International Hydrogen Ramp-up Programme - H2Uppp

Diagnosis of Decarbonization, Infrastructure and Hydrogen Applications in Brazilian Ports

Executive Summary

Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH

ANTAQ Agência Nacional de Transportes Aquaviários

MINISTÉRIO DE PORTOS E AEROPORTOS

GOVERNO FEDERAL BRASIL UNIÃO E RECONSTRUÇÃO

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"The International Hydrogen Incentive Program (H2Uppp) of the German Federal Ministry for Economic Affairs and Climate Action (BMWK) promotes projects and market development for green hydrogen in selected emerging and developing countries as part of the National Hydrogen Strategy."

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LIST OF ACRONYMS

ANP – Brazilian Agency for Petroleum, Natural Gas and Biofuels
ANTAQ – Brazilian Agency for Waterway Transportation
CDP – Carbon Disclosure Project
CII – Carbon Intensity Indicator
CNPE - National Energy Policy Council
EPA – Environmental Protection Agency (United States Environmental Protection Agency)
EPI – Environmental Performance Index
ESI – Environmental Ship Index
ETC – Cargo Transshipment Station
GHG – Greenhouse Gases
GRI – Global Report Initiative
IAPH - International Association of Ports and Harbors
IMO – International Maritime Organization
LNG – Liquefied Natural Gas
MCTI – Ministry of Science, Technology and Innovations
MMA – Ministry of Environment and Climate Change
MPOR – Ministry of Ports and Airports
OPS – On-shore Power Supply
PNH2 - National Hydrogen Program
SBTi – Science Based Targets Initiative
SIRENE – National Emissions Registration System
TA – Leased Terminal
TT – Terminal Tractors
TUP – Private Use Terminal
WPSP - World Port Sustainability Program

1 PRESENTATION

The H2Uppp International Hydrogen Incentive Program, financed by the German Ministry of Economy and Climate Action (BMWK) and implemented by the Brazil-Germany Cooperation for Sustainable Development through the *Deutsche Gesellschaft für Internationale Zusammenarbeit* (GIZ) *GmbH*, aims to identify, prepare and monitor the implementation of projects for the production and use of green hydrogen and derivatives applications, as well as raise awareness and transfer knowledge for project development. Considering the importance of the port sector as a strategic actor in the implementation of the green hydrogen value chain, the H2Uppp program promoted the project of Diagnosis of Decarbonization, Infrastructure and Hydrogen applications in Ports.

The project is carried out within the scope of a Technical Cooperation Agreement (ACT) between GIZ and the Brazilian Agency for Waterway Transportation (ANTAQ), which already has consolidated action in promoting the sustainability of Brazilian ports and terminals, through initiatives such as the Environmental Performance Index (EPI) and port, local and institutional environmental agendas. The present study was structured around three analytical axes: Axis 1 - Review of International Experience; Axis 2 - Diagnosis of Decarbonization, Infrastructure and applications of Hydrogen in Ports; and Axis 3 - Case Study. Axis 1 was prepared by ANTAQ and consisted of mapping the main regulatory measures adopted by the International Maritime Organization (IMO) and other countries to reduce Greenhouse Gas (GHG) emissions in maritime transport, in addition to a contextualization of measures to the decarbonization of transport carried out by vessels and the operation of ports.

WayCarbon was hired by the Brazil-Germany Cooperation - GIZ to prepare Axis 2 of the project, related to the Diagnosis of Decarbonization, Infrastructure and applications of Hydrogen in Ports. Its objectives are to evaluate the preparation of port infrastructures to receive vessels that use zero carbon fuels, map emission reduction initiatives in ports, identify the potential of green hydrogen for export and decarbonization of ports and, based on this diagnosis, publish a guide for recommendations on the subject. The diagnosis was carried out in cooperation with the Brazilian Agency for Waterway Transportation – ANTAQ and the Ministry of Ports and Airports (MPOR). This document presents the Executive Summary of Axis 2, which compiles the most important points of contextualization, methodology, results, conclusions and recommendations of the diagnosis, carried out based on a questionnaire and advisory meetings with representatives of public ports and terminals. In addition, Axis 2 encompasses the Diagnostic Final Report in full and the Guidelines.

Axis 3 will be conducted by ANTAQ and will consist of a case study based on field surveys and semi-structured interviews. The set of three axes is expected to provide a comprehensive overview of the current situation and future perspectives for the decarbonization of the port sector, helping Brazilian ports and terminals to anticipate possible more restrictive regulations and pressures as well as associated opportunities, and to position themselves as protagonists in the transition to a low-carbon economy.

2 INTRODUCTION

Maritime transport plays a key role in the global economy, being responsible for more than 80% of the volume of cargo transported in international trade, a percentage that is even higher in developing countries (UNCTAD, 2021). GHG emissions from this activity represent 3% of global values and have increased by 20% in the last decade, with growth expected to continue in the coming years. The global shipping fleet still operates almost exclusively on fossil fuels, but 21% of vessels in production will use alternatives such as liquefied natural gas (LNG), methanol and hybrid technologies. Achieving the GHG emission reduction targets proposed for 2050 will require significant investments in cleaner fuels and technologies to improve efficiency, but there is still debate about the best methods to achieve decarbonization. At the same time, given the sector's vulnerability to the impacts of climate change, the cost of not acting could outweigh these investments (UNCTAD, 2023).

The International Maritime Organization (IMO) has been adopting measures to reduce emissions from international maritime transport. In 2018, resolution MEPC.304(72) was published, referring to the IMO Initial Strategy for Reducing GHG Emissions from Ships, which was updated in 2023 by MEPC.377(80). This way, objectives, guiding principles, and instruments were defined to direct countries in the decarbonization of maritime transport (IMO, 2023). Furthermore, objective decarbonization targets were stipulated:

- Reduce the carbon intensity of international maritime transport, on average, by at least 40% by 2030, compared to 2008;
- Reduce total carbon emissions of international maritime transport, by at least 20%, aiming for 30%, by 2030, compared to 2008;
- Reduce total carbon emissions of international maritime transport, by at least 70%, aiming for 80%, by 2040, compared to 2008;
- Peak emissions as quickly as possible and achieve net-zero emissions by 2050, while considering the different circumstances of each country.

In 2021, IMO approves amendments to Annex VI of the International Convention for the Prevention of Pollution from Ships (MARPOL) that require ships to reduce their GHG emissions. MARPOL Annex VI comprises 100 parties, representing 96.65% of global merchant shipping by tonnage. One of the measures includes encouraging more energy-efficient ships, classified in categories A or B on the Carbon Intensity Index (CII). Port authorities and other interested parties, such as port administrators, are encouraged to provide benefits to such classes of ships.

In addition to changes in ship technology, the decarbonization of maritime transport will require large investments in infrastructure for production, storage, distribution and refuelling of vessels with alternative fuels. Among the possibilities is low-carbon hydrogen, which encompasses green hydrogen technology, with one of the routes of obtainment being through the electrolysis of water with electrical energy generated by renewable sources. In this scenario, ports and terminals emerge as strategic locations to develop projects that meet the needs of this entire value chain, acting as a facilitator of reducing emissions in their chain through the adoption of structures that favor the use of lower carbon-intensive fuels on vessels. Brazil has great potential in this market, especially due to the great availability of renewable energy. A survey carried out in 2022 indicates that there are already 30 billion dollars in hydrogen projects announced for Brazil, and the country has the technical potential to produce 1.8 gigatons per year. The National Hydrogen Program (PNH2), whose guidelines were established in 2021, shows the country's quest for protagonism and leadership in the energy transition (MME and EPE, 2023).

Another important action area for ports and terminals is the adoption of measures to mitigate emissions from their operations, which is responsible for a variety of direct and indirect GHG emissions, related, for example, to cargo movement, support activities to vessels and industries, and energy consumption for administrative activities. In this context, decarbonization opportunities are presented through the implementation of OPS (On-Shore Power Supply) systems, which provide the supply of electricity on land for moored vessels, energy efficiency measures, electrification and the use of biofuels in operational equipment, such as forklifts and TTs (Terminal Tractors), intelligent technologies for managing port logistics and optimizing routes, and the generation of renewable energy for administrative and operational activities.

In recent years, the urgency of reducing Greenhouse Gas (GHG) emissions has become more evident in the face of so many extreme weather events and significant changes in the planet's temperature. Among the various possible paths to reducing emissions, the energy transition is the basis, as it cuts across several sectors. Specifically for the port sector, the energy transition presents itself as both a challenge and an opportunity: a challenge given the countless actions that need to be put into practice in the short term, an opportunity given the competitive position that ports assume in this context of change. The location of ports subjects them to being highly exposed to extreme environmental events, such as winds, storms and rising sea levels, all resulting from the increase in the global average temperature. In addition to initiatives to adapt their infrastructure to climate change, ports position themselves as key elements in mitigation processes and achievement of global emissions neutrality targets, a context in which the energy transition is inserted.

The present work has substantial relevance in placing Brazilian ports as protagonists in the transition process to a low-carbon economy, anticipating more restrictive regulations and pressures and becoming more resilient in the face of this new market. The objectives of this work are:

- Carry out diagnosis regarding the current situation of port infrastructures (readiness) to receive vessels that use low-emission fuels;
- Carry out diagnosis regarding decarbonization initiatives in ports and port services provided;
- Identify the potential of low-carbon hydrogen and its derivatives for decarbonization of Brazilian ports;
- Disclose the diagnosis obtained;
- Create and publish a guide on good practices and recommendations for the decarbonization of ports.

This Executive Summary was prepared considering the most important aspects of the project, including the contextualization of the sector, the adopted methodology, analysis of results and the conclusions and recommendations on regulatory analyses, maturity level, challenges and opportunities for new technologies for the sector were included, with a focus on low-carbon hydrogen and its derivatives.

3 METHODOLOGY

The project to develop the Decarbonization Diagnosis, Infrastructure and Hydrogen applications in Ports was divided into 3 stages, with the delivery of 6 products, as shown in Figure 1 detailed below:

- **Stage 1 – Work Plan:** describes the associated products and activities corresponding to Product 1. Work Plan.
- **Stage 2 – Diagnosis:** presents the second part of the project, which includes the stages involved in carrying out the diagnosis of ports, mapping stakeholders, preparing the survey and holding a workshop, corresponding to P2 products. Diagnostic Planning, P3. List of Stakeholders, P4. Survey Application and P5. Partial Report.
- **Stage 3 – Results and Recommendations:** aimed at systematizing project results and preparing recommendations, corresponding to Product 6. Final Report, Executive Summary, and Guidelines.

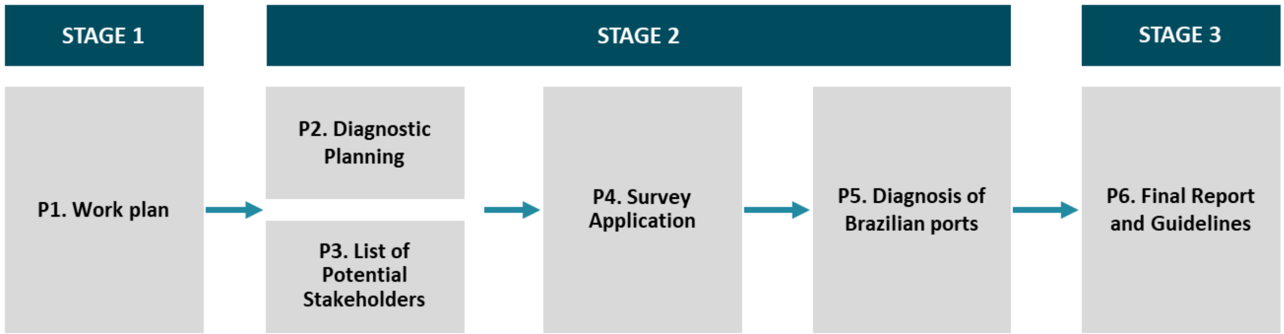


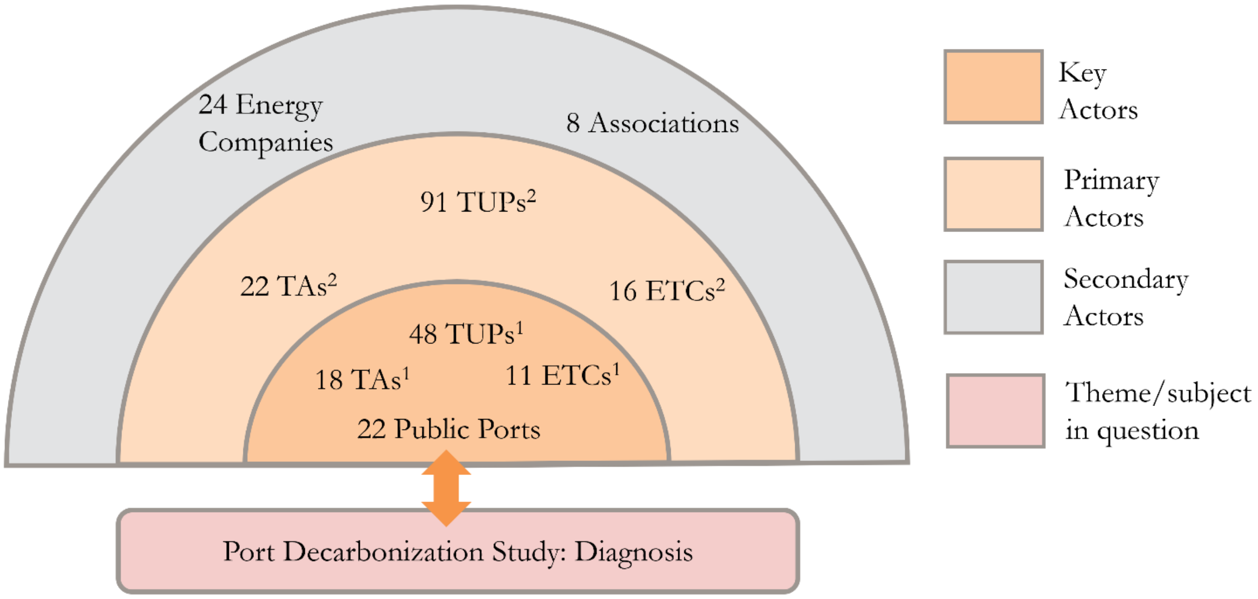
Figure 1. Stages of development of the Decarbonization Diagnostic Study, Infrastructure and applications of Hydrogen in Ports.
Source: Prepared by WayCarbon, GIZ, ANTAQ, MPOR (2023).

The **Stakeholder Mapping** involved the definition of a target audience for the research, which is made up of: public ports, private use terminals (TUPs), leased terminals (TAs) and cargo transshipment stations (ETCs), which went through a prioritization process based on cargo handling and geographical representation criteria. Additionally, a survey was carried out of port sector associations and companies that have already signed investment partnerships or have ongoing projects related to green hydrogen technology and derivatives in Brazil, with a focus on port facilities. Figure 2 presents the mapping of diagnosis actors, prepared according to the method called Capacity *WORKS* (GIZ, 2015), and Table 1 explains the criteria for actor classification.

Table 1. Actor classification methodology.

Classification	Criteria
Key Actors	Relevant actors mapped to ensure representativeness of the diagnosis and prioritization for in-person participation in the Leveling and Engagement Workshop. Contacts were made with priority actors to achieve greater involvement.
Primary Actors	Actors with less relevance to the study, but included in the diagnostic survey. They were invited to participate online in the Leveling and Engagement Workshop.
Secondary Actors	Actors relevant to the topic, who were invited to participate in person in the Leveling and Engagement Workshop, but are not part of the target audience defined for the form prepared for the diagnosis.

Source: Prepared by WayCarbon, GIZ, ANTAQ, MPOR (2023).



1. Private Use Terminals (TUPs), Cargo Transshipment Stations (ETCs) and Leased Terminals (TAs) **considered priorities** for the study based on cargo movement and geographic representation criteria.
2. Private Use Terminals (TUPs), Cargo Transshipment Stations (ETCs) and Leased Terminals (TAs) **considered non-priority** for the study based on cargo movement and geographic representativeness criteria.

Figure 2. Map of diagnosis actors.
Source: Prepared by WayCarbon, GIZ, ANTAQ, MPOR (2023).

A **Leveling and Engagement Workshop** was held on 09/18/2023, with the aim of leveling knowledge about the project, such as work objectives, sector decarbonization challenges, diagnostic activities, expected results, and of guiding focal points responsible for filling out the questionnaires and interviews. The event was held in a hybrid format to engage different audiences in the project, 43 guests having attended the event in the in-person format, and 45 in the virtual format.

In the **Diagnostic Planning** stage, the questionnaire was prepared for the collection of quantitative and qualitative information through an electronic form. The questions were based on a previous study of decarbonization opportunities in the sector, the potential of green hydrogen and other renewable fuels, the sector's maturity in the face of necessary adaptations. The questionnaire was divided into 4 sections, presented in Table 2.

Table 2. Questionnaire sections.

Section	Objective
General information	Data on the identification of the port facility and the person in charge of filling out the information, in addition to the consent form for the use of personal data.
General Information of the Port Facility	General characteristics of the port facility, such as the most handled type of merchandise, structure provided for vessels, mooring length, type of fuel most used, etc., with the aim of qualifying the research sample.
Management of Greenhouse Gas (GHG) Emissions	The first step towards the transition to a low-carbon economy agenda is to have a consistent diagnosis of GHG emissions. Therefore, this first section is dedicated to identifying the preparation of an emissions inventory and detailing its level of deepening and publicization, describing the emission reduction targets and carrying out public reports.
Emissions reduction initiatives, port structure, opportunities and challenges	Diagnose the decarbonization initiatives of ports and port services, focusing on initiatives that reduce GHG emissions, but also possible applications of fuels, hydrogen and derivatives, the preparation of port infrastructures to receive vessels that use low-emission fuels, the opportunities and challenges related to the energy transition, with a focus on green hydrogen technology.

Source: Prepared by WayCarbon, GIZ, ANTAQ, MPOR (2023).

The **Survey Application** took place through the *SurveyMonkey electronic platform* and had a total completion period of 22 days. During this period, a systematic monitoring was performed in order to guarantee the largest number of respondents and the completeness of the answers. After reaching 93 responses, a significant engagement was obtained, which is further analyzed in section 4.1 Sample Characterization.

In this stage, **Advisory Meetings** were also held with the mapped actors, focusing on the five key points defined for preparing the diagnosis:

i) the maturity of the sector in the face of the energy transition and transition to a low-carbon economy;
ii) best decarbonization practices, taking into account the ports subject to research, reference guidelines and literature, providing an opportunity for new technologies such as hydrogen derivatives;
iii) future perspectives of the sector;
iv) opportunities and challenges, technological, market and regulatory limitations, focused on the topic of energy transition;
v) potential partners and key actors to enable the decarbonization of the sector and the applications of hydrogen and its derivatives.

For the actors responding to the questionnaire (Public Ports, TUPs, TAs and ETCs), the questions were directed based on a preliminary diagnosis of the results, as well as the specific responses of the actors present. In the case of the port sector associations, the proposal was to collect the perceptions of actors who did not participate in the questionnaire. In total, 5 advisory meetings were held, with the participation of 43 people, without counting the members of the GIZ, ANTAQ and WayCarbon teams.

4 RESULTS

The results presented below were based on quantitative and qualitative analysis of the responses received to the form. Graphics were produced with the aim of highlighting the survey elements that are most relevant to the objectives proposed for the diagnosis. The open responses sent and comments made in the advisory meetings were considered. For the purpose of presenting the results, the types of stakeholder were grouped into the categories "Public Ports" and "Terminals (TUPs, TAs and ETCs)", the latter of which includes Private Use Terminals (TUPs), Leased Terminals and Cargo Transshipment Stations (ETCs).

4.1 Sample Characterization

Table 3 presents the sample systematization and engagement analysis, comparing the number of responding actors with the number of mapped actors. An engagement of 87% was achieved for Public Ports and 31% for Terminals (TUPs, TAs and ETCs). When the sum of port movement of each of the facilities considered is considered as an indicator, these indicators increase to 88% and 70%, proving the representativeness of the sample obtained.

Table 3. Engagement Analysis – Number of actors and Port Movement.

Stakeholder Category	Number of actors			Port Movement [1] in 2022 (t)		
	Mapped Actors	Responding Actors	Engagement percentage	Mapped Actors	Responding Actors	Engagement percentage
Public Ports	31	27	87%	421,037,122	371,541,679	88%
Terminals (TUPs, TAs and ETCs)	213	66	31%	955,412,679	672,956,176	70%
Total	**244**	**93**	**38%**	**1,376,449,801**	**1,044,497,855**	**76%**

Source: Prepared by WayCarbon, GIZ, ANTAQ, MPOR (2023).

4.2 GHG Emissions Management

The GHG Emissions Inventory is a management tool that allows the mapping of emission sources from an activity, process, organization, economic sector, city, state or even a country, followed by the quantification, monitoring and recording of these emissions, in addition to being fundamental for monitoring goals and evaluating the performance of investments in low-emission equipment, technologies and processes. The preparation of GHG inventories must follow internationally recognized standards and methodologies for greater reliability and comparability of results between organizations. Furthermore, it is important that they be made available on public platforms for greater transparency.

One of the main references is the GHG Protocol, which defines GHG emissions accounting standards for the corporate sector, value chains, cities, among others. The project includes guidelines, instructions, tools, and training for measuring and managing emissions by companies and governments, constituting the main methodology used worldwide by private organizations and cities (WRI, 2015). The Brazilian GHG Protocol Program, developed in 2008 by the FGV Sustainability Studies Center (FGVces) and the World Resources Institute (WRI), in partnership with the Ministry of the Environment (MMA) and actors from the business sector, is responsible for adapting the GHG Protocol method to the Brazilian context. In addition to producing publications and

[1] The sum of the port movement of public ports and terminals was carried out only for the purposes of the engagement analysis. The port movement of a public port, for example, may include the movement of leased terminals present in its area. Therefore, the total values presented here should not be considered as a real indicator of the sum of port movement of all facilities.

tools and providing training, the program maintains the Public Emissions Registry, a platform for disclosing corporate inventories of private or public companies, as well as third sector entities. Among the 434 organizations that joined the initiative until 2022, within the "Transport, storage and mail" category, are some actors in the port sector, such as BTP – Brasil Terminal Portuário, Hidrovias do Brasil, Porto do Açu, Porto Itapoá, Porto Sudeste do Brasil, Portos RS, VLI and Wilson Sons (FGV EAESP, 2023).

Faced with the enormous challenges associated with decarbonization, the first step on this journey is the preparation of the GHG Emissions Inventory, an indispensable tool for understanding the sources of emissions and the factors that influence the carbon intensity of port activities. Figure 3 presents the current situation of carrying out GHG inventories in ports and terminals, in which a notable difference in profile is observed between Public Ports and Terminals (TUPs, TAs and ETCs). Among terminals, there is a higher percentage of facilities that have GHG Emission Inventories, which can be attributed to several reasons.

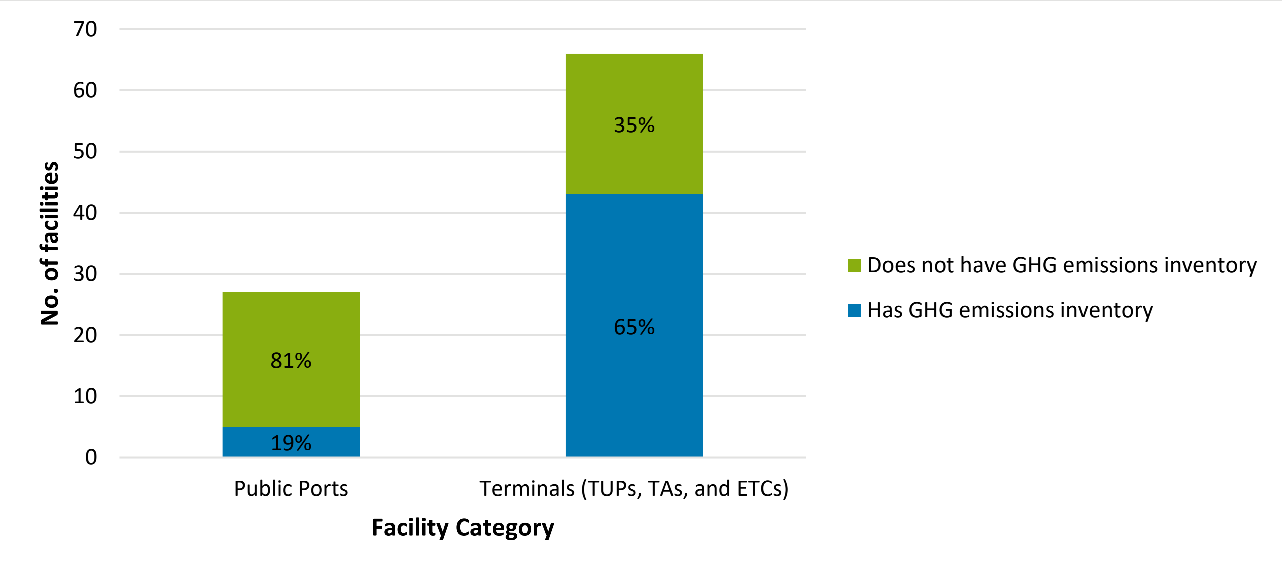


Figure 3. GHG Emissions Inventory by facility category.
Source: Prepared by WayCarbon, GIZ, ANTAQ, MPOR (2023).

Firstly, carrying out an inventory is not a regulatory obligation, which means that the motivation to adopt this practice varies considerably. One of the main drivers for private terminals is market demand and reporting requirements from the sustainability area. Furthermore, many terminals are managed by large companies, such as Petrobras, Transpetro, Vale and Cargill, which already carry out GHG emissions inventories for all their operations. Consequently, these companies include port operations in their reports, which increases transparency regarding GHG emissions. Another important motivation mentioned for preparing GHG inventories is the Environmental Performance Index (EPI), an ANTAQ initiative. Facilities seeking to improve their EPI rating often view the inventory as a means of improving their environmental performance and, consequently, their rating on the index. Other facilities mentioned that the inventory came as a requirement for environmental licensing.

Preparing GHG inventories involves several challenges, including a lack of training, difficulties in data collection, insufficient staff, and lack of financial resources. Preparing an inventory requires technical knowledge and the ability to collect and analyze complex data related to GHG emissions, which are often not available. Even when training is in place, many facilities do not have enough staff to effectively conduct the inventory process, which, because it is not a regulatory requirement for most organizations, is not considered a priority initiative. Additionally, conducting a GHG inventory can involve significant costs, from data collection to analysis and reporting, and many facilities may face financial constraints that hinder the allocation of resources for this purpose.

According to the *GHG Protocol,* the GHG emissions inventory must follow five principles: relevance, completeness, consistency, transparency, and accuracy (WRI, 2015). Generally, the first inventory is more succinct in relation to the emission sources considered. However, as organizations advance along this path, such inventories become more complete, incorporating techniques and improving their methodology to increase measurement accuracy. GHG emissions inventories comprise three distinct scopes: 1 - direct emissions (under the control of the organization); 2 - emissions associated with electrical energy purchased; 3 – indirect emissions (which are not under the direct control of the organization).

Among the terminals, 56% consider Scopes 1 and 2, while 44% already take into account Scopes 1, 2 and 3. Most of these terminals are managed by large companies that have been preparing the inventory for longer and are under greater pressure from the market for its completeness. On the other hand, in the case of public ports, only five of them claimed to carry out inventories: Port of São Sebastião, Port of Fortaleza, Port of Santos, Port of Suape, Port of Itaqui, with only the last three considering all three scopes, which demonstrates a greater difficulty for public ports in advancing on this point.

Even among facilities that carry out Scope 3 inventory, there is a difference between the categories considered. There is greater difficulty in calculating, for example, the categories involving coordination with suppliers and customers to obtain information, such as Goods and Services purchased and Transport and distribution (*upstream*).

Another important point that differentiates GHG emissions inventories is the level of transparency and reliability of the data, analyzed in the graph in Figure 4. It is noted that terminals have made greater progress in this regard, as 65% of those who carry out the inventory have it published and audited by a third party. This can be explained by greater market pressure and the need to comply with information transparency requirements associated with the reports made by companies. In any case, it is noteworthy that 28% have inventory, but have not made it publicly available. In the case of public ports, only two facilities disclose their inventories: Port of Itaqui and Port of Santos.

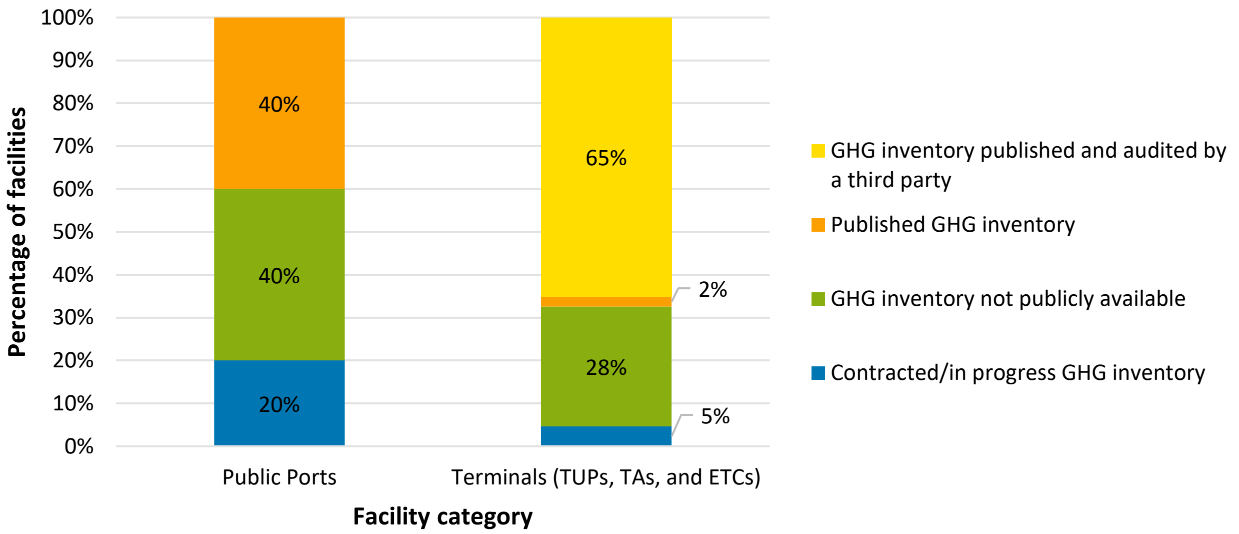


Figure 4. Reporting and checking of the GHG Emissions Inventory.
Source: Prepared by WayCarbon, GIZ, ANTAQ, MPOR (2023).

One of the primary functions of a GHG emissions inventory is to provide the necessary bases for formulating emission reduction targets, which in turn guide the prioritization and detailing of initiatives to be taken. Only 26% of terminals stated that they had GHG emissions reduction targets. However, it is worth noting that, among the 74% who indicated their absence, there were 10 cases of facilities that claimed to have corporate-level goals, but which had not yet been transposed to their local context. This highlights the need to align global and national goals with direct actions in port operations.

The situation is even more challenging in the category of public ports, where only 7% of respondents stated they had a target, which corresponds to just two facilities: Port of SUAPE and Port of Natal. One of the main reasons is the lack of an inventory of GHG emissions. Some facilities are in the initial process of preparing these inventories, with the intention of later establishing concrete goals and building effective decarbonization plans.

Communication to the market and society as a whole of the diagnosis and targets for reducing GHG emissions must be done through public reports, which follow different standards. Based on the diagnosis results, it is noted that 24% do not carry out any type of public reporting. Among the facilities that do so, the Sustainability Report, standardized by the Global Reporting Initiative (GRI), is the most common, being present in the practices of 49% of respondents. Next is the GHG Protocol (35%), which establishes standards and guidelines for accounting and reporting GHG emissions, and the Institutional Environmental Agenda (24%), an instrument for planning and managing the sustainability of ports that is part of the EPI – Environmental Performance Index scoring criteria. Finally, 25% of facilities report to CDP, the global information disclosure system, and 11% meet the reporting requirements of ISE B3, the Stock Exchange's Corporate Sustainability Index. In the "Others" category, Integrated Reporting, another corporate reporting approach, was mainly mentioned.

4.3 Initiatives to Reduce GHG Emissions and possible applications of renewable fuels, green hydrogen and derivatives.

The decarbonization of port facilities requires an integrated approach that involves initiatives in several dimensions, such as electrification of port equipment, generation and use of renewable energy, adoption of measures aimed at energy efficiency, use of intelligent systems, encouraging the use of alternative fuels, such as hydrogen and its derivatives, implementation of structures to supply energy or renewable fuels to vessels, among others. To diagnose the effectiveness of these measures, respondents were invited to classify 15 types of initiatives according to their implementation stage, considering the following scale:

Implementation stages
N6 - Implemented
N5 – Under implementation
N4 – Pilot project
N3 – Agreement or memorandum of understanding signed
N2 – Planned (included in strategic planning or some facility action plan)
N1 – Not implemented
N0 - Not applicable to the type of operation

Figure 5 presents the results of this survey, with the initiatives being ordered according to the highest percentage of responses classified as "N6 - Implemented". The initiatives that stand out most due to their more advanced implementation stage are intelligent port logistics management systems, the supply of less polluting fuels, the planning and implementation of energy efficiency measures, and the generation of renewable energy for operational and administrative activities.

The OPS System (*On-Shore Power Supply)* draws attention, a technology for supplying electrical energy on land to docked ships, replacing the use of engines powered by fossil fuels, which has a high potential for reducing GHG emissions and is already one of the criteria evaluated in the EPI. Only 1 (one) facility declared to be in the pilot project phase: TPET/TOil – Açu Oil Terminal, whose initial system already serves tugboats and support vessels for action in emergencies, with plans to expand to dynamic positioning tankers (DPSTs) and very large crude carriers (VLCCs). No facility has the system completely implemented and 15% of facilities are in the planning phase, such as the port authority Portos RS, which included in its strategic plan, among other measures, the implementation of an OPS energy supply system.

Regarding initiatives related to the value chain of low-carbon hydrogen and its derivatives, four initiatives were evaluated: production, vessel refuelling, current infrastructure for export and import and the adaptation of infrastructure for these purposes. In general, none of the facilities have any of these actions implemented or being implemented. On average, among the initiatives presented, around 59% do not consider them applicable to their type of operation and around 31% classified them as "N1 – Not implemented". On the other hand, considering that this is a new technology, there is already a significant number of actors that have included some of these measures in their planning. In the "N2 – Planned" implementation stage, the percentage of responses was 12% for infrastructure adaptation, 8% for current infrastructure, 6% for refuelling and 5% for production. Considering the stage "N3 – Agreement or memorandum of understanding signed", this percentage was 2% for infrastructure adaptation, 0% for current infrastructure, 2% for refuelling, and 4% for production.

It is important to highlight here the port facilities that are already most engaged in initiatives related to low-carbon hydrogen:

- Five (5) facilities already have at least one of the initiatives related to low-carbon hydrogen with a signed agreement/memorandum of understanding: Port of Suape, Port of Antonina and Port of Paranaguá, among the public ports; Pecém Port Terminal and Port of Açu, within the terminals.
- Fourteen (14) facilities do not yet have a signed agreement, but have already included this type of initiative in their strategic planning.
    - Terminals (TUPs, TAs and ETCs): Ponta da Madeira Maritime Terminal, Hidrovias do Brasil - Vila do Conde S.A. (ETC Tapajós - HBSA), Hidrovias do Brasil - Vila do Conde (TUP) and TPET/TOil Oil Terminal – Açu.
    - Public ports: Port of Pelotas, Port of Porto Alegre, Port of Santos, Port of Aratu, Port of Ilhéus, Port of Salvador, Port of Angra dos Reis, Port of Itaguaí, Port of Niterói, Port of Rio de Janeiro.

Other measures evaluated are economic-financial incentives and the replacement of operational equipment used in the port area, with electric models and/or powered by biofuels or hydrogen and derivatives. In the first case, the score in energy efficiency and carbon intensity indexes, such as the Environmental Ship Index (ESI)[2], is used as a criterion for offering discounts on port fees. Regarding operational equipment, 5% of facilities have already implemented electrification measures, 4% are in the implementation process and another 3% are in the pilot project phase.

[2] The Environmental Ship Index (ESI) is an environmental performance index that classifies ships according to GHG emissions standards defined by IMO, allowing to identify those that meet or exceed current regulations. The initiative is led by the World Ports Sustainability Program (WPSP), an international sustainability program linked to the International Association of Ports and Harbors (IAPH) (WPSP, 2024).

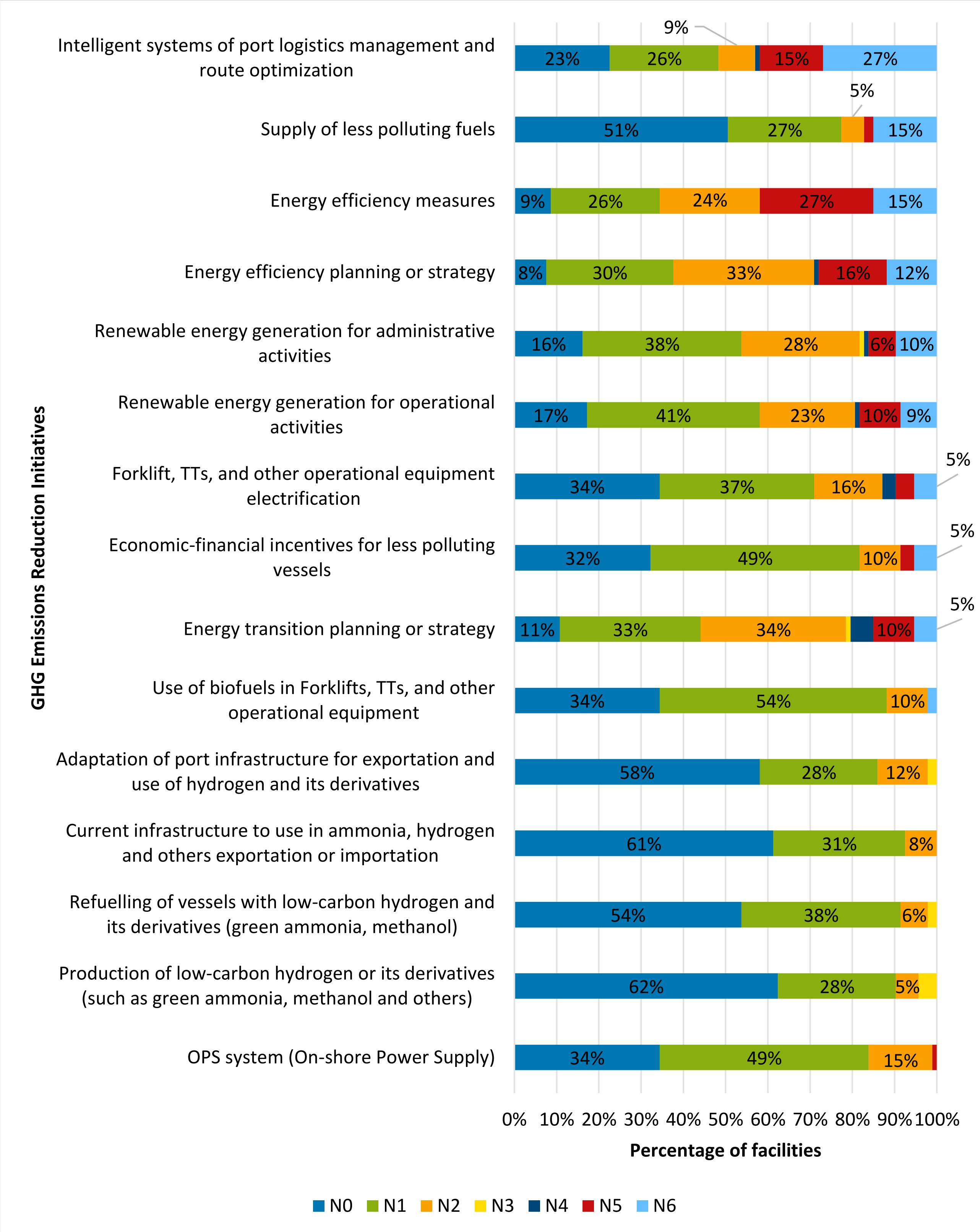


Figure 5. GHG Emissions Reduction Initiatives.
Source: Prepared by WayCarbon, GIZ, ANTAQ, MPOR (2023).

To complement the assessment of initiatives to supply less polluting fuels, the profile of the fuels most used by vessels was analyzed. From Figure 6, it can be seen that there is a predominance in the use of fossil fuels, such as marine diesel and conventional bunker, with a portion of facilities adopting bunker with a low sulfur content. Less emission fuel options, such as biodiesel, LNG and methanol, are still little used. Furthermore, only 11 facilities (1 Public Port and 10 Terminals) reported that they have a record of docking ships using low-carbon fuels. These results reinforce the perception of a current scenario of significant dependence on fossil fuels and still incipient use of alternative fuels, which makes the transition to lower-emitting fuels even more challenging.

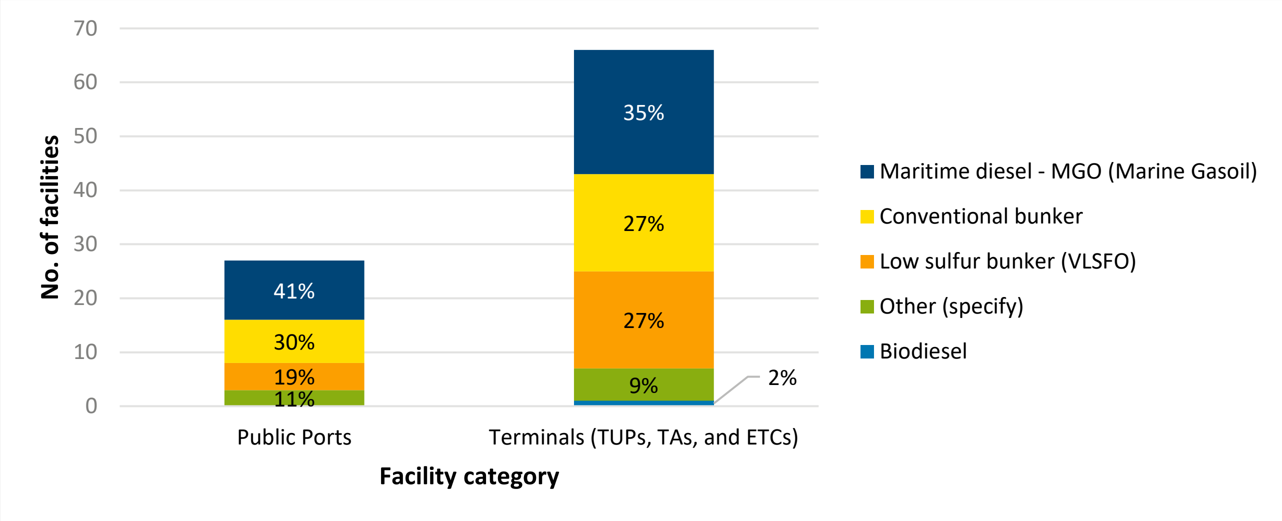


Figure 6. Fuel currently most used by vessels.
Source: Prepared by WayCarbon, GIZ, ANTAQ, MPOR (2023).

4.4 Challenges of the Transition to a Low Carbon Economy

All the measures presented in the previous section involve serious implementation challenges, of a technological, marketing, regulatory, financial nature, among others. An overview of the challenges considered by respondents to be most relevant to each of the initiatives presented was prepared. Financial challenges predominate in the vast majority of actions, while technological challenges stand out most in measures linked to the production and export of low-carbon hydrogen and its derivatives, in OPS systems (On-Shore Power Supply), energy efficiency measures and electrification. The marketing aspect appears to be the most relevant in actions to supply less polluting fuels, and has a significant participation in the actions of intelligent port management systems, energy transition planning, and actions linked to low-carbon hydrogen. The least mentioned challenge by respondents as the most relevant was the regulatory one. In the comments sent along with the form and in the advisory meetings, it was possible to collect some of the actors' perceptions about these challenges, which are detailed in the following paragraphs.

Although the regulatory aspect did not appear as one of the most relevant in the quantitative survey performed, one of the themes cited by several respondents was the lack of regulation and incentives for sustainability in the port sector. The absence of tax incentives, clear regulatory policies, and technologies for purchasing equipment and inputs for clean energy production represents a significant challenge. Many actions related to decarbonization face obstacles due to the complexity and bureaucracy of regulatory policies, which can result in long waiting periods to obtain licenses and authorizations.

To promote the decarbonization of port operations, it is essential that the sector's regulatory bodies get involved in partnership with other Ministries, encouraging investments and works in this direction. The creation of initiatives, such as a line of the Growth Acceleration Program (PAC) aimed at the decarbonization of ports, could be a relevant solution. Furthermore, the

Union can play a crucial role by requiring port operations to adopt low-carbon emission equipment. To boost these efforts, the implementation of public policies, such as economic and tax incentives, is necessary, particularly with regard to the acquisition of new equipment and the transition to cleaner energy sources. However, for these measures to be effective, it is essential to have greater clarity on market demand and regulatory trends, in order to properly direct investments towards decarbonization.

An initiative considered important by participants in the diagnosis is Bill 2308/23, recently approved in the House of Representatives, amending the Petroleum Law (Law No. 9.478/1997) to officially include green hydrogen and fuel hydrogen in the national energy matrix and define legal criteria for their classification. The project will still go to the Senate and may undergo changes. Meanwhile, the National Hydrogen Program (PNH2), established by Resolution No. 6/2022 of the Brazilian Energy Policy Council (CNPE), published in August 2023 its Three-Year Plan 2023-2025, which places as a short-term strategy (until 2025) the dissemination of low-carbon hydrogen pilot plants in all regions of the country. In the medium term (until 2030), the objective is to consolidate Brazil as the most competitive producer in the world and, in the long term (until 2035), to consolidate low-carbon hydrogen hubs in the country. Regarding the challenges associated with technology, another initiative cited in the advisory meetings as a promising path is the establishment and promotion of technology parks focused on innovation and entrepreneurship. Two examples are Porto do Futuro, located in front of the Belém Waterway Terminal, and Porto Digital, located close to the Port of Recife.

Specifically regarding the OPS system, it was stated that, as long as there is no national regulation on the subject, with imposition of use, it is unlikely that there will be sufficient mobilization to carry out the necessary adaptations on ships so that they start using shore energy while docked. The existence of facilitated financing is essential to provide the necessary infrastructure in ports/terminals, whose projects are not financially viable if the amortization of the investment needs to be reversed in a tariff increase, after all, the shipowners' priority is the cost of the energy supplied. In the same vein, another comment states that, as the system is expensive, it is of no interest to shipowners, and will only occur due to regulation.

Regarding measures to replace operational equipment, advances in technology or even the availability of synthetic fuels at competitive prices are still awaited. Charging time for equipment electrified by batteries is still a challenge, as current technology is not yet robust enough from the point of view of power and duration of charges. Another issue lies in the important space that the equipment storage and recharging structure will occupy in the terminals, which are already reaching their occupancy limit. These factors make electrification difficult, giving way to the possibility of synthetic fuels.

The transition to cleaner and more sustainable energy sources in ports is a complex task that requires in-depth studies to determine the specific vocations of each port or region of the country. This analysis must consider factors such as the types of cargo handled, the types of ships operating, and market demands. Discussion about the feasibility of specific energy solutions for each location is essential to ensure an effective transition. This approach will help direct strategic investments, either in hydrogen, ammonia or other energy alternatives.

It is important to highlight that the technology necessary for this transition is still expensive and, in many cases, inaccessible. The cost of implementation is a significant barrier and the transition involves substantial investments in infrastructure and technology, which can be complicated due to existing port structures. Uncertainty regarding new energy legislation and regulations makes cooperation between all stakeholders imperative, which has the potential to reduce the time, effort and, in many cases, costs involved in transitioning to more sustainable energy sources in ports.

Additionally, some challenges were raised to advance in the construction of a decarbonization strategy:

- Port facilities
    - Internal management of port facilities, such as the lack of autonomy in the environmental sector and little interaction with the engineering sector.

    - Difficulty in hiring a specialized consultancy that would be capable of proposing a decarbonization plan that adheres to the port reality.
- Port authorities
    - Difficulty in influencing private port operators and terminals to implement energy transition and decarbonization measures.
    - Deficiency in infrastructure, which often needs improvements to accommodate larger and more modern (less polluting) vessels, opening up business opportunities.
    - Regulatory difficulties and lack of financial investment.

4.4.1 Future Sector Perspectives and Key Partners

One of the questions on the form asked about the existence of announced demand from vessels for the supply of renewable fuel, especially hydrogen and derivatives. Five (5) actors (Porto do Açu, Porto do Itaqui, Terminals of Tubarão and Praia Mole, and Cattalini Terminais Marítimos) responded that they believe this demand has been announced, citing ammonia, biofuel, HVO and ethanol. Other non-renewable fuels were also mentioned, but with reduced emissions compared to those most used today, namely LNG and VLSFO mixed with biocomponents.

Vessels of the future will have to migrate to low-carbon fuels to meet IMO targets. As an example on the international scene, Maersk ordered the first methanol-powered container ship, which will enter into operation at the beginning of 2024. In addition, the company has an order for another 24 methanol-powered ships to be delivered between 2024 and 2027 (EPBR, 2013). Despite not yet receiving demand for vessels for the service, it is clear that there is an understanding on the part of the facilities regarding the importance of preparing the necessary infrastructure. Shipowners working in Brazil are understanding what direction the market is taking and it would not be viable to pay for facilities without having a counterpart, or even local or national market regulation that requires the advancement of these technologies. On the other hand, one of the actors responded that an informal survey carried out indicated that there was no interest in the subject on the part of the ships.

A survey was also carried out on how each port facility understands its vocation in relation to the low-carbon hydrogen value chain, shown in Figure 7. It draws attention to the large number of respondents who stated that they did not see potential in this market or were unaware of its application possibilities. In the case of terminals, this proportion is 82%, compared to 37% in the case of public ports. The remaining terminals are divided between 8% who see opportunities in creating a green hydrogen hub, another 8% in vessel refuelling and just 3% in exports, with none highlighting the possibility of production. On the other hand, among public ports, attention is drawn to the significant 26% who consider their vocation to be linked to the production of green hydrogen, followed by the creation of a hub, with 19%, exports, with 11%, and supply, with 7%. Table 4 presents some prominent initiatives by public ports and terminals in the low-carbon hydrogen value chain, gathered from the responses to the form and supplemented with publicly available information.

One hypothesis for this difference in the panorama in the responses from public ports and terminals is the profile of the groups of actors that made up the research sample. Despite the differences in cargo movement, the Public Ports category covers a more homogeneous sample of actors, which are the port authorities in charge of managing these ports. Meanwhile, the Terminals category covers a large number of Private Use Terminals (TUPs), Leased Terminals and Cargo Transshipment Stations (ETCs), which have very different characteristics in relation to size, type of operation, services provided, increasing the possibility of including actors for whom opportunities related to hydrogen do not present such significant potential.

A strategic factor for the success of low-carbon hydrogen initiatives in port facilities is the presence of industry in their area, which could consume part of the hydrogen and its derivatives produced, as an energy source or raw material for the production of low-emission products. 59% of responding facilities have at least one industry in their area of operation, with emphasis on the liquid and gaseous bulk sectors (20%), petrochemicals (12%), naval and offshore (11%), food and beverages (11%), power generation (10%), steelmaking (9%) and metallurgy (9%). The refinery, fertilizer and steel industrial sectors, for example, already consume large quantities of hydrogen produced from fossil fuels and port facilities could benefit from the proximity of industries like these.

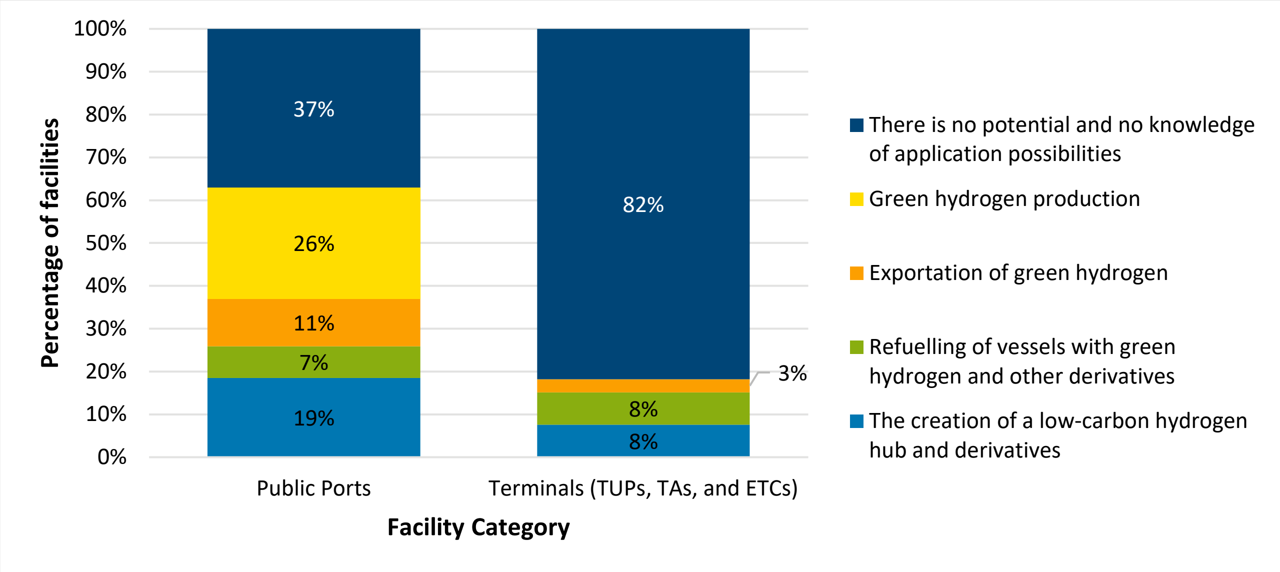


Figure 7. Vocation of the port facility in relation to the low-carbon hydrogen value chain.
Source: Prepared by WayCarbon, GIZ, ANTAQ, MPOR (2023).

Table 4. Highlight initiatives by public ports and terminals in the low-carbon hydrogen value chain.

Port Facility	Initiatives in the low-carbon hydrogen value chain
Pecém Industrial and Port Complex	Launched in 2021, the Pecém Complex Green Hydrogen Hub is the result of a partnership between the Government of the State of Ceará, the Federation of Industries of the State of Ceará (FIEC) and the Federal University of Ceará (UFC), with the aim of transforming the state into a major global supplier of this fuel. Since then, around 30 memorandums of understanding have been signed with several companies interested in setting up in the area to produce and export green hydrogen. Three of the partnerships, with AES, Casa dos Ventos and Fortescue, evolved into pre-implementation contracts, with the intention of building a structure within the port for the transport and shipment of fuel. In May 2023, agreements were signed to create the Green Hydrogen Corridor between the Port of Pecém and the Port of Rotterdam, and the Green Ports Partnership, between Ceará and the Netherlands. In September 2023, the environmental license was approved for Hub deployment. The memorandum of understanding with Qair provides for more than R$32 billion in the facility of the Dragão do Mar offshore wind farm, under licensing at Ibama.
Port of Açu	The implementation of a 100 ha green hydrogen hub in the Porto do Açu area is in the environmental licensing process. In recent years, the port facility has been seeking partners to invest in green hydrogen production plants, photovoltaic solar energy, offshore wind, biomass, biogas and industries that are part of this value chain. Port of Açu has already signed partnerships to install hydrogen plants with Shell Brasil, Linde, Comerc, Casa dos Ventos, Comerc and Neoenergia. For offshore wind energy production, partners to date are EDF Renewables, TotalEnergies, SPIC and Neonergia. The coast of Port of Açu already has 33GW of offshore wind projects under licensing at Ibama, making the port-industry a platform for low-carbon industrialization. In addition, partnerships were established with ZEG Biogás and Geo Biogas & Tech to install biogas plants.

Port Facility	Initiatives in the low-carbon hydrogen value chain
Suape Port Industrial Complex	In 2022, the TechHub Hidrogênio Verde proposal was launched, with the aim of transforming the Suape Port Industrial Complex into a space for research, development and innovation focused on the fuel of the future. The result of a partnership between CTG Brasil, the National Industrial Learning Service (SENAI) and the government of the State of Pernambuco, the initiative aims to concentrate in Suape the implementation of innovative projects focused on the production, transport, storage and management of green hydrogen (H2V), with an initial investment forecast of up to R$45 million. In 2023, TechHub was one of those selected by the Brazil-Germany bilateral call to develop technologies aimed at producing green hydrogen (H2V), with a total amount of financing of R$21 million.
Ports of Paranaguá and Antonina	The port authority Portos do Paraná, which manages the Ports of Paranaguá and Antonina, signed a memorandum of understanding with the Port of Rotterdam in 2023 to promote sustainable initiatives, as part of the Green Ports Partnership collaboration program. Lasting three years, the agreement involves a partnership to establish the development of renewable energy in the Ports of Paranaguá and Antonina, with a focus on wind energy and green hydrogen. Furthermore, the government of the State of Paraná sanctioned the State Renewable Hydrogen Policy and created the Green Energy Program, which includes the establishment of economic incentives for the sector.

Source: Complexo do Pecém (2023), Port of Açu (2023), Portal da Indústria (2022), Suape (2023) and Government of the State of Paraná (2023).

Another question on the form concerns the existence of local and international cooperation agreements, MoU (memorandum of understanding) or letter of intent with other ports and companies for low-carbon hydrogen initiatives and projects and its derivatives, with seven actors answering yes. Based on the comments sent and the advisory meetings, it was possible to compile some key actors for the decarbonization process, presented in Table 5. It should be noted that this is a non-exhaustive list, which only includes the actors mentioned by the participants in the diagnosis throughout the study.

Table 5. Key actors for decarbonization identified by participants in the diagnosis.

Type of stakeholder	Key Actors
International actors cooperation/coalitions	Climate Action Platform and UN Global Compact Ocean Business WG, Port of Rotterdam, Port of Aveiro, Green Ports Partnership collaboration program, Clean Energy Marine Hubs, CEM-Hubs Getting to Zero Coalition – LATAM Task Force
Forums and networks	CEBDS - Climate Thematic Chamber, FIRJAN - Climate WG and ATP – Sustentar, Cubo Itaú
Sector entities and associations	Senai, Brazilian Wind Energy Association (ABEEólica), International Renewable Energy Center (CIBiogás), Brazilian Oil and Gas Institute (IBP), Association of Private Port Terminals (ATP) and other associations in the port sector
Energy companies	Galp, Casa dos Ventos, Neoenergia, Qair, Biocarbono, Casa dos Ventos, EDP Renewables, Lorinvest, Shell, Total Energies, Universal Kraft, Linde/White Martins, SPIC, Ocean Winds and GeoTech
State actors	ANTAQ, MPOR, ANP, MCTi, MMA, Ministry of Finance, state governments (Ceará, Rio Grande do Sul and Rio de Janeiro were mentioned, which already have some type of policy or initiative for green hydrogen), energy concessionaires (Copel was cited), sanitation companies (Sanepar was cited), universities (the Federal University of Maranhão was cited)

Source: Prepared by WayCarbon, GIZ, ANTAQ, MPOR (2023).

5 CONCLUSIONS AND RECOMMENDATIONS

As discussed in the results, the preparation of the GHG Emissions Inventory is a crucial step in the journey towards decarbonizing ports. Understanding the sources of emissions and the factors that affect the carbon intensity of port operations is essential for the formulation and effective implementation of measures to reduce GHG emissions. Although there are marked differences between public ports and terminals in relation to carrying out inventories, in general there is a significant gap in this regard, due to factors such as lack of training, insufficient staff and limited funding. Preparing an emissions inventory is a great opportunity to enable the identification and evaluation of GHG emissions reduction projects, as well as defining decarbonization goals.

The decarbonization of port facilities is a pressing need that requires an integrated approach, involving a combination of different types of actions to achieve a significant reduction in emissions, which must be evaluated and selected according to the local reality of each port facility. The survey results demonstrate that some initiatives are already demonstrating greater progress, especially in areas such as intelligent logistics management systems, supply of clean fuels, energy efficiency measures and renewable energy generation. Measures that encourage energy efficiency through discounts on port fees and the replacement of operational equipment with cleaner models demonstrate positive progress, although still in the early stages. On the other hand, measures with high potential for reducing emissions, such as the OPS System, encounter greater difficulties in implementation.

The decarbonization of port facilities faces a series of challenges, ranging from technological and financial barriers to regulatory and marketing complexities. The prevalence of financial challenges was found to be most relevant in many initiatives, indicating that the availability of resources for implementation is a central concern. Furthermore, the lack of regulation and clear incentives for sustainability in the port sector represents an important obstacle that requires action by regulatory bodies and the government. Diagnosis participants also reported challenges internal to the organizations, such as the lack of autonomy in the environmental sector and little interaction with other areas. Given this scenario, the promotion of public policies and financial incentives has the potential to enable and accelerate the transition to more sustainable port operations.

Achieving IMO's GHG emission reduction targets for 2050 will require profound changes in the technology and fuels used by vessels. One of the most promising long-term solutions is the use of low-carbon hydrogen and its derivatives, such as ammonia and methanol, to replace fossil fuels. This will require adaptations to production, storage and distribution infrastructure, and port facilities have the potential to lead this movement. The majority (60%) of the diagnostic respondents do not see the potential or are unaware of the applications of low-carbon hydrogen. On the other hand, 40% of respondents already understand the potential of this market, with around 7.5% seeing a vocation for hydrogen production, 5.4% for export, and 7.5% for refuelling vessels. Almost 11% of facilities perceive as their vocation the creation of a low-carbon hydrogen and derivatives hub, which is already being planned or implemented in some Brazilian ports, with emphasis on the Pecém Complex, the Port of Açu, the SUAPE and the Ports of Paranaguá and Antonina. Brazil has good conditions to be a protagonist in the market for low-carbon hydrogen and its derivatives, in particular due to its installed capacity and potential for clean energy generation, and to the perspective of being able to produce low-emission fuel at competitive costs in the future.

Cooperation between interested parties, the promotion of effective public policies and investment in accessible technologies are key elements to overcome these challenges. The journey towards decarbonization must continue with a collaborative and strategic approach, aiming for a more sustainable future for port facilities. Based on the results of the diagnosis carried out, recommendations were drawn up for port facilities, structured based on the steps necessary to achieve greater maturity in relation to the decarbonization process. In addition, the next steps for sectoral action were proposed, which outline possible paths for joint action by actors to enhance the sector decarbonization in a broad way. The recommendations and next steps are presented below, in a summarized format, and are detailed in the Guidelines and Final Report documents.

Recommendations for port facilities

1. Prepare the GHG Emissions Inventory of port facilities;
2. Robust assessment of Scope 3 of existing GHG Emission Inventories;
3. Audit and publication of reports for greater reliability and transparency of GHG emissions inventories;
4. Mapping opportunities to reduce GHG emissions (including energy and operational efficiency actions, supply of less polluting energy and fuels, and action in the value chain of low-carbon hydrogen and its derivatives);
5. Preparation of the cost-benefit analysis of emission reduction measures; and
6. Establishment of SBTi target[3] (based on science).

Next steps for sectorial action

1. Awareness program for preparing inventories and decarbonization strategies;
2. Structuring a national discussion forum that articulates the various networks that deal with decarbonization;
3. Preparation of Sectoral Inventory of GHG Emissions;
4. Development of a sectoral emissions trajectory with survey of projects and construction of the cost-benefit analysis;
5. Incorporation of more questions about decarbonization in the EPI form;
6. Definition of inducing mechanisms for the implementation of the OPS System; and
7. Regulation that promotes the use of alternative fuels on vessels, in conjunction with the Ministry of Mines and Energy.

[3] The SBTi Standard (Science Based Targets Initiative) is based on the need to establish a common understanding of what net-zero emissions targets are, based on the most recent and updated climate science, providing guidance, foundations, criteria and recommendations for their definition (SBTi, 2022).

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ANTAQ Agência Nacional de Transportes Aquaviários

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