Ports Energy and Carbon Savings

Deliverable 1.1.4

Protocol and guidelines for port energy audit methodology, including procedure, questionnaires, and formats

Project No. 2S03-009

With the financial support of

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Revision history

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Glossary of terms

Carbon footprint	Measure of carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulphur hexafluoride (SF_6), a set of perfluorocarbons (PFCs), and hydrofluorocarbons (HFCs), represented in carbon dioxide equivalents (CO_2e).
Carbon sink	A natural or artificial reservoir that accumulates and indefinitely stores a carbon containing compound.
CH_4	Methane
CO_2	Carbon dioxide
CO_2E	Carbon dioxide equivalent
Emission factor	The average emission rate of a given GHG for a given source, relative to units of activity
Emission source	A process, system, or location which emits or leads to the emission of GHGs.
Energy audit	Systematic investigation and reporting of the use of energy in a system or process.
GHG	Greenhouse Gas
GWP	Global Warming Potential
HFC	Hydrofluorocarbons
LCA	Life Cycle Assessment
NO_X	Nitrous oxides
PFC	Perfluorocarbons
Scope 1	Direct emissions of GHGs from owned or controlled processes.
Scope 2	In-direct emissions of GHGs associated with the consumption of electricity.
Scope 3	Indirect emissions (not included in scope 2) that occur in the value chain, including both upstream and downstream emissions.
SF_6	Sulphur hexafluoride
Tier 1 method	Applies default IPCC emissions factors and other parameters and may make assumptions about some sources and sinks.
Tier 2 method	Applies country specific emissions factors and other parameters.
tier 3 method	Applies specific emissions factors and other parameters relevant to the activity, source, or sink.
IPCC	Intergovernmental Panel on Climate Change

1. Introduction

Concerns over the adverse effects of climate change resulting from the anthropogenic discharge of GHG emissions has prompted governments and organisations worldwide to make efforts to reduce emissions associated with fossil fuel consumption.

To enable better management, a variety of tools have been developed and are being implemented, such as energy audits and energy auditing programmes. Whilst these programmes are widespread, there is also an increasing move to implement carbon footprinting and life cycle assessment (LCA) techniques to better to measure the full extent of greenhouse gas (GHG) emissions associated with specific operations.

The need for such measurement and the introduction of these tools is seen as an imperative for all businesses in all sectors of industry, none more so than the maritime industry, and ports and port operating environments in particular. It is widely documented that the industry has been slow to respond to the challenges of anthropogenic climate change, with small and medium sized ports facing a specific set of issues that have held back the introduction of innovative interventions. By way of enabling more efficient energy consumption and reduced GHG production, such ports require easily operable and efficient systems for measuring energy usage as well as enabling a better understanding of subsequent atmospheric emissions.

This protocol outlines the procedure and guidelines relating to the energy audit methodology discussed in D1.1.1. It outlines a comprehensive system of energy auditing and associated GHG emissions, detailing approaches to calculating the carbon footprint of the three key 'scopes'. The key in utilizing the tool, is to enable it to direct data gathering so as to better manage energy efficiency in the future, but also to see it as a flexible system that allows for different boundaries to be drawn based on what is realistic at the time. Going forward, if ports are committed to reducing their carbon footprint, then the tool will allow them both to consider their impacts and identify their solutions.

2. Who should use this protocol?

This protocol is written from the perspective of a port, or a port operating company, seeking to perform an energy audit and develop a carbon footprint of their business operation, either across their jurisdictional area or a part thereof. Equally it may apply to companies operating within a port environment, or whose primary business operation is related directly to the operation of a port or similar environment (e.g. container terminal operators, marina operators). The protocol and related tools will provide quantification of energy use in the study area, carbon footprint, and will quantify offsets related to low carbon initiatives.

It should be noted that it is considered unlikely that individual ports will be able to collect all relevant data highlighted in this Protocol. However, it is assumed they will be able to provide some, and that this would then act as the minimum baseline against which to assess any future carbon savings made as a result of purposeful interventions.

3. Guiding principles

Energy audits and carbon footprints are closely related, serving to identify and improve energy efficiency and reduce GHG emissions. The purpose of an energy audit therefore is also to enable the identification of actions and barriers to improve energy efficiency.

The process consists of a systematic examination of the use of energy in a system. Generally, audits are applied for the identification of energy losses and their quantification; an estimation of conservation potential; the development of the technological options available for energy conservation; and the economic feasibility of those options. The carbon footprint further develops this process and seeks to reduce the risk of climate change through the identification of sources and sinks of GHG emissions. The method therefore enables effective and targeted reductions in GHG emissions.

For both methods, users should ensure the audit and footprint is *effective*, *timely*, and *representative* to enable appropriate action.

3.1. Effective

The objective of any energy audit is to improve energy efficiency. In physical terms, efficiency is defined as the ratio between the useful output from a system and input of an energy conversion process. The EC (2006) defines energy efficiency as “a ratio between an output of performance, service, goods or energy, and an input of energy” (EC, 2006). Importantly, energy efficiency should not be confused with effectiveness – a highly inefficient system that wastes most of its input power, but performs its intended function is effective but inefficient. Efficiency therefore must consider the desired effect of the system; with system effectiveness maintained in the pursuit of efficiency.

In addition, any measure to improve energy efficiency should not cost more in material and energy investment than is saved through the change in the system. This requires improvement measures to fulfil two specific requirements: i) the improvement in energy efficiency is made with no negative effect on the function or performance of the system; and, ii) the improvement demonstrates an energy saving across the life cycle of the intervention.

3.2. Timely

Results of both the energy audit and the carbon footprint should be calculated and delivered in a timescale, to be current, and to enable effective action. Results should be calculated for the most recent period for which data are available, to provide an accurate picture of energy consumption and emissions. For example, where investment programs are dependent in cycles of financial reporting, current and effective data should be available to enable effective strategic decision-making and budgetary allocation. Similarly, if progress and monitoring is set to intervals, then the objective should be to prepare the most recently available data for those periods.

3.3. Representative

The results of an energy audit and/or a carbon footprint should enable identification, evaluation, and application of energy saving and GHG emissions reduction opportunities. It should therefore be as inclusive, broad, and accurate as is practicable in order that cost-effective GHG reduction strategies can be realized. Data should be presented in a manner that enables the most effective analysis and action. The presentation of a single headline figure may obscure the ability to provide targeted action, therefore the results should be presented with enough granularity to represent specific areas of operation and business.

4. Energy audit

Energy audits are applied for the identification of energy losses, their quantification, estimation of conservation potential and the development of technological options for energy conservation and the economic feasibility of those options. An 'energy audit' can describe a broad spectrum of activities ranging from simple visual walk-through inspections to detailed computer simulations of building energy physics. There is no single agreed-upon set of defined terms for the various types and levels of energy audits. The simplest audits consist of a walkthrough (alternatively called a preliminary or screening audit) to provide a brief review of operational energy costs and to identify areas for immediate improved energy conservation. Examples might include adjustments to heating temperatures, repairs to broken building fabric, or insulation on exposed pipework. Corrective measures are only briefly considered, and more detailed investigation would be required to make informed decision on actions to be taken. More detailed audits might examine the operating costs of a facility. The data can be interrogated over several years to provide patterns of daily, weekly, monthly, and annual energy use. The detail provided enables the identification of peak energy demand – both by location and time, the effects of weather patterns, seasonality.

5. Carbon footprint

The concept of the carbon footprint is closely related to the practice of energy auditing, with the data necessary for the calculation of a carbon footprint commonly provided by some derivation of an energy audit. Indeed, the carbon footprint calculation is in large part driven by energy consumption within the system of study. The carbon footprint in this instance refers to the total emission of the 'Kyoto Basket', which includes six important GHGs namely carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), sulphur hexafluoride (SF_6), a set of perfluorocarbons (PFCs), and hydrofluorocarbons (HFCs). These six are also referred to as a 'climate footprint'.

At its most simple the carbon footprint is calculated as a mass of emissions of a GHG per unit of activity, an '*emissions factor*', represented using carbon dioxide equivalents ($kgCO_2e$). Carbon dioxide equivalents are calculated using Global Warming Potential (GWP) values, released by the IPCC, expressed as the equivalent amount of CO_2 for a given GHG that would have the same effect on climate if emitted to the atmosphere. The carbon footprint is commonly used as the GWP or climate change impact category in Life Cycle Assessment (LCA).

5.1. Emissions factors

The most common approach to the calculation of a carbon footprint is using emissions factors. An emissions factor is a representative value that attempts to relate the mass of a pollutant released to an activity associated with the release of that pollutant. For example, the activity could be tonnes of coal combusted (mass of coal combusted), which is multiplied by a given emissions factor for the combustion of coal, providing quantity of GHG emitted per of unit combustion. These factors are normally developed based on previous detailed studies of specific emission sources. Rarely is it efficient or indeed possible to measure emissions directly, therefore emissions factors are applied throughout the protocol for the calculation of the carbon footprint.

5.2. Scopes

Most carbon footprint methods consider emissions in terms of 'scopes', defined by the World Resource Institute and World Business Council for Sustainable Development, which relate to the spatial boundary and level of control over the emission source. 'Scope 1' is defined as a direct emission within the boundary of the port; emissions sources include all emissions arising as a direct result of the organisation or system (e.g. emissions from in-boundary fuel combustion). 'Scope 2' considers emissions from grid connected electricity, steam, and heat. Typically, electricity generation is essential for supplying most activities in the port. 'Scope 3' expands the definition to include other indirect up- and down-stream emissions associated with the port. For example, emissions from marine transportation within the boundary of the port.

This protocol considers all emissions sources in terms of the scope definition. Emissions sources and guidance is presented in accordance with scope 1, 2, 3. To meet the principle of the carbon footprint being *representative* it is highly recommended that all relevant scope 1, 2, 3 emission sources are included in the calculation.

5.3. Tiers

The IPCC emphasises the requirement to follow standardised and recognised, scientifically accepted principles for the measurement of a carbon footprint. Additionally, the IPCC consider data in the concept of tiers of complexity; the more complex the data, the more representative. Tier 1 methods are simple and quick, but also are the least accurate and specific. The methods rely on national and international statistics and emission factors, with limited region or case specificity. Tier 2 methods apply more region-specific data such as country-specific emissions factors or engineering estimates of technology efficiency. These methods are likely to require more work but yield more accurate results that are more specific to local conditions. Tier 3 methods are the most complex to apply but yield the most accurate results. Utilizing material mass balance calculations for fuel combustion; direct emissions monitoring and further mathematical modelling, estimates can be extremely accurate. The methods applied through the protocol are generally a mixture of tier 2 and 3 approaches, defined primarily on data availability.

5.4. Carbon dioxide equivalents and global warming potential

The carbon footprint accounts for a range of GHG emissions (for example CO_2, CH_4, N_2O, SF_6, CF_4, PFCs, HFCs), it is desirable to represent a single metric, rather than quantified emissions for each GHG. The unit applied for this purpose is CO_2 equivalents (CO2e), based on the calculation of Global Warming Potential (GWP). The GWP represents a given amount of GHG release over a time period, expressed as the amount of CO_2 that would cause the same effect if emitted to atmosphere. GWP values are released by the IPCC for three-time horizons, 20 years (GWP20), 100 years (GWP100) and 500 years (GWP500), although GWP100 is used almost universally in accounting methodologies and protocols. The IPCC published its first series of GWP values in its Second Assessment Report and have subsequently updated these values twice (refinements in climate science); it is important to note the most recent GWP (Table 1).

GHG	Global Warming Potential
CO_2 (Carbon dioxide)	1
CH_4 (Methane)	28
N_2O (Nitrous Oxide)	298
SF_6 (Sulphur hexafluoride)	23,500
PFCs (Perfluorocarbons)	1-7,240
HFCs (Hydrofluorocarbon)	1550

Table 1: GWP values and lifetimes from climate change 2013 (Myhre, 2013)

5.5. Biogenic sources and renewable fuels

It is often practice in carbon accounting to disregard emissions arising from biogenic sources. This is due to the assumption of 'carbon neutrality', where the emission of biomass-derived CO_2 over a short time period (i.e. less than 100 years) is negated by the photosynthetic absorption during the growth of new bio matter. There are noted risks in this approach – the absorption of CO_2 may not be instant (i.e. there may be a lag); it may produce erroneous recommendations, for example where deforestation is seen as preferable for fuel production. Therefore, all emissions whether biogenic or non-biogenic should be included and noted as such in reporting.

6. System boundaries

Ports primarily act as logistics platforms for the transfer and movement of people, goods, and services. They not only perform the requirements of the senders and receivers of goods and services but act as business partners alongside shipping companies, terminal operators, forwarding companies; whilst also operating as landlords to occupying industries. Furthermore, the operation of a port includes the wider system of maritime transport as a mutual derived logistics function (i.e. the port exists because of the demand for service, and the maritime operations visit because of the port). Ports seeking to undertake an energy audit, and/or a carbon footprint must first examine the issue of boundary selection. In very simple terms the boundary to consider all relevant sources of energy consumption, and emissions arising, from port activity. There are two key considerations when setting the boundary of the audit and/or footprint – geographic boundary and process boundary.

6.1. Geographic boundary

Simply put, the port is a place that handles ships, cargo, and passengers. In geographic terms the port serves as a transfer point for goods and services. Modern definitions also include a multi-functional logistic centre but simply put ports are at the intersection between transport, trade and customs. The geographic boundaries of the port are usually clearly defined by the limits of the port authority or port occupied land.

When developing an energy audit and/or carbon footprint sources related to the services rendered by the port authority and those industries operating within the port boundaries should be included; placing emphasis on the landside landward operations of the port authority and port operators. The advantage of the geographic definition is that it provides for an easily definable boundary for the port. Individual operations within the port can then be further disaggregated by operator or location for improved data granulation. Ports and harbours can apply these methods to recognise the energy and associated emissions arising from within their geographical operations. However, where these methods can recognise and stimulate local policy and response, they are not sensitive to the role of specific organisations within the port, nor the wider supply chain emissions occur outside the geographical boundaries of these communities. Therefore, it is also important to consider the process boundary of the port system.

6.2. Process boundary

Ports are responsible for a range of in-boundary energy consuming and GHG emitting processes (e.g. port transport, manufacturing), but also for a range of demand led transboundary processes (e.g. grid-connected electricity; imported products; water supply; maritime transport). These processes can be considered as 'direct' and 'indirect' processes. Direct processes include all those processes occurring within the geographic boundary of the port (6.1), not associated with grid connected energy production. This includes all emissions associated with in-boundary fuel consumption, industrial processes and port transport. Grid connected electricity (and other energy) are excluded from 'direct' processes owing to the commonly national nature of energy distribution (scope 1).

Indirect processes include all those that are outside of the geographic boundary of the port, including those associated with scope 2: electricity generation, and scope 3: primary energy production; out-of-boundary transport; water; waste, and products and services. These processes can be further classified by the position in the supply chain – upstream or downstream. Upstream emissions processes include services, energy and products supplied to a port. Downstream processes consider the outputs of in-boundary processes, including waste, and exported products and services. Significant sources of energy consumption and GHG emission will be associated with these sources, it is therefore important to consider all associated processes to maximise potential for energy reduction and carbon saving. Figure 1 considers a typical port and categorises the high-level energy consuming and GHG emitting processes that may be present. It is important to note that not all ports may exhibit all processes, therefore the boundary of the port should be established on a case by case basis, capturing the most *representative* picture of the port.

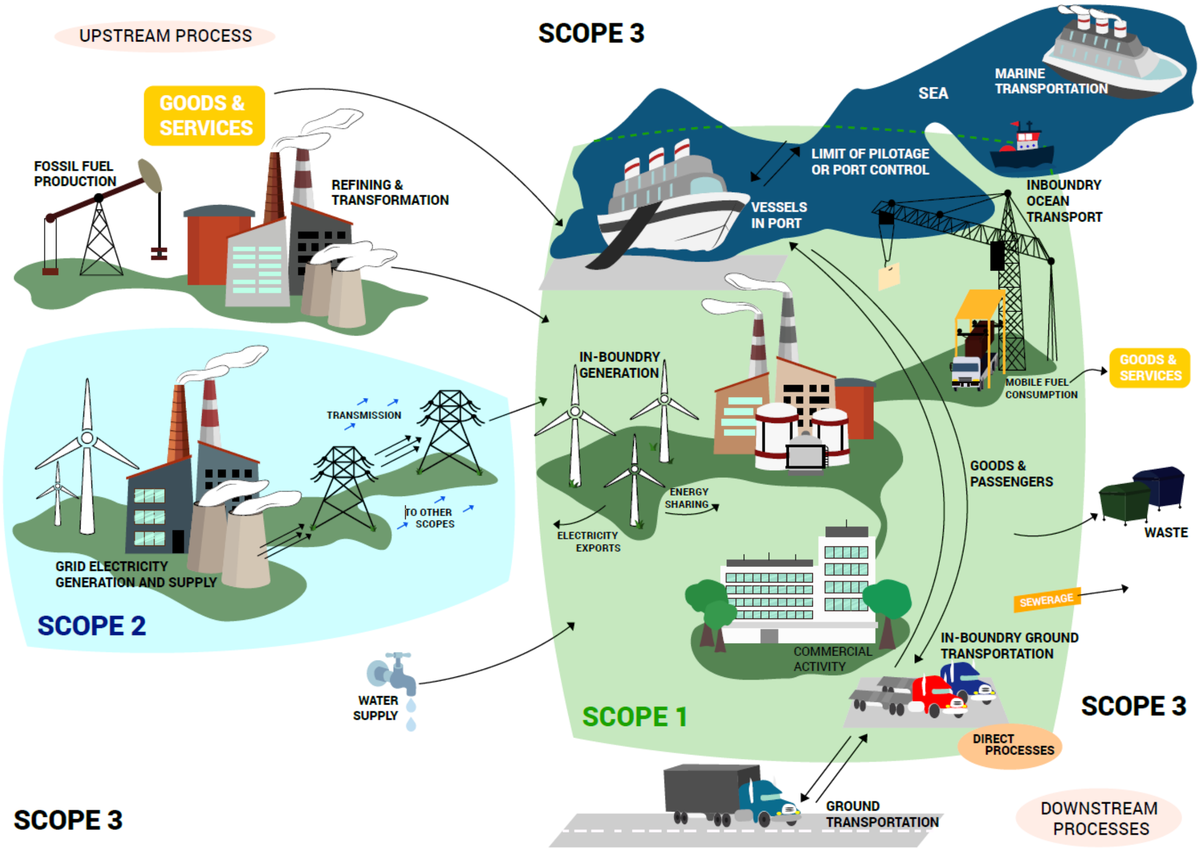

Figure 1: Port diagram indicating all energy and CO_2 emissions flows.

7. Calculation

The following sections present the calculation protocol for the development of an energy audit and carbon footprint of a port environment. The calculation protocol is structured to follow the scope 1, 2, 3 concept (5.2) and includes all processes that may be linked to a typical port. The overall process of the port audit methodology is shown in Figure 2, which includes reference to the subsequent relevant figures detailing specific aspects of the methodology.

Important note: Not all processes may be present at all ports; though those processes identified during boundary setting should be included.

7.1. Calculation process

Step 1: Set the goals, scopes and resources required to implement energy measure.

- Get acquainted with the entire process, activities and undertakings in the port.
- Set a boundary/scope of audit in the port. For example, the scope of study might focus on the main activities in the port such as the cargo handling, the logistic activities and not include leisure activity. Alternatively, the scope of study could consider every activity in the port.
- Decide on the time period for comparison and frequency for conducting the audit. This could depend on the available of data. For example, electricity consumption data in the port might be available for past three years or only available for the latest year. It is better to see the trend or change of energy consumption by using date from more than one year.
- Identify all areas within the port where significant potential energy saving may exist

Step 2: Check activities in the port regarding activities in scope 1, 2 and 3.

- It is important to know quantities, sources and types of fuels consumed in each activity using energy in the port. Identify each action or process which requires energy.
- For each action, ascertain the type of energy required (e.g. electricity, gas, oil, petrol, diesel etc.)
- Check the availability of data and choose type of data (for example either the amount of fuel consumed or the amount billed by the fuel provider). Check the availability of data in regional level or industry level to create a comparison or provide a best estimate where the exact data is unknown.

Step 3: Carbon footprint calculation (data processing)

- Each scope has different approach to obtain a total of GHG emissions and carbon footprint. The PECS tool will provide the output of a carbon footprint.
- By entering the amounts of fuel consumed in each port activity the final output will be total carbon footprint for the defined area of the port.

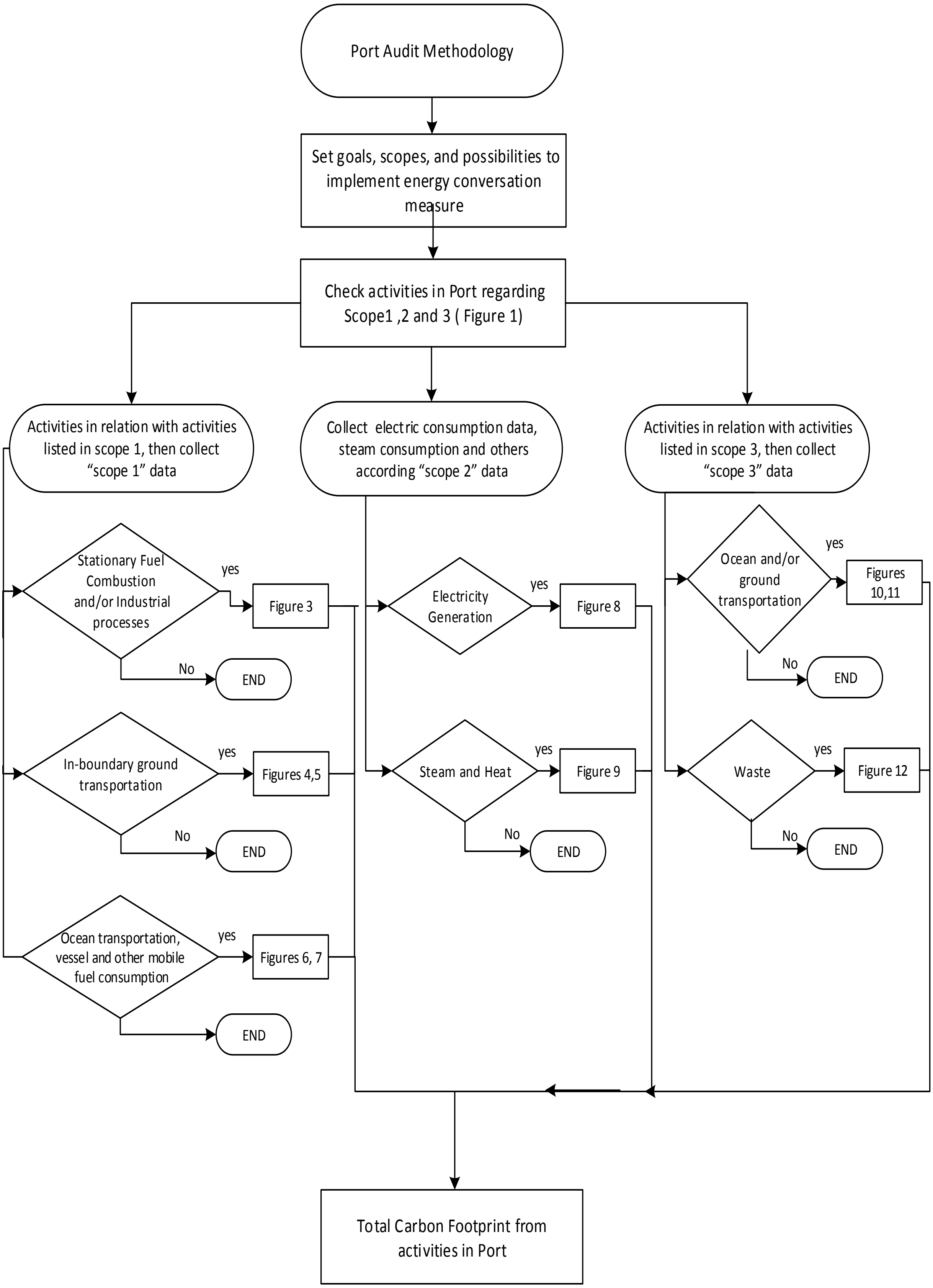

Figure 2. Port audit methodology

7.2 Scope 1

'Scope 1' is defined as a direct emission within the boundary of the port; including all emissions arising as a direct result of the organisation or system (e.g. emissions from in-boundary fuel combustion). Whilst it may be difficult to get a complete set of data associated with the direct operation of the port, it is nevertheless important to get as complete a set as possible so as to enable a meaningful assessment of the C footprint.

7.2.1 Stationary fuel combustion

Solid and liquid fuels may be consumed in a range of stationary (i.e. non-mobile, note some equipment is 'stationary', but in principle still mobile – e.g. cranes) processes, for example in generators or boilers. The consumption of these fuels represents an energy consuming process, and a source of GHG emissions.

An energy audit of these fuels, as shown in Figure 3, is completed through the calculation of total fuel consumption (mass) and total energy content (GJ). The carbon footprint for the combustion of solid and liquid fuels is calculated using the total mass or energy of the fuel consumed and recognised emissions factors for the fuel in question. These fuels also contain an embodied GHG emissions from the process of supply and refining prior to consumption. These emissions should be included in the calculation, using recognised life-cycle emissions factors. Table 2 summarises the data required to complete this calculation.

Where data is unavailable – for instance where the site is operated by a third-party organisation – proxy data may be estimated from energy intensity in the particular process (See appendix).

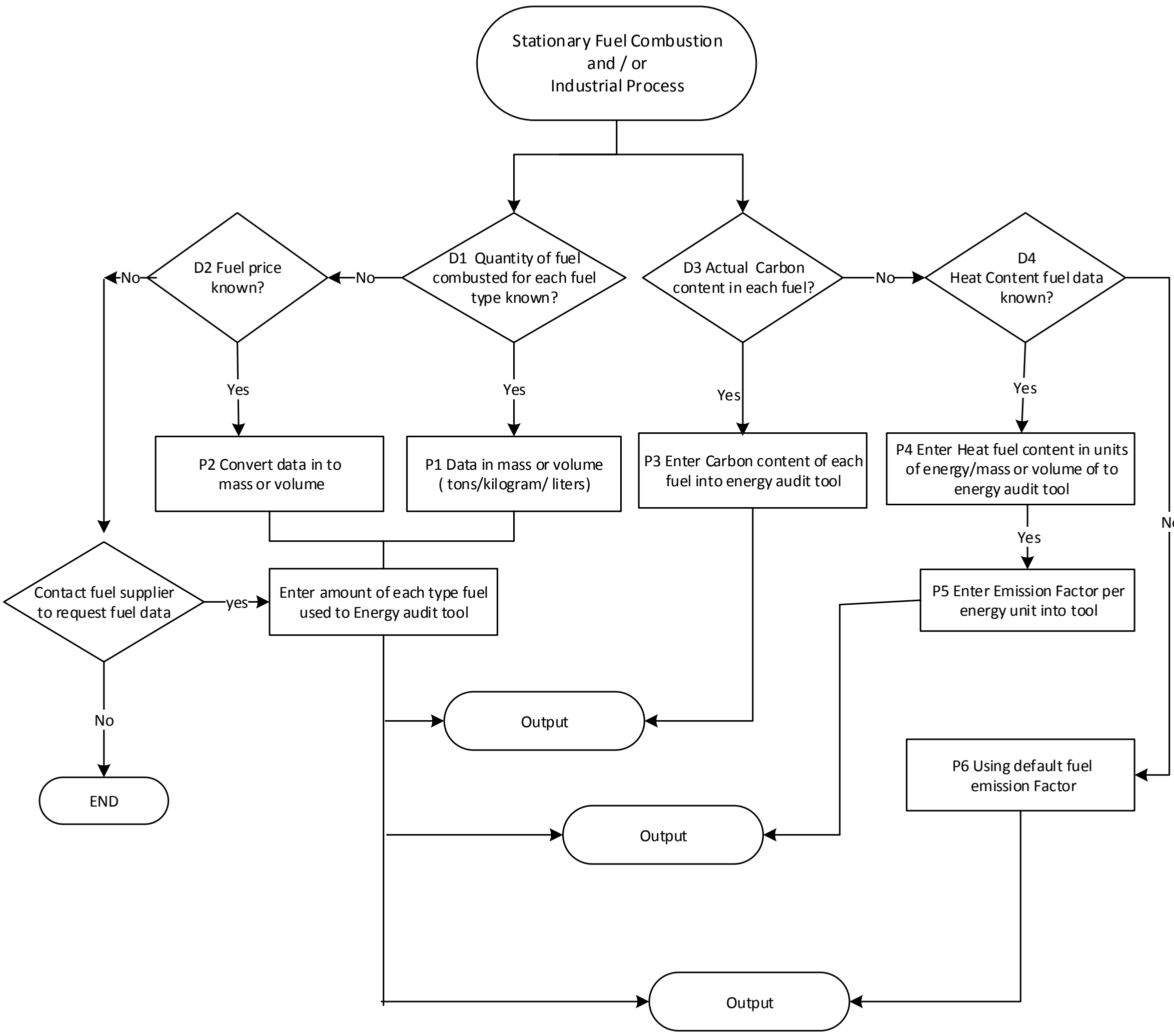

Figure 3. Procedure for the calculation emissions from stationary fuel consumption and industrial process

Data	Documentation Source
Total consumption (mass/cost) of fuel by type	Metered consumption reading, Utility bills, receipts, other documentation or records.

Table 2. Summary of data required and potential sources of data for the calculation of stationary fuel consumption

7.2.2 Industrial processes

Emissions from commercial and industrial activity occur as a result of energy consumption associated with physical or chemical processing (i.e., production/consumption of minerals; metal production; chemical production; and petroleum product end-uses). This category, shown in Figure 3, includes those processes relating to an industrial operation whose primary purpose is not energy generation. To avoid double counting, emissions associated with energy consumption should therefore be reported as being from either stationary fuel combustion, in the case of solid or liquid fuels; or electricity consumption in the case of electricity sources.

Table 3 identifies the data required, including potential sources of information, and the carbon footprint should be calculated using recognized emission factors relating to the activity or process in question. Similar to stationary fuel combustion, where data are unavailable – for instance where the site is operated by a third-party organisation – proxy data may be estimated from energy intensity in the particular process (see appendix).

Data	Documentation Source
Total consumption (mass/cost) of fuel by type	Metered consumption reading, Utility bills, receipts, other documentation or records.

Table 3. Summary of data required and potential sources of data for the calculation of carbon footprint of industrial processes

7.2.3 In-boundary ground transportation (port owned)

Ground transportation processes that consume energy and emit GHGs emissions include various means of transport such as passenger cars, heavy-duty trucks, trains, as well as mobile machinery with combustion engines, such as agricultural tractors. This category is concerned with ground transportation occurring within the geographic boundary of the port, from transport machinery owned and operated by the port, with the calculation process shown in Figure 4.

There are two methods which can be applied for calculating the energy demand and carbon footprint of transportation; namely an activity-based approach or an energy-based approach. Where data are available for actual fuel consumed (e.g. through metered sources or supply) this should be used, and relevant emissions factors applied. Alternatively, an activity-based approach allows for an estimate of distance travelled to be applied to calculate energy demand and carbon footprint. This method requires transport volume by transport mode and average transport distance by transport mode. Table 4 highlifghts the data required as well as potential sources.

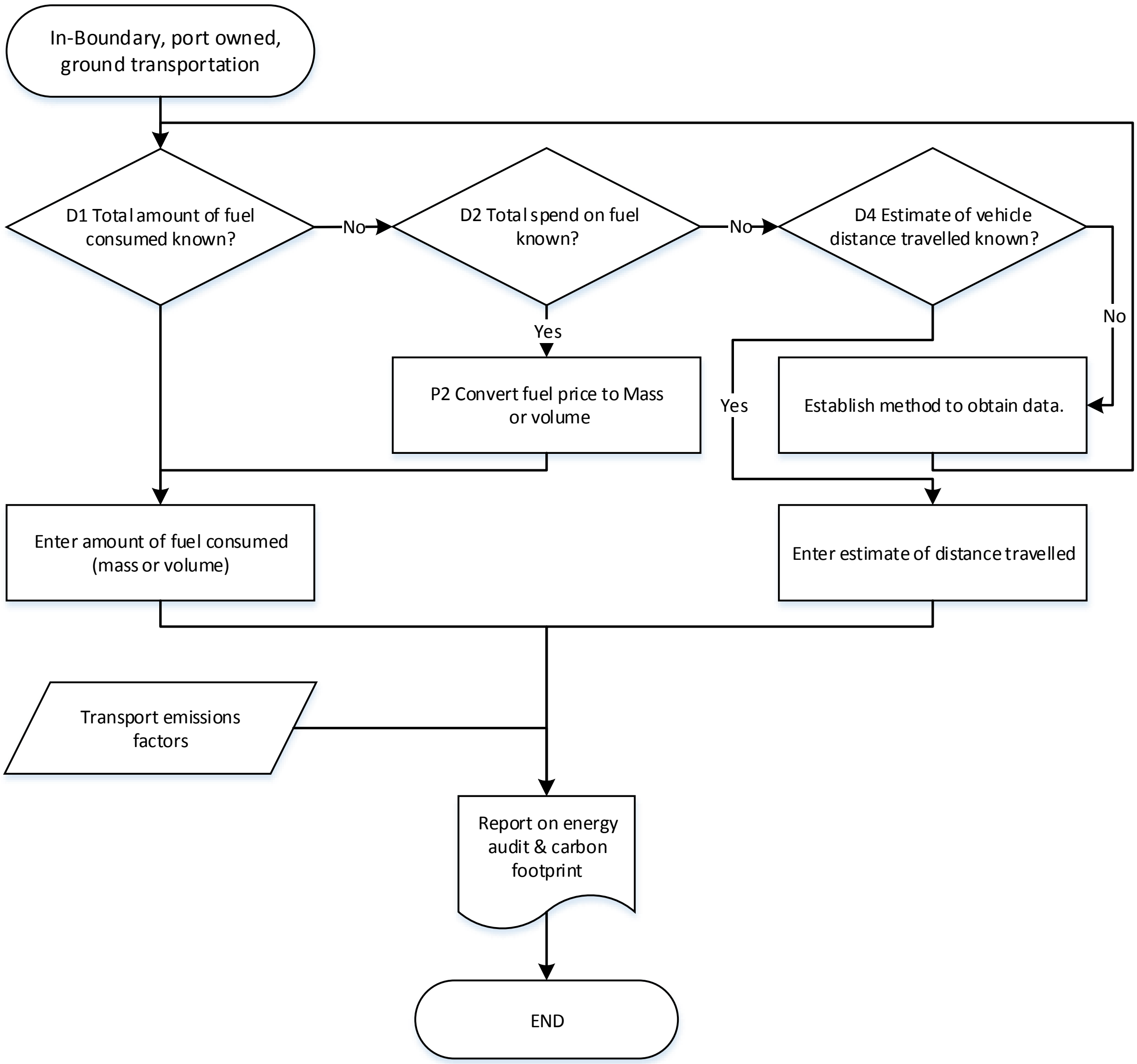

Figure 4. Procedure for the calculation emissions from port owned in-boundary ground transportation

Data	Documentation Source
Fuel consumption data (quantity of fuel used in physical unit) (mass or volume)	Purchase receipts or utility bills, delivery receipts, Stock inventory documentation, metered fuel documentation
Distance travelled data (kilometre or miles)	Vehicle meter reading or other records of vehicle distance travelled.
Fuel price data and fuel cost data per energy unit (e.g. money spent on diesel oil for each vehicle type and how much diesel oil cost per litres)	Purchase receipt, delivery receipts, contract purchase or firm purchase records, industry records

Table 4. Data requirements and documentation sources for the calculation of emissions from transportation

7.2.4 In-boundary ground transportation (non-port owned)

This category is concerned with ground transportation occurring within the geographic boundary of the port, from transport machinery not-owned and operated by the port. It is included as ports have the capacity to influence the behaviour and use of these sources through regulation and physical infrastructure within their operations (e.g. enforced no-idling zones)

An activity-based approach allows for an estimate of distance travelled to be applied to calculate energy demand and carbon footprint. This method, as shown in Figure 5, requires transport volume by transport mode and average transport distance by transport mode. Average distance travelled may be estimated from average road length or distance to key transport nodes within the port.

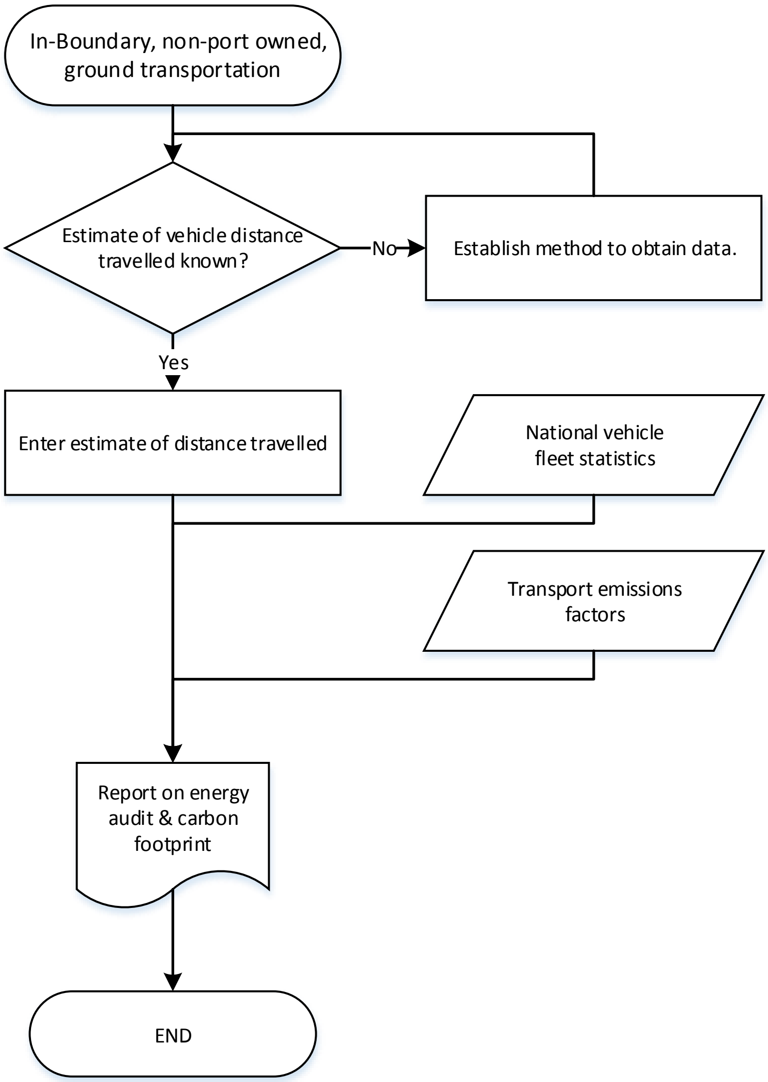

Figure 5. Procedure for the calculation emissions from port non-owned in-boundary ground transportation

7.2.5 In-boundary marine transportation (port owned)

Many ports own and operate their own fleet of marine transportation (e.g. pilot boats, tugs), and as these ports have direct control over the performance and operation of these vessels, it is important to consider them in the audit and carbon footprint. Energy and carbon footprint can be calculated either from a fuel consumed approach or via an activity approach (Figure 6). Where total fuel consumed is known this can be used to calculate total energy and carbon footprint through the application of the relevant emissions factors or conversions.

Where total fuel consumption is unknown, methods to collect this data should be established, but it is also possible to estimate emissions by the application of emissions factors for vessel type and configuration, and distance travelled emissions factors.

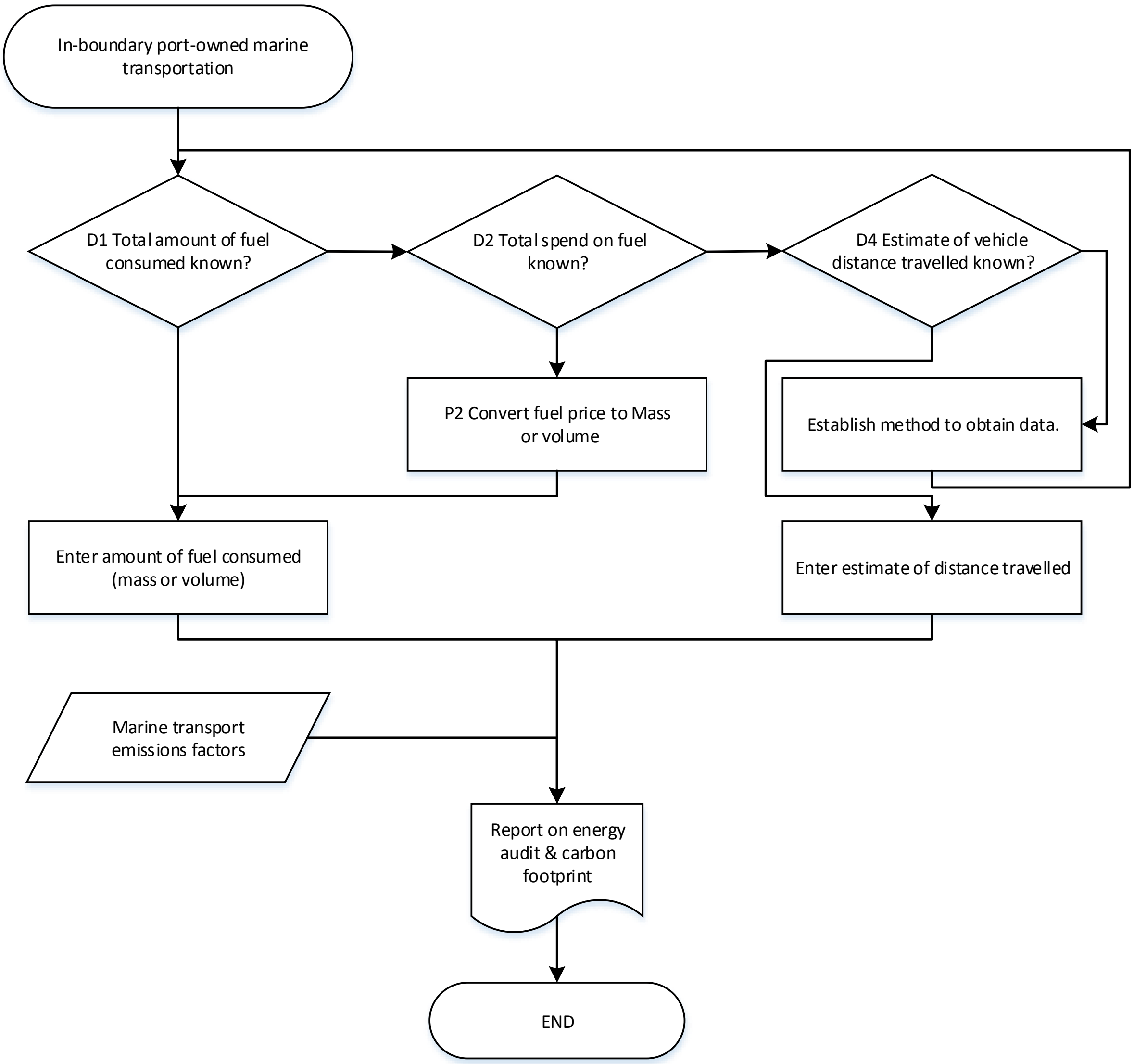

Figure 6. Procedure for the calculation of in-boundary emission from ocean transportation, vessel and other mobile fuel consumption

7.2.6 In-boundary marine transportation (non-port owned)

Ports are dependent on visiting maritime vessels of course, whether they be commercial shipping at larger ports, or private leisure craft in smaller harbours and marinas. Ports also have a level of regulatory control over the marine area under their own jurisdiction, including for example enforcement of speed limits; and navigational restrictions etc.. Given this jurisdiction and authority, visiting vessels could also be considered as sources of GHG emissions. This particular assessment is not considered within the remit of the PECS project specifically, but if taken into account, it would represent a more holistic and comprehensive assessment of GFHG emissions and the port-related carbon footprint.

As shown in Figure 7, the methodology for this involves determining various factors based on the quantity of fuels (unit mass or volume e.g. tons, kilograms, or litres) used in ocean transportation, whether that be for individual vessels or other mobile fuel consumption. If available this can be entered into the energy audit tool, selecting CO_2, CH_4 and N_2O emissions factor in energy audit tool according to type of fuel used. If no fuel quantity data is available however, then an alternative would be to use fuel price data or expenditure on each type of fuel used instead. If this is available, converting fuel price to the amount of fuel used can be calculated using the expenditure divided by fuel prices per energy unit. If fuel price data is also not available, then it would be possible to check the availability of fuel data (per energy unit) from fuel suppliers, estimating the amount of fuel used in each vessel.

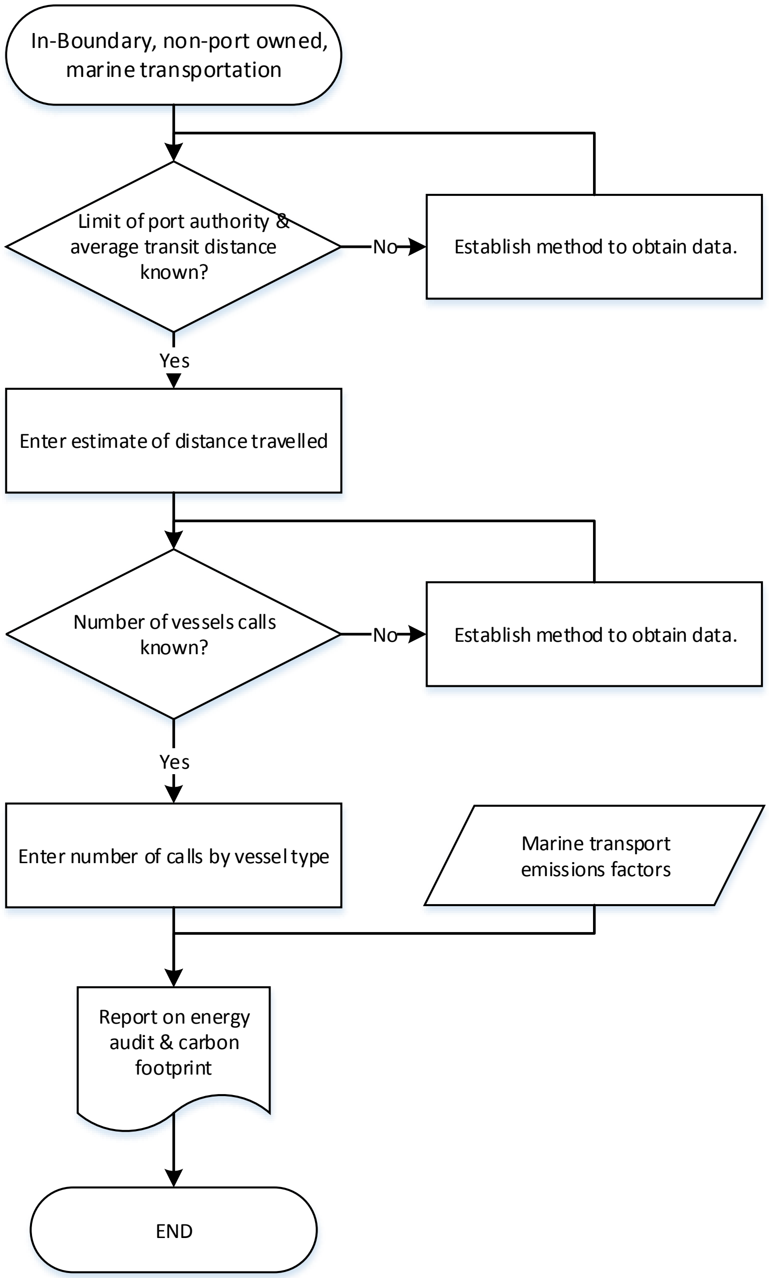

Figure 7. Procedure for the calculation of in-boundary emission from ocean transportation, vessel and other mobile fuel consumption

7.2.7 Other in-boundary mobile machinery

Mobile off-road emissions sources represent an extremely diverse range of emissions sources (e.g. generators; lawnmowers; straddle carriers), and machinery which is, in principle, mobile, but remains in-situ for an extended period (e.g. tower cranes). These sources may contribute significantly to overall port GHG emissions totals. Usage patterns of mobile machinery range from controlled to chaotic. Controlled activities are consistent and follow specific procedures (e.g. grab loader loading dockside vessels); chaotic activities follow no pre-determined procedure and activity patterns are difficult to quantify (e.g. lawn mowers). Fuel sales data may be a viable indicator of emissions, where the operation of off-road machinery is geographically constrained to the location of fuel purchase. Where this method is not suitable (e.g. fuel usage is not metered by site), emissions may be calculated using estimates of run-time and power configuration of the equipment.

7.3 Scope 2

Scope 2 considers emissions from grid connected electricity, steam, and heat and as electricity generation is essential for supplying most activities in the port, this is considered to be a relevant scope to address.

7.3.1 Consumed electricity

In most countries creation of electricity is a centralised process, with large power stations and a national distribution network. Electricity is generated at power plants and moves through the grid of electricity substations, transformers and power lines that connect electricity producers and consumers. Most local grids are interconnected for reliability and commercial purposes, forming larger, more dependable networks that enhance the coordination and planning of electricity supply.

In order to ensure equity and fairness GHG emissions associated with electrcity consuption are representative of the GHG intentisity of the generation grid. Emissions are allocated to the point of energy consumption rather than the point of production. Commonly emissions related to electricity are calculated using an aggregated emissions factor for a national system of generators and transmission network. Emissions factors are calculated using an aggregate for all generation GHG emissions, pro-rated to per unit energy consumption (kgCO_2e/kWh). End-user (i.e. port) emissions are cacluated on the basis of total energy consumption (Figure 8). Table 5 identifies the data required, as well as highlightiong the potential documentation sources.

Note: emissions associated with in-boundary generated electrcity (e.g. through solar or wind installation) entirely used within the port boundaries are calculated separately.

Data	Documentation Source
Actual electric consumption data and actual steam and heat consumption (in kilowatts-hours)	Metered reading documentation, any record documentation.
Electric bills and gas bill per month (or per three months or per years)	Utility bills, electric receipts, other record documentation.
Energy tariff in unit of electricity and gas prices per kWh Money spend per electricity unit (energy unit)	Electric supplier, industry records
Any in-boundary generation (other electric consumption that happens in the system) bills/ payment	Utility bills, electric receipts, other record

Table 5. Documentation sources for calculation emissions from electricity generation and steam and heat

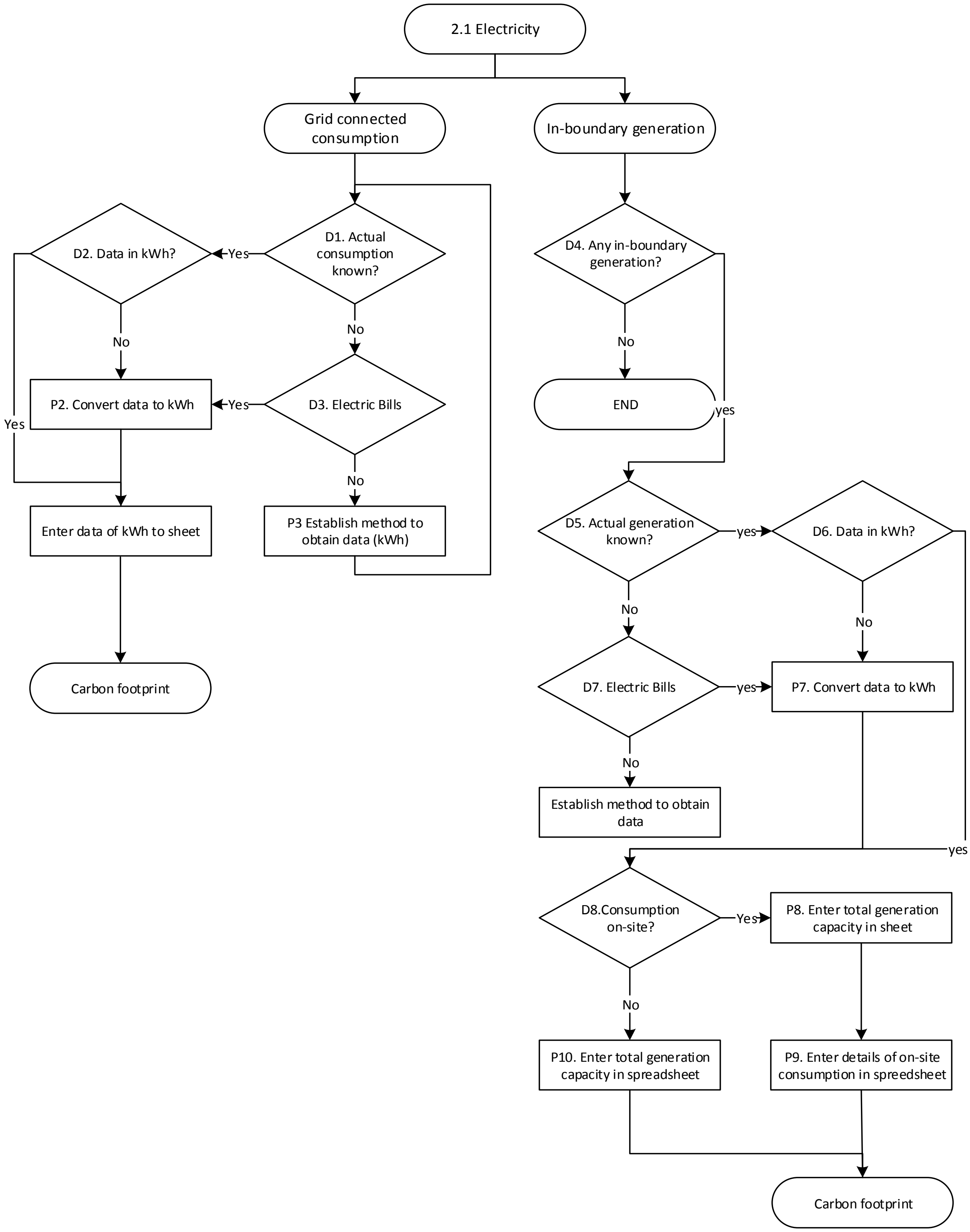

Figure 8. Procedure for the calculation of emissions from grid supplied electricity

7.3.2 In-boundary generation (offsets)

Many ports have installed or might consider installing in-boundary energy generation capacity. This generation capacity may be used to provide electricity to the national or regional energy supply grid or it may be used solely to provide energy within the port.

Where energy is supplied to the grid, the energy audit a record should be reported of the total generation of the system. For the carbon footprint, the benefit to the carbon footprint is captured in the national gird connected emissions factor. A note should be made for the generation, but no further calculation should be undertaken.

Where energy is supplied within the port boundary, the energy audit should report the generation total to be considered against total consumption. The carbon footprint should calculate an offset (i.e. the saving against grid electricity) to be reported as an 'offset'. Note, it is not valid to subtract or otherwise claim a lower carbon footprint because of this offset, as the saving is already captured through reduced reliance on grid connected sources (Figure 8). Table 5 identifies the data required, as well as highlightiong the potential documentation sources.

7.3.3 Steam and heat

Steam and heat may be supplied to or by the port for heating. As part of Scope 2 accounting, the C footprint can be calculate using the methodology defined in Figure 9.

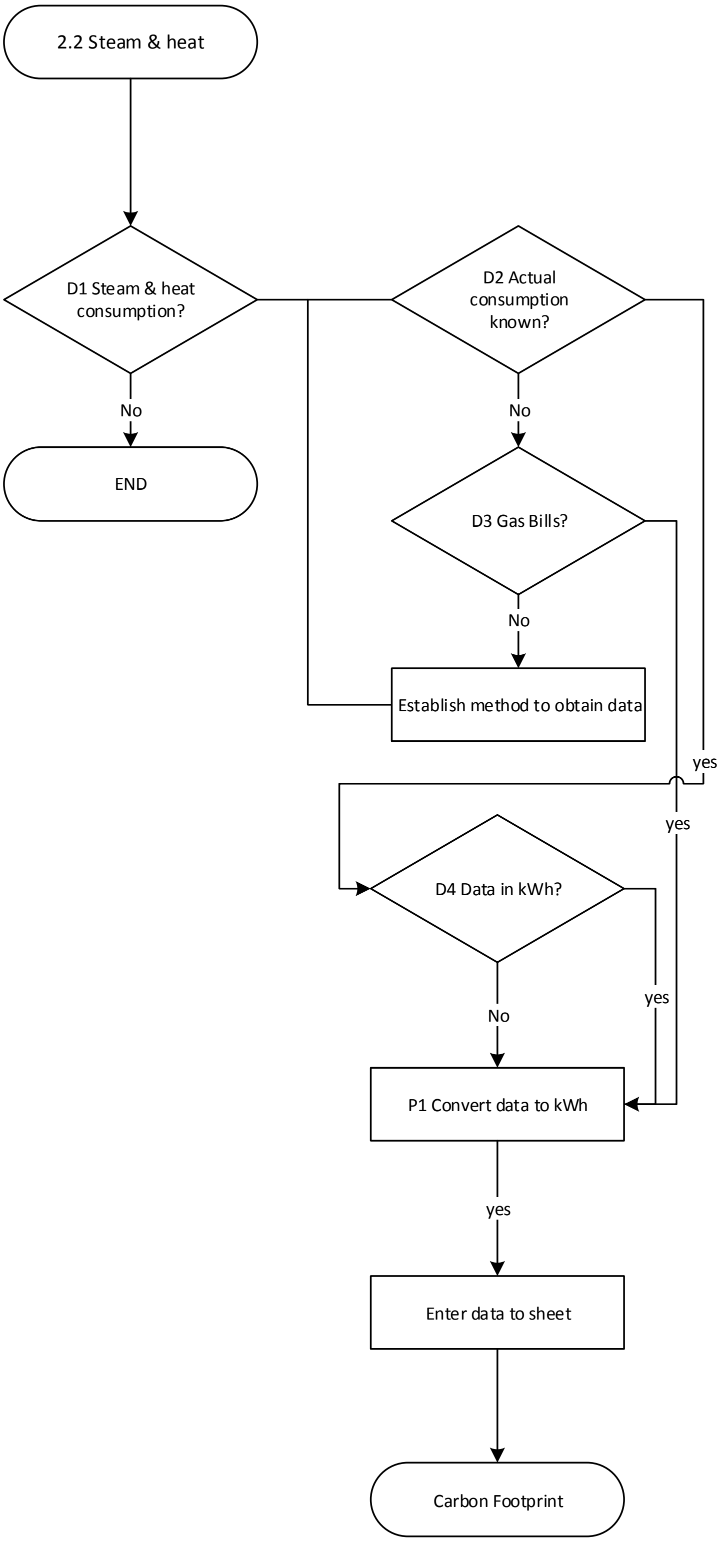

Figure 9. Procedure for the calculation of emissions from steam and heat process

7.4 Scope 3

Scope 3 includes indirect up- and down-stream emissions associated with the port. Calculation steps are included to enable a complete energy audit and carbon footprint of a port. Note, that not all steps are likely to be completed in all partners of the PECS project.

7.4.1 Water supply & sewerage

The provision of water and waste water services are similar to the provision of electricity. In many communities, water is supplied through a national or regional "grid" with centralized treatment and supply facilities. Emissions associated with water are calculated on an end-user basis for water processing, treatment and transportation using per unit consumed emissions factors. Where water usage is metered, direct emissions factors for unit of supply can be applied. However, water use is not always metered and thus no actual consumption data are available. Emissions can be calculated using standard estimates of water consumption provided by water suppliers or consumers.

7.4.2 Out-of-boundary ground transportation

Out of boundary ground transportation indicates the extent of the port's hinterland and its catchment area and therefore represents an interesting metric. The methodology for this is outlined in Figure 10.

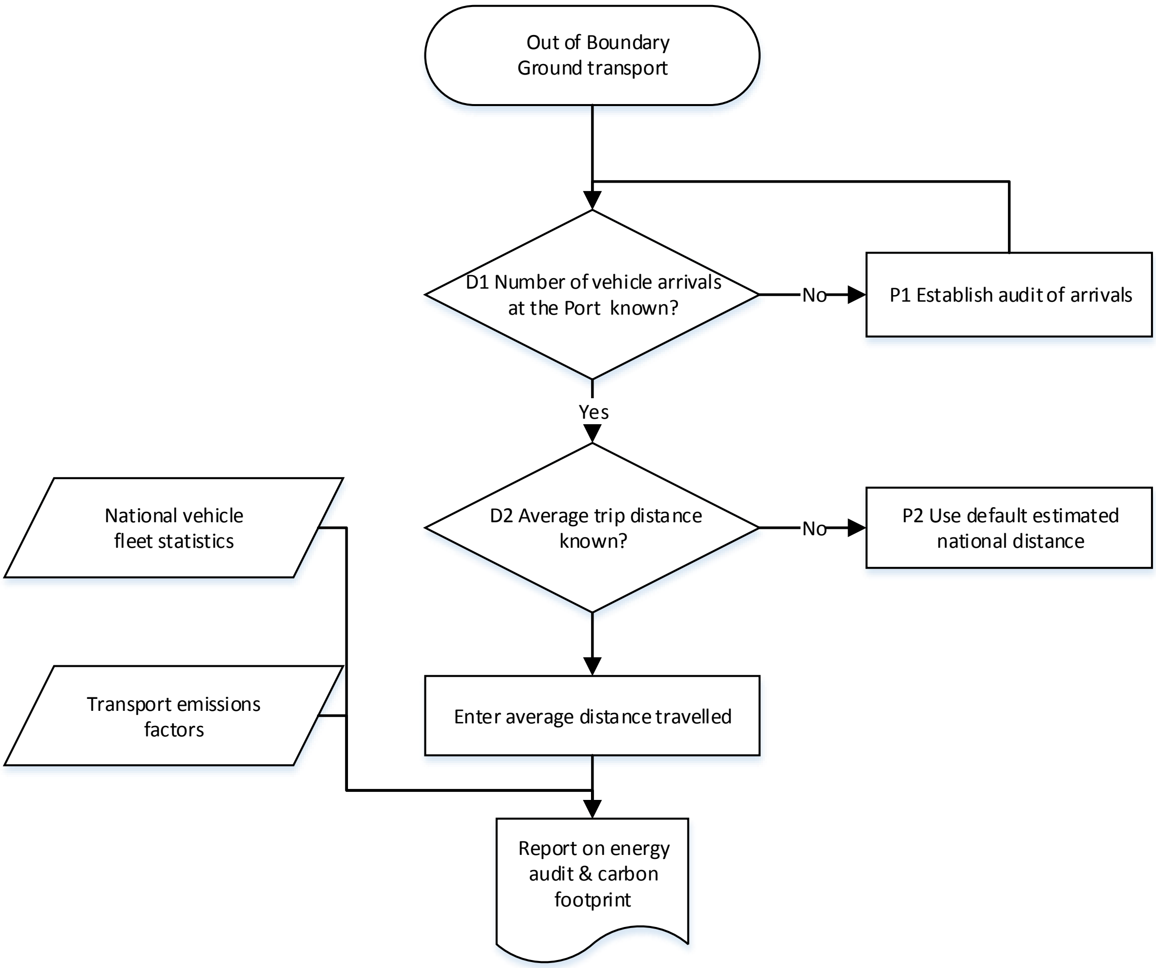

Figure 10. Procedure for the calculation of out-of-boundary emissions from ground transport

7.4.3 Out-of-boundary marine transportation

Similarly, total emissions from out-boundary marine transportation represents another interesting metric demonstrating the extent of the port's influence and its gravity for attracting trade. As in Figure 11, it can be calculated using vessel engine data and fuel emissions data.

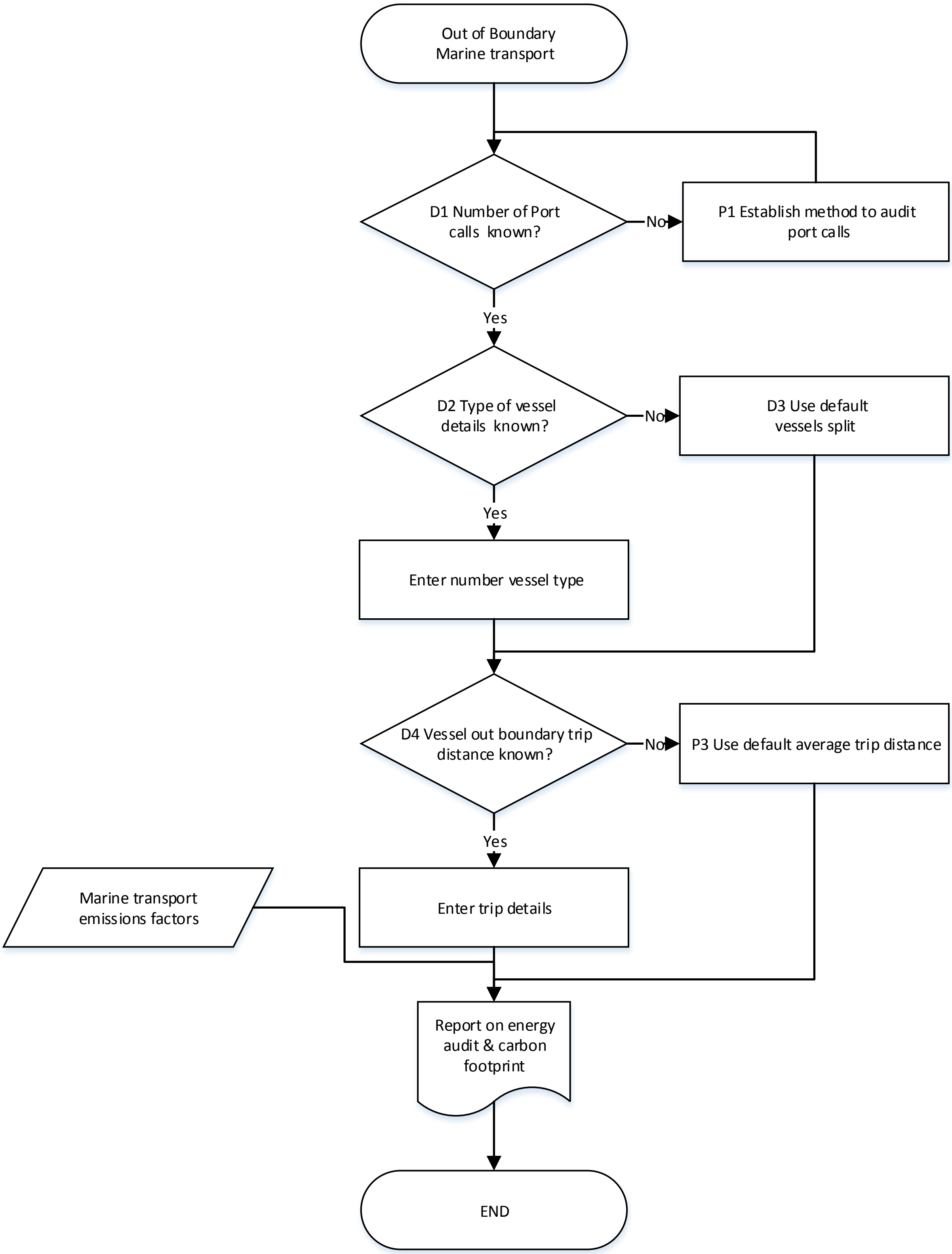

Figure 11. Procedure for the calculation of out-boundary emissions from marine transport

7.4.4 Waste

In order to calculate CO_2e emissions from waste, it is important to know the total amount of waste produced in the system; the waste type and waste treatment specific emission factor. Figure 12 outlines the methodology for calculating the carbon footprint of scope 3 waste emissions, whilst Table 6 outlines the data and sources relevant to completing this assessment.

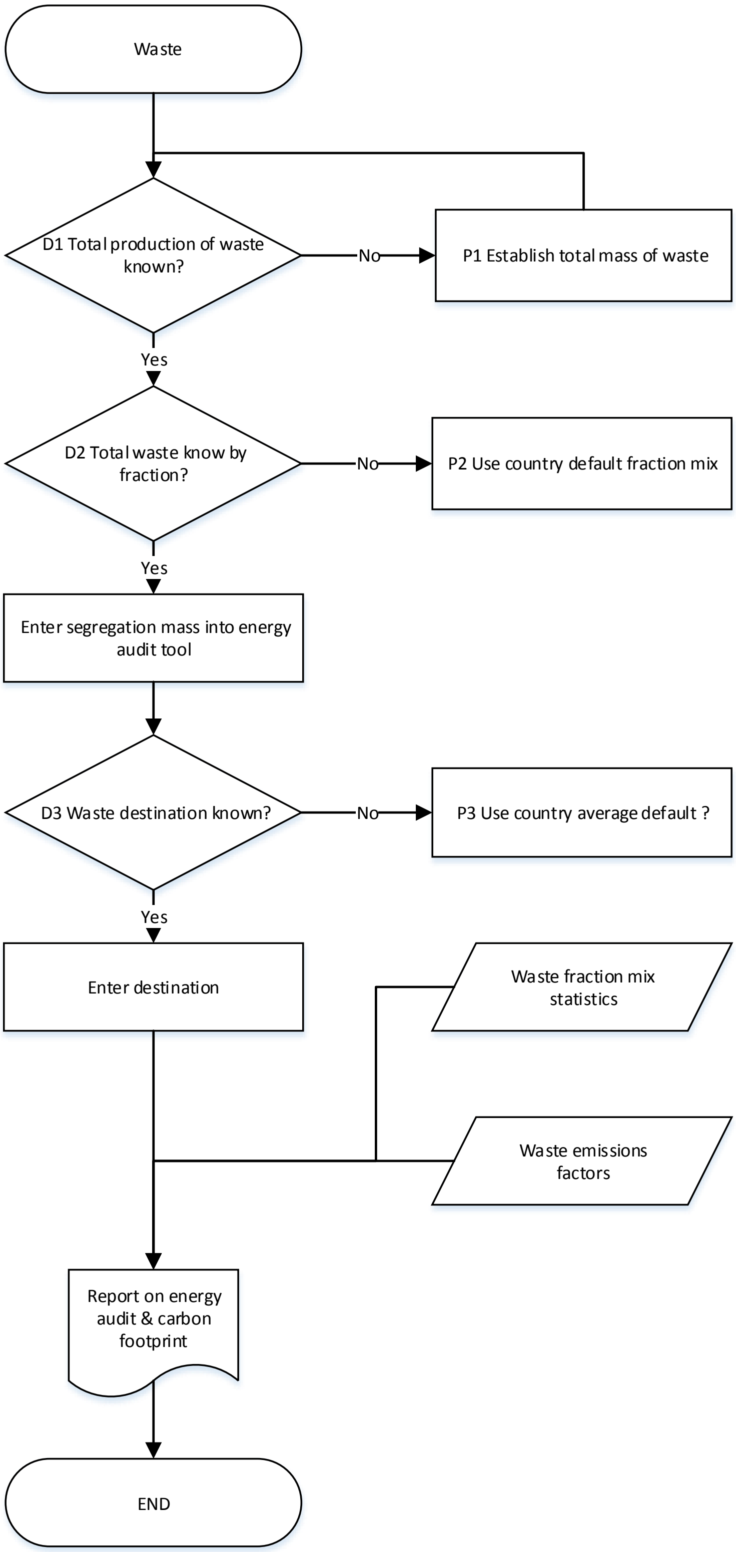

Figure 12. Procedure for the calculation of waste emissions

Data	Documentation Source
Waste Produced (tonne/cubic meter)	Waste record documentation
Type of waste and mass of waste generated in operation	Waste Documentation or any related waste document
Destination of waste disposal	Waste Documentation or any related waste document
Waste type-specific and waste treatment- specific emission factor.	Intergovernmental Panel on Climate Change (IPCC) 2006. Guidelines for National Greenhouse Gas Inventories Volume 5

Table 6. Documentation sources for calculation emissions from waste

7.4.5 Purchased goods and services

It is generally accepted that inclusion of embodied GHG emissions in supply chains extends the policy and mitigation potential of a carbon footprint considerably. Considerable GHG emissions are emitted along the supply chains of ports, inclusion of these sources enables ports to make informed decisions to improve performance. The footprint is modelled through the use of per unit spend emissions factors – a per unit expenditure GHG emission on a given category of product or service.

Within the PECS project it is recognised that this final category may be viewed as 'optional', but where included would help ports develop their understanding and policy response.
In the first instance a spreadsheet of data requirements will be circulated to enable the collection of port specific data sets. However, the purpose of the auditing tool is to allow for ports to utilize the methodology themselves thereby enabling a long term and sustainable system of measuring their own (including indirect) carbon footprint.

8. Conclusions

To summarize, this protocol outlines a comprehensive system of energy auditing and associated GHG emissions, detailing approaches to calculating the carbon footprint of the three key 'scopes'. For individual ports, it is unlikely they will be able to collect all relevant data, though it is assumed they will be able to provide some, and that this would then act as the minimum baseline against which to assess any future carbon savings as a result of purposeful interventions.

The key in utilizing the tool, is to enable it to direct data gathering so as to better manage energy efficiency in the future, but also to see it as a flexible system that allows for different boundaries to be drawn based on what is realistic at the time. Going forward, if ports are committed to reducing their carbon footprint, then the tool will allow them both to consider their impacts and identify their solutions.

9. Appendix

Proxy data estimates for non-port-owned in-boundary facilities

Point data from larger facilities may be available from legislative emissions reporting schemes; however, this often does not encompass smaller installations or entities (Gurney et al., 2002). Records of fuel sales may serve as a proxy to actual fuel data. However, this assumes fuel combustion at place of purchase and may not accurately reflect the source of emissions (i.e. where fuel is exported/imported). In some instances, the energy and carbon footprint can be calculated directly from corporate records. In the case of ports, the manging authority commonly operate their own estate, facilities, procurement and services. Whilst this method is extremely valuable, it does not capture the full range of operations within a port environment, nor will provide the required granularity.

Alternatively, a top-down approach can be applied to provide comparable audit results. Aggregate data at the industry or regional levels are used to attribute energy use to the sector, region and building scale based on ratio factors (e.g. employment, building area, industrial output). Gurney et al. (2012) describe a model to simulate energy demand based on building parameters combined with known local atmospheric emissions. The same study notes that this method is only suitable for large point source emitters. Therefore, they describe a proxy estimation, whereby total national energy consumption statistics are divided by total national floor area by industry, allocated to the local level. A similar method, using publicly available Dutch datasets, has been applied successfully to calculate energy consumption and savings potential for the Odijmond area (TNO, no date). Similarly, employment by industrial sector can be used to pro-rata known national emissions (I Tsagataskis, 2008). These methods rely heavily on the correct industrial classification of facilities in the local community, where facilities are incorrectly classified this will produce erroneous results.

Employment totals per industry or floor area may offer a good proxy indication of energy consumption (Tsagataskis, 2008, Gurney et al., 2012). Total energy consumption can be estimated using 'employment-intensity' factors - the ratio of total national or regional (where data is available) employment by sector ($\mathrm{Emp_{nat_j}}$), to fuel use by type ($\mathrm{C_{nat_i}}$) (Eq. 1). Where data for the consumption of grid electricity and mains natural gas is available at meter point - emissions can be directly calculated. However, other fuels (e.g. propane, coal) are often used for commercial and industrial activities, known as other 'residual' fuel consumption. To estimate local fuel consumed ($\mathrm{C_{lcl_i}}$) (commercial and industrial energy related emissions), the factors are combined with local employment totals ($\mathrm{Emp_{lcl_j}}$) as describes in Eq. 2.

$$\text{Employment intensity factor} = \frac{\sum_{j=1}^{n} Emp_{nat_j}}{\sum_{i=1}^{n} C_{nat_i}} = \frac{Total\ national\ or\ regional\ employment\ by\ sector\ (j=1..n)}{type\ of\ fuel\ used\ (\,i=1...n)} \tag{1}$$

The calculation of commercial and industrial energy related emissions is expressed by following Eq.

$$C_{lcl_i} = \left(\frac{C_{nat_i}}{Emp_{nat_j}}\right) Emp_{lcl_j} \tag{2}$$

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