Carbon footprint in ports: how to measure and understand its impact

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Calculating the carbon footprint of ports has become an essential tool for understanding and managing the climate impact of these strategic infrastructures. Measuring greenhouse gas emissions enables the identification of the main sources of emissions, the evaluation of the efficiency of the measures adopted, and the development of mitigation strategies based on quantifiable data.

Given that ports are complex ecosystems where multiple stakeholders, activities and energy flows converge, the process requires clearly defining the boundaries of the calculation, gathering reliable information from various organisations and selecting appropriate emission factors. Defining the boundaries is fundamental to ensuring the robustness and comparability of the calculation, whilst coordination between port authorities, shipping companies, terminal operators, transport providers and other organisations is essential for obtaining accurate data.

Beyond regulatory compliance, calculating the carbon footprint offers ports the opportunity to optimise processes, improve energy efficiency, drive joint emission reduction initiatives and strengthen their sustainability. Ultimately, calculating the carbon footprint enables ports to take an active role in the global energy transition and consolidate their relevance in an increasingly sustainable and resilient international trade.

Climate change is one of the main challenges of the 21st century. This phenomenon poses a significant risk to ports, their operations and infrastructure, and consequently to local, national and global economies. Against this backdrop, it is essential that all productive sectors take responsibility, adopt measures to reduce greenhouse gas emissions, drive the transition towards more sustainable energy sources and contribute to **mitigating** the impacts of climate change.

To understand an organisation's impact on the climate, the first step is to measure its **carbon footprint**. The carbon footprint is defined as the calculation of the total greenhouse gases emitted directly or indirectly as a result of an organisation's activities over a given period of time. These gases, known as **greenhouse gases (GHGs)**, accumulate in the Earth's atmosphere and have the ability to absorb infrared radiation, trapping heat and contributing to global warming.

This measurement approach, widely adopted across numerous sectors, takes on particular significance when applied to complex and strategic infrastructure such as **ports**, where multiple activities, stakeholders and energy flows converge. Whilst ports play an essential role in global trade, and maritime transport is one of the most energy-efficient modes of transport, they are also a significant source of GHG emissions. At the same time, the port sector is adopting an increasing number of emission reduction commitments, reflecting a clear commitment and laying the foundations for the **energy transition**.

What does 'carbon footprint' mean in a port context?

Calculating a port's carbon footprint is a labour-intensive process that requires taking into account the various organisations involved: port authorities, shipping companies, terminal operators, trucking and rail companies operating at the port, etc., depending on the specific configuration of each port. It also involves the collection of detailed data on port activities, such as the **energy consumption** of ships and technical-nautical services in port waters, terminal machinery, lorries moving within the port area, and in buildings, etc., with the aim of obtaining an accurate and comprehensive assessment of the port's impact on GHG emissions.

By calculating their carbon footprint, ports can identify their main **sources of emissions**, implement **mitigation measures** and assess their effectiveness, as well a , develop more effective strategies to **reduce their environmental impact**. Beyond **regulatory compliance**, calculating the carbon footprint supports broader **sustainability** objectives. By improving energy efficiency, optimising operational processes and implementing mitigation measures, ports can **reduce their emissions,** achieve **cost savings**, enhance their **corporate reputation**, attract **responsible investment** and access **sustainable markets** and **financing** opportunities**.**

Defining the scope of the calculation: where to start and what to include

To calculate a port's carbon footprint, the first step is to establish the **calculation year**; the first year of calculation is particularly important, as it will define the **base year**, and future years will be calculated based on the figures established for that year, in order to compare **trends** and, where applicable, **calculate reductions**. When establishing the base year, it is recommended to use the most recent calendar year for which robust data is available, although this study can be adjusted to a financial year, or a previous year may be used.

Next, the **calculation boundaries** are defined, using the guidelines of the GHG s Protocol (WRI et al., 2004), as a reference, which distinguish between the following aspects:

- **Organisational boundaries**: these define the scope of the organisation to be included in the calculation. There are two main approaches to establishing them:
  - **Control**: considers all emissions from operations over which the organisation has operational or financial control.
  - **Ownership share**: considers the proportion of emissions for which it holds a shareholding.
- **Operational boundaries**: these define which sources of GHG emissions are included in the calculation based on the organisation's operational activities. The typical structure of a port's carbon footprint, in accordance with the provisions of the "Methodological Guide for the Calculation of the Carbon Footprint in Ports" developed by Puertos del Estado (Puertos del Estado, 2024), would be as follows:
  - **Scope 1**: direct emissions from sources directly controlled by the port authority.
  - **Scope 2**: indirect emissions associated with the generation of electricity purchased and consumed by the port authority.
  - **Scope 3**: other indirect emissions from the remaining organisations that form part of the port, such as ships, technical and nautical services, terminals, lorries, railways, etc.
- **Geographical boundaries**: in a port environment, these define the physical boundaries taken into account for the movement of ships, lorries, trains and other mobile emission sources. For example, in the case of ships, one might consider whether to include the anchorage area or part of the journey from the previous port.

Emission sources and data: how to calculate the carbon footprint

Once the boundaries have been defined, the next step is to identify the **emission sources**, that is, those activities, processes or pieces of equipment within the port boundaries that release GHGs into the atmosphere. In the port environment, emission sources are numerous and diverse, as they encompass both maritime operations and land-based

activities. It is therefore necessary to carry out a systematic **inventory** of all elements within the various port organisations that may generate GHGs, ranging from terminal machinery and ship engines to building lighting.

Once the emission sources have been identified, the process of compiling **data on port activity** during the study year and within the predefined limits of the calculation begins. In practice, this process involves reviewing invoices, delivery notes, operational records, meters, maintenance reports and any other available source of information reflecting consumption and the activities carried out by port organisations. **The quality of the calculation depends largely on the accuracy of the data collected**; therefore, it is important to organise the information carefully, distinguishing between different types of consumption and using the appropriate units.

At the same time, it is necessary to identify the **emission factors**, which are conversion coefficients indicating the amount of GHG emitted for each activity data point. These values can be found in official databases, reports from international organisations, and even in documents provided by the energy producers or suppliers themselves. In Spain, the Ministry for Ecological Transition and the Demographic Challenge (MITECO), through the Spanish Office for Climate Change (OECC), publishes the country's official emission factors annually (MITECO, 2024). These values include emission factors for fossil fuels, refrigerant gases, electricity, and other supplies, taking into account the specific characteristics of each electricity supplier and energy source. For GHG emissions from ships, the International Maritime Organisation's "Fourth Greenhouse Gas Study" provides specific emission factors according to the type of ship and fuel used (IMO, 2020). In order to obtain reliable emissions results, it is important **to select appropriate emission factors, specific to each type of activity, which are up to date and adapted to the region and the corresponding type of consumption**.

Once the activity data and relevant emission factors have been collected, the carbon footprint can be calculated using the following formula:

GHG emissions = Activity data * Emission factor

In a port, the carbon footprint is calculated separately for each type of organisation (port authority, ships, technical and nautical services, terminals, lorries, railways, etc.), taking into account their specific emission sources, applying the corresponding emission factors and paying attention to the units used. Once the GHG emissions from each source have been calculated, they are added together to obtain the value for each **area**, for each **scope**, and finally, the **port's** total **carbon footprint**. Generally, the results are expressed in **tonnes of carbon dioxide equivalent (tCO_2e)**.

From theory to practice: challenges and recommendations for calculation

The concept of a carbon footprint is relatively simple: it involves **measuring the impact of an organisation's activities on the climate**. In practice, however, ports are complex ecosystems where multiple stakeholders, processes and energy flows converge, making the application of this concept far more labour-intensive, as it requires not only technical understanding but also experience, coordination and strategic decisions tailored to the operational reality of each facility.

One of the main difficulties in calculating a port's carbon footprint is the very nature of **the port environment**. Unlike other entities, a port functions as an ecosystem where multiple organisations operate with very different activities, consumption patterns and, consequently, emissions. This organisational diversity complicates the **definition of scope** and the **setting of boundaries**, and requires close **coordination** to ensure that all parties understand what is to be measured, using what criteria and how. To this end, it is recommended to clearly **define** from the outset the **boundaries** of what will be included in the calculation, distribute data collection **templates** to standardise the necessary information, hold regular **meetings** with the various parties involved to resolve queries, and constantly **monitor** the **data collection and validation** process.

In the same vein, another challenge in calculating a port's carbon footprint is **defining its boundaries**. Beyond a simple administrative demarcation, it is necessary to specify exactly what is meant by 'port' for the purposes of the calculation. This raises questions such as whether to include companies located outside the port area whose activities are closely linked to it, such as the potential inclusion of logistics *depots*. It is also necessary to define the geographical boundaries for land transport (for example, how far to take into account lorry journeys) and the point from which ship emissions are accounted for. In practice, these decisions have a significant influence on the results and on the ability to **compare** the carbon footprint, both with other ports and with measurements taken in previous or future years. It is therefore recommended that the **criteria** used to define the scope of **the base year** calculation be clearly and consistently defined **and documented**, so that the **scope** of the study is understandable, consistent and appropriate to the stated objectives.

Another recurring difficulty relates to **obtaining** reliable and consistent **data**. This requires a thorough understanding of the operations of each type of organisation in order to request the specific data that truly reflects their GHG emissions. Furthermore, much of this information does not depend directly on the port authority, but on third parties who do not always have data collection systems designed for environmental purposes. It is common to encounter incomplete data, rough estimates or information presented in disparate formats, which necessitates making assumptions and simplifications. In practice, the greatest effort in calculating a carbon footprint is not usually in applying the methodology, but in the collection, validation and processing of the available data. In this regard, it is recommended to establish standardised data collection **templates** from the

outset to ensure consistency of information, hold regular **meetings** with the various stakeholders to clarify any doubts, and constantly monitor the quality and consistency of the data throughout the process.

Finally, in many ports, the majority of the carbon footprint stems from **indirect emissions** associated with activities over which the port authority has no direct operational control, such as maritime transport, terminal operations or land traffic. At first glance, this may give the impression that the results are beyond its influence and that its scope for action is limited. However, measuring these emissions makes it possible **to identify where the main impacts on the climate are concentrated and where the greatest opportunities for action lie**. In this regard, calculating a port's carbon footprint enables the **port authority** to **collaborate** with the various organisations involved, **promoting and facilitating joint initiatives** to reduce the port's emissions and improve its **sustainability**.

From calculation to action: the carbon footprint as a tool for more sustainable ports

Calculating the carbon footprint has become an **essential tool** in a context marked by growing concern over climate change and an increasingly stringent regulatory framework regarding GHG emissions. For ports, this exercise goes beyond regulatory compliance: it represents a necessary first step towards understanding their actual climate impact and positioning sustainability as a **strategic pillar** of their operations.

As we have seen, a port's carbon footprint is not a simple concept, but the result of the **interaction** of multiple stakeholders, activities and energy flows coexisting within the same environment. Properly defining the **boundaries**, identifying the main **sources of emissions** and collecting **reliable data** are key decisions that determine both the robustness of the calculation and the usefulness of the results obtained. Far from being a mere technical exercise, calculating the carbon footprint requires **knowledge** of port operations, **coordination** between organisations and informed, transparent **decision-making**.

Despite the challenges it may entail, measuring the carbon footprint delivers significant value. It enables **the identification of** where **GHG emissions** are concentrated, **the prioritisation of actions**, **the assessment** of the impact of **measures** implemented, and **the development** of data-driven **mitigation strategies**. Furthermore, in an environment where a large proportion of GHG emissions are indirect, this analysis provides port authorities with a solid basis for exercising **leadership, collaborating and** driving joint initiatives with the various organisations within the port.

In this regard, calculating a port's carbon footprint should not be seen as an end in itself, but as a tool for **continuous improvement**. Used consistently and with a medium- to long-term vision, it facilitates **process optimisation**, **improved energy efficiency**, **access to funding** linked to environmental criteria, and the **strengthening of the** port's **position** in an economic context increasingly focused on sustainability.

In short, making progress in the calculation and management of the carbon footprint enables ports to tackle the challenges of climate change more effectively, actively contribute to the **energy transition**, and consolidate their role as essential infrastructure for more **sustainable** and **resilient** international trade.

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