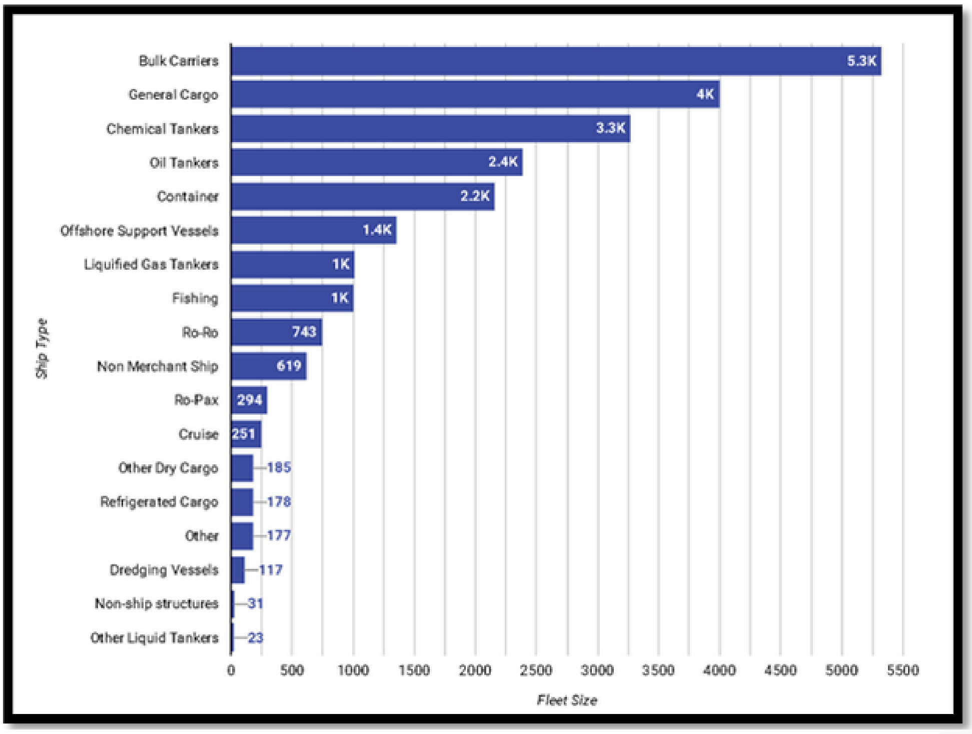

Figure 4.3-1: Fleet of scope – ship type breakdown and size.

[1] Online, available at: https://www.spglobal.com/marketintelligence/en/mi/products/sea-web-maritime-reference.html
[2] Available at TENtec Map Viewer, available at: https://webgate.ec.europa.eu/tentec-maps/web/public/screen/home
[3] Online, available at: https://alternative-fuels-observatory.ec.europa.eu/transport-mode/maritime-sea/ports-and-infrastructure

The ship dataset was the most demanding, since it needed additional information to be filled in, apart from the data described in the dataset specifications. First of all, the statcode5 field needed to be further analysed into additional attributes, for a more standardised approach in the ship types naming and categorisation. This resulted in the attributes statcode5_type and statcode5_group, based on relevant references[4], for representing more accurately the ship types, in two levels. The attribute used for ship type classification was the statcode5_type. In addition, for possible use in the future, an attribute showing whether the operational environment refers to inland waterways was included (i.e., iwt), Finally, based on the tables from sub-section 4.1 regarding the IMO, EMSA and load factors assumptions, the following attributes were included as well, depending on the ship type and size (either deadweight, gross tonnage or teu): load_factor, signifying the load factors, voltage, power_avg_emsa and power_peak_emsa, referring to the numbers from EMSA, the power_aux_imo signifying the power output from IMO and power_aux_calc which is the calculation of power demand based on the aforementioned load factors by using the total installed auxiliary power where available. The dataset was once again formatted appropriately for all of its records, in order to be further processed.

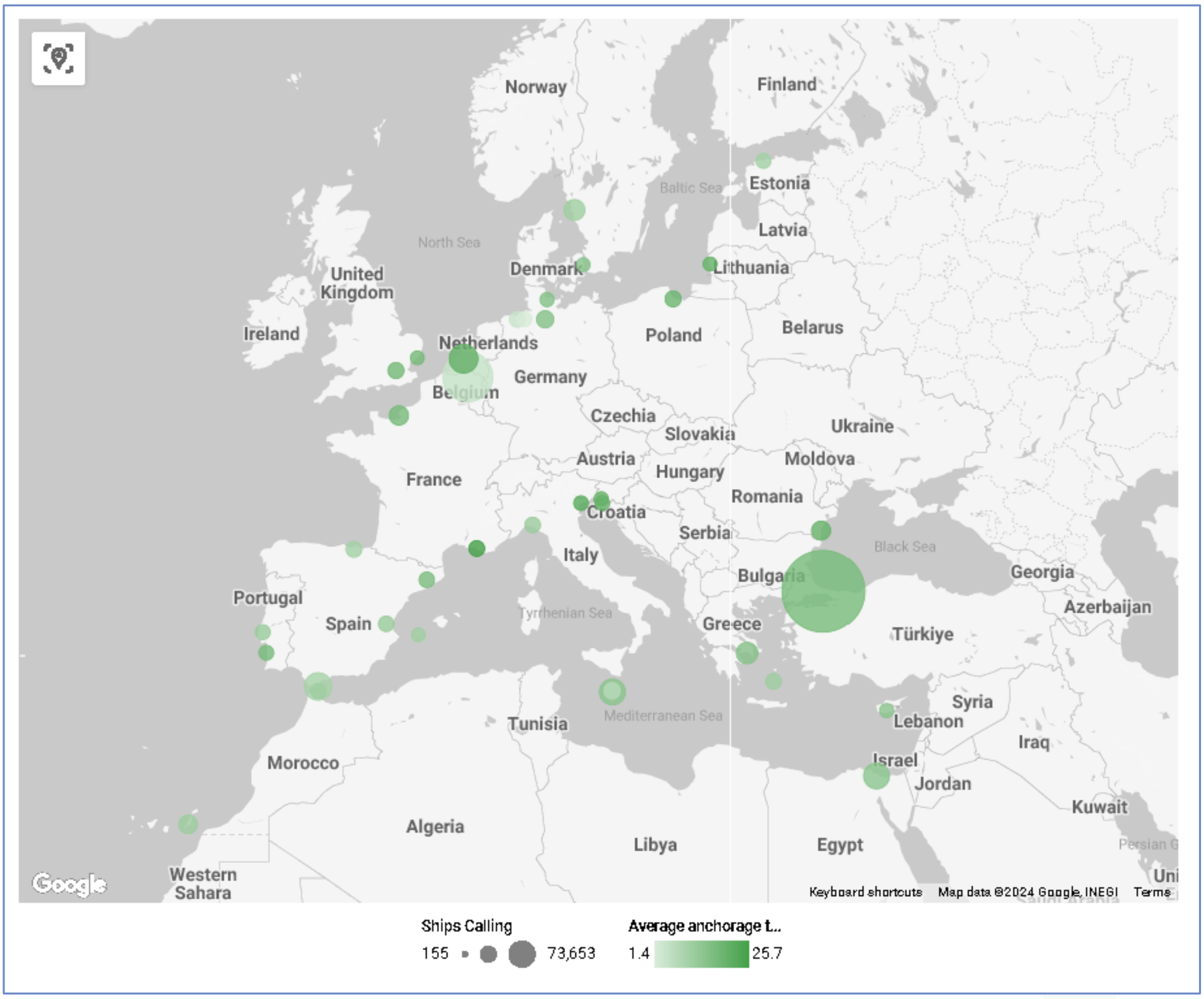

Figure 4.3-2: Mapping of all ports of scope showing the magnitude of ships calling and average anchorage time.

[4] Available only by S&P Global: https://cdn.ihs.com/www/pdf/Statcode-Shiptype-Coding-System.pdf

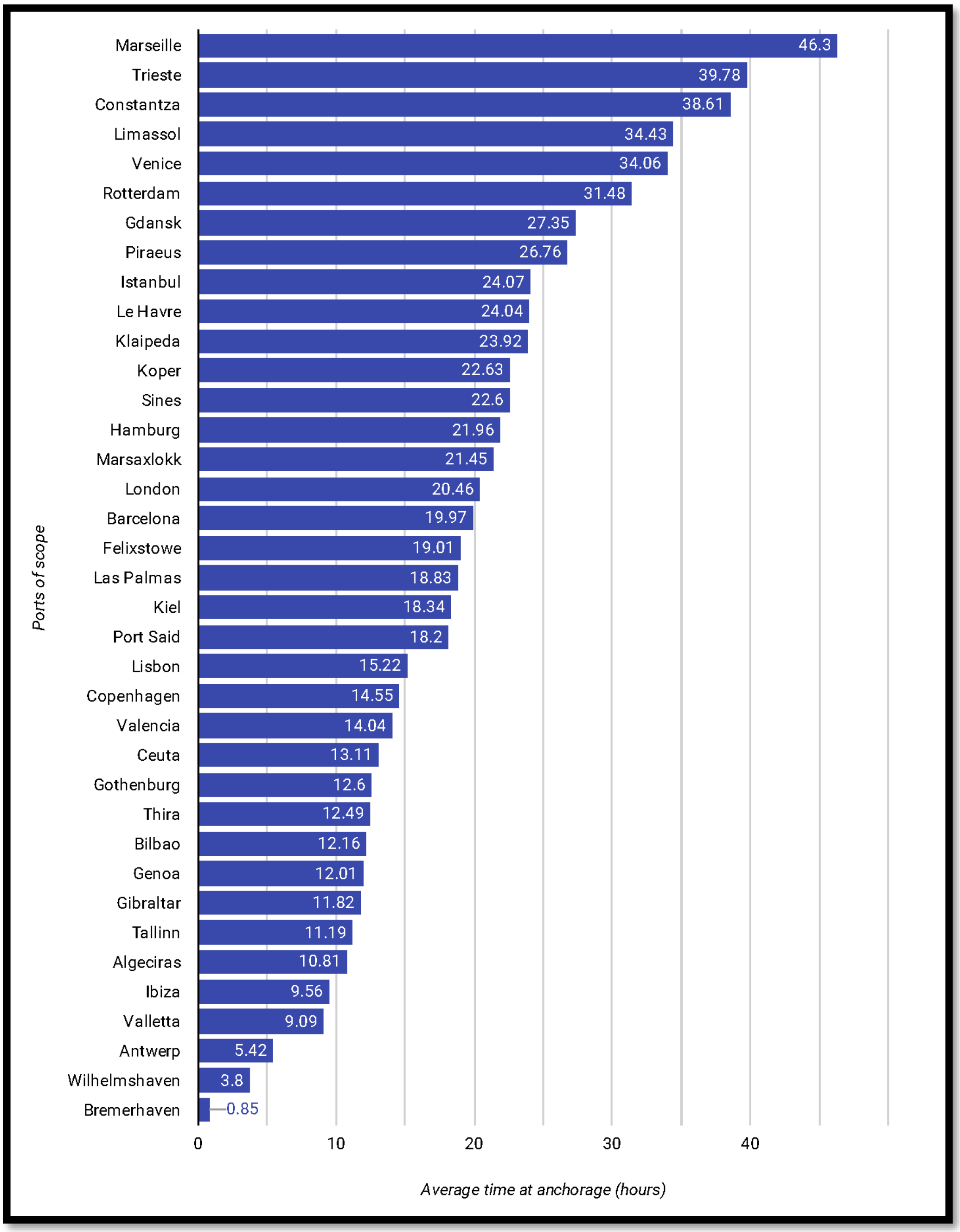

Figure 4.3-3: Ports of scope showing the average time at anchorage.

With the data sets completed, they were introduced in an SQL programming environment, in order to easily query the datasets for all relevant information and visualisations. All queries were filtered appropriately, in order to provide with useful and reasonable data. The filtering included the exclusion of several ship types for which there were not clear information regarding their power demand, i.e., non-merchant ships, other dry cargo ships, other and non-ship structures, the various missing values (e.g., where the total installed auxiliary power was missing), as well as for the case of increased anchorage time. The latter is crucial, as it excludes cases where the anchorage time exceeded the threshold of 96 hours (4 days). This was used in order to explore reasonable waiting at anchorage (UC1) cases, and not other (outliers), that refer to abnormal situations in terms of operations (e.g., ship detained, ship under maintenance for long periods, ship waiting for commercial dispute reasons, etc.). Such filtering allowed for the results that are presented in this sub-section and the next, regarding results for power and energy demand; the final results represent over 90% of the initial sample, which means that filtering did not affect the initial data in a way that deformed them.

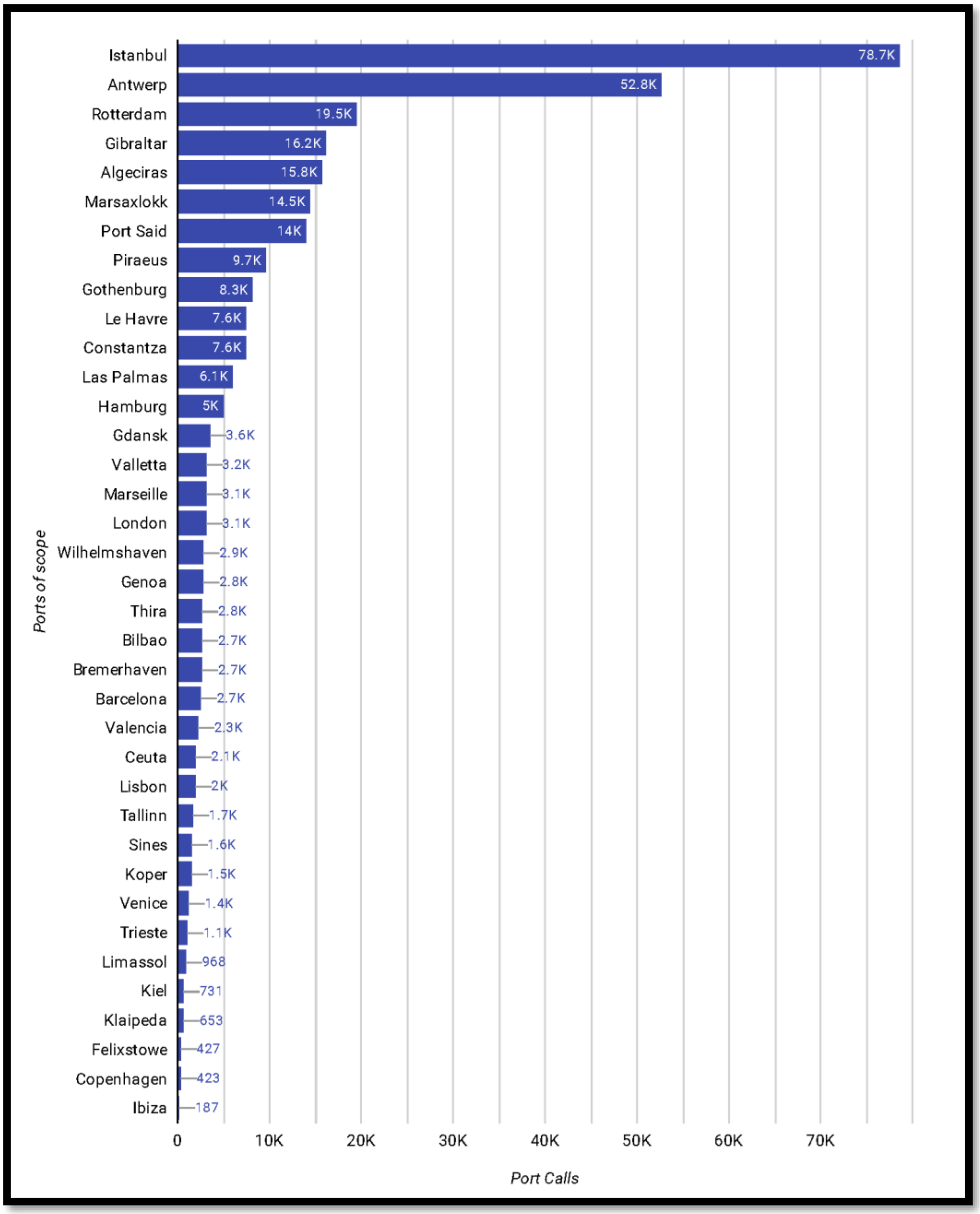

Figure 4.3-4: Ports of scope showing the total port calls under analysis.

Finally, it was decided to limit the analysis on specific ports and ship types in order for the results to be easily presented in this deliverable. For the latter, the main ship types where considered, which also have the largest representation in the sample, along with the ship types that are specifically referenced in the Grant Agreement. These are Cruise ships, Ro-Pax, Container ships, Bulk carriers, Tankers, Ro-Ro and General Cargo ships. As for the ports, based on the plot in Figure 4.3-5, the most prominent ports in terms of power and/or energy demand were considered, i.e., Istanbul, Rotterdam, Antwerp, Venice and Marseille, as well as the Port of Piraeus, as a prominent case in the Mediterranean shipping. Thus, Figure 4.3-5 provides an overview of the composition of the fleet for these ports.

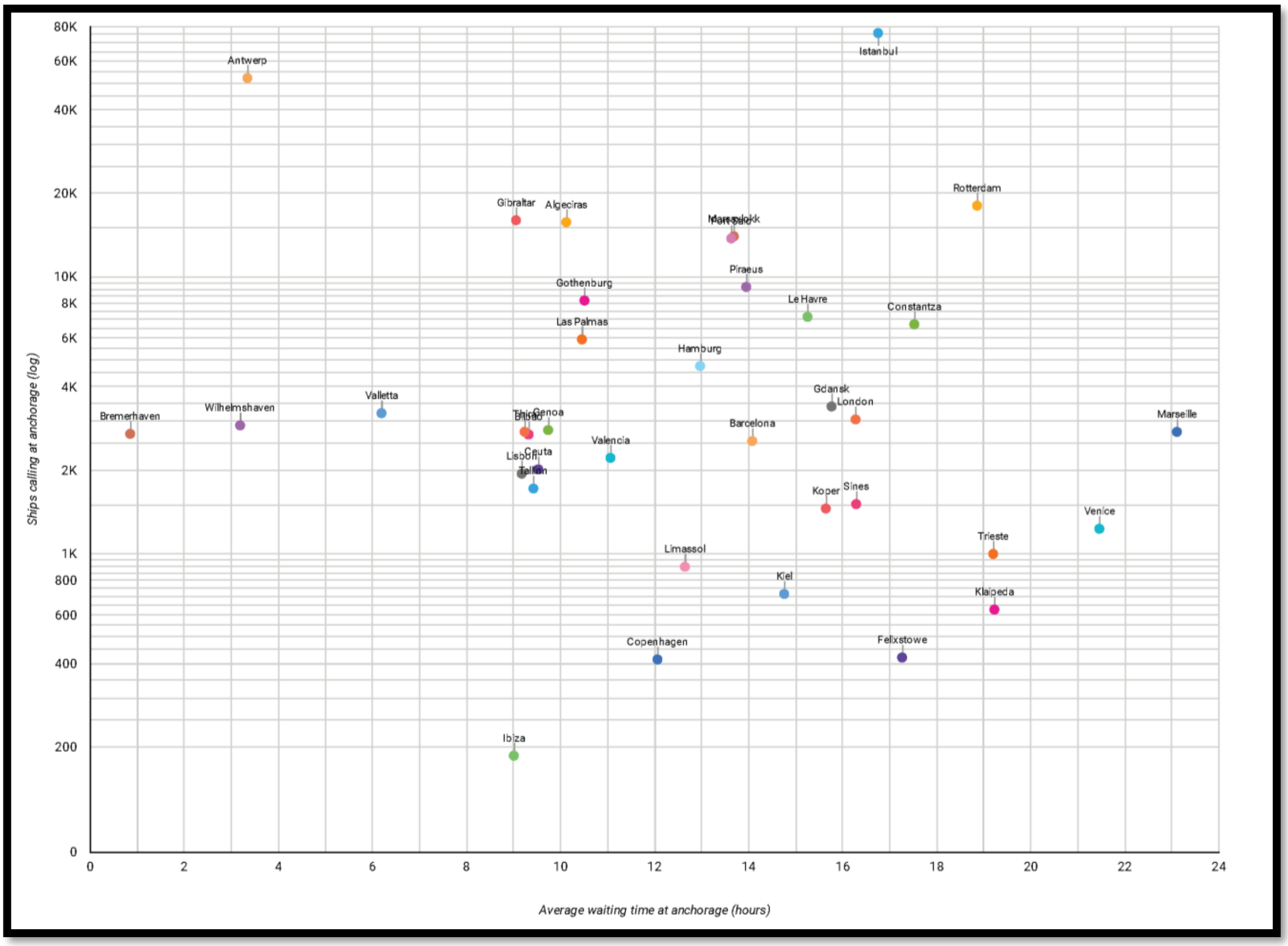

Figure 4.3-5: Port calls and average waiting time at anchorage per port.

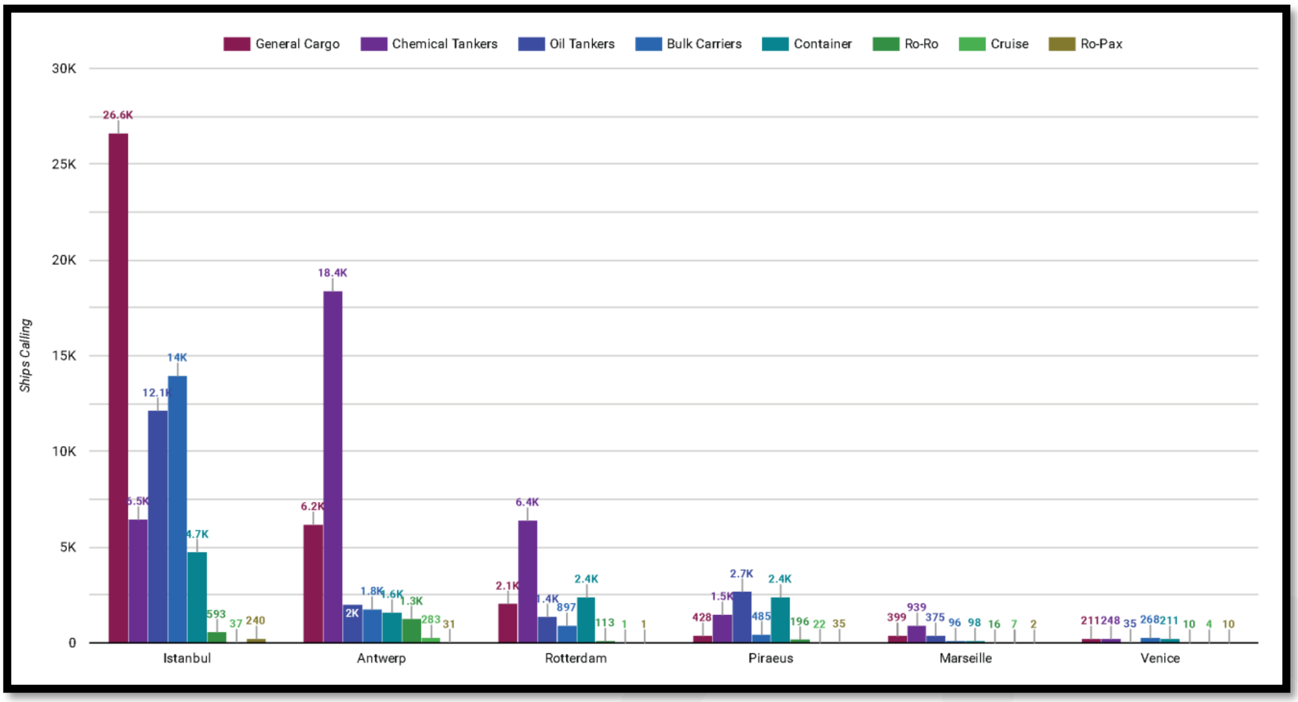

Figure 4.3-6: Fleet analysis of selected ports

4.4 – Data analysis and descriptive statistics

This sub-section, following the data collection and relevant processing, presents the results of the performed analysis regarding the power and energy demands. As explained previously, the results refer to calculations made with respect to the IMO assumptions, from the 4th GHG Study, with respect to the EMSA assumptions, from the SSE guidelines, and with respect to the identified load factors. In the following paragraphs, the overall results are presented, followed by a more focused presentation of results per port and ship type.

4.4.1 – Overall Results

The overall results are clear enough through Tables 4.4-1 and 4.4-2 regarding ship types and ports, respectively. These refer to the IMO assumptions approach, while the other two approaches are shown in Appendix II. The tables include the total port calls within the reference period, i.e., the year 2023, the average anchorage time for all ship types and ports respectively, and of course the mean and peak power demand in MW, as well as energy demand in MWh in each case. With respect to ship types, the most demanding ships are the Liquified Gas Tankers and Cruise ships, followed by the Refrigerated Cargo ships; this is most reasonable, since all three ship types require increased power for supporting either cargo maintenance or hoteling loads. On the other hand, in terms of ports, the most demanding ports are Thira (Santorini) in Greece, most probably due to the high demand of Cruise ships in its anchorage, followed by Marseille and Sines. Regarding the energy demand, it is most affected by the power demand, with a significant influence of anchorage time in some cases, thus the same ship types are most prominent. The same goes for ports; however, it is noted that other ports are also seen with increased average energy demand due to their increased anchorage time, such as Venice, Hamburg and Rotterdam. Figure 4.4-1 summarises the relation between power and energy demand for most usual ship types (and larger in fleet size); Cruise ships as by far the most demanding ships, followed by container vessels. In addition, the previously presented Figure 4.3-5 shows a similar relationship – but with anchorage time – where Istanbul, Rotterdam and Marseille stand out if considering both power demand and anchorage time (and thus energy demand).

Table 4.4-1: Power and Energy Demand Results per ship type (IMO assumptions)

Ship Type	Total Ships Calling	Average Time at Anchorage	Mean Power Demand (IMO)	Max Power Demand (IMO)	Average Energy Demand (IMO)
Liquified Gas Tankers	9,327	17.24	5.57	7.2	99.58
Cruise	1,378	7.63	5.15	11.5	53.28
Refrigerated Cargo	728	12.19	2.4	3.1	26.46
Container	23,231	14.07	1.06	1.95	14.28
Ro-Ro	4,220	9.77	0.86	0.95	8.19
Other Liquid Tankers	2,517	11.06	0.5	0.5	5.53
Oil Tankers	49,476	14.37	0.41	0.77	6.46
Chemical Tankers	50,996	13.4	0.4	0.55	6.19
Ro-Pax	2,744	6.86	0.35	1.95	3.15
Dredging Vessels	1,433	7.52	0.32	0.32	2.41
Offshore Support Vessels	17,448	4.86	0.32	0.32	1.56
Bulk Carriers	35,694	16.63	0.28	0.4	4.68
Fishing	7,160	5.98	0.2	0.2	1.2

Table 4.4-2: Power and Energy Demand Results per port (EMSA assumptions).

Port	Total Ships Calling	Average Time at Anchorage	Mean Power Demand (IMO)	Max Power Demand (IMO)	Average Energy Demand (IMO)
Thira	2133	10.67	2.73	11.5	31.2
Marseille	2459	25.78	1.18	11.5	35.91
Sines	1403	17.28	1.17	7.2	22.53
Venice	1160	22.41	1.07	11.5	28.76
Hamburg	2598	22.59	1.06	7.2	26.92
Port Said	12989	14.12	0.99	11.5	14.37
Genoa	2250	11.82	0.95	11.5	9.51
Valencia	2047	11.96	0.95	7.2	9.41
Gdansk	2808	18.97	0.82	7.2	17.32
Barcelona	2129	16.83	0.82	11.5	13.17
Rotterdam	14847	22.56	0.8	7.2	19.54
London	2730	17.97	0.79	7.2	15.69
Ceuta	1720	11.09	0.78	11.5	8.71
Gibraltar	14924	9.6	0.78	11.5	8.09
Piraeus	8484	15.02	0.71	11.5	9.86
Le Havre	6197	17.4	0.7	7.2	14.9
Tallinn	1576	10.17	0.67	7.2	6.94
Klaipeda	585	20.43	0.66	7.2	12.25
Gothenburg	7945	10.78	0.65	7.2	8.99
Trieste	931	20.03	0.64	11.5	13.3
Marsaxlokk	13289	14.32	0.63	11.5	10
Kiel	632	16.32	0.63	7.2	10.5
Algeciras	14025	11.14	0.62	7.2	8.42
Antwerp	37625	4.38	0.61	7.2	5.17
Koper	1134	19.49	0.6	1.95	12.91
Ibiza	61	11.02	0.59	11.5	3.1
Lisbon	1462	11.51	0.52	11.5	6.6
Las Palmas	5405	11.25	0.52	11.5	6.73
Limassol	782	14.39	0.49	11.5	6.82
Bilbao	2474	10.08	0.43	7.2	5.96
Valletta	2927	6.72	0.42	11.5	2.73
Constantza	5777	19.96	0.41	7.2	7.81
Bremerhaven	1610	1.33	0.38	7.2	0.49
Istanbul	72630	17.32	0.34	7.2	5.8
Wilhelmshaven	1950	3.92	0.31	7.2	1.39
Copenhagen	317	15.19	0.24	7.2	3.4
Felixstowe	309	20.62	0.19	0.91	3.39

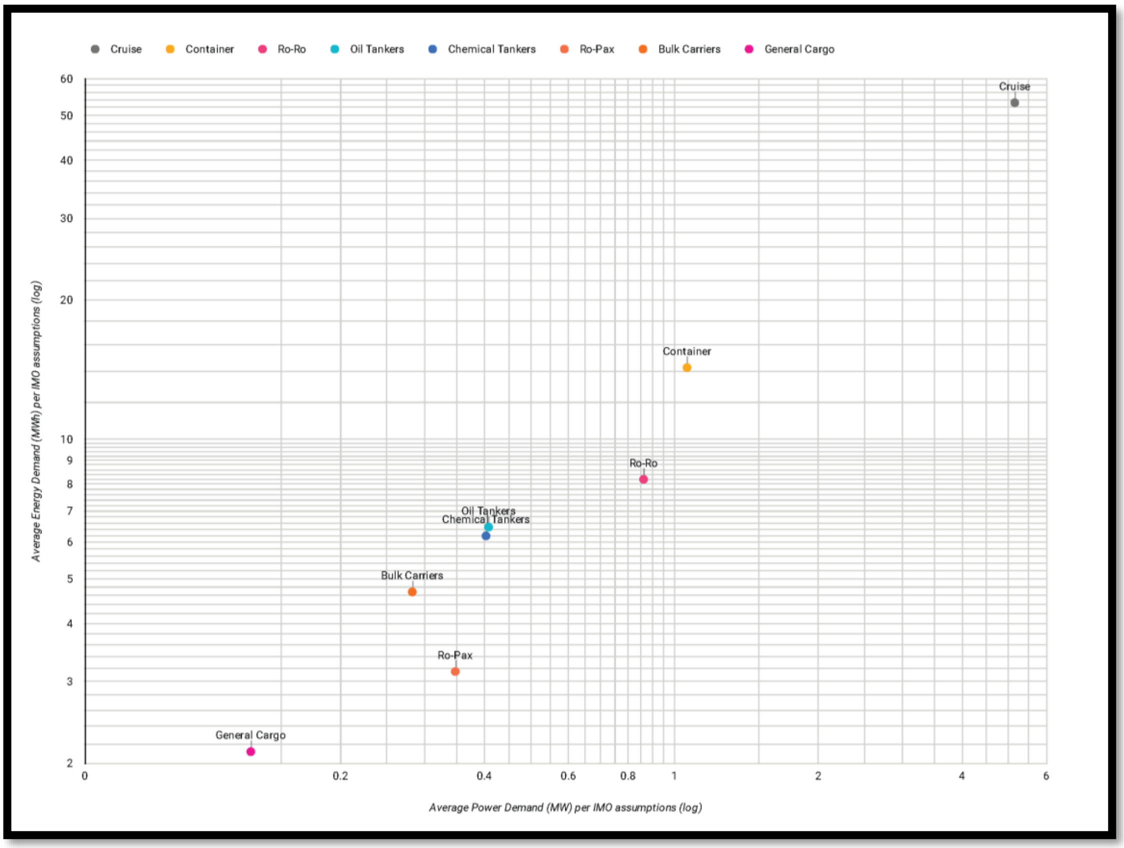

Figure 4.4-1: Power and Energy demand plot per ship type (IMO assumptions).

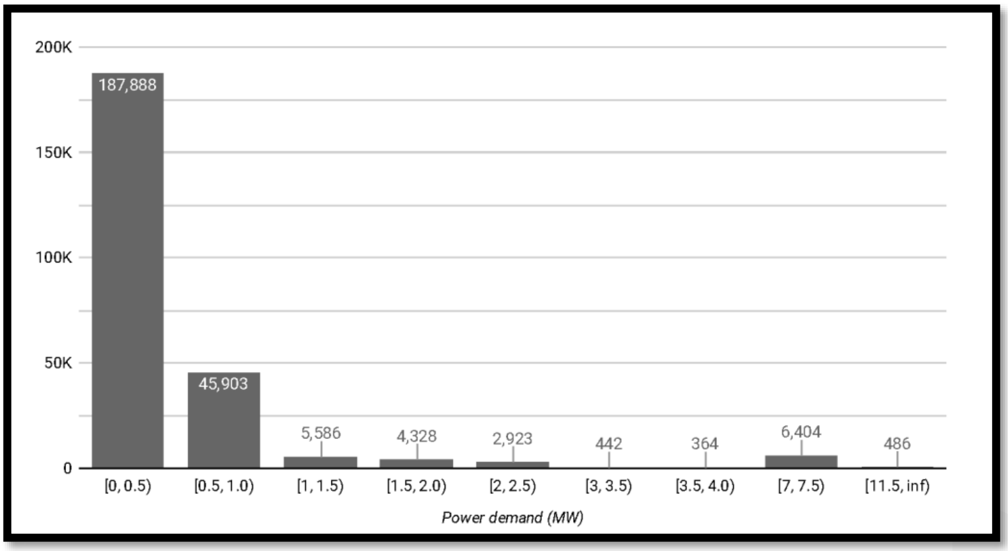

Figure 4.4-2: Power Demand overall (in MW).

With respect to the analysis of overall results shown for IMO assumptions, it is crucial to compare them with the results from the approaches with EMSA and load factors assumptions presented in the Appendix II. EMSA mean power demands seem to be in various cases extremely increased, which is probably since they correspond to the mode of operation when ships are in port, and may need increased loads (e.g., for cargo handling), resulting also in high energy demands. On the other hand, the results from load factors approach seem to be more realistic, depending also on the installed auxiliary power; however, due to the oversimplification through the load factors, and the lack of data for all ships regarding their total installed auxiliary power, this approach can be of limited use yet. Thus, the main part of the analysis refers to the IMO approach, without – however – excluding the others, as may be of use in the next project steps.

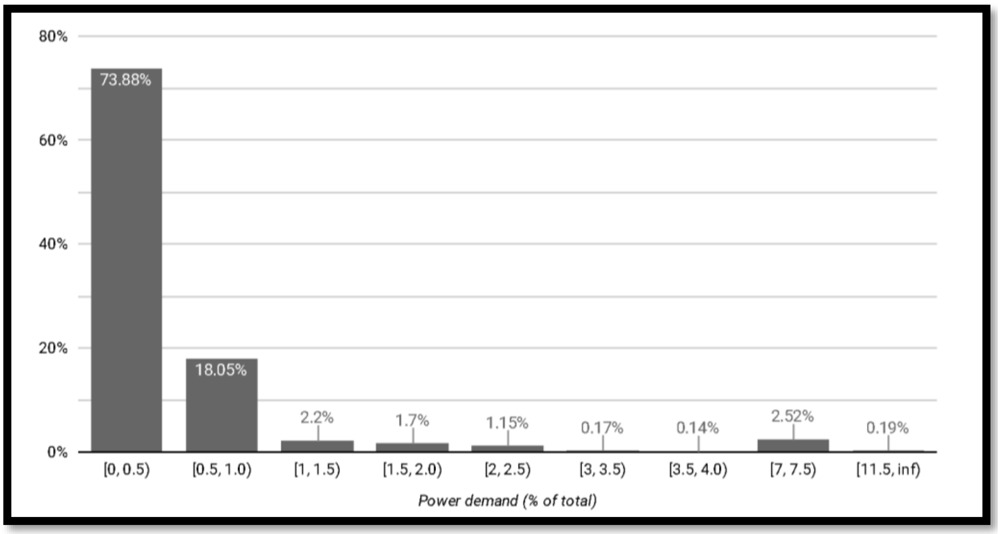

Figure 4.4-3: Power Demand overall (in % of total anchorage calls).

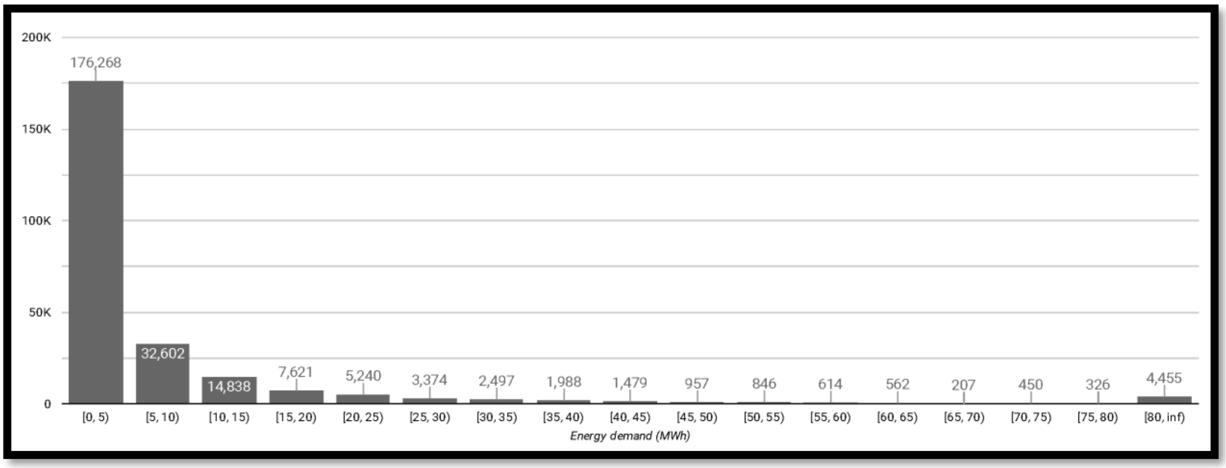

Figure 4.4-4: Energy Demand overall (in MWh).

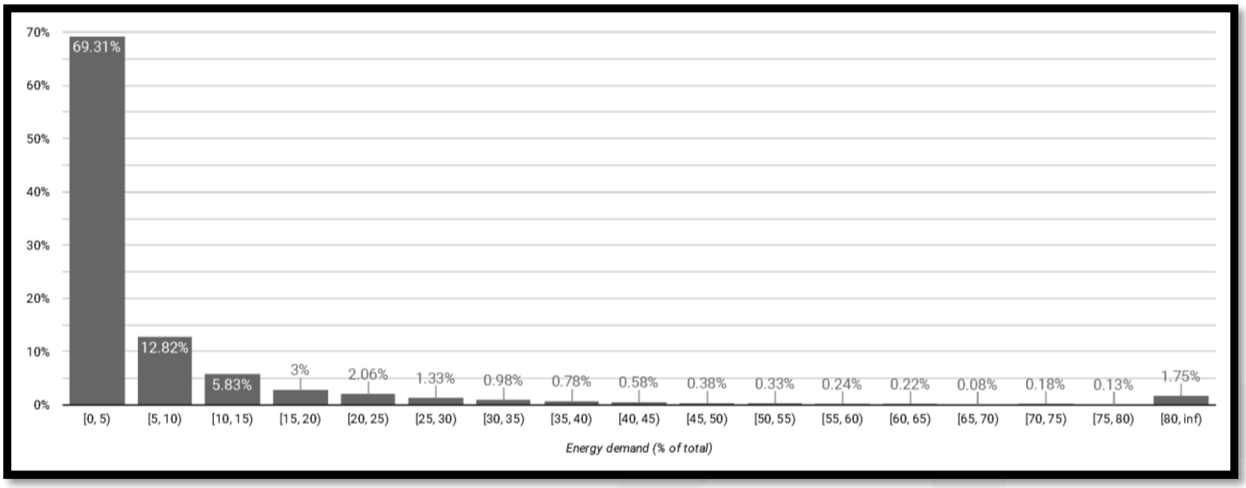

Figure 4.4-5: Energy Demand overall (in % of total anchorage calls).

Thus, by considering the Figures 4.4-2 to 4.4-5, where the overall distribution for power and energy demand, both in MW and MWh respectively, but also in percentage of total anchorage calls, it is shown that over 90% - 95% of the cases can be well-supported by the BlueBARGE system, if the relevant KPIs are considered, namely the 3MW and 35 MWh that are included in the project Grant Agreement.

4.4.2 – Power and Energy Demand per port

In the same sense as the previous comment, the below presented figures are exploring the same KPIs for the selected ports of Rotterdam, Istanbul and Piraeus.

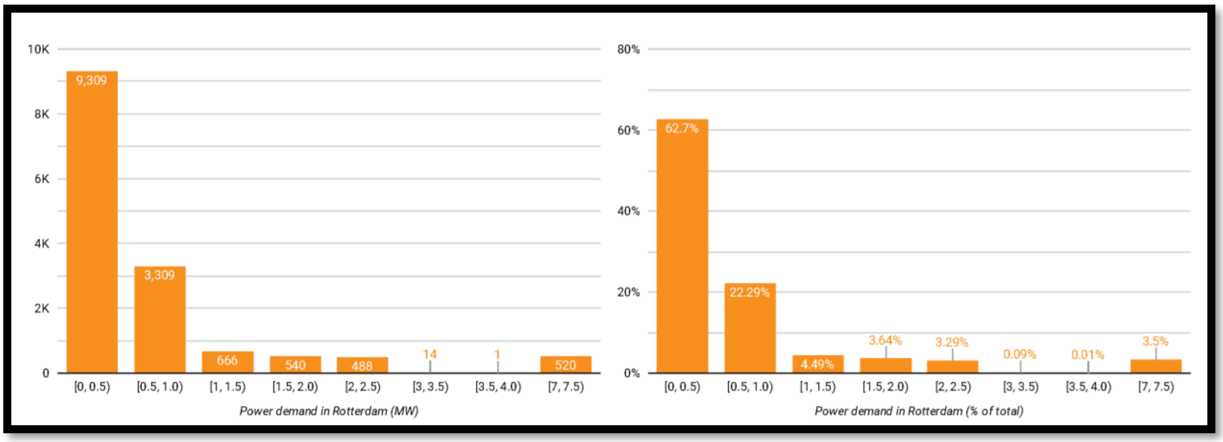

Figure 4.4-6: Power Demand in Rotterdam (in MW and % of total anchorage calls).

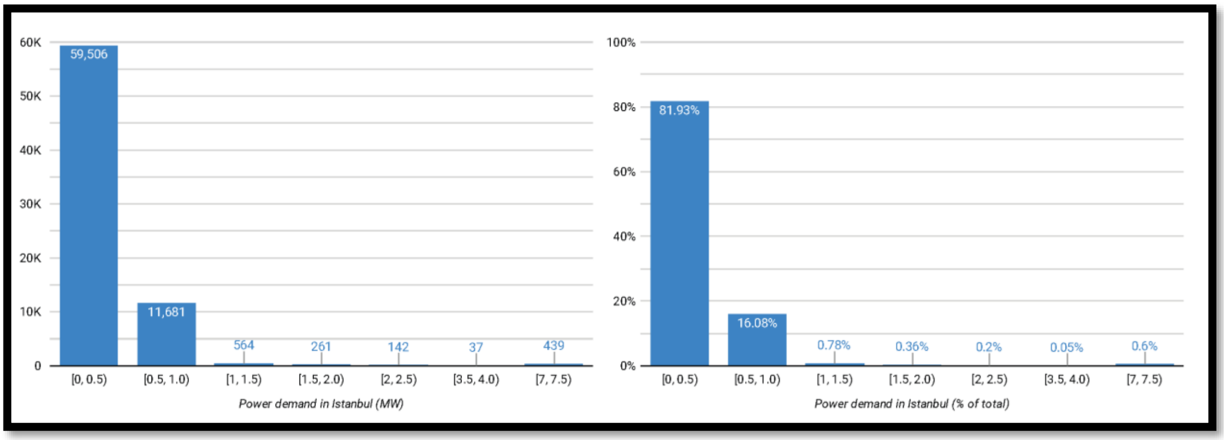

Figure 4.4-7: Power Demand in Istanbul (in MW and % of total anchorage calls).

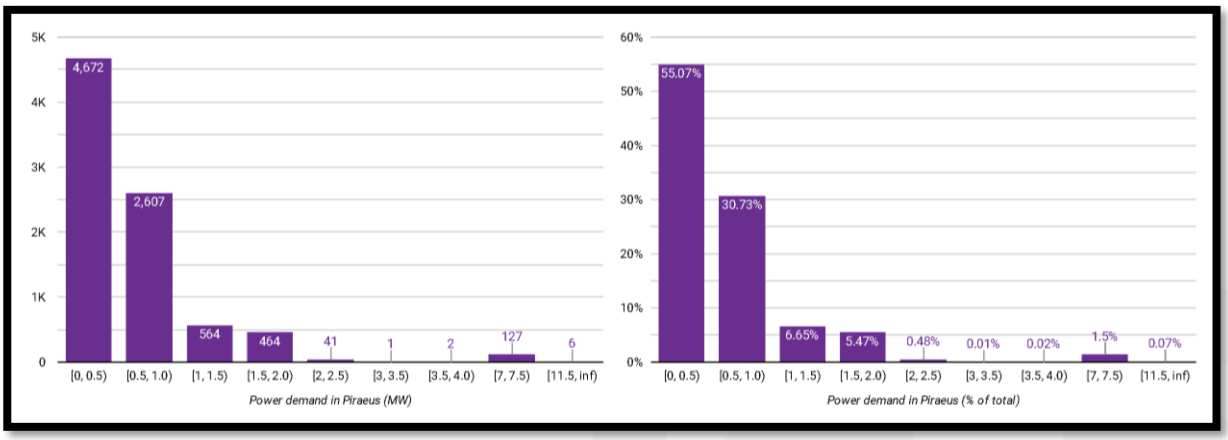

Figure 4.4-8: Power Demand in Piraeus (in MW and % of total anchorage calls).

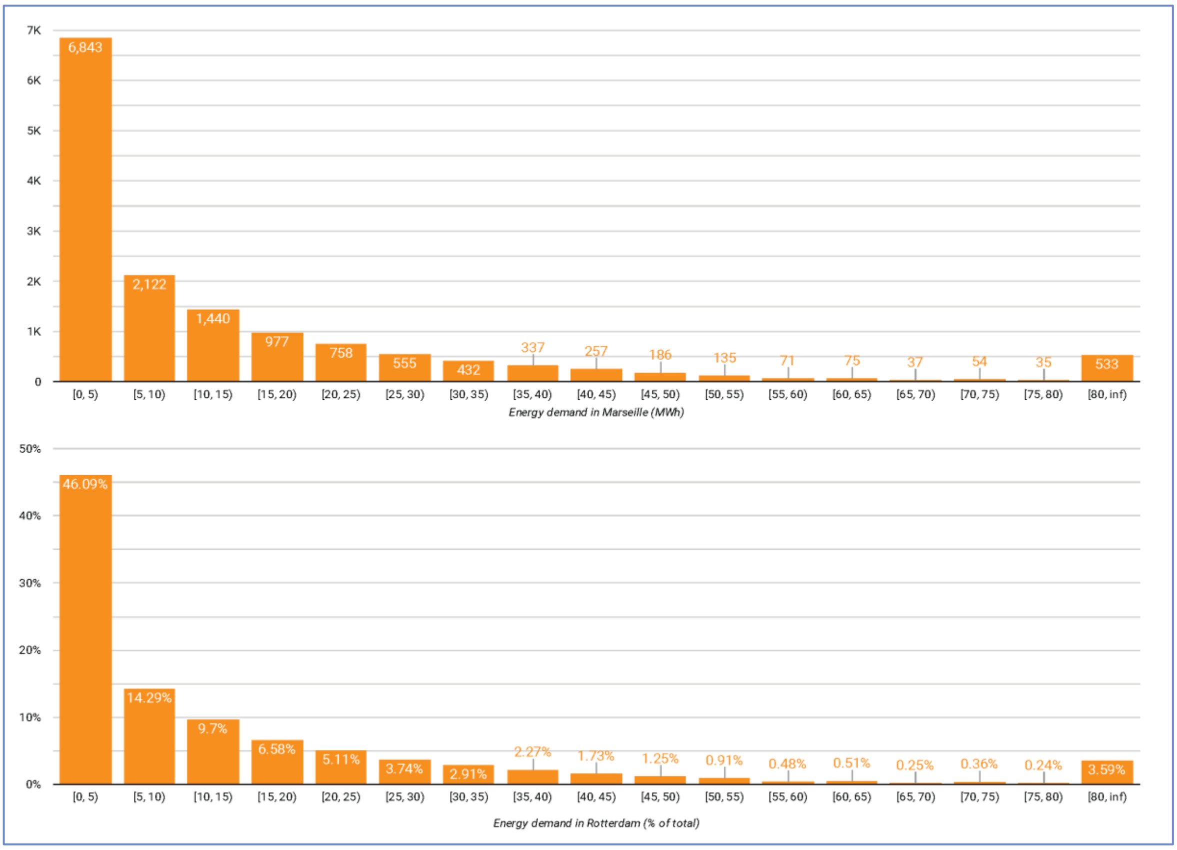

Figure 4.4-9: Energy Demand in Rotterdam (in MWh and % of total anchorage calls).

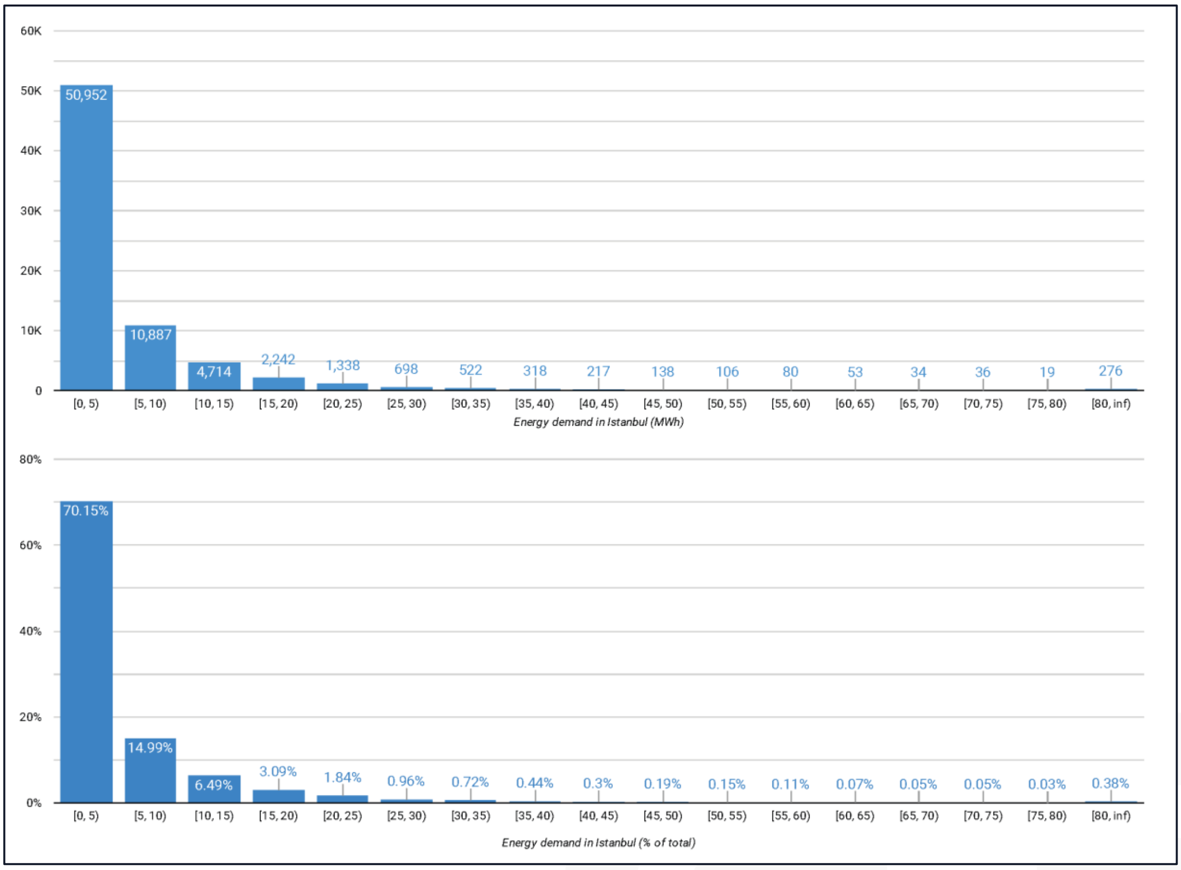

Figure 4.4-10: Energy Demand in Istanbul (in MWh and % of total anchorage calls).

It is evident that in most cases, the KPIs are met, if the whole picture is considered. For example, in Rotterdam, the 96.5% of power demand and the 88.42% of the energy demand is met. The numbers are similar for the other two cases, as well as for other ports presented in the Appendix II, Venice, Antwerp and Marseille. Of course, there will be cases that the barge will not be able to support either the power demand – especially the peak loads – or the energy demand. The latter is mostly due to increased anchorage times; it is once again mentioned that extremely large anchorage waiting time periods are excluded from the analysis, as they cannot be considered within reasonable limits (over 96 hours). In summary, when considering the overall picture for ports, in most of the cases, based on the results, the proposed system and its scalability, as it may go well-beyond the proposed KPIs, can effectively support the demands.

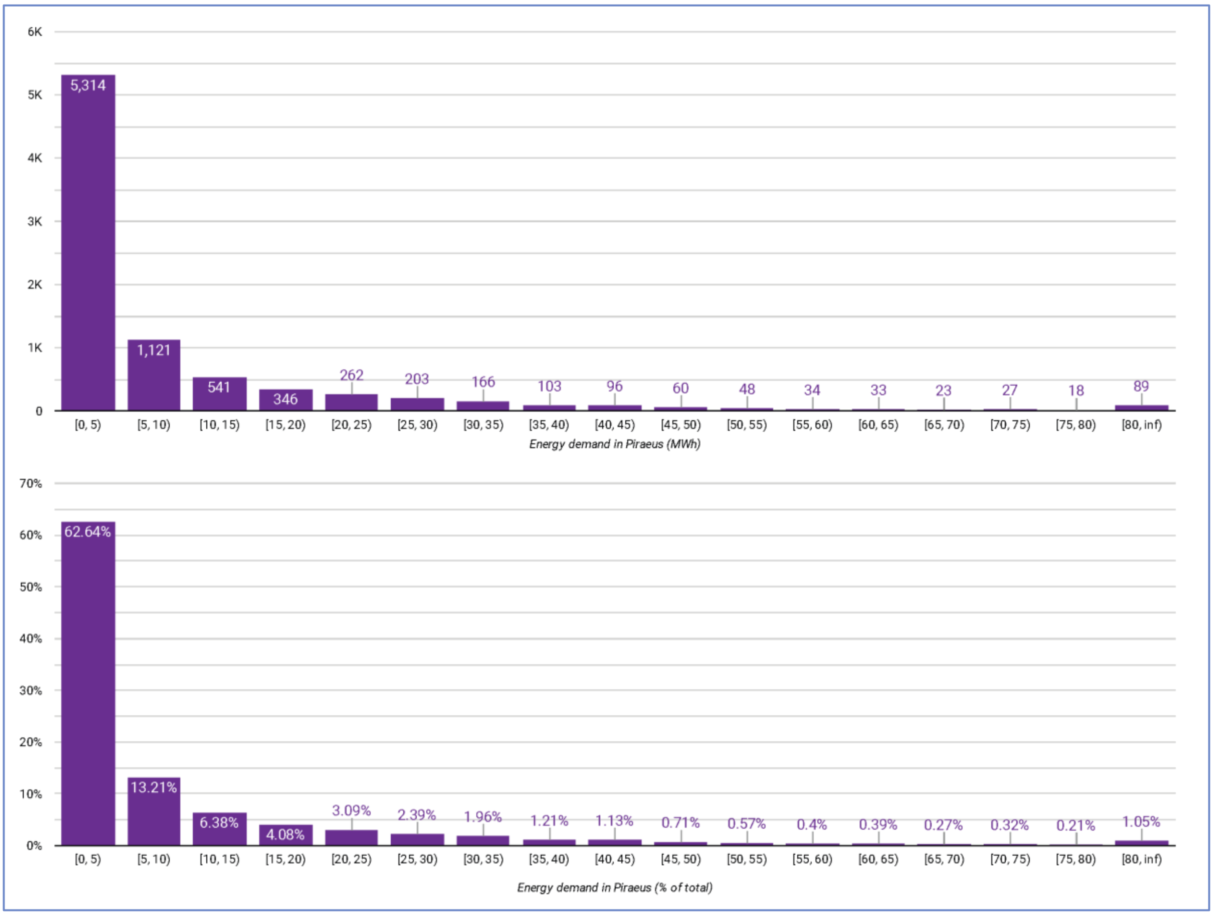

Figure 4.4-11: Energy Demand in Piraeus (in MWh and % of total anchorage calls).

4.4.3 – Power and Energy Demand per ship type

A similar analysis is presented here as well, in the following figures for the most prominent ship types, namely Cruise ships, Ro-Pax and Container ships, which are shown below, as well as Tankers, Ro-Ro, General Cargo and Bulk Carriers presented in the Appendix II. The main focus is the first three ship types, since the KPIs of the project refer to them mostly for the case of offshore power supply. The results show – again – that in most cases, the proposed system with the 3 MW and 3MWh performance can cover the demand. For example, for Container ships, the mean power demand can be met in full (100%), while 91.22% of the energy demand can be also met. Peak loads may be a bit concerning in order to support the full spectrum of needs; however, it can be balanced from the possible scalability of the solution, while for increased demand, onboard auxiliary systems may be used to ensure safe operation.

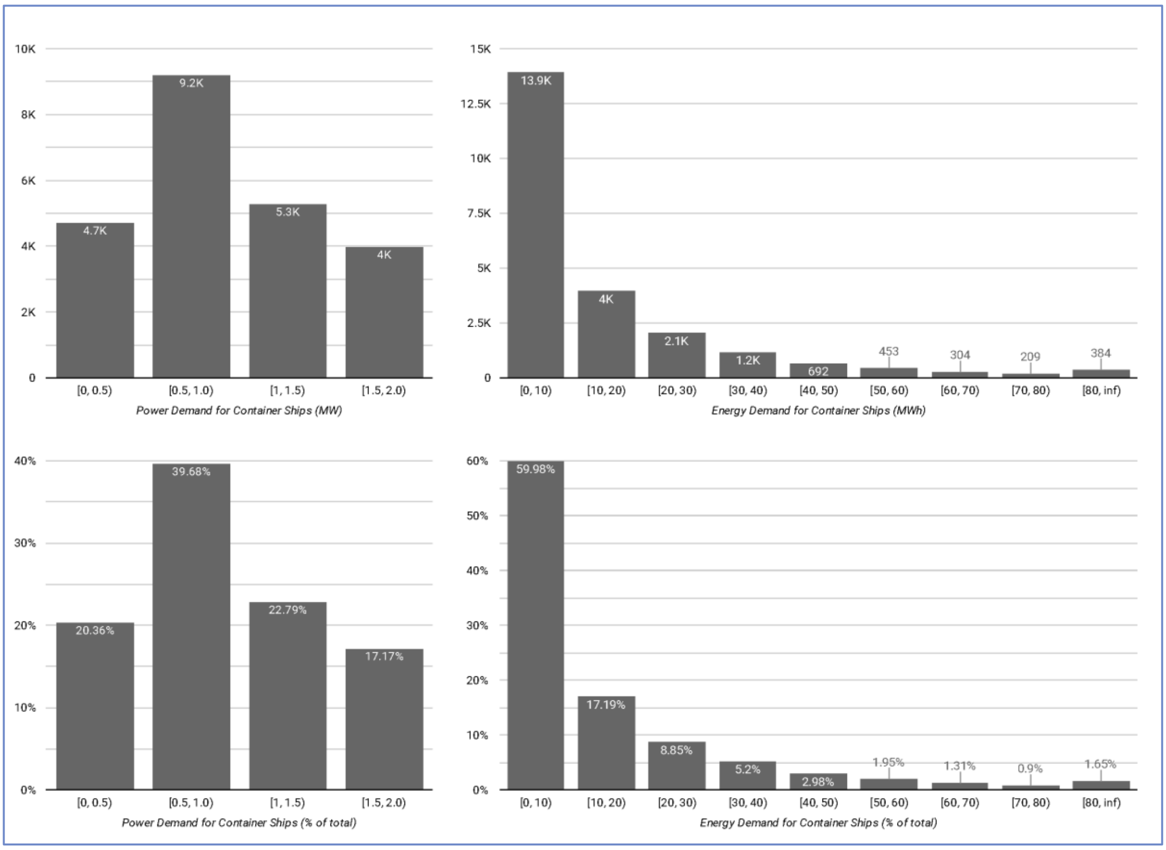

Figure 4.4-12: Power Demand Per ship type - Container Ships.

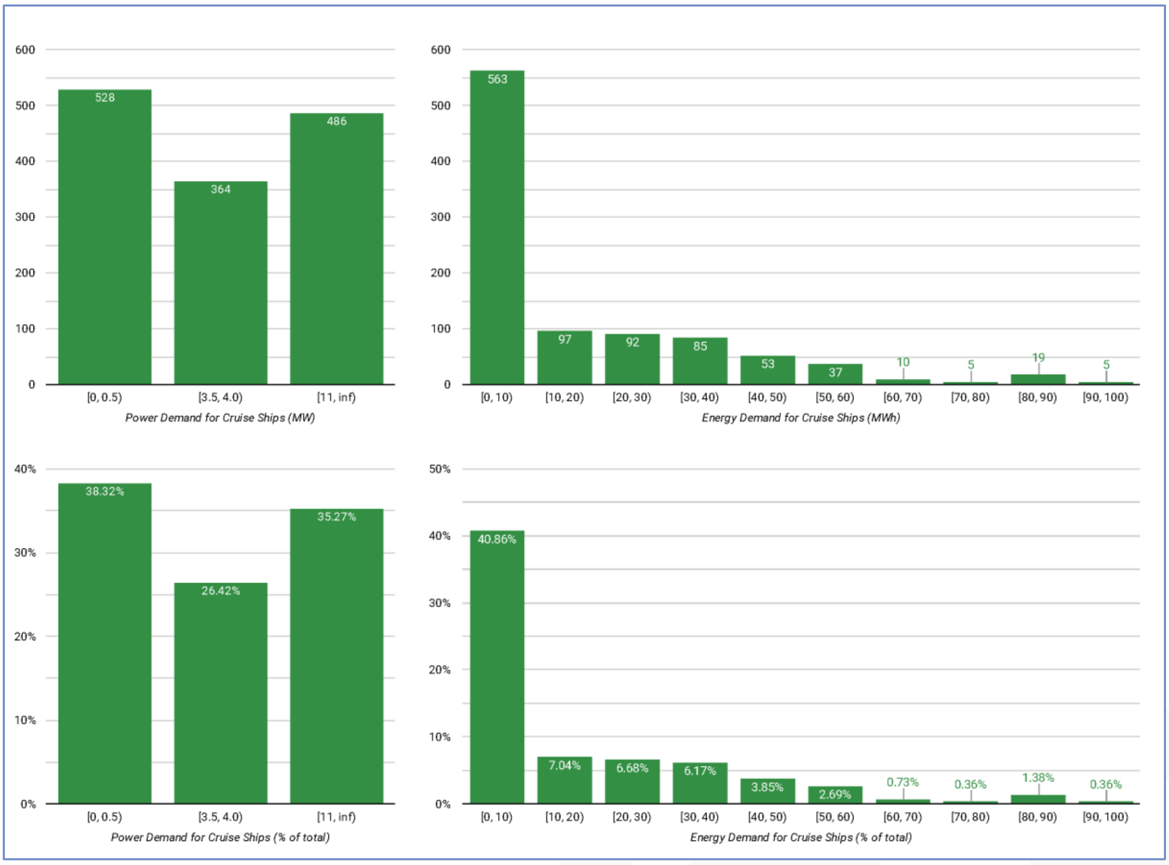

Figure 4.4-13: Power Demand Per ship type - Cruise Ships.

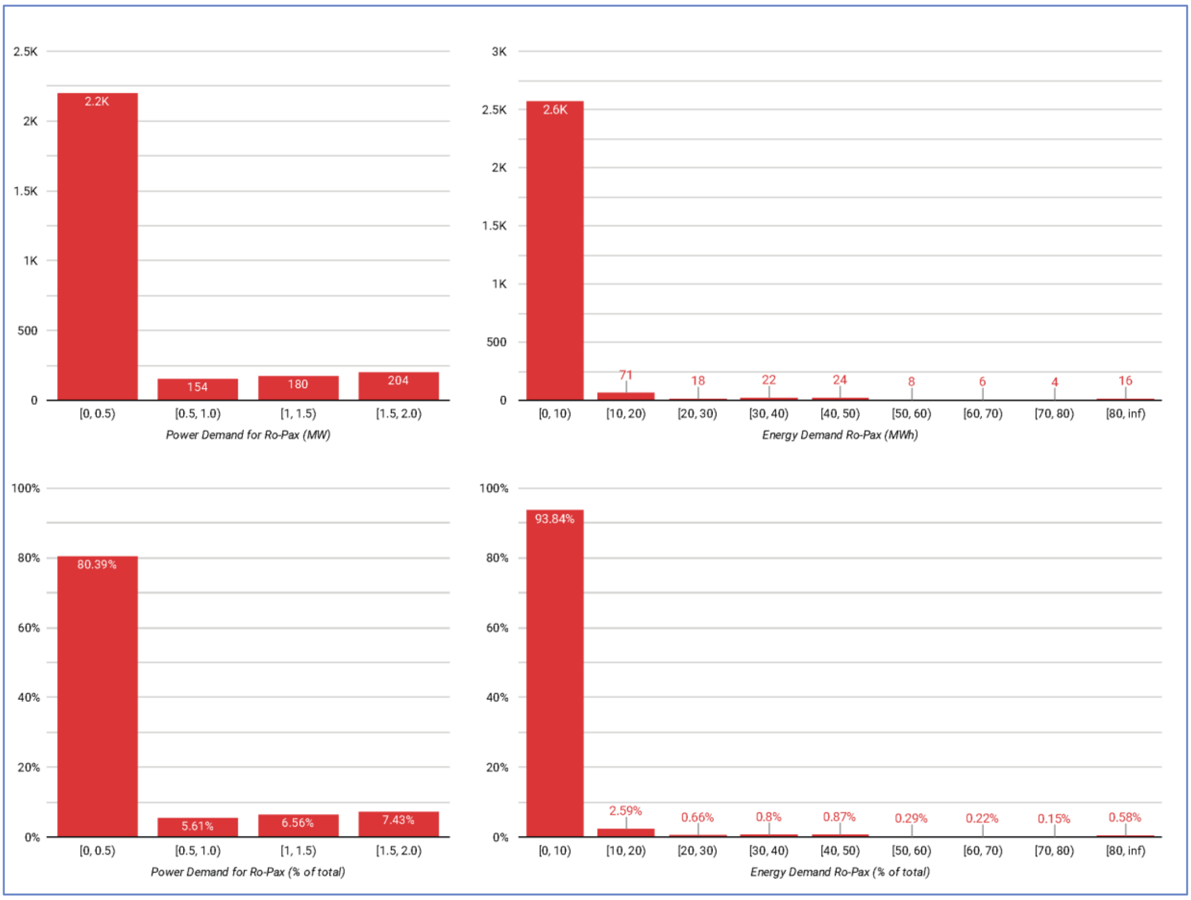

Figure 4.4-14: Power Demand Per ship type - Ro-Pax Ships.

A combination of the available data, as presented and commented above, will be further used to predict the power and energy demands, capitalising on possible additional data from ship operators, as data may become more available in the future for auxiliary systems power output or fuel consumption. The power and energy demands will facilitate the design process for the BlueBARGE system, in order for the solution to perform as expected.

Under WP3, “Power Supply and Integration Modules”, as well as WP4, “Performance assessment and Optimization” which are directly related to the power barge modules and the assessment of the BlueBARGE capacity, the calculations will be conducted in detail.

5 – Requirements Elicitation

This Section refers to the work conducted under T2.2 and refers to the elicitation of requirements for the BlueBARGE system, both the design of the full-scale system and the prototype that will be used for the demonstration (demo) case of the project, which will be conducted on a specific ship from Columbia Management Shipping (project partner) in the port of Limassol. The Section firstly sets the background, namely the standardisation context and relevant regulatory framework, then maps existing industry practices to expand the background, performs a gap analysis in this respect, and concludes with the user requirements elicitation and the final user requirements.

5.1 – Literature Survey on Standardisation and Regulatory Framework

Ongoing or recently finished Horizon EU projects already had a full report on available standards for shore power applications. To save effort and prevent redundancy, the available standards are sourced from the Ealing Project [5.1-1], and only fresh or updated versions are provided. The following input is gathered from the Ealing project deliverables (Table 5.1-1).

Table 5.1-1: Review of Applicable Standards in Force [5.2-1].

DISCOVERING THE CLASSIFICATION SOCIETIES AND FLAGSHIP QUESTIONNAIRE

EALING

Co-financed by the Connecting Europe Facility of the European Union

Could you point out the type of documentation in force or in-house now?

LIST OF ITEMS	DOCUMENTATION 1	DOCUMENTATION 2	DOCUMENTATION 3	DOCUMENTATION 4	DOCUMENTATION 5	DOCUMENTATION 6	DOCUMENTATION 7
OPS RULES/ GUIDES/ GUIDANCE NOTES/ STANDARDS	YES	Additional Notation	STANDARDS	RULES	STANDARDS	Guidance	Lloyd's Register Rules and Regulations for the Classification of Ships
TITLE OF DOCUMENTATION	Guide for High Voltage Shore Connection	Requirements stated on NR467	Electrical Shore Connections / Cold Ironing	SECTION 5 ELECTRICAL SHORE CONNECTIONS - SHORE POWER	Utility connections in port	ON-SHORE POWER SUPPLY	-
TYPE OF DOCUMENTATION (RULE, GUIDE, GUIDANCE NOTE, STANDARD, OTHER)	Rules, Guide	PtF, Ch9	DNV Standards for Certification (previously Certification Notes)	DNV RULE	NEK IEC/IEEE Standard	Guidance note	Rules
PUBLICATION NUMBER	-	-	No. 2.25	Part 6 Chapter 7 Section 5 Rules for classification: Ships — DNV-RU-SHIP Pt.6 Ch.7. Edition	80005-1:2019	MEPC.1/Circ.794	Part 7 Chapter 13
PUBLICATION DATE	-	-	JULY 2014	July 2021	2019	9 October 2012	2009
LAST UPDATE	July 2021	Rules ed. 07/21	-	-	-	MEPC.1/Circ.794/Corr.1	2021
TYPE OF VESSEL DOCUMENT APPLIES FOR	All	every vessel	All	All	All	All	Ships
GENERAL DESCRIPTION	Class requirements related to safety	-	-	-	-	-	Optional Notation deals with hazards onboard the ship and considers interface with shore equipment.

Note: 4/6 replies. Only Classification societies

E D C - REGULATORY AND ADMINISTRATIVE ASPECTS B A

44

The table illustrates the response of class societies to the question about the regulations in force for shore power. As mentioned in the text, ISO 80005:1 & 2 are already in force but ISO 80005: 3 is not a regulation yet which constitutes the guidelines for Low Voltage Shore Connection (LVSC). Some details are provided below:

IEC PAS 80005-3:2014 Utility connections in port – Part 3: Low Voltage Shore Connection (LVSC) Systems – General requirements document is still under development. The PAS (Publicly Available Specifications) document describes LVSC systems, on board the ship and on shore, to supply the ship with electrical power from shore. It is applicable to the design, installation and testing of LVSC and addresses.

Table 5.1-2: Electrical standards in various shore-to-ship inter-connections [5.1-2].

TABLE II
ELECTRICAL STANDARDS IN VARIOUS SHORE-TO-SHIP INTER-CONNECTIONS (BASED ON DATA FROM EUROPEAN MARITIME SAFETY AGENCY)

		Connection	Interoperability	Communication	Directive/ Regulation
CI (Cold Ironing)	HVSC	IEC 62613-1:2016 (General) IEC 62613-2:2016 (Connectors)	IEC/IEEE 80005-1	IEC/IEEE 80005-2	IMO-CI Guidelines EU AFID
	LVSC	IEC 60309-5	IEC/IEEE 80005-3 (under review)	IEC/IEEE 80005-2	IMO-CI Guidelines
	LVSC (inland waterways)	EN 15869-2:2019 (<125A) EN 16840: 2017 (>250A)		Possible application of IEC/IEEE 80005-2	CCNR CESNI – ES-TRIN2019
	Recreational vessels	IEC 60309-2	No standardization	No standardization	Not applicable
Onshore Battery Charging	ac charging	IEC 60309-5 IEC 62613-2	IEC/IEEE 80005-1 IEC/IEEE 80005-3	No standardization (possible application of IEC/IEEE 80005-2 or ISO15118)	Not applicable
	dc charging	No standardization	No standardization		

The standard IEC-62613-1 (2019) - General Requirements applies to accessories which have rated currents not exceeding 500 A and rated operating voltages not exceeding 12 kV 50/60 Hz, while the standard IEC-62613-2 (2016) applies to accessories of High Voltage Shore Connection (HVSC) systems up to 12 kV, 500 A, 50/60 Hz and includes the dimensional compatibility and interchangeability requirements for accessories to be used by various types of ships, that will be presented in detail. Concerning the respective accessories for LVSC systems (plugs, socket-outlets, ship connectors and ship inlets) intended to connect ships to dedicated shore supply systems described in IEC/IEEE 80005-3, these are regulated by the standard IEC 60309-5 (2017).

LVSC onboard the ship applicable for ships requiring up to 1 MVA at berth and the LVSC systems exceeding 250 A, equal or exceeding 400 V AC nominal voltage, they are covered by the international standard IEC/IEEE 80005-3. It is expected that IEC/IEEE 80005-3 will cover voltages over 400 V to use in inland waterways instead of EN16840:2017 as it does not allow 400V for safety [5.1-3].

IEC 60309-2 defines the plugs or sockets to be used in industrial applications. However, IEC60309-5 is defined for sea going vessels under IEC/IEEE 80005-3. So, for over 400V applications, there may be a discrepancy between vessels navigating through both inland waterways and open sea. Another discrepancy is on the grid type; IT-grid is enforced for OPS whereas for inland OPS IT, TN and TT are available [5.1-3].

Finally, it is crucial to note that the ES-TRIN regulation restricts the use of OPS for energy consumers installed in the cargo hold of inland vessels. Additionally, loading and unloading is restricted during OPS for inland waterways [5.1-3].

There are currently no recognized standards for ship-to-ship charging. The same holds true for shore-to-barge charging. In both circumstances, the applicable guidelines from the existing standards shall be used. During the project, suggestions for new regulations will be developed in cooperation with ABS.

The following table summarizes the applicable standards for SSE installations (Table 5.1-3):

Table 5.1-3: Applicable standards for SSE installations [5.1-1].

Table 6: Applicable international standards directly affecting SSE installations onboard vessels

Ship Type	IEC /IEEE Standards – Operability & Connectivity	
	LVSC	HVSC
Oil tankers	(80005-3 – Annex D) IEC 60309-5	(80005-1 – Annex F) 62613-2 – Annex I
Chemical/Product Tankers	(80005-3 – Annex D) IEC 60309-5	(80005-1 – Annex F) 62613-2 – Annex I
Gas Tankers	(not defined) IEC 60309-5	(80005-1 – Annex E) 62613-2 – Annex I
Bulk Carriers	(not defined) IEC 60309-5	(not defined) 62613-2 – Annex I
General Cargo Vessels	(not defined) IEC 60309-5	(not defined) 62613-2 – as appropriate
Container Vessels	(80005-3 – Annex C) IEC 60309-5	(80005-1 – Annex D) 62613-2 – Annex I
Ro-Pax Vessels	(not defined) IEC 60309-5	(80005-1 – Annex B) 62613-2 – Annex J
Cruise Ships	(not defined) IEC 60309-5	(80005-1 – Annex B) 62613-2 – Annex H
Offshore Supply Vessels	(80005/3 – Annex B) (IEC 60309-5)	(not defined) 62613-2 – as appropriate
Fishing Vessels	(not defined) IEC 60309-5	(not defined) 62613-2 – as appropriate

Considering the demo case, the application will be conducted on a tanker vessel. Since the vessel will be at anchorage, there will not be any cargo operations (or other types of operations), then the application will be below 1MVA and considered as a LVSC. In this case, we may reduce the complexity of the demo case by considering the data communication, ISO 80005-2. This item will be clarified when the technical requirements are gathered for the demo application.

Some applicable technical requirements for the demo case are listed below:

1) IEC 60092-502, Electrical installations in ships - Part 502: Tankers - Special features
2) IMO SSE Guidelines – Interim Guidelines on Safe Operation of Onshore Power Supply (SSE) Service in Port for Ships engaged on international voyages
3) The European Maritime Safety Agency (EMSA) published its “Guidance on Shore side Electricity (SSE) for Port Authorities and Administrations” in July 2022.
4) CENELEC published in 2015 the Harmonization Document (HD) 60364-7-730:2016, titled “Low voltage electrical installations - Part 7-730: Requirements for special installations or locations - Onshore units of electrical shore connections for inland navigation vessels
5) Regarding ship electrical systems, the IET and BSI jointly publish BS 8450:2006 Code of Practice for Installation of Electrical and Electronic Equipment in Ships, and the IET provides the secretariat for the national committee JPEL/18 (electrical installations of ships and mobile and fixed offshore units).

For the demo case, further applicable safety requirements and analysis are shared in sub-section 5.3, while a preliminary risk analysis, regardless of the work conducted under T2.3 of the project, has been conducted and shared under sub-section 5.6 - Technical, Operational and Safety Requirements.

Other international and EU regulations are briefly listed as follows:

International Regulations related to SSE and offshore power supply:

- SOLAS Ch II-1, Part D: Electrical Installations
- MARPOL Annex VI
- STCW

EU Regulations related to SSE and offshore power supply:

- 2030 Climate target plan
- Sustainable and Smart Mobility Strategy
- Fit for 55 package
- Efficient & Green Mobility package
- Revision of the Alternative Fuels Infrastructure Regulation (EU AFID)
- FuelEU Maritime
- Revision of the EU ETS Scheme
- Revision of the Energy Taxation Directive
- Revision of the Effort Sharing Regulation
- Revision of TEN-T Regulation
- EU Directive 2005/33/EC on the sulphur content of marine fuels
- EC Recommendation 2006/339/EC on the promotion of SSE for use by ships at berth in Community ports
- EC Communication (2007) 575 on an integrated maritime policy for the EU
- EU Directive 2008/50/EC on ambient air quality and cleaner air for Europe
- EU Machinery Directive 2006/42/EC
- Commission Delegated Regulation - Regulation (EU) 2019/1745
- EU Port Service Regulation - Regulation (EU) 2017/352
- EU Sulphur Directive - Directive 2016/802/EU
- Directive EU 2016/1629 - Establishment of requirements for inland waterway vessels

International and EU Standards related to SSE and offshore power supply:

- IEC/IEEE 80005-1 Utility connections in port
    - Part 1: High Voltage Shore Connection (HVSC) Systems - General requirements
    - Part 2: High and low voltage shore connection systems - Data communication for monitoring and control
    - Part 3: Low Voltage Shore Connection (LVSC) Systems - General requirements
- IEC 62613 - Plugs, socket-outlets, and ship couplers for high-voltage shore connection (HVSC) systems
- IEC 60309-1:2021 - Plugs, fixed or portable socket-outlets and appliance inlets for industrial purposes

- IMO MSC.1-Circ.1675-2023 - Interim Guidelines on the safe operation of OPS service in port
- IEC 60092 Electrical installations in ships
- IEC 61363-1 Electrical installations of ships and mobile and fixed offshore units
- 1662-2008 IEEE Guide for the Design and Application of Power Electronics in Electrical Power Systems on Ships
- IEEE 45.4-2018: IEEE Recommended Practice for Electrical Installations on Shipboard
- EMSA SSE Guidance to Port Authorities and Administrations

Guidelines from Classification Societies:

- ABS High Voltage Shore Connection
- BV High-Voltage Shore Connection System
- DNV Electrical Shore Connections - Shore Power

ABS construction and design rules and guidance:

- ABS Rules for building and classing steel barges (2009)
- ABS Rules for building and classing steel barges (2018)
- ABS Requirements for Power Service for Marine and Offshore Applications
- ABS Requirements for Use of Lithium-ion Batteries in the Marine and Offshore Industries (Lithium-ion Batteries Requirements)
- ABS Guidance notes on FMEA for Classification
- ABS Guidance notes on Risk Assessment applications for the marine and offshore industries
- ABS Rules for Building and Classing Mobile Offshore Units (MOU Rules)
- ABS Guidance on Qualifying New Technologies (NTQ)

5.2 – Mapping of Existing Industry Practices

One of the earliest references to the concept of a power ship dates back to the early 20th century, when ships were converted into power ships to support local power grids during bad weather, natural disasters, or increased summer electricity demand. As a definition, a power ship is a special purpose ship, which is equipped with an onboard powerplant to serve as a power generation resource [5.2-1].

In this sense, power plants could be installed on a barge, thus creating a power barge design; such designs were initially developed during World War II as a transportable large-scale power generation resource. Power barges were equipped with single or multiple gas turbines, diesel or gas engines, boilers or even nuclear reactors for electricity generation.

Today, there are several commercial projects providing power to various parts of the world. The well-known conventional ones are Karadeniz Shipping and The Power Barge Company [5.2-1].

The benefits of such systems include mobile energy and quick delivery wherever needed, dynamic capabilities, high-efficiency, multi-fuel capability and increased modularity and scalability in the design. However, a business plan cannot be guaranteed as the product has a more on-demand nature. Of course, supporting ships was not the case, as they could use their own installed auxiliary engines for producing the necessary electricity for onboard loads. Whereas, they also have disadvantages such as GHG emissions, noise and pollution due to the type of generation methods.

A significant step for the recent power barge concepts – and their consideration for ships – was the introduction of Liquefied Natural Gas (LNG). In more detail, in contrast to ship's own diesel generators, the energy source LNG does not cause any SO_x or particulate matter (PM) and the emissions of NO_x and CO_2 are significantly reduced. Therefore, the environmental impact of using LNG is much better than the ship's own generators, which can be switched off during their stay in port. The case of HUMMEL, the LNG Hybrid Barge, destined to operate in the port of Hamburg already from 2015, was such an example [5.3-2]. With the LNG Hybrid Barge, the energy is generated in cogeneration engines and generators using liquid gas. The five generators produced 7.5 MW (50/60 Hz). The electricity generated in this way was fed flexibly into the supply network of the respective cruise or other ship as required. Today, the barge is out of service due to ownership and other issues, but its example can provide significant insight regarding other power barge concepts.

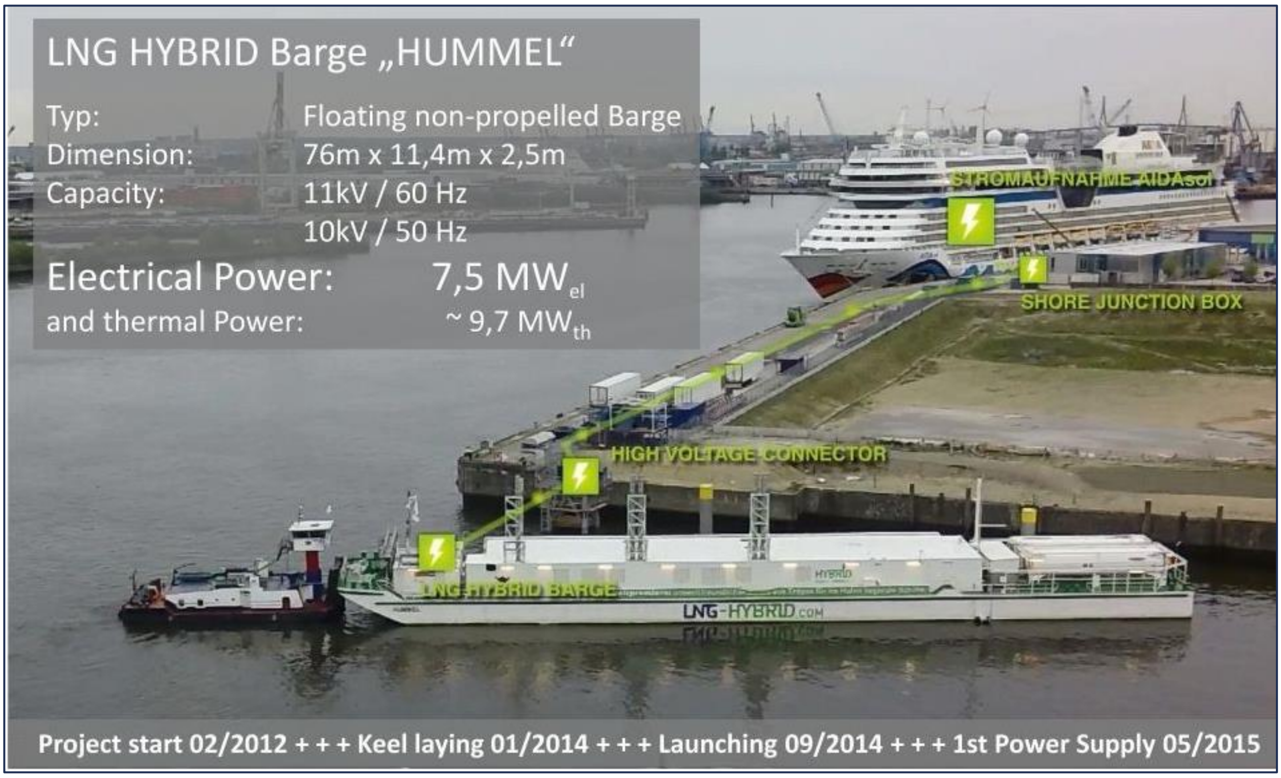

Figure 5.2-1: Hummel Hybrid LNG to provide shore power to Cruises [5.2-2].

Furthermore, Therma Marine Inc. (TMI), a subsidiary of Aboitiz Power Corporation, one of the Philippines' leading companies involved in power generation, distribution, and retail electricity services, has ordered a barge-mounted 54 MW / 32 MWh energy storage system to be delivered by Wärtsilä. The order was placed in September 2020. The project was handled fast-track, with delivery scheduled to be completed by the end of 2021. The “floating power barge” project is claimed as a first-of-its-kind for the Southeast Asia region and the battery storage will be integrated with customer Therma Marine Inc's (TMI's) 100 MW thermal power barge in the Maco municipality of the Philippines province Davao de Oro. Wärtsilä said that the existing power barge runs on diesel engines and the energy storage system would help it provide fast response ancillary services to the grid, for which TMI has a contract with the transmission operator, National Grid Philippines. The addition of the short-duration battery system will reduce the power barge's ramping time from 15 minutes to just 3 minutes [5.2-3].

Figure 5.3-2: Therma Marine Application in Operation [5.2-3].

Another application is also from Wartsila where a methanol fueled barge is under development to provide power to ships. The target is to provide 6 to 16 MW of power. The project recently started as understood from the text. So, this application can be considered as a design alternative (fuel alternative) in floating power barge applications (Figure 5.2-3) [5.2-4].

Figure 5.2-3: Wartsila Methanol Barge [5.2-4].

In the case of TECO 2030 power barge, the energy units are fully integrated into containers for power supply at berth and anchor, with the inclusion of fuel cells, batteries, and hydrogen storage (Figure 5.2-4) [5.2-5].

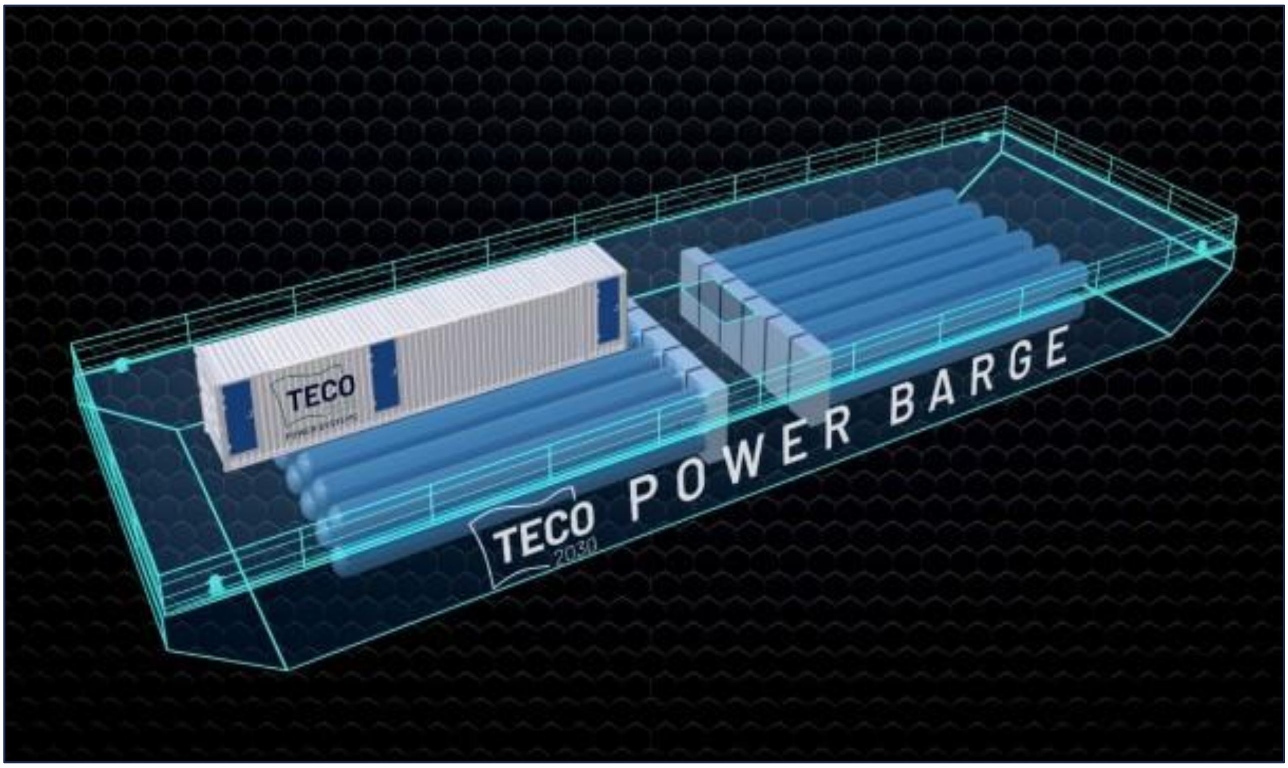

Figure 5.2-4: TECO Power Barge [5.3-5].

As briefly discussed in Chapter 3.4.8 UC8: Charging from offshore power plants and wind farms, PowerX company recently declared the conceptual design of a power barge which will make use of the excess electricity generated by PV plants and will be operated at Seto Inland Sea providing 240MWh capacity for about 24000 homes. The barge is 81m and will hold 96 containerized batteries (Figure 5.2-5) [5.2-6].

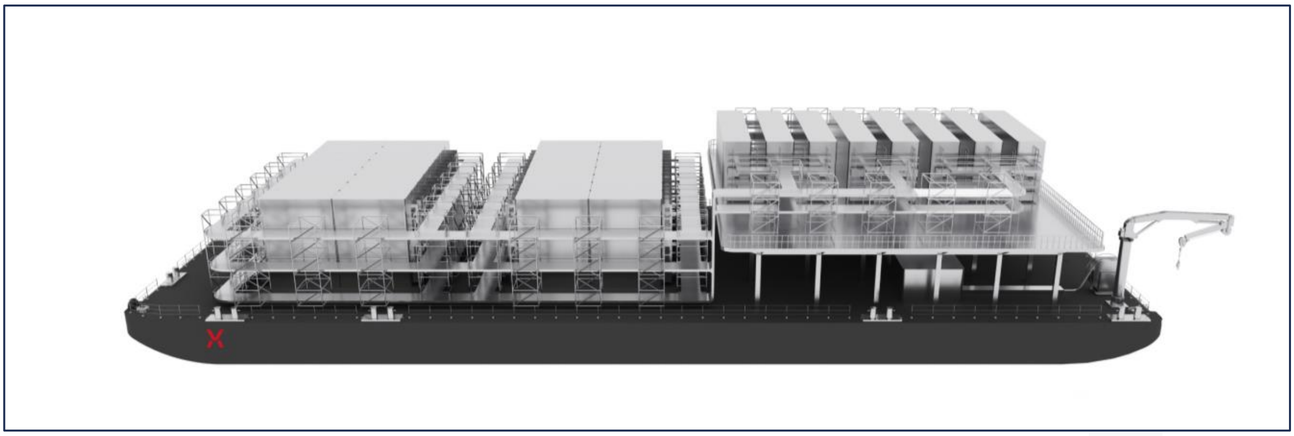

Figure 5.2-5: PowerX Battery Barge [5.2-6].

Another floating BESS application is going on in Singapore. The Seatrium's floating living lab as shown in Figure 5.2-6 will be serving as a test bed for further development and improving smart grid structure. The system operations are currently starting. It holds 7.5MWh of batteries with a novel methodology to reduce the area footprint of battery storages by 40% (Figure 5.2-7). This system combines the use of Hydrogen, LNG and BESS to respond to needs for demands from the land side or from the ship side.

Figure 5.2-6: FueLNG Venosa takes part in Seatrium's floating lab commissioning milestone [5.2-7].

Figure 5.2-7: Seatrium's Floating Living Lab [5.2-8].

MAGPIE Horizon EU project [5.2-9] is very comprehensive with 45 partners working on the introduction of solutions for smart green ports. The project covers the whole port ecosystem including the road (trucks and rail), ocean and IWTs. There are several instances in the deliverable documents in which the application of an e-barge was addressed. However, there direction taken was towards using a batterized container system (ZES) to be swapped at the IWTs using the available infrastructure for container handling. The idea was realized with the participation of Port or Rotterdam, Ebusco, ING and Warstila. BlueBARGE and ZES applications seem to have an overlap for many possible applications. The solution was also covered under Current Direct Horizon EU project [5.2-10].

For ocean ports, the recommended option is to make use of charging buoys. The proposed application is very similar to UC8: Charging from offshore power plants and wind farms. Therefore, the details will not be repeated here. However, a combination of the solutions may extend the range of applications increasing operational efficiency.

These advancements will need to be gradually introduced, making them highly beneficial for developing more sustainable energy systems. As technologies develop further, the expenses of these systems will eventually decrease, making them invaluable for creating crucial sustainable energy solutions in the future.

5.3 – Gap Analysis on Regulations and Existing Practices

Ship air pollution is a significant source of impact on the environment for a port city. OPS solves this challenge by allowing ships to run on shore-side electricity while they are at berth, reducing both local air and GHG emissions. The FuelEU Maritime regulation—the EU 'Fit for 55' package—will make it obligatory for all container vessels and passenger vessels above 5,000 GT to use shore-side supply in all EU ports as of 1 January 2030 [5.3-1, 5.3-2]. The AFIR deals with port infrastructure about alternative fuels: LNG, hydrogen, and electricity. However, the ports need to meet only 90% of the electricity demand, and this would allow a few ships to use their auxiliary engines, thereby reducing CO2 emissions by 24% under a condition when the ship is berthed. Non-standardized connection points and limited interface compatibility with terminal systems present a challenge [5.3-2].

5.3.1. Gap Analysis - Regulations

Regulations on air pollution from ships exist, but very often, they do not contain explicit provisions for OPS. Current regulations can do little to require the use of OPS, and much clearer legislation is lacking, leaving a lack of effective enforcement mechanisms. Added to this is a lack of economic incentives for ports and ship owners to invest in OPS infrastructure. Fee systems or OPS-related tax exemptions could be adopted to achieve better acceptance and compliance. The International Maritime Organization is among the influential bodies in regulating the emission of air from ships. MARPOL Annex VI: Regulations for Prevention of Air Pollution from Ships is the one limiting the emissions of pollutants like SOx, NOx, and particulate matter [5.3-3]. The IMO 2020 Sulphur Cap further tightened the stranglehold on SOx and promoted cleaner fuels or emission control technologies, but no IMO regulation directly imposes the use of OPSs [5.3-4]. Local and national regulations have more stringent standards on ship emissions. For example, EU Directive 2016/2386 dictates rigidly low limits on pollution for Emission Control Areas, including vessels at anchor [5.3-5]. The California Air Resources Board provides for OPS use in the case of ocean-going vessels at California ports. These local rules show that there is a tendency toward stricter emission controls and thus promote the use of OPS indirectly [5.3-6].

5.3.2. Gap Analysis - Existing Practices and Challenges

Next-generation OPS research needs greater exploitation of relatively unexplored areas, such as site situation-based comparisons of different OPS solutions, economic analyses for OPS costs and benefits, and an environmental footprint of OPS compared with non-OPS use. Another relevant research includes the powering of OPS through renewable sources like wind, solar, and water turbines. This means that a holistic approach to the benefits and risks associated with OPS investments in port areas is of essence, including understanding the technical readiness of various ship types related to OPS and shore power connectivity. The success will lie in the international standardization of the operation of the infrastructure and the execution of the social impact studies to engage all stakeholders while reducing by a considerable margin air emission, noise, and GHG at ports. These challenges involve the high costs of capital investments, lack of standardized connectivity solutions, and retrofitting ships. The environmental benefit makes shore power very interesting for a greener port and low-carbon maritime industry. Even though some ships will require conversion to shore power capabilities, shore power is the cleaner option for the maritime future and can, with advancing technology, offset some of the environmental impact of shipping [5.3-7, 5.3-8 and 5.3-9].

Current levels of OPS use differ significantly among the world's ports. Driving forces for adoption include initiatives from port authorities -some of which are incentivizing OPS use through rebates and onshore infrastructure investments. Another driver is vessel type: cruise ships and container ships are among the first movers because of their longer length of stay in ports and higher energy demand. However, EMSA reports that only about 15% of the cruise vessels and 10% of container ships are OPS-ready [5.3-16].

Several technical difficulties limit the wider adoption of OPS. First, incompatibility between the shore-side infrastructure and onboard connections of different vessel types may be experienced. It is yet to be established regarding the availability of shore power facilities at every port. All ships are still not fitted for shore power connections [5.3-7, 5.3-16]. Furthermore, already installed OPS infrastructure can lack sufficient power to larger vessels with high energy demands, and the length of shore power cables can limit OPS use for vessels moored further away from the quayside.

Cost remains a challenge to both ports and ship owners. For ports, the infrastructure setup for OPS requires port authorities to invest heavily at the forefront. For ship owners, electricity prices against on-board fuel consumption may act as a disincentive since electricity prices are volatile. Additionally, there is a lack of detailed cost-benefit analyses, making it challenging for the different stakeholders to form effective decisions. The installation of shore power infrastructure in harbors can be an expensive undertaking [5.3-7].

Operational challenges include non-standardized connections between shore-side infrastructure and vessels, which logistically bring about the next area of challenge in terms of possible delays to connection times. Effective scheduling and coordination between the vessels and the port authorities is very important when using OPS effectively, to avoid any undue downtime and ensure smooth running of the port's operations. The crew needs to be properly trained and shown procedures and best practices regarding OPS operations. Further research and development in technical limitations should be continuously undertaken to enhance the compatibility and power capacity and extend the reach of shore power cables. Exploring financial incentives and cost-sharing models for cost issues and raising awareness of long-term environmental and economic benefits is realized through OPS. Standardization of the connections at all harbors and terminals will help in easy operation and increase its adoption. Clear guidelines and training programs for crew members will ensure the efficient and safe usage of OPS.

Current shore power practices open a chasm in terms of risk assessment for tankers with hazardous cargo [5.3-11]. The senior vice president and global segment manager of DNV Maritime comments that the electrical risks are more significant on tankers than dry bulk and container vessels, and, as such, it requires further attention when it comes to system safety and the safety of the personnel operating it [5.3-12]. This stems from the increased electrical risks associated with tankers, in comparison with other vessel types, and the shortcomings of current practices in mitigating these risks. To that end, what is required is industry-standard guidance on the safe application of shore power with tankers. The guidelines should contain safety procedures for onboard systems and quayside infrastructure. In building standardized practices, the efforts that the Environment Committee of Oil Companies International Marine Forum (OCIMF), particularly its Onshore Power Supply Work Group, are making are quite encouraging. Their efforts surely can hasten shore power uptake and reduce industry emissions [5.3-13]. Also [5.3-7] and [5.3-8] underline some key gaps between regulations and practices on the use of shore power. These include the lack of international legislation to demand and standardize the use of shore power, thereby leaving a wide gap in terms of diffusing its common use. In addition, the varied policies and practices at country and port levels create policy inconsistency and hence inability to coordinate efforts in terms of implementation. Further, inadequate data with respect to the extent and efficiency of shore power use pose challenges that inhibit informed decision-making and the reviewing of its impact. These gaps collectively act as a barrier to the wide application of shore power in harbors.

MAGPIE project shared the results of a literature review and interview with relevant stakeholder on the barriers associated with OPS applications [5.3-18]. Table 5.3-1 and Table 5.3-2 summarize the results for seagoing shipping and inland shipping.

Depending on the business models there are small variations in the responses. However, major concerns are in line with the documented information mostly concerning the business case, adaptation of new technologies, unclear directions in the path (fuel selection etc.) and unalignment.

Table 5.3-1: Literature review and Survey Results for Barriers for Seagoing Shipping [5.3-18].

Economic	Uncertainty on emission pricing / energy carrier subsidies
	Risk of (economic) lock-in with new technology with long term assets
	Absence of a level playing field
	Lack of, or uncertain, customer willingness to pay for sustainable innovations
Knowledge	Lack of capacity to build expertise for actors in comparison to the complexity of the (technical, operational, regulatory) changes
	Lack of system level insight (e.g., data, decision models) for policy makers
Standards & Regulation	Lack of integrated and sufficiently flexible standards (e.g., unintended mistakes fit for 55)
	Permit uncertainty
Interaction between stakeholders	Difficulty to align, externally and internally to the wide variety and scale of stakeholders
	Global political and strategic interests in shipping
	Lacking unity or rallying for leading stakeholder(s)
	Difficulty for small stakeholders to align with major initiatives
Directionality (Cohesive policy direction)	Potential negative business impact due to unbalanced directives (e.g., fuel directives)
	Harmonization of policy on National, European and where possible global level
Technology	Too many new (immature) technologies options
	Lifecycle of technology (lock in)
Infrastructure	Uncertainty about the presence of new infrastructure and impact of stranded assets

Table 5.3-2: Literature review and Survey Results for Barriers for Inland Shipping [5.3-18].

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

The recommendations for the challenges in using shore power with its potential to reduce emissions from the maritime sector are proposed in [5.3-7] and [5.3-8]. In [5.3-14], an analysis of the gap between regulations and existing practice on the implementation of shore power in harbors is presented. There are, at present, no uniform policies that require its use; rather, its use is voluntary. The shore power infrastructure has been developed based on policy initiatives and subsidies. To encourage wider adoption of shore power, however, international regulations and standards will be required. Within the next five years, the European Commission shall come up with new policies that will set the trend in shore power development [5.3-14]. In contrast, the status of fossil diesel refueling is very accessible, serves well, is flexible, and has relatively low prices in the short term. It will be hard for alternative clean energy infrastructure to match this, particularly in an initial phase.

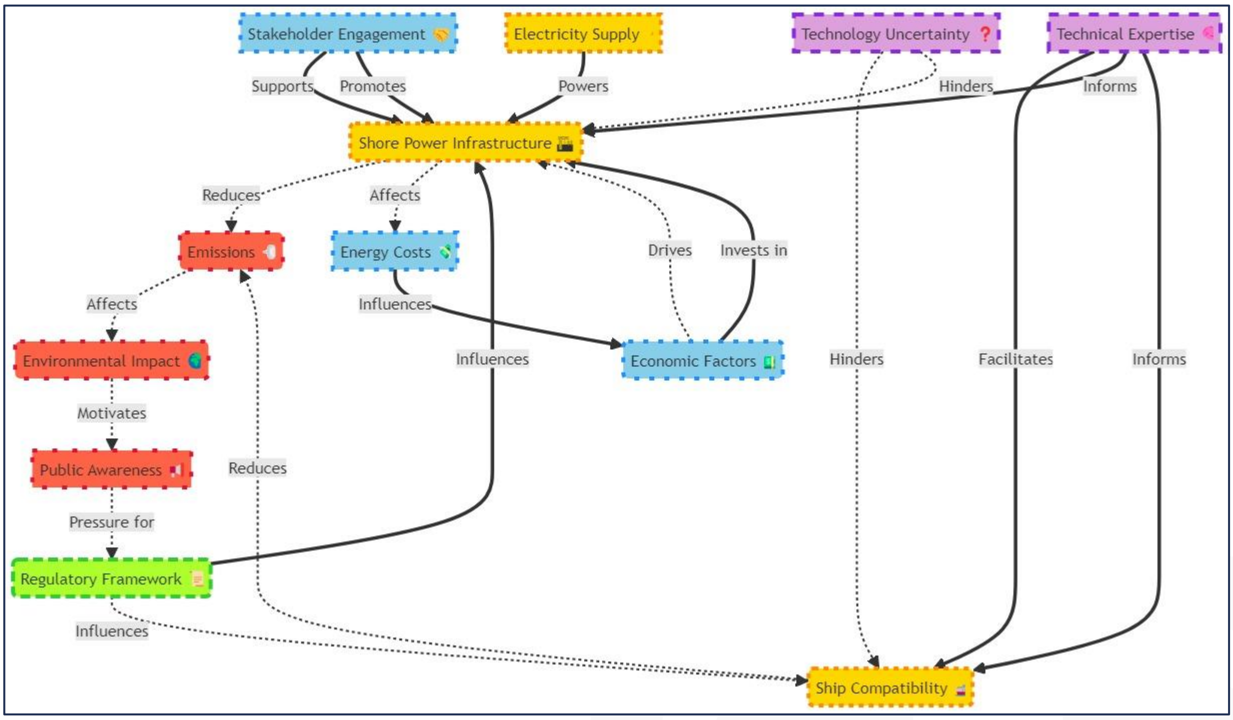

Figure 5.3-1: Casual loop diagram for Shore Power Penetration.

The need for requiring the use of OPS on certain vessel categories or during certain periods of time, along with enhanced emission limits in port areas, may be ways to force compliance [5.3-7]. Further, economic incentives in terms of reduced fees or tax breaks for OPS users are proposed to encourage more adoption [5.3-9]. Another operational strategy is to ensure that the policies are harmonized internationally, as well as collaboration, with respect to shore power utilization, to spur its further adoption in nations and ports [5.3-14].Additional points that need further debate, in particular, concern the cost of implementation and its potential impact on competitiveness, as well as social and environmental considerations that must be borne out for holistic decision-making in further research or policy discussions. The above information is summarized below by creating a gap analysis matrix [5.3-14, 5.3-15 and 5.3-16].

Table 5.3-3: Gap Analysis Matrix

Requirement	Current Practice	Gap	Impact	Recommendation
Capacity	- Available shore power capacity at ports - Compatibility with various vessel sizes	- Insufficient capacity to meet future demand - Limited compatibility with specific ship types	- Increased vessel wait times - Reduced shore power adoption	- Invest in infrastructure upgrades for higher capacity - Develop standardized connection systems for wider compatibility
Safety	- Existing safety protocols for shore power connection - Risk assessment procedures	- Lack of specific safety protocols for hazardous cargo - Limited training for personnel on shore-ship interface safety	- Increased risk of accidents - Delays due to safety concerns	- Develop industry-standard guidelines for tankers and other high-risk cargo vessels - Implement comprehensive safety training programs for personnel at ports and onboard vessels
Standardization	- Existing regulations and standards for shore power equipment - Compatibility with international standards - Offshore charging standards are not available	- Inconsistent implementation across ports - Lack of harmonization with international regulations - ISO/IEEE 80005 does not cover offshore charging	- Reduced efficiency and interoperability - Increased integration challenges	- Advocate for wider adoption of existing international standards - Develop regional or national standards based on best practices - Extend existing standards or develop new ones for power bunkering and offshore charging applications
Monitoring & Control	- Data collection and monitoring systems for shore power usage - Remote control and management capabilities	- Limited data on power usage patterns and inefficiencies - Difficulty in optimizing power delivery and billing	- Reduced transparency and accountability - Inefficient resource utilization	- Implement smart metering systems for real-time data collection - Develop remote control systems for optimizing power delivery and billing
Environmental Impact	- Emission reduction achieved through shore power compared to on-board generators	- Focus on air quality improvements	- Limited life-cycle assessment of shore power infrastructure - Potential environmental concerns related to cable production and disposal	- Incomplete understanding of overall environmental benefits - Risk of unintended environmental consequences

With the feedback provided, a system thinking model was generated (Figure 5.3-1).

5.4 – User Requirements Elicitation

The user requirements elicitation is to identify and understand the needs and expectations of all relevant stakeholders and ensure that the final BlueBARGE solution meets the functional and non-functional requirements of its users. The following can be users of the BlueBARGE project and their requirements, as already identified in detail in sub-section 3.1 in the stakeholder analysis, as well as through the various personas described in sub-section 3.3.

5.4.1 - Industry

Port authorities:

- power capacity: high energy output to supply power to multiple docked ships simultaneously.
- connection interface: compatibility with different types of ships' electrical systems.
- environmental compliance: emissions reductions & adherence to port environmental standards.
- mobility: ability to reposition the barge to serve different areas within the port.

Operator of BlueBARGE:

- reliability: consistent and uninterrupted power supply for critical ship systems.
- remote monitoring: real-time monitoring and control of the energy supply from the ship.
- scalability: ability to scale power supply based on the size and requirements of different vessels.
- energy storage options: flexibility to use various battery types, including those that can be swapped or recharged efficiently.

Shipping companies

- durability: robust design to withstand conditions, e.g. including saltwater corrosion and storms.
- autonomy: long autonomous operation periods without the need for frequent maintenance.
- safety standards: compliance with offshore safety regulations, including fire and explosion prevention.

5.4.2 - Emergency response and disaster relief

- Rapid deployment: quick and easy deployment to disaster-stricken areas.
- multi-utility support: ability to power a variety of essential services like medical facilities, communication centers, and water purification systems.
- resilience: operability under extreme conditions, including when operating close to natural disasters.
- scalability: configurable energy output to meet varying demands in different emergency scenarios.
- cross-sector utility: versatility to serve various needs, from powering shelters to supporting field hospitals.
- off-grid operation: ability to function independently of existing power grids.
- energy security: secure energy supply with backup options in case of primary battery failure.

5.4.3 - Renewable energy sector

- Integration with renewables: can charge from renewable energy sources like solar and wind.
- Grid connectivity: ability to feed excess energy back into the grid or serve as a grid-balancing solution.

- Grid stabilization: ability to provide energy during peak demand or supply gaps.
- Load balancing: dynamic load balancing capabilities to manage fluctuations in energy demand.
- Backup power: instantaneous backup power provision during outages.

5.4.4 - Tourism and leisure

Cruise Operators:

- passenger comfort: silent and emission-free power supply to enhance passenger experience while docked.
- flexible capacity: adjustable power supply based on the cruise ship's varying energy needs.
- environmental compliance: compliance with environmental regulations to reduce the carbon footprint of cruise operations.
- brand enhancement: aesthetic design and branding opportunities to align with luxury or eco-friendly market positioning.

5.5 – Preliminary Technical, Operational and Safety Requirements

The BlueBARGE solution refers to an integrated energy system including the power barge and the shore microgrid, which will provide flexibility, resilience, and sustainability of the power supply. The success of these objectives depends on the identification and fulfillment of technical, operational, and safety requirements. These preliminary requirements are defined to ensure that the solutions function efficiently, adhere to regulatory standards, and operate safely within diverse maritime environments. Hence, this section outlines the key technical specifications, operational procedures, and safety protocols necessary for the development and deployment of BlueBARGE. Adherence to the requirements will ensure that BlueBARGE not only meets the operational demands of modern ports but also meets the highest standards of safety and environmental protection. The listed requirements will be further refined, in accordance with the first steps of the design process, and will be included in a later deliverable, as part of the work conducted under WP2 and specifically T2.2.

5.5.1 - Technical requirements

The technical requirements are primarily centered around the electrical infrastructure, power management systems, and integration with port/shore and onboard/vessel systems.

- **Power Generation and Storage:**
  - **Power Capacity:** the BlueBARGE solution must provide sufficient power to meet the demands of anchored vessels, typically having load demand between 1 MW and 10 MW, depending on vessel sizes and types.
  - **Fuel Flexibility:** should support multiple fuel types, including hydrogen, and biofuels, to ensure adaptability and compliance with future decarbonization goals.
  - **Energy Storage Systems (ESS):** Integration of high-capacity batteries or other ESS technologies is required to provide energy buffer and ensure continuous power supply, especially in ports with variable renewable energy sources.
  - **ESS Energy Capacity:** the ESS capacity must provide the energy demand of anchored vessels, typically between 3 MWh and minimum 35 MWh, depending on vessel sizes and types. The ESS must be designed to handle these varying demands efficiently, ensuring consistent and reliable power delivery during anchoring.

  - **ESS Energy Density**: The ESS needs to achieve as high a power capacity as possible on the BlueBARGE to ensure that it can provide power for long periods without frequent charging. This means that the energy storage systems used in designated areas on the barge must have a high energy density.
  - **Duration of Power Supply:** BlueBARGE solution should be capable of providing uninterrupted power for extended periods (e.g., up to 24 hours or more), ensuring reliability during peak operational times or in remote locations with weak grid access.
  - **Energy Efficiency:** the system must incorporate high-efficiency power converters and management systems to minimize energy losses during transmission.
- Electrical and Control Systems:
  - **Grid Connectivity:** BlueBARGE must interface seamlessly with existing port electrical grids, necessitating advanced grid connection systems, including transformers, switchgear, and control systems for load balancing.
  - **Automation and Monitoring:** Implementation of a robust control system with real-time monitoring capabilities to manage power distribution, fault detection, and system diagnostics is essential. The control system should also enable remote operations and monitoring.
  - **Emission and Environmental Control Systems:** The barge should include environmental control systems to manage emissions, noise, and other environmental impacts, ensuring compliance with local and international environmental regulations.
- Design and Engineering:
  - **Modular Design:** The barge should feature a modular design to allow for easy scalability and adaptability to different port configurations and vessel types.
  - **Scalability:** The system should allow for the expansion of the barge solutions to accommodate varying and increasing demands from different vessels and port operations. This includes the ability to add additional battery modules or other storage technologies and power generation units based on demand.
  - **Durability and Corrosion Resistance:** Given the harsh maritime environment, all components must be designed with materials that resist corrosion and withstand extreme weather conditions.

5.5.2 - Operational and Management Requirements

Operational requirements focus on the practical aspects of deploying and managing BlueBARGE in port environments. These operational requirements are designed to ensure that the BlueBARGE system can deliver reliable, efficient, and safe power to vessels, seamlessly integrating with existing port infrastructure while maintaining operational flexibility and resilience.

- Power Management and Integration:
  - **Seamless Power Transfer:** The BlueBARGE system must facilitate smooth and uninterrupted power transfer between the barge and the vessel. This includes ensuring that the power demand of the vessel is met without fluctuation during the switchover from onshore-based power to barge-supplied energy. Synchronization protocols are to be in place to prevent disruptions in the vessel's operations during connection or disconnection from the barge.
  - **Dynamic Load Balancing:** The power management system must dynamically balance the load between the barge and the vessel, adapting to real-time energy demands. This requires intelligent energy distribution mechanisms to prioritize critical systems on the vessel while optimizing overall energy efficiency.

- Port Power Integration: The BlueBARGE must integrate seamlessly with the port's existing power infrastructure. It should be capable of either supplementing the port's power supply during high-demand periods (grid-connected) or operating in islanded mode when the port's power grid is unavailable. This includes the capability to safely switch between grid-connected and off-grid modes.
- Energy Management and Optimization: an Energy Management System (EMS) will be useful to optimize the charging and discharging cycles of the ESS units and optimize the power flow in the entire energy system, based on real-time demand and supply conditions. This ensures that the barge has sufficient energy reserves to meet vessel requirements while maximizing efficiency and prolonging battery life.

- Communication and Coordination:
  - Automated Control and Monitoring: The BlueBARGE system must feature an automated control and monitoring system. This system should manage the power flow between the vessel, barge, and port infrastructure, with capabilities for remote monitoring and control. It should also generate real-time reports and alerts for any fault situation in the power system.
  - Real-Time Communication: Secure and efficient communication channels must be established between all power system units to ensure coordinated operations and prompt response to any operational challenges.
- Resilience:
  - Redundancy and Backup Systems: To ensure operational reliability, the BlueBARGE system should include redundant power management components. In case of a system failure, backup systems must automatically maintain continuous power supply to the vessel, preventing operational downtimes.
  - Safety Protocols: Robust safety protocols must be established for power transfer operations. This includes voltage and frequency synchronization, grounding procedures, and emergency shutdown mechanisms. The system should also have safeguards to prevent electrical faults, short circuits, or other hazards during power transfer operations.
  - Scalability and Flexibility in Operation: The BlueBARGE system should be scalable and flexible to accommodate different types of vessels and varying energy demands. This includes the ability to service multiple vessels simultaneously if required, and to adjust power output based on the size and type of vessel connected.
- Sustainability Integration:
  - Renewable Energy Integration: The system should prioritize the integration of renewable energy sources, such as solar or wind, to reduce reliance on fossil fuels and enhance the overall sustainability of port operations.
  - Environmental Impact Monitoring: The BlueBARGE must include systems for monitoring and reporting environmental impacts in real-time, allowing for adjustments to operations to minimize emissions and other environmental footprints.
- Operational Procedures:
  - Communication and Coordination: Effective communication channels must be established between the vessel's crew, the barge operators, and port authorities. This ensures coordinated operations, particularly during connection or disconnection of power. Real-time data exchange and decision-making support must be facilitated through secure communication systems to address any operational challenges promptly.

- **Mooring and Maneuvering:** The barge must be equipped with an advanced mooring system and tugboat support to ensure safe and efficient positioning alongside vessels, considering varying water levels and tidal conditions.
- **Connection to Vessels:** Standardized power connections (such as IEC/ISO standardized plugs and cables) must be established to ensure compatibility with different types of vessels. Quick-connect systems to minimize downtime are also recommended.
- **Load Management:** Procedures for load management, including prioritizing power distribution during peak times and ensuring stable power delivery without interruptions, shall be defined.

- Maintenance and Servicing:
  - **Routine Maintenance:** A comprehensive maintenance schedule for all systems, including power generation units, storage systems, and electrical components, is necessary to ensure operational reliability.
  - **Emergency Response:** Protocols for emergency situations, such as system failures or environmental hazards, should be established, including on-site technical support and remote troubleshooting capabilities.
- Training and Staffing:
  - **Crew Training:** Training programs for crew members handling BlueBARGE operations must cover all aspects, including safety procedures, technical operation, and emergency response. Certification programs should be considered to ensure competency.
  - **Operational Staffing:** A clear staffing plan detailing the number of operators, technicians, and support staff required for the barge's operation must be developed, including considerations for workload management.

5.5.3 - Safety Requirements

Safety requirements are utmost to protect personnel, vessels, and the environment during BlueBARGE operations.

- Regulatory Compliance:
  - **Maritime Safety Regulations:** The BlueBARGE must comply with all relevant maritime safety regulations, including SOLAS (Safety of Life at Sea), MARPOL (Marine Pollution), and local port authority regulations.
  - **Fire Safety and Prevention:** The barge must be equipped with fire detection and suppression systems, including automatic fire extinguishers, smoke detectors, and fireproof materials in high-risk areas.
- Environmental Protection:
  - **Spill Containment:** Systems for the containment and management of any fuel spills or hazardous material leaks must be in place, including absorbent materials, containment booms, and emergency shutdown procedures.
  - **Emission Control:** BlueBARGE must be equipped with emission control technologies to minimize air pollution and ensure zero discharge of pollutants into the water.
- Risk Management:
  - **Risk Assessment and Mitigation:** A comprehensive risk assessment must be conducted to identify potential hazards, including operational risks, environmental risks, and safety risks. Mitigation strategies should be developed and implemented based on these assessments.

- **Incident Reporting and Response**: A clear protocol for reporting and responding to incidents, including near-misses and accidents, must be established. This includes communication channels, incident documentation, and post-incident analysis.
- **Robust Structural Integrity:** The barge's structural design must meet maritime safety standards, ensuring resilience against extreme weather conditions, collisions, and other potential hazards.
- **Emergency Preparedness**: The BlueBARGE must be equipped with comprehensive emergency response systems, including fire suppression, spill containment, and emergency shutdown procedures, to ensure safety during operations.
- **Training and Certification:** Personnel operating the BlueBARGE must be thoroughly trained and certified in both the technical and safety aspects of the barge's operations, ensuring safe and efficient use of the system.

5.5.4 - Integration with Operations

The BlueBARGE system must be fully integrated with port operations to ensure seamless service delivery in cooperation with port and the port grid.

- **Coordination with Port Authorities:** Regular communication and coordination with port authorities are needed to align BlueBARGE operations with port schedules, traffic management, and security protocols.
- **Vessel Scheduling and Power Allocation:** The barge's operations must be synchronized with vessel arrival and departure schedules to optimize power delivery and minimize waiting times.
- **Port Infrastructure Compatibility:** BlueBARGE must be designed to work with existing port infrastructure, including docks, berths, and electrical systems, to avoid costly modifications or disruptions to port operations.

5.5.5 – Requirements Engineering

Requirements engineering is the field that mediates between the acquirer and the supplier or developer to establish and maintain the requirements to be met by a system, software or service of interest (ISO/IEC/IEEE, 2018). It comprises of several activities, i.e. discovering, eliciting, developing, analyzing, verifying, validating, communicating, documenting and managing requirements. The stakeholder needs and requires definition is a core process of (ISO/IEC/IEEE, 2015). One of the first activities of that particular process is the identification of the stakeholders, i.e. the individuals who have a legitimate interest in the system. They can be the users, operators, developers, manufacturers, suppliers, trainers, maintainers, regulatory bodies, and others who will have any form of interaction with the system throughout its life cycle. Having identified the stakeholders, the stakeholder needs an elicitation strategy to be drawn. The strategy includes the approaches, methods, and resources to be utilized to capture the stakeholder needs and transform them into stakeholder requirements. Based on the elicitation strategy, the stakeholder needs and expectations are identified. The stakeholder needs can be elicited directly from the stakeholder by implementing appropriate techniques. They can also be determined indirectly by studying and understanding the relevant domain, and by identifying gaps from previous studies (ISO/IEC/IEEE, 2015). The collected stakeholder needs are then transformed into stakeholder requirements. The stakeholder requirements, along with any relevant constraints, are the input for the system requirements definition process, which transforms the user-desired capabilities into a technical solution that meets their operational needs (ISO/IEC/IEEE, 2015). They also serve as the basis of the validation criteria for the system. Furthermore, ISO/IEC/IEEE indicates that it is typical to have one or more formally scheduled points in the requirements engineering process where the requirements are validated. The validation's purpose is to feed back the stakeholder requirements back to them to validate that their needs and expectations have been adequately captured and reflected in the requirements (ISO/IEC/IEEE, 2015). The validation activities should verify that the requirements are complete, consistent and fit for purpose. Namely, that they define the right system, i.e. the system that the stakeholder expects. The objective is to timely identify any failures, misconceptions, or areas of improvement regarding the elicited requirements before resources are devoted to producing a system solution for the elicited requirements.

In this respect, based on the sub-sections 5.6.1 – 5.6.4 the formal process of requirements engineering has been initiated, by referring to and involving a number of stakeholders, either from within the project, or from outside of the project, in order to accumulate possible requirements. These have been further refined and were formally documented in a specific template, as adapted from relevant works (Table 5.5-1). These are provided in Appendix III in detail.

Table 5.5-1: Requirements template

<table>
<tr><th>ID: Unique identification number</th><th>Type: Functional/ Non-functional</th><th colspan="2">Priority: MUST/ MUST NOT/ SHOULD / SHOULD NOT/ COULD</th></tr>
<tr><td colspan="4">Title:</td></tr>
<tr><td colspan="4">Description: A short statement describing the requirement.</td></tr>
<tr><td colspan="4">Rationale: A short description that justifies the necessity of the requirement and the goals achieved from its implementation.</td></tr>
<tr><td colspan="4">Stakeholders/Users: One (or more) in the following list:
Bunkering services, Ports/Port Authorities, Port/Port Operators, Ship Owners, Ship Operators/Crew, Tugboat Owners, Tugboat Operators/Crew, Traffic management services, Regulatory/Standardisation Bodies, Public Authorities, Classification Societies, Shipyards and Designers, Power Systems Manufacturers, Automation and Control Systems Manufacturers, Energy Providers, Financiers and Investors, The Public/Citizen Organisations (the identified stakeholder groups)</td></tr>
<tr><td colspan="2">Category: One (or more) in the following list:
Integration, performance, deployment, interoperability, usability, etc.</td><td colspan="2">BlueBARGE Component: List of individual (or all) components that are directly or indirectly affected by the requirement.</td></tr>
<tr><td colspan="2">Dependencies: List of requirements that directly or indirectly depend on the subject of analysis.</td><td colspan="2">Conflicts: List of blocking requirements that may be affected by the accomplishment of the current one.</td></tr>
</table>

The provided listing of formally documented requirements, per the requirements engineering approach described above will be further refined, within the context of T2.2, and will be included in later deliverables, along with the first system design specifications.

6 – Conclusions and Next Steps

This deliverable focused on the use cases, technical specifications and the requirements for power barge applications. It is the first part of WP2, while subsequent tasks under this WP will elaborate on further detailed analysis, focusing mainly on the refinement of requirements and the detailed definition of the Concept of Operations, considering the information in this document, as well as the further elaboration on requirements and operation aspects.

Potential applications and uses cases have been identified along with the survey results which indicated the feasibility of power barge applications, provided that the potential capacity barriers can be resolved with the use of hybrid battery solutions or alternative fuels. This proposition is further confirmed by the ongoing projects, for which the details are shared. The results also highlight significant potential for ships at anchorage or moored, or for environmentally protected areas and delivering power to land after natural disasters.

An estimate of power requirements for ship types and the consumed power at various ports has been gathered from available data, through a methodology that adopts the assumptions of IMO, EMSA and available literature regarding loading factors. The results are very promising as they are showing that the current targets for the BlueBARGE system, namely the 3 MW power output and the 35 MWh energy capacity, can cover the industry needs at an extend over 90% - 95%, especially for the vessels highlighted in the project's Grant Agreement, namely Cruise ships, Ro-Pax and Container ships.

Finally, a detailed review of applicable standards has been shared, with relationships established in connection to the concept of operations, that will be presented in later deliverable, with respect to the early design aspects. Preliminary requirements are well-identified and can provide an important basis for designing the system at this point.

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Appendix I – Survey for the BlueBARGE UCs

The BlueBARGE project (https://BlueBARGE.eu/) focuses on designing, developing and demonstrating an optimum power-barge solution to enable offshore power supply, either considering vessels in multiple occasions, or other applications and use cases. This allows limiting local polluting emissions and global GHG footprint in a life cycle perspective. The project follows a modular, scalable, adaptable and flexible design approach which will facilitate the commercialization of the BlueBARGE solution by 2030.

In these first stages of the project and the BlueBARGE design and development, it is crucial to strongly involve industry stakeholders, to drive the process with their early input regarding the concept, the possible use of the system and the challenges ahead. Thus, this survey's goals focus on the following aspects:

- Assess the BlueBARGE concept and provide their feedback and views
- Verify and assess the identified use cases and the possible impact of BlueBARGE
- Identify additional use cases for the BlueBARGE
- Provide real-life examples/scenarios with respect to the use cases
- Identify early business enablers, business models and value propositions

Questionnaire

The survey questionnaire is structured in three sections. The first section includes demographic questions, that will allow the identification of organisational details and their relevance to the BlueBARGE project for participants. The second section refers to the BlueBARGE concept and its scope. Finally, the third section focuses on the BlueBARGE use cases, as a whole, and individually. For the latter, the goal is to verify and assess them in terms of importance, as well as identifying additional use cases and real-life scenarios/examples to support them. The survey takes 10 to 15 minutes.

Demographics

Q1.01 – Are you a member of the BlueBARGE consortium? *[single choice]*

- Yes
- No

Q1.02 – In which stakeholder group do you belong? *[single choice]*

- Bunkering services
- Ports/Port Authorities
- Port/Terminal Operators
- Ship Owners
- Ship Operators/Crew
- Tugboat Owners
- Tugboat Operators/Crew
- Regulatory/Standardisation Bodies
- Public Authorities
- Classification Societies

- Shipyards and Designers
- Power Systems Manufacturers
- Automation and Control Systems Manufacturers
- Energy Providers
- Research Institutes and Academia
- Financiers and Investors
- The Public/Citizen Organisations
- Other *[free text]*

Q1.03 – What is your role within your organisation? *[multiple choise]*

- Executive (CEO, C-Level)
- Senior Management (Director)
- Middle Management (Manager, Supervisor)
- Team Leader/Coordinator
- Professional Contributor (Engineer, Analyst, Specialist)
- Administrative Support
- Sales/Customer Service Representative
- Human Resources
- IT/Technical Support
- Marketing/Communications
- Finance/Accounting
- Operations/Logistics
- Research and Development
- Legal/Compliance
- Intern/Tranee
- Other *[please specify]*

BlueBARGE concept

The BlueBARGE system will consider different alternatives as containerized power supply modules in a variety of configurations, where battery modules will serve as basis due to their high energy efficiency and readiness level. The project will address electrical integration issues, interfacing challenges of the barge with ships, ports and local grid, operational safety and regulatory compliance aspects, delivering a high-readiness and complete “power bunkering” solution. The BlueBARGE concept is summarized in Figure 1.

Figure App.1-1: BlueBARGE concept

For the BlueBARGE design, battery systems, fuel cells, and on-board generators powered by alternative fuels will be explored, to achieve an optimum selection of power supply modules, in the right configuration, appropriate integration and interfacing connections towards shore and ships. Design focuses on the non-self-propelled barge option but will also examine the self-propelled barge option, to cover the entire design spectrum. In addition, for the interfaces, namely the shore-to-barge and barge-to-ship connections, the design of the Cable Management System (CMS) will consider mainly manual but also semi-automated solutions, while fully automated solutions are of low readiness, thus presenting with a lot of challenges.

Q2.01 – Do you think that the BlueBARGE concept for offshore power supply can be a promising electrification solution, leading to emission reduction, complementing shore side electricity where needed? *[single choice]*

- Strongly agree
- Agree
- Not sure
- Disagree
- Strongly Disagree

Q2.02 – Which do you think are the most prominent difficulties for the implementation of the BlueBARGE concept? *[multiple choice]*

- Reach the rated power demand.
- Reach the energy capacity demand.
- Electrical integration.
- Novelty of power supply modules.
- Technical safety aspects.

- Operational safety aspects.
- Lack of standardization and regulatory framework.
- Stakeholder resistance.
- Increased cost.
- Other *[free text]*

Q2.03 What could be the most promising solutions as power supply modules for the BlueBARGE concept, if we consider 2030 as the year to be available in the market ? *[multiple choice]*

1. Lithium-Ion batteries
2. Vanadium Radox Flow Batteries (VRFB)
3. Other types of batteries *[free text]*
4. Hybrid battery system/Combination of batteries
5. Gen sets running on LNG
6. Gen sets running on methanol
7. Gen sets running on other alternative fuels *[free text]*
8. Fuel cells running on alternative fuels *[free text]*
9. Other hybrid systems/Other combinations

Q2.04 – Do you think that a self-propelled solution is more suitable, or a tugboat supported design should be more suitable to reduce complexity in the design ? *[single choice]*

- Self-propelled design
- Tugboat-supported design
- Not sure

Q2.05 – Please provide any additional comments or explanations regarding your choices above. *[open-ended ; optional]*

Use Cases

In general, the proposed concept will support a number of Use Cases that have been already identified. All Use Cases are summarised below, with a short description and specific examples to enhance comprehension:

- **Anchored vessels (UC1) :** The BlueBARGE will provide power to vessels in anchorage areas in case of increased waiting time due to terminal traffic (e.g., Piraeus anchorage, Rotterdam anchorage), audits or other operations (e.g., cargo operations, waste disposal), to mainly reduce GHG emissions and local pollution, to complement OPS/SSE systems.
- **Moored Vessels (UC2) :** The BlueBARGE will provide power to vessels in smaller, inland or island ports (e.g., Greek islands, TEN-T comprehensive network ports), as well as mooring and berthing dolphins cases, where OPS/SSE is limited or not available.
- **Isolated inhabited areas (UC3) :** The BlueBARGE will provide power to land, to support local grid in case of increased power demand (e.g., in summer months) or lack of energy, such as the case of islands not connected to main land through underwater cables (e.g., Madieras, Greek islands).
- **Environmentally critical areas (UC4) :** The BlueBARGE will provide power to vessels anchored in environmentally critical areas, where there is a requirement for zero-emissions (e.g., UNESCO heritage sites such as fjords in Norway, or Venice).

- **Charging of small transportation vessels (UC5) :** The BlueBARGE will provide power to small transportation vessels (e.g., ferries, crew transport vessels), to support either SSS or IWT routes (e.g., river routes in central Europe) through electrification, as well as other transportation needs.
- **Powering leisure boats along the coast (UC6) :** The BlueBARGE will provide power to leisure boats along the coasts and popular anchorages (e.g., Greek islands, Monaco), either by supporting their electric loads for as long as they stay anchored or charging their batteries.
- **Powering offshore platforms - oil rigs (UC7) :** The BlueBARGE will provide power to offshore platforms for a certain period, as a sustainable power option, mainly for limiting their emissions for compliance reasons, while also limiting emission-related costs.
- **Charging from offshore power plants (UC8) :** The BlueBARGE will work as a power storage solution allowing offshore power plants to limit losses of excess energy produced, and not consumed through the grid; this Use Case is complementary to the ones where BlueBARGE provides power.
- **Providing power to land after natural disasters (UC9) :** BlueBARGE will provide power to land in emergencies, for a certain extent of time. Some examples from recent natural disasters were shared.
- **Charging BlueBARGE from anchored vessels (UC10) :** The BlueBARGE will work as a power storage solution, charging with excess power from ship generators working in an optimal level, limiting loss of excess energy; this Use Case is complementary to the ones where BlueBARGE provides power.

Q3.01 – Can you specify, in your opinion, the significance of the need that BlueBARGE covers? *[single choice for each use case]*

- Very High
- High
- Normal
- Low
- Very Low

Q3.02 – Can you specify, in your opinion, the expected impact for each use case? *[single choice for each use case]*

- Very High
- High
- Normal
- Low
- Very Low

Q3.03 – What would be the priority, in your opinion, from an industry perspective, for each use case? *[single choice for each use case]*

- Very high
- High
- Normal
- Low
- Very low

Q3.04 – Can you think of any real-life scenarios/examples (e.g., specific port or anchorage area, island or inland or smaller port to support moored vessels, isolated inhabited areas that may need support, ECAs that require zero-emission compliance, etc.) where the BlueBARGE could be employed, with respect to any of the use cases ? *[open ended]*

Q3.05 – For the case of increased waiting time at anchorage, in relation to **UC1**, several reasons and examples are mentioned previously; since this is a fact, can you specify, in your experience or opinion, the reasons behind these long waiting hours?

- Terminal unavailability
- Not engaged in charter contract
- Bunkering operations
- Cargo operations
- Audits and surveys
- Detentions/regulatory compliance
- Technical reasons/repairs
- Other *[please specify]*

Q3.05 – From the following identified Use Cases, which ones in your opinion seem realistic and promising for the BlueBARGE solution? *[multiple choice or ranking]*

- Anchored vessels (UC1)
- Moored Vessels (UC2)
- Isolated inhabited areas (UC3)
- Environmentally critical areas (UC4)
- Charging of small transportation vessels (UC5)
- Powering leisure boats along the coast (UC6)
- Powering offshore platforms – Oil rigs (UC7)
- Charging from offshore power plants (UC8)
- Providing power to land after natural disasters (UC9)
- Charging BlueBARGE from anchored vessels (UC10)

Q3.06 – Can you identify additional Use Cases for the BlueBARGE concept? *[open ended]*

Q3.07 – Please provide any comments regarding your previous choices. *[open-ended ; optional]*

Appendix II – Power and Energy Demand

This Appendix is used to complement the analysis in Section 4 regarding power and energy demand. The following tables and figures provide the results of the analysis per port and ship type, based on the assumptions from EMSA and from the load factors assumptions provided by the literature.

Table App.2-1: Power and Energy Demand Results per ship type (EMSA assumptions)

Ship Type	Total Ships Calling	Average Time at Anchorage	Mean Power Demand (EMSA)	Peak Power Demand (EMSA)	Mean Energy Demand (EMSA)
Chemical Tankers	50,996	13.4	7.98	13.68	115.35
Liquified Gas Tankers	9,327	17.24	7.75	10.75	136.29
Cruise	1,378	7.63	7.07	8.35	64.23
Oil Tankers	49,476	14.37	5.45	7.45	84.37
Ro-Ro	4,220	9.77	4.89	6.4	48.19
Container	23,231	14.07	2.45	4.59	33.1
Ro-Pax	2,744	6.86	2.19	2.91	17.42
General Cargo	47,972	16.33	1.51	3	24.58
Refrigerated Cargo	728	12.19	1.5	2	18.28
Dredging Vessels	1,433	7.52	1.35	2.02	10.29
Offshore Support Vessels	17,448	4.86	1.03	1.54	5.2
Bulk Carriers	35,694	16.63	0.61	0.86	10.14
Fishing	7,160	5.98	0.52	0.74	3.17

Table App.2-2: Power and Energy Demand Results per ship type (Load Factors assumptions)

Ship Type	Total Ships Calling	Average Time at Anchorage	Mean Power Demand (LF)	Peak Power Demand (LF)	Mean Energy Demand (LF)
Cruise	1,378	7.63	7.71	37.12	77.54
Liquified Gas Tankers	9,327	17.24	2.69	30.55	46.29
Other Liquid Tankers	2,517	11.06	2.24	3.82	28.34
Refrigerated Cargo	728	12.19	1.36	3	14.2
Chemical Tankers	50,996	13.4	1.35	10.97	20.79
Oil Tankers	49,476	14.37	1.31	20.1	22.78
Container	23,231	14.07	1.2	5.2	15.39
Ro-Pax	2,744	6.86	1.1	25.19	9.89
Ro-Ro	4,220	9.77	1.05	2.97	9.08
Bulk Carriers	35,694	16.63	0.42	1.58	6.78
Fishing	7,160	5.98	0.38	1.3	2.12
Dredging Vessels	1,433	7.52	0.33	4.75	2.7
General Cargo	47,972	16.33	0.17	1.53	2.69

Table App.2-3 Power and Energy Demand Results per port (EMSA assumptions)

Ports	Total Ships Calling	Average Time at Anchorage	Mean Power Demand (EMSA)	Peak Power Demand (EMSA)	Mean Energy Demand (EMSA)
Marseille	2,459	25.78	5.96	9.24	173.41
Rotterdam	14,847	22.56	5.45	8.91	135.23
Sines	1,403	17.28	5.1	8.25	109.65
Antwerp	37,625	4.38	4.89	7.92	25.64
Tallinn	1,576	10.17	4.7	7.26	54.15
Marsaxlokk	13,289	14.32	4.6	7.15	77.75
Port Said	12,989	14.12	4.45	6.61	64.28
Gothenburg	7,945	10.78	4.44	6.97	57.49
Ceuta	1,720	11.09	4.44	6.74	53.82
Barcelona	2,129	16.83	4.4	7.19	92.5
Trieste	931	20.03	4.35	6.32	94.76
Thira	2,133	10.67	4.29	5.39	47.24
Hamburg	2,598	22.59	4.27	6.7	104.59
Piraeus	8,484	15.02	4.22	6.72	66.7
Le Havre	6,197	17.4	4.14	6.65	87.92
London	2,730	17.97	3.98	6.67	86.53
Gibraltar	14,924	9.6	3.98	6.01	41.39
Algeciras	14,025	11.14	3.96	6.05	50.97
Venice	1,160	22.41	3.93	6.68	95.91
Genoa	2,250	11.82	3.78	6.15	51.96
Las Palmas	5,405	11.25	3.52	5.41	41.17
Klaipeda	585	20.43	3.31	5.69	73.45
Valletta	2,927	6.72	3.24	5	25.29
Kiel	632	16.32	3.17	5.33	56.03
Gdansk	2,808	18.97	3.03	4.73	61.09
Valencia	2,047	11.96	2.99	5.17	39.28
Ibiza	61	11.02	2.94	4.82	32.39
Copenhagen	317	15.19	2.88	4.91	44.84
Bremerhaven	1,610	1.33	2.72	3.97	3.16
Istanbul	72,630	17.32	2.67	4.42	47.14
Koper	1,134	19.49	2.64	4.68	58.51
Bilbao	2,474	10.08	2.6	4.27	40.11
Lisbon	1,462	11.51	2.53	4.1	31.19
Limassol	782	14.39	2.35	3.76	36.61
Constantza	5,777	19.96	2.31	3.79	49.03
Felixstowe	309	20.62	2.06	3.62	41.32
Wilhelmshaven	1,950	3.92	1.23	1.86	4.75

Table App.2-3 Power and Energy Demand Results per port (EMSA assumptions

Ports	Total Ships Calling	Average Time at Anchorage	Mean Power Demand (LF)	Peak Power Demand (LF)	Mean Energy Demand (LF)
Thira	2,133	10.67	5.55	37.12	58.86
Sines	1,403	17.28	1.79	20.1	32.47
Hamburg	2,598	22.59	1.62	13.4	39.33
Port Said	12,989	14.12	1.58	30.55	22.58
Tallinn	1,576	10.17	1.38	10.29	16.95
Trieste	931	20.03	1.36	5.2	31.29
Genoa	2,250	11.82	1.34	37.12	18.06
Rotterdam	14,847	22.56	1.34	30.55	33.5
Valencia	2,047	11.96	1.32	4.7	12.34
London	2,730	17.97	1.32	30.55	30.14
Ceuta	1,720	11.09	1.28	30.55	15.62
Marseille	2,459	25.78	1.22	30.55	33.87
Marsaxlokk	13,289	14.32	1.22	37.12	20.89
Piraeus	8,484	15.02	1.21	27.65	18.87
Barcelona	2,129	16.83	1.19	10.29	20.12
Bilbao	2,474	10.08	1.18	11.36	19.82
Le Havre	6,197	17.4	1.15	13.4	26.29
Gibraltar	14,924	9.6	1.13	30.55	12.18
Valletta	2,927	6.72	1.1	37.12	8.12
Algeciras	14,025	11.14	1.02	30.55	14.64
Antwerp	37,625	4.38	1.01	16.08	6.72
Venice	1,160	22.41	1.01	3.98	24.12
Las Palmas	5,405	11.25	0.98	20.1	13.3
Gdansk	2,808	18.97	0.9	15.08	17.95
Gothenburg	7,945	10.78	0.84	13.4	13.05
Ibiza	61	11.02	0.82	4.12	10.4
Koper	1,134	19.49	0.81	5.2	18.76
Klaipeda	585	20.43	0.71	10.29	15.43
Istanbul	72,630	17.32	0.65	13.13	11.69
Lisbon	1,462	11.51	0.64	16.08	8.1
Constantza	5,777	19.96	0.61	7.93	12.41
Limassol	782	14.39	0.58	9.76	8.07
Kiel	632	16.32	0.58	8.04	9.64
Bremerhaven	1,610	1.33	0.38	3.84	0.42
Copenhagen	317	15.19	0.37	2.65	6.39
Felixstowe	309	20.62	0.25	2.08	4.36
Wilhelmshaven	1,950	3.92	0.16	1.85	0.8

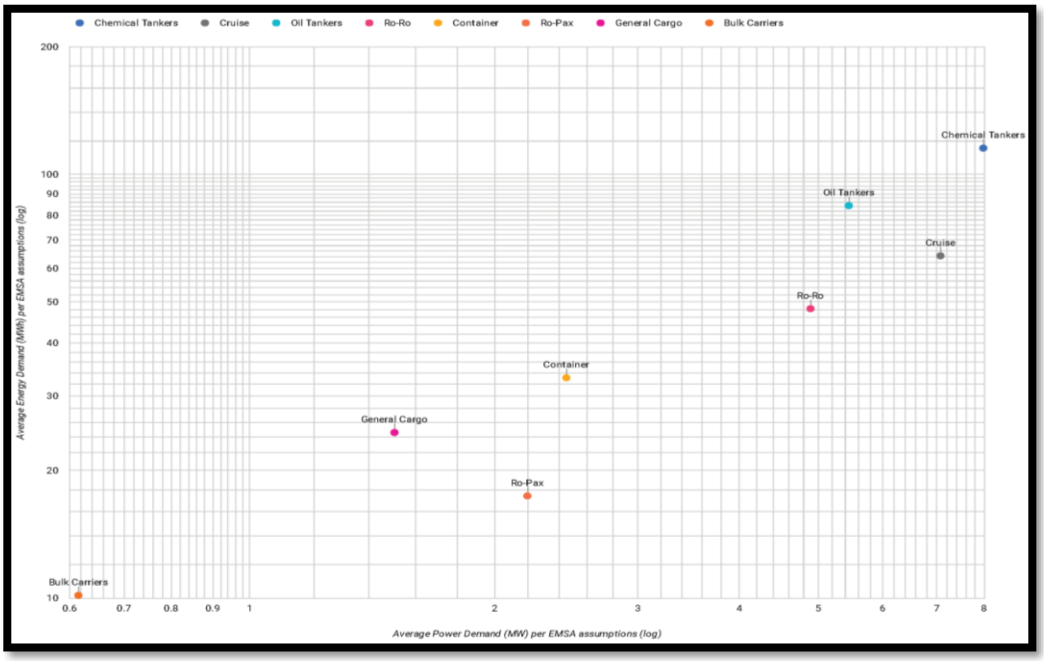

Figure App.2-1: Power and Energy demand plot per ship type (EMSA assumptions)

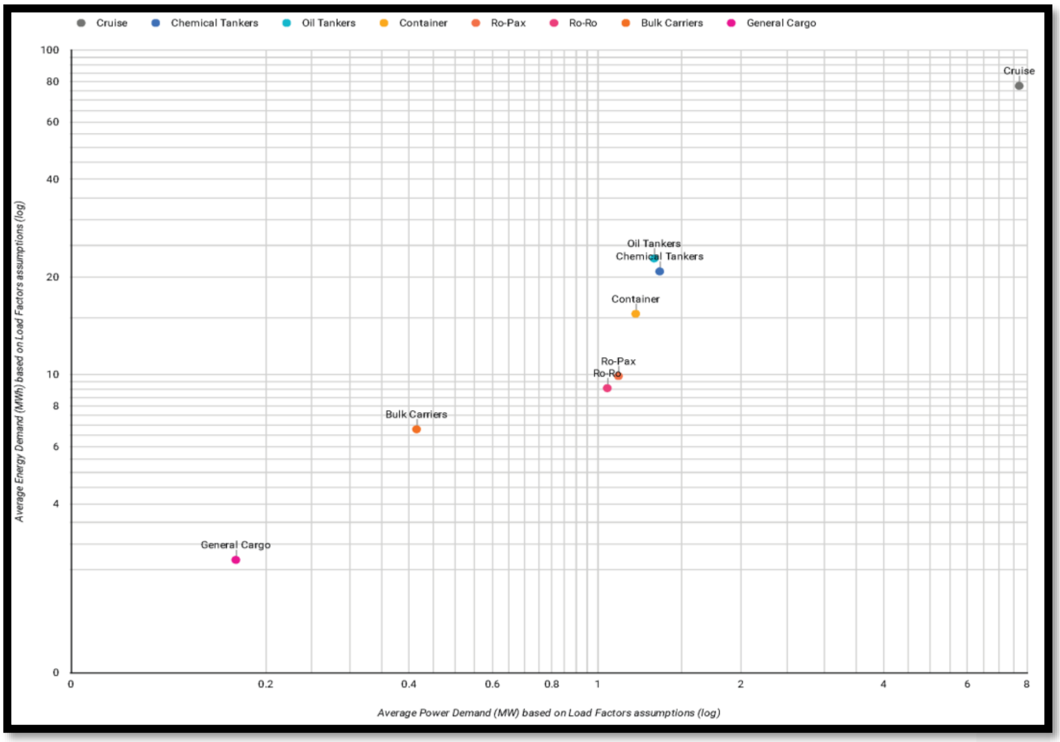

Figure App.2-2: Power and Energy demand plot per ship type (Load Factors assumptions).

Following the above, the figures below focus on the analysis regarding the IMO assumptions, as more realistic. The figures refer to the rest selected ports and ship types for a more complete picture over the power and energy demands – apart from those presented in Section 4.

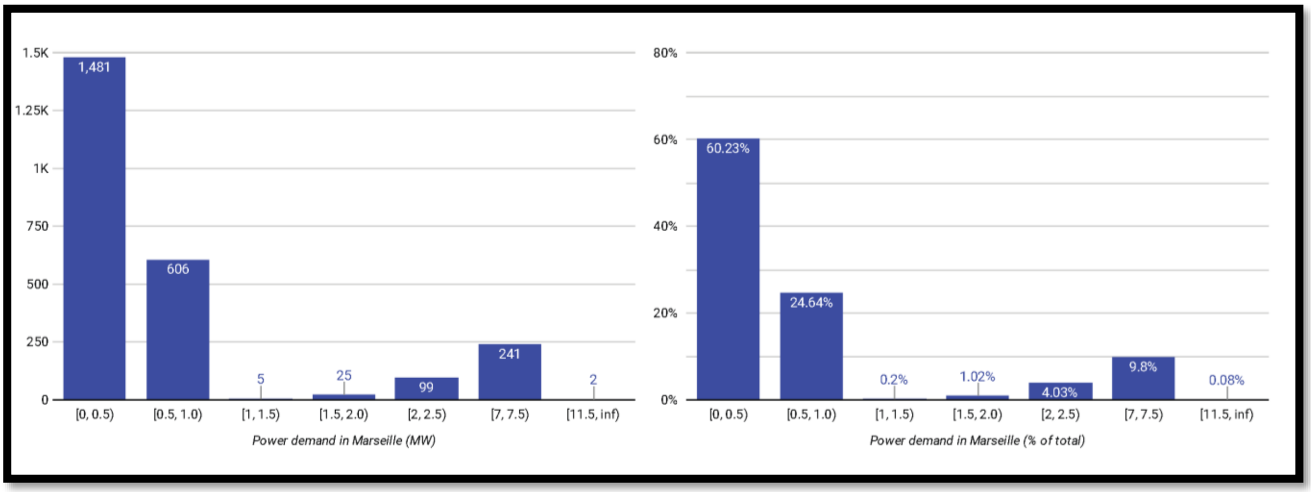

Figure App.2-3: Power Demand in Marseille (in MW and % of total anchorage calls).

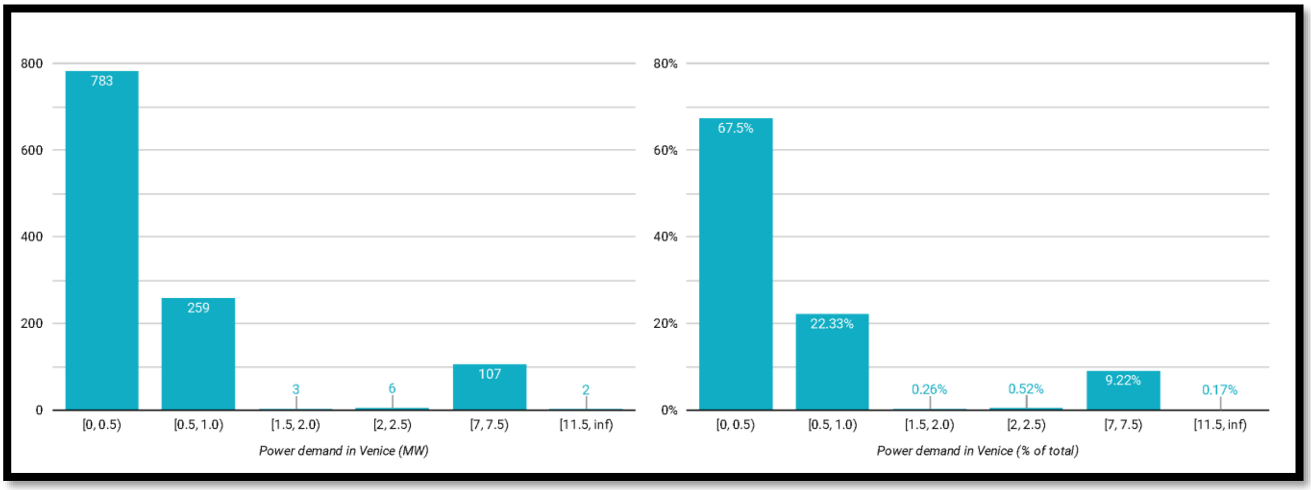

Figure App.2-4: Power Demand in Venice (in MW and % of total anchorage calls).

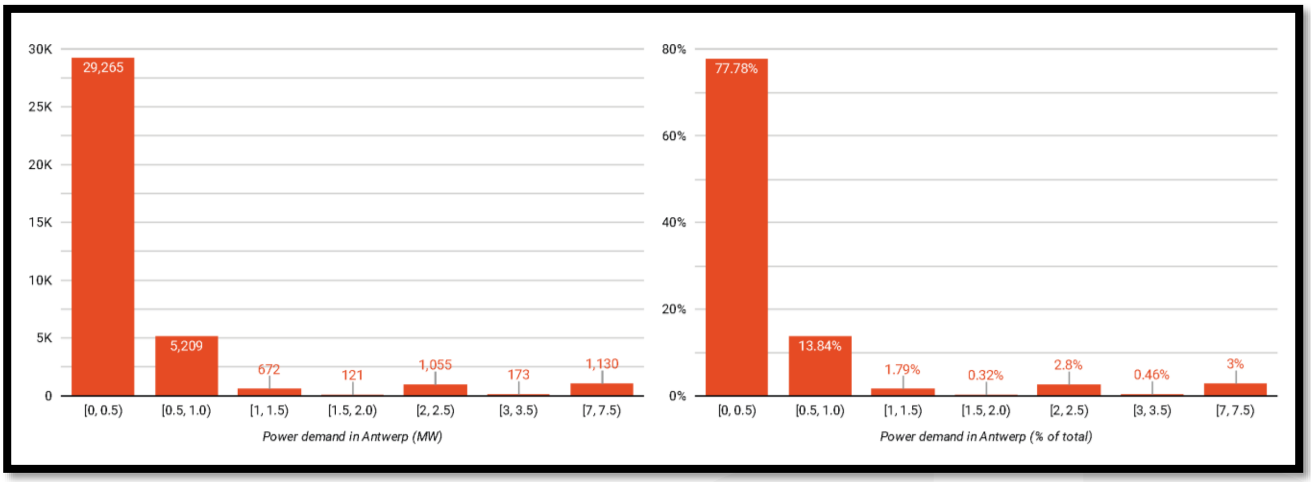

Figure App.2-5: Power Demand in Antwerp (in MW and % of total anchorage calls).

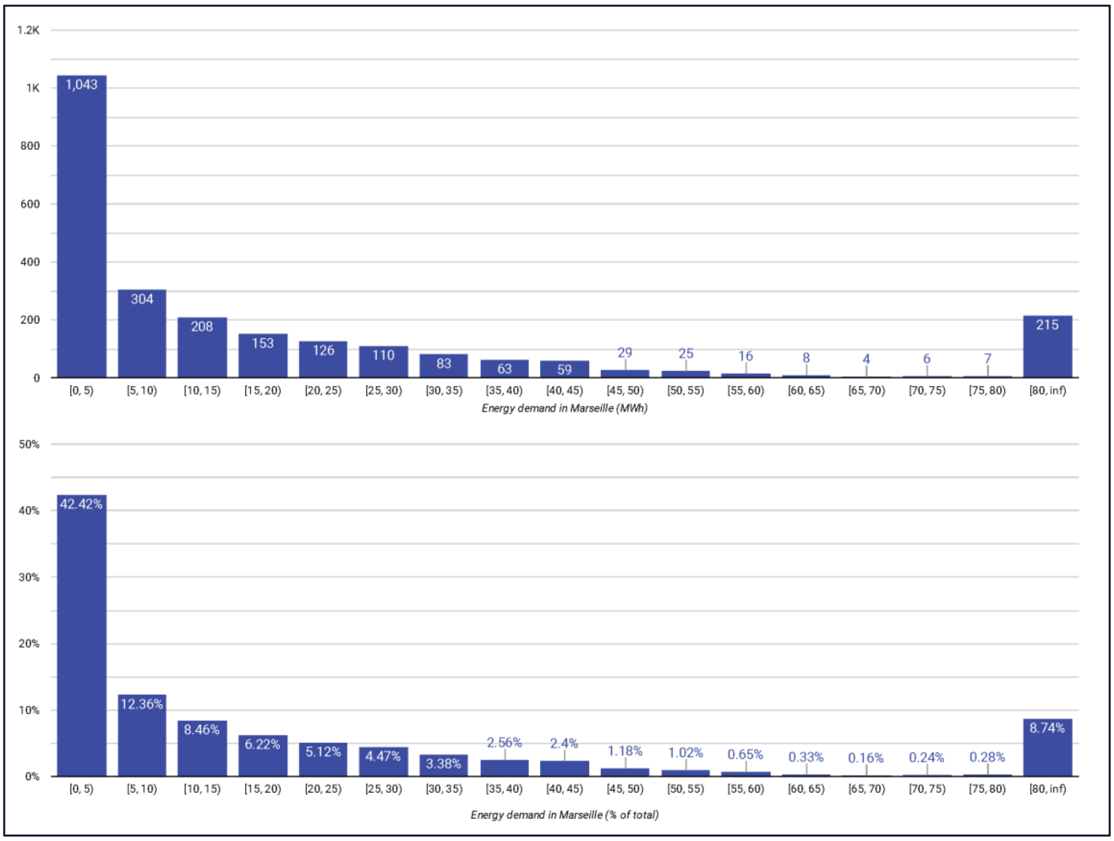

Figure App.2-6: Energy Demand in Marseille (in MWh and % of total anchorage calls).

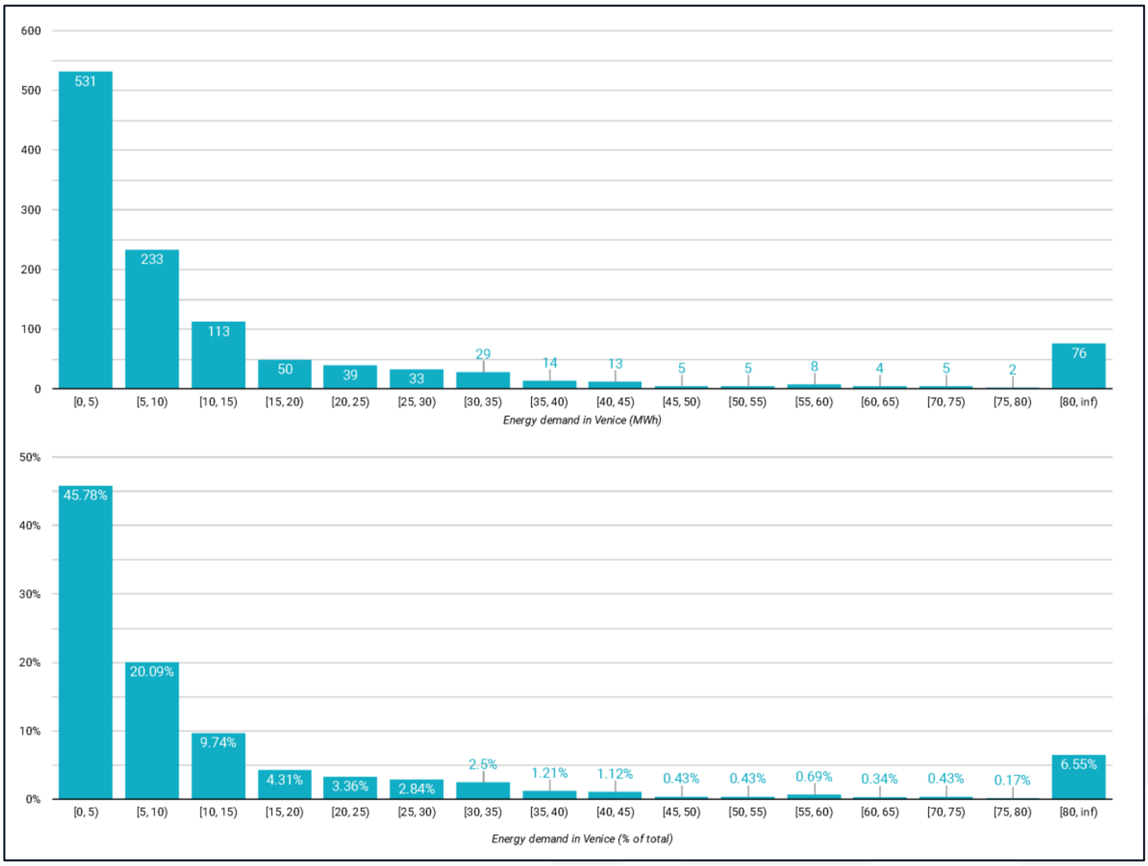

Figure App.2-7: Energy Demand in Venice (in MWh and % of total anchorage calls).

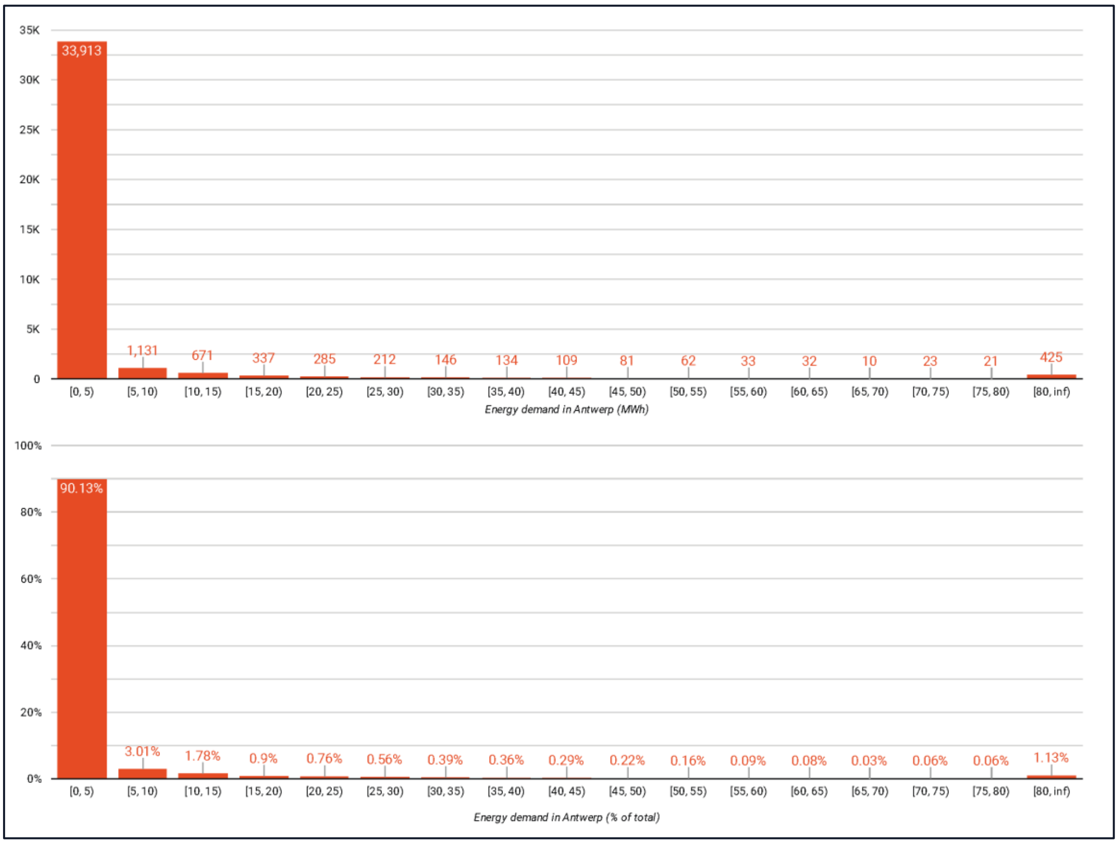

Figure App.2-8: Energy Demand in Antwerp (in MWh and % of total anchorage calls).

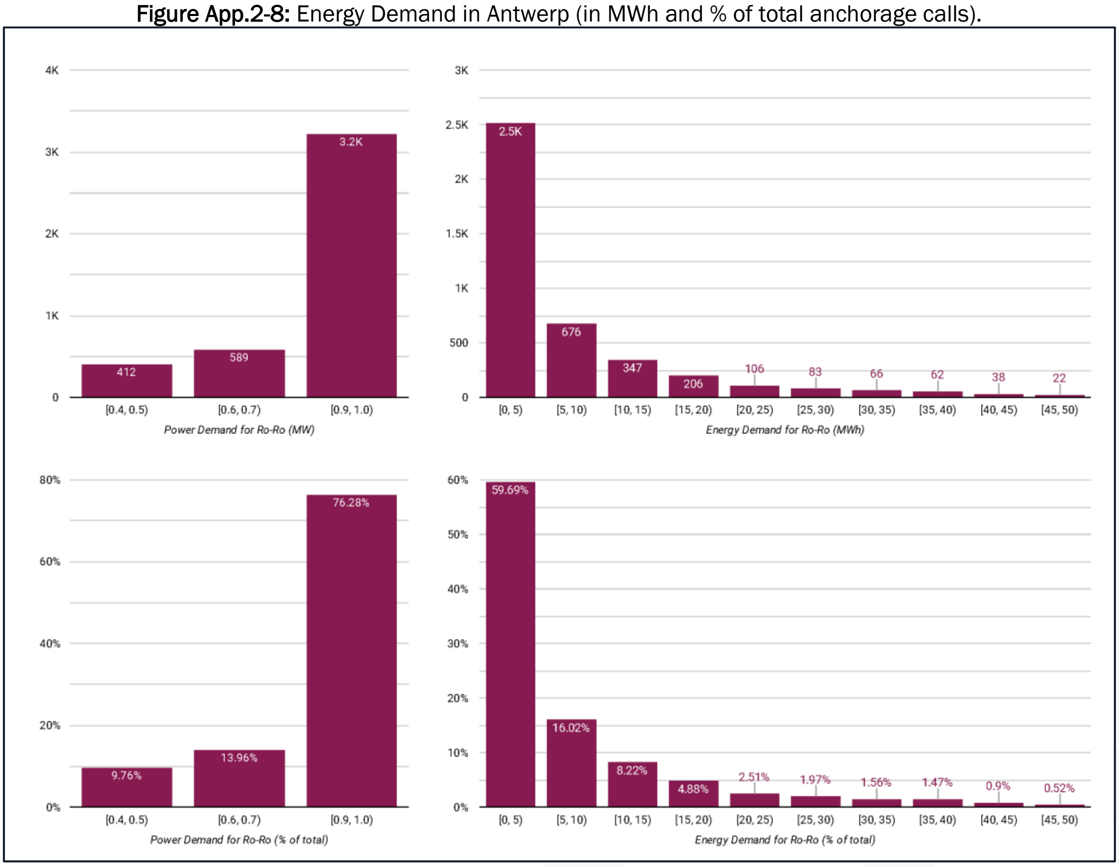

Figure App.2-9: Power and Energy Demand for Ro-Ro (in MW and MWh, and % of total anchorage calls).

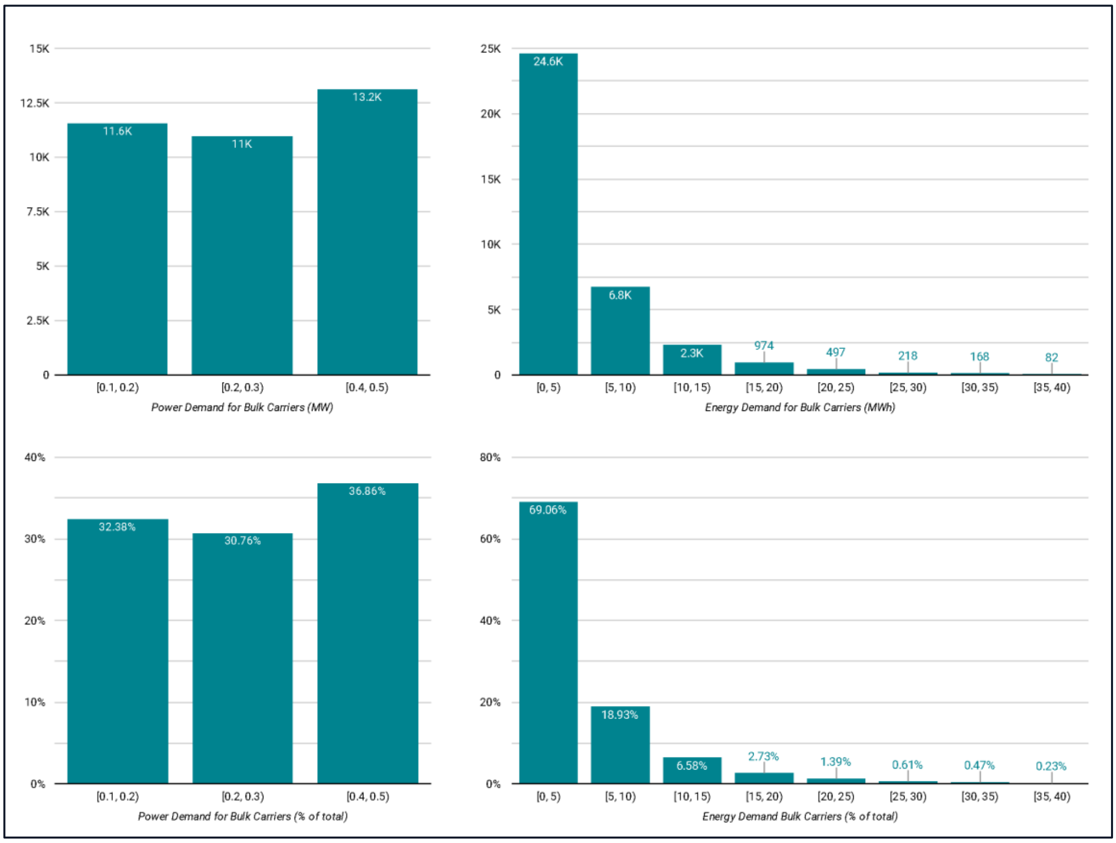

Figure App.2-10: Power and Energy Demand for Bulk Carriers (in MW and MWh, and % of total anchorage calls).

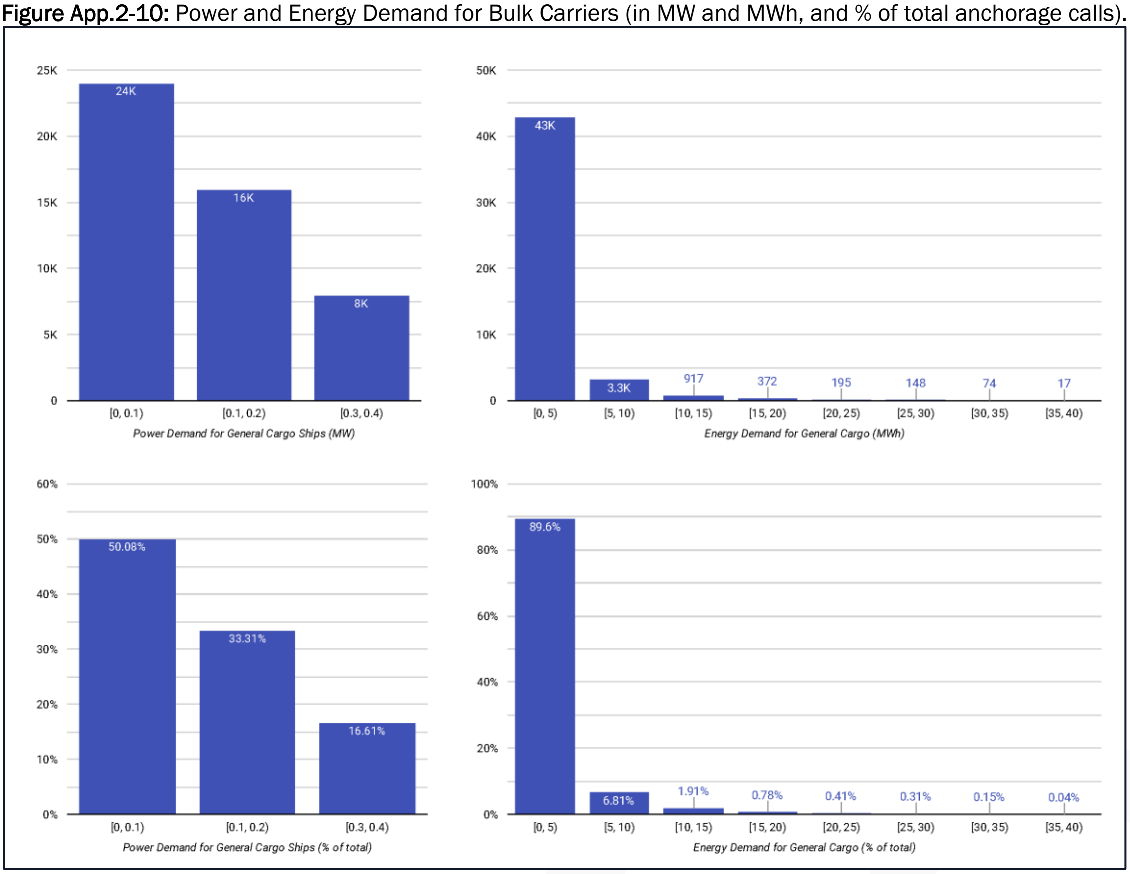

Figure App.2-11: Power and Energy Demand for General Cargo Ships (in MW and MWh, and % of total anchorage calls).

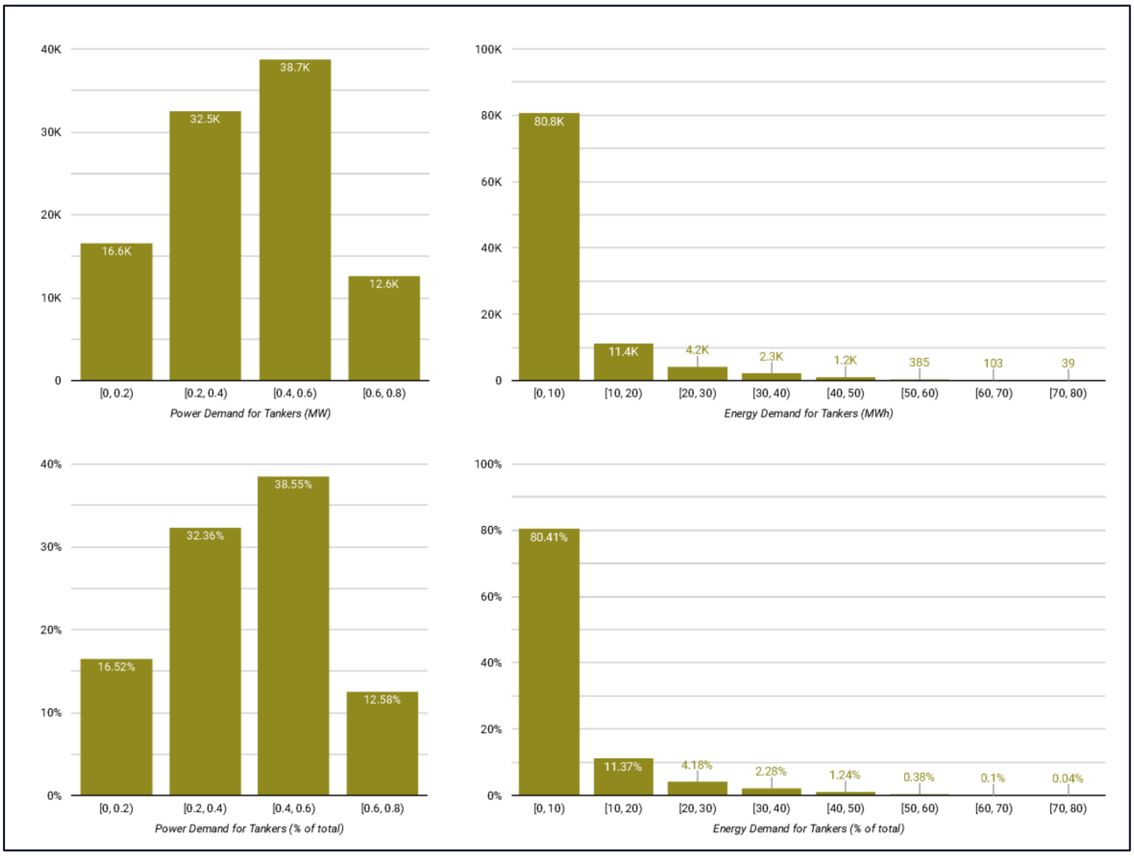

Figure App.2-12: Power and Energy Demand for Oil and Chemical Tankers (in MW and MWh, and % of total anchorage calls).

Appendix III – Requirements

With reference to Section 5, and more specifically to sub-section 5.6, the part of the Appendix provides a detailed listing of formally documented requirements, per the requirements engineering approach already described. The consortium partners will further elaborate on the listed requirements in later deliverables.

<table>
<tr><th>ID: 01</th><th>Type: Functional</th><th>Priority: MUST</th></tr>
<tr><td colspan="3">Title: Power supply standards for shore- barge</td></tr>
<tr><td colspan="3">Description: BlueBARGE electrical design compliance to IMO and ICE standards
All the electrical designs must compile to IEC 62271-200 for cable design. The shore connection of the barge must the comply with the IEC/IEEE 80005-1 (High Voltage Shore Connection) and IEC/IEEE 80005-2 (Low Voltage Shore Connection).</td></tr>
<tr><td colspan="3">Rationale: It is necessary, since these are the standards for power supply for shore to barge power connections as well as global standards for electrical connections for High Voltage</td></tr>
<tr><td colspan="3">Stakeholders/Users:
Bunkering services, Port/Port Operators, Classification Societies, Shipyards and Designers, Power Systems Manufacturers, Automation and Control Systems Manufacturers.</td></tr>
<tr><td colspan="2">Category: Technical</td><td>BlueBARGE Component: Interface module (i.e., cable management system)</td></tr>
<tr><td colspan="2">Dependencies:
Vessel sizes
Vessel types
Power demands
Average waiting times at anchorage</td><td>Conflicts:
Incompatibility of sockets/plugs due to discrepancies between High (IEEE 80005-1) and low voltage (IEEE 80005-3) shore connections
Connectivity issues between the shore and the barge side (especially in cases where the shore grid is weak)</td></tr>
</table>

<table>
<tr><th>ID: 02</th><th>Type: Functional</th><th>Priority: SHOULD</th></tr>
<tr><td colspan="3">Title: Emergency release (in case of tide, draught or wind)</td></tr>
<tr><td colspan="3">Description: Emergency release function should be considered for the interface between the ship and the barge, but also the barge and the land/port infrastructure, including the cable management system as well as the mooring of the barge for the ship-barge case.</td></tr>
<tr><td colspan="3">Rationale: The necessity for emergency release, especially in the case of the ship-barge connection, including the cable management system as well as the mooring system, arises from the challenges for onshore and offshore power supply. For ship to ship charging case, the relevant movement of the two floating bodies should be considered. For the onshore application, environmental conditions may prevent operation.</td></tr>
<tr><td colspan="3">Stakeholders/Users:
Bunkering services, Port/Port Operators, Ship Owners, Ship Operators/Crew, Tugboat Owners, Tugboat Operators/Crew, Classification Societies, Shipyards and Designers, Power Systems Manufacturers, Automation and Control Systems Manufacturers,</td></tr>
<tr><td colspan="2">Category: Safety</td><td>BlueBARGE Component: Interface module (i.e., cable management system), mooring system</td></tr>
<tr><td colspan="2">Dependencies: Ship to barge communication protocol, acknowledgment of both parties, mechanical systems to respond in a given timeframe.</td><td>Conflicts: In emergency release case, blackout of the ship should be prevented. PMS control on the ship side should take this case into consideration.</td></tr>
</table>

ID: 04	Type: Functional	Priority: COULD
Title: Universal solution for different vessel types		
Description: In order to reduce complexity of the offshore barge to ship charging a universal barge with alternative options on board is preferred.		
Rationale: Preferably single barge can serve multiple vessel types at anchorage. This is especially good for scalability of the application.		
Stakeholders/Users: Bunkering services, Port/Port Operators, Ship Owners, Ship Operators/Crew, Tugboat Owners, Tugboat Operators/Crew, Classification Societies, Shipyards and Designers, Power Systems Manufacturers, Automation and Control Systems Manufacturers,		
Category: Interoperability, usability		**BlueBARGE Component:** Barge, CMS, onboard power electronics, PMS, EMS
Dependencies: Different vessel types require different types of sockets along with different power requirements, resulting in cables with various diameters and onboard equipment compatible with HV and LV and sockets/plugs.		**Conflicts:** The technical requirements associated with a universal barge solution increases drastically. While the business model is simplified, product development challenges increase.

ID: 05	Type: Functional	Priority: SHOULD
Title: Universal solution for different ports (inland and deep ports)		
Description: Inland waterway ports are an important part of the total available ports in the EU. They experience many issues related to shore power applications.		
Rationale: Powerbarges should also support inland waterway ports along with main ports. So, the design must consider inland waterway applications.		
Stakeholders/Users: Bunkering services, Port/Port Operators, Ship Owners, Ship Operators/Crew, Tugboat Owners, Tugboat Operators/Crew, Classification Societies, Shipyards and Designers, Power Systems Manufacturers, Automation and Control Systems Manufacturers,		
Category: Interoperability, usability		**BlueBARGE Component:** Barge, CMS, onboard power electronics, PMS, EMS
Dependencies: Vessel types and the concept of operations are different in the identified cases. So, if possible, a design and product should be developed to meet the goals in the intersection of both port types.		**Conflicts:** Vessel types and operations are different. The differences should be identified to minimize the gaps.

ID: 06	Type: Functional	Priority: MUST
Title: Availability of port infrastructure and capacity		
Description: For the powerbarge application to scale, ports should provide spaces for charging of these barges. Another option may be to allocate dedicated areas outside of the ports (such as in moored case) to allow the charging of multiple barges at once.		
Rationale: In case the capacity or infrastructure is not enough, then charging of barges at the ports may cause additional congestion preventing the successful operation of the concept.		
Stakeholders/Users: Bunkering services, Port/Port Operators, Ship Owners, Ship Operators/Crew, Tugboat Owners, Tugboat Operators/Crew, Classification Societies, Shipyards and Designers, Power Systems Manufacturers, Automation and Control Systems Manufacturers,		
Category: Performance		**BlueBARGE Component:** Barge, Batteries
Dependencies: Port infrastructure, areas to be allocated for the application, available power capacity		**Conflicts:** Ports hesitate to invest in costly infrastructure.

ID: 07	Type: Functional	Priority: MUST
Title: Availability of tugs/captains		
Description: For a non-self-propelled power barge, the operation depends on a tug or additional push boat to navigate. In this case, the availability and the number of tugs limits the performance of the overall operation.		
Rationale: Non self-propelled barges rely on tugs to be moved around. So, the total number of tugs available for the operation defines the limit of the whole operation performance.		
Stakeholders/Users: Bunkering services, Port/Port Operators, Ship Owners, Ship Operators/Crew, Tugboat Owners, Tugboat Operators/Crew, Classification Societies, Shipyards and Designers, Power Systems Manufacturers, Automation and Control Systems Manufacturers,		
Category: Performance		**BlueBARGE Component:** Barge, Tug
Dependencies: Bluebarge relies on a tug to operate. So, a tug captain and/or operator is also a dependency. The communication between the tug operator and the barge system operator is another dependency.		**Conflicts:** Tug operators may allocate resources if the operation is profitable for them.

ID: 08	Type: Functional	Priority: SHOULD
Title: Clarification of ownership		
Description: Powerbarge ownership should be clearly identified.		
Rationale: The ownership of the barge will determine the roles and responsibilities of the stakeholders in the business. A bunkering service operator can own the power barges only when they have the necessary expertise on OPS.		
Stakeholders/Users: Bunkering services, Port/Port Operators, Ship Owners, Ship Operators/Crew, Tugboat Owners, Tugboat Operators/Crew		
Category: Governance		**BlueBARGE Component:** Barge, Tug, Bunkering
Dependencies: The success of such an operation relies on the clear description of ownership, roles and responsibilities in between the stakeholder and users.		**Conflicts:** Who will own the financial and technical risks of a failure?

ID: 09	Type: Functional	Priority: MUST
Title: Manufacturing and assembly of power barges		
Description: Once the ownership is clear, the responsible parties should have the technical and financial capacity to get the power barges built.		
Rationale: Since the product development and manufacturing of a power barge is an interdisciplinary case, the owner should be able to control each of the parties to complete a successful project.		
Stakeholders/Users: Bunkering services, Port/Port Operators, Shipyards and Designers		
Category: Governance, Integration		**BlueBARGE Component:** Barge, CMS, Bunkering, Electrical systems
Dependencies: The power barge operator should be able to manage the manufacturing and integration process which requires technical know-how.		**Conflicts:** Power barge systems operator may need a wider range of technical expertise to realize a system and operation.

ID: 10	Type: Functional	Priority: COULD
Title: Making use of alternative fuels in Bluebarge		
Description: Current Bluebarge product will provide power from batteries. However, depending on the ease of application and the costs associated with it, alternative fuels may be used.		
Rationale: Considering possible bottlenecks on battery dependent barges at different ports, alternative fuels may be an alternative such as Hydrogen+fuel cell, LNG or methanol.		
Stakeholders/Users: Bunkering services, Port/Port Operators, Shipyards and Designers, Energy Suppliers		
Category: Integration, Energy	**BlueBARGE Component:** Barge, CMS, Bunkering, Electrical systems	
Dependencies: Battery based solutions rely on electricity on the port side.	**Conflicts:** Battery based solutions may cause a snowball effect further increasing congestion. However, alternative fuel and system prices and availability of resources are the defining factors.	

ID: 11	Type: Functional	Priority: SHOULD
Title: Maintenance and Updates on the Bluebarge		
Description: Ship to ship charging standards are not available and with the successful application of these solutions, new regulations may be introduced. This may result in updates on the Bluebarge.		
Rationale: Assuming that the standards will be constantly updated as the applications involve many novelties, updates on the system may be required.		
Stakeholders/Users: Bunkering services, Port/Port Operators, Shipyards and Designers, PMS, EMS, Equipment Manufacturers		
Category: Usability	**BlueBARGE Component:** Barge, CMS, Bunkering, Electrical systems	
Dependencies: In the case of the operator being different than the developer and manufacturers, then the updates require the contribution of all parties.	**Conflicts:** Update costs, change of concept of operations, time allocation for the updates.	

ID: 12	Type: Functional	Priority: SHOULD
Title: Space allocated for the Powerbarges to berth		
Description: When at idle, power barges should be berthed, moored or anchored.		
Rationale: Location allocation may be an important issue for the scalability and the successful operation of the barges.		
Stakeholders/Users: Bunkering services, Port/Port Operators, Shipyards and Designers, PMS, EMS, Equipment Manufacturers, Tugboat Owners, Tugboat Operators/Crew		
Category: Usability, Performance	**BlueBARGE Component:** Barge, Tug	
Dependencies: Depending on the location, port and quay operations and tug operators may be responsible.	**Conflicts:** In case if the barges consume space when at idle at the terminals, in time this may cause congestions and extra costs.	

ID: 13	Type: Functional	Priority: SHOULD
Title: Compatibility for bi-directional charging		
Description: Some use cases involve the BlueBarge to provide charging from offshore rigs, wind turbine farms and anchored ships.		
Rationale: To increase operational efficiency, BlueBarge may be charged from vessels, rigs or farms. So, the structure and the interfaces should allow such type of an application.		
Stakeholders/Users: Bunkering services, Port/Port Operators, Shipyards and Designers, PMS, EMS, Equipment Manufacturers, Tugboat Owners, Tugboat Operators/Crew, Offshore Plants		
Category: Integration		**BlueBARGE Component:** Barge, Tug
Dependencies: Type of voltage and current provided from each of these sources may vary. Also, the interfaces may be different.		**Conflicts:** Limits on the charging duration due to safety, allowed minimum distance to charging sources may cause conflict.

ID: 14	Type: Functional	Priority: SHOULD
Title: n-number of cycles target for the life of the Bluebarge		
Description: Systems on the barge need to meet n-number of cycles to achieve a feasible economical life.		
Rationale: There are several components with limited durability life cycles. These include batteries, plugs, cables, breakers etc. So, the useful life of the components should be taken into consideration in feasibility analysis.		
Stakeholders/Users: Bunkering services, Port/Port Operators, Shipyards and Designers, PMS, EMS, Equipment Manufacturers, Tugboat Owners, Tugboat Operators/Crew, Offshore Plants		
Category: Usability		**BlueBARGE Component:** Barge, Hardware on the Barge
Dependencies: Mechanical and electrical equipment		**Conflicts:** In case of very small durability cycles, the whole operation may be infeasible.

ID: 15	Type: Functional	Priority: COULD
Title: High Voltage Supply Option		
Description: Include an option for providing high voltage supply (6.6 kV and/or 11 kV) directly from the barge, with onboard transformers to elevate voltage as necessary.		
Rationale: Accommodating high voltage vessels expands market applicability and ensures compliance with IEC 80005-1, catering to most container and passenger vessels.		
Stakeholders/Users: Port Authorities, Ship Owners, Ship Operators, Power Systems Manufacturers, **Shipping Classification Societies**		
Category: Integration, Interoperability		**BlueBARGE Component:** High voltage transformers, Power conversion modules
Dependencies: Requirement ID 01		**Conflicts:** One barge serving both LV and HV may be costly.

ID: 16	Type: Non-functional	Priority: MUST
Title: Environmental Adaptability		
Description: The system should be operable in various environmental conditions, including extreme weather, to ensure consistent performance.		
Rationale: Ensures reliability and usability of the BlueBARGE solution across different ports and operational environments.		
Stakeholders/Users: Ship Operators/Crew, Port Operators, Public Authorities		
Category: Usability, Performance		**BlueBARGE Component:** All components
Dependencies: Durability of mechanical structure, safety limits		**Conflicts:** Allowable design limits, cost

ID: 17	Type: Functional	Priority: MUST
Title: Seamless Integration with Port Infrastructure		
Description: Ensure that the BlueBARGE integrates seamlessly with existing port infrastructure, including electrical and control systems.		
Rationale: Facilitates ease of use and reduces the complexity of setting up shore-side power connections.		
Stakeholders/Users: Port Authorities, Port Operators, Ship Operators		
Category: Integration, Interoperability		**BlueBARGE Component:** Interface modules, Control systems
Dependencies: Port infrastructure, communication protocols		**Conflicts:** NA

ID: 18	Type: Functional	Priority: MUST
Title: Operational complexity should be low, minimal.		
Description: Each use case has its different concept of operation. However, end users do not want to complicate their way of running operations. Therefore, the solution should not cause extra burden on the user side and complicate the current workflow.		
Rationale: If Use Case 1 is considered, when a bulk vessel is at anchorage and requires shore power from a barge, depending on the total anchorage duration (generally couple of hours to days), there may be enough time to for the connection process, without causing any additional effort to the ship operator. However, in an emergency application such as Use Case 9, the connection and the manoeuvring should be very aligned with ongoing rescue efforts, not causing additional barriers, Same is valid for smaller vessel operations, where each time can make a difference on productivity.		
Stakeholders/Users: Bunkering services, Port/Port Operators, Shipyards and Designers, PMS, EMS, Equipment Manufacturers, Tugboat Owners, Tugboat Operators/Crew, Offshore Plants		
Category: Performance, integration		**BlueBARGE Component:** Barge, Interfaces, Integration systems
Dependencies: Mechanical and electrical equipment, interfaces		**Conflicts:** Universality in this case may cause complexity in a specific use case.

ID: 19	Type: Functional	Priority: SHOULD
Title: Costs associated with the barge operation should be feasible against the port charging and other alternatives.		
Description: For commercial uses cases, the costs constitute an important parameter. In case if the costs for the barge to ship charging is higher than potential fines and or alternative means of charging then the business case cannot be realized.		
Rationale: One of the reasons for slow penetration of shore power solutions is the investment amount to be handled by the port or terminals. Bluebarge can be a very good solution (or an interim solution) to reduce the investment burden on the ports as long as the investment and operation is cheaper compared to the shore side investment.		
Stakeholders/Users: Bunkering services, Port/Port Operators, Shipyards and Designers, PMS, EMS, Equipment Manufacturers, Tugboat Owners, Tugboat Operators/Crew, Offshore Plants		
Category: Performance, Feasibility		**BlueBARGE Component:** Barge concept, manufacturing, energy means
Dependencies: Costs of running the operation, ETS System, bunkering subsidies		**Conflicts:** Universality or dependency on a single power source may reduce the solution robustness to prices, ETS pricing

ID: 20	Type: Functional	Priority: MUST
Title: Maintenance of the BlueBarge		
Description: Maintenance of the system should be regularly done to make sure that the useful life target is met, and the system is active when need to be used.		
Rationale: Maintenance planning is important in such operations because, there are safety and life related attributes. So, in case if a maintenance plan is not active, then all use cases may be affected.		
Stakeholders/Users: Bunkering services, Port/Port Operators, Shipyards and Designers, PMS, EMS, Equipment Manufacturers, Tugboat Owners, Tugboat Operators/Crew, Offshore Plants		
Category: Performance		**BlueBARGE Component:** Barge concept, manufacturing, energy means
Dependencies: Barge operators, system integrators, component suppliers		**Conflicts:** Ownership of the components and reaction durations

ID: 21	Type: Functional	Priority: MUST
Title: Readiness of the receiving part		
Description: Depending on the use case, the receiving part should have the necessary infrastructure and the components (either regulated or not) so that the BlueBarge can deliver the power required.		
Rationale: For example, considering Use Case 3, if the island infrastructure is not ready or compatible with the BlueBarge, it is not possible to make the connection and deliver the power. This is not limited to the power electronics or mechanical connection only, but also providing a suitable quay to the barge to berth to.		
Stakeholders/Users: Bunkering services, Port/Port Operators, Shipyards and Designers, PMS, EMS, Equipment Manufacturers, Tugboat Owners, Tugboat Operators/Crew, Offshore Plants		
Category: Usability		**BlueBARGE Component:** Barge concept,
Dependencies: Design of receiving parts, infrastructure on the receiving party		**Conflicts:** Costs for investment may be high, receiving part may not have the technical expertise

ID: 22	Type: Functional	Priority: MUST
Title: Training of personnel on the receiving and delivering units		
Description: Due to technical aspects involved in shore power applications, for safety and the accuracy of the application, it is important to have trained personnel on each side.		
Rationale: At some point, the safety related issues are addressed in regulations. However, during low and high voltage connections, there are several issues identified in gaps analysis which can be fail safe with the correct procedures and trained personnel.		
Stakeholders/Users: Bunkering services, Port/Port Operators, Shipyards and Designers, PMS, EMS, Equipment Manufacturers, Tugboat Owners, Tugboat Operators/Crew, Offshore Plants		
Category: Performance, Safety		**BlueBARGE Component:** Barge concept, manufacturing, energy means
Dependencies: Training on both side of the application, a unified and harmonized platform		**Conflicts:** N/A

ID: 23	Type: Functional	Priority: SHOULD
Title: Power Source Flexibility for the Barge		
Description: Barge operators due to the size of the enterprise (SME) may hesitate to invest in a single technology (tech lock-in) to provide power barge services.		
Rationale: Considering that the power barge operations will be owned by barge owners, investing in a single technology may be hard. Therefore, the power source system may be modular (interchangeable) with alternative sources (ex. Containerized hydrogen, batteries etc.). Especially, for cases when the directions are yet not clear.		
Stakeholders/Users: Bunkering services, Port/Port Operators, Shipyards and Designers, PMS, EMS, Equipment Manufacturers, Tugboat Owners, Tugboat Operators/Crew, Offshore Plants		
Category: Useability		**BlueBARGE Component:** Barge concept, power sources
Dependencies: Alternative fuel infrastructure, electric infrastructure, system integration flexibility		**Conflicts:** If the sources are containerized with plug and play property, the rest of the barge electric and mechanical system staying the same, there may be conflicts with standards (or lack of standards).

ID: 24	Type: Functional	Priority: MUST
Title: Keeping up with the regulatory changes		
Description: Regulations are continuously updated with the data generated at the field applications.		
Rationale: All parties involved in the operation of maritime applications and barge to offshore or barge to land applications should constantly		
Stakeholders/Users: Bunkering services, Port/Port Operators, Shipyards and Designers, PMS, EMS, Equipment Manufacturers, Tugboat Owners, Tugboat Operators/Crew, Offshore Plants		
Category: Useability		**BlueBARGE Component:** Barge concept, regulatory compliance
Dependencies: Technical expertise, updates on the ecosystem (receiving and delivering parties)		**Conflicts:** Lack of standardization for some applications and use cases

ID: 25	Type: Functional	Priority: COULD
Title: Quick/opportunity charging option		
Description: For Use Cases involved with offshore charging (Use Case 8), BlueBarge can be used to provide charging/ recharging for transit ships. Or for inland cases (Use Case 5), quick charging from a barge can be very useful application.		
Rationale: In case if a long-haul vessel travels along a Green Corridor and is full electric, high power quick charging can be provided. Inland waterway vessels hold a bigger potential due to the limited travel range. As battery swapping was introduced as an operation mode, quick charging from barges will reduce a lot of operational, investment and space related issues.		
Stakeholders/Users: Bunkering services, Port/Port Operators, Shipyards and Designers, PMS, EMS, Equipment Manufacturers, Tugboat Owners, Tugboat Operators/Crew, Offshore Plants		
Category: Useability, Performance	**BlueBARGE Component:** Barge concept, availability of HV	
Dependencies: Technical expertise, high power availability for quick charging	**Conflicts:** Allocating space on the barge may be a problem unless the batteries can be stacked	

ID: 26	Type: Functional	Priority: MUST
Title: Emergency Shutdown		
Description: Emergency shutdown facilities are to be provided such that they are automatically activated in case of emergency. Loss of equipotential bonding between ship-barge, failure of connection safety circuits, high tensions levels due to either the ship or barge movements.		
Rationale: It is necessary, since the ship's and the barge's movements are affeceted by the weather and the sea environment (especially in harsh conditions).		
Stakeholders/Users: Bunkering services, Port/Port Operators, Classification Societies, Shipyards and Designers, Power Systems Manufacturers, Automation and Control Systems Manufacturers.		
Category: Safety	**BlueBARGE Component:** Interface module (i.e., cable management system)	
Dependencies: TBD	**Conflicts:** TBD	

ID: 27	Type: Functional	Priority: SHOULD
Title: Backup power supply		
Description: Backup power supply of emergency generator for operation of at least 30 minutes should be provided for the instrumentation devices. In the event of a breakdown of this backup power supply, alarm should be activated in the machinery control room of the ship.		
Rationale: In case of a blackout or a connection error between the ship and barge should be a backup system in place for the continuity and safety of the machinery.		
Stakeholders/Users: Bunkering services, Classification Societies, Power Systems Manufacturers, Automation and Control Systems Manufacturers.		
Category: Technical, safety	**BlueBARGE Component:** Interface module (i.e., cable management system)	
Dependencies: TBD	**Conflicts:** TBD	

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