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D5.4 PEI Manual for adoption in ports and guidelines for environment and society

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Type	Report	**Dissemination Level**	Public
Version	1.0	**Status**	Final
Description	This deliverable will provide an overview and analysis of the currently applied metrics for assessing the port's overall environmental performance in the EU28 countries, leading to a set of adoption guidelines. Furthermore, it will formulate a set of guidelines for minimising a port's PEI and thus mitigating the possible negative environmental aspects.		
Work Package	WP5		

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Abstract

The scope of this deliverable is to provide a manual for the adoption of the Port Environmental Index (PEI), which is an IoT based composite indicator delivered by the project, and a set of guidelines for minimising its value. Furthermore, it aims to provide an overview of the environmental metrics currently applied by the TEN-T ports in order to identify the gap which PEI is intended to cover and thus help define its added value and prove its feasibility.

The document collects and analyses data from TEN-T ports regarding the currently applied environmental metrics and indicators, relating the results to the corresponding Environmental Key Performance Indicators (eKPIs) used by PEI and evaluating in this way its feasibility in terms of data availability. At the same time, the large number of individual indicators recorded together with an analysis of the details of the related metrics, create awareness of the added value of PEI. More specifically, the methods and frequencies currently used for capturing data and the methods of sharing the results along with the problems encountered by ports in their attempt to implement and operate a port environmental measurement system, reveal the usefulness of an IoT based composite environmental indicator. Finally, taking all information into account, the document draws a set of adoption guidelines for implementing PEI and a set of guidelines in the form of recommendations based on the specific indexes of PEI, with the purpose to improve the environmental performance of ports and at the same time minimise the value of PEI.

Statement of originality

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List of acronyms

Acronym	Explanation
CO	Carbon monoxide
CO_2	Carbon dioxide
CSR	Corporate Social Responsibility
eKPI	Environmental Key Performance Indicator
ESR	Environmental Sustainability Report
GA	Grant Agreement
GHG	Green House Gases
IoT	Internet of Things
L_{DEN}	Overall day-evening-night noise level
LNG	Liquefied Natural Gas
L_{night}	23:00 - 7:00 hrs noise level
MARPOL	International Convention for the Prevention of Pollution from Ships
NGO	Non-Government Organisation
NMVOCs	Non-methane volatile organic compounds
NO_x	Nitrogen oxides
O_3	Ozone
OPS	On-Shore Power Supply
PA	Port Authority
PAS	Port Activity Scenario
PCS	Port Community System
PEI	Port Environmental Index
PIXEL	Port IoT for Environmental Leverage
PM	Particulate matter
SO_2	Sulphur dioxide
SO_x	Sulfur oxides
TEN-T	Trans-European Transport Network
TEU	Twenty-foot Equivalent Unit
TOS	Terminal Operating System
WP	Work Package

1. About this document

The main focus of this deliverable is to provide a guide for the successful implementation of the PEI solution and to provide suggestions for the minimisation of its value. In addition to facilitating the proper implementation and utilisation of the PEI, its purpose is to demonstrate the added value and the ease of use and adaptability of PEI in relation to the existing methods for environmental performance monitoring which can support the promotion of the PEI solution to ports.

1.1. Deliverable context

Keywords	Lead Editor
Objectives	The main objective of the deliverable is (a) to develop evidence-based, standardised and cost-effective procedures for environmental monitoring in port areas through a set of guidelines to implement the PEI solution and (b) to develop guidelines for mitigating possible environmental and health effects of port activities through a set of guidelines to minimise the PEI value. In addition, the recommendations for PEI minimisation will be integrated to the operational tool of PEI in the form of a suggestion's engine.
Exploitable results	The results presented in this deliverable will contribute to the PEI exploitable result by providing a set of guidelines for adoption and also for the minimisation of its value. Furthermore, it will help prove its feasibility in terms of data availability and define its added value thus contributing to the promotion of the PEI solution.
Work plan	The deliverable is the result of the work performed in the context of tasks 5.4 - Practices for PEI metrics and adoption (M19 – M33) and 5.5 - Guidelines for improvement of environment and society (M24 – M37), both of which end with the delivery of this document. It will contribute to the implementation of PEI to the project's pilots and will play an important role to the integration of environmental impact mitigation suggestions to the operational tool of PEI as well as for task T8.4.
Milestones	This delivery is the verification of milestone MS8 under WP5: PEI and environmental recommendations and conclusions fetched
Deliverables	The deliverable is a part of the PEI development approach and builds on the previous deliverables of WP5 which defined the environmental aspects and provided the definition and algorithm of PEI, by providing a manual for its adoption and guidelines for minimising its value.
Risks	WP5#10: Data availability – the needed data/KPIs for computing PEI will not be available (for pilot ports). Although not dealing directly with the issue of data/KPI availability for the pilot ports, this deliverable will evaluate the general feasibility of PEI in terms of data availability by recording the available data by TEN-T ports and correlating them with the corresponding data/KPIs for calculating PEI. This deliverable also includes an overview of the data needed to be provided by a port to compute all eKPIs for calculating the PEI.

2. Methodological approach

2.1. Methodology overview

2.1.1. Metrics & adoption guidelines of port environmental performance

According to the GA, the work undertaken in Task 5.4 and reported in the present deliverable has the objective "to provide an overview and analysis of the currently applied metrics for assessing ports' overall environmental performance in the EU28 countries, leading to a set of adoption guidelines". To meet its objective, the project followed a 4-step approach:

- Step 1: Analysis of the currently available information on environmental metrics being used by European ports. This analysis was performed by reviewing the content of the Environmental Sustainability Reports published by European ports and has been used as a validation of the feasibility of the PEI structure defined in D5.1 and D5.2 in terms of data availability.
- Step 2: Expansion of the results of Step 1, through the use of a questionnaire survey to a number of representative ports in order to: (i) expand the scope of the analysis covering the aspects of data collection methods, problems faced, information sharing & use of benchmarking by the ports in relation to environmental aspects; (ii) collect information also from a number of TEN-T ports that do not publish an Environmental Sustainability Report.
- Step 3: Undertaking a number of online interviews with port representatives further focusing on the issue of adopting and implementing a structured environmental performance management system and also addressing any other specific areas of interest that may be identified from the results of the previous Steps.
- Step 4: Using the results of the previous three Steps to define the added value provided by a composite indicator-based port environmental performance system and to draw a set of guidelines for its adoption.

2.1.2. Guidelines for minimising a port's PEI

According to the GA, the work undertaken in Task 5.5 and reported in the present deliverable has the objective "to provide provide guidelines for assessing and minimising a port's PEI, having the society as the focus stakeholder".

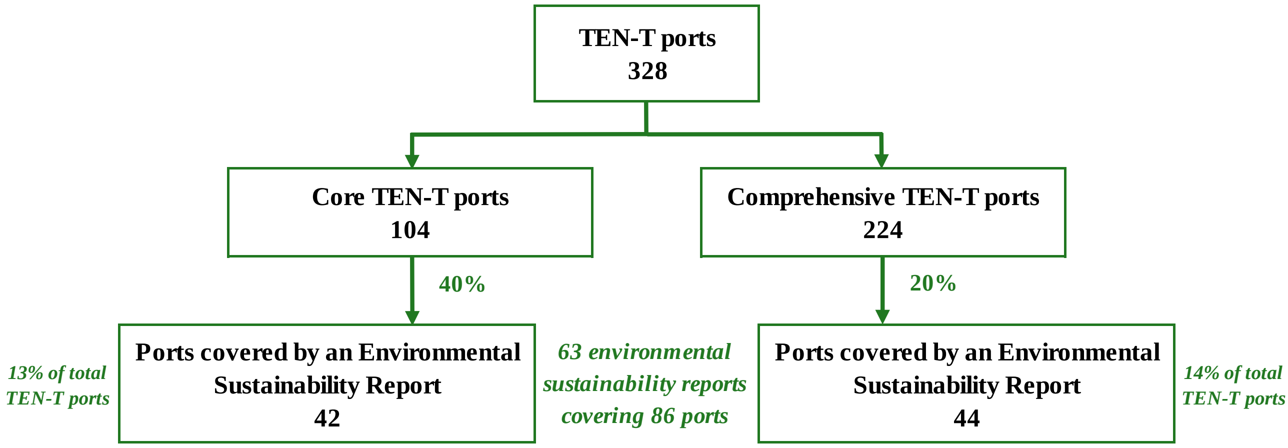
In this context, a collection of practices was created based on a review of papers published to scientific journals and also on documents with guidelines for the improvement of the environmental performance of ports published by national and international organisations related to maritime transportation. These practices were related to specific indexes and subindexes of PEI in order to facilitate the objective of minimizing the PEI value in addition to the improvement of the environmental performance of ports. Furthermore, these guidelines will allow the provision of individualised intervention recommendations to ports, based on their overall PEI score but also their sub-index results.

2.2. Content analysis of port sustainability reports

The first step of the content analysis, consisted of accessing the websites of all 328 maritime ports of the core & comprehensive TEN-T network (in two access rounds: April to June 2019 and December 2019 to February 2020) and collecting the publicly available reports addressing the ports' environmental performance. The analysis revealed a total number of 63 relevant reports, providing information on 86 ports (some Port Authorities manage more than one port and report their environmental performance in the same report[1]). These reports are issued under different titles, such as Corporate Sustainability Report, Sustainability Report, Environmental Report, or the environmental aspects are incorporated in the port's Annual Report. In the present document, the

[1] For this reason, throughout the document we use the phrase 'ports covered by an ESR' instead of 'ports publishing an ESR'

term 'Environmental Sustainability Reports (ESR)' is used as an umbrella term for all port reports addressing environmental issues. An overview of the core and comprehensive ports covered by the content analysis, is provided in Figure 1.



Source: Analysis of TEN-T ports websites

Figure 1 – TEN-T ports covered by an Environmental Sustainability Report

To provide an indication of the size of the average European port that is included in the content analysis, existing traffic data of the TEN-T ports have been used (see Figure 2).

Figure 2 – Average size of the TEN-T ports included in the ESR content analysis

The range of size of the ports publicly reporting environmental performance through an ESR varies widely, from the top-10 European ports to much smaller ones with a few hundred thousand tonnes of goods handled.

The average port covered by an ESR, handled 8.7 million tonnes in 2017 (median value of gross weight handled)[2].

2.3. Questionnaires & interviews

2.3.1. Questionnaires

2.3.1.1. Questionnaire design

The questionnaire used was structured in five parts, each one focusing on one of the following areas:

1. environmental impact and resource consumption metrics currently used by European ports,
2. data collection methods used and frequency,
3. main problems faced in introducing and operating a port environmental impact measurement system,
4. extent of sharing environmental impact measurements with actors outside the port,
5. extent of use of industry benchmarks for assessing port environmental performance.

The questionnaire design is provided in Annex A. The questionnaire was made available online through a specialised web platform and also in the form of a document at:

https://pixel-ports.eu/wp-content/uploads/2020/07/Questionnaire-Environmental-performance-metrics-used-by-the-TEN-T-ports.docx

2.3.1.2. Respondent group & response

A number of ports was selected to participate to the questionnaire survey in order to provide information regarding data collection methods, problems faced, information sharing & use of benchmarking in relation to environmental aspects, covering different port sizes and also ports belonging to the core and comprehensive network. For the purpose of this report, a simplified approach was used to differentiate port sizes based on the annual total quantity of cargo handled; small sized ports are considered the ones which handle less than 10 million tonnes of cargo annually, medium size ports handle between 10 and 50 million tonnes of cargo while large ports handle over 50 million tonnes of cargo (ESPO, 2010).

An email invitation was sent to the selected ports which belonged to core & comprehensive TEN-T network, explaining the objectives of PIXEL, the aim of the questionnaire and inviting them to complete it. Email addresses used for sending the questionnaire were collected in two ways: (i) through the ports' contact details included in their websites; (ii) from personal contacts of the PIXEL partners. In the first case, the order of preference was the following: (a) contacting the person responsible for port environmental management; (b) contacting the port department responsible for environmental issues; (c) contacting the port's CEO; (d) using the port's general email address.

Overall, a sum of 13 responses was collected, including 3 ports participating to the project as pilot ports and covering ports of all sizes, belonging to core and comprehensive network. More specifically, the answers included 6 small ports (2 core and 4 comprehensive), 4 medium ports (3 core and one comprehensive) and 3 large ports, all belonging to the core network. The list of participating ports and their size according to the annual quantity of cargo handled are presented in Table 1.

Table 1: TEN-T ports which participated to the survey and their corresponding size

Port	Annual total quantity of cargo handled in 2019 (in tonnes)	Port size	TEN-T Network
Port of Barcelona	65,846,328	Large	Core
Port of Bayonne	2,283,938	Small	Comprehensive

[2] 2017 is the year with the latest available Eurostat figures

Port	Annual total quantity of cargo handled in 2019 (in tonnes)	Port size	TEN-T Network
Port of Bilbao	35,561,021	Medium	Core
Port of Bordeaux	7,265,926 (2017 data)	Small	Core
Port of Castello	20,721,000	Medium	Comprehensive
Port of Koper	22,792,646	Medium	Core
Port of La Rochelle	8,900,000 (2020 data)	Small	Comprehensive
Port of Monfalcone	4,093,425	Small	Comprehensive
Port of Nice	395,271 (2017 data)	Small	Comprehensive
Port of Piraeus	56,825,000	Large	Core
Port of Sevilla	4,393,669	Small	Core
Port of Sines	41,795,603	Medium	Core
Port of Trieste	61,998,318	Large	Core

Source: Based on data collected from the ports' websites

2.3.2. Online interviews

2.3.2.1. Discussion items

In the context of task 5.4, a number of interviews (4 in total) with port representatives was also performed, in order to gain more insight into the possible problems with respect to the implementation of systems for measuring the environmental impact of port operations. Regarding the form of these interviews, after a short initial presentation of the PEI solution a structured interview based on a questionnaire followed, aiming for the interviewees to develop their point of view around the subjects of discussion. These subjects included the current implementation of environmental metrics by their ports, and more specifically the problems faced during the initial implementation or during operations on a daily basis. The participants were also requested to provide their opinion regarding the implementation of a composite environmental indicator and possible deterrents for such an adoption. The questionnaire design is provided in Annex B.

2.3.2.2. Interviewees group

All participants were representatives of small size TEN-T ports, which is the main target group of the PEI solution, namely of the ports of Volos, Patra and Igoumenitsa from Greece and the port of La Rochelle from France. Besides the port of La Rochelle the other participants had not previously participated to the questionnaire survey, in order to further widen the number of the respondent ports and thus of the different opinions collected regarding the currents practices and the problems in introducing and operating a port environmental impact measurement system.

The small number of ports interviewed is largely due to the time period of the corresponding project activity which coincided with the COVID pandemic. The pandemic has disrupted port operations and created the need to give priority to other matters thus making difficult the arrangement of the interviews. This difficulty was also reinforced by the fact that the majority of ports, especially of small and medium size, currently do not have plans for IoT environmental monitoring.

However, this activity will not be finalised within the context of this deliverable. There is an intention to perform 6-7 additional interviews within tasks T8.4 (Proof of Concept and future R&D potential) and T9.4 (Exploitation & Business Plan), with significant higher chances of success because of the gradual improvement of global freight trade and due to the involvement of external entities in this process (ALICE, AIVP).

3. Currently applied metrics for assessing port environmental performance by TEN-T ports

3.1. Environmental sustainability reports

An overview of the number of ports per European country, covered by an ESR report, is provided in Table 2.

Table 2: TEN-T ports covered by an environmental sustainability report

Country	TEN-T ports[3]		TEN-T ports covered by an ESR		Environmental Sustainability Reports	
	Number	%	Number	%	Number	%
Belgium (BE)	4	1.2	1	1.2	1	1.6
Bulgaria (BG)	2	0.6	0	0	0	0
Croatia (HR)	7	2.1	1	1.2	1	1.6
Cyprus (CY)	2	0.6	0	0	0	0
Denmark (DK)	22	6.7	5	5.8	5	7.9
Estonia (EE)	8	2.4	1	1.2	1	1.6
Finland (FI)	17	5.2	2	2.3	2	3.2
France (FR)	27	8.2	3	3.5	2	3.2
Germany (DE)	21	6.4	11	12.8	3	4.8
Greece (EL)	25	7.6	0	0	0	0
Ireland (IE)	5	1.5	1	1.2	1	1.6
Italy (IT)	39	11.9	2	2.3	2	3.2
Latvia (LV)	3	0.9	1	1.2	1	1.6
Lithuania (LT)	1	0.3	1	1.2	1	1.6
Malta (MT)	4	1.2	0	0	0	0
Netherlands (NL)	13	4.0	4	4.7	4	6.3
Poland (PL)	5	1.5	1	1.2	1	1.6
Portugal (PT)	13	4.0	6	7.0	5	7.9
Romania (RO)	5	1.5	0	0	0	0
Slovenia (SI)	1	0.3	1	1.2	1	1.6
Spain (ES)	37	11.3	35	40.7	24	38.1
Sweden (SE)	25	7.6	6	7.0	4	6.3
United Kingdom (UK)	42	12.8	4	4.7	4	6.3
Total	**328**	**100**	**86**	**100**	**63**	**100**

Source: Based on analysis of reports made available online

As can be seen in Table 2, the larger number of reporting ports is located in Spain, mainly due to the obligation established by the Spanish Royal Legislative Decree 2/2011 of September 5, to prepare an environmental sustainability report. Most of these reports are based on the 'Guide for the elaboration of sustainability reports

[3] As defined in Regulation (EU) 1315/2013

of the Port Authorities'[4], provided by the Spanish Ports Association (*Puertos del Estado*), defining a common way for publishing environmental data.

The majority of the reporting Port Authorities state that measurements of various environmental indicators are performed continuously or through specific campaigns. However, the following analysis includes only the indicators for which quantitative data and/or the units/methodology/legislation used for their measurement is provided by the port.

In the case of Port Authorities managing multiple ports, the indicators are provided in their reports either at an aggregate level (for example in the case of the ESR of the Ports of las Palmas), implying a common measurement approach in the respective ports.

The indicators used are mainly related to the environmental impacts and the consumption of resources for port operations. The first category includes measurements of air (such as emissions and concentrations of particles and gaseous pollutants) and water quality (such as physical-chemical and biological parameters), measurements and estimations of noise pollution and quantitative data on waste production (from ships and ports operations), wastewater disposal, dredging and land use. The second category includes quantitative data regarding the consumption of energy, water and various materials (such as paper and printer toners). For the vast majority of these indicators, their annual evolution is also presented in the ESRs.

3.2. Questionnaire survey

In addition to the ports which are covered by an environmental sustainability report, information regarding the environmental metrics used was also collected for the ports which participated to the questionnaire survey. Approximately half of these ports do not publish Environmental Sustainability Reports and therefore the corresponding information from the survey was added to the analysis, bringing the total number of ports for which information was collected to 92 (28% of the total number of TEN-T ports).

3.3. Environmental metrics applied

3.3.1. Air quality

3.3.1.1. Greenhouse Gases/CO_2 emissions

The 53 of the total 92 ports (57.61%) for which information was collected through the content analysis of the environmental sustainability reports and the questionnaire survey, use indicators related to the emissions of Greenhouse Gases. These indicators include either the emissions of all the main chemical compounds classified as Greenhouse Gases (CO_2, NH_4, N_2O, CFCs, HCFCs and HCFs) as CO_2 equivalent, or only the CO_2 emissions. In the following table the eKPIs related to CO_2/GHG emissions and the corresponding shares of relevant available data are presented.

Table 3: CO_2 emissions eKPIs and corresponding percentage of relevant available data

eKPI category (*)	**eKPI**	**Description**	**Num. of ports/ % of ports for which information was collected**	**Data description**
Emissions to the atmosphere	CO_2 emissions	Measure or calculation of the total amount of CO_2 emissions that is directly and indirectly caused by an activity	53/ 57.61%	Calculation of annual total CO_2 or GHG emissions (tCO_2 or tCO_2 equivalent) in the port area (by the PA and/or other parties)

(*) As defined in PIXEL Deliverable D5.2

[4] Guia para la elaboración de las memorias de sostenibilidad de las Autoridades Portuarias

Analysing further the collected data, the indicator used by the vast majority of ports is the annual total CO_2/GHG emissions measured in tCO_2 or tCO_2 equivalent, followed by the annual average CO_2/GHG emissions per employee (17.39% of ports), the annual average CO_2/GHG emissions per square meter of port area (6.52% of ports, all from Spain) and the annual average CO_2/GHG emissions per port throughput (6.52% of ports) measured in tCO_2/ton of cargo or tCO_2/TEU. Furthermore, other interesting indicators were recorded during the research (one or two occurrences of each indicator) which include the annual total CO_2 emissions in the port area from shipping (tCO_2), the annual total CO_2 emissions in the port area from shipping per ship type (tCO_2) and the annual average CO_2/GHG emissions per ship served by the port. It is also worth mentioning that in some cases the PA provided additional data and more specifically the CO_2/GHG emissions in the wider port area (port of Rotterdam) or the emissions from other (industrial) activities existing in the port area (ports of Antwerp, Moerdijk). In the following table the indicators used and the corresponding percentages are presented.

Table 4: Greenhouse Gases/CO2 related indicators

	Number of ports using the indicator(s)	% of ports for which information was collected	% of TEN-T ports
GHG/CO_2-related indicators:	**53**	**57.61**	**16.16**
Indicators:			
Annual total CO_2 or GHG emissions (tCO_2 or tCO_2 equivalent)	52	56.52	15.85
Distribution of annual total CO_2 or GHG emissions (tCO_2 or tCO_2 equivalent) per:			
Scope 1	37	40.22	11.28
Scope 2	37	40.22	11.28
Scope 3	9	9.78	2.74
Annual average CO_2 or GHG emissions per employee (tCO_{2e}/employee)	16	17.39	4.88
Annual average CO_2 or GHG emissions per square meter of port area (tCO_{2e}/m^2)	6	6.52	1.83
Annual average CO_2 or GHG emissions per throughput (tCO_{2e}/ton of cargo or $kgCO_{2e}$/TEU)	6	6.52	1.83
Annual total CO_2 emissions from shipping in the port area (tCO_2)	2	2.17	0.61
Annual total emission of CO_2, broken down by source of emission (vehicle fleet, boilers) (t)	1	1.09	0.30
Annual total CO_2 emissions from shipping in the port area per ship type (tCO_2)	1	1.09	0.30
Annual average CO_2 or GHG emissions per vessel served by the port (tCO_{2eq}/vessel)	1	1.09	0.30

Regarding the universally used indicator of annual total CO_2/GHG emissions, in 72.0% of cases (36 out of 50 ports publishing reports) the data is reported according to the Global Reporting Initiative (GRI) standards (GRI disclosure numbers: 305-1/305-2/305-3 or the older GRI G4 Sector disclosures: G4-EN15/G4-EN16/G4-EN17), distributed to all or some of Scope 1/2/3 emission categories. Scope 1 includes the direct GHG emissions from the consumption of fuel, Scope 2 includes indirect emissions from the consumption of electricity and Scope 3 includes other indirect emissions to which the port has no control of, such as the car transportation of employees and emissions from relevant air travel. As for the latter, 75.0% of the ports using the GRI standards do not provide data for Scope 3 emissions. Finally, 63.9% of the ports (23 out of 36) using the GRI standards provide additional information regarding the Scope 1/2/3 categories of emissions by breaking down each category to specific emission sources (for example scope 1 emissions may consist of emissions from the consumption of diesel, natural gas, gasoline, heating oil etc.). However, this additional information is tailored to each reporting port's needs, not following a specific pattern and thus is not included in the present analysis. Overall, 56.0% of ports (28 out of 50) publishing CO_2/GHG emissions indicators (according to GRI standards or not) provide this type of additional data.

3.3.1.2. Other air pollutant concentrations and emissions

Unlike the case of Greenhouse Gases in which the indicators are mainly based on a calculation of the emissions, in the case of the other air pollutants (organic and inorganic compounds, particulate matter), the majority of indicators is based on measurements of their actual concentration in the air. These measurements are performed continuously or periodically (campaigns) in appropriate locations, in or near the ports. Overall, 44.6% of the ports for which data was collected through their reports or the survey (41 out of 92 ports) use indicators related to air pollutants other than Greenhouse gases. Several of these indicators have to do with the compliance of the concentrations of a number of pollutants to limits opposed by EU regulations. These limits are presented below.

Table 5: Air quality standards according to EU legislation

	Concentration	Averaging period	Legal nature	Permitted exceedances each year
Fine particles (PM2.5)	25 µg/m^3	1 year	Target value to be met as of 1.1.2010 Limit value to be met as of 1.1.2015	n/a
Sulphur dioxide (SO2)	350 µg/m^3	1 hour	Limit value to be met as of 1.1.2005	24
	125 µg/m^3	24 hours	Limit value to be met as of 1.1.2005	3
Nitrogen dioxide (NO2)	200 µg/m^3	1 hour	Limit value to be met as of 1.1.2010	18
	40 µg/m^3	1 year	Limit value to be met as of 1.1.2010 (*)	n/a
PM10	50 µg/m^3	24 hours	Limit value to be met as of 1.1.2005 (**)	35
	40 µg/m^3	1 year	Limit value to be met as of 1.1.2005 (**)	n/a
Lead (Pb)	0.5 µg/m^3	1 year	Limit value to be met as of 1.1.2005 (or 1.1.2010 in the immediate vicinity of specific, notified industrial sources; and a 1.0 µg/m3 limit value applied from 1.1.2005 to 31.12.2009)	n/a
Carbon monoxide (CO)	10 mg/m^3	Maximum daily 8 hour mean	Limit value to be met as of 1.1.2005	n/a
Benzene	5 µg/m^3	1 year	Limit value to be met as of 1.1.2010(**)	n/a
Ozone	120 µg/m^3	Maximum daily 8 hour mean	Target value to be met as of 1.1.2010	25 days averaged over 3 years
Arsenic (As)	6 ng/m^3	1 year	Target value to be met as of 31.12.2012	n/a

Cadmium (Cd)	5 ng/m^3	1 year	Target value to be met as of 31.12.2012	n/a
Nickel (Ni)	20 ng/m^3	1 year	Target value to be met as of 31.12.2012	n/a
Polycyclic Aromatic Hydrocarbons	1 ng/m^3 (expressed as concentration of Benzo(a)pyrene)	1 year	Target value to be met as of 31.12.2012	n/a

(*) According to Directive 2008/50/EU, the Member State could apply for an extension of up to five years (i.e. maximum up to 2015) in a specific zone. The request is subject to an assessment by the Commission. In such cases within the time extension period the limit value applies at the level of the limit value + maximum margin of tolerance (48 µg/m^3 for annual NO2 limit value).

(**) According to Directive 2008/50/EU, the Member State was able to apply for an extension until three years after the date of entry into force of the new Directive (i.e., May 2011) in a specific zone. The request was subject to assessment by the Commission. In such cases within the time extension period the limit value applies at the level of the limit value + maximum margin of tolerance (35 days at 75µg/m3 for daily PM10 limit value, 48 µg/m3 for annual Pm10 limit value).

In the following table the eKPIs related to gaseous emissions other than CO_2/GHG and the corresponding percentage of the relevant available are presented.

Table 6: NO_x, SO_x and NMVOC emissions eKPI and corresponding percentages of relevant available data

eKPI category (*)	eKPI	Description	Num. of ports/ % of ports for which information was collected	Data description
Emissions to the atmosphere	NO_x and SO_x emissions	Measure or estimation of NO_x and SO_x emissions	NO_x: 28/ 30.43% SO_x: 26/ 28.26%	Measurements of concentration or calculation of emission of NO_x and SO_x in the port area
Emissions to the atmosphere	Non-Methane volatile organic compounds emissions (NMVOC)	Total emission of non-methane volatile organic compounds in ports	7/ 7.61%	Measurements of concentration or calculation of emission of NMVOC (total or of specific compounds or of specific sources) in the port area

(*) As defined in PIXEL Deliverable D5.2

The detailed indicators related to organic and inorganic gaseous pollutants other than CO_2/GHG are presented in Table 7.

Table 7: Indicators related to organic and inorganic gaseous pollutants other than CO2/GHG

	Number of ports using the indicator(s)	% of ports for which information was collected	% of TEN-T ports
AIR QUALITY			
Nitrogen Oxides			
NO-related indicators:	**2**	**2.17**	**0.61**
Indicator:			
Annual/Campaign average concentration of NO (µg/m^3)	2	2.17	0.61

		Number of ports using the indicator(s)	% of ports for which information was collected	% of TEN-T ports
NO_2-related indicators:		**19**	**20.65**	**5.79**
	Indicators:			
	Annual average concentration of NO_2 ($\mu g/m^3$)	16	17.39	4.88
	Annual total number of exceedances of the hourly limit value of NO_2	7	7.61	2.13
	Real time, on-line publishing of NO_2 hourly average value ($\mu g/m^3$)	1	1.09	0.30
NO_x-related indicators:		**4**	**4.35**	**1.22**
	Indicators:			
	Annual average concentration of NO_x ($\mu g/m^3$)	4	4.35	1.22
	Annual total number of exceedances of the daily limit value of NO_x	1	1.09	0.30
Sulphur Oxides				
SO_2-related indicators:		**16**	**17.39**	**4.88**
	Indicators:			
	Annual and/or monthly average concentration of SO_2 ($\mu g/m^3$)	12	13.04	3.66
	Annual total number of exceedances of the daily limit value of SO_2 (125$\mu g/m^3$)	7	7.61	2.13
	Annual total number of exceedances the hourly limit value of SO_2 (350$\mu g/m^3$)	7	7.61	2.13
	Average winter concentration of SO_2 ($\mu g/m^3$)	1	1.09	0.30
	Maximum hourly value of SO_2 during campaign	1	1.09	0.30
	Maximum daily value of SO_2 during campaign	1	1.09	0.30
	Monthly average concentration of SO_2 on the quayside ($\mu g/m^3$)	1	1.09	0.30
Carbon Monoxide (CO)				
	Related indicators:	**6**	**6.52**	**1.83**
	Annual/campaign average concentration of CO (mg/m^3)	2	1.09	0.61
	Annual total number of exceedances of the maximum daily 8-hour mean limit value of CO (10mg/m^3)	2	1.09	0.61
	Annual maximum hourly value of CO (mg/m^3)	1	1.09	0.30
	Real time, on-line publishing of CO 8-hour average value (mg/m^3)	1	1.09	0.30
	Annual total number of exceedances of the maximum hourly limit value of CO (350$\mu g/m^3$)	1	1.09	0.30
Ozone (O_3)				
	Related indicators:	**5**	**5.43**	**1.52**
	Annual/campaign average concentration of O_3 ($\mu g/m^3$)	4	4.35	1.2

		Number of ports using the indicator(s)	% of ports for which information was collected	% of TEN-T ports
	Annual total number of exceedances of the maximum daily 8-hour mean limit value of O_3 (120μg/m^3)	3	3.26	0.91
	Real time, on-line publishing of O_3 hourly average value (μg/m^3)	1	1.09	0.30
	Real time, on-line publishing of O_3 8-hour average value (μg/m^3)	1	1.09	0.30
	Annual total number of exceedances of the maximum hourly limit value of O_3 (180μg/m^3)	1	1.09	0.30
Non-Methane Volatile Organic Compounds				
	Related indicators:	**4**	**4.35**	**1.22**
	Annual average concentration of C_6H_6 (μg/m^3)	3	3.26	0.91
	C_6H_6 daily average concentration (μg/m^3)	1	1.09	0.30
	Annual average concentration of Toluene (μg/m^3)	1	1.09	0.30
	Annual average concentration of Xylene (μg/m^3)	1	1.09	0.30
Other				
• Real time, on-line publishing of the 30-minute average Volatile Organic Compound (VOC) concentration (mg/m^3)				
EMISSIONS TO THE ATMOSPHERE				
Nitrogen Oxides				
NO_2-related indicators:		**1**	**1.09**	**0.30**
	Indicators:			
	Annual total emission of NO_2 from shipping in the port area (t)	1	1.09	0.30
NO_x-related indicators:		**10**	**10.87**	**3.05**
	Indicators:			
	Annual total emission of NO_x (kg or t)	6	6.52	1.83
	Annual total emission of NO_x from vessels in the port area (t)	2	2.17	0.61
	Annual average emission of NO_x per throughput (kg/t of cargo)	1	1.09	0.30
	Annual total NO_x emission from shipping in the port area (t)	1	1.09	0.30
	Annual total emission of NOx, broken down by source of emission (vehicle fleet, boilers) (t)	1	1.09	0.30
	Annual total NO_x emission from shipping in the port area per ship type (t)	1	1.09	0.30
Sulphur Oxides				
SO_2-related indicators:		**9**	**9.78**	**2.74**
	Indicators:			
	Annual total emission of SO_2 (kg or t)	4	4.35	1.22

	Number of ports using the indicator(s)	% of ports for which information was collected	% of TEN-T ports
Annual total emission of SO_2 from vessels in the port area (t)	2	2.17	0.61
Annual total emission of SO_2 from shipping (t)	2	2.17	0.61
Annual total emission of SO_2 per throughput (kg/t of cargo)	1	1.09	0.30
Annual total emission of SO2, broken down by source of emission (vehicle fleet, boilers) (t)	1	1.09	0.30
Annual total emission of SO_2 from shipping in the port area per ship type (t)	1	1.09	0.30
SO_x-related indicators:	**4**	**4.35**	**1.22**
Indicators:			
Annual total emission of SO_x (kg or t)	3	3.26	0.91
Annual total emission of SO_x from the PA fleet of ships & vehicles (t)	1	1.09	0.30
Carbon Monoxide (CO)			
Related indicators:	**1**	**1.09**	**0.30**
Annual total emission of CO from shipping in the port area per ship type (t)	1	1.09	0.30
Annual total emission of CO from shipping in the port area (t)	1	1.09	0.30
Non-Methane Volatile Organic Compounds			
Related indicators:	**3**	**3.26**	**0.91**
Annual total emission of C_6H_6 (kg or t)	1	1.09	0.30
Annual total emission of Non-Methane Volatile Organic Compounds (NVOC) from shipping in the port area (t)	1	1.09	0.30
Annual total emission of Non-Methane Volatile Organic Compounds (NVOC) from shipping in the port area per ship type (t)	1	1.09	0.30
Annual total losses of o-xylene on the liquid cargo terminal (kg)	1	1.09	0.30
Annual total losses of Methanol on the liquid cargo terminal (kg)	1	1.09	0.30
Annual total losses of Styrene on the liquid cargo terminal (kg)	1	1.09	0.30
Annual total emission of Ethan (kg)	1	1.09	0.30
Annual total losses of gas-oil on the liquid cargo terminal (kg)	1	1.09	0.30
Annual total losses of jet-fuel on the liquid cargo terminal (kg)	1	1.09	0.30
Other			
• Annual total emission of Methane (kg)			

	Number of ports using the indicator(s)	% of ports for which information was collected	% of TEN-T ports
• Annual total emission of NH_3 (kg)			
• Annual total emission of Hydrocarbons from shipping in the port area (t)			
• Real time, on-line publishing of the 30-minute average Volatile Organic Compound (VOC) concentration (mg/m^3)			
• Annual total emission of Volatile Organic Compound (VOC) (t)			
• Participation (%) of the port & industrial emissions to the concentrations of PM_{10}, NO_2 and Benzene in an adjacent settlement			

With regard to the particulate matter air pollutants, the related eKPI and the corresponding percentage of the relevant available data are presented in Table 8.

Table 8: Particulate Matter emissions eKPI and corresponding percentages of relevant available data

eKPI category (*)	eKPI	Description	Num. of ports/ % of ports for which data was collected	Data description
Emissions to the atmosphere	Particulate Matter (PM) emissions	Measure or estimation of the total amount of particulate matter emissions	38/ 41.30%	Measurements of concentration or calculation of total emissions of PM or of specific particulate matter categories (PM_{10}, $PM_{2.5}$, Black Carbon)

(*) As defined in PIXEL Deliverable D5.2

The detailed particulate matter indicators published by the reporting Port Authorities are presented in Table 9.

Table 9: Indicators related to Particulate Matter air pollutants

		Number of ports using the indicator(s)	% of ports for which information was collected	% of TEN-T ports
PM_{10}-related indicators:		**35**	**38.04**	**10.67**
	Indicators:			
	Annual/monthly/campaign average concentration of PM_{10} ($\mu g/m^3$)	30	32.61	9.15
	Annual total number of exceedances of the maximum 24-hour limit value of PM_{10} ($50\mu g/m^3$)	19	20.65	5.79
	Annual total emission of PM_{10} from vessels in the port area (t)	3	3.26	0.91
	Annual total emission of PM_{10} (kg or t)	3	3.26	0.91
	Annual average concentration of PM_{10} excluding the days with high Saharan dust levels ($\mu g/m^3$)	1	1.09	0.30
	Annual total emission of PM_{10} from vessels in the port area per ship type (t)	1	1.09	0.30
	Real time, on-line publishing of PM_{10} 24-hour average value ($\mu g/m^3$)	1	1.09	0.30

$PM_{2.5}$-related indicators:		**16**	**17.39**	**4.88**
	Indicators:			
	Annual/campaign average concentration of $PM_{2.5}$ (μg/m^3)	13	14.13	3.96
	Annual total emission of $PM_{2.5}$ from vessels in the port area (t)	2	2.17	0.61
	Real time, on-line publishing of $PM_{2.5}$ 24-hour average value (μg/m^3)	1	1.09	0.30
Other indicators observed				
	Average daily/campaign concentration of Sedimentable particles (mg/m^2)	4	4.35	1.22
	Annual average concentration of Black Carbon (μg/m^3)	2	2.17	0.61
	Annual total number of exceedances of the daily limit value of Sedimentable Particles (300mg/m^2)	2	2.17	0.61
	Annual total emission of PM, broken down by source of emission (vehicle fleet, boilers) (t)	1	1.09	0.30
	Annual/campaign average daily concentration of Suspended Particles (μg/m^3)	1	1.09	0.30
	Annual total number of exceedances of the daily limit value of Suspended Particles (150μg/m^3)	1	1.09	0.30
	Annual total number of days with significant Saharan dust concentration	1	1.09	0.30
	Annual total number of days with Saharan dust concentration exceeding regulatory limits	1	1.09	0.30
	Annual total particle emission from shipping (t)	1	1.09	0.30
	Annual average concentration of Particulate Matter (mg/m^3)	1	1.09	0.30
	Average annual total dust concentration inside the port (mg/m^2)	1	1.09	0.30
	Annual total number of exceedances of the 250mg/m^2 limit value of the average dust concentration	1	1.09	0.30

Other types of indicators are also used, reflecting the perception of the public about the impact of the port operations to air quality. The 40.22% of the ports for which data was collected (mainly the ports of Spain) use as an indicator the annual total number of complaints received by the port authority regarding the air quality while in one case, in addition, a distribution % of the air-related complains per source of air quality deterioration is provided. Finally, in the case of the port of Koper an annual poll is conducted which, among other parameters, measures the percentage of the citizens that regard the port as a source of air quality deterioration.

3.3.2. Port waste & wastewater

A significant part of the ports for which information was collected through content analysis of environmental sustainability reports or through the survey are using indicators related to the production of waste in the port, which comes from the Port Authority's operation and/or from other stakeholders/companies which may operate in the port (55 ports or 59.8% of ports). However, in the majority of cases it is not specified whether the quantities of produced/collected waste reported include also waste from other actors operating in the port area besides the Port Authority, which depends on port's waste management policy (outsourced or not) and the port governance model (e.g., in the landlord port model, several terminal operators may operate in the port thus their waste management and reporting may differ from the PA). The waste-related eKPIs and the corresponding percentages of the relevant available data are presented in Table 10.

Table 10: Waste production eKPI and corresponding percentages of relevant available data

eKPI category (*)	eKPI	Description	Num. of ports/ % of ports for which information was collected	Data description
Waste production	Amount or total of waste produced	Sum of all waste produced by port authorities and terminal operators	43/ 46.74%	Annual total quantity of waste produced by the PA and /or other port actors (concessionaires, vessels etc)
Waste production	Generation of hazardous waste	Sum of hazardous waste produced by port authorities and terminal operators	38/ 41.30%	Annual total quantity of hazardous waste produced by the PA and /or other port actors (concessionaires, vessels etc)
Waste production	Generation of non-hazardous waste	Sum of all solid urban waste produced by port authorities and terminal operators	39/ 42.39%	Annual total quantity of non-hazardous waste produced by the PA and /or other port actors (concessionaires, vessels etc)
Waste production	Percentage of waste recycled in a port	Sum of all recycled waste on port and separately collected	14/ 15.22%	Annual total quantity of recycled waste produced by the PA and /or other port actors (concessionaires, vessels etc)

(*) As defined in PIXEL Deliverable D5.2

Analysing the indicators used, they can be classified into three categories according to the information they provide. The first category includes indicators that provide information regarding the quantity of waste, broken down by general categories, such as hazardous, non-hazardous and inert waste and/or by detailed waste types, such as paper and cardboards, solid urban waste etc. The second category includes indicators which provide information regarding the shares of the collected waste by type of collection (segregated, non-segregated), and also by type of handling/destination of waste, such as the energy recovery, recycling, incineration, landfill etc. Finally, the third category includes indicators related to the collection of floating waste from the surface and water body of ports, and more specifically the quantity of waste, broken down by general types, such as solid, organic etc. and/or by detailed waste types such as wood, plastic etc. Due to the heterogeneous nature of waste most of these indicators are customised to each port's needs, thus giving a large part of indicators which are not used by multiple ports. In the following table, the set of waste related indicators are presented.

Table 11: Indicators related to waste production in ports.

		Number of ports using the indicator(s)	% of ports for which information was collected	% of TEN-T ports
Port waste-related indicators:		**55**	**59.78**	**16.77**
	Indicators:			
	Annual total quantity of collected floats by the cleaning service (kg, t, m^3)	28	30.43	8.54
	PA waste production (t) broken down by type (Hazardous/Non-hazardous) (t, % of total waste)	23	25.00	7.01

		Number of ports using the indicator(s)	% of ports for which information was collected	% of TEN-T ports
	PA waste that has been segregated (% of total PA waste) and recovered (% of total PA waste), broken down by type (Solid Urban/Hazardous/Oils):	16	17.39	4.88
	PA hazardous waste production broken down by detailed waste type (e.g., batteries, fluorescent) (t, % of total hazardous waste)	13	14.13	3.96
	PA non-hazardous waste production broken down by detailed waste type (e.g., glass, paperboard, organic) (t, % of total non-hazardous waste)	12	13.04	3.66
	Annual total quantity of waste collected by the port cleaning services for the purpose of landfill, broken down by type (Hazardous/Non-hazardous/Inert) (t and % of total quantity collected)	6	6.52	1.83
	PA annual total quantity of waste production, broken down by type of handling (e.g., recycling/recovery/landfill) (t, % of total waste)	4	4.35	1.22
	Annual total quantity of collected floats broken down by general waste category (e.g., solid/oily liquid or organic/inert) (t)	4	4.35	1.22
	Annual total quantity of collected floats broken down by detailed waste type (e.g., wood/plastic) (t, % of total floats collected)	4	4.35	1.22
	Annual total quantity of waste collected by the port cleaning services for the purpose of landfill, broken down by type (Solid Urban/Hazardous/Oils) (t)	4	4.35	1.22
	PA waste production broken down by detailed waste type (e.g., glass, paperboard, mixture) (t):	4	4.35	1.22
	Annual total quantity of waste produced in the port area, broken down by type (Hazardous/Non-hazardous/Inert) (kg, t, % of total)	3	3.26	0.91
	PA waste that has been recovered (% of total PA waste), broken down by type of waste (Hazardous/Non-hazardous):	3	3.26	0.91
	Segregated waste collected by the PA, broken down by detailed type of waste (e.g., Paper/Glass/Plastic) (kg, % of total segregated waste):	2	2.17	0.61
	Annual total quantity of waste collected by the PA and/or by the authorised cleaning services of the land area (t), broken down by type of collection (Segregated/ Non-Segregated) (t, % of total waste)	2	2.17	0.61
	Waste production from the companies (e.g., concessionaires) located in the port broken down by type (Hazardous/Non-hazardous) (t)	2	2.17	0.61
	Waste production of controlled origin, broken down by type (Hazardous/Non-hazardous) and detailed waste type (e.g., light packaging) (t)	2	2.17	0.61

		Number of ports using the indicator(s)	% of ports for which information was collected	% of TEN-T ports
	Waste production of accidental origin, broken down by type (Hazardous/Non-hazardous) and detailed waste type (e.g., light packaging) (t)	2	2.17	0.61
	Annual total quantity of Solid Urban Waste (kg)	2	2.17	0.61
	PA waste that has been segregated (% of total PA waste) and recovered (% of total PA waste), broken down by detailed waste type (Solid Urban/glass/wood etc):	1	1.09	0.30
	PA waste that has been segregated (t), broken down by type of waste (Hazardous/Non-hazardous):	1	1.09	0.30
	Hazardous waste collected by the PA (% of total waste collected) and has been segregated (% of total hazardous waste):	1	1.09	0.30
	PA Non-hazardous waste that has been recovered (t and % of total PA waste), broken down by detailed waste type (Solid Urban/glass/wood etc):	1	1.09	0.30
	PA Hazardous waste (t), broken down by handling type (recovered/ elimination) (t):	1	1.09	0.30
	PA non-Hazardous waste (t), broken down by handling type (recovered/ elimination) (t):	1	1.09	0.30
	Waste collected by the PA (including Solid Urban Waste from ships) (t), broken down by handling type (recovered/ elimination) (t and % of total waste collected) and detailed waste types (e.g., used oils, urban waste) (t):	1	1.09	0.30
	PA Hazardous waste that has been recovered (% of total hazardous waste):	1	1.09	0.30
	PA waste that has been recovered (% of total PA waste), broken down by detailed type of waste (% of total recovered waste):	1	1.09	0.30
	PA waste that has been recovered broken down by detailed type of waste (kg):	1	1.09	0.30
	PA waste handling (landfill/ composting/ recycling/ authorised managers) broken down by detailed waste type (t):	1	1.09	0.30
	Waste collected and managed by the PA and has been recovered (% of total waste collected):	1	1.09	0.30
	PA waste broken down by type of handling (recycling/ landfill) (% of mixed waste)	1	1.09	0.30
	PA construction contracts waste recycling rate (%)	1	1.09	0.30
	Waste that has been recovered (% of total waste), broken down by method of recovery (as compost/ as materials/ via energy recovery) (%)	1	1.09	0.30
	Annual total quantity of waste collected by the PA and/or by the authorised cleaning services of the land	1	1.09	0.30

		Number of ports using the indicator(s)	% of ports for which information was collected	% of TEN-T ports
	area (t), broken down by source of waste (Buildings/ Urban cleaning) (t)			
	Commercial waste collected by the PA broken down by type of handling (kg) and by detailed waste type (kg)	1	1.09	0.30
	PA commercial waste production per throughput (kg/1000t of cargo)	1	1.09	0.30
	Annual total quantity of waste produced in the port (by the cleaning of common areas and water bodies, ships) (t), broken down by type of collection (segregated/ non-segregated) (t and % of total waste)	1	1.09	0.30
	Annual total quantity of waste produced in the port (t), broken down by source of waste (land area/ water bodies/ ships) (t)	1	1.09	0.30
	Annual total quantity of general waste produced in the port (by the PA, the tenants, the contractors and vessels) (t), broken down by type of handling (recycling/ energy recovery/ landfill) (%)	1	1.09	0.30
	Annual total quantity of hazardous waste produced in the port (by the PA, the tenants, the contractors and vessels) (t), broken down by type of handling (recycling/ energy recovery/ sorting/ biological treatment) (%)	1	1.09	0.30
	PA waste production broken down by waste category (household/ commercial/ hazardous/ industrial) and by detailed waste types of each category (kg)	1	1.09	0.30
	PA waste production broken down by waste & treatment type (recyclable/general waste-energy production/hazardous-treatment/miscellaneous-landfill) (t)	1	1.09	0.30
	Waste production by the port community collected by the cleaning services broken down by detailed waste types (kg)	1	1.09	0.30
	Waste production by the construction works contracted in the port area (kg)	1	1.09	0.30
	PA waste production broken down by type (Hazardous/recoverable) (t, % of total waste)	1	1.09	0.30
	Waste production from the companies located in the industrial area and the port, broken down by type (Hazardous/Non-hazardous) (t)	1	1.09	0.30
	Waste production from the companies located in the industrial area and the port, broken down by type of handling (recycling/energy production/incineration/ landfill/ sorting) (t)	1	1.09	0.30
	Accidental hazardous waste production of unknown origin, broken down by detailed waste type (Impregnated solids/oils residue with water/soil with hydrocarbons) (kg):	1	1.09	0.30

		Number of ports using the indicator(s)	% of ports for which information was collected	% of TEN-T ports
	Annual total quantity of polluted soil (t)	1	1.09	0.30
	Annual total quantity of sweep debris and bulk cargo residues (t), broken down by type of handling (Biogas/sorting-recycling/incineration)	1	1.09	0.30
	Annual total quantity of waste, broken down by type (Hazardous/Non-hazardous) and handling method (reutilisation/ recycling/ composting/ reprocessing/ incineration/ landfill/ on-site storage/other) (t)	1	1.09	0.30
	port waste production per employee (kg/employee) and evolution (%) of the indicator in relation to a base year	1	1.09	0.30
	port waste production per throughput (kg/ton transported) and evolution (%) of the indicator in relation to a base year	1	1.09	0.30
	port waste production per ship served (kg/ship) and evolution (%) of the indicator in relation to a base year	1	1.09	0.30
	Annual total quantity of waste collected in the port common areas (t), broken down by detailed waste type (e.g., Solid Urban waste, packaging) (% of total waste collected)	1	1.09	0.30
	Annual total quantity of waste collected in the port common areas broken down by waste type (Hazardous/Non-hazardous) (% of total waste collected)	1	1.09	0.30

Regarding the production of wastewaters in ports, the related eKPIs and the corresponding percentages of the relevant available data are presented in Table 12.

Table 12: Wastewater production eKPI and corresponding percentages of relevant available data.

eKPI category (*)	eKPI	Description	Num. of ports/ % of ports for which information was collected	Data description
Wastewater emissions	Stormwater network (%)	Percentage of the port area that has a system for the collection and treatment of rainwater	22/ 23.91%	Percentage of the surface of the service area that has rainwater collection which has some treatment before discharged (%)
Wastewater emissions	Sanitary wastewater (m^3 per unit cargo)	Sanitary wastewater produced by port activities	27/ 29.35%	Annual total volume of wastewater produced by the PA or is discharged in PA collectors (m^3)

(*) As defined in PIXEL Deliverable D5.2

The indicators related to the production of wastewater in ports are mainly published by the Spanish ports according to the guidelines for the preparation of sustainability reports and focus on three aspects of wastewater handling, namely the area of coverage of the wastewater collection system, the volume and types of wastewater and the methods of treatment/destination of wastewater. The set of indicators is presented in the following table:

Table 13: Indicators related to wastewater production in ports.

		Number of ports using the indicator(s)	% of ports for which information was collected	% of total number of TEN-T ports
Wastewater-related indicators:		**37**	**40.22**	**11.28**
	Indicators:			
	Percentage of the surface of the service area that has wastewater collection and is connected to the municipal collector or a WWTP (Waste Water Treatment Plant) (%)	27	29.35	8.23
	Percentage of the surface of the service area that has a wastewater collection network (regardless of where it is discharged or if it is treated) (%)	26	28.26	7.93
	Percentage of the surface of the service area that has its wastewater discharged into septic tanks (%)	26	28.26	7.93
	Percentage of the surface of the service area that has a network of rainwater collection (regardless of whether the water is treated or not) (%)	25	27.17	7.62
	Percentage of the surface of the service area that has rainwater collection which has some treatment before discharged (%)	22	23.91	6.71
	Annual total volume of wastewater produced by the PA or is discharged in PA collectors broken down by wastewater type (Urban/ Industrial/ Mixed) (m^3, % of total wastewater)	17	18.48	5.18
	Annual total volume of wastewater produced by the PA or is discharged in PA collectors broken down by destination (Municipal collector/ Septic tanks/ Own treatment/ Other) (m^3, % of total wastewater)	16	17.39	4.88
	Annual total volume of wastewater produced by the PA or is discharged in PA collectors (m^3)	5	5.43	1.52
	Annual total volume of urban wastewater produced by the PA or is discharged in PA collectors (m^3)	1	1.09	0.30
	Annual total volume of wastewater discharge broken down by treatment method (none/ sedimentation and nitrification/ sedimentation and deferrisation/ purification plan) and by place of discharge (m^3)	1	1.09	0.30
	Annual total volume of wastewater discharged by the port, broken down by type (Sanitary/ Industrial/ Rainwater) and by port area (excl. Sanitary water) (m^3)	1	1.09	0.30

		Number of ports using the indicator(s)	% of ports for which information was collected	% of total number of TEN-T ports
	Annual total volume of wastewater discharged by the PA buildings and by ships (m^3)	1	1.09	0.30
	Annual total volume of wastewater discharge from the port and industrial estate (m^3 and pollution units)	1	1.09	0.30

3.3.3. Waste from ships

Approximately half (52,17%) of the ports for which information was collected through content analysis of environmental sustainability reports or through the survey use indicators related to the collection of waste from ships. The ship waste-related eKPIs and the corresponding percentages of the relevant available data are presented in Table 14.

Table 14: Ship waste production eKPI and corresponding percentages of relevant available data.

eKPI category (*)	eKPI	Description	Num. of ports/ % of ports for which information was collected	Data description
Waste production	Total garbage from ships	The amount of waste to be landed from ships	35/ 38.04%	Total amount of ship garbage collected by the port (MAPROL V Annex - Garbage) (m3)
Wastewater emissions	Grey and black wastewater recuperation (m3 per unit cargo)	Total volume of grey and black wastewaters collected by port	16/ 17.39%	Total volume of Black & Grey wastewater collected by the port (MAPROL IV Annex - Sewage) (m^3)
Wastewater emissions	Ballast water recuperation from ships (m3 per unit cargo)	Total volume of ballast water collected by port	-	-

(*) As defined in PIXEL Deliverable D5.2

The majority of these ports (36 of 48 or 75.0%) provide the waste data analysed according to the MARPOL waste categories. The categories mostly used are the Annex I (Oil & oily water) and AnnexV (Garbage) which are used by almost all ports using MARPOL categorisation (35 ports), followed by Annex IV (Sewage water) used by 16 ports. A significantly smaller number of ports uses Annexes II (noxious liquid substances in bulk) and VI (air pollution), 6 and 4 ports respectively. Furthermore, a large number of more specialised ship-waste indicators and also indicators concerning barges were recorded and are presented in Table 15.

Table 15: Ship waste-related indicators

		Number of ports using the indicator(s)	% of ports for which information was collected	% of TEN-T ports
Ship waste-related indicators:		**48**	**52.17**	**14.63**
	Indicators:			
	Annual total waste collected from ships per MARPOL category:	**36**	**39.13**	**10.98**
	Annex I (l, m^3or t or % of total)	35	38.04	10.67
	Annex II (l, m^3 or t or % of total)	6	6.52	1.83
	Annex IV (l, m^3 or t or % of total)	16	17.39	4.88
	Annex V (l, m^3 or t or % of total)	35	38.04	10.67
	Annex VI (l, m^3 or t or % of total)	4	4.35	1.22
	Annual average volume of waste collected per MARPOL category and per ship (m^3)	1	1.09	0.30
	Annual total amount of ship waste collected by the port (t)	8	8.70	2.44
Other indicators observed				
	Total amount of ship waste (t) broken down per type of handling (%)	5	5.43	1.52
	Annual total amount of ship waste collected, per type (hazardous/non-hazardous) (t)	3	3.26	0.91
	Annual total amount of ship sludge collected (t)	2	2.17	0.61
	Annual total amount of sea waste collected from fishing boats (t)	2	2.17	0.61
	Annual total amount of black and grey water collected (m^3)	1	1.09	0.30
	Annual total amount of waste from barges collected, per type (t)	1	1.09	0.30
	Annual total amount of bilge oil & waste water collected from barges (m^3)	1	1.09	0.30
	Annual total amount of waste water collected from ships (m^3)	1	1.09	0.30
	Annual total amount of sewage collected from cruise ships (m^3)	1	1.09	0.30
	Percentage of ship waste reused (%)	1	1.09	0.30
	Annual total amount of Solid Urban Waste collected from ships (t)	1	1.09	0.30

3.3.4. Noise

The 50.0% of the ports for which information was collected through content analysis of environmental sustainability reports or through the survey use indicators related to port noise. However, 22 of these ports (47.8%) report only on the annual total number of complaints related to the noise produced by the port activities rather than actual measurements. Overall, this indicator (number of complaints) is used by the 43.0% of the reporting ports. The noise-related eKPIs and the corresponding percentages of the relevant data published by the reporting Port Authorities are presented in Table 16.

Table 16: Noise emission eKPIs and corresponding percentages of relevant available data

eKPI category (*)	eKPI	Description	Num. of ports/ % of ports for which information was collected	Data description
Noise emissions	Compliance with limits at day, evening and night-time	Measures of the number of overruns of the legal limits	23/ 26.74%	Annual total number of exceedances of noise limits day and/or night
Noise emissions	L_{DEN} (overall day-evening-night noise level)	Measure of the average sound level over a 24-hour period	22(**)/ 25.58%	Annual/campaign average level L_{den} of the port area in db(A)
Noise emissions	L_{night} (23:00 - 7:00hrs noise level)	Measure of the average sound level by night	13(**)/ 13.95%	Annual/campaign average level L_{night} of the port area in db(A)

(*) As defined in PIXEL Deliverable D5.2

(**) The ports which state in their reports that have drawn a noise map or are part of the noise map of an adjacent municipality, are considered to calculate L_{DEN} and L_{night} indicators, according to the EU Directive 2002/49/EC relating to the assessment and management of environmental noise which defines as common noise indicators the L_{den}, to assess annoyance, and L_{night}, to assess sleep disturbance.

The noise-related indicators recorded are presented in the following table:

Table 17: Noise-related indicators

		Number of ports using the indicator(s)	% of ports for which information was collected	% of TEN-T ports
Noise-related indicators:		**46**	**50.00**	**14.02**
	Indicators:			
	Annual total number of complaints related to noise produced by the port operations	42	45.65	12.80
	Annual/Campaign average sound levels in the day, evening and night period (L_{DEN}) (dB(A))	26	28.26	7.93
	Annual/Campaign average sound levels in the night period (L_{night}) (dB(A))	23	25.00	7.01
	Annual total number of exceedances of noise limits day and/or night	13	14.13	3.96
	% of public opinion of the port as a source of increased noise levels	1	1.09	0.30
	Noise level measured at the edge of the container terminal and in the nearest residential areas in relation to the number of containers handled (db(A)/I million TEU)	1	1.09	0.30
	Distribution of people to various noise levels exposure at day, evening and night hours (number of people and %)	1	1.09	0.30

	Total number of residents exposed to port noise	1	1.09	0.30
	Total number of residents exposed to port noise >55dB(A)	1	1.09	0.30
	Campaign twice a year using LAeq index (total port area)	1	1.09	0.30

3.3.5. Dredging

Approximately 44.57% of the ports (12.50% of total TEN-T ports) for which data on environmental indicators was collected through content analysis of the environmental sustainability reports and the survey, use indicators related to their dredging operations. The majority of these ports are Spanish (73.17% of ports) as a result of a national reporting obligation. This obligation for the Spanish ports includes also the requirement of following a national Guide for the elaboration of sustainability reports that includes a relevant field (A_25). However, due to the absence of dredging operations in several Spanish ports (19 out of 31 ports) during the available ESR reference years, the proposed indicators by the Guide are used in the following analysis.

The classification of dredged materials used by the Spanish ports is according to the CEDEX and the newer CIEM guidelines, while in the case of other ports the annual total volume is provided without any further classification of the dredged materials. Finally, it is worth mentioning that in the case of the ports of Bremen and Bremerhaven which are river ports and thus dredging is an important activity for their uninterrupted operation, the ports publish multiple dredging-related indicators providing in-depth information of these activities (the last 5 indicators in Table 18).

Table 18: Dredging-related indicators

	Units	Number of ports using the indicator(s)	% of ports for which information was collected	% of TEN-T ports
Dredging-related indicators:	**-**	**41**	**44.57**	**12.50**
Indicators:				
- Annual total volume of dredged materials	m^3	39	42.39	11.89
- Annual total volume of each type of dredged material, according to the dredging guidelines of CIEM*	m^3	18	19.57	5.49
- Percentage of contaminated dredged materials (types II & III) on the total dredged materials	%	7	7.61	2.13
- Annual total volume of contaminated dredged materials (categories II & III of CEDEX** guidelines)	m^3	6	6.52	1.83
- Percentage of dredged materials of type I on the total dredged materials	%	6	6.52	1.83
- Annual total amount of deposited dredged materials on the spray field	m^3	1	1.09	0.30
- Annual total volume of dredged sand reused	m^3	1	1.09	0.30
- Annual total volume of dredged sand in barge contentment (wet) and % distribution per handling (relocated/ directly reused/ deposited)	m^3	1	1.09	0.30
- Annual total volume of dredged mud in barge contentment (wet) and % distribution per handling (relocated/ directly reused/ washed	m^3	1	1.09	0.30

onto dewatering fields for treatment/ directly deposited)				
- Annual total amount of removed dredging spoils in field volume (wet) and %, m^3 distribution per handling (reuse/ deposited in dry state)	m^3	1	1.09	0.30
- Deposited dredging spoils as a percentage of the dredged mud	%	1	1.09	0.30
- Percentage of dredged materials reintroduced into the receiving system	%	1	1.09	0.30
- Distribution of dredged materials to contamination classes	%	1	1.09	0.30
- Annual total amount of dredged materials in relation to the port area	m^3/m^2	1	1.09	0.30

** CIEM: Comisión Interministerial de Estrategias Marinas (Interministerial Commission for Marine Strategies)*
*** CEDEX: Centro de Estudios y Experimentación de Obras Públicas del Ministerio de Fomento (Center for Studies and Experimentation of Public Works of the Ministry of Development)*

3.3.6. Environmental incidents

The majority of ports (56.52%) for which information was collected through content analysis of environmental sustainability reports or through the survey use indicators related to environmental incidents. The environmental incident-related eKPIs and the corresponding percentages of the relevant available data are presented in table 18.

Table 19: Environmental incidents eKPIs and corresponding percentages of relevant available data.

eKPI category (*)	eKPI	Description	Num. of ports/ % of ports for which information was collected	Data description
Wastewater emissions	Accidental leakage or spill (per unit cargo)	Number of accidental leakages or spills for chemicals products based on environmental management	38/ 41.30%	Annual total number of water contamination incidents that required the activation of Maritime Plans for pollution emergency response

(*) As defined in PIXEL Deliverable D5.2

Besides the number of incidents, a significant part of ports provides information regarding the level of response to these incidents according to their pollution emergency response plans. In some cases, the ports provide data regarding the corresponding annual total quantity of spills along with the number of contamination incidents. The environmental incidents-related indicators are presented in Table 20.

Table 20: Environmental incidents-related indicators

		Number of ports using the indicator(s)	% of ports for which information was collected	% of TEN-T ports
Environmental incidents-related indicators:		**52**	**56.52**	**15.85**
	Indicators:			
	Annual total number of incidents that required the activation of Maritime Plans for pollution emergency response	14	15.22	4.27
	Annual total number of incidents that required the activation of Maritime Plans for pollution emergency response, broken down by type of response (e.g., no response, national maritime plans)	25	27.17	7.62
	Annual total number of water contamination incidents	17	18.48	5.18
	Annual total quantity of spills (l)	5	5.43	1.52
	Annual total number of oil spill incidents on or around the water surface, broken down by cause (e.g., bunkering operations, activities on board ship)	1	1.09	0.30
	Annual total number of oil spill and pollution reports, broken down by type of pollution (e.g., insignificant, historical) (number & % of total reports)	1	1.09	0.30

3.4. Resource consumption metrics applied

3.4.1. Energy consumption

The majority of the PAs (managing 82 out of 92 ports or 89.13%) provide some type of indicators regarding their consumption of energy. Based on the research findings, the energy-related indicators published by the PAs or were stated in the survey can be grouped into the following categories: total energy, electricity, fuel/gas, district heating energy and heating energy consumption. In several cases fuel consumption is characterised as direct energy consumption while the electricity and district heating energy consumption as indirect energy consumption. Most of the indicators used refer to the consumption of energy by the Port Authority, though one must always keep in mind that the main part of energy is consumed by the terminal operators in a port. Nevertheless, in some cases, the indicators used cover the consumption of the total port area, including the concessionaires or third parties operating in the port, the ships in the port or of an industrial area located within the port. Furthermore, additional indicators are used in several cases which provide details of each of the categories above (for example: the total fuel consumption of the PA analysed to each type of fuel used). In the following table, the indicators used are presented per consumption category.

Table 21: Energy consumption related indicators

		Units	Number of ports using the indicator(s)	% of ports for which information was collected	% of TEN-T ports
Total energy consumption-related indicators:			**29**	**31.52**	**8.84**
	Indicators:				
	Annual total energy consumption by the PA	KWH, MWh, GJ, PJ	21	22.83	6.40

		Units	Number of ports using the indicator(s)	% of ports for which information was collected	% of TEN-T ports
	Annual average total energy consumption by the PA per throughput	KWH /t or 1000t, GJ/t or 1000t of cargo	11	11.96	3.35
	Annual total energy consumption in the port area	MWH	6	6.52	1.83
	Annual average total energy consumption in the port area per throughput	KWH/t	1	1.09	0.30
	Annual average total energy consumption in the port area per employee	MWH/employee	1	1.09	0.30
	Annual average total energy consumption in the port area per ship served	KWH/ship	1	1.09	0.30
	Annual total energy consumption by the PA, broken type by type of energy (e.g., electricity, Biogas) (MWh)	MWh	1	1.09	0.30
	Annual total energy consumption in the port area (including the industrial zone), per business sector	PJ	1	1.09	0.30
	Annual total energy consumption in the public docks	MWh	1	1.09	0.30
Electricity consumption-related indicators:			**79**	**85.87**	**24.09**
	Indicators:				
	Annual total consumption of electricity by the PA	KWH, MWH, GJ, % of total energy	71	77.17	21.65
	Annual average electricity consumption by the PA per port service area	KWH/m^2	26	28.26	7.93
	Annual total consumption of electricity by the PA, per use	KWH, MWH, % of total electricity	20	21.74	6.10
	Annual total consumption of electricity by the PA, per source type (green/conventional)	GJ, % of total electricity	18	19.57	5.49
	Annual total electricity consumption in the port area	MWH, GJ	8	8.70	2.44
	Annual total consumption of electricity by the concessionaires or third parties	GJ, KWH	5	5.43	1.52
	Annual total consumption of electricity by ships	GJ, KWH	3	3.26	0.91
	Annual average consumption of electricity by the PA per throughput	KWH/t or 1000t of cargo	2	2.17	0.61
	Annual average electricity consumption of PA buildings per building area	KWH/m^2	2	2.17	0.61
	Annual average electricity consumption by the PA per employee	MWH/employee	2	2.17	0.61
	Annual total primary energy consumed for the production of electricity for the PA	KWH, GJ	2	2.17	0.61

		Units	Number of ports using the indicator(s)	% of ports for which information was collected	% of TEN-T ports
	Annual change in electricity consumption by the PA	%	2	2.17	0.61
	Annual average consumption of electricity by the port cranes per throughput	KWH/1000t of cargo	1	1.09	0.30
	Annual average electricity consumption by the PA for heating per building area	KWH/m^2	1	1.09	0.30
	Annual total consumption of electricity for port activities (operators & others)	KWH	1	1.09	0.30
	Annual total consumption of electricity for public lighting	KWH	1	1.09	0.30
	Annual total consumption of electricity in the economic zone	GJ, KWH	1	1.09	0.30
	Annual total electricity consumption by the service companies of general interest	MWH, GJ	1	1.09	0.30
Fuel consumption-related indicators:			**70**	**76.09**	**21.34**
	Indicators:				
	Annual total fuel consumption by the PA	l, m^3, t, MWH, KWH, GJ, % of total energy	61	66.30	18.60
	Annual total consumption of fuel by the PA, per type	KWH, MWH, GJ, l, m^3, t, % of total fuel energy	43	46.74	13.11
	Annual total consumption of fuel by the PA, per use	KWH, % of total fuel energy	31	33.70	9.45
	Annual average fuel consumption by the PA per port service area	KWH/m^2	22	23.91	6.71
	Annual average fuel consumption by the PA per throughput	l/1000t or l/t, KWH/1000t of cargo	4	4.35	1.22
	Annual average fuel consumption by the PA per employee	MWH/employee	2	2.17	0.61
	Annual total fuel consumption in the port area	MWh	2	2.17	0.61
	Annual total fuel consumption by the PA & companies in the port area	m^3	1	1.09	0.30
	Annual total fuel consumption for port activities (operators & other companies in the port)	l	1	1.09	0.30
	Annual total fuel consumption by the service companies of general interest	MWH	1	1.09	0.30
District heating energy consumption-related indicators:			**10**	**10.87**	**3.05**
	Indicators:				

		Units	Number of ports using the indicator(s)	% of ports for which information was collected	% of TEN-T ports
	Annual total district heating and/or cooling used by the PA	m^3, KWH, MWH, GJ, % of total energy	10	10.87	3.05
	Annual average district heating energy consumption by the PA per building area	KWH/m^2	1	1.09	0.30
Heating energy consumption-related indicators:			**14**	**15.22**	**4.27**
	Indicators:				
	Annual total heating and/or cooling energy consumption by the PA	GWH, KWH, % of total energy	9	9.78	2.74
	Annual total heating energy consumption in the port area	MWH	4	4.35	1.22
	Annual total heating energy consumption by the PA, per source of consumption	MWH	1	1.09	0.30
	Annual average heating energy consumption by the PA per throughput	KWH/1000t of cargo	1	1.09	0.30
	Annual average heating energy consumption by the PA per building area	KWH/m^2	1	1.09	0.30
	Annual total heating energy consumption by the service companies of general interest	MWH	1	1.09	0.30

3.4.2. Water consumption

As in the case of energy consumption, the majority of the ports (60 ports out 92, 65.22%) use indicators regarding the consumption of water. These indicators mainly refer to the water consumption by the PAs but also indicators regarding the consumption by the port users (e.g., concessionaires, ships) are also used. Furthermore, a large number of indicators which correlate consumption with the port characteristics (e.g., total or building area, number of employees, throughput) have also been recorded. These indicators are presented in Table 22.

Table 22: Water consumption-related indicators

		Units	Number of ports using the indicator(s)	% of ports for which information was collected	% of TEN-T ports
Water consumption-related indicators:			**60**	**65.22**	**18.29**
	Indicators:				
	Annual total water consumption by the PA	m^3	50	54.35	15.24
	Annual average water consumption by the PA per service area	m^3/m^2	24	26.09	7.32
	Efficiency of water supply network	%	21	22.83	6.40
	Total water consumption by the PA per type of use	m^3, % of total consumption	20	21.74	6.10
	Annual total water consumption in the port area	m^3	8	8.70	2.44

		Units	Number of ports using the indicator(s)	% of ports for which information was collected	% of TEN-T ports
	Annual total volume of water supplied to ships	m^3	5	5.43	1.52
	Annual total water consumption per end user (PA, concessionaires, ships supply)	m^3	4	4.35	1.22
	Annual total water consumption in the port area including water supplied to ships	m^3	3	3.26	0.91
	Annual total water consumption per source of water	m^3	2	2.17	0.61
	Annual average water consumption of the PA per employee	m^3/employee	2	2.17	0.61
	Annual average water consumption per throughput	l/t, m^3/1,000t or 100,000t	2	2.17	0.61
	Annual total water consumption by the service companies of general interest	m^3	1	1.09	0.30
	Annual average total port water consumption per employee	m^3/employee	1	1.09	0.30
	Annual average total port water consumption per throughput	m^3/t	1	1.09	0.30
	Annual average total port water consumption per ship served	m^3/ship	1	1.09	0.30
	Annual average water consumption of the port administration per building area	m^3/m^2	1	1.09	0.30
	Annual average water consumption of the port administration per employee	m^3/employee	1	1.09	0.30
	Ratio of unaccounted water/total water used	%	1	1.09	0.30
	Annual total volume of rainwater harvesting	l	1	1.09	0.30
	Annual total drinking water consumption by barges	m^3	1	1.09	0.30
	Annual total drinking water consumption in the port area	m^3	1	1.09	0.30
	Annual total drinking water consumption per throughput	m^3/t	1	1.09	0.30
	Annual total drinking water consumption by the PA	m^3	1	1.09	0.30
	Annual total drinking water consumption by the ships & other port users	m^3	1	1.09	0.30

3.4.3. Materials

Several Port Authorities also use indicators related to the consumption of materials used for the port's everyday operations, being mainly the consumption of paper. These indicators are presented in Table 23.

Table 23: Materials consumption-related indicators

		Units	Number of ports using the indicator(s)	% of ports for which information was collected	% of TEN-T ports
Material consumption-related indicators:			**14**	**15.22**	**4.27**
	Indicators:				
	Annual total consumption of paper by the PA:		12	13.04	3.66
		t, kg	5	5.43	1.52
		A4/employee	1	1.09	0.30
		number of sheets	1	1.09	0.30
		t/employee	2	2.17	0.61
		Plotter paper (number)	1	1.09	0.30
		Reams of A3 & A4	1	1.09	0.30
	Annual total number of printed copies and photocopies		6	6.52	1.83
	Consumption of excipients broken down by type (e.g., Grease, lubricants, hydraulic oils, engine oils, paint)	Kg, kg/1000t of cargo	5	5.43	1.52
	Annual total consumption of Toner	kg, number	2	2.17	0.61
	Annual total consumption of light bulbs	number	1	1.09	0.30
	Annual total consumption of batteries	number	1	1.09	0.30

3.4.4. Land use

The efficiency of land use is an indicator used mainly by the Spanish ports according to the guidelines for drawing up their sustainability reports. It is defined as the percentage of the port area that is occupied by active installations (owned or under concession or authorisation). Approximately 74% of the Spanish TEN-T ports (26 ports) include this indicator in their reports. Other relevant indicators used also by the Spanish ports are: the total build up area (m^2) per employee (observed in one PA report – two ports) and the total green area of the port, broken down by grass area (m^2) and garden area (m^2).

Table 24: Land use-related indicators

		Number of ports publishing the indicator(s)	% of ports for which information was collected	% of TEN-T ports
Land use-related indicators:		**30**	**32.61**	**9.15**
	Indicators:			
	Percentage of the terrestrial service zone that is occupied by the active installations, whether these are owned or under concession or authorisation (%)	28	30.43	8.54
	Total built-up area of the port (m^2/employee)	2	2.17	0.61
	Total green area of the port, broken down by type (grass and garden area) (m^2)	2	2.17	0.61

3.5. Composite metrics applied

No composite metrics bringing together the various environmental impacts were found in the ESR reports of the TEN-T ports. Only in one case, a composite index in an environmental sub-area was identified, but with very limited scope, and of qualitative nature. This was the case of the Cleanliness Index of the port of Antwerp, being ‘a measurement based on the presence or absence of litter, fly tipping, weed growth, road defects etc’. As clarified, the index ‘does not measure the amount of litter or fly tipping in absolute terms, but rather it expresses the degree of cleanliness of public spaces’ (Port of Antwerp, 2018).

4. Adoption practices & implementation problems

This chapter will focus on the adoption practices of environmental impact measurements by the European ports in terms of data capture methods and sharing of results and on the problems faced in introducing and using them on a daily basis. Furthermore, it will examine the current use of industry benchmarks by ports in order to assess their environmental performance in comparison to them.

From the content analysis, no composite metrics were found to be used by the ports. The interviews with ports will further explore the use or plans for a composite indicator and the ports' perception towards using it.

4.1. Data capture

4.1.1. Survey structure

In the context of the survey, a sum of 13 responses was collected covering ports of all sizes, belonging to core and comprehensive TEN-T, including also 3 ports participating to the project as pilot ports. More specifically, the answers included 6 small ports (2 core and 4 comprehensive), 4 medium ports (3 core and one comprehensive) and 3 large ports, all belonging to the core network.

The participants were offered a range of choices based on the results from the content analysis of the ESRs in order to state the capture method used from their ports to collect data regarding air pollution emissions (GHG, Particulate Matter, NO_x, SO_x, O_3 and NVOC emissions), waste production and wastewater discharge (waste from ships, port wastewater and port waste) and also noise emissions and dredging. For each of these categories the options included the manual collection of data, the automatic collection through IoT sensors and not collecting actual data but calculating through emission/discharge factors. In the case of waste from ships, an additional option was offered, that of the automatic collection of data through o Port Community System (PCS) or a Terminal Operating System (TOS).

In terms of the data collection frequency, in the case of manual capture of data and calculation using emission/discharge factors the suggested frequency used was once, twice a year or monthly with the exception of the waste from ship category where there was also an option for measuring manually and continuously the quantity of waste (per ship call). In the case of the automatic collection of data, through IoT sensors or through a PCT/TOS system, the only option was the continuous (online) collection of data.

Finally, in all categories of metrics (air emissions, waste etc.) the "other" option was provided to the participants to state a different capture method or a different frequency of data collection.

4.1.2. Data collection methods & frequency

Based on the results of the survey, with respect to air emissions, all participating medium and large size ports and also half of small ports stated to be capturing GHG emission data. Regarding the most commonly used methods and the frequencies of data capture, in the majority of cases (70%) it is made through calculations using emission factors once a year (in one case monthly) followed by the manual collection of data through on-site measurement once a year (40%). Furthermore, in 30% of all cases, more than one method was used including manual capture together with calculations through emission factors and also in one case the automatic collection through IoT sensors. These was also recorded a case of a small size port in which environmental measurements area are an obligation of the industry established in the port are and therefore no further information regarding methods and frequencies is available.

In the case of PM emissions, a clear trend toward the automatic and continuous measure of PMs through installed IoT sensors was recorded in approximately 90% of cases, while in 25% of these cases also a second method is used including the monthly manual measurements and/or the calculations using emission factors monthly/once a year. Overall, the method of calculations using emission factors is used by 30% of ports which provided information about PM emissions measurements.

Similar to the PMs, also in the cases of NO_x, SO_x, O_3 and NMVOCs measurements the same trend toward the use of IoT sensors to capture automatically and continuously data was recorded in the survey. For NO_x and SO_x

measurements the percentages were 83% and 80% respectively with only one case using a different method, that of performing calculations using emission factors once every year. In the case of NMVOCs the IoT sensors was the only method used, however only the 25% of participants provided information regarding the methods and frequencies used for collecting data. Finally, in the majority of O_3 measurements (approximately 60% of cases) the IoT sensors are used but also the method of calculations through emission factors is implemented once a year in approximately 40% of cases.

Regarding waste production and wastewater discharge, according to the results of the survey, the preferred method in the vast majority of ship waste measurements is the manual collection of data (over 90% of cases). The most common frequency used is monthly (over 70% of the manual collection cases) while the other frequencies recorded but with a very low share include weekly, twice a year and per ship call collection of data. As for other methods used, a case of calculations using discharge factors monthly and a case of automatic collection of data through the Port Community Systems were recorded.

In the case of wastewater discharge measurements, the manual collection of data through on-site measurements is the method used in all cases with one case implementing also calculations of annual volume of wastewater using discharge factors. In more than half of cases the measurements have a frequency of one time per year. Other frequencies recorded but with a very low share include monthly and twice a year collection of data.

Similar responses to ship waste and wastewater discharge were also recorded regarding port waste in relation to the data capture methods used. According to the results of the survey, the only method used is the manual collection of data through on-site measurements. Regarding the frequency of measurements, in the majority of cases (60%) these are performed monthly, followed by the frequency of once per year (30%).

In relation to noise pollution, the results of the survey showed an almost equal sharing of results between the automatic continuous collection of data through installed IoT sensors and performing manually measurements on-site with one case using both methods. It is also worth noting that in the cases of manually performing noise measurements, the frequencies vary depending on the individual needs of each port; the frequencies recorded include monthly, twice per year, once every three years measurements and also in the context of a noise pollution study conducted whenever deemed necessary.

Finally, regarding the methods and frequencies used to capture data on dredging operations, the only method used is the manual collection of data through on-site measurements. Also in this case the frequency of performing measurements vary depending on the individual needs of each port; the frequencies recorded include the daily, monthly, once or twice a year and also a case in which the measurements are performed whenever deemed necessary.

Concluding from the above analysis of the questionnaire survey results, an extensive use of manual, on-site measurements for collecting data in ports is recorded, especially regarding waste, wastewater and dredging but also GHG emissions and noise pollution. Furthermore, the use of calculating methods through emission factors instead of actual field measurements is also used in the case of GHG emissions while the preferred method regarding the other gaseous pollutants (PM, NO_x, SO_x, O_3 and NMVOC) is the automatic and continuous collection of data through IoT sensors.

4.2. Data/information sharing

4.2.1. Survey structure

In addition to the information collected about the methods and frequencies used for capturing data, the survey also examined the methods used for sharing this data/information with relevant stakeholders, including all main categories of metrics identified in the previous stages (emissions to the atmosphere, waste & wastewater discharge and noise). For each of these categories, three main types of stakeholders were identified: the city/regional authority, the ports users and the citizens/NGOs. Regarding the methods used for data/information sharing, for each stakeholder type the proposed methods included were: ad-hoc meetings, through a permanent stakeholder committee, press releases, regular publishing of Sustainability Reports and through a PCS/TOS system online. It should be noted that in the lists of main categories of metrics, of stakeholders and of sharing methods, the participants had the “other” option in order to add information if they deemed it necessary.

4.2.2. Practices used

According to the results of the survey, the two most preferred practices used by ports (in approximately half of the cases) to share the results of their environmental metrics with all relevant stakeholders, are the organization of ad-hoc meetings and the publication of annual sustainability reports. The latter method was largely expected as about half of participating ports stated that they publish sustainability reports annually. Regarding ad-hoc meetings, these are mostly targeted towards city/regional authorities and port users, however approximately half of ports stated that are organising such meetings also with citizens and NGOs. As for the other practices used, issuing press releases and the sharing of information through an online PCS/TOS system are used in a limited number of cases while the least used practice is the establishment of permanent stakeholder committees.

4.3. Benchmarking

4.3.1. Survey structure

The ports which participated to the survey were asked to state the possible use of industry benchmarks in order to assess their performance in the environmental impact area and also in the resource consumption in comparison to them. In the case of a positive answer, an open question followed, allowing the participants to define the specific method(s) used.

4.3.2. Benchmarking approaches used

According to the results of the survey, the majority of participating ports, regardless of their size, do not use benchmarks to assess their performance in the environmental impact or the resource consumption area. The detailed results for both areas and for each aspect of environmental performance are presented in Figure 3.

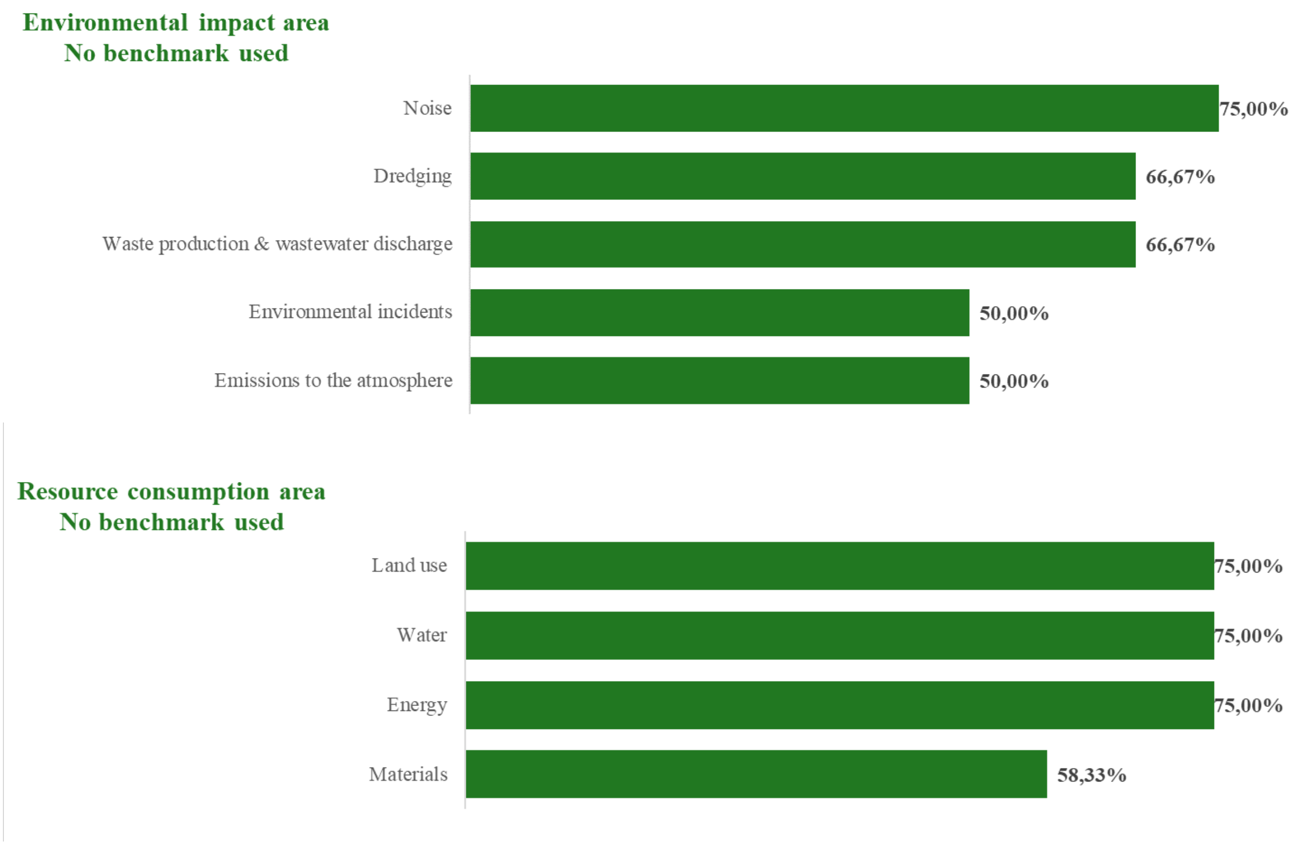


Figure 3 – Percentage of ports not using benchmarks, per category of environmental performance

As for the specific benchmarks used, even in the cases of positive answers in most cases there was not an actual use of standardised industry benchmarks but rather an attempt to approximate benchmarking through methods varying significantly among participating ports.

One of those methods which is commonly used includes the collection of relevant data from other, possibly competing, ports through newsletters, press releases or direct contact in order to be used for comparison. Another similar method recorded includes the extraction of information from annual reports of the port industry or magazines, related to the environmental performance of the industry (at national or international level) in order also to be used for comparison. Finally, the acquisition and regular renewal of the validity of environmental certificates is used as a benchmark to confirm the good environmental performance of a port.

4.4. Integration of individual metrics

4.4.1. Survey structure

In the third part of the survey, the participating ports were asked to state their opinion regarding the level of significance of the automated data collection systems and also of the lack of a standardised list of metrics when it comes to introducing and operating a port environmental impact measurement system. In addition to that, participants were encouraged to state more possible problems.

4.4.2. Implementation problems faced

The majority of ports which participated to the survey ranked higher the significance of the lack of automated data collection in comparison to the lack of a standardised list of metrics. More specifically, "very significant" and "significant" was the choice of 75% of participants in the first case while the second had a total of 50%. The high percentage of the lack of automated data collection is aligned to other findings from the questionnaire survey and more specifically to the ones related to the methods of data capture, according to which in all cases of environmental metrics, with the exception of air emissions, the manual collection of data is the dominant method used.

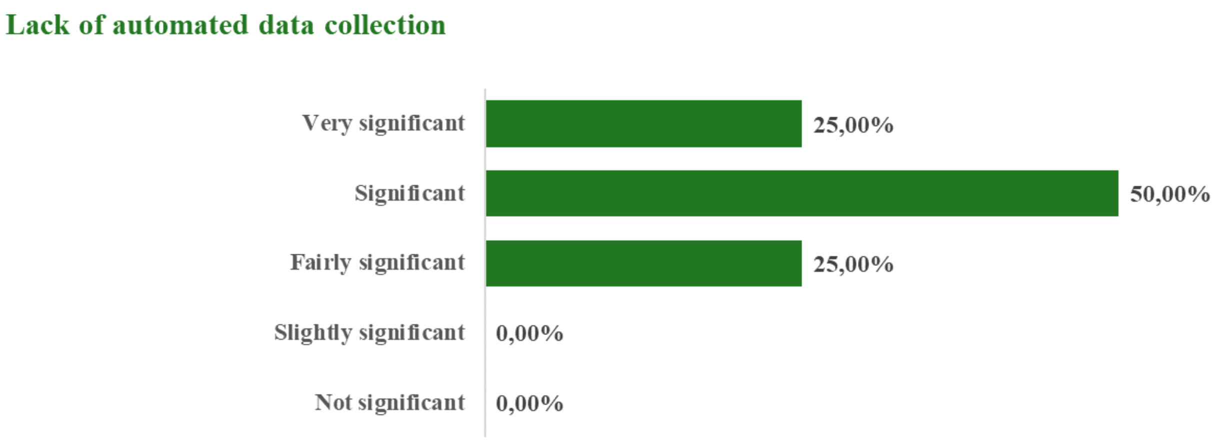


Figure 4 – Significance of the lack of automated data collection as a problem in introducing and operating a port environmental impact measurement system

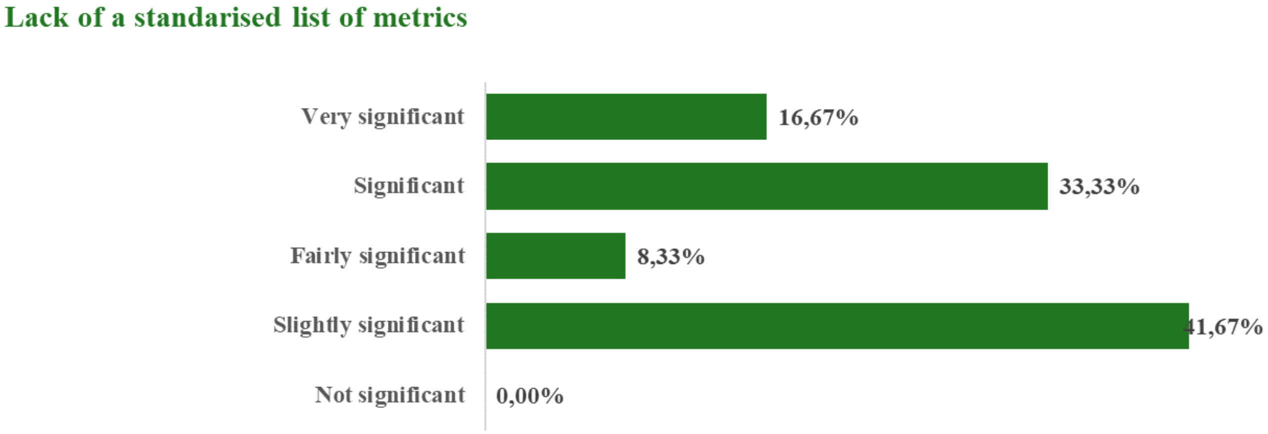


Figure 5 – Significance of the lack of a standardised list of metrics as a problem in introducing and operating a port environmental impact measurement system

With respect to other problems identified by the participants to the survey regarding the introduction and operation of a port environmental impact measurement system, these include the problematic management of systems for automated data collection (where such systems exist), the constant need for verification of the validity of the collected data and also issues in the communication between the different systems implemented. Furthermore, other possible problems identified are related the cost of such platforms which is considered high and also to the lack of corporate will and the low prioritisation given to such actions.

4.4.3. Further discussion

In addition to the questionnaire survey, in order to gain more insight into the problems of implementing and operating a port environmental measurement system, a number of online interviews was performed with representatives from small ports. The discussion during these interviews focused on the problems encountered during the installation and day-to-day operations of such systems and also on their opinions regarding the implementation of a composite indicators.

All participating ports in the interviews appeared to be environmental aware and to show particular interest in the protection of the environment. This became evident also by the fact that despite their small size they perform a significant number of individual metrics, covering important environmental aspects such as air pollution, noise, waste production and water pollution as well as the consumption of energy, fuel and water. To an extent, these metrics are performed for compliance to national regulations but in most cases, ports move beyond their obligations and perform additional measurements.

Regarding the identified problems in the installation of environmental measurement systems, the cost of the systems and the difficulty to employ specialised personnel in order to support environmental monitoring and activities were highlighted by most of the interviewees. In the case of Greek ports, the issue of costs has been addressed to some extent through the participation in co-financed programs for the acquisition and installation of equipment while the issue of lack of specialised staff is addressed through the cooperation with external entities such as universities.

As for the problems in day-to-day operation of the currently installed systems, not many significant issues were highlighted. Problems of technical nature which require external support for addressing them along with the lack of automation in the calculation of the indicators were some of the issues raised by the interviewees. Furthermore, the lack of connection of indicators to a regulatory framework in order to have a reference point was also highlighted.

None of the participating ports does currently have implemented a system for calculating a composite metric nor has plans to do so. However, all interviewees were very interested and positive towards the possibility to use a composite metric like PEI, understanding the value of a single indicator integrating all individual metrics.

The interviewees recognised the advantages in the form of facilitating port extroversion and better connection with society through the simplicity of the information which PEI provides. They also highlighted the possibility for automated monitoring of the overall environmental protection progress over time and also for comparison to other ports. Furthermore, the interviewees foresaw the possibility for lowering the port operation cost through a better monitoring of the resource consumption and also the possibility for using PEI as a tool for decision making regarding investments in environmental impact mitigation measures but also for day-to-day operations. Finally, the opportunity of the indicator to be part of a benchmark which would be widely adopted as a tool for measuring the performance and progress of the ports vis-à-vis this benchmark was also highlighted.

On the other hand, the complexity of a composite index like PEI and the mixing of several different aspects and units created some doubts to some interviewees in relation to the scope and the correctness of the indicator in terms of the weighting of the different parameters which largely depend upon the characteristics of each port. However, the efforts on devising an all-encompassing index targeted to all kinds of ports was appreciated and valued as a sound step forward towards environmental benchmarking of ports.

Regarding the possible problems which the interviewees foresaw in the implementation of a composite indicator system like PEI, these were mainly related to possibly high installation costs and also the possible lack of simplicity in use which can make it difficult for the personnel to get acquainted with the new system.

5. Guidelines for adopting/implementing a composite indicator for assessing environmental performance

5.1. Needed data

The work on the identification and outlining of the environmental impacts was described in the previous three deliverables published as part of the WP5 (D5.1, D5.2 and D5.3). In order to perform the task while minimizing errors to the lowest possible degree, relevant port activities had to be pinpointed and related environmental aspects had to be identified. The definition of those aspects was taken from (ISO 2015) and they are seen as a component of all port-related activities, products and services that have an influence on the environment. The term "significant environmental aspects" (SEA) was used to describe all those aspects that have a significant impact on the environment and are, thus, relevant for the calculation of the Port Environmental Index (Darbra et al. 2005). The identification of those aspects was done using two different approaches – the first one consisted of reading of the relevant literature already published on the subject and by taking into account the researches that seemed to be the most reliable and accurate. The second approach (or stage) in identifying those SEAs consisted of sending the questionnaire to the four pilot ports (Ports of Bordeaux, Monfalcone, Piraeus and Thessaloniki) and by examining the answers provided by those ports.

Finally, the six following environmental aspects were deemed as most important ones and were chosen for the use in the calculation of the Port Environmental Index:

- Emissions to the atmosphere (air emissions)
- Wastewater emissions
- Waste production
- Noise pollution
- Light pollution
- Odour pollution

ENVIRONMENTAL KEY PERFORMANCE INDICATORS (eKPI)

The identification of the SEAs was only the first step in the process, as representative and relevant indicators (here dubbed as "environmental Key Performance Indicators (eKPIs)") had to be linked to each of the environmental aspects previously labelled as "significant". Four different criteria were used in order to evaluate the relevance of those aspects:

- Significance
- Measurability – the chosen indicators should be measured either using real-time IoT equipment or by examining the data that is already regularly obtained by the ports
- Representativeness – the environmental impacts of port activities should be clearly separated from the impacts not resulting from those activities (such as traffic and industries not related to the ports)
- Correlation

In order to present the chosen indicators as clearly and concisely as possible, table 1 (for ship-related eKPIs) and table 2 (for eKPIs related to port authorities and terminals, as well as all of the activities) were provided.

Table 25: eKPIs for the calculation of the ship environmental index

eKPI name	associated index	eKPI description	SEA	units
CO2	ships	C02 emissions by ships	emissions to air	kg or tonnes

NOx	ships	NOx emissions by ships	emissions to air	kg or tonnes
PM10	ships	PM10 emissions by ships	emissions to air	kg or tonnes
PM2.5	ships	PM2.5 emissions by ships	emissions to air	kg or tonnes
SO2	ships	S02 emissions by ships	emissions to air	kg or tonnes
HC	ships	HC emissions by ships	emissions to air	kg or tonnes
CO	ships	C0 emissions by ships	emissions to air	kg or tonnes
N20	ships	N20 emissions by ships	emissions to air	kg or tonnes
CH4	ships	CH4 emissions by ships	emissions to air	kg or tonnes
Plastics	ships	Plastics wasted by ships	waste	kg or tonnes
Food waste	ships	Food wasted by ship crew and passengers	waste	kg or tonnes
Domestic waste	ships	Domestic waste created by ship crew and passengers	waste	kg or tonnes
Cooking oil	ships	Cooking oil used by the ship crew and passengers	waste	kg or tonnes
Incinerator ashes	ships	Incinerator ashes created	waste	kg or tonnes
Operational waste	ships	Waste created during maintenance or ship operations	waste	kg or tonnes
Animal carcass(es)	ships	Self-explanatory	waste	kg or tonnes
Fishing gear	ships	Self-explanatory	waste	kg or tonnes
E-waste	ships	Electronic waste (from electronic devices)	waste	kg or tonnes
Cargo residues (harmful)	ships	Self-explanatory	waste	kg or tonnes
Cargo residues (non-harmful)	ships	Self-explanatory	waste	kg or tonnes
Passively fished waste	ships	Waste caught in the next during fishing	waste	kg or tonnes
other substances	ships	All waste not covered with other categories	waste	kg or tonnes
Oily bilge water	ships	Water accumulated in the bilge	wastewater	m^3
Oily residues (sludge)	ships	mixture of oily residues created by ships	wastewater	m^3
Oily tank washings	ships	Washing out the residue using crude oil	wastewater	m^3
Dirty ballast water	ships	Seawater pumped in fuel tanks for ship stability	wastewater	m^3
Scale and sludge from tank cleaning	ships	Self-explanatory	wastewater	m^3

Other - oil	ships	Oil substances not covered above	wastewater	m^3
Noxious liquid substances (NLS) - type X	ships	Present major hazard to marine resources or human health, prohibited from discharging	wastewater	m^3
NLS - type Y	ships	Present hazard to marine resources or human health, limited discharging allowed	wastewater	m^3
NLS - type Z	ships	Minor hazard to marine resources or human health, more discharging allowed	wastewater	m^3
NLS - other	ships	No harm to marine resources or human health	wastewater	m^3
Sewage	ships	Domestic wastewater created by crew and passengers	wastewater	m^3

Table 26: eKPIs for the calculation of the terminal and port authority index

	eKPI name	associated index	eKPI description	subindex	units
Terminals/Port Authority	CO_2	terminals/Port Authority	CO_2 emissions by terminals	emissions to air	kg or tonnes
	NO_x	terminals/Port Authority	NOx emissions by terminals	emissions to air	kg or tonnes
	PM_{10}	terminals/Port Authority	PM_{10} emissions by terminals	emissions to air	kg or tonnes
	$PM_{2.5}$	terminals/Port Authority	$PM_{2.5}$ emissions by terminals	emissions to air	kg or tonnes
	SO_2	terminals/Port Authority	SO2 emissions by terminals	emissions to air	kg or tonnes
	HC	terminals/Port Authority	HC emissions by terminals	emissions to air	kg or tonnes
	CO	terminals/Port Authority	CO emissions by terminals	emissions to air	kg or tonnes
	N_2O	terminals/Port Authority	N_2O emissions by terminals	emissions to air	kg or tonnes
	CH_4	terminals/Port Authority	CH4 emissions by terminals	emissions to air	kg or tonnes
	Sanitary wastewater	terminals/Port Authority	Wastewater created by usual domestic activities	wastewater	m^3
	Technological wastewater	terminals/Port Authority	Wastewater created by industry and ship maintenance	wastewater	m^3
	Storm water	terminals/Port Authority	Water resulting from rain, snow, etc.	wastewater	m^3
	Municipal solid waste	terminals/Port Authority	garbage ("everyday items discarded by the public")	waste	kg or tonnes
	Inert waste	terminals/Port Authority	Waste that is not decomposable, but also not chemically or biologically active	waste	kg or tonnes
	Hazardous waste	terminals/Port Authority	Waste hazardous for public health or environment	waste	kg or tonnes
Al	Noise pollution (Lden)	terminals/Port Authority	Noise levels calculated from day, evening and night levels	noise	dB

	Noise pollution (Lnight)	terminals/Port Authority	Noise levels during the night	noise	dB
	Odour	terminals/Port Authority	Self-explanatory	odour	ouE/m^3
	Light pollution	terminals/Port Authority	Self-explanatory	light pollution	lx

5.2. Data retrieval

This subsection dwells into the available approaches for acquiring all the data listed and described in the previous subsection. These approaches are described in detail in Deliverable 5.3 (PEI definition and algorithms v2) .

5.2.1. Ships

5.2.1.1. Emissions to air

Emissions to the atmosphere resulting from ship activities are calculated using the proxy data and is not based on the direct measurements. The procedure for the calculation was provided in detail in the subsection 3.2 of D5.3, so it would not be repeated here. In the D5.3, it was concluded that the following data is needed in order to successfully complete the calculation procedure:

- Engine and fuel type
- Engine power (both for main and auxiliary engines)
- Load and emission factors
- Manoeuvring and berthing time

The third data requirement listed, load and emission factors, can be taken from the available literature, provided that all the other information is known. However, the acquisition of other data differs from port to port, as approaches encountered during the work with different pilot ports show. In order to know the engine and fuel type of a vessel, it is important to know the identification number of the ship. This number can be either IMO number or MMSI number.

Some ports can develop their own tools for acquiring such data. An example of this is a software VIGIESip used in the Port of Bordeaux, which can be used, among others, to collect the data on the vessel call and the related data, such as the type of ships (based on the cargo it is transporting) and the amount of cargo those ships are carrying. Also, it is possible to calculate the berthing and manoeuvring time based on the time spent in the port (VIGIESip) and the data from the PAS execution can be used to find out berthing times. The PAS records and uses the time of the cargo handling equipment working on a newly berthed vessel for its calculations. These timestamps can be used to calculate the time of berth for the PEI. Manoeuvring time will then be the time ship has spent in the port minus the berthing time.

Another way of obtaining the data on berthing and manoeuvring times is by using the AIS data of the vessels. Also, the data can be obtained using an API, such interface was developed in the Port of Thessaloniki and can be used to calculate the required times in way similar to those when other approaches are used.

The data on the power of engines, regardless of if main or auxiliary, was approximated using the procedure also described in the D5.3 (subsection 3.2.1.2.). It should be noted that the data on auxiliary engines is extremely hard to come by, even if the port has subscription to a commercial database, like the Lloyd's.

5.2.1.2. Wastewater and solid waste

Contrary to the data on the emissions to the atmosphere, which is both calculated using proxy and has different approaches used to obtain the required data, the collection of the ship waste and wastewater data is relatively straightforward. Management of these two environmental aspects is regulated by the MARPOL convention, more precisely its Annex IV. As it can be seen from the table 25, this data is collected in a simple manner, with the final result being the weight or volume of the pollutant. The only thing that can differ in the collection of ship wastewater and waste data is in how it will be stored or available for calculation. However, those are considered to be minor issues and not relevant for this subsection.

5.2.2. Terminals

5.2.2.1. Emissions to the atmosphere

Similar to calculation of air emissions from ship activities, those emissions resulting from activities related to the terminals and port authorities are also calculated using proxy data. As stated in the Deliverable 3.2 (chapter 1), this data consists of the following:

- Sources used to handle each ship at the terminal: machines, time being used each machine, consumption of each machine
- Energy consumption for operating each vessel (in kWh)
- Type of the energy each machine is using i.e., electricity, gas, etc

There are different approaches that can be used in order to collect this required data. One approach is to extract all information using the Port Activity Scenario (PAS) models and process the relevant information. If this is impossible, or inconvenient, it is also possible to use bills that port terminals pay for energy consumption.

5.2.2.2. Wastewater emissions

As there are three associated eKPIs (technological and sanitary wastewater and stormwater) that are of different origins, some differentiation can be made between the first two and the third eKPI. The stormwater "emissions" can be simply calculated using the meteorological data for the port area (amount of precipitation) and the surface of port area – having those two pieces of information, it is a routine calculation to calculate the amount of stormwater.

Contrary to that, the way of obtaining the information of sanitary and technological wastewater vary from port to port and there is not a single "go to" solution. Some of the approaches encountered during the implementation in pilot ports were:

- Manually updating Excel file (or similar form) with relevant data, having in mind some reasonable frequency for doing it
- Using the water consumption bills and making reasonable assumptions of the amount of the water used as "technological wastewater" and "sanitary wastewater"
- Use of web-forms where a user can fill in all the required data

It should be noted that the first and the third "approach" would in practice mean one and the same, since all wastewater data that is to be used for the calculation of the PEI should be available in some kind of web-form.

5.2.2.3. Waste production

Similarly, to the previously described wastewater emissions for the port terminals, there are different ways to do the data acquisition for the amount of solid waste resulting from the activities of those terminals. Those "ways" are the following:

- Manually updating Excel file (or similar form) with relevant data, having in mind some reasonable frequency for doing it
- Use of web-forms where a user can fill in all the required data

5.2.3. Port authorities

Differentiation between port terminals and port authorities is sometimes hard to make, as is the case with the Port of Thessaloniki, where the usual tasks of port authorities (e.g., long-term planning) and of terminals (e.g., overtaking load/unload of cargo to/from ships) are managed by the same legal entity. However, in this description of the methods for data acquisition, it is assumed those two entities are in most cases different from each other and are thus covered in different subsections.

5.2.3.1. Emissions to the atmosphere

For the calculation of the atmospheric emissions resulting from the activities of port authorities, manual filling of the relevant (web-)forms was used in pretty much all the pilot ports.

5.2.3.2. Wastewater emissions and waste production

The procedures used for the calculation of the amount of wastewater and waste produced in port terminals are also applicable here.

5.2.4. Environmental aspects associated to the port as a whole (noise, light and odour pollution)

For all three eKPIs related to noise (L_{DEN} and L_{night}) and light pollution, the use of relevant sensor is effectively being used in all four pilot ports. Odour pollution was not recognised as a relevant aspect by those ports. However, in a hypothetical scenario in which a port decides to measure the level of odour pollution, the use of a specialised sensor ("electric nose") is the most convenient (and possibly – the only) solution. Possible alternative would be to have a person assess the level of odour, but it would turn out to be too subjective for the use in the calculation of the PEI.

Table 27 shows the summary of the data available in each of the pilot ports, as of the time of writing this Deliverable.

Table 27: Available data in pilot ports

	Needed data	AUTORITA PORTUALE DI TRIESTE (APT)	GRAND PORT MARITIME DE BORDEAUX (GPMB)	PIRAEUS PORT AUTHORITY (PPA)	THESALONIKI PORT AUTHORITY (THPA)
SHIPS emissions to air	SHIP ID	✔	✔	✔	✔
	Type of cargo	✔	✔	N/A	✔
	Amount of cargo (tonnes/m^3/TEU/ passengers)	✔	✔	✔	✔
	Ship type	✔	N/A (cargo type will be used)	✔	✔
	Fuel type	Not available	Not available	Not available	Not available
	Main engine power (kW)	Approximation	Approximation	Approximation	Approximation
	Auxiliary engine power (kW)	Approximation	Approximation	Approximation	Approximation
	Load factors (%)	Literature	Literature	Literature	Literature
	Emission factors (%)	Literature	Literature	Literature	Literature
	Manoeuvring time (hr)	Average time	Average time	Subscription	✔
	Time at berth (hr)	Average time	Average time	Subscription	✔

SHIPS wastewater	11 categories	MARPOL	MARPOL	MARPOL	MARPOL
SHIPS waste	13 categories	MARPOL	MARPOL	MARPOL	MARPOL
TERMINAL/ PA air	Fuel quantity	Provided by the PAS	Provided by the PAS	Provided by the PAS	Provided by the PAS
	Electricity consumption (kWh)	Provided by the PAS	Provided by the PAS	Provided by the PAS	Provided by the PAS
TERMINAL/ PA wastewater	Stormwater	✔	✔	✔	✔
	Sanitary wastewater (m^3)	Webform	Webform	Webform	Webform
	Technological wastewater (m^3)	Webform	Webform	Webform	Webform
TERMINAL/ PA waste	Non-hazardous waste	Webform	webform	Webform	✔
	Hazardous waste (tonnes)	Webform	webform	Webform	✔
ALL	Noise	Sensor	Sensor	Sensor	Sensor
	Odor	N/A	N/A	N/A	N/A
	Light	Sensor	Sensor	Sensor	Sensor

* data is not available as of writing the Deliverable 5.4, but is in the process of being obtained in the context of the PEI pilot – task T7.5.

5.3. About PEI as a tool

The PEI is a combination of methodology and technology that, after receiving certain inputs, provides a composite environmental indicator as an output.

As commented in D5.3, technologically, the spot of the PEI within the PIXEL architecture is exactly as the rest of the models/predictive algorithms developed and to be integrated in a final deployment in a port. However, it is highly dependent on the pre-processing of data (cleaning, adjusting, converting to eKPI), therefore it was decided to split the computation of the PEI in two clearly differentiated parts. The conversion from raw data to eKPIs must be done at the agents, in order to insert the eKPIs info in the context broker and into the I.H. as so.

In the next sub-sections, there are presented the considerations and steps on how to successfully deploy the PEI and how to interpret the results of its execution.

5.3.1. Technical considerations for PEI adoption

Before thinking of executing PIXEL, the exercise of analysing technical needs must be done.

PEI is a software designed to be run on premises (executed by a server within the port's local network premises). Although it supports remote, externally hosted cloud mode (on-going exploitation discussions), hereby it is considered that it will be running in the servers of the port wishing to deploy it.

The following table outlines the technical aspects that must be complied with in order to run the PEI. These aspects refer to the implementation of PEI as part of the PIXEL platform, as designed within the context of the project. It should be noted that it is also possible to run the PEI software without implementing the full PIXEL platform, using the existing port infrastructure in terms of data acquisition solutions, data storage capacity and dashboard, through proper modifications. Being a containerised model, any system complying to their inputs (EnvironmentalKeyPerformanceIndicators) and able to process its outputs will be valid for executing the PEI as a model. However, it is highly recommended to use the PEI within a broader, full PIXEL ecosystem installation.

Table 28: Technical considerations for running the PEI

Hardware	PIXEL as a whole (all modules and configurations included) requires the following: • 2 virtual machines (VM), CORE and PUBLIC. Each of them must have: o 4 cores o 16GB RAM o HD 300-500 GB According to the tests conducted in the context of T8.3, the PEI model can be represented (in terms of HW resources consumption): • Mean CPU usage: 16.35% (if PEI scheduled monthly), 17.2% (if PEI scheduled yearly) • Mean memory usage: 23 MB (monthly), 35.4 MB (yearly) Finally, the PEI also requires the execution of a series of NGSI agents (normally, between 4 and 10) that will also run in the same server (core virtual machine). It is expected that the requirements stated above will be enough to run such agents.
Software - General	To run just PEI as a model, Docker (and enough HW resources would be enough). As it has been said, it is considered to be run using PIXEL, therefore the software requirements are: • OpenSSH • FIWARE ORION (included in DAL) • ELK stack (Elasticsearch, Logstash, Kibana), Apache Kafka and Zookeeper (included in Information Hub) • FIWARE KeyRock and Wilma (included in the PIXEL Security module) • Vue.js, Apache eCharts, FIWARE ElastAlert (included in the Dashboard) • Nagios and MySQL For running the agents, again Docker + Data Acquisition Layer should be enough. If it is selected to run agents isolatedly, then a compiler/executor of the language used must exist (in general, Python). If the pyngsi library (developed by ORANGE for facilitating the development of NGSI agents) is used, it also must be installed.
Software - PIXEL dependencies	Being part of the PIXEL project, the PEI has been developed making use of its basic components, then relying on Data Acquisition Layer, Information Hub, etc. Although the PEI as a model has been conceived to be used standalone (outside of PIXEL), in this table it is assumed that PEI will also be used by a port upon PIXEL basic infrastructure. In addition, the PEI *may* make use of the following PIXEL products (models): • PAS model, as the tool for estimating Air Pollution associated to the activities of the port terminal. If this option is selected, an additional agent is needed. • PARES model, to make use of AIS data to obtain berthing and manoeuvring time per vessel. This has not been tested in PIXEL as no pilot needed it. This would also need a special agent and, of course, data obtained from AIS technology (via AIS antenna or via subscription to external services such as MarineTraffic or VesselTracker)
Data requirements	Check section about Data Requirements for PEI in D5.3 and Section 5.2 in this document.

Code Adaptation	The PEI as a model does not need to be adapted. It will be used as a Docker image (model) loaded from the Operational Tools and scheduled through them. The only code adaptation (actually, pure development) needed is the creation and integration of enough NGSI agents to connect the data sources to PIXEL's context broker (in the DAL) in the form of eKPIs. What a port will need to do before tackling the development of agents is: • Analysing which of the eKPIs apply to their case (see Section 5.1 to check the table) • Analysing which of the "data origins" apply to their case (e.g., dropping the "terminal" eKPIs as the user will only be the Port Authority). • Obtaining, from the previous, a final list of eKPIs to be feeding the PEI. • Analysing which data is needed to obtain those eKPIs. • Identifying (some consultancy action may be needed from PIXEL partners here) which must be the proper process in each case to convert from raw data to eKPIs (involving units, pre-processing, associated reliability rating – check deliverable D5.3). Only then the agents can be coded. A guide on how to create agents can be found here. Some examples have been developed in PIXEL and may be provided by partners if (and only if) the exploitation analysis (on-going, WP9) agrees on their publication. Afterwards, the agents must be connected to PIXEL infrastructure and integrated in to the IH. A guide for doing so is here. To check whether the data is being properly retrieved and stored, the responsible for the deployment in the port should check the Information Hub registries (see here).

5.3.2. Operative adaptations for PEI adoption

Apart from the technical actions and requirements posed above, the port using the PEI will need to make a series of operating adaptations to ensure proper execution of the tool. The actions can be divided by "port staff involved in PIXEL" category.

- The IT Manager, or the responsible of PEI (and PIXEL) deployment in the port:
    - Drawing from the previous analysis of the data availability and agents to be developed (see Table 28), the IT Manager must define the **Tree** that will be used for calculating PEI and RR composite indicator. This is done as follows:
        1. Via the user interface (UI)
            1. Loading default values
            2. Adding/removing eKPIs as appropriate

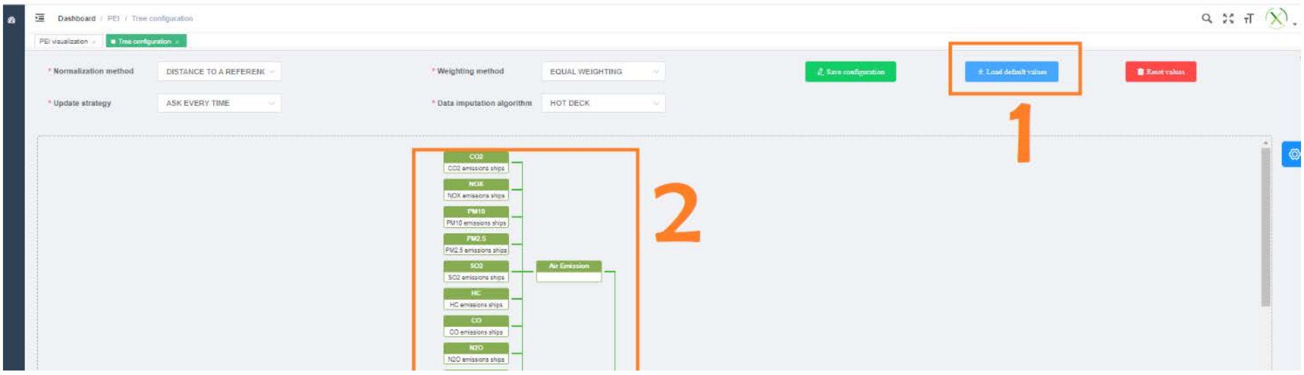


Figure 6 – Tree configuration for PEI and RR composite indicators

- The Environmental Manager, or the responsible of PEI supervision in the port:

- To indicate the mathematical and data treatment options to be applied for the calculation of the Port Environmental Index (all the following – options, meaning, etc.- is indicated in the corresponding section of deliverable D5.3).
    1. Normalisation method (*distance to a reference port* is set as default).
    2. Update strategy (*ask every time* is set as default).
    3. Weighting method (*equal weighting* is set as default).
    4. Data imputation algorithm (*hot deck* is set as default).

Figure 7 – Configuration of mathematical tools to be used for calculating the PEI

- The Port Manager, or the person in charge of interpreting the results and interact more usually with the tool in order to exploit the information:
    - Loading and scheduling the running of PEI through the Operational Tools. Here, the Port Manager can decide the frequency of execution of the PEI – usual values are: monthly, quarterly or yearly (the most common).
        1. Go to the Operational Tools, go to the row of the PEI model.
        2. Select "schedule"
        3. Select "add schedule"
        4. Configure accordingly.

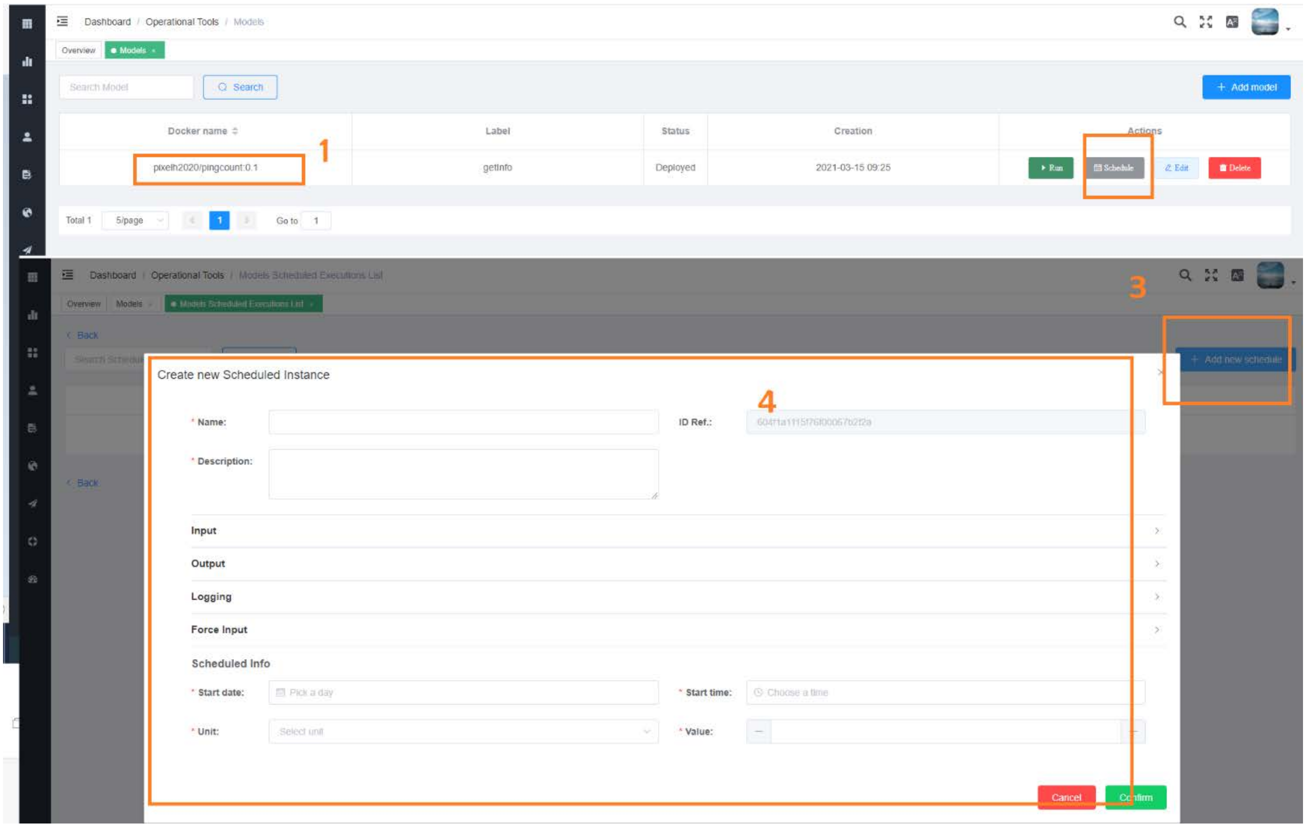


Figure 8 – Using O.Tools for scheduling PEI execution

5.3.3. Usage of the tool and interpretation of results

The PEI visualisation has been created for observing the results of the PEI execution. As explained before, the PEI calculation can be scheduled to be run with specific periodicity. The images shown below are extracted from a PEI execution of “yearly” periodicity.

The overall aspect of the tool showing results of the PEI is the following:

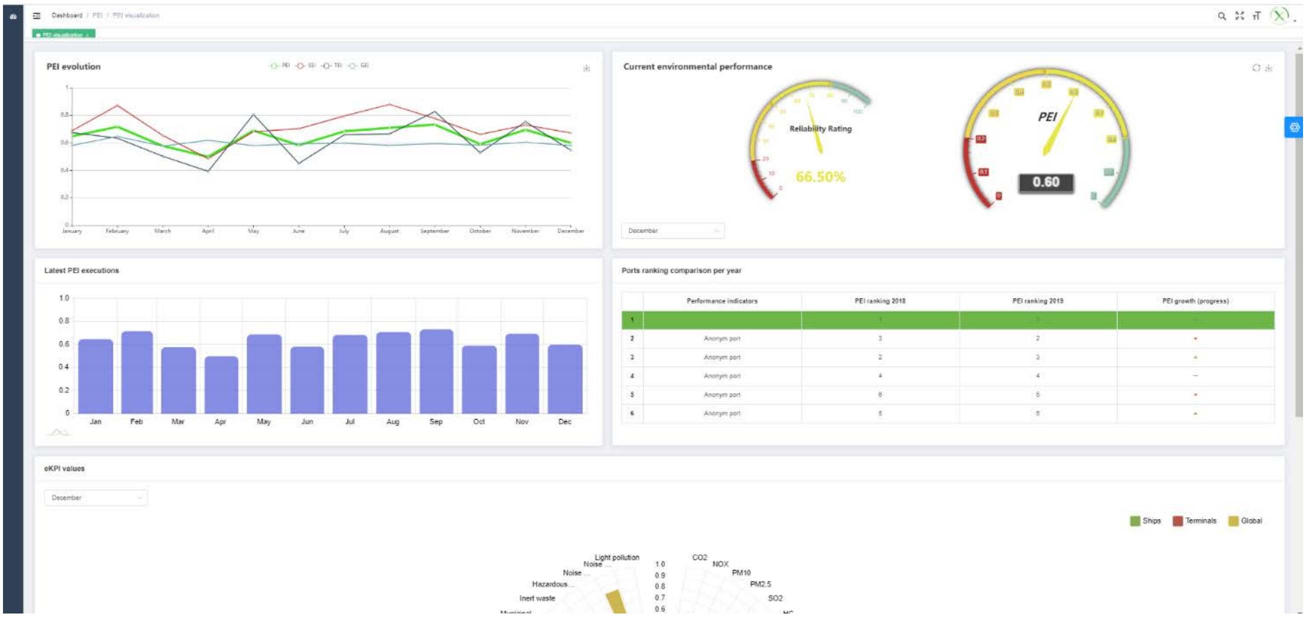


Figure 9 – Overall aspect of PEI tool

Here below there are the different parts of the UI explained:

- PEI evolution chart: multi-line chart with the PEI and the indices (SEI, TEI, PAEI, GEI) values month by month.

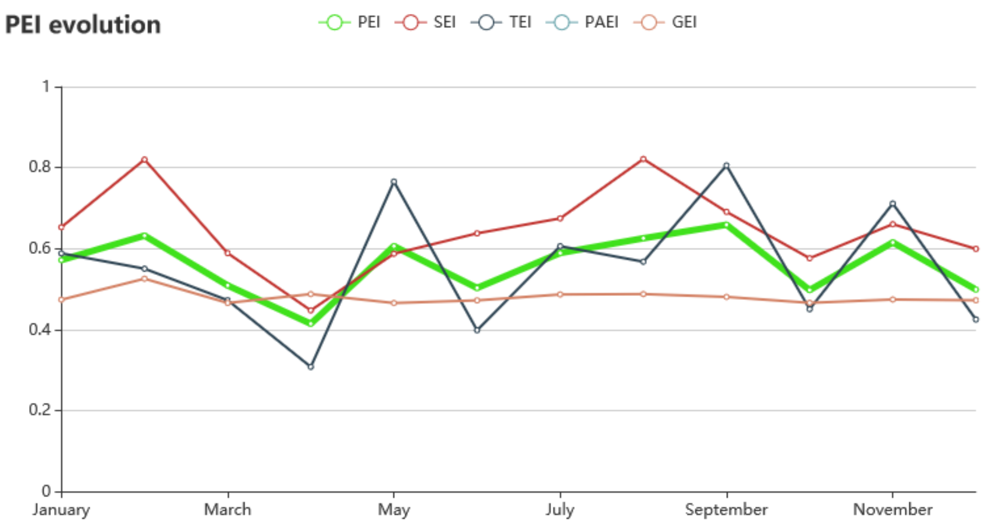


Figure 10 – PEI evolution chart

- Current environmental performance: current values (actually, the values of the last execution of the PEI registered in the platform) of the PEI and the RR displayed in a gauge meter chart. The user can select the month to be displayed using a drop-down menu.

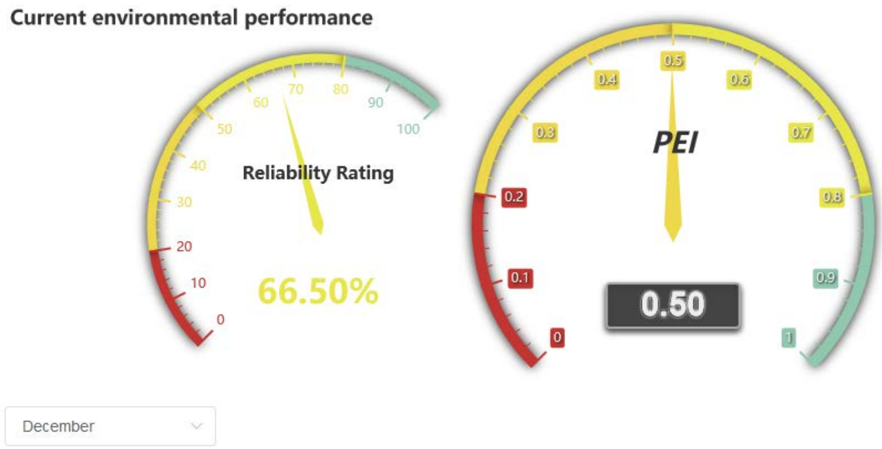


Figure 11 – PEI gauge meter

- Latest PEI executions: PEI values of the latest executions, displayed month by month. The same PEI values displayed at the PEI evolution chart, but shown in a bar graph. If the selected periodicity would be of 1 year, this bars graph would showcase the last years, etc.

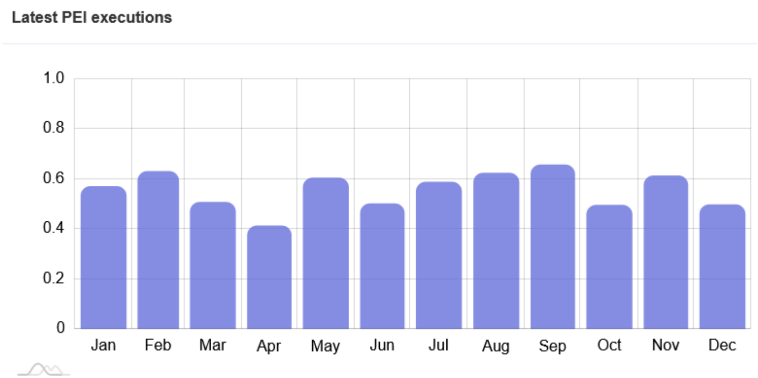


Figure 12 – Latest PEI executions

- Ports ranking comparison per year: a table with all the ports (that are currently using the PEI) ordered by the mean of the PEI values of the last two years. The table also shows the progress of each port in the ranking. Only is displayed the name of the current port due to privacy constraints. No port will be able to check the value of other ports (identifying which is which).

Ports ranking comparison per year

	Performance indicators	PEI ranking 2018	PEI ranking 2019	PEI growth (progress)
1	Your port	1	1	—
2	Anonym port	3	2	▼
3	Anonym port	2	3	▲
4	Anonym port	4	4	—
5	Anonym port	6	5	▼
6	Anonym port	5	6	▲

Figure 13 – Ports ranking comparison

- eKPI values chart: consists of a polar chart displaying the normalised value of each eKPI in the latest PEI calculation. The user can select the month to be displayed using a drop-down menu, and
- Month selector: the user can select the month to be displayed using a drop-down menu

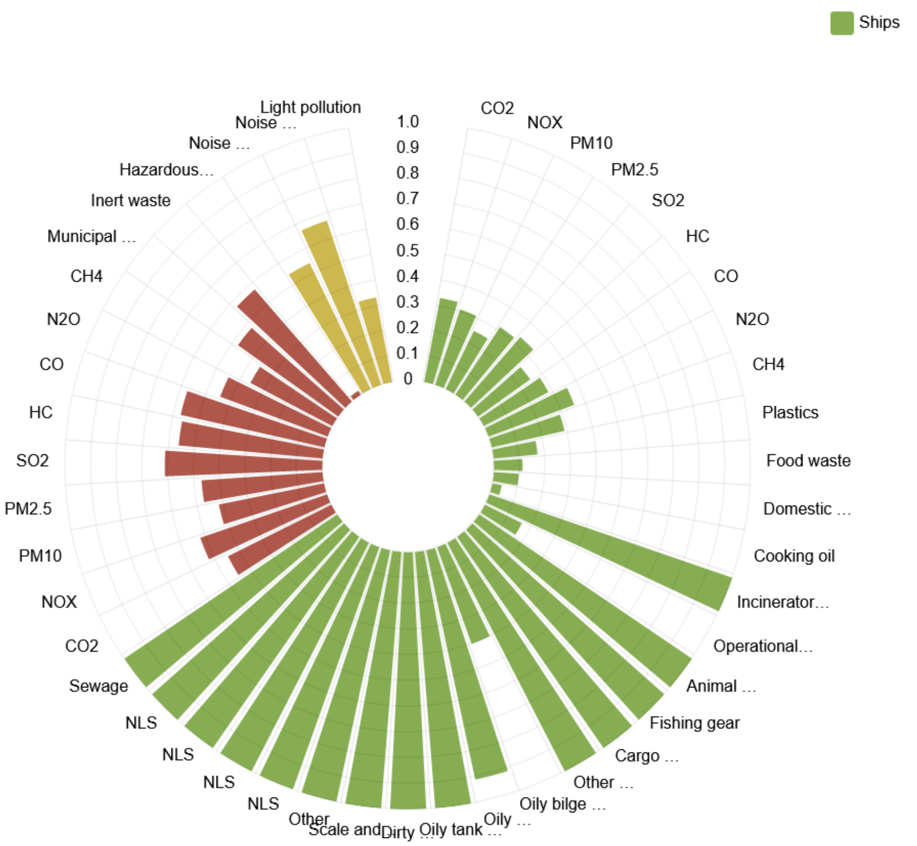


Figure 15 – eKPI values chart

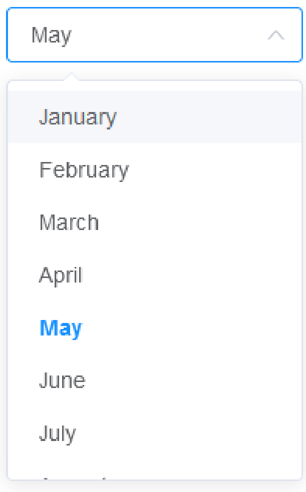


Figure 14 – Month selector

- Reliability Rating values: a table displaying the results of the RR obtained in the last execution of the PEI.

Data origin	Subindex	Piece of data	Optimal retrieval way	Current retrieval way	Reliability Rating	Aggregated RR (subindex)	Aggregated RR (origin)
Ships	Air Emission	IMO number and gross tonnage of ships	Real time API	Periodic API	80.56 %	67.96 %	83.47 %
		Main and auxiliary engine of ships	Periodic API	Average value from literature	36.84 %		
		Berth and maneuvering time of ships	Sensors	Periodic API	86.49 %		
	Waste	MARPOL annexes about waste	Pixel proxy tool	Periodic API	97.14 %	97.14 %	
	Wastewater	MARPOL annexes about wastewater	Pixel proxy tool	Periodic API	85.29 %	85.29 %	
Terminal	Air Emission	Emissions produced by terminal machinery	Sensors	Periodic API	73.47 %	73.47 %	85.42 %
	Waste	Waste produced by the terminals	Pixel proxy tool	Periodic API	97.37 %	97.37 %	
Global	Noise	Noise values (Lden, Lnight, Leq)	Sensors	Average value from literature	34.69 %	34.69 %	30.61 %
	Light pollution	Luminosity (lux)	Sensors	Average value from literature	26.53 %	26.53 %	

Figure 16 – RR values of the last execution of the PEI

- Download of a report of the execution. The report includes a summary of all the previous and a series of recommendations for the port to minimise the result value (recommendations are triggered – or not- depending on the values of the resulting eKPIs of the last period of PEI execution).

6. Guidelines for minimising a ports PEI

In this chapter a collection of practices is presented, aiming to minimise the environmental impact of port operations and thus minimise PEI value through the improvement of the corresponding five indexes it includes (Air, Water, Waste, Noise and Light). These recommendations were collected through a literature review of papers published in journals and also from published guidelines provided by maritime related national and international organisations. Following this first step, the effectiveness of selected practices was related to specific metrics and their value in order to prioritise the suggestion of these practices in each port case based on the individual results of the sub-indexes of PEI. The results of this activity feed a recommendations engine which is integrated to the PEI tool.

6.1. Air pollution

The recommendations in this paragraph include all types of interventions, namely technical, operational and organisational. These measures aim to minimise the emissions from ships and installations within the port area, either by the use of more environmentally friendly power sources, either by the increase in the efficiency of energy use (less energy/fuel consumption) or by using technology to reduce the emissions of pollutants.

6.1.1. Air pollution reduction measures

6.1.1.1. Onshore Power Supply

The connection of docked ships to an onshore power supply, also termed “cold ironing” is a method for providing the required electrical power without the use of the ship’s auxiliary engines. This results in the elimination of the emission of air pollutants at local (port area) level which are transferred to the point of electricity production where the emissions are depending on the technology and the energy source used; the emission reduction technology of electricity generation plants can reduce the CO_2 emissions by more than 30% and the Nitrogen oxides and particulates by more than 95% (Arduino et al. 2011), compared to the use of the ship’s auxiliary engines. Furthermore, it is possible that the source of the electrical power can be from low carbon or zero carbon energy sources, such as wind power, hydro power, solar power or nuclear power which reduces further the environmental footprint of onshore power supply (Xing et al. 2020).

It should be noted though that the large infrastructure investments needed along with the increased complexity of the ship operations in port possibly require a strong regulatory framework and a national financial support in order for the ship operators and Port Authorities to implement cold ironing technology (Winkel et al. 2016).

6.1.1.2. Alternative Fuels Bunkering

The construction of the necessary infrastructure to supply ships with alternative fuels will attract ships using alternative fuels thus result in the reduction of the emissions during the ship operations in port during the entire Ship Turnaround Time.

Liquefied natural gas is increasingly adopted as a marine fuel partly due to the rule known as “IMO 2020”, which came into force on 1 January 2020 and limits the sulphur in the fuel oil used on board ships operating outside designated emission control areas to 0.50% m/m (mass by mass) - a significant reduction from the previous limit of 3.5%. Within specific designated emission control areas, the limits were already stricter (0.10%)[5]. The use of LNG can reduce CO_2 emissions by 20%, nitrogen emissions by 85.0–95.0%, Particulate Matters by 95% and achieve zero sulphur emissions (Bekaert 2016). However, despite CO_2 emissions being lower compared to fuel oils, the total emissions of CO_2 equivalents are not necessarily in favor of LNG because of the fuel methane slip through the combustion process which is a potent GHG 72 times more powerful than CO_2 (Winnes et al. 2015).

[5] https://www.imo.org/en/MediaCentre/HotTopics/Pages/Sulphur-2020.aspx

Finally, as in the case of Onshore Power Supply, alternative bunkering also requires large infrastructure investments while there are also safety, security, supply, and market issues that need to be addressed and taken into account (Alamoush et al. 2020).

6.1.1.3. Reduction of Ship Turnaround Time

The reduction of the total time between the arrival of a ship and its departure from the port, termed "Ship Turnaround Time", results in the reduction of the total emissions from the ship while in the port area. This can be achieved through the use of specialised systems such as the Automated Mooring Systems and also through better planning of the operations, namely the berth and yard allocation and scheduling.

The Automated Mooring Systems allow the quicker mooring of ships and are based on a vacuum system that pulls ships towards the quay keeping them steady while the ship's engine can be shut off at the beginning of the process. The implementation of such systems can reduce the time from possibly 30 min for a large container vessel to only a few seconds thus reducing the Ship Turnaround Time.

Regarding the planning of the operations, the use of tools and methods in order to plan the ships berthing time and quay space in advance, together with the planning of the allocation and scheduling of port equipment will optimise operations and reduce the Ship Turnaround Time (Alamoush et al. 2020).

6.1.1.4. Vessel Speed Reduction

The vessel speed reduction concerns the speed of ships within the coastal water of a port or within the port area during their approach and departure. According to several studies, the speed of the ships when limited to 10-12 knots or even less depending on the ship design and speed optimisation, can result in significant reduction of ship fuel consumption and thus the corresponding emissions.

The speed reduction can be achieved mainly in three ways: through mandatory actions, through voluntary actions and through actions based on the port queuing management. The latter, also termed "Virtual Arrival" is a process that involves an agreement to reduce a ship's speed on voyage to meet a revised arrival time when there is a known delay at the discharge port. Regarding the mandatory reduction of speed, it can have an impact on port competitiveness and this is the reason why it is more difficult to be accepted by the industry and is not widely observed (Alamoush et al. 2020).

6.1.1.5. Exhaust gases control

Exhaust Gas Cleaning Systems (EGCS) or "Scrubbers" are systems used to remove particulate matter and other air pollutants, such as Sulphur oxides (SO_x) and nitrogen oxides (NO_x) from the exhaust gasses generated as a result of combustion processes in marine engines, auxiliary engines and boilers, onshore and onboard ships. Greenhouse gas emissions are not drastically reduced via this technology.

Based on their technology, they can be open-loop, closed-loop or hybrid. Their use has increased as an economic way to comply with the new regulation of the International Maritime Organisation (IMO) which came into force on 1 January 2020 imposing significant lower sulphur content in ship fuels. The new regulation requires that the ships either use expensive fuel with low sulphur content or clean the exhaust gases by using exhaust scrubbing systems[6].

Finally, some consequences which must be taken into account are the production and handling of sludge and the local impact on water quality by the discharge of the used seawater if the system works with a seawater open loop.

6.1.1.6. Green Ship promotion

Providing incentives based on ship fuel consumption profiles and ship specifications in order to motivate ships to become more environmentally friendly. This can be achieved through the setting up by ports of an award scheme related to reduced port dues (Green fees) or right of entry (Green passport) for ships having a good environmental performance according to specific environmental indices (Gibbs 2014).

[6] https://www.marineinsight.com/tech/scrubber-system-on-ship/

Examples of environmental indices which can be used are: The Environmental Ship Index (ESI) which focuses mainly on NO_x and SO_x reduction and is the most widely used, the Clean Shipping Index (CSI) which assesses ships environmental performance based on SO_x, PM, NO_x, CO_2 emissions and the chemicals, water and waste control and finally the Energy Efficiency Design Index (EEDI) which focuses on CO_2 emissions and is currently applicable only to new ships.

6.1.1.7. Equipment upgrade

The physical change or replacement of older equipment which is used in the port operations introducing new cleaner and energy-efficient technologies will result in significant reduction of air emissions in the port area. This equipment includes all vehicles, machinery and vessels used by the Port Authority or the port's tenants such as harbor tugs, the container handling equipment and trucks. It can be achieved through the purchase of new cleaner and more efficient equipment as a replacement of the old one, through repowering the existing equipment by changing old engines or by adding emission control technology (Alamoush et al. 2020).

6.1.1.8. Alternative energy sources

This measure concerns the provision to all consumers in ports (besides ships) of alternative energy sources in order to run their equipment and crafts for operations as a replacement for conventional fossil fuels. It can include the provision of: 1. alternative, cleaner fuels, 2. alternative power supply and 3. renewable energy.

Regarding alternative fuels, LNG can be used to power a wide range of equipment and craft, such as RTGs, yard hostlers and trucks, reach stackers, and tugboats. It provides an efficiency approximately 10% higher than conventional fuels per kilometer while producing 25% less CO_2 (Alamoush et al. 2020). It should be noted thought, that the issue of Methane slip from engines using LNG can eliminate the benefits of CO_2 reduction since it has 25 times more warming potential. The production of Methane depends on the engine heat cycle with the diffusion (heterogeneous) burning of Diesel (high press) engines practically ensuring that no methane escapes unburned from the combustion chamber while the premixed (homogenous) principle of combustion in Otto (low press) engines cycle allows some fuel to escape at the exhaust. This is primarily during the gas exchange phase of the cycle, and from incomplete combustion at crevices in the combustion chamber and top piston area. However, Otto engines have covered a long distance in their development and today they are capable to demonstrate a very low total Hydro-Carbon (THC) emissions level[7].

Other alternative fuels include Methanol which generates less CO_2 emissions than conventional fuels and does not have the methane slip at low loads and also Ammonia which can be used as cleaner marine fuel.

The alternative power supply refers to the utilisation of electricity as source of power as a replacement of fossil fuel to run engines and generators in order to achieve less air emissions. Full electrification can be applied in a significant part of the port equipment such as the in case of Container Handling Equipment (CHE), to shore to ship (STS) cranes, rail mounted gantry (RMG) cranes and cable reel RTGs). Furthermore, rechargeable battery systems can also be used in CHE which however require a high initial investment in extra batteries for swaps. Another alternative is the use of hybrid port equipment which can be fuel-electric hybrids (engine and battery), plug-in electric hybrids (using a rechargeable battery) or diesel-hydraulic hybrid where the hydraulic power accumulated drives the motor and the wheels (Alamoush et al. 2020).

Finally, regarding renewable energy, ports are located in areas that are advantageous for renewable energy production and especially for solar, wind and tidal/wave energy. Furthermore, the use of hydrogen in fuel cell devices can be considered a renewable energy source if it is generated using renewable electricity. Biomass and biofuels are also renewable energy sources and can be used in vehicles or equipment when mixed with fossil fuels or can be used to produce heat and electricity.

6.1.1.9. Energy saving in buildings and installations

It includes a set of technical measures aiming to reduce port energy consumption and improve energy efficiency when their application is possible (Alamoush et al. 2020):

[7] https://safety4sea.com/methane-slip-from-lng-fueled-engines/

- Use of light emitting diode (LED) lights in buildings, docks, yards, storages, warehouses and tugs together with automatic lighting controls and sensors and high mast lighting outdoors to reduce light loss,
- Insulation of buildings and installation of green roofs. Design of new buildings in a way that minimises cooling demand and heat loss. Installation of wall and roof insulation on storage tanks and pipelines in liquid bulk terminals,
- Energy efficient control of HVAC in buildings and warehouses,
- Painting external walls white, cleaning lamps, cold storage insulation and curtains in warehouses and storages,
- Reefer monitoring systems and reefer sun protection roofs. The gaps between adjacent reefers can be isolated from surrounding air by elastic seals,
- Design port layouts and installations to minimise travel distances and transfer points and to avoid/minimise restorage and reshuffling of cargo.

6.1.1.10. Truck emissions reduction

The reduction of air emissions by vehicles entering the port area to load/unload cargo can be achieved in several ways. The implementation of a voluntary clean truck program and providing incentives will support the gradual renewal of the fleet of vehicles entering the port area with newer technology vehicles. Furthermore, the congestion of vehicles outside, at the gate, and in terminals can be addressed through the implementation of IT systems such as a truck appointment system (TAS) for booking time before the arrival to the terminal and a smart gate system for automated and efficient gate processing. Finally, the congestion can be mitigated through imposing measures such as peak hours traffic mitigation fees (Alamoush et al. 2020).

6.1.1.11. Modal shift/split

The shift of cargo, moving from ports to the hinterland and vice versa, from road transportation to rail, barges, and short sea shipping will help to reduce emissions in the port areas in two ways. First, it will move cargo to more energy efficient modes compared to trucks. Rail is considered both economically and environmentally superior to moving cargo by trucks; the port of Gothenburg reported a 70% reduction of transport energy consumption as a result of the extensive use of rail shuttles. Second it will help reduce the congestion of trucks within the port limits which is another significant source of air emission. However, especially in the case of rail transportation, the modal shift in many cases will require large infrastructure investments for the development of the network to support the increased rail flows (Alamoush et al. 2020).

6.1.1.12. Employees environmental awareness

The implementation of appropriate programs for improving employee's awareness of energy efficiency through environmental training (such as eco driving lessons) together with providing incentives (e.g., for car sharing, use of public transport) will result in the reduction of the consumption of energy in the administration buildings, in port operations and also during commuting to/from work.

6.1.2. Relation of air pollution reduction measures to eKPIs

The eKPIs affected by the implementation of each of the recommended air pollution reduction measures are presented in table 25.

Table 29: Air pollution mitigation practices and corresponding affected eKPIs

	Recommended practices	**eKPIs**
AIR		
1	Onshore Power Supply	NO_x, PM, SO_2, HC, CO_2
2	Alternative fuel bunkering	NO_x, PM, SO_2, HC, CO_2
3	Reduction of ship turnaround time	NO_x, PM, SO_2, HC, CO_2

4	Vessel speed reduction	NO_x, PM, SO_2, HC, CO_2
5	Exhaust gases control	NO_x, PM, SO_2, HC, CO_2
6	Green Ship promotion	NO_x, PM, SO_2, HC, CO_2
7	Equipment upgrade	NO_x, N_2O, PM, SO_2, HC, CO_2, CO, CH_4
8	Alternative energy sources	NO_x, N_2O, PM, SO_2, HC, CO_2, CO, CH_4
9	Energy saving in building and installations	NO_x, N_2O, PM, SO_2, HC, CO_2, CO, CH_4
10	Truck emissions reduction	NO_x, N_2O, PM, SO_2, HC, CO_2, CO, CH_4
11	Modal shift/split	NO_x, N_2O, PM, SO_2, HC, CO_2, CO, CH_4
12	Employees environmental awareness	NO_x, N_2O, PM, SO_2, HC, CO_2, CO, CH_4

6.2. Water

Includes technical and operational measures for the reduction of water consumption by all port actors and also through voluntarily and mandatory actions based on the ESPO Green Guide (2012).

6.2.1. Water consumption and pollution reduction measures

6.2.1.1. Water network losses

Reduction of the indirect water consumption through the minimisation of water network losses caused by leaks. This can be achieved through regular inspection and maintenance of the water network and also through continuous monitoring of water demand to identify leakages.

6.2.1.2. Stormwater collection

Increase of the volume of stormwater which is collected through the network in order to be treated before discharged to the environment by providing surface water infrastructure (construction or expansion of the stormwater network) and installation of monitoring systems to manage runoff waters which may carry contamination into the water bodies.

6.2.1.3. Involvement of port users

Raising awareness of port users regarding the reduction of water consumption can be achieved mainly in two ways: through encouragement by providing incentives to green port users and through enforcement by setting rules and ensuring compliance.

The first case includes measures such as the setting up a rewarding scheme for port users which comply with or exceed minimum requirements. The second case includes measures such as the introduction of expected standards regarding water consumption into contract documents at the tender stage, incorporating water consumption criteria and good operational practices in tendering procedures associated with concession and lease agreements and undertaking site environmental audits and/or periodically requesting for environmental reports to ensure that port users and/or contractors comply with the rules and agreements.

6.2.1.4. Accidental spills/leakages

The reduction in the number and severity of accidental leakages and spills which pose a significant thread to the marine environment can be achieved through the following measures which in some cases require the cooperation between Port Authorities and other port users:

- Establishing spill monitoring and proven emergency response procedures for both land and marine operations,

- Ensuring that cargo handling equipment is in line with best environmental practice (e.g., enclosed grabs, Eco-Hopper) that minimise spillages,
- Conducting joint exercises to improve partnership in handling incidents that impact on water quality (e.g., spills),
- Enforcing the 'polluter pays' principle when incidents occur.

6.2.1.5. PA water consumption management plan

Establishing a water consumption management plan includes among others the mapping of water consumption, creating user profiles, planning measures and setting targets on reducing own direct water usage and indirect consumption within the estate infrastructure. It will help ports to develop strategic action plans for improvement, prioritise projects and measure the effectiveness of interventions thus leading in a more efficient water use in the long term.

6.2.2. Relation of water related measures to eKPIs

The eKPIs affected by the implementation of each of the recommended water consumption and pollution reduction measures are presented in table 26.

Table 30: Water related practices and corresponding affected eKPIs

	Recommended practices	**eKPIs**
WATER		
1	Water network losses	Storm water, Sanitary wastewater, Technological wastewater
2	Stormwater collection	Storm water
3	Involvement of port users	Technological wastewater, Sanitary wastewater
4	Accidental leakages/spills	Technological wastewater
5	PA water consumption management plan	Sanitary wastewater

6.3. Waste

Includes technical and operational measures for the reduction of waste production by all port actors and also through voluntarily and mandatory actions according to the ESPO Green Guide (2012).

6.3.1. Involvement of port users

Raise awareness of port users regarding the reduction of waste and also regarding waste separation and recycling. This can be achieved mainly in two ways: through encouragement by providing incentives to green port users and through enforcement by setting rules and ensuring compliance.

The first case can include the setting up of an incentive scheme rewarding waste reduction, waste separation and recycling through revised waste charges to reflect the value of these initiatives. The second case can include incorporating good waste management practices in tendering procedures associated with concession and lease agreements and monitoring and ensuring the compliance of port users with the rules and agreements.

6.3.2. Employees environmental awareness

The implementation of appropriate environmental training programs by the Port Authorities for improving employee's awareness will result in the increase of recycling and the reduction of waste and will also help PAs demonstrate excellence while managing port authority generated waste (offices, fleet, vehicles, own operations).

6.3.3. Waste management plan

The establishment of a waste management plan in consultation with shipowners, tenants and other port users will help to set targets and plan the investments to the port's reception facilities and equipment for optimal handling of waste. This will ensure the effectiveness of handling, storage, transportation and disposal of waste and will lead to the reduction of port generated waste and increase of recycling in the long term.

Table 31: Waste related practices and corresponding affected eKPIs

	Recommended practices	eKPIs
WASTE		
	Involvement of port users	Hazardous waste, Non-hazardous waste
	Employees environmental awareness	Hazardous waste, Non-hazardous waste
	Waste management plan	Hazardous waste, Non-hazardous waste

6.4. Noise

The list of recommendations for reducing noise emissions at the port area are based on the Good Practice Guide on Port Area Noise Mapping and Management published by the NoMEPorts (Noise Management in European Ports) Project in 2008. They are categorised in measures of technical and operational measures aimed at reducing the level of noise produced directly at its source, measures aimed to reducing the propagation of noise and finally measures aimed to facilitate the long-term planning against noise pollution.

6.4.1. Technical source mitigation measures

The reduction of noise produced in the port area through equipment and structural measures can include the following:

- Covering of the equipment components which are sound intensive with noise insulation materials to reduce the emitted noise,
- Silent exhaustion pipes and ventilators,
- Use water cooling instead of air cooling when possible,
- Use electricity instead of diesel or diesel-electric moving equipment,
- Preference for low noise version of port equipment when available,
- Use of noise absorbing building materials in new constructions and noise insulation of existing noise emitting buildings,
- Transfer noise sources into buildings or construct barriers around them when possible,
- Use softer ground materials where activities allow (e.g., quiet asphalt),
- Provision of on-shore power connection to ships during berthing.

6.4.2. Operational source mitigation measures

The reduction of noise produced in the port area through operational measures can include the following:

- Reduction of the noise produced during cargo handling operations (e.g., reduction of the speed of putting a container down or the distance from ground for opening a bulk grab, automatic positioning of the spreaders),
- Prevent the use of loud speakers when feasible and not affecting security (at ships & berths),
- Promotion of low noise driving (Eco driving) & respect of speed limits within the port area,

- Avoiding having a night-open terminal when feasible. The seaside activities can continue during the night hours but without land-operations involving movements of trailers through gates,
- Reduce transport distances.

6.4.3. Measures against noise propagation

The measures for the reduction of the propagation of noise produced in the port area can include the following:

- Construction of noise barriers to road and rail infrastructure inside the port area,
- Turning the noise source so that it is directed away from surrounding areas,
- Appropriate yard planning, e.g., positioning of container racks so they can act as a barrier to noise,
- Relocation of most noisy activities to optimal locations regarding the reduction of noise propagation,
- Move the entrance gate away from residential areas,
- Plant trees as a sound barrier,

6.4.4. Noise emissions assessment

The reduction of noise pollution can be achieved through the development of appropriate action plans. Within the ports areas there is a wide range of potential noise emitting sources, ranging from the cargo handling operations to rail and road transportation and also industrial activities. Therefore, there is a need for proper mapping of all noise sources which can be performed through the use of a noise mapping software that will be used as a decision support tool. This tool will provide port authorities with the necessary information to identify the sources that cause the greatest impact and thus to come up with the most effective mix of measures in the form of action plans.

Table 32: Noise related practices and corresponding affected eKPIs

	Recommended practices	**eKPIs**
NOISE		
	Technical source mitigation measures	L_{DEN}, L_{night}
	Operational mitigation measures	L_{DEN}, L_{night}
	Measures against noise propagation	L_{DEN}, L_{night}
	Noise emission assessment	L_{DEN}, L_{night}

6.5. Light

The list of recommendations for reducing light pollution from ports are based on a best practice included in a report prepared for the Department of Sustainability, Environment, Water, Population and Communities, Canberra, Australia (GHD 2013) regarding the development of a light management plan aiming to reduce the impact of port lighting on the natural environment.

6.5.1. Reduction of light misuse

The reduction of light pollution can be achieved through measures targeted to reduce the unnecessary use of lights and also to reduce the amount of light that is not used for the purpose intended. These measures can include:

- Shielding of lights in order to prevent them from being visible from areas outside the port (beaches, residential areas) and also to prevent the upward light spillage. This measure can be combined with appropriate height of lighting masts and appropriate lamp fittings,
- Provide multiple levels of control on light intensity, depending on the purpose of use (security, operational purposes),

- Applying systems such as timers and motion detectors in order to turn off lights when they are not needed for security reasons,
- Drafting of a light management plan by Port Authorities and requirement of all port tenants to submit individual light management plans for any new construction that must be consistent with it.

Table 33: Light related practices and corresponding affected eKPIs

	Recommended practices	**eKPIs**
LIGHT		
	Reduction of light misuse	Light

7. Conclusion

Based on the research results presented in the chapters of this document, useful conclusions are drawn regarding the feasibility and the added value of the proposed composite environmental metrics by the PIXEL project.

More specifically, through the results of the content analysis of the ESRs with respect to the monitoring of the environmental impact of port operations, it is evident that today a significant part of European ports is already environmentally aware, recognising their responsibility towards society and thus putting effort in complying with the EU policy for the protection of the environment. All of the environmental aspects included in the PEI are monitored by a significant number of ports, with the emissions to air, energy consumption and waste production appearing to gather the most attention, followed by water consumption and noise pollution. Therefore, there is already a significant amount of data collected by ports which can be used for the PEI calculations thus contributing to its feasibility in terms of data availability.

The same applies in relation to the available infrastructure which also contributes to the feasibility of PEI. According to the analysis of the questionnaire results regarding the current methods used for the collection of data there is already an IoT (including sensors) infrastructure available in several ports for collecting measurements related to air emissions and can be used for the calculation of PEI.

Regarding the added value of PEI, another important conclusion from the collected information is the large number of different indicators used to monitor in each environmental aspect. The lack of an established and commonly accepted EU framework for performing environmental metrics has led to the existence of a large number of differentiated indicators for monitoring each environmental aspect, customised to the specific needs of each measuring port. Despite this fact being logical to an extent, the lack of uniformity of indicators, is limiting their potential uses to the internal self-evaluation of ports and the monitoring of the evolution of their value as an early indicator for specific operational problems. The implementation of PEI can add value to all these metrics by integrating them into a single metric for assessing their environmental performance in a comprehensive way and can also be used for decision making and for comparison with other ports. In relation to the latter, the questionnaire survey showed that currently there is a very low use of industry benchmarks by the ports for assessing their environmental performance in comparison to them. The PEI can fill this gap to an extent by providing a universal single metric that can be used for comparison among ports regardless of the port size or specialisation.

Finally, the questionnaire survey showed that the main means used for communicating and sharing the results of the environmental monitoring by ports is through the ESRs and ad-hoc meetings, mainly with port users and city/regional authorities. The implementation of PEI can contribute to improving this communication by providing a single metric which is easier to share and comprehend rather than having many disperse values of several indicators, especially when the communication is related to society, with stakeholders from outside the port community.

7.1. Future Work

The future work described in this sub-chapter is mainly related to the feedback which will be provided from the real-life implementation of the PEI tool in port operations. In this context, possible problems which will be encountered during the implementation of the PEI methodology can be analysed and the solutions can be integrated to the guidelines for its adoption included in the present document.

Furthermore, as mentioned in paragraph 2.3.2.2, more information on possible implementation problems will also be collected through additional interviews which will be performed in the context of tasks T8.4 (Proof of Concept and future R&D potential) and T9.4 (Exploitation & Business Plan).

Finally, regarding the practices for minimising PEIs value, the application of the suggested measures in real life will also provide feedback on their effectiveness which will allow the revision or change of their prioritisation and possible the adding of more recommendations to the list.

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Appendix A

Questionnaire: Environmental performance metrics used by the TEN-T ports

This project has received funding from the European's Union Horizon 2020 research innovation program under grant agreement No. 769355

Questionnaire
Environmental performance metrics used by the TEN-T ports

Participant Information Sheet

PIXEL – Port-IoT for Environmental Leverage

Funder: *European H2020-MG-7-3 through agency INEA*

Lead Institution: *UNIVERSITAT POLITÈCNICA DE VALÈNCIA*

Duration: *36 months*

Project Coordinator: *Carlos E. Palau (UPV)*

Ethics Mentor: *Dimitrios Spyrou (PPA – Piraeus Port Authority)*

1. *Information about the project*

PIXEL is a three-year (May 2018-April 2021) Research and Innovation Action, under the framework of H2020-MG-7-3 topic, aiming at enabling a two-way collaboration of ports, multimodal transport agents and cities for optimal use of internal and external resources, sustainable economic growth and environmental impact mitigation, towards the Ports of the Future. PIXEL is pilot-centric and has planned 5 different trials at Italy, Greece, France and Croatia. Its Consortium is formed by ICT experts, environmental-related enterprises, ports, stakeholders and public authorities.

PIXEL will leverage technological enablers to voluntary exchange data among ports and stakeholders, thus ensuring a measurable benefit in this process. The main outcome of this technology will be efficient use of resources in ports, sustainable development and green growth of ports and surrounding cities/regions. Built on top of the state-of-the art interoperability technologies, PIXEL will centralise data from the different information silos where internal and external stakeholders store their operational information.

In order to achieve those objectives, PIXEL needs to process data from several heterogeneous sources. Probably, data coming from you, as an individual (or entity) will include some personal data. That's why you need to be informed (through the forthcoming clauses) about the nature of the data processing to be performed, and why your consent is requested.

2. *Why am I participating?*

You have been chosen as the competent person to provide information regarding the environmental activities of your port.

3. *Which is my role in the project?*

To provide information regarding the environmental metrics currently used by your port.

4. *Information about the data to be collected*

The data from your contribution together with the corresponding data from other TEN-T ports will be used for statistical analysis in order to form an overview of the current status of the environmental monitoring by EU ports.

5. *Procedures and protocol*

PIXEL has enabled mechanisms to ensure that Data collection will be done with respect for private and family life and the protection of personal data in compliance with the Charter of Fundamental Rights in the European Union. Furthermore, the collection of data will be conducted in compliance with data protection acts, legislation, and directives, both at the European and the national level.

6. Which treatment will I have for my personal data?

No personal data will be stored. Information provided by your feedback (in any context) will be securely stored in our own repository. Data will only be used for research purposes and will not be shared publicly, online or by other means.

7. Benefits of taking part

You will have the opportunity to gain knowledge about an innovative project with modern technologies in the field of environmental impact in transport and logistics.

8. Withdrawal request

You can withdraw from the study and request your information be deleted at any time, without giving a reason, up to 28 days following the date of your final participation.

9. Sharing of results

The sharing of the survey findings with the participants will be realised through the dissemination of the project results according to its timeplan. Furthermore, the research findings will be broadly shared through journal publications and conferences.

10. Reference contacts

Project Coordinator – Carlos E. Palau (UPV) – cpalau@dcom.upv.es – Camino de Vera s/n, 46022, Valencia, Spain.

Ethics Mentor – Dimitris Spyrou (PPA) – dspyrou@olp.gr

If you have any questions or you change your mind regarding your participation to this survey, you may contact Mr. Orestis Tsolakis, Research Associate at the Centre for Research and Technology Hellas (CERTH)/ Hellenic Institute of Transport (HIT) - email: ortsolakis@certh.gr

11. Further information

For further details please refer to the PIXEL website at: http://www.pixel-ports-eu/

Certificate of consent

Country where data will be provided:

1. *I confirm that I have received the Participant Information Sheet, I have read it and have had the opportunity for asking questions*
2. *I know the purpose of collecting the data and its processing*
3. *I am informed about the effect to be expected, about possible advantages and disadvantages and about possible risks verbally and in writing by the data controller*
4. *I know the degree of confidentiality and the protection strategy that data will go through*
5. *I am aware that personal data will used anonymised at the publication of the experiments results. I approve of the fact however under a strict compliance with the confidentiality that the responsible experts of the authorities and the Ethics Mentor may take a look for examining and control purposes of my original data.*
6. *I voluntarily participate in this research without pressure and I recognise my right wo withdraw my participation at any moment*
7. *I understand that the content that will be generated from my participation will generate useful information to be stored in a secure data repository with research purposes*
8. *I had sufficient time to take my decision*
9. *I agree to take part in the research of the project*
10. *I do not agree to take part in the project*

Respondent details

Port name:						
Country:						
Organisation type:	Port Authority	☐	Port terminal operator	☐	Both	☐
Person filling the questionnaire:	Name:		Position:			
	Email:					

Question 1

Which metrics do you currently use for assessing the environmental impact and resource consumption of your port/terminal?

Environmental impact area				
Emissions to the atmosphere	**Metrics being used**			
GHG emissions	Total CO_2 equivalent or GHG emissions	☐	CO_2 or GHG emissions - Scope 1	☐
	CO_2 or GHG emissions - Scope 2	☐	CO_2 or GHG emissions - Scope 3	☐
	Average CO_2 or GHG emissions / throughput (per tonne or per TEU)	☐	Other (specify):	☐
Particulate Matter (PM)	PM_{10} concentration ($\mu g/m^3$)	☐	Number of exceedances of maximum 24-hour limit of PM_{10}	☐
	$PM_{2.5}$ concentration ($\mu g/m^3$)	☐	Sedimentable particles concentration (mg/m^2)	☐
	Number of exceedances of daily limit of particulate matter	☐	Annual PM emissions (t)	☐
			Other (specify):	☐
NO_x emissions	Annual total NO_x emissions (t)	☐	NO_x annual average concentration ($\mu g/m^3$)	☐
	Annual total NO_x emissions from vessels in the port area (t)	☐	NO_2 annual average concentration ($\mu g/m^3$)	☐
	Number of exceedances of hourly limit value of NO_2	☐	Other (specify):	☐
SO_x emissions	Annual total SO_x emissions (t)	☐	Annual and/or monthly average concentration of SO_2 ($\mu g/m^3$)	☐
	Annual total number of exceedances of the daily limit value of SO_2 ($125 \mu g/m^3$)	☐	Annual total number of exceedances the hourly limit value of SO_2 ($350 \mu g/m^3$)	☐
	Annual total emission of SO_2 (kg or t)	☐	Other (specify):	☐
Non-Methane volatile organic compounds (NMVOC) emissions	Annual total NMVOC emission from shipping (t)	☐	C_6H_6 annual average concentration ($\mu g/m^3$)	☐
			Other (specify):	☐
Other air quality indicators	Annual total number of complaints regarding air quality	☐	Other (specify):	☐

Environmental impact area				
Waste production & wastewater discharge	**Metrics being used**			
Waste from ships	Total amount of ship waste collected by the port (t)	☐	Total amount of ship waste per type (hazardous/non-hazardous) (t)	☐
	Total amount of ship waste per type of handling (t)	☐	Total amount of ballast water received (Litres or m^3)	☐
			Other (specify):	☐
Waste from ships per MARPOL category	Annex I: oily bilge water, oily residues (sludge), oily tank washings (slops), dirty ballast water, scale and sludge from tank cleaning (Litres or m^3)	☐	Annex II: cargo residues containing noxious liquid substances (NLS), ballast water, tank washings or other mixtures containing such substances (Litres or m^3)	☐
	Annex IV: sewage (Litres or m^3)	☐	Annex V: garbage, including plastics, food wastes, domestic wastes, cooking oil, incinerator ashes, operational wastes, etc. (Litres or m^3)	☐
	Annex VI: ozone-depleting substances & equipment containing such substances, & exhaust gas cleaning residues (Litres/m^3)	☐	Other (specify):	☐
Port wastewater	Percentage of service area surface that has wastewater collection and is connected to the municipal collector or a Waste Water Treatment Plant (%)	☐	Percentage of service area surface that has a wastewater collection network (regardless of where it is discharged or if it is treated) (%)	☐
	Percentage of the service area surface that has its wastewater discharged into septic tanks (%)	☐	Annual total volume of wastewater produced by the port or discharged in port collectors broken down by wastewater type (Urban/ Industrial/ Mixed) (m3, % of total wastewater)	☐
	Annual total volume of wastewater produced by the port or discharged in port collectors broken down by destination (Municipal collector/ Septic tanks/ Own treatment/ Other) (m3, % of total wastewater)	☐	Other (specify):	☐
Port waste	Annual total quantity of collected floats by the cleaning service (kg, t, m^3)	☐	Port waste production (t) broken down by type (Hazardous/Non-hazardous) (t, % of total waste)	☐
	Port waste that has been segregated (% of total port waste) and recovered (% of total port waste), broken down by type (Solid Urban/Hazardous/Oils):	☐	Port hazardous waste production broken down by detailed waste type (e.g. batteries, fluorescent) (t, % of total hazardous waste)	☐
	Port non-hazardous waste production broken down by detailed waste type (e.g. glass, paperboard, organic) (t, % of total non-hazardous waste)	☐	Other (specify):	☐

Environmental impact area					
Noise	**Metrics being used**				
	Annual total number of complaints related to noise produced by the port operations	☐	Annual/Campaign average sound levels in the day, evening and night period (L_{DEN}) (dB(A))	☐
	Annual/Campaign average sound levels in the night period (L_{night}) (dB(A))	☐	Annual total number of exceedances of noise limits day and/or night	☐
			Other (specify):	☐
Dredging	**Metrics being used**				
	Annual total volume of dredged materials (m^3)	☐	Annual total volume of each type of dredged material, according to the dredging guidelines of CIEM (Spanish ports)	☐
	Annual total volume of contaminated dredged materials (categories II & III of CEDEX guidelines – Spanish ports)	☐	Percentage of contaminated dredged materials on the total dredged materials	☐
			Other (specify):	☐
Environmental incidents	**Metrics being used**				
	Annual total number of incidents that required the activation of Maritime Plans for pollution emergency response	☐	Annual total number of incidents that required the activation of Maritime Plans for pollution emergency response, split by response type	☐
	Annual total number of water contamination incidents	☐	Annual total quantity of spills (Litres)	☐
			Other (specify):	☐

Resource consumption area				
The resource consumption metrics reported below, refer to:				
the Port Authority only:			☐	
the port area as a whole (including port operators and tenants):			☐	
Energy	**Metrics being used**			
Total energy	Annual total energy consumption by the port (KWH, MWh, GJ, PJ)	☐	Annual average total energy consumption by the port per throughput (KWH /t, GJ/t of cargo)	☐
	Annual total energy consumption in the port area (MWH)	☐	Other (specify):	☐
Electricity	Annual total electricity consumption by the port (KWH, MWH, GJ, % of total energy)	☐	Annual average electricity consumption per port service area (KWH/m^2)	☐
	Annual total electricity consumption by the port, per use (KWH, MWH, % of total electricity)	☐	Annual total electricity consumption by the port, per source type (green/conventional) (GJ, % of total electricity)	☐
	Annual total electricity consumption in the port area (MWH, GJ)	☐	Other (specify):	☐
Fuel	Annual total fuel consumption by the port (l, m^3, t, MWH, KWH, GJ, % of total energy)	☐	Annual total consumption of fuel by the port, per type (KWH, MWH, GJ, l, m^3, t, % of total fuel energy)	☐
	Annual total consumption of fuel by the port, per use (KWH, % of total fuel energy)	☐	Annual average fuel consumption per port service area (KWH/m^2)	☐
	Annual average fuel consumption by the port per throughput (l/1000t or l/t, KWH/1000t of cargo)	☐	Other (specify):	☐
Heating energy	Annual total heating and/or cooling energy consumption by the port (GWH, KWH, % of total energy)	☐	Annual total heating energy consumption in the port area (MWH)	☐
	Annual average heating energy consumption by the port per throughput (KWH/1000t of cargo)	☐	Annual average heating energy consumption by the port per building area (KWH/m^2)	☐
			Other (specify):	☐
Water	**Metrics being used**			
	Annual total water consumption at the port (m^3)	☐	Annual average water consumption at the port per service area (m^3/m^2)	☐
	Efficiency of water supply network = Water volume purchased by the PA / water volume consumed by the PA and port tenants (%)	☐	Total water consumption at the port per type of use (m^3, % of total consumption)	☐
	Annual total water consumption in the port area (m^3)	☐	Other (specify):	☐

Resource consumption area				
Land use	**Metrics being used**			
	Percentage of the terrestrial service zone that is occupied by the active installations, whether these are owned or under concession or authorisation (%)	☐	Other (specify):	☐
Materials	**Metrics being used**			
	Annual total consumption of paper by the port (t, kg, A4/employee, number of sheets, t/employee)	☐	Annual total number of printed copies and photocopies	
	Consumption of excipients broken down by type (e.g. grease, lubricants, hydraulic oils, engine oils, paint) (kg, kg/1000t of cargo)	☐	Other (specify):	☐

Question 2:

How do you capture data for the environmental impact metrics being used and how often?

Emissions to atmosphere	Data collection methods used	Data collection frequency			
GHG emissions	Manually, through on-site measurements	Once per year	☐	Twice per year	☐
		Monthly	☐	Other (specify):	
	Automatically, through installed IoT sensors	Continuously (online)	☐	Other (specify):	
	No data capture, calculation using emission factors (proxy data)	Once per year	☐	Twice per year	☐
		Monthly	☐	Other (specify):	
	Other (specify):				
Particulate Matter (PM)	Manually, through on-site measurements	Once per year	☐	Twice per year	☐
		Monthly	☐	Other (specify):	
	Automatically, through installed IoT sensors	Continuously (online)	☐	Other (specify):	
	No data capture, calculation using emission factors (proxy data)	Once per year	☐	Twice per year	☐
		Monthly	☐	Other (specify):	
	Other (specify):				
NOx emissions	Manually, through on-site measurements	Once per year	☐	Twice per year	☐
		Monthly	☐	Other (specify):	
	Automatically, through installed IoT sensors	Continuously (online)	☐	Other (specify):	
	No data capture, calculation using emission factors (proxy data)	Once per year	☐	Twice per year	☐
		Monthly	☐	Other (specify):	
	Other (specify):				

SOx emissions	Manually, through on-site measurements	Once per year	☐	Twice per year	☐
		Monthly	☐	Other (specify):	
	Automatically, through installed IoT sensors	Continuously (online)	☐	Other (specify):	
	No data capture, calculation using emission factors (proxy data)	Once per year	☐	Twice per year	☐
		Monthly	☐	Other (specify):	
	Other (specify):				
O3 pollutants	Manually, through on-site measurements	Once per year	☐	Twice per year	☐
		Monthly	☐	Other (specify):	
	Automatically, through installed IoT sensors	Continuously (online)	☐	Other (specify):	
	No data capture, calculation using emission factors (proxy data)	Once per year	☐	Twice per year	☐
		Monthly	☐	Other (specify):	
	Other (specify):				
NMVOC	Manually, through on-site measurements	Once per year	☐	Twice per year	☐
		Monthly	☐	Other (specify):	
	Automatically, through installed IoT sensors	Continuously (online)	☐	Other (specify):	
	No data capture, calculation using emission factors (proxy data)	Once per year	☐	Twice per year	☐
		Monthly	☐	Other (specify):	
	Other (specify):				

Waste production & wastewater discharge	Data collection methods used	Data collection frequency			
Waste from ships	Manually, by compiling information through FAL forms	Once per year	☐	Twice per year	☐
		Monthly	☐	Continuously (per ship call)	☐
				Other (specify):	
	Automatically, by receiving information through a PCS/TOS[8]	Continuously (online)	☐	Other (specify):	
	Automatically, through installed IoT sensors	Continuously (online)	☐	Other (specify):	
	No data capture, calculation using discharge factors (proxy data)	Once per year	☐	Twice per year	☐
		Monthly	☐	Other (specify):	
	Other (specify):				
Port wastewater	Manually, through on-site measurements	Once per year	☐	Twice per year	☒
		Monthly	☐	Other (specify):	
	Automatically, through installed IoT sensors	Continuously (online)	☐	Other (specify):	
	No data capture, calculation using discharge factors (proxy data)	Once per year	☐	Twice per year	☐
		Monthly	☐	Other (specify):	
	Other (specify):				
Port waste	Manually, through on-site measurements	Once per year	☐	Twice per year	☐
		Monthly	☐	Other (specify):	
	Automatically, through installed IoT sensors	Continuously (online)	☐	Other (specify):	
	No data capture, calculation using discharge factors (proxy data)	Once per year	☐	Twice per year	☐
		Monthly	☐	Other (specify):	
	Other (specify):				

[8] Port Community System / Terminal Operating System

Noise	**Data collection methods used**	**Data collection frequency**			
	Manually, through on-site measurements	Once per year	☐	Twice per year	☐
		Monthly	☐	Other (specify):	
	Automatically, through installed IoT sensors	Continuously (online)	☐	Other (specify):	
	No data capture, calculation using emission factors (proxy data)	Once per year	☐	Twice per year	☐
		Monthly	☐	Other (specify):	
	Other (specify):				
Dredging	**Data collection methods used**	**Data collection frequency**			
	Through on-site measurements	Once per year	☐	Twice per year	☐
		Monthly	☐	Other (specify):	
	Automatically, through installed IoT sensors	Continuously (online)	☐	Other (specify):	
	Automatically, through other means (e.g. scales on trucks, etc.)	Continuously (online)	☐	Other (specify):	
	Other (specify):	Once per year	☐	Twice per year	☐
		Monthly	☐	Other (specify):	

Question 3:

Based on your experience, which are the main problems faced in introducing and operating a port environmental impact measurement system?

	Significance of problems faced				
Problems	**Not significant**	**Slightly significant**	**Fairly significant**	**Significant**	**Very significant**
Lack of automated data collection	☐	☐	☐	☐	☐
Lack of a standardised list of metrics	☐	☐	☐	☐	☐
Other (specify):	☐	☐	☐	☐	☐
Other (specify):	☐	☐	☐	☐	☐
Other (specify):	☐	☐	☐	☐	☐
Other (specify):	☐	☐	☐	☐	☐
Other (specify):	☐	☐	☐	☐	☐

Question 4:

Do you share your environmental impact measurements with other actors/stakeholders?

Environmental impact	Shared with	Through			
Emissions to the atmosphere	City / regional authority	Ad-hoc meetings	☐	Permanent stakeholder committee	☐
		Press releases	☐	Annual sustainability reports	☐
		A PCS/TOS[9] online	☐	Other (specify):	
	Port users	Ad-hoc meetings	☐	Permanent stakeholder committee	☐
		Press releases	☐	Annual sustainability reports	☐
		A PCS/TOS online	☐	Other (specify):	
	Citizens / NGOs	Ad-hoc meetings	☐	Permanent stakeholder committee	☐
		Press releases	☐	Annual sustainability reports	☐
		A PCS/TOS online	☐	Other (specify):	
Waste & wastewater	City / regional authority	Ad-hoc meetings	☐	Permanent stakeholder committee	☐
		Press releases	☐	Annual sustainability reports	☐
		A PCS/TOS online	☐	Other (specify):	
	Port users	Ad-hoc meetings	☐	Permanent stakeholder committee	☐
		Press releases	☐	Annual sustainability reports	☐
		A PCS/TOS online	☐	Other (specify):	
	Citizens / NGOs	Ad-hoc meetings	☐	Permanent stakeholder committee	☐
		Press releases	☐	Annual sustainability reports	☐
		A PCS/TOS online	☐	Other (specify):	
Noise	City / regional authority	Ad-hoc meetings	☐	Permanent stakeholder committee	☐
		Press releases	☐	Annual sustainability reports	☐
		A PCS/TOS online	☐	Other (specify):	
	Port users	Ad-hoc meetings	☐	Permanent stakeholder committee	☐
		Press releases	☐	Annual sustainability reports	☐
		A PCS/TOS online	☐	Other (specify):	
	Citizens / NGOs	Ad-hoc meetings	☐	Permanent stakeholder committee	☐
		Press releases	☐	Annual sustainability reports	☐
		A PCS/TOS online	☐	Other (specify):	

[9] Port Community System / Terminal Operating System

Other (specify):	City / regional authority	Ad-hoc meetings	☐	Permanent stakeholder committee	☐
		Press releases	☐	Annual sustainability reports	☐
		A PCS/TOS online	☐	Other (specify):	
	Port users	Ad-hoc meetings	☐	Permanent stakeholder committee	☐
		Press releases	☐	Annual sustainability reports	☐
		A PCS/TOS online	☐	Other (specify):	
	Citizens / NGOs	Ad-hoc meetings	☐	Permanent stakeholder committee	☐
		Press releases	☐	Annual sustainability reports	☐
		A PCS/TOS online	☐	Other (specify):	

Question 5

Do you use any industry benchmarks to assess your environmental performance in comparison to them?

Environmental impact area	No benchmark is used	Yes, we use the following benchmark (please specify)
Emissions to the atmosphere	☐	
Waste production & wastewater discharge	☐	
Noise	☐	
Dredging	☐	
Environmental incidents	☐	
Other (specify):	☐	
Resource consumption area	**No benchmark is used**	**Yes, we use the following benchmark (please specify)**
Energy	☐	
Water	☐	
Land use	☐	
Materials	☐	
Other (specify):	☐	

Appendix B

Questionnaire: Problems in introducing and operating a port environmental impact measurement system

This project has received funding from the European's Union Horizon 2020 research innovation program under grant agreement No. 769355

Online interviews questionnaire

Participant Information Sheet

PIXEL – Port-IoT for Environmental Leverage

***Funder**: European H2020-MG-7-3 through agency INEA*

***Lead Institution**: UNIVERSITAT POLITÈCNICA DE VALÈNCIA*

***Duration**: 36 months*

***Project Coordinator:** Carlos E. Palau (UPV)*

***Ethics Mentor**: Dimitrios Spyrou (PPA – Piraeus Port Authority)*

12. Information about the project

PIXEL is a three-year (May 2018-April 2021) Research and Innovation Action, under the framework of H2020-MG-7-3 topic, aiming at enabling a two-way collaboration of ports, multimodal transport agents and cities for optimal use of internal and external resources, sustainable economic growth and environmental impact mitigation, towards the Ports of the Future. PIXEL is pilot-centric and has planned 5 different trials at Italy, Greece, France and Croatia. Its Consortium is formed by ICT experts, environmental-related enterprises, ports, stakeholders and public authorities.

PIXEL will leverage technological enablers to voluntary exchange data among ports and stakeholders, thus ensuring a measurable benefit in this process. The main outcome of this technology will be efficient use of resources in ports, sustainable development and green growth of ports and surrounding cities/regions. Built on top of the state-of-the art interoperability technologies, PIXEL will centralise data from the different information silos where internal and external stakeholders store their operational information.

In order to achieve those objectives, PIXEL needs to process data from several heterogeneous sources. Probably, data coming from you, as an individual (or entity) will include some personal data. That's why you need to be informed (through the forthcoming clauses) about the nature of the data processing to be performed, and why your consent is requested.

13. Why am I participating?

You have been chosen as the competent person to provide information regarding the environmental activities of your port.

14. Which is my role in the project?

To provide information regarding the environmental metrics currently used by your port.

15. Information about the data to be collected

The data from your contribution together with the corresponding data from other TEN-T ports will be used for statistical analysis in order to form an overview of the current status of the environmental monitoring by EU ports.

16. Procedures and protocol

PIXEL has enabled mechanisms to ensure that Data collection will be done with respect for private and family life and the protection of personal data in compliance with the Charter of Fundamental Rights in the European Union. Furthermore, the collection of data will be conducted in compliance with data protection acts, legislation, and directives, both at the European and the national level.

17. Which treatment will I have for my personal data?

No personal data will be stored. Information provided by your feedback (in any context) will be securely stored in our own repository. Data will only be used for research purposes and will not be shared publicly, online or by other means.

18. Benefits of taking part

You will have the opportunity to gain knowledge about an innovative project with modern technologies in the field of environmental impact in transport and logistics.

19. Withdrawal request

You can withdraw from the study and request your information be deleted at any time, without giving a reason, up to 28 days following the date of your final participation.

20. Sharing of results

The sharing of the survey findings with the participants will be realised through the dissemination of the project results according to its timeplan. Furthermore, the research findings will be broadly shared through journal publications and conferences.

21. Reference contacts

Project Coordinator – Carlos E. Palau (UPV) – cpalau@dcom.upv.es – Camino de Vera s/n, 46022, Valencia, Spain.

Ethics Mentor – Dimitris Spyrou (PPA) – dspyrou@olp.gr

If you have any questions or you change your mind regarding your participation to this survey, you may contact Mr. Orestis Tsolakis, Research Associate at the Centre for Research and Technology Hellas (CERTH)/ Hellenic Institute of Transport (HIT) - email: ortsolakis@certh.gr

22. Further information

For further details please refer to the PIXEL website at: http://www.pixel-ports-eu/

Certificate of consent

Country where data will be provided: ☐

11. *I confirm that I have received the Participant Information Sheet, I have read it and have had the opportunity for asking questions* ☐
12. *I know the purpose of collecting the data and its processing* ☐
13. *I am informed about the effect to be expected, about possible advantages and disadvantages and about possible risks verbally and in writing by the data controller* ☐
14. *I know the degree of confidentiality and the protection strategy that data will go through* ☐
15. *I am aware that personal data will used anonymised at the publication of the experiments results. I approve of the fact however under a strict compliance with the confidentiality that the responsible experts of the authorities and the Ethics Mentor may take a look for examining and control purposes of my original data.* ☐
16. *I voluntarily participate in this research without pressure and I recognise my right wo withdraw my participation at any moment* ☐
17. *I understand that the content that will be generated from my participation will generate useful information to be stored in a secure data repository with research purposes* ☐
18. *I had sufficient time to take my decision* ☐
19. *I agree to take part in the research of the project* ☐
20. *I do not agree to take part in the project* ☐

Respondent details

<table>
<tr><td>Port name:</td><td colspan="4"></td></tr>
<tr><td>Country:</td><td colspan="4"></td></tr>
<tr><td>Organisation type:</td><td>Port Authority ☐</td><td colspan="2">Port terminal operator ☐</td><td>Both ☐</td></tr>
<tr><td rowspan="2">Person filling the questionnaire:</td><td colspan="2">Name:</td><td colspan="2">Position:</td></tr>
<tr><td colspan="4">Email:</td></tr>
</table>

The Port Environmental Index (PEI)

The Port Environmental Index (PEI) is a composite index developed in the context of the PIXEL project, aiming to cover the lack of a standardised evidence-based and quantitative measure of port environmental performance. The current estimate methods of the port's environmental impacts are not homogeneous and they don't allow for addressing trends in environmental performance nor interport comparisons. PEI may serve as basis for monitoring the environmental progress of a port and comparisons against a benchmark. Furthermore, PEI may assist port management by providing insight into ports environmental issues. It also represents a tool for communication of environmental performance towards stakeholders and thus has the possibility to serve as a marketing tool.

The main idea behind the development of the Port Environmental Index PEI is based on the analysis and integration of all aspects of port processes which impact the environment. All the relevant environmental Key Performance Indicators (eKPIs) reflecting the impact of port processes on the environment will be merged into subindices and finally aggregated into one unique port environmental impact metric. Some environmental eKPIs are directly measured whereas others are obtained through proxy data.

Discussion topic 1

Problems in introducing and operating a port environmental impact measurement system

Do you currently use an environmental impact measurement system in order to calculate indicators to assess the environmental performance of your port? (individual indicators e.g., CO2 emissions, annual electricity consumption or composite indicators like PEI):

Yes ☐ / No ☐

If yes:

1. Which where the problems (if any) you encountered during the installation of the environmental impact measurement system you currently use?

Answer:

2. What are the problems (if any) you have in using your environmental impact measurement system on a day-to-day basis?

Answer:

If no:

1. In your opinion, what are the reasons that your port is not having an environmental impact measurement system today (in terms of internal matters of your port and also the characteristics of the system)?

Answer:

2. In your opinion, which would be the preconditions in order to install an environmental impact measurement system (in terms of internal matters of your port and also the characteristics of the system)?

Answer:

Discussion topic 2

Implementation of a port environmental impact measurement system for calculating a composite indicator

Would you consider installing a composite indicator like PEI?

Yes ☐/ No ☐

If yes:

1. What do you believe that are the main benefits (or disadvantages) of using a composite indicator instead of individual indicators?

Answer:

2. What possible problems (if any) do you believe that you may encounter during the installation of the environmental impact measurement system of a composite index like PEI?

Answer:

If no:

What are the main reasons which prohibit you today from implementing a system for calculating a composite indicator like PEI?

Answer:

Appendix C
List of reports used for the content analysis

Port of Antwerp (2018) Sustainability Report 2017

Port of Rijeka (2015) Semi-Annual Environmental Report 2015

Port of Aalborg (2017) Environmental key figures 2016

Port of Esbjerg (2017) Environmental Profile Report 2016

Port of Odense (2015) Environmental Report 2013-2014

Port of Ronne (2018) Corporate Social Responsibility Report 2017

Ports of Copenhagen-Malmo (2018) Sustainability Report 2017

Port of Tallin (2019) Annual Report 2018

Port of Pori (2019) Sustainability Report 2018

Port of Turku (2019) Environmental Report 2018

Port of Nantes St. Nazaire (2019) Annual & Corporate Social Responsibility Report 2018

Ports of Boulogne-Calais (2015) Environmental Report 2014

Port of Hamburg (2017) Sustainability Report 2015-2016

Ports of Bremen-Bremerhaven (2017) Sustainability Report 2016

Ports of Niedersachsen (2019) Sustainability Report 2018

Port of Dublin (2018) Sustainability Report 2017

Port of Savona-Vado (2015) Sustainability Report 2014

Port of Trieste (2015) Environmental Report 2014

Port of Riga (2016) Environmental Report 2015

Port of Klaipeda Environmental monitoring (online) https://www.portofklaipeda.lt/oro-tarsos-monitoringas

Port of Amsterdam (2019) Annual Report 2018

Port of Den Helder (2017) Environmental Report 2015-2017

Port of Moerdijk (2018) Environmental Report 2017

Port of Rotterdam (2019) Annual Report 2018

Port of Gdynia (2019) Corporate Social Responsibility Report 2018

Port of Aveiro (2019) Sustainability Report 2018

Port of Leixoes (2018) Sustainability Report 2017

Port of Lisbon (2009) Sustainability Report 2008

Port of Setubal (2012) Sustainability Report 2011

Port of Sines-Portimao (2018) Sustainability Report 2017

Port of Koper (2019) Sustainability Report 2018

Port of Gothenburg (2019) Sustainability Report 2018

Port of Helsingborg (2019) Annual Report 2018

Port of Trelleborg (2019) Environmental Report 2018

Ports of Stockholm (2018) Annual & Sustainability Report 2017

Port of A Coruna (2018) Sustainability Report 2017

Port of Algeciras (2018) Sustainability Report 2017

Port of Alicante (2015) Sustainability Report 2014

Port of Aviles (2018) Sustainability Report 2017

Port of Barcelona (2018) Sustainability Report 2017

Port of Bilbao Sustainability Report 2017 (online) https://www.bilbaoport.eus/en/corporate-social-responsibility-csr/green-commitment/sustainability-report/

Port of Cadiz (2019) Sustainability Report 2018

Port of Cartagena (2018) Sustainability Report 2017

Port of Castello (2018) Sustainability Report 2017

Port of Ceuta (2018) Sustainability Report 2017

Port of Gijon (2018) Sustainability Report 2017

Port of Huelva (2017) Sustainability Report 2016

Port of Melilla (2018) Sustainability Report 2017

Port of Motril (2018) Sustainability Report 2017

Port of Santander (2012) Sustainability Report 2011

Port of Sevilla (2015) Sustainability Report 2014

Port of Tarragona (2018) Sustainability Report 2017

Port of Vigo (2018) Sustainability Report 2017

Ports of Authority of Almeria (2018) Sustainability Report 2017

Ports Authority of Ferrol-San Cibrao (2018) Sustainability Report 2017

Port Authority of Baleares (2018) Sustainability Report 2017

Port Authority of las Palmas (2018) Sustainability Report 2017

Port Authority of Santa Cruz de Tenerife (2018) Sustainability Report 2018

Port Authority of Valencia (2018) Environmental Statement 2017

Port of Aberdeen (2019) Annual Review 2018

Port of Dover (2019) Environmental Report 2018

Port of Felixstowe (2018) Environmental Report 2017

Port of London (2018) Annual Report 2017