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Title: **Method for the objective assessment of sustainability in port handling facilities**

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Subject: **Method for the objective assessment of sustainability in port handling facilities**

Sustainability is a rapidly growing topic and impacting many industries nowadays. This also includes the port sector. In contrast to other sectors, ports are faced with environmental issues for air, water and soil. For this reason port operations are closely watched by governments and environmental organizations. They are faced with a continuous pressure on lowering their environmental impact.

In the last decade the concern about sustainable designs has been spread towards many design activities. Various ports have taken different approaches and measures to operate in a more sustainable way. Because of this, there are no clear definitions for a port how to evaluate their efforts, both in lowering their environmental impact and to achieve a certain level of sustainability. Unfortunately, but understandably, there is also not yet one generally accepted method for the assessment (calculation) of sustainability.

The assignment is to study literature on this topic and to come up with a method that could be used as a general method for the assessment of the degree of sustainability. Prior to the assessment method a research should provide insight in what sustainability means for the port sector, what efforts already have been taken and what regulations are applicable for port operations. The assessment method should be based on calculation with parameters that can be verified or derived from generally known material/process/equipment characteristics.

The report should comply with the guidelines of the section. Details can be found on the website.

The professor,

Prof. Ir. J.C. Rijsenbrij

Contents

Nomenclature

The abbreviations as listed here are used or referred to in the report.

AAPA	American Association of Port Authorities
AMP	Alternative Maritime Power
BCA	Building and Constructing Authority
BEV	Battery Electric Vehicle
$CO_{(2)}$	Carbon (di)Oxide
dB	Decibel
CCS	Carbon Capture and Storage
CDM	Clean Development Mechanism
CNG	Compressed Natural Gas
CSI	Clean Shipping Index
CSR	Corporate Sustainable Responsibility
DPF	Diesel Particulate Filter
DPM	Diesel Particulate Matter
ECOSLC	ECO Sustainable Logistic Chain
EIA	Environmental Impact Assessment (Dutch version: see MER)
EMS	Environmental Management System
ESPO	European Sea Ports Organization
EC	European Commission
ECA	Emission Control Area
EMAS	Eco-Management and Audit Scheme
EOP	Environmental Operating Practices (used by USACE)
EPA	Environmental Protection Agency (US)
EPI	Environmental Performance Indicator
EPP	Environmental Preferable Purchasing / Procurement
ESI	Environmental Ship Index
EU	European Uniun
FCEV	Fuel Cell Electric Vehicle
GHG	GreenHouse Gases
GRI	Global Reporting Initiative
HC	HydroCarbon
HDV	Heavy-Duty Vehicle
HEV	Hybrid Electric Vehicle
IAPH	International Association of Ports and Harbors
ICEV	Internal Combustion Engine Vehicle
IMO	International Maritime Organization
ISO	International Organization for Standardization
LCA	Life Cycle Analysis
LDV	Light-Duty Vehicle
LEED	Leadership in Energy and Environmental Design
LNG	Liquid Natural Gas
LPG	Liquid Petroleum Gas
LSD	Low Sulphur Diesel
NAAQS	National Ambient Air Quality Standard (US)
NEC	National Emission Ceiling
MER	Milieu Effecten Rapportage (International version: see EIA)
NOx	Oxides of Nitrogen
NRMM	Non-Road Mobile Machinery
O3	Ozone
KPI	Key Performance Indicator
PAH	Poly Aromatic Hydrocarbons
PCB	Printed Circuit Board
PDCA	Plan, Do, Check, Act (-cycle)
PERS	Port Environmental Review System

PHEV	Plug-in Hybrid Electric Vehicle
PM	Particulate Matter
PPCAC	Pacific Ports Clean Air Collaborative
PPRISM	Port Performance Indicators: Selection and Measurement
REE	Rare Earth Element
RMG	Rail Mounted Gantry crane
Ro-Ro	Roll-On Roll-Off (vessel)
ROI	Return On Investment
RTG	Rubber Tired Gantry crane
SDM	Self Diagnosis Method
SECA	Sulphur Emission Control Area
SOx	Oxides of Sulphur
SPL	Sound Pressure Level (in dB)
SPPSDM	Sustainable Port Policy Self Diagnosis Method
TEU	Twenty-feet Equivalent Unit
ULSD	Ultra-Low Sulphur Diesel
USACE	United States Corps of Engineers
VOC	Volatile Organic Compound
WHO	World Health Organization

Summary

Sustainability is a rapidly growing topic and impacting many industries nowadays. This also includes the port sector. Which is faced, in contrast to other sectors, with environmental issues for air, soil and water. Sustainability in the port area means that every effort has to be taken to eliminate the use of non-renewable natural resources and for protection of the environment, both direct and indirect. But sustainability means more than reducing emissions alone.

This report aims to provide insight in what sustainability exactly means for the port sector, what measures have been taken by ports around the world to lower their environmental impact, how ports have achieved a certain level of sustainability and how this is presented to (local) stakeholders as the local community. The report contains a 'Proposed Assessment Method' that is based on the state-of-the-art 'best practices' on sustainability taken by ports around the world. An extensive list of these items has been included in the Appendix (Appendix 6). The first chapter gives a description of 'sustainability in the port sector', the assignment and base of this research.

The second chapter discusses the environmental organizations that are related to the port sector. The work of the European Sea Ports Organization (ESPO) has been studied. They have provided two important 'environmental review programs'. The 'Self Diagnosis Method' (SDM) is a first basis of ports to check their environmental risks and helps to establish port-specific environmental priorities. The Port Environmental Review System' (PERS) is a more comprehensive tool that is designed to help implementing environmental measures as proposed by ESPO. The most complete environmental management tools for the ports are the 'Eco-Management and Audit Scheme' (EMAS) and ISO 14001. Both tools are internationally recognized and a port can apply for an independent certification. A noteworthy project is PPRISM (Port Performance Indicators: Selection and Measurement'). This project was intended to measure the environmental performance of ports with some key indicators. During the project 125 indicators were proposed of which merely 7 were considered as 'relevant and feasible'. The outcome of this project indicates that measuring 'environmental performance' between ports has many implications and direct comparison on a 'degree of sustainability' is difficult, and can only be done on a generic (basic) and limited scale.

For this project the top environmental priorities of ports have been studied. It turns out that they have continuously changed during the last 15 years, and likely will change in the future. Priorities as 'noise' and 'air quality' have become top priority items that were of less importance years ago. It stresses that a state-of-the-art definition of sustainability today is likely to be outdated in the future. For that reason it is important to continuously check what issues have importance. As well noteworthy is the item 'garbage and waste', which is a concern for smaller and larger ports. Small ports are faced with smaller quantities and might have problems with a proper treatment, while larger ports are faced with regulatory problems due to the large amounts of waste they generate. They have to take extensive measures for proper collection and treatment. The key priorities as emissions (to air, water, soil, noise and light), energy-, fuel- and heat demand, material and waste, land use and local environment are discussed in Chapter 3.

The 'best practices' of ports around the world have been combined into an 'inventory list' of possible measures to achieve a lower impact on the environment. A categorization of this list, which is also used as framework for the 'Proposed Assessment Method' is presented in Chapter 4. This chapter also briefly denotes some items that require additional explanation and presents some results from measures that have been taken.

Because ports are faced with many environmental issues, they are also faced with a large amount of regulations that are set to lower the impact of operations. The fifth chapter discusses the regulations that are related to air emissions, water-, noise and light pollution. The air emission regulations can be divided in 'National Emission Ceilings' that set a maximum to certain pollutants in kilotons per year, and 'air quality standards' that set requirements on the maximum concentrations of certain pollutants in the air in micrograms per cubic meter. Engines in on-road and non-road applications are restricted

to regulations as well. These are also presented. The EURO V and TIER III standard are currently into force (2012). In the forthcoming years the tighter EURO VI and TIER IV standards will be gradually put into force. These standards oblige lower emissions per kWh. The Chapter is concluded with information on carbon dioxide regulations, which is, for the transportation sector, very scattered. For shipping, for example, there is no global approach in regulating carbon dioxide emissions up to today. This in contrast with sulphur content in marine fuels, which have to be decreased from 1,5% to 0,5% as of 2020.

The 'Proposed Assessment Method' is presented in Chapter 6. This chapter includes some limitations of measuring in general and provides some examples of calculating emissions and fuel consumption. The assessment itself contains 14 sections, majorly based on 'polluting sources', which can be assessed on sustainability. The categorization of these 14 sections is explained and illustrated in Chapter 3. The idea of the 'Proposed Assessment Method' is that a port can check whether they have done sufficient effort on sustainability. The assessment shows what measures still could be taken to lower the environmental impact. Just as with the 'Self Diagnosis Method' (SDM) and 'Port Environmental Review System' (PERS) by ESPO it provides direct insight how good current practice is. The assessment reflects that the best way to achieve sustainability is by lowering the environmental impact of 'pollutant sources'. This is a contrast of the 'conventional' approach of taking all kinds of 'preventive measures' to lower the environmental issues that are caused by these 'pollutant sources'.

A 'Quick Scan' (shortened) Assessment Method is provided at the end of Chapter 6, it uses 22 items from the general 'Proposed Assessment Method', and describes port sustainability in a large degree. It is based on the 'Pareto Principle', which means that 20% of the items in the general 'Proposed Assessment Method' describe 80% of the sustainability in a port. The shortened 'Proposed Assessment Method' can be used as first basis to check port sustainability, before 'diving into details' of the general version.

The report is concluded with a brief view on the research results, developments and opportunities of sustainability in the port sector. Some recommendations for further research are proposed.

Special thanks to Prof. Ir. J.C. Rijsenbrij for providing this literature assignment and support. And to Ir. C. Klaver, Port of Rotterdam (Havenbedrijf Rotterdam), for the interview about sustainability in the Port of Rotterdam at Maasvlakte II and sharing his thoughts on possibilities for sustainability in the port sector.

M.J. de Vries

1. Sustainability

1.1 Introduction

Sustainability is a rapidly growing topic and impacting many industries nowadays. In general, sustainability is about continuing current business while protecting and sustaining human and natural resources. The original statement dates from 1984 and in the meantime the description of sustainability is presented in many different ways. And so does the implementation of it. It has a strong linkage to environmentally friendly operation by keeping the ecology and nature in mind. [27] The terms 'sustainability' and 'environmental friendly' are often interchanged. The latter does not imply the conservation of natural resources (the use of hybrid technology is environmental friendly), while the first certainly does (prevent using fossil fuels is sustainable). One could say that 'sustainability' is a subject with a long-term perspective.

'Sustainability in ports' means environmental friendly operation by having –obviously– a very limited impact on the local environment (to the water, soil and air), a strong focus on energy efficient operations and material reuse, –ideally– eliminating the use of fossil fuels and continuously monitoring the environmental performance of the port and actively take measures to lower environmental impact. Sustainability is an ongoing topic that requires a proactive approach at any time. In this way a port assures to have the lowest environmental impact as possible to secure future operation.

Depleting natural resources, as fossil fuels, and pollution of local environments were the major drivers of sustainability for many years. In the last tens of years a several things have changed. Proper uses of materials and incorporate recycling in the product development processes have become more important. Many studies have shown that materials have a finite availability, this introduced lifetime, quality, usage rates, waste-streams, reuse, recycling and many other subjects.

One of the largest changes in recent years is the increased awareness of the society. The society sets continuously higher requirements for the quality of life and expects that the industry take sufficient measures to achieve that. With harbors that is difficult. Most of the European sea harbors are located very close to metropolitan areas and have to compete with a scarce amount of space for housing, nature and recreation. [32] Not incorporating any measure of sustainability is generally not accepted. Companies that do take sufficient effort on sustainability also have a better 'image' in public, and gain business preference to other companies that do less on sustainability. Imagine a company that puts everything into effort to have a sustainable business, such a company only does business with other sustainable companies.

The question rises what it does take to be sustainable? Or when is a company performing sustainable? The answer on these questions is not very straightforward since it depends on the particular industry and individual company. When focusing on the port sector there are different types of terminals to distinguish, all with their specific pressure on the local environment. For instance: a terminal for chemicals or oils should take other environmental measures than a container terminal.

Terminals can be categorized into:

- Bulk terminals:	designed for special commodities as oil/fuels, chemicals, perishable goods, paper, dry bulk, coal, ore, LNG
- Container terminals:	specialized for export/import of cargo/containers
- Community terminals:	designed for ferries, cruise liners, roll-on-roll-off vessels

"Already for several decades, sustainability is a design aspect with (necessarily) a growing importance. Unfortunately there is not one clear definition of sustainable design." [40, p3]

1.2 Awareness in port sector

Terminals are continuously looking for cost reductions, for instance by decreased life cycle costs. For many years cost control has been dominant. [40, p2] The economic role of the port area is undeniably fundamental, but the importance of the economy is no longer absolute. It is now generally accepted that the economy, social support and ecology should be in a balanced relationship, and not be seen as separate items to focus on. [27]

The 'Environmental Code of Practice' for sustainable port development and management practice, as adopted by the European Sea Ports Organization (ESPO), has indicated that the European port sector should seek to:

- Exchange experiences of best practices on environmental issues
- Increase the awareness and integrate into the port's policies of sustainable development
- Continuous improvement of the port environment by means of 'Environmental Management System' (EMS) tools should be stimulated
- Environmental performance indicators should be measured [66]

Port managements, port tenants, research institutions, social responsible organizations, international and regional governments have agreed that ports are faced with 5 key issues: [33]

- Air quality
- Energy, CO2 and rest flows of energy
- Land utilization
- Nature conservation and development
- Water quality and management

Many ports recognize the mismatch between supply and demand of fossil energy resources, ores, water, food and minerals. They recognize a force on more efficient production, proper use of residual materials and re-use. [30] Port authorities are convinced that in today's regulatory environment a port cannot be developed or operated without proactively considering the environmental impacts a port generate. [81]

The port of Antwerp described it in their 2010-annual report as: "for the first time, policy makers are being confronted with the concept of 'finiteness' in the port planning, as a result of which the concept of 'sustainability' is rapidly gaining importance." [27] And the Port of Rotterdam as "it is recognized by companies at Maasvlakte II that operating in an energy efficient way, environmental friendly and in harmony with the environment is the only way to have an opportunity to grow in the future. [28] And that sustainability becomes more important not only from a climatic point of view, but also customers are taking this into account when choosing products and services. [30]

Figure 1: *Emissions from shipping are significant (courtesy: Port of Busan, Korea)*

1.3 Assignment description

The concern about sustainable designs has spread out towards many design activities. As part of the assignment this report aims to provide insight in what sustainability means for the port sector, what measures have been taken by ports around the world and in Europe, how ports have achieved a certain level of sustainability, how this is 'presented' or reported to stakeholders and to the local community.

The focus in this report is on how sustainability can be assessed, and if a general method could be developed to assess the sustainability in ports and their handling facilities. This assignment method will be based on absolute values (for the entire port) and relative values (in comparison to an industry average or standard). Also qualitative items from best practices will be included, which cannot be made quantitatively in all cases, but certainly help to improve 'sustainability' of port operations. The assignment method will be based on (calculation of) parameters that can be verified or derived from generally known materials/process/equipment characteristics.

1.4 Base of this research

Environmental awareness and sustainability are 'trends' in the port sector that have developed in recent years. Many ports have started an environmental program or started reporting on their environmental status within the last 5 years. Because of this recent development, different approaches can be observed. At this moment, there is no general description how good a port performs on their sustainable efforts. Also many differences are found in environmental reports on performance, making a direct comparison difficult or even impossible.

The former section explained that the aim of this report is to propose a method for assessment of sustainability in ports. To describe what sustainability means a quick scan is made of the 20 largest ports (because of their size they have a higher pressure to incorporate sustainability) and several large terminals in USA as Long Beach, Los Angeles and San Diego. From information of their websites, in magazines and environmental reports a selection will be made of best practices on sustainability in the port area. This will lead to an extensive list of measures that can be used to improve the sustainability of a port and its operations.

Together with regulations (as European Directives) and/or indicators of environmental performance that are made publicly will be estimated which actions are the most sustainable / provide the best environmental protection. In this manner criteria can be set up as benchmarks for the entire sector, rather than comparing to a port-specific annual level. Benchmarking is energy- or emission related in many industrial sectors, but there are also a lot of other factors that are only qualitatively observable (the appearance) but can help to improve sustainability as well.

This first chapter presents a general description of sustainability, the assignment and the grown awareness of the port sector. The second chapter names organizations that focus on the port sector's environment and sustainable programs that form a basis for a more sustainable organization, in this chapter is explained how certain programs can help to improve sustainability and to what level. The third chapter describes what sustainability in the port area means and the environmental issues that are present. The fourth chapter summarizes the best practices of sustainability that ports have reported on. Also a categorization for the best practices and 'Proposed Assessment Method' will be presented. The fifth chapter appoints applicable legislation around main topics of sustainability, which potentially can be used as framework for a sustainability assessment. The sixth chapter will present the 'Proposed Assessment Method' based on quantitative and qualitative items found from the best practices ports have taken on sustainability (as presented in Chapter 5 and in Appendix 6). The report is concluded with a view on current regulatory problems for sustainability, recommendations for further research and a conclusion of the work provided in this literature research.

> During the report some (considerable) information will be presented that might be useful for the 'Proposed Assignment Method'. If an additional note, remark, summary or conclusion is required this will be presented in these purple colored boxes. This helps as a quick scan which information might be used or not. The 'Proposed Assignment Method' will be abbreviated as 'PAM'.

2. Sustainability organizations and programs

2.1 Introduction

In many cases an organization moves towards sustainability or a more sustainable business by means of 'objectives' from a 'sustainable program'. Those objectives can be long-term perspectives or short-term actions to improve the quality of the local environment. The North Carolina Ports Authority describes it as "an effective 'sustainable environmental plan' incorporates all elements of the natural and social environment into daily planning". [82]

The Port of Long Beach in the USA states that they have already 20 years of experience in environmental protection programs, and that these are very comprehensive. They use a 'Green Port Policy' as from 2005 as guide for decision-making and framework for environmentally friendly Port operations. [84] They see themselves as a leader in environmental 'stewardship' and compliance. [84] The ports of Los Angeles and Long Beach have both implemented a program for 'clean air' and sustainability in 2006. [83] The port of 'New York & New Jersey' has expanded sustainability initiatives and environmental policy as of March 2008. [21] The port of San Diego founded their 'Green Port Program' with environmental, social and economic long-term goals in 2008. [81] The first 'sustainability report' of the port of Antwerp was published in 2010 with data from 2009, since almost all data are available for that year. [27] This stresses that incorporating 'sustainability' and reporting on 'environmental performance' is a development of recent years. For many other ports not listed here applies the same.

In this chapter will be explained which environmental organizations are of special importance for the port sector and what sustainability programs (or environmental programs) are commonly used in the port area. A 'sustainability program' is a common collective term for programs (with efforts, long- / short-term perspectives, single / continuous improvements, stakeholder engagement, commitment, reduced costs etc.) regarding the environment and/or sustainability. The programs are intended to provide environmental, social and economical benefits. Decisions in these programs are usually made on costs (investment) and the beneficial effects on the environment, on safety, on the economy and/or for port users. The ISO14001 standard is of specific importance for the port sector. It is comparable to ISO9000 but focused on environmental issues. It is discussed in section 2.4. This section also denotes other environmental review programs that help to implement an Environmental Management System (EMS) as ISO14001.

2.2 Collaborative organizations in the port sector

There are many organizations that support collaboration and the share of information between ports that are related to environmental issues and sustainability. The major organizations that operate worldwide are the 'American Association of Port Authorities' (AAPA) with 160 members in America, Mexico and Canada, the International Association of Ports and Harbors (IAPH) with 230 members worldwide and 'Pacific Ports Clean Air Collaborative' (PPCAC) with members along the Pacific Rim. In this section ESPO and EcoPorts are discussed. These organizations focus on European ports and have many programs and reports concerning the environment and more specific on sustainability. Also the 'environmental operating principles' of the United States Corps of Engineers (USACE), a federal engineering organization that has its origin in the US Army, will be discussed.

ESPO / ECOPORTS

The European Sea Ports Organization (ESPO) was founded in 1993 and represents port authorities, port associations and port administrations of seaports in the European Union. It is intended to share best practices, knowledge and experience within the port sector and between port professionals, to achieve improvement of the sector's environmental performance. [60]

Ecoports is a network of 54 collaborating ports [60] on environmental issues in the port sector. The ports associated to the Ecoports network are located in the European Union, some in Norway and in countries neighboring the European Union. The Port of Amsterdam, Netherlands joined Ecoports recently in October 2012.

To achieve improvement of performance ESPO offers tools to its member ports like the Self Diagnosis Methods (SDM) and Port Environmental Review System (PERS). The information from these systems is used to report on the sector's trends, developments and benchmarks, and give guidelines to improve environmental performance. This information is published on a yearly basis in annual reports.

Other publications of ESPO are 'best practice guides', for example 'Noise mapping and management' and 'Birds and Habitats Directives'. Most recently, in October 2012, ESPO has published a new 'Green Guide' that will replace the last version from 2003. This guides ports with a clear vision, best practice examples and highlights environmental challenges and common approaches to sustainability. Secondly the Green Guide informs on legislation that influences the European Ports.

Both annual reports with sector's information and Green Guides are made publicly available through their website.

ECOSLC

One of the major activities of ECOSLC (ECO Sustainable Logistic Chain) is the development, promotion and implementation of tools and methodologies for the Port Environmental Management System (PERS) developed by Ecoports. These tools collect and exchange practical know-how and good practices between port communities.

USACE

The United States Army Corps of Engineers (USACE) is a federal engineering organization that has its origin in the US Army. The Corps fulfills military projects and missions, and infrastructure- and civil works, in- and outside the United States. Sustainability and environmental protection are their guiding principles. Their environmental programs include restoring and cleanup of degraded ecosystems as brownfields and formerly used defense sites, with a strong focus on water-related ecosystems. Also protecting environmental quality (compliance, conservation and prevention of pollution), regulating waterways (navigation), operation of dams, programs for shore protection and managing natural resources (water supply). [101] [102, p20]

They embrace 'four pillars' (compliance, conservation, prevention, restoration), as they call them, of the 'Army Environmental Strategy' since 1992. This strategy guides the Corps with managing their projects to have a maximum environmental potential. [102, p2] The strategy is listed below. Notice that also restoring previously contaminated sites is one of their priorities.

- Compliance: give immediate priority to compliance with environmental laws and regulations
- Conservation: conserving, preserving and restoring natural resources for future generations
- Prevention: focus on preventing pollution and damage to natural resources
- Restoration: restoring previously contaminated sites (for civil 'customers' of USACE)

In 2002, the Corps has introduced seven 'Environmental Operating Principles' (EOP), besides the 'four pillars', for current activities and future work based on sustainability and environmental responsibilities. The seven principles are used as guideline in all of their programs and projects in 'the earliest stage possible'. [102, p3] They represent a possible approach in activities in projects while continuously taking the environment into account. For that reason the seven principles are presented here.

1. Strive to achieve environmental sustainability (healthy, diverse and sustainable condition)
2. Proactively consider environmental consequences of programs
3. Seek balance between human development and natural systems, which support and reinforce one another

4. Accept corporate responsibility and accountability under the law for activities and solutions that impact natural systems
5. Bring systems approaches to the full life-cycle impacts (to the environment) of processes and work
6. Build and share knowledge that supports greater understanding of environment and impact of work
7. Respect views of groups interested in (Corps) activities, listen to them and learn from their perspective. Search for win-win solutions that also protect and enhance the environment.

From these principles, ports can learn that they should address (environmental) consequences of solutions they provide (to problems) in earlier stages in a project, rather than focusing on fixing the problem first. Also sharing knowledge and involving stakeholders is key to find more comprehensive solutions and they should learn from other perspectives by involvement and collaboration with stakeholders. At least, the environmental impact of the total life cycle of systems should be considered, instead of focusing on current environmental impacts.

In the 'nomenclature' a summary of environmental organizations and management systems has been included.

2.3 Sustainable development

Sustainability is strongly linked to and often described as 'sustainable development' [83], a concept developed in 1992 [41, p9] covering Social-, Environmental- and Economical responsibility. Sometimes 'Politics' is included as separate aspect. Later the concept was named as 'People, Planet and Profit'. Many sectors have used this concept to implement sustainability in their daily practice.

For the port sector it means that: [84]
- Environmental responsibility covers items as air quality improvements, energy and fuel efficiency improvements, ecological health, and other items that improve the quality of the local environment
- Economical responsibility covers items as continuing / maintaining port's operations
- Social responsibility covers items as stakeholder and employee engagement, job creation, job enrichment, quality work environment, human health, etc.

The three items of 'sustainable development' should all have been considered, balanced and mutually reinforcing. [83] The use of the 'sustainable development' is a more-or-less voluntary commitment. The exact interpretation of this program differs from company to company, whereby different environmental improvements can be taken and included. Unfortunately, there is no such criteria as 'doing well' of 'doing moderately' on 'sustainable development'. With this concept the first question companies ask themself is "what can we do on sustainable development" rather than "what does it take to reach a certain level of sustainability".

> 'Sustainable development' does not contain a 'level of conformity' in the concept itself. The implementation (and content) of 'sustainable development' is voluntary. Some items that are quantitatively measureable are included in the 'Proposed Assessment Method'.

2.4 Environmental Review Programs

A more comprehensive 'environmental program' is the incorporation of a review system. These programs have a fixed framework to which a company can assess themselves. These reviews will in-/directly show how well a company performs on environmental issues and which actions should be taken to perform better. It will assure that operation, products and services are aligned with the corporate environmental policy. And minimize adverse environmental aspects and impacts, and ensure an ongoing commitment to regulatory compliance. [15]

A first basis, according to ESPO [60], is to perform the Self Diagnosis Method (SDM). After this preliminary diagnosis a port can identify environmental aspects and perform a Port Environmental Management System (PERS). This will help as guideline to implement a basic 'Environmental Management System' (EMS). The ultimate aim is to implement an 'Environmental Management System' (EMS) as ISO14001 or Eco-Management and Audit Scheme (EMAS) which are both international recognized standards and certifications.

2.4.1 SDM

The 'Self Diagnosis Method' (SDM) is developed by ESPO together with port managers. It is a method for 'identifying environmental risk' and establishing priorities for action and compliance by regularly review environmental performance in a port. It is basically a first step towards an Environmental Management System (EMS). It helps to identify the current environmental situation and priorities, to assess new plans for port developments and assists in setting-up an environmental reporting system. Many large ports associated with ESPO use SDM. [45]

SDM is based upon a checklist in form of a questionnaire developed with port managers. After completing the SDM the port manager receives immediate results from the checklist: a summary and GAP analysis (gap between current performance and environmental friendly perfromance). From this GAP analysis already can be seen how the current management and international standards requirements from EMAS for example deviate. [45]

The SDM checklist can be submitted to Ecoports for analysis, after which Ecoports will send back a benchmark, SWOT analysis and recommendations. The SWOT-analysis shows the weaknesses in the current management and shows opportunities to improve, helping to identify the environmental priorities. The threats give information on legal changes concerning the environment.

A recent addition is Sustainable Port Policy Self Diagnosis Method (SPP SDM), which is focusing on environmental policies rather than environmental management. This is more suitable for smaller ports. [60]

> SDM is a self-assessment tool. Some items from the checklist of SDM and the application of SDM are included in the 'Proposed Assessment Method'.

2.4.2 PERS

'Port Environmental Review System' is developed by ESPO as well. It is a tool primarily designed to assist ports to implement the recommendations set in the ESPO Environmental Review of 2001 and 2010. [61]

Distinct from other Environmental Review Systems, PERS is suited for the Port's specific environments. Based on professional best practices that are recognized internationally by the port sector. The system includes general requirements of recognized standards as ISO 14001, but is more 'adapted' to the specific port environment. The general environmental topics of ISO 14001 are not always sufficient to cover the port area environment. It incorporates topics of sustainable development, and helps to achieve port specific goals set by this method.
According to ESPO, this review system is 'custom made' and a vital approach for the "highly specific nature of environmental challenges in port areas". [60]. Secondly this system can help to describe an environmental policy statement and help to set up an environmental management organization.

A port that complies with PERS can apply for an independent assessment by Lloyd's Register (an classification society that has contributed to the development of PERS). When the review of the port's PERS report is positive, the port will receive a 'PERS certificate of verification'. [44]

> PERS is a self-assessment tool using global best practices. Some items from the checklist of PERS and the application of PERS are included in the 'Proposed Assessment Method'.

2.4.3 PPRISM

'Port Performance Indicators: Selection and Measurement' (PPRISM), started as a European Commission funded project in February 2010 until 2012 and strived to establish a culture of performance measurement specifically for European ports. The aim of the project was to identify a set of performance indicators that are relevant especially for the port sector, since up to then no general accepted set of indicators have been set up to measure performance.

The project was intended to set up an approach for impact measurement of the European port system as well as defining the relevant indicators to monitor performance. Secondly it could potentially be used as a self-assessment tool for individual port's performance. Both ESPO members (ports) and relevant stakeholders were involved.

The Environmental Performance Indicators (EPI's) are of particular interest for this research. The initial list contained 125 indicators that were reduced during four stages to 7 indicators that are relevant and feasible: [62]

- Total energy consumed
- Carbon footprint
- Total water consumption
- Amount of waste
- The use of Environmental Management System (EMS)
- Existence of Aspects inventory
- Existence of monitoring program

All 125 initial indicators have been considered, together with the 7 final 'relevant and feasible indicators'. Some of these indicators are easily quantitatively measureable and generic for ports. These are used in the 'Proposed Assessment Method'.

2.4.4 ISO 14001

ISO 14001 is a worldwide recognized and encouraged standard to set-up and certificate an Environmental Management System (EMS). It helps any kind of organization to develop and implement a policy and objectives that helps to manage the impact of activities on the environment. It concerns compliance with applicable laws and the management of environmental risks, and continuous search for improvement of the environmental performance. It has a strong connection with ISO 9001, a worldwide-accepted standard for quality requirements. [63]

ISO 14001 itself does not state specific environmental performance criteria. As many ISO standards, the ISO 14000 series incorporates a PDCA-cycle (Plan, Do, Check, Act). ISO 14001 focuses on 'Planning' the Environmental Management System. It systematically indicates which laws and regulations that are applicable for the organization and monitors the company's compliance.

The port of Los Angeles was ISO 14001 certified in 2007. Continual environmental improvements were achieved through the use of a PDCA-model (Plan, Do, Check, Act). Upward of 2007 there have been measurable improvements in recycling, minimizing hazardous waste streams, pollution activities and improved environmental awareness and compliance. [83]

The content of ISO14001 is not 'fixed' and does not contain specific environmental criteria. Only the application of ISO14001 will be assessed in the 'Proposed Assessment Method'.

2.4.5 EMAS

Eco-Management and Audit Scheme (EMAS) is a management tool for companies and organizations to evaluate, report and improve their environmental performance. It provides a framework for measurement and evaluation of environmental performance against objectives and targets. On top of ISO 14001 the employee involvement is more extensive, the environmental core indicators allow to be compared between organizations and the communication to the public is more transparent. [48]

This environmental program was originally restricted to industrial sectors as of 1995, but has undergone a first revisit in 2001 to open it up for economic sectors and have seen a secondary revision in 2009 (European Regulation 1221/2009 EC) which came into force as of January 2010. [64]

As with ISO14001 only the application of EMAS will be assessed in the 'Proposed Assessment Method'.

2.5 Commitment of European ports

According to the recent 'Green Guide' of ESPO around 91% of the European ports had applied an Environmental Policy in 2012. This number was 72% in 2009, 58% in 2004 and a little 45% in 1996. The European ports that have an Environmental Management System (EMS) implemented are 62% in 2012 and were 21% in 2004. [38]

85% of the European ports have made their policy available to the public, but only 73% report on their environmental performance, this is a noticeable increase with 31% in 2004. This means that there is improvement in reporting on environmental performance and this is recent practice. From other numbers listed in the 'Green Guide' of EPSO indicates that environmental awareness in the European port sector is developing, but still 9% of the European ports do not have an Environmental Policy and 38% doesn't report on environmental performance to their local community. [38]

> The difficulty is that many ports have put their sustainable efforts / actions into an own developed 'program' (port specific program) that cannot be easily compared to programs of other ports. To assess the content of such programs is a tremendous amount of work. For that reason, and convenience, it should be better to judge the outcomes of the various programs as separate 'sustainable actions' that have been taken or as the result in 'performance', regardless of the program it is in involved. This is what has been done in the 'Proposed Assessment Method'.
>
> The environmental programs as SDM, PERS, EMS, ISO14001 and EMAS are assessed for their presence in a port area, ordered upwards in terms of comprehensiveness. This is an indication that a serious policy and 'action plan' is developed for sustainability.

3. Sustainability in port area

3.1 Port information

The World Shipping Council has published a list of the 50 world's largest container ports based on their throughput in million TEUs. [65] The top 10 lists six ports that are located in China. Amongst these are the Ports of Shanghai, Hong Kong and Shenzhen. Surprisingly the information on sustainable programs and efforts of the top 10 ports is limited, although they put substantial effort in these programs. The difficulty is that not all information is available in the English language. In this way much potential useful information and best practices are not available for interested readers. Nevertheless, some ports do have extensive information on sustainability and document it very well.

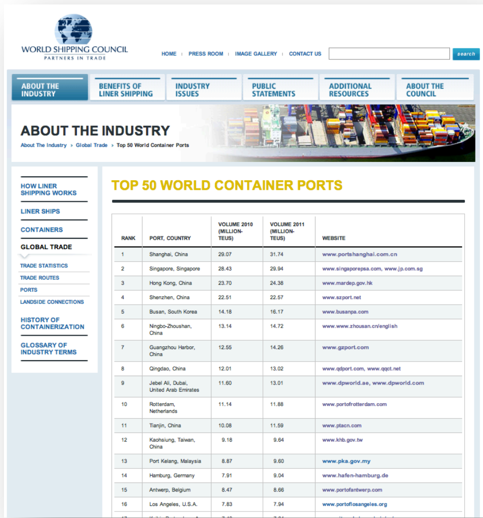
Fifteen ports that are highest in rank have been investigated on environmental programs, performance and practices, since large ports have a higher pressure from governments and society to lower their environmental impact. Also ports at the West- and East cost in the United States have been studied, especially those located at the West coast in the state California, where they have high standards on environmental protection. Also larger ports in the Netherlands and neighboring countries have been studied as well. The ports that have been extensively studied on environmental- and sustainable practices are:

Worldwide
- Port of Shanghai, China (ranked 1st)
- Port of Singapore, Singapore (ranked 2nd)
- Port of Hong Kong, China (ranked 3rd)
- Sidney Ports, Australia

Europe
- Port of Rotterdam, The Netherlands (ranked 10th)
- Port of Antwerp, Belgium (ranked 15th)
- Hamburg Port, Germany (ranked 14th)
- Bremen Ports, Germany (ranked 22nd)
- Port of Gothenburg, Sweden

USA West Coast (California)
- Port of Long Beach (POLA), USA (ranked 21st)
- Port of Los Angeles, USA (ranked 16th)
- Port of San Diego, USA

USA East Coast
- Port of New York & New Jersey, USA (ranked 25th)
- North Carolina Ports (NC Ports), USA
- Georgia Ports, USA (ranked 44th)



RANK	PORT, COUNTRY	VOLUME 2010 (MILLION-TEUS)	VOLUME 2011 (MILLION-TEUS)	WEBSITE
1	Shanghai, China	29.07	31.74	www.portshanghai.com.cn
2	Singapore, Singapore	28.43	29.94	www.singaporepsa.com, www.jp.com.sg
3	Hong Kong, China	23.70	24.38	www.mardep.gov.hk
4	Shenzhen, China	22.51	22.57	www.szport.net
5	Busan, South Korea	14.18	16.17	www.busanpa.com
6	Ningbo-Zhoushan, China	13.14	14.72	www.www.zhousan.cn/english
7	Guangzhou Harbor, China	12.55	14.26	www.gzport.com
8	Qingdao, China	12.01	13.02	www.qdport.com, www.qqct.net
9	Jebel Ali, Dubai, United Arab Emirates	11.60	13.01	www.dpworld.ae, www.dpworld.com
10	Rotterdam, Netherlands	11.14	11.88	www.portofrotterdam.com
11	Tianjin, China	10.08	11.59	www.ptacn.com
12	Kaohsiung, Taiwan, China	9.18	9.64	www.khb.gov.tw
13	Port Kelang, Malaysia	8.87	9.60	www.pka.gov.my
14	Hamburg, Germany	7.91	9.04	www.hafen-hamburg.de
15	Antwerp, Belgium	8.47	8.66	www.portofantwerp.com
16	Los Angeles, U.S.A.	7.83	7.94	www.portoflosangeles.org

For this report also European ports that are associated with ESPO are studied. By sharing their knowledge and environmental good practices, other ports can be encouraged by taking over measures, programs or initiatives. Most of the practices that are documented are meant to exemplify current actions. The implementation is mostly based on encouragement and engagement rather than enforcement. [38]

3.2 Environmental issues in port area

Many stakeholders of the port sector and related industries are concerned with sustainability:
Governments and Authorities, Politicians, Associated organizations, NGOs, Trade unions, Transport industry, Shipping lines, Shipping related companies, Associated industry, Business partners, Railroad companies, Truckers, Municipalities, City of location, Port authorities, Port tenants (terminal operators), Employees, Local community, General public, etc. [89]

First of all, different types of terminals have different equipment and sustainability issues. A container terminal has to implement other measures to protect the environment as a chemical terminal. But all

terminals have environmental impacts. The review report [37] by ESPO shows that environmental issues (categorized by European ports to their priority) have changed over time. Items that were considered important in 1996 were 'water quality' and 'port development'. Items as 'noise', 'air quality' and 'waste' have been introduced in the top 10 and are considered as the most important items anno 2009. The top 10 items are shown in the table below. The colors mark new items that were being introduced in 2004 and/or 2009 as top priority items.
The change of importance over time also implies that sustainability issues that are important nowadays are likely to change in importance in, let's say, 5 or 10 years. An excellent example is acid rain, which was a major concern in the eighties. Due to measures from local governments and the European Union the 'emissions of oxides of sulphur from transportation and industry' (which was the major cause of acid rain) has been decreased significantly (e.g. by about 90% in The Netherlands). [53] The acidity of rain has lowered since 30 years ago, and the 'priority' of acidification has gained less importance. This is likely to happen with other environmental items as well that have a top priority today. Predictions which items it may concern are very uncertain.

	1996	2004	2009
1	Port development (water)	Garbage / waste	Noise
2	Water quality	Dredging operations	Air quality
3	Dredging disposal	Dredging disposal	Garbage / waste
4	Dredging operations	Dust	Dredging operations
5	Dust	Noise	Dredging disposal
6	Port development (land)	Air Quality	Relation with local community
7	Contaminated land	Hazardous cargo	Energy consumption
8	Habitats loss/ degradation	Bunkering	Dust
9	Traffic volume	Port development (land)	Port development (water)
10	Industrial effluent	Ship discharge	Port development (land)

Table 1: *Environmental priorities of European ports, source: ESPO, February 2010* [37]

When the top environmental issues are categorized to port size (2009-data), as shown in the table below, a several things can be observed. First a growing throughput increases the priority of 'air quality' and 'noise'. A noteworthy item is 'garbage/waste' that covers the most important priority for smaller ports, but also is important again for larger ports. [37] Possibly, the 'economy of scale' (for smaller ports) and 'diseconomy of scale[1]' (manageability for larger ports) has an influence on these scores. Smaller ports may have difficulties with certain waste streams since they are relatively small (e.g. small quantities of hazardous waste), while larger ports are faced with problems rising from large amounts of waste (extra fees, required pre-treatment, limiting measures obliged by regulations, measures to reduce large amounts of toxic waste, etc.). 'Energy consumption' is also a new top priority item as of 2009, but this depends on the type of equipment a port uses and the type of port itself. A chemical plant and/or refineries in a port area are the biggest energy consumers. [27]

[1] *'Diseconomy of scale' means growing costs or other cost-related problems due to a increased size of production/manufacturing/throughput, etc. It appears when a company does not lower costs (diseconomy) by increasing their production/manufacturing/throughput (scale).*

	< 1 million tons	1-10 million tons	10-25 million tons	> 25 million tons
1	Garbage / waste	Dredging operations	Air quality	Air quality
2	Noise	Air quality	Port development	Noise
3	Dredging disposal	Energy consumption	Noise	Garbage / waste
4	Dredging operations	Noise	Dust	Dredging operations
5	Energy consumption	Dust	Local community	Port development

Table 2: *Environmental priorities of European ports by port size, source: ESPO, February 2010* [37]

In general, the emission to air is seen as the most significant item of 'sustainability'. This is not surprising since various substances that are emitted to the air, regardless of the source, influences both human health and local environment. The emission of greenhouse gases (GHG) has gained a lot of publicity in the last 15-20 years. The Kyoto protocol, ('Al Gore's') theories on global warming and many other sources have lead to growing awareness of the society, companies and governments of this particular substance. Many companies like car manufacturers, of household appliances, of electronics and (some) industrial companies proactively communicate about GHG reductions, energy labels and their 'carbon footprint'. For this reason some of the numbers presented in [37] are remarkable. It turns out that 'merely' 33% of the European ports measure or estimate their carbon footprint, and 51% take measures to reduce their carbon footprint. 57% of the European ports have a program to increase energy efficiency. (2009-data) [37] This also stresses that incorporating an Environmental Policy or -program (72% of the European ports had an Environmental Policy in 2009, see section 2.5), does not necessarily implies that GHG are measured or reduced.

The top 10 indicates the priority of the environmental issues in ports. The entire top 10 issues (from 2009 and years before) are included in the 'Proposed Assessment Method'. The reason for also including 'older' priorities is that while they might have gained less importance, they still define a sustainable operation!

3.2.1 Emissions to air, water, soil, noise, light

One of the main items sustainability is concerned with is emission to the atmosphere, into the water, into the soil, as noise or as light. Emissions to the atmosphere have gained a lot of attention in recent tens of years. With increased awareness of the society this has lead to stricter regulations on one hand and lower acceptance to 'pollution' on the other hand.

The baseline emissions of industrial and transportation sources, as recognized by the industry, international environmental organizations and governments are: carbon dioxide (CO_2), oxides of nitrogen (NOx), oxides of sulfur (SOx), carbon monoxide (CO), Hydrocarbons (HC), Particulate matter less than 10 microns in diameter (PM10) and less than 2.5 microns in diameter (PM2.5), diesel particulate matter (DPM), poly aromatic hydrocarbons (PAHs) and volatile organic compounds (VOCs). These emissions individually or combined lead to local problems as acidification (acid rain) and eutrophication (water pollution) and cause health hazards as respiratory diseases and lead to global problems by the increase of greenhouse gases (problem of global warming). Emissions sources are direct (vehicle fleet of port, dust from bulk sources, buildings, etc.), indirect (from purchased electricity) and from tenants (shipping lines, truckers, railroad companies, buildings, etc.).

Figure 2: Excessive ship emissions to air

Besides emissions to air, the industry also emits hazardous substances to the water and soil in such quantities that it forms local environmental problems. Examples are oils or fuels, heavy metals, chemicals, etc. that contaminate soil and water. The Water Framework Directive (2000/60/EC) describes hazardous substances as "substances or groups of substances that are toxic, persistent and liable to bio-accumulate, and which give rise to and equivalent level of concern". From dredging operations soil and sediment is collected that have to be treated in an environmental friendly way.

Industrial and transportation noise are emissions that affects the local community. "About 98% of industrial noise is in the 80–105 dB range, and it is estimated that 20% of all noise complaints is about industrial noise." [43, p137] High noise levels or certain frequencies can keep people out of their sleep and be very annoying for employees. In the European Union about 40% of the population is exposed to road traffic noise exceeding a sound pressure level of 55 dB(A) and 20% of levels exceeding 65 dB(A). Both sound pressure levels should be avoided. And more than 30% of the population are exposed to sound pressure levels exceeding 55 dB(A) during night causing disturbance to sleep. [43] The levels denoted 'during night' are measured at 'façade level' (which is at the wall) of residential homes. Explanation of the terms used is given in 'Appendix 4: Noise'. The regulations and allowable levels are presented in section 5.3.

Industrial noise sources are various: port services and facilities, cargo handling, warehousing, machinery, workshops, vessel repair or maintenance, shunting yards, engine noise of vessels when berthed, traffic (roads, railways), marine (vessels, barges), etc. [36]
The important characteristics for noise are: the proximity of urban areas (or other areas of special attention as habitats or tourism/recreations areas) and the intensity and concentration of the noise source. There is a significant difference between the frequency content and intensity of noise, both can affect humans, birds, small animals, etc. Only reports that focus on humans are studied here.

Light emission of the industry is a relatively recent concern since local ecology is highly affected by a disturbed circadian rhythm (24h cycle of day and night). By illumination of the port area also the surrounding environment is illuminated. Small animals and vegetation have to adapt to this different situation. Secondly a highly illuminated area in a majorly 'dark' environment is for both animals and humans a tedious source of distraction.

> Sustainability is involved in all of these emissions (air, soil, water, noise and light). By taking sufficient measures to reduce or even eliminate the emissions, a higher level of environmental protection can be achieved. Many possible measures to achieve reductions or eliminations are included in the 'Proposed Assessment Method'. A benefit is that emissions are quantitatively measureable in standardized (accepted) units.

3.2.2 Energy, Fuel, Heat

Energy use is another concern of sustainability. Since a large part of the energy is produced in coal-fired power plants, the use of energy implicates indirect emissions of substances as listed in the former section. For this reason energy should be seen as indirect fossil fuel usage. The amount of indirect emitted CO2 can be calculated for each kWh of energy consumed. Next to fossil fuels for the transport sector, it is important to reduce the use of these resources since they have limited supplies. Ideally we should eliminate the use of any fossil fuel by making use of 100% renewable energy.

Unfortunately, renewable energy as solar or wind power has a very limited share in the total energy production. By new emission ceilings set by European Union and other governmental organizations it is assumed that the share of renewable energy will increase in the future.

Heat for residential or industrial buildings and chemical sector can be generated by renewable sources as well. Many systems that provide 'heat' in form of steam use fossil fuels like compressed natural gas (CNG). But the use of geothermal heat, solar heating systems and combined heat and power plants is increasing since they all have efficiency, economical and emission benefits.

Sustainability for energy, fuel and heat means elimination of fossil fuels and the use of renewable sources for the production of energy and heat. The reduction of energy use, heat demand and fuel usage is environmentally friendly. All of these aspects are included in the 'Proposed Assessment Method'. Also applies that energy and heat are quantitatively measureable in standardized (accepted) units. The use of renewable sources is measureable as 'share of total'.

3.2.3 Material

As discussed in the introduction, material scarcity plays an increased role nowadays. For many materials, it is 'predicted' that resources will deplete within 50 years with the current increasing consumption. The concept of 'three R's': Reduce, Reuse, Recycle is applicable here.

Recycling of steel can save around 74% of energy in comparison to mining and since energy is mainly produced in coal-fired power plants it reduces air pollution by 86%. For aluminum an energy and air pollution reduction of 95% is possible. Sustainability cuts both ways here since recycling can contribute significantly to reduce air emissions and reduces the need for new (raw) materials. [51]

Materials of special concern are the Rare Earth Elements (REE's) that are frequently found in electrical appliances, electric motors, batteries and printed circuit boards (PCB's). There are a several problems with this group of special metals. At first they exist in small quantities and the concentration of these materials from mining is very small. Secondly, when applied the materials are very difficult to recover by recycling. This is due to limitations of current technology and small quantities in which they are applied. Thirdly, China is the major 'producer' (by mining them) of these materials and has limited export quota of these materials. It is assumed that they consume the larger part for their own industry however there is no sufficient proof for that. These materials are used in large quantities for electric and hybrid drives, and in batteries. One might ask if hybrid technology is 'sustainable' when the material use is considered as the most important factor.

In the search for lighter equipment to reduce the engine power installed some new materials are used that have a negative influence on the recyclability. In the aviation industry a trend is observable to use composites instead of aluminum. Also the automobile industry is taking efforts to use composites because of their low weight and high strength. The downside is that the recycling-industry currently has no profitable system to recycle composites, with the result that the majority of composites (from windmills for example) are being incinerated or landfilled. The economic focus is on the carbon- or glass fibers used, not the matrix, but currently recycling operations are not cost-efficient. Thus from an energy point of view composites are advantageous since they have a lower weight, but from material point of view the use of composites is very disadvantageous. Unfortunately, the economic factor is the decisive factor for much choices rather than the environmental impact.

Waste from ports (operations) is a new environmental priority as described in section 3.2. For example, not all ports have a good collection system for hazardous waste and do not separate their waste streams very well. There are high recycling advantages of (good) separate collection, and many materials in the port area can be reused or recycled for secondary purposes. From the recycling industry data can be gathered of recycling rates and recovery rates, both are measures for the 'recovery' of collected waste (thus how much material from the waste actually can be recovered). For separated waste streams of plastics for example, this is an indication of the 'quality' of the waste.

Material use is hard to determine exactly, especially since different ports have different needs for materials. The material consumption (demand) will be part of the assessment. There are also a lot of factors concerning 'port's waste' that can be assessed on their existence and rates. Also measures on the environmental impact of materials used for equipment can be assessed.

3.2.4 Land use and environment

A port uses land that otherwise was available for ecology. Secondly a port's operation has a significant influence on the local ecology (habitants, birds) and vulnerable environment (vegetation, sight). It is no surprise that environmental organizations and government closely watch port operations and port influences on the local environment. 'Port development' on water and land are two environmental priorities that have been very important already for many years. See also section 3.2. Governments do make agreements on nature conservation and -development, which in the view of environmental organizations never reach far enough. These agreements are often locally in force and apply to the port's environment.

How a port affects the environment in reality depends on their geographical location, habitats, vegetation and many other factors. Also the manner of operation plays an important role. It is a difficult trade-off between the ecological status at current and economical interests of the port. National regulations on environmental protection differ from country to country. In the Netherlands it is agreed with the European Commission that land reclamation can be compensated with protected areas at sea or development of protected dune areas. [32]

Another emission to the local 'ecology' is the flow of ballast water. In the North Sea and Baltic Sea every year 20 million tons is 'discarded'. This introduces creatures such as small fish, crabs, shells and microorganisms that come from other waters where the ship has loaded ballast water. These species and organisms are intruders that cause damage to the local water's ecosystem. A proposal of IMO to oblige treatment of ballast water for all vessels as from 2016 (Ballast Water Convention) is not into force because not enough nations have ratified the convention yet. [24]

Land use and local ecological impacts are very specific for an individual port. Many items that relate to both issues can only be assessed qualitatively. However the efficiency of land use, utilization of the port area, landscaping, etc. can be assessed quantitatively.

4. Best practices in port area

4.1 Categorization

The port of San Diego states that "understanding current practices and establishing baselines is critical to the development of successful conservation strategies. [81] The figure below shows the categorization that is made for the 'best practices' on sustainability based on 4 environmental issues, 6 main sources of pollution, 2 secondary sources of pollution and 2 groups of environmental policies. All groups are indicated in blue colored boxes. The categorization is based on 'sources' of pollution rather than the 'environmental issues' they cause. But some 'environmental issues' are very generic and dependent on multiple 'pollutant sources'. I.e. 'air quality' can be influenced by choices made in nearly all 'pollutant sources': vessels, equipment, energy resource, infrastructure, buildings, etc. Due to this generic nature there are 4 environmental issues selected as separate groups; air quality, waste, water and local environment.

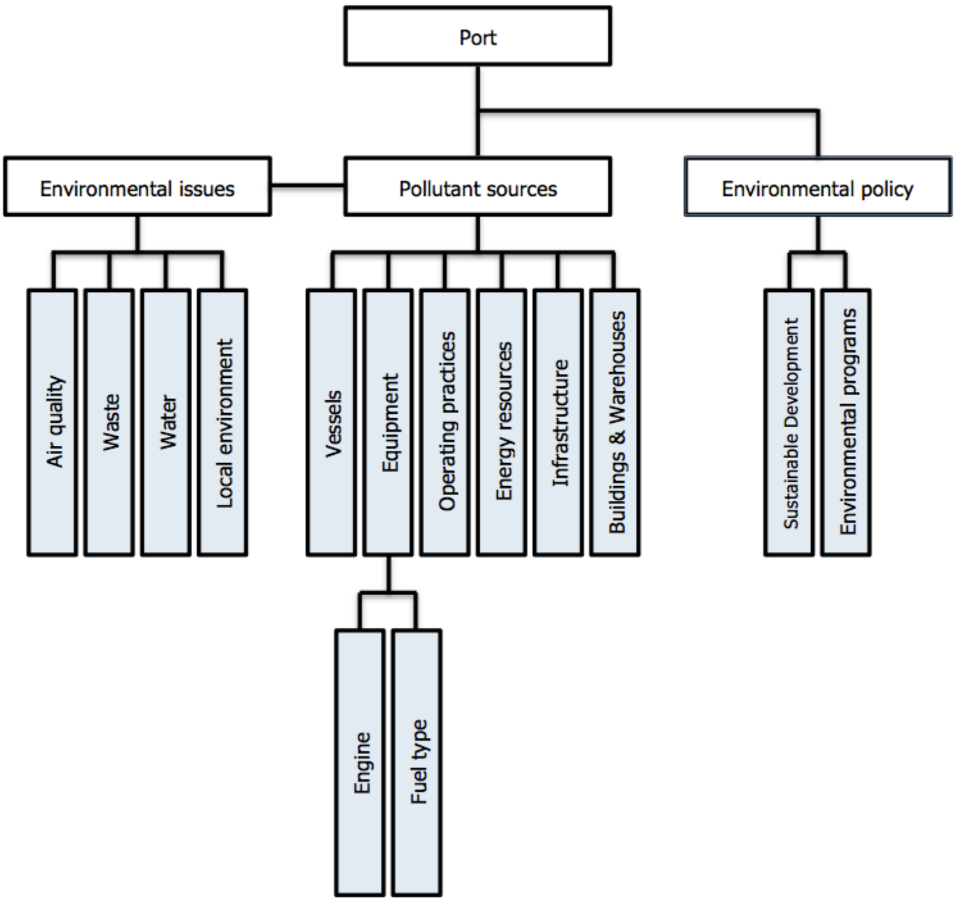


Figure 3: *Categorization of environmental aspects in ports*

Appendix 6 contains a very extensive list of 'best practices' that ports have taken on environmental issues and sustainability. The best practices have been selected from reports, magazines and websites from various ports worldwide (section 3.1 lists the ports that were studied). The categorization as proposed above should cover all aspects of sustainability, and will be the basis for the 'Proposed Assessment Method' (PAM) in chapter 6. The idea is that a port can check in which degree the 'polluting sources' are sustainable, how they perform on the more generic 'environmental themes (air quality, waste, water and local environment) and how the environmental policy help to achieve their goals.

Typical 'environmental issues' are: air, biodiversity, chemicals, Green House Gas (GHG), land use, natural resources, noise, light, soil, waste, water, energy, efficiency and policy. The issues that are not categorized in the 4 separate groups are included in the 'pollutant sources'.

Below a small part from Appendix 6 ('Best sustainability practices in the port sector') is shown. The group 'waste' is shown, this is actually an 'environmental issue' but also a 'pollution source'. The group contains items that either can be measured quantitatively or checked qualitatively on its presence (appearance) in the port area. Eventually the list will be made as quantitatively as possible and will form the basis for the 'Proposed Assessment Method' (PAM).

Aspect	Issue *(pollution)*	Quantitative (unit)	Qualitative (appearance)
Waste			
Hazardous materials surveys and removal	Waste		y/n
Chemical waste: collection points	Waste		y/n
Chemical waste: centralized storage center	Waste		y/n
Chemical waste: amount	Waste	kg / TEU	
Chemical waste: collection rate (X)	Waste	% X	
Chemical waste: treatment in port area	Waste		y/n

Table 3 *example from Appendix 6: best practices (Group: 'waste')*

Explanation: for chemical waste a port can check whether they have a collection point for chemical waste, if this point is centralized and if treatment of the chemical waste take place in the port area. The amount of chemical waste can be measured on an absolute basis (total chemical waste in tons), relative basis (amount of chemical waste per transported unit ~ TEU or tons) or in percentages as the collection rate. Blue colored items indicate absolutely measureable aspects.

For each of the groups (4 environmental issues, 8 sources of pollution and 2 groups of environmental policies) a list is composed as indicated above. Note that the table above is just a small part of the group 'waste'.

The following sections will 'highlight' best practices that ports have reported on. The aspects that are described are noteworthy, have lead to major improvements of sustainability in a port, or are extensively discussed and reported on. The sections do not completely cover the entire 'group', but are intended to help the reader to get an idea which sustainability actions can be taken. It basically describes some of the aspects as listed in Appendix 6 that require additional explanation.

> A complete list of sustainability aspects is enclosed in Appendix 6 ('Best sustainability practices in the port sector'). The categorization in 'groups' as proposed in this section will also be used for the 'Proposed Assessment Method' in Chapter 6.

4.1.1 Air quality

Air quality was the second most important 'environmental issue' in the port area in 2009 (see section 3.2). Ports take different approaches to improve the air quality in and around port areas. Some of these measures also influence the operation outside the port area. The ports of Long Beach and Los Angeles, USA have introduced a 'clean truck program'. This program allows both ports to ban trucks based on conformity to certain federal emission standards or building year. [83] Between 2009 and 2012 cleaner trucks were encouraged by a fee ($35 per TEU) to help finance truck replacement and implement this program. The Port of Rotterdam (Maasvlakte 1 and 2) also has designated an 'environmental zone' in which polluting trucks are banned. [28]

This use of the different modes of transport to the hinterland transport is called the modal split. From the different modes of transport to the hinterland available, non-road transport as inland shipping and rail transport are the least polluting. Inland shipping is beneficial since the fuel consumption per TEU and noise pollution is fairly lower in comparison with road transport. [31] From a sustainability perspective, it is important to increase the share of these environmentally friendly modes of transport. [27] This can be achieved, for example, by obligating a modal split (distribution road, rail, inland vessel) to tenants. [28] The hinterland transport system should be enabling rapid switching between rail, road and inland waterway. Intermodal hubs offer a solution. [30] The share of road transport less than 50% is preferable. [27] [28] But still trucking is a low cost and flexible mode of transport. [58, p240] Shortsea shipping, as alternative, introduces complicated port procedures and limited flexibility that has not contributed to lower the share of road transport so far. [58, p240]

Avoiding rush hour operations helps to improve air quality as well, since the emission of a truck during rush hour traffic is triple as much than at normal speed. [28] And since less congestion appears, the logistic process improves and transportation costs will lower. [31]

Greenhouse Gas emission is a concern that has a leading role in emission control and prevention. The port of Los Angeles has a very extensive program called 'Clean Air Quality Program' that involves active air quality monitoring of various substances and includes also the 'Polycyclic Aromatic Hydrocarbons' (PAHs). They state that Particulate Matter (PM) is highly varying due to the time of the year and due to weather conditions. The results of air quality are publicly available on a website. [83]

An important observation is that ports, as expected, use different 'baselines' (or benchmarks) to check emissions in a relative way. The port of Los Angeles uses a 2008-baseline to measure future strategies to lower emissions. [15] The ports of New York and New Jersey use a 2006-baseline to oblige themselves to reduce greenhouse gas emissions by 80% in 2050. [21] Some ports set a goal of zero-GHG emission from their own operations. [21] [30] Although they do not exactly report how they achieve and/or measure this.

There are two difficulties arising from these baselines. They do no indicate how 'well' the emission reduction actually is, since benchmarking to a certain standard level is not performed. Secondly a 'target reduction' (e.g. 50% greenhouse gas reduction in 2030) is very subjective since the 'baseline' is no standard level. Such targets have a very limited meaning.

Carbon Capture and Storage (CCS) is a technology in childhood to reduce emissions. The port of Rotterdam intends to capture the Greenhouse Gases from the coal-fired power plants in the port area to store it in empty gas and oil fields offshore. [30] Other applications of CCS are direct pipelines to 'greenhouse growers'. The port of Rotterdam supplies 0.3 million tons of carbon dioxide from own operations to greenhouse growers annually. [30, p107]

4.1.2 Waste

Port waste is a growing 'environmental issue' of importance. Nearly all ports that have been studied recognize that proper collection and treatment of both port and ship's waste is important and helps to reduce the environmental impact. The port of Singapore reports that the disposal rate of solid waste in the port area is over 90%, but the remaining 10% is still piled up somewhere without a proper treatment. [3] The environmental reports do not inform extensively on this topic. Some ports expand their recycling program by trying to reuse and recycle materials within the port area. The port of Los Angeles has expanded their efforts to its tenants by obligating recycling. [83]

4.1.3 Water

Water pollution is an 'environmental issue' that has a strong linkage to the local environment. It can be divided in water demand (consumption) and water pollution. Both have their negative impact on the environment.

A large source of water pollution is ballast water from ships. For environmental reasons collection and treatment of all ballast water is preferable. Ballast water can be treated by; filters, removal of oxygen, heat, ultrasound, magnetic radiation and ultraviolet light. [33] Bremerhaven has developed a ballast water cleaning system that can be used on-board of vessels that uses a filter and UV technology. According to them the system performs well, and is an environment friendly alternative to systems that use disinfecting chemicals as chlorine. [24]

Other sources of water pollution are contaminated bottom sediments and spills of liquid bulk products. A port should prevent the release of any liquid bulk products to water and soil, particularly petroleum and chemicals. The port of Los Angeles states that release of these substances should be immediately detected to recover any contaminated product. [83] The port of Antwerp reports that oil spills are registered as incidents in three groups: with unknown cause, with known cause, and during bunkering activities and/or loading. [27] In this way a port can check whether preventive measures are effective. To give an indication: they reported between 2007 and 2010 between 70-100 incidents per year.

The port of Antwerp also reports that: "there are currently no environmental quality targets for bottom sediment in brackish and saline water bottoms". [27] For this reason they have measured a number of substances (concentrations) in 2002 and 2010 and compared them to determine if concentrations have changed. [27] But still challenges arise from contaminants such as polluted rainwater that flow into a harbor from land (waterfront run-off). [83] [58, p238]

Water consumption should be lowered wherever possible. A closed water system (reuse of water) can help to lower the consumption. However the use of water depends on the type of port. Cooling water is generally pumped out of the harbors and pumped back in when used. In the port of Antwerp this accounts for 97% of the total water consumption due to the chemical industry. [27] The higher temperature of cooling water that is pumped back, can also have a (negative) influence on the local environment. It is common that 'exotic' species (fishes, etc.) prosper well in these 'warmer' waters.

4.1.4 Local environment

The local environment is the surroundings a port operates in. Due to port operations the 'quality' of the local environment is negatively influenced. The aim of environmental friendly operation is to lower the negative impact on the local environment as much as possible. Sustainability aims is to eliminate the negative impact on the local environment, a significant difference.

An 'Environmental Impact Statement' (EIS) (in Dutch: Milieu Effecten Rapportage (MER)) describes the local environmental characteristics in detail and the impact of a proposed action (with alternatives and no-action alternatives). [82] It is an obligatory tool to check the environmental impacts of development or redevelopment of the port area, changes in operation, and so on.

A common practice is to 'restore' the land occupied for port operations elsewhere, either by redevelopment of brownfields or development of core nature outside the port area. The port of Bremen states 'what the environment loses when port facilities are built has to be restored elsewhere'. This also includes impact of nature caused by port projects, such as construction works. They call it 'a conflict that can be resolved'. [24] At the Maasvlakte 2 in the port of Rotterdam, to compensate for the loss of sea area, a large water area close to the new Maasvlakte 2 is conserved for nature and habitats. Due to development of the port area they had to move nature- and recreation areas to other locations and expanded the recreational area by 1,5 times. [28]

Inside the port area a port can designate areas with 'ecological value' as flora and fauna areas, bird islands, etc. The port of Antwerp has 'reserved' 5% of their total area as habitats for plants and animal species. [27] A port can also plant trees in the port area. Trees have many benefits: they 'capture' Greenhouse Gases and help to reduce emissions, reduce smog and lower noise. Secondly they improve landscape in an aesthetical way. [15] Visual appearance of a port is important since many ports are located closed to recreational or residential areas.

Sediment and contaminated soils in water are problems that ports take different actions on. Some ports as the port of Long Beach has set up a 'contamination plan' to remove and treat contaminated soils as a result of historical activities [84] That goes beyond responsibility for current activities. The port of Bremen has special equipment to suspend particles from the harbor bottom. Two special vessels are in use that flush up fresh deposits from the bottom and keeps them suspended, so that the material is carried off with the outgoing tide instead of sinking to the bottom as sediment. This is achieved by injection of water by a dredger; it flushes the sediments up from the bottom. [24] More and more ports have facilities to treat sediments (silt and mud) from dredging activities in harbor. After dewatering in large fields the sediment is treated to remove hazardous substances. The dried harbor silt can be used for dykes (instead of sand that has to be imported), filling harbor basins (new area) or land construction. Using the dredged material within the port area is most preferable in terms of ecological sustainability. [24] Dredging for maintenance and expansion activities are restricted to strict (local) directives that can seriously delay such terminal expansion projects. [58, p238] [59]

Light emission has a negative impact on the local environment. The port of Bremen reports that they use special lamps with a smaller light spectrum that has a low attraction on insects. [24] A port should take sufficient measures (screens, shields) to prevent light pollution to the surrounding environment and into the water. The installation of proper light pole heights will also help. [58, p239]

4.1.5 Vessels

Different ships have different emissions. Some of them are very polluting, since some engines are based on older standards or shipping lines can be originated in countries with fewer requirements on emissions. A 'sustainable port' can take several actions to lower the emissions from ships calling the port. 'Differentiated harbor taxes' [35] based on emission or extra fees for the most polluting barges [28] are common examples. Some ports oblige shipping lines to switch to low-emission diesel engines by retrofitting the engines. If these actions do not lower emission rates to a sufficient level, the ships are obliged by a maximum (lower) speed. [28] The change to other fuels as ULSD (Ultra Low Sulphur Diesel) can be supported as well. [89] The Port of Los Angeles pays the difference between bunker fuel and cleaner distillate in their 'Clean fuel incentive'. [83] Also alternative fuels for inland shipping as LNG can be used. [30]

The ship emissions can be registered in the international recognized 'Environmental Ship Index' (ESI). It is a method for calculating; NOx emissions from exhaust fumes, SOx emissions from the fuel used and, very limited, the CO2 emissions. The score (between 0-100) represents the impact on the air quality. The method includes Onshore Power Supply (OPS) as well. A ship gets rewarded with additional points when such a system is installed on a ship, but surprisingly irrespective whether the system is used or not. ESI requires that this OPS-system is approved and certificated by a Classification Society. [90] Also local (port specific) ship indexes exist as, for example, the Clean Shipping Index (CSI) in the Port of Gothenburg, Sweden. [89]

The 'Green Ship Incentive Program' is a voluntary program of the Port of Los Angeles to reduce NOx emissions from ships calling at the berth. Based on Tier 2 or Tier 3 standards (see Appendix 2), a reward (incentive) will be given to the shipping line if they comply with these standards. The Port of Los Angeles has calculated that Tier 2 engines (as of 2011) and Tier 3 engines (as of 2016) in vessels reduce NOx emissions by 15 and 80 percent respectively. [91] This program is besides the 'Low-Sulphur Incentive program', in which vessels are encouraged to use 0,2% sulphur content Marine Diesel/Gas Oils and contains 'Onshore Power' incentives.

Another example of emission reduction efforts for shipping is a 'vessel speed reduction program'. The Port of Los Angeles calls it 'Green Flag Incentive Program', a voluntary program for vessel speed reduction. Operators of vessels that slow their vessels down to 12 knots within a 20 or 40 nautical mile range will receive a reward in form of dockage rate reductions. This plan helps to improve the air quality in the port and surroundings. The program in Los Angeles is very successful since 90% of the vessels are participating in the program. Even 70% of the vessels slowed down within the wider 40 nautical mile range from the port. [92] The port of Long Beach also participates in this program. [84]

The Port of San Diego reports that their vessel speed reduction program (12 knots limit for cargo vessels and 15 knots limit for cruise vessels within 20 nautical miles of the port) resulted in a reduction of 10-11% of NOx, CO, PM, VOC and CO2 emissions from the participating vessels. In 2012 they reported a 13-18% reduction of air pollutants. [14] The reductions were calculated, thereby using the engine type specifications, and compared to emissions that would have been generated with typical cruising speeds. The number of ships in the second quarter in 2009 participating was approximately 69%. [12]

Cold ironing (shore-to-ship power supply) is a much debated and proposed alternative to reduce ship emissions in a port. The port of Los Angeles was a pioneer in 2004 by opening a new Terminal (West Basin Container Terminal) with cold-ironing capabilities. They have set up specifications for 'Alternative Maritime Power' (AMP) to build in ships or vessels. Other terminals in the Port of Long Beach have AMP systems installed in 2006, 2010 and 2011 respectively. Driven by strict regulations of California to reduce emissions for auxiliary engines, a certain percentage of vessels calling the port have to shut down auxiliary-engines in new regulation in 2007 and use grid-based power. In 2014 that is 50% of the fleet's vessel visits and increases to 70% in 2017 and 80% in 2018, regulated by the California Air Resources Board (CARB). [93]

This rapid increase is due to 'forced' regulation. In 2006 the European Commission adopted a recommendation (2006/339/EC) to promote the consideration of shore-side electricity for use by ships at berth in 'Community ports' (ferries, Ro-Ro) as a means to reduce emissions in EU ports. It was recommend (not obliged) particularly for populated areas, which suffer from poor air quality. It presents the benefits and costs and calls for harmonized standards, as is recognized by ports in the Netherlands [30]. The difficulty is that while shore power is cheaper than light diesel [1], shore-to-ship power supply is not a reasonable alternative for quay facilities in tidal areas which are constantly used by different vessels and which have no fixed berth allocations. [24] ESPO is reflecting findings in California that shore-side power is not cost effective. [1] Different power supply frequencies and demands and high investment costs for shipping lines and ports are the reasons that the application in ports is very limited. At this moment it is more appropriate for ferry terminals, Ro-Ro vessels and inland waterway vessels. [24]

An alternative to cold ironing is the use of solar power to decrease the demand of a ship's diesel-powered auxiliary engines. The 'Augria Leader', a car freighter vessel, has 328 solar panels installed that provide 40kW of electricity as experiment to help cutting air emissions. [84] But this is still a minor contribution.

The trend of larger container vessels is continuously growing. In 2010 Maersk Line has purchased 10 of the largest and efficient containerships, the Triple-E container vessels. "These will emit 20% less CO2 per container moved compared to the most efficient container vessel operating today and 50% less than the industry average for vessels operating on the Asia - Europe trade. The Triple-E will be a key component in reaching our goals for low carbon leadership." [6]
Maersk Line has committed itself to reduce its CO2 emissions by 25% by 2020 per container moved, compared to 2007 levels and have committed themselves to 'slow steaming' in 2008. [6] This indicates that upgrading (cleaner engines or increasing capacity) lowers the amount of emissions per TEU (or tons of cargo) moved.

4.1.6 Equipment

The type and capacity of equipment, besides the manner of operation, determines the fuel- and energy demand of a port in the beginning. Ports continuously seek for the most economical way of operating. And since fuel- and energy saving has both economical and environmental benefits, retrofitting or purchase of new (less fuel demanding) equipment can be advantageous. New techniques and developments cut emissions and fuel consumption so that the 'Return On Investment' (ROI) can be relatively small. Retrofitting is in most cases less expensive and less radical in terms of change of infrastructure or operation, in comparison to buying new equipment.

In July 2012 the Port of Los Angeles successfully completed an initial test of two electric driven Rubber Tired Gantry Cranes (eRTG) and showed the benefits of reducing emissions locally. An electric infrastructure for the eRTGs had to be installed. The eRTGs are now put into daily operation for demonstration. [83] The Port of Hong Kong has proved that eRTGs reduce costs by 65% and eliminate SO2, NO2, PM and black smoke emissions significantly. Additional advantages of electric drives are no engine noise and elimination of frequent engine maintenance (less disposal of lubricants, filters, engine components, etc.) [1] They estimated that the payback time of retrofitting RTGs with electric drives is 3,6 years. Other applications of full electric drives are seen in AGV's as in a recent project of HHLA (Hamburger Hafen- und Logistik AG). [26]

There are also examples of fuel cell implementations. The Port of Los Angeles has currently two test programs of 'Plug-In on-road Trucks' and 'Hydrogen Fuel Cell on-road Trucks' running. They will put these test vehicles into operation to see which emission benefits can be achieved. [83] In 2008 the Port of Hamburg started to use forklifts with a fuel cell powertrain, in the same year a hydrogen tank went into operation for refueling the forklifts. Fuel Cells have the advantage that they do not emit any greenhouse gases or polluting substances locally, only water (H_2O). [26]

A more simple solution is the use of hybrid technology to lower emissions. There are different hybrid technologies in series-, parallel and series-parallel arrangements. [40, p17] The use of hybrid technology will lower emissions but not completely eliminate them, since still fossil fuels are used. Hybrid locomotives (with a hybrid powertrain) can reduce the fuel consumption by 60%. The reduction in emissions of NOx and PM are estimated at 80-90% in comparison to a conventional locomotive's powertrain. This estimation is the result of a study by CE Delft for the Port of Amsterdam to choose for a hybrid powertrain rather than a modern diesel. [34] An advantage of hybrid technology is the recuperation of braking energy and no demands on the current infrastructure (no need for electric infrastructure). Since still fossil fuels are required it is more a 'short-term solution'.

The choice of the right equipment can also help to improve the efficiency of land use. The port of Georgia, USA has converted many of their top lifts to RTGs, they use less terminal space but also have variable-speed engines that reduce consumption of fuel (in their case ULSD) and emissions. [9] Many new technologies contribute to the reliability of equipment, and thus to sustainability: increased productivity and less back-up equipment is required. [40, p10]

Adjustments on the equipment itself can also help to improve sustainability. Travelling on rubber tires requires more power, since rubber-asphalt (with RTGs) has a larger rolling (friction) coefficient than metal-metal (with RMGs). [40, p12] But the right choice of tires helps to reduce resistance (low-resistance tires are available) and may help to lower rolling noise. There are ports that mute loud hailers during night and replace them by warning lights. These measures help to lower noise emissions and are examples of 'active noise protection'. The opposite is 'passive noise protection' as sound barriers, hearing protection, etc. The port of Hong Kong reports that installing electronic ballasts on crane floodlights help to reduce energy consumption of the lightning equipment by 40%. [1]

A port authority can also oblige sustainability to their tenants (port operators), e.g. in the Port of Rotterdam where tenants have an agreement in their contracts to use hybrid technology in AGVs. [28]

4.1.7 Equipment: Engines

According to the Port of Los Angeles, repowering or replacing a vehicle's engine has a larger greenhouse gas reduction potential than incorporation of an alternative fuel. Replacement of engines is beneficial since a EURO VI (2014) engine emits 95% less than a EURO III engine (2000). [30] If equipment is equipped with engines based on these older standards it will help to lower emissions significantly in the port area when these are replaced with state-of-the-art engines with EURO VI or

TIER 4 certification. A recent example of upgrading took place in the Port of Savannah under Georgia Ports Authority. They have upgraded their rubber-tired gantry cranes (RTG) with cleaner TIER-4 engines with new controls that can automatically switch engines in idle or load (variable speed engines). This helped to reduce emissions of NOx by 60% and PM by more than 80%, and reduce diesel consumption significantly. [9] It must be stressed that these 'reductions' were based on the old (polluting) equipment, but shows that the reductions can be significantly when engines are replaced with 'cleaner' ones. Also research of 'van Duin, R.' shows that fast replacement of diesel equipment can save up to 19% emissions. This research was focused on container terminals. [42, p9]

Also engine speed reduction is a simple way to realize fuel savings, an example in the Port of Hong Kong showed that lowering the engine speeds from 1800rpm to 1500rpm saves 15% fuel and the payback period is only 3,5 months. [1]

4.1.8 Equipment: Fuel type

The type of fuel used in equipment will influence emissions as well. This applies in particular for emissions of oxides of sulphur. In March 2011 Maersk Line has switched from bunker fuel to low-sulphur fuel in New Zealand, which reduces the port's sulphur emissions by 80-95%. [6] The port of Hong Kong reports on a 90% reduction of sulphur dioxide emissions since the change from 0,5% sulphur fuel (5000ppm sulphur) to 0,005% sulphur fuel (ULSD, 50ppm), but the additional costs were approximately 4 million dollars per year. [1] Most regulations in and outside the European Union require sulphur content between 10–50ppm, dependent on the application of the fuel and validity year of the regulation. Another option is to blend low-sulphur fuel and biodiesel. This helps to reduce Particulate Matter emissions by approximately 80%. [6]

Blended biodiesel may work in any diesel engine and has a little impact on performance. In many cases blended biodiesel can be used without any modification to the engine or fuel system. However the production of biodiesel uses more fuel than is required for production of a 'conventional' fuel. [1] There is also a continuous debate on the competition with the production of food. With the 'second generation' of biofuels (materials which cannot be used for human consumption) the debate is ongoing, since still land is used (indirectly) which otherwise would be available for agriculture. There are three 'generations' of biofuels, of which the latest is more or less in a preliminary (test) phase:
- Generation 1 biofuels made from; soy, rape, palm, sugarcane, wheat and/or corn [30]
- Generation 2 biofuels made from; wood, straw and/or waste [30]
- Generation 3 biofuels made from algae [30]

A recent study of 'van Duin, R.' shows that blending 30% of biodiesel with diesel can save up to 21% emissions. This research was focused on container terminals. [42, p9]

Alternatively a fuel additive can be used to lower certain emissions. The port authority of Georgia, USA has performed a study to the effect of fuel additives on emissions. They monitored their RTG fleet with their current fuel and with a fuel additive. It turned out that with the fuel additive NO_2 was reduced by 5-15%, CO was reduced by 4-14% and PM_{10} by 37-66%. There was no conclusion on SO_2 emissions since it directly relates to the sulphur content in the fuel utilized, which in this case was ULSD with a 15ppm sulphur content. The low sulphur content of the fuel has inherently showed that the current sulphur emissions were compliant with the EPA requirements, regardless of fuel additive. The fuel efficiency monitoring indicated that fuel consumption (l/h) was reduced by approximately 5%. Another conclusion was that the age of equipment affects fuel efficiency in some degree. [8]

In recent years a trend toward the use of 'Liquid Natural Gas' (LNG) for inland shipping can be observed. Using LNG instead of other fuels has a several important benefits. When compared to all ship fuels that are available nowadays, LNG has the lowest contribution to air emissions. LNG does not emit sulphur oxide and particles (both 100% reduction). Nitrogen oxides are reduced by 85-90% and even carbon dioxide is reduced by 10-25%. [22]

LNG is a temporarily liquid form of (Compressed) Natural Gas (CNG). It has been cooled down to minus 163^{o} Celsius and turned into a liquefied phase. In this way volume is reduced by 600 times which has an advantage for storage and transport. LNG is non-corrosive and non-toxic. [22]

4.1.9 Operating practices

The manner of operation of equipment determines the fuel (or energy) consumption of port equipment, as is recognized by ports and research. There are many operational factors having a negative influence on sustainability. The most common is 'pedal-to-the-metal' mentality of operators. [40, p13] The fuel consumption depends on how the equipment is operated. Driver or operator refreshing courses may help but is no guarantee for fuel-efficient operation. Here automated equipment can contribute to relative consumption.

Another item is 'idling' which can be caused by too much equipment or insufficient planning. [40, p9] Prevention of idling can be achieved by 'automating' port operations and planning (logic control system), [40, p7] which can minimize waiting times on both seaside and landside. [28] Automation can help to lower peak demands, [40] eliminating the need for equipment with a too large capacity. As a secondary benefit automation is expected to reduce the need for lightning the yard.

Using higher capacity containers can also increase efficiency and lower emissions per TEU [3]. APL introduced 45', 48', and most recently, 53' containers to increase capacity, which resulted in fewer drayage (short distance) moves and lower emissions per TEU. [6] The port of Hamburg, Germany uses double 20' feet Automated Guided Vehicles (AGVs) to improve the total efficiency and lower the number of drayage's. On a yearly basis they reduce 600 tons of CO2. [26] The use of higher capacity containers can be indicated with a 'TEU factor'; the ratio of different size containers (20', 40' and 45') that is handled. [41, p96] It has to be taken into account that the efficiency has to be considered over the total logistic chain. [40, p7] If one part of the chain (one type of equipment) has a far lower efficiency, the total chain will be negatively affected. But it also means that 'over-design' of one or some of the sub-processes will have a very limited benefit in terms of energy- or emissions reduction. [40, p7]

4.1.10 Energy resource

The demand and resources of energy, fuel and heat determine the 'sustainability' of a port in a high degree. These types of energy are commonly produced from non-renewable sources as coal and gas. Ideally a port should produce its own renewable energy, or at least purchase renewable energy (energy from wind, solar or biomass).

A cost-effective way of producing renewable energy on a small scale is solar power. Many buildings in ports that have been studied are equipped with solar panels to provide renewable energy on site. But sometimes limitations apply. The port of Antwerp was faced with a limited uptake of the electricity grid and older regulation that set a maximize capacity of solar systems to be installed. [27] Also when 'dust' is a problem in the port area, the solar system should be kept clean.

The sharing of residual heat between companies can be a solution to lower the energy demand. In 2011 the company 'Air Products' build a new hydrogen plant with a production of 300 tons of hydrogen per day. This plant is located on the ExxonMobil site in the port of Rotterdam, and is one of the largest hydrogen production plants in the world. It is a good example of co-siting since 'Air Products' uses the steam that is produced at the site (from the chemical industry) as feedstock to drive compressors that power the hydrogen plant. There is no need to produce their own steam. [29] Low value of residential heat (steam) can also be used for district heating. Feasibility studies have started recently for the use of low value heat from the (petro-)chemical industry in the port of Antwerp. [27]

4.1.11 Infrastructure

The infrastructure of a port can provide possibilities and at the same time introduce limitations for sustainability measures. Limitations that a port can be faced with are limited space for expansion or changes, inadequate capacity of the road-, rail- or inland water infrastructure, restrictions from local regulations, etc. [31]

The choice of a terminal design depends on local factors as the availability of land, infrastructure that is connected to the port and geographic setting of the port. For terminal design there are a lot of different designs proposed in the last decades, e.g. RTG- and RMG-stacking concepts for container terminals that have preference. [40, p11] Rijsenbrij et al. reports that for terminal designs the focus is often on minimizing the investment cost rather than minimizing the annual operational costs. [40, p2]

If a layout of a port area allows for 'sustainable operation' depends on many factors like the equipment used, the manner of operation, planning, etc. Sometimes a rail connection is not available in the port. Redevelopment of the port area is then the ideal time to invest in infrastructure systems as rail connections, pipeline systems or landside on-shore power supply. This is also true for decontamination of the bottom soil of the docks. [27]

Efficient land use and efficient site planning are both important topics for sustainability. When expansion of the port area is required, e.g. due to increased transport, it has preference to use 'inward expansion', meaning renovating older parts of the port and improve industrial area utilization.

Some ports have designated heavyweight areas for storage of containers and heavy-duty vehicles, and designated lightweight areas for empty containers. The port of Los Angeles has a special area for trucks called 'truck stop electrification' where reefers can be connected to the power grid and the cabins of trucks can be connected to a centralized HVAC-system (Heating Ventilation and Air Conditioning). In this way the trucks do no need fossil fuels during (un)loading or idling. [94]

From an ecological viewpoint, ground sealing is never desirable but owing to technical reasons and statutory regulations unavoidable. [95] The infrastructure should include drainage systems at locations where oil- or chemical spills are likely to occur, as in maintenance facilities, workshops and at parking areas for equipment. The port of San Diego has a 'smart irrigation system' that shuts down immediately when leaks are detected. [81]

To reduce the amount of noise the port can be enclosed with barriers. This is an example of 'passive noise protection'. The most 'sustainable' versions are hills that enclose the industrial area. Otherwise natural materials as trees, stones or wood should be used. Also applications of containers as barrier are proposed. [41, p8] Metal shields or fences should be avoided; these have the lowest lifetime and do not contribute to an attractive view (the visual appearance of a port is important, see section 'local environment'). The World Health Organization (WHO) reports that screens are more effective at higher frequencies (not for low-frequency noise) and when placed either close to the sound source or the receiver. And although higher screens are better to reduce noise emissions, in practice it is difficult to achieve reductions of more than approximately 10 dB. [43, p33]

Lighting of the port area has also implications on energy. To reduce energy consumption many ports have (or will) change to LED lighting. Also voltage-regulating transformers help to reduce energy consumption of 'ordinary' lighting systems. The port of Bremen has equipped their mooring dolphins with LED lighting and small solar panels. A light switch automatically turns the lights on and off, and a connection to the electricity is not required anymore. (They estimated that the batteries have to be replaced every 5 years and the LED lamps used have an approximated lifetime of 100.000h). [95]

4.1.12 Buildings & Warehouses

Buildings and warehouses can contribute to sustainability by lowering their impact during construction and operation. A very practical approach is to reduce the energy-, heat- and water demand, which has been done by many ports. Conserving water will also reduce energy use indirectly since energy is required to pump and treat water. [14] The installation of automatic water taps can save 15% of water [1], and seawater flushing can also help to reduce the demand of fresh water.

APL Logistics in the port of Singapore uses an internally designed tool to calculate the carbon footprint of warehouses. By estimating the amount of Greenhouse Gases from the operations at each warehouse, APL can focus on Greenhouse Gas reduction measures in an efficient manner. [6]

During construction of buildings various measures can be taken on sustainability. A port can oblige constructing companies to use low-emission equipment, use cleaner fuels, take measures on dust control and acoustical control, minimize the impact on soil and vegetation, conserve materials and resources, and so on. Materials from demolition can be reused or recycled. Examples include concrete recycling for new pavements, asphalt reuse as additive in new asphalt mixes, steel scrap recycling from railroad steels, rebar's, pipes etc. [9] [15]

When buildings are constructed or renovated, the port (or constructing company) should apply for an energy certification or a green building policy. Systems that are applicable vary for each country. 'LEED certification' (Leadership in Energy and Environmental Design) is founded in the United States but internationally recognized. Also 'visual appearance' of buildings is important, high-rise of buildings should be avoided and 'natural' colors should be used to match the surroundings. [95]

4.1.13 Sustainable development

Sustainable development contains topics from the 'triple bottom line' (people, planet, profit). Employee engagement by training programs will increase employee awareness and understanding of resource conservation. The port of San Diego reports that small behavior changes (they give examples from the office area as turning off computers at night, double sided printing and scrap paper for concept printing) results in cost savings. [81] Both 'people' and 'profit' topics are involved.

Noise is a concern that also applies to sustainable development. The port of Rotterdam stresses that a buffer zone between residential and business areas is important. The buffer zones may not be used to build new homes to preserve the quality of life. [30] Noise mapping is a crucial part of noise-eliminating measures. By mapping the high-intensity noise areas (hotspots) more specific preventive measures can be taken, and the effects of improving measures can be checked more easily. [36] An example of a measure, resulting from noise mapping, is relocation of noisy sources away from residential areas. [58, p238]

Many times in this report it is stated that reporting on emissions, reductions or performances is important to inform and raise goodwill from the local society. This can be presented in 'cold numbers' that much people do not attract or understand, or in a more 'simple' and attractive way by comparing them to known figures (like cars, trees or homes). On first hand it seems to be very simplistic. But this is important since much people don't know terms like sulphur dioxide, particulate matter, etc. and have no idea what it means if, for example, 600 metric tons on Greenhouse Gas is reduced. The Port of San Diego has used figures in their annual report for an easy comparison and understanding. [13] [14] (see figure 4)

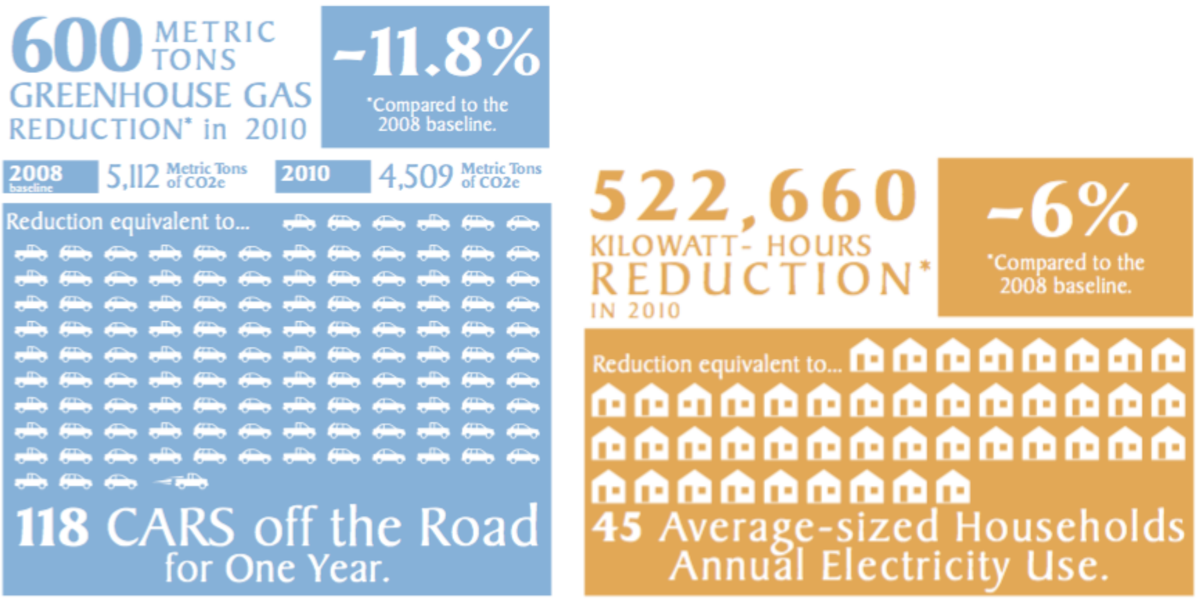


Figure 4: *Example of an attractive way to present environmental performance (courtesy: Port of San Diego, USA [13] [14])*

Other possibilities to involve society are community outreach, sponsorship of public or private sector (culture, education, sport, social events, etc.), foster public-private partnerships to reduce carbon dioxide emissions [83] [27], subsidize of preventive measures as sound-proof windows and doors for residential houses nearby. [24]

4.1.14 Environmental Programs

The incorporation of an Environmental Management System (EMS) is a basic step towards the application of sustainable measures and the awareness of sustainability in daily operations. There are various ways and systems that can be applied, as is described in Chapter 2. Besides an EMS, a port can incorporate a 'green purchase policy'. This policy sets requirements to products to have a reduced effect on human health and the environment when compared to other products with the same purpose. Such requirements include "conservation of natural resources, elimination of toxins, reduction of materials that put into landfills, encouragement of manufactures to reduce environmental impacts in production and distribution systems, etc." [15]

A 'knowledge center' can be developed to gather information and data for implementation of an environmental policy. [27] Also 'task force' can be helpful. A 'task force' is a team of employees, most likely from different departments, with a mutual goal. They can help to promote sustainable policies and procedures. [84] It also helps to involve stakeholders as 'environmental organizations' and have an open dialogue with them during (re-)development and design phases. This was the case with the development of the Maasvlakte 2 in the port of Rotterdam. 'Sustainability' and 'environmental organizations' were included in a very early stage of the development process. This helped to gain a greater acceptance of their plans. [28]

The guidelines of the Global Reporting Initiative (GRI) can be used as well. The port of Antwerp has used the most relevant indicators that were applicable for the port area, and supplemented them with relevant indicators from other external organizations as the European Sea Ports Organization (ESPO).
The GRI guideline is like a checklist, which was originally intended for multinational companies. [27]

A 'noise management plan' or 'noise mapping plan' can be part of an EMS. It allows for cost savings by prevention of negative influences of port-city planning and port development. And improves transparency in communication to the local society which turns into greater potential for acceptance. [36]

A port that encourages its customers, tenants, and partners to conduct their businesses in a more sustainable fashion, including reductions in (Greenhouse Gas) emissions, is doing a good sustainable effort that goes beyond the responsibilities of their own operations. [21]

5. Sustainability and legislation

5.1 EU port sector

The European Commission has, as well as other governments outside the European Union, set up regulations that will affect harbors as well as transport. These directives relate to air quality, trade in emission rights of greenhouse gases, water quality, regulation on noise and noise sources and environmental items and responsibility. [32] The regulations form a framework for the transport sector wherein certain pollution is 'accepted'. Many of these regulations are deduced from long-term perspectives as European strategies on environmental issues, environmental covenants, the Kyoto protocol, agreements with the industry, etc.

The transport system in the European Union is not sustainable, and will not be in the near future due to increase of the sector. The growing carbon dioxide emissions are threatening the European target under the Kyoto protocol: a 20% decrease of carbon emissions in 2020, based on 1990 level. [67]
Carbon dioxide has the largest share in the group of Greenhouse Gases (GHG). The industry and transport sector together are responsible for 32%, or roughly 1/3rd, of total GHG emissions worldwide. (Others: forestry 17%, agriculture 14%, energy supply 26%, waste 3%, buildings 8%) (2007 data) [79] In Europe transportation has a GHG share of 25%, of which 17,9% is due to road transport and 3,2% due to shipping. [49, p2] This indicates that there is still large room for improvement.

Besides the greenhouse gases there are more gases and substances that affect both global and local environment. The most common from burning fossil fuels and substances that are likely to be emitted in the port sector are listed in Appendix 3 with a short description of their impact.

5.2 Air emission control

A port is a significant contributor to air emissions, but not only the port is a polluting source. Shipping lines calling at the port and inland transportation from and to the port affects local air quality as well. For these and other reasons certain gases as listed in *Appendix 3* are subjected to limits in various ways. Emission control is performed by legislation on European level of which most have to be turned into national regulations.

Emission control applicable for the port area includes:

- National Emission Ceilings (NEC)	= max. values in kton
- Air quality standards	= max. concentrations in µg/m3
- Emission standards	= max. emissions from combustion engines
- Fuel quality standards	= requirements on substances in fuels

The directives and national regulations include emission 'stages' that have to be met in the near future (new limits that go into force from a certain date in the future). At any time there is latitude between complying with the legislation and performing better. The degree how 'well' a current situation is can be seen as an indicator for sustainability. Performing worse is in many cases not allowed or being penalized, therefore not taken into consideration.

The four emission control areas that are mentioned above will be discussed shortly. The applicable values are listed in Appendix 1: Air quality and Emission ceilings, and Appendix 2: Emission standards for vehicles. The substances that are covered are described in Appendix 3: Pollutant substances of air emissions.

5.2.1 National Emission Ceilings

The European Directive 2001/81/EC set standards and various actions to limit emissions of acidifying substances, these actions include National Emission Ceilings (NECs) for four emissions: sulphur dioxide (SO_2), nitrogen oxides (NO_X), volatile organic compounds (VOCs) and ammonia (NH_3). These ceilings had to be converted into national programs. Unfortunately, the Directive lacks ceilings on particulate matter.

Values applicable for The Netherlands and neighboring countries are listed in the table below:

	SO2 kton/year	NOx kton/year	VOC kton/year	NH3 kton/year
Belgium	99	176	139	74
Germany	520	1051	995	550
Netherlands	50	260	185	128
UK	585	1167	1200	297
Sweden	67	148	241	57
Finland	110	170	130	31

Source: 2001/81/EG Directive on national emission ceiling for certain atmospheric pollutants, October 2001
Further reading: Appendix 1: Emission ceilings

5.2.2 Air quality standards

The European Directives concerning air quality are 2008/50/EC for major pollutants and 2004/107/EC for specific substances. The older directive 96/62/EC can be seen as the framework for air quality standard. The three directives 1999/30/EC, 2000/69/EC and 2002/3/EC concerned specific air polluting substances and are together with 96/62/EC withdrawn as of June 2010.

The European Directive 2008/50/EC on air quality prescribes maximum pollutant concentrations as of 2015:

Substance	Limit
SOx	No 'annual average' specified for humans (125 µg/m3 one-day limit value)
NOx	40 µg/m3 average annually
PM10	40 µg/m3 average annually (from June 2011 in NL) 50 µg/m3 daily value, which may be exceeded 35 times annually
PM2.5	25 µg/m3 average annually (20mg/m3 as target value as of 2020)
CO	10 mg/m3 eight-hour limit value
O3 (ozone)	120 µg/m3 eight-hour limit value

These limit values are imposed for protecting human health. Limit values for protecting vegetation are significantly lower:

Substance	Limit
SO2	20 µg/m3 average annually
NOx	30 µg/m3 average annually

Source: 2008/50/EC Directive on air quality and cleaner air in Europe, May 2008
(This Directive will be revised in 2013)

In the United States a comparable legislation under the name 'National Ambient Air Quality Standards' (NAAQS) is applicable. The maximum concentrations are slightly higher (the regulation is less 'stringent') as stated in the European Directive 2008/50/EC.

Directive 2004/107/EC sets voluntary targets for polycyclic aromatic hydrocarbons (PAHs), as of 31 December 2012 all EU Member States shall meet these standards (by using best available techniques rather than making excessive costs in reducing measures):

Substance	Limit
Arsenic	6 ng/m3 target
Cadmium	5 ng/m3 target
Nickel	20 ng/m3 target
Benzo(a)pyrene (1)	1 ng/m3 target

1. Benzo(a)pyrene should be used as a marker for the carcinogenic risk of polycyclic aromatic hydrocarbons in ambient air.

Source: 2004/107/EC Directive on arsenic, cadmium, mercury, nickel and polycyclic aromatic hydrocarbons in ambient air, May 2008

More extensive numbers are given in Appendix 1 (Air quality and Emission ceilings).

> Air quality standards for the concentration of substances can be used for measuring the air quality in and around the port area. This can be assessed.

5.2.3 Emission standards

Directives on emissions of particular vehicles are divided into separate groups, namely 'Light-duty vehicles' (cars, vans, small trucks), 'Heavy-duty vehicles' (trucks) and 'Non-road mobile machinery' (aggregates, port equipment, inland vessels, railcars, locomotives). On top of these Directives, there is also separate emission regulation on 'Shipping' and 'Fuel quality'.

Light-duty vehicles
These vehicles have a weight of less than 3500 kg, like consumer cars, vans and small trucks.

Stage	Validity year	Pending Directive
EURO III	2000	Directive 98/70/EC
EURO IV	2005	Directive 98/70/EC
EURO V	2009	Regulation 715/2007
EURO VI	2014	Regulation 715/2007

Heavy-duty vehicles
These vehicles have a weight of more than 3500 kg, like trucks, heavyweight carriers.

Stage	Validity year	Pending Directive
EURO III	2000	Directive 1999/96/EC
EURO IV	2005	Directive 1999/96/EC
	2005	Directive 2005/55/EC re-stated emission limits, due to OBD (On-Board Diagnosis system) requirements
EURO V	2009	Directive 1999/96/EC (EURO V into force as of Oct 2008)
EURO VI	2013	Regulation 582/2011, proposal made in December 2007, adopted in June 2009, info force as of January 2013

Non-Road Mobile Machinery (NRMM)

This machinery includes excavators, bulldozers, front loaders, back loaders, compressors etc. and mobile equipment. The emissions of NRMM are regulated in four directives. Each of these Directives include 'stages' that are increasing stringent on emissions with corresponding compliance dates. Directive 97/68/EC is the 'basis' Directive on emissions from 'internal combustion engines'. Directive 2004/26/EC also includes constant speed engines, railcars, locomotives and inland waterway vessels.

The Directives for diesel engines focus on carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NOx) and particulate matter (PM) emissions in grams per kWh of power installed. Manufacturers of new engines have to comply with the limits stated in these directives.

	Validity year	Stage	Pending Directive
Diesel engines 37-560 kW	Jan. 1999	Stage I	Directive 97/68/EC + 2006/105/EC(1)
Diesel engines 37-560 kW	Jan. 2001	Stage II	Directive 97/68/EC + 2006/105/EC(1)
Diesel engines 19-560 kW	Jan. 2006	Stage III A	Directive 2004/26/EC
Diesel engines 37-560 kW	Jan. 2011	Stage III B (2)	Directive 2004/26/EC
Diesel engines 56-560 kW	Jan. 2014	Stage IV	Directive 2004/26/EC

1. Directive 2006/105/EC is a revision of Directive 97/68/EC, which introduces a modification to the numbering system of the accession of Bulgaria and Romania.
2. More stringent limits for railcars and locomotives

The Directive for petrol engines especially focuses on carbon monoxide (CO) and hydrocarbons (HC) typically emitted in large quantities by petrol-fueled engines. The website of EU states that "one hour use of a normal chainsaw equipped with a two-stroke engine emits as much hydrocarbons (HC) as driving a modern passenger car for 2000km". [68] Also limits for nitrogen oxides (NOx) are included. The limits are stated in grams per kWh of power installed.

	Validity year	Stage	Pending Directive
Petrol engines (1)	Aug. 2004	Stage I	Directive 2002/88/EC
Petrol engines (1)	Aug. 2006	Stage II	Directive 2002/88/EC

1. Only petrol engines with a displacement > 225 cubic cm, which belong to the class SN:4, non-hand-held machinery with a net power > 19 kW are considered for this research.

The TIER standards for non-road vehicles of the United States Environmental Protection Agency (EPA) are partly comparable to the European Directives on Non-Road Mobile Machinery. The term 'TIER' is synonymous for 'Stage' as used by the European Commission. More strict regulations are applied in stages, of which the latest TIER 4 standard will be into force in phases between 2008 for small engines (up to 56kW) and 2014 for large engines (56kW and higher). With the introduction of TIER 4, the standard is more in line with Stage IV of Directive 2004/26/EC.

	Validity year	Stage	Pending directive
Diesel engines	1996-2000 (1)	TIER 1	EPA
Diesel engines	2001-2006 (1)	TIER 2	EPA
Diesel engines 37-560 kW	2006-2008 (1)	TIER 3	EPA
Diesel engines	2008-2015 (1)	TIER 4	EPA

1. Phased-in years, depending on engine power

More extensive numbers are given in Appendix 2 (Emission standards)

> The EURO or TIER emission standards can be used as assessment for measuring compliance of the port's or tenant's vehicle fleet. Equipment that performs better than the current standard into force can be considered as 'environmental friendly'.

Inland Shipping (NRMM)
The European Commission has, as from Directive 2004/26/EC (which describes emission standards of Non-Road Mobile Machinery), also included inland waterway vessels, railcars and locomotives. This Directive lists Stage IIIA and higher. The former Directive 97/68/EC lists Stage I and II, but these earlier Stages were not applicable for these three categories of equipment. Railcars and locomotives have to comply with stages IIIA and IIIB, and inland waterway vessels have to comply with Stage IIIA. The emissions in Stage IIIA are categorized on swept volume (in liter) per cylinder. As of December 2007 vessels with a swept volume above 5 liters per cylinder were subjected to this regulation under category 'V2'. (see Appendix 2: Emission standards)

Subject	Validity year	Stage	Pending Directive
Inland waterway vessels	2005–2007	Stage IIIA (V1, V2)	Directive 2004/26/EC
Inland waterway vessels	withdrawn	Stage IIIB	-
Inland waterway vessels	2016	Stage IV	-

Besides the European Directive, the 'Central Commission for Navigating on the Rhine' (CCNR) has introduced emission standards known as 'CCNR Stage I' and 'CCNR Stage II'. CCR Stage I (abbreviated as CCR1) was valid until 30 June 2007. CCR Stage II (CCR2) is valid as of 1 July 2007. The emissions in CCR are categorized on rated engine power in kilowatts. The standard of CCNR is more stringent, so an inland vessel that is compliant to the 'CCR2' standard also is compliant to the applicable Stage IIIA emission standard. In general, CCR regulations are applicable in 'Rhine States' and Belgium, and the European Stage IIIA (V1 and V2) regulations are applicable in all European inland waters.

Subject	Validity year	Stage	Pending Directive
Inland waterway vessels	Jan. 2003	CCR Stage I	CCNR
Inland waterway vessels	Jul. 2007	CCR Stage II	CCNR
Inland waterway vessels	withdrawn	CCR Stage III	CCNR
Inland waterway vessels	2016	CCR Stage IV	CCNR

The next CCR Stage 3 (CCR3, amending CCR2) was intended to be in force as of 2012 but has been withdrawn even before the introduction in 2012. This was due to unsuccessful discussions between European Member States, engine manufacturers and the 'Centrale Commissie voor de Rijnvaart' (CCR) to set up a proposal for the CCR3 emission standard. The discussion reached the initial introduction date in 2012 very close, so they decided to withdrawn CCR3 and focus on the forthcoming CCR4. It is generally expected that Stage 4 (CCR4) will be put into force as of 2016.

'Stage IIIA (EU)' has a strong linkage to 'CCR2', which is also the case with 'Stage IIIB' and 'CCR3', and 'Stage IV' and 'CCR4'. Due to the withdrawn CCR3 standard, also the European Stage IIIB will be skipped. In 2016 a new stricter emission standard will be introduced as CCR4 and/or Stage IV for inland waterway vessels. Up to 2016 the current Stage IIIA will be still into force. [103]

The new CCR4 and/or Stage IV for inland waterway vessels have not yet been approved. By the end of 2012 the European Commission should have reviewed possible Stage IV emission limits for inland waterway vessels. [68] Many sources, as TNO, report the following limits in advance:

Stage	Validity year	NOx	PM
CCR3-standard (withdrawn)	2012	4,8 – 5 g/kWh	0,11 – 0,14 g/kWh
CCR4-standard (not definitive)	2016	0,025 – 0,04 g/kWh	0,4 – 1,8 g/kWh

The Municipality of Amsterdam reports that the European Commission has instructed the 'Centrale Commissie voor de Rijnvaart' (CCR) to stop developing the CCR-standard. Since inland waterway vessels are part of the 'Non-Road Mobile Machinery' (NRMM) and thus should follow that development. [104] If this is true, it will mean that the next standard in 2016 will be introduced as 'Stage IV' for inland waterway vessels.

These developments mean that the inland waterway sector will tighten the deviation in emission standards just in 2016. But at current, still many inland waterway vessels do not comply with the CCR2 standard. It is expected that in 2016 a significant larger amount of vessels cannot comply with the tighter CCR4. This is due long 'write off' periods, high investment costs for new engines and poor economical situation of inland shipping. [105]

Shipping

The Port of Bremen described: "ship emissions are a significant source of pollutants, especially as the quality of fuels is far lower than the standards which apply on land. Sulphur dioxide (SO_2) and carbon dioxide (CO_2), nitrous oxides (NOx) and soot particulates (PM) not only have a local impact, but also disperse over large areas, contributing to climate change and promoting the increase of nutrients in rivers and lakes as well as soil acidification." [24]

For the emissions of shipping there are two European Directives that regulate sulphur emissions by limiting the sulphur content of marine fuels (heavy fuel oils and gas oil). Directive 1999/32/EC was amended by Directive 2005/33/EC. It designated certain areas in the EU as 'Sulphur Emission Control Areas' (SECA's). Besides European regulation also the MARPOL (International Convention for the Prevention of Pollution from Ships) applies. EU has been active in IMO discussion on tightening emission standards in Annex VI. Annex VI of MARPOL contains regulation of Sulphur emission and is agreed by IMO (International Maritime Organization) in 2011. It is expected that Annex VI enter into force as of January 2013. The table below shows the allowable amount of sulphur content of marine fuels by mass:

Sulphur limit	Validity year	Applicable area
1,5% sulphur limit by mass (1)	Aug. 2006	In Baltic Sea
1,5% sulphur limit by mass (1)	Aug. 2007	In Baltic Sea, North Sea and English Channel
0,1% sulphur limit by mass (1) (2)	Jan. 2010	In inland waterways and at berth or anchorage
0,1% sulphur limit by mass (3)	2015	In (new designated) ECA's (4)
0,1% sulphur limit by mass (3)	2015	In 12-mile zone of EU coasts
0,5% sulphur limit by mass (3)	2020	Outside (new designated) ECA's (4) but in EU-waters

1. The sulphur limit is 1,5% by mass of marine diesel oils sold in EU, and 0,1% by mass of marine gas oils sold in EU

2. Under certain conditions abatement technology is allowed, but provided that these ships should achieve emission reductions that are at least equivalent (it is not clear whether gas cleaning systems will still be allowed with the 2015 and 2020 limits.)

3. MARPOL Annex VI regulation adopted by IMO

4. The MARPOL Annex VI amendment allows designation of pollution control areas for SOx, NOx and PM emissions from shipping. These areas will be called 'Emission Control Area' (ECA) instead of 'Sulphur Emission Control Area' (SECA). 'Exclusive Economic Zones'

MARPOL Annex VI contains emission limits for outside SECA's / ECA's. For the purpose of the Assessment of port environment this is not included in this report. More information can be found on the IMO-website. [85]

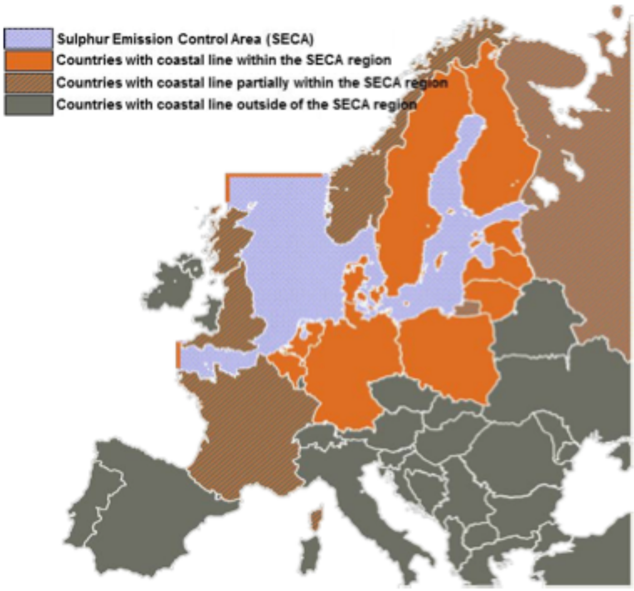


Figure 5 *SECA waters in purple, countries with SECA coasts in Orange and Brown.*

> SECA's are obliged by the European Union. There are ports located in the SECA area and ports outside these areas. For that reason only measures that shipping lines have been taken or a port takes on ship's emission reduction can be measured and assessed.

5.2.4 Fuel quality

EU Legislation (Directive 2009/30/EC) requires a reduction of GHG intensity of the fuels by up to 10% in 2020. Reduction by means of Carbon Capture and Storage (CCS) and by Clean Development Mechanism (CDS) is allowed. Reductions will be calculated from a 2010-baseline of fossil fuel greenhouse intensity. As well certain criteria are set for GHG emission reduction of biofuels. As of 2018 a biofuel should have 60% lower GHG emissions than a 'fuel competitor' (non-biofuel). The calculation should also take direct land-use (land occupied for biodiesel production) and indirect land-use (land occupied for agriculture elsewhere due to biodiesel production) for biofuel production into account. [70]

> Fuel quality is not taken into account. The use of alternative fuels as (ultra) low-sulphur, LNG, biofuels and additives are assessed by the 'share of total'. Secondly the demand can be assessed.

5.2.5 Carbon Dioxide emissions

The greenhouse gas emissions of vehicles, mobile machinery and shipping are very scattered and non-consistent. In the 'short term' the European Union has to comply to the 20% GHG reduction as agreed in the Kyoto protocol, but nevertheless there is no general 'guideline' how these reductions should be spread over the different sources in the transport sector.

For light-duty vehicles as normal road cars and vans there is extensive and strict regulation for both CO2 emission and fuel consumption per distance travelled. However, while heavy-duty vehicles are responsible for roughly a quarter of the CO2 emissions of road transport in the EU, currently there is no regulation on CO2 emissions or fuel consumption. The amount of heavy-duty traffic is still rising. The European commission is working on a 'comprehensive strategy' to reduce the CO2 emissions from these vehicles, this is also mentioned in the '2010 Strategy on Clean and Energy Efficient Vehicles'. [71]

To give an idea of CO2 limits, the numbers for light duty vehicles are added to Appendix 2: Emission standards

For shipping there has been a recent regulation on sulphur emissions, see section 4.2.3. Unfortunately there is currently no such a regulation for GHG of shipping. Maritime transport emissions account internationally for approximately 3% of the global CO2 emissions and will double by 2050 without sufficient regulation. The European Union states: "despite many years of efforts, in particular in the IMO and the United Nations Framework Convention there has been no agreement on an effective global approach to regulating these emissions. Although considerable efforts are being made, progress so far has been limited." [72]

> Carbon dioxide emissions can be estimated (by calculations) or measured in the port area. Since no clear regulation (for shipping and heavy-duty vehicles) is applicable it is difficult to assess when a port is performing 'well' or 'moderate'. An industry average can be used for assessment.

5.2.6 Measuring

The main, or significant, emissions that can be measured in port areas are carbon dioxide (CO2), nitrogen dioxide (NO2), sulphur dioxide (SO2) and particulate matter (PM). Besides extensive calculation that can be performed on the emissions of equipment and vessels, the manner of operation will define the total emissions in the end. The average fuel consumption from specifications of equipment is generally not the same as the actual fuel consumption due to the human factor (fast acceleration, etc.) and ageing of equipment. [40, p13] To measure the emissions of a port over a certain period in a quantitative way, air-measuring stations are necessary.

Air-measuring systems commonly used in ports measure the following concentrations: SOx, NOx, PM10, PM2.5, O3, CO. These concentrations are measured in µg/m3 and recorded on an hourly basis. This information can be presented in reports or real-time via websites. Examples of these websites give indications of local air quality indicating from good, reasonable, fair, poor to very poor. The data informs on the times per year that maximum concentrations are exceeded and helps to find critical sources. Sometimes the European air quality standards are not met. This happens occasionally in western countries on PM10 and NO2. And can be partly caused by a high population density, dense road networks, concentrated industrial zones and air pollution from other countries. [27]

> - Estimating or measuring gives a good indication how a port performs. This can be compared with the national air quality standards, which gives a 'delta' of how well the air quality actually is.
> - Sometimes it is preferred to calculate in terms of CO2 equivalence, SO4 equivalence, PO4 equivalence or HC equivalence. This is particularly when emissions are (or should be) investigated specifically on the effect of climate change, acidification, eutrophication or carcinogenicity.
> - Each location has specific problems (e.g. concentrations that are regularly exceeded) with certain emissions. For that reason it is more suitable to calculate the amounts of those emissions (and thus incorporating the local environment), rather than calculating all emissions to an equivalent factor. For example, an extra 'weight factor' can be added to 'problematic emissions'.

5.3 Emission to local environment

Environment, Habitats and Birds
On European level there is a Directive (92/43/EC) of 1992 on the conservation of habitats and of wild flora and fauna, known as 'Habitats Directive'. This version was updated in 2007 by incorporating a 'Birds Directive' (2009/147/EC). [73]

National regulations on environmental protection differ from country to country. In the Netherlands it is agreed with the European Commission that land reclamation can be compensated with protected areas at sea or development of protected dune areas. [32] As with many industries an Environmental (Impact) Assessment (EIA) has to be performed to "ensure that plans, programs and projects likely to have significant effects on the environment are made subject to an environmental assessment". [74] The result shows the positive and negative influences on the local environment, and from that possible measures can be obliged to reduce impacts. As with national regulations these reports have to be performed for a specific port or industrial area. The Directive 2011/92/EU ("assessment of the effects of certain public and private projects on the environment") indicates criteria and characteristics that have to be reported on.

> The environment is very port specific. Although different items can be quantitatively measured. See Appendix 6 section 'Environment'.

Water
There are many Directives concerning groundwater, pollution and prevention control. For surface waters (rivers, lakes, transitional waters, coastal waters) there applies a Water Framework Directive (2000/60/EC) with the goal to achieve 'good environmental conditions' in steps for 2015, ultimately in 2021 and with full compliance in 2027. KRW sets requirements on water quality of inland water up to coastal zones, to achieve this a management plan have to be set up per basis or area. The Directive lists quality elements for the classification of ecological status and monitoring. [33] [75] [76]

> The water quality is very port specific. Concentrations of substances can be measured, as well as water demand. See Appendix 6 section 'Water'.

Noise
On noise emission there is a European Directive 2002/49/EC ('assessment and management of environmental noise') and legislation on national basis as the 'wet geluidshinder' in the Netherlands.
The latter describes a several limits to noise around industrial areas. Depending on the 'use zone plan' ('bestemmingsplan') the noise limit has been set at 50dB(A), for projected houses 55dB(A) and homes under construction 60dB(A). (Wet geluidshinder, Chapter V, Art. 40, 44 and 45).

According to the World Health Organization (WHO) the sound pressure levels at the outside façades of living spaces should not exceed 45 dB inside and 60 dB outside during night-time, so that people may sleep with their bedroom windows open. These values have been obtained by assuming that the noise reduction from outside to inside with the window partly open is 15 dB. [36] [43] The European Commission Directive 2002/49/EG states that the maximum allowable levels of sound pressure in residential / urban areas is defined in ISO1996-2:1987. This ISO standard lists 40dB(A) during night-time since there is no sufficient evidence that biological negative effects are observed with levels below this value, this is a average sound level determined over all the night periods in a year.

The World Health Organization (WHO) has published an extensive report on noise in 1999 ('Guidelins for Community Noise). According to the report noise exceeding 45 dB(A) should be limited during night-time to prevent sleep disturbance. Levels around 50-55 dB(A) cause people to be annoyed during daytime and levels exceeding 80 dB(A) increases aggressive behavior.

For residential homes a sound pressure level of 30dB(A) in bedrooms is advised for continuous noise and 45 dB for single sound events. During daytime the continuous noise should not exceed 55 dB(A), while 50dB(A) is better.

	Time base	L_{Aeq} – equivalent	L_{Amax} – maximum
Sleep disturbance (night-time), inside bedroom (3)	8 h	30 dB(A) (1)	45 dB (2)
Sleep disturbance (night-time), outdoor values (3)	8 h	45 dB(A) (1)	60 dB (2)
Serious annoyance (daytime and evening)	16 h	55 dB(A) (1)	-
Moderate annoyance (daytime and evening)	16 h	50 dB(A) (1)	-
Industrial / traffic areas – hearing impairment	24 h	70 dB(A) (1)	110 dB (2)

1. L_{Amax} = maximum level of individual sound events
2. L_{Aeq} = continuing sounds from road traffic, industrial noise, ventilation systems in buildings, etc. *Source:* [43]
3. Levels for 'sleep disturbance' measured at Façade Level (see Appendix 5: Noise measurement)

Reference [41, p78] shows that equipment in port areas on average produces 99 dB(A) (Automated stacking crane) up to 112 db(A) (Straddle carrier). In this report several container terminal layouts were proposed with sound pressure levels between 102,1 dB(A) and 113,8 dB(A). [41, p87] To reduce hearing impairment of employees the sound pressure level should always below 110dB(A). [43] An equivalent sound pressure level for 8 hours of 85dB(A) is the obliged limit for unprotected occupational noise exposure, beyond that limit passive hearing protection is obliged. (4h of 83dB(A) without protection is allowed, if during the following 4h the sound pressure level doesn't exceed this 83 dB(A)). [77] If the sound pressure level at residential homes exceeds the guideline, depends on the distance between the port (or noise source) and residential area. Secondly noise-reducing measures as screens, trees or hills can lower the sound pressure levels for the surroundings as well. As a comparison, data collected from densely travelled roads show equivalent sound pressure levels for 24 hours of 75 – 80 dB(A). [43]

An explanation of the abbreviations for the different 'sound pressure levels' and measurement methods are given in Appendix 5: Noise Measurement.

> The European Directive and WHO report show clear sound pressure levels that should no be exceeded. These numbers form a good benchmark to the performance of a port on noise. Measures to reduce noise emissions mainly have a qualitative character (applied: yes or no).

Light

In Europe there is no general regulation on light emissions, -pollution and/or intensity. The only regulation for light emission is applicable for greenhouses (horticulture). The 'environmental protection act' ('wet milieubeheer') [86] in the Netherlands states that companies have the obligation to:

- Prevent light emission to the environment to the maximum extent possible
- Protect dark surroundings that are allocated by authorities

Both of these statements have a voluntary character and do not oblige port authorities to present light emission to certain levels. Lowering the level and amount of lighting has an energy saving potential, and thus helps to save costs. However safety control and work environment ask for more lighting. [58] It is a contradiction that has to be weighted in importance. From a sustainability perspective the lowest amount of light has preference.

> The measures relating to light can have beneficial effects on energy use, ecology and cost. Brighter/light colored road surfaces reduce the amount of lighting required (dark colors 'absorb' light, it is comparable to the light effect of snow in wintertime), although reflection of light to the surroundings increases.

6. Sustainability assessment

6.1 Explanation

Sustainability in the port area means that every effort has to be taken to eliminate the use of natural resources and to protect the environment, both direct and indirect. But sustainability is more comprehensive than eliminating emissions alone. In Chapter 4 the 'best practices' on sustainability of ports were combined into an extensive list (see Appendix 6) of possible sustainable actions. This list is included in Appendix 6 and forms the basic framework for the 'Proposed Assessment Method' for sustainability of ports and its operations, as presented in this Chapter.

The same categorization is used as was presented in section 4.1 (Figure 3). The items from the list in Appendix 6, which can be applied to any kind of terminal, have been used. The 'performances' of these items can be measured on an absolute basis (for the port itself) or on a relative basis (as comparison to applicable regulations or sector's average). Also qualitative items are included which are difficult to quantify in 'numbers', but can be checked on their 'appearance' or 'application'.

During the research it turned out that comparing two ports on a 'degree of sustainability' is very difficult and introduces many limitations. The PPRISM project, as discussed in section 2.4.3, is a good example that general 'performance measurement' is difficult. From a list of 125 indicators that were initially proposed in the project, only 7 feasible indicators remained at the end of the project. These 7 indicators (energy consumed, carbon footprint, water consumption, amount of waste, use of environmental management system, -aspects inventory and –monitoring program) are very generic and describe 'sustainability' in a very basic degree. One even might ask whether these 7 indicators alone are sufficient to monitor sustainable performance.

The idea of the 'Proposed Assessment Method' is that a port can check whether it has done sufficient efforts on sustainability, by looking at the 'pollutant sources'. The assessment shows what state-of-the-art measures still could be taken to lower the environmental impact and learns how good current practice is. For example, based on what has been done or achieved in other ports. The best way to achieve sustainability is by lowering the environmental impact of 'pollutant sources' (the cause of pollution). This is a contrast to taking all kinds of 'preventive measures' to lower various environmental impacts (the effects of pollution), without considering the 'sources'.

The next section 6.2 describes some limitations of measuring sustainability, and denotes some difficulties in measuring and comparing. Section 6.3 gives some examples for calculation of emissions, energy consumption, etc. from various sources, which are used in the assessment. The 'Proposed Assessment Method' itself, based on the categorization of section 4.1, is presented in section 6.4.

6.2 Limitations

There are some characteristics that by definition won't lead to a higher degree of sustainability when increased, these are: port size and port throughput (TEU's or million tons). Scaling them down will lower the environmental impact, but that is for both economical and practical reasons not a preferable solution. Also the type of terminal determines the environmental impact in some degree. But this is an aspect a port wouldn't change to become more sustainable. The port size and throughput are included in the 'Proposed Assessment Method' on an absolute basis and for comparison to other items on a relative basis.

In section 2.3 is presented that only 33% of the European ports measure or estimate their carbon footprint [37]. This assessment of sustainability should include 'real' emissions or estimation of the emissions to describe the air quality in and around the port area. To do so, a port has to perform these air measures. This means that (100% – 33% =) 66% of the remaining ports in Europe should start to measure or estimate their carbon footprint in the future.

‘Reduction’ is a very widely used term to inform that a product or service (in this case a port) is more environmental friendly. But what is the use if different benchmarks are used to estimate these reductions? Replacing very polluting vehicles (EURO I for example) by cleaner ones will result in massive ‘reductions’, but a port that already has state-of-the-art vehicles (EURO V) for many years may perform even better although they cannot report on ‘reductions’. The term ‘reduction’ is very subjective and referring to a non-comparable standard. This assessment will use emissions per tons of throughput (or per TEU) and air quality limits as benchmarks, since they are comparable between ports.

Secondary to ‘current reduction’ are ‘future reduction goals’. It is often heard that a company aims to lower its carbon footprint by, for example, 30% in 2020. As with ‘reduction’ in general, here also applies that there is no clear baseline. If the company performs ‘poor’ on carbon footprint an aim of 30% reduction requires moderate efforts, while for a ‘good’ performing company this might require a tremendous amount of effort. It is a subjective statement if a company only reports in this way.

‘What to include and what not to include’ is a question that is difficult is some ways. Imagine a port that replaces all the current vehicle fleet by BEVs (Battery Electric Vehicles). In this way emissions will be significantly lower as before, but buying a new fleet and discarding the older fleet will result in indirect emissions from manufacturing and discarding ELVs (End of Life Vehicles). Are these indirect emissions always included? Unfortunately, the answer will be ‘no’ since much decisions are based on costs, not on the emissions of the total lifecycle. This ‘Proposed Assessment Method’ includes ‘only’ current emissions, but when replacing vehicles the total life cycle should be taken into account. (See calculation of replacing a vehicle in the next section)

Another example: truckers and railroad companies. What decision is being made if a more pollutant company with lower costs is compared to a ‘greener’ company that is more expensive? Would this decision change if you will be more expensive than competitors in the same market, due to selecting a ‘greener’ company? The difficulty here is that obligating ‘sustainability’ to transportation companies could lead that a port prices itself out of the market. And economics will prefer over the environment. But a careful selection of transportation companies can make a difference. A sustainable port shouldn’t accept any polluting vehicles. The ‘Proposed Assessment Method’ will include the air quality in the port area, and thus being influenced by the emissions of visiting transportation companies as well. (Not only emissions of the port alone). The air quality is a measure that should take into account: the national emission ceiling (NEC), air quality standard (concentrations), the focus or emissions of concern in the area (NOx and PM in western countries) and local air quality standards.

On-shore power is often designated as ‘the solution’ to lower emissions from vessels at berth. This is partly true since the application has limitations. The installation of such equipment on both the vessel and on the quay requires a large investment. Some reports have indicated that on-shore power will not be cost-efficient in the short-term. [1] [24] [30] For vessels frequently calling at the same port it might be an option to invest, but there is a large amount of ports receiving much different vessels. They cannot oblige all shipping lines to install in-board installations, besides there is the difficulty in voltage/current-deviations (50Hz-, 60Hz difference, for example). If a port should oblige it, shipping lines will simply moor in another port that has less strict rules. [59]

6.3 Calculation examples

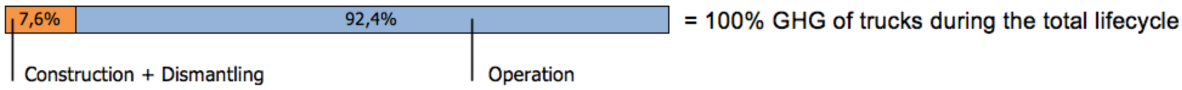
This section gives some calculation examples for some of the ‘required’ numbers in the ‘Proposed Assessment Method’.

Greenhouse Gas reductions from hybrid and electric drives

New technologies as hybrid drives allow to lower fuel consumption, and full electric drives allow to get rid of fuel use completely. These options are of particular interest for port equipment since they can lower the total emissions of the port. The question is whether and when the current operational equipment should be retrofitted or replaced, both from an economical (savings from fuel consumption) and environmental (reduction of emissions, materials) point of view. A small example of how ‘life cycle’-decisions could be made based on the GHG emissions of trucks will be given here.

The European report on Greenhouse Gas (GHG) savings in 2050 [50, fig.7.5, fig.7.6] provides research details on the total amount of GHG emitted during construction, operation and dismantling of cars, small trucks, large trucks, locomotives and vessels.

The numbers indicate that 'trucks' (regardless of their size; large, medium, small) produce 92,4% of their GHG during 'operation' when considering the total lifecycle, and thus 100% – 92,4% = 7,6% of lifecycle GHG is emitted during 'construction + dismantling'. This is illustrated below:



With 92,4% of GHG emitted during operation, a reduction of 8,22% during operation (7,6% / 92,4% = 8,22%) will equal the amount of GHG emitted for 'construction and dismantling' a truck (vice versa: 8,22% reduction x 92,4% operation = 7,6%). This implies that a vehicle reducing 8,22% of the GHG from operation equals the construction and dismantling of a new cleaner vehicle. But replacing a vehicle that just equals both is of no use. It is a more logical decision to replace a vehicle if the emissions are reduced ≥ 8,22%. This is possible with new engine- or hybrid technologies.

The study [50, table 6.4] also lists the GHG emissions in tons of the total lifecycle for different technologies. Hybrid Electrical Vehicles (HEVs) and Battery Electrical Vehicles (BEVs) contain batteries, electric motors and many electronics that increases the amount of GHG from construction, but also for dismantling the End-of-Live Vehicle (ELV). For a medium truck with conventional engine the total lifecycle GHG is 16,76 tons of GHG, with hybrid technology it is 18,44–20,96 tons of GHG (depending on size of battery; for example, a Plug-In Hybrid Electrical Vehicle (PHEV) has a larger battery), with a full electric drive it is 29,34 tons of GHG. The latter is almost double the amount of GHG in comparison to a conventional (Internal Combustion Engine) fuel powered truck, but this number is due to indirect emissions from 'grey' energy production. The numbers are estimated by using 'grey electricity' with the current limited share of renewable energy (solar, wind, water) in the overall energy consumption. This share is likely to increase in the coming tens of years. Hence, the difference between GHG emissions from BEVs and conventional vehicles will decrease. [50]

When considering production separately, the GHG emissions will rise with 10% for HEV (Hybrid Vehicles), 25% for PHEV (Plug-In Hybrid Vehicles) up to 75% for BEV (Battery Electric Vehicles). This has to be incorporated in a lifecycle calculation for GHG for vehicle replacement.

An example to illustrate the numbers above:
(GHG during operation = 92,4%, GHG for construction + dismantling = 7,6%)

A port has a several Straddle Carriers that are already 5 years in operation. What GHG reduction should be achieved by replacement with Plug-In Hybrid Electrical (PHEV) Straddle Carriers, with taking the total lifecycle into account?

- Assume that the economical lifetime of the vehicles is 15 years. They are 5 years in operation. So, they have already produced 1/3rd of the GHG during operation:

  (1 – 1/3) x 92,4% Lifecycle GHG = 61,6% Lifecycle GHG is left during the remaining 10 years;

- Construction + Dismantling of an PHEV (plug-in hybrid) is:

  *7,6% production GHG * 1,25 (+25%) = 9,5% production GHG*

- A minimum reduction of GHG should be:

9,5% production GHG / 61,6% remaining GHG= 0,1542 => 15,42%

The calculation shows that replacing the Straddle Carriers with PHEV-technology require at least 15,42% reduction in GHG to equal the GHG emitted from 'construction + dismantling'.

The economical factors (purchase cost vs. cost benefit of lower fuel consumption) are not included and prevail in many cases. Also the (re)use of materials is neglected in this calculation. The lifetime of a vehicle assumed by [50] is 238.000km. Other emissions as SOx, NOx and PM are not taken into account.

Materials

During vehicle manufacturing and disposal there are Greenhouse Gases emitted, as shown in the example on the former page. Some future technologies will have significantly higher emissions, as battery electric and hydrogen fuel cell cars. This is also dependent on the type and size of battery and electrical systems used. At current 60% of the emissions of production are due to the use of materials, and it is likely that these will rise with future technologies as electric- and fuel cell drives [50, p77]. Therefore careful selection of materials and incorporate higher recycling rates help to lower these predominant emissions from vehicle manufacturing.

Primary production with materials from mining will have the highest CO2 emissions per kg material produced. For flat carbon steel this is 2,355 kgCO2/kg material and cast iron 2,005 kgCO2/kg. The production of aluminum requires a lot of electrical energy, which results in 9,667 kgCO2/kg material. When compared to flat carbon steel this is four times as much.

- The production of carbon steel from recycled material emits 0,884 kgCO2/kg material, which reduce: *100% – (100% x 0,884 kgCO2 / 2,355 kgCO2)* ≈ 62% of CO2.
- The production of cast iron steel from recycled material emits 0,534 kgCO2/kg material, which reduce: *100% – (100% x 0,534 kgCO2 / 2,005 kgCO2)* ≈ 73% of CO2.
- The production of aluminum from recycled material emits 0,506 kgCO2/kg material, which reduces a remarkable: *100% – (100% x 0,506 kgCO2 / 9,667 kgCO2)* ≈ 94,5% of CO2!

Source: [50, table 2.2, table 2.3]

The recycling of aluminum has, from all metals, the largest savings in CO2 emissions and energy. Aluminum from recycling requires only 5% of the energy and produces only 5% of the CO2 emissions compared to primary aluminum production. In the production process also 6kg of bauxite and 4kg of chemical products are saved. Aluminum is therefore the most cost-effective material to recycle, due to the energy savings compared to primary production. For this reason it is important, when applying aluminum, that the material has a large recycled content.

All metals, including aluminum, can be recycled indefinitely since reprocessing does not damage the metal structure of the metal. This is a large advantage since materials as 'concrete' and 'asphalt' can only be reused in new structures as additive. Thermoplastics can be recycled but the quality of the material will generally decrease. This common fact is called 'low-value added material recycling' (or in popular terms: 'downgrading'). Thermosets are not recyclable at all and can only be used for 'energy recovery' (recover the calorific heating value of the material, instead of landfilling).

When a port purchases equipment or other products (or buildings) that contain large amounts of materials, they should pay attention that the materials applied have a large share of recycled content.

An overview of the CO2 emissions of primary material production, recycled material production, average material production and current recycling rates are included in Appendix 4 ("CO2 emissions from energy- and material production'). These numbers give an indication what CO2 emission reductions are possible when selecting materials that have a higher recycled content.

Power plants

The electrical energy that is produced from a 'conventional' coal/gas fueled power plant is named 'grey electricity'. [41] For electrical energy that is produced from renewable sources as solar, wind and water is named 'green electricity'. The CO2 emissions per kWh from electricity generation vary enormously depending on the 'fuel mix' of different countries. There are some drawbacks rising from these fuel mix indices. The data of 'energy only' output of a Combined Heat and Power plant (CHP) in terms of CO2 is difficult to obtain, which implies that countries having large amounts of district heating will generally see a higher energy efficiency (lower CO2 emission) than countries with less district heating. [55, p39] The data from the International Energy Agency (IEA, [55, p111]) has been corrected by introducing a methodology to calculate the share of CO2 emission from electricity generation in CHP plants, but still contains some assumptions. An overview of the CO_2 emissions per kWh for various countries is included in Appendix 4 ("CO2 emissions from energy- and material production').

The emissions from 'grey' and 'green' electrical energy consumption per kWh are given in the table below. The data is applicable for electrical energy in The Netherlands.

	CO2	SO2	NOx	PM
'Grey' Electricity	415–566 g/kWh(1)	0,425 g/kWh	0,150 g/kWh	0,0 g/kWh
'Green' electricity	0,0 g/kWh (2)	0,0 g/kWh (2)	0,0 g/kWh (2)	0,0 g/kWh (2)

1 566g/kWh (2007, [57, p21]), 520g/kWh (2009, [42, p4], 415g/kWh (2010, [55, p111])

2 zero emission based on current energy production, emissions from manufacturing/construction not included!

Fuel consumption

The emissions from diesel and CNG fuel consumption per liter are given in the table below.

	CO2	SO2	NOx	PM
Diesel (1)	2618 g/l (2)	0,714 g/l (2)	19,6 g/l (3)	0,245 g/l (3)
Conventional gas (4)	1780 g/m3	0,016 g/m3	0,550g/m3	≈ 0,0 g/m3

1 source: CO2+SO2 [41, p156], NOx+PM [41, p73], the numbers are regardless of any exhaust gas treatment system and/or fuel additive. A ULSD will emit less SO2 than presented here.

2 CO2 and SO2 emissions based on fuel with 84% carbon content and 0,042% sulphur content

3 NOx and PM emissions based on Stage IIIB standard, and conversion of 1l diesel = 9,8 kWh [41, p156]

4 source: CO2+SO2+NOx [57, p21], SO2+PM [22], regardless of any exhaust gas treatment system

Since LPG has a lower caloric value (MJ per liter), the fuel economy of LPG is on average 20% lower when compared to diesel or petrol (in general 15–25% is reported by various sources). Also the composition (butane and propane) of LPG has influence on these numbers. A vehicle on LPG will consume 20% more fuel. On the other hand, the price of LPG is significantly lower than diesel or petrol. This is also due to low excise (duty) on LPG. In the Netherlands this is 'only' 9%, which is a contrast to diesel (36%) and petrol (50%). [100] This cost benefit of using LPG should be weighted against the investment of a LPG installation in a vehicle.

GHG emissions from fuels and energy including refineries

A significant consideration is the inclusion of Greenhouse Gas emissions of the refinery in the total fuel chain emissions. Including this in known as 'Well-to-Wheel' emissions. In many cases the GHG emissions are calculated from the fuel as basis. However there is noticeable part of indirect GHG emissions (17-19%) that is 'neglected' in this way. The total chain consists of:

Well-To-Wheel (WTW) = Well-To-Tank (WTT) + Tank-To-Wheel (TTW)

'Tank-To-Wheel' (TTW) is the general applied consideration of fuel from vehicle tank (tank) to the vehicle's emission (wheel). 'Well-To-Tank' (WTT) is the indirect part of fuel emissions from resource recovery (well) at the refinery to the vehicle tank (tank). It includes emissions from production of fuels as recovery, refining and blending, storage and transportation of fuels. On average the WTT emissions account for 17-20% of the total WTW fuel emissions. But due to new (cleaner) technologies this share is likely to decrease in the future. [109] [110] The total fuel chain is called 'Well-To-Wheel', and integrates both WTT and TTW. The numbers for 'Tank-To-Wheel' (TTW) and 'Well-To-Wheel' (WTW) are presented in the table below, alongside the percentages of 'Well-To-Tank' (WTT).

Oil refining is a very complex production system in which it is difficult to estimate the exact and correct WTT GHG emissions. Source [110] lists the GHG emissions of crude oil extraction from different countries. A deviation is observable between fuel productions in different countries. The largest GHG emissions are found in Nigeria, Oil sands in Canada (not 'conventional' production) and Angola. They are almost double of the 'weighted average' in the world. The lowest GHG emissions are found in Iraq, Kuwait and Saudi Arabia. 'Well-To-Tank' (WTT) emissions are calculated on a 'world average' level.

Fuel [(1)]	GHG emissions (TTW)	GHG emissions (WTW)	WTT percentage
Gasoline	≈ 2400 g/l	2780–3170 g/l	≈ 19–20%
Diesel	≈ 2600–2700 g/l	3135–3190 g/l	≈ 17–18%
Diesel (5% Biodiesel)	[(2)]	3140 g/l	≈ 17–18%
LPG	≈ 1600 g/l	1796–1860 g/l	≈ 10–15%

1. Data based on [106] [107] [108], 2011-data CE Engineering Delft, Essent
2. Incomplete data

More or less the same applies for energy. When considering 'green electricity' the GHG emissions of production, transportation and construction of renewable energy sources (as wind mills or solar panels) are normally not taken into account. Reporting a zero emission per kWh (0 gCO2/kWh) is basically comparable to a 'Tank-To-Wheel estimate' with fuels. When the indirect emissions are included it can be seen that 'green electricity' does produce some GHG emissions over its lifetime. Although, compared to 'grey electricity' (from coal or gas) the numbers are very low.

Electricity [(1)]	CO2 (current output)	CO2 (total chain)
Grey electricity: coal, gas	415–566 g/kWh	[(2)]
Green electricity: wind power	0 g/kWh	15–19 g/kWh
Green electricity: water power	0 g/kWh	15 g/kWh
Green electricity: solar power	0 g/kWh	50–168 g/kWh

1. (Based on 2011 data from CE-Delft, also reported by energy producer Essent, Netherlands)
2. Incomplete data

The GHG emissions are equally spread over the lifetime of the particular renewable source. For a windmill it might be 15 years, a solar panel can have a 30-year+ lifetime. Continuous developments in efficiency and lifetime will certainly reduce the GHG emissions of renewable sources in the future on a continuous basis. For this reason the numbers for WTW have to be redefined every few years. The numbers as presented here are the state-of-the-art (2011-data).

For carbon footprint estimation the Well-to-Wheel emissions of the total fuel chain should be taken into account when calculating the emissions of a particular vehicle. Data for NOx, SOx and PM of 'Well-to-Tank' (WTT) emissions or from renewable energy production are too scarce and incomplete to report at this moment.

Fuel consumption calculation for equipment

There are different approaches to determine the 'fuel utilization rate' (the amount of fuel that one type of equipment utilizes). Reference [42, p5], for example, has calculated it in 'fixed consumption per container move' and 'variable consumption per kilometer driven'. In this report, a way to calculate the 'fuel utilization rate' per hour is presented. This can be used to determine the amount of CO2 of equipment. The 'fuel utilization rate' of average hourly fuel consumption can be calculated with: [8, p17]

***Fuel utilization rate** (l/h) = total fuel utilized (l) / total hours of utilization (h)*

Or the 'fuel utilization rate' for an entire group of equipment [8, p17]:

***Group fuel utilization rate** (l/h) = Σ total fuel utilized by group (l) / Σ total hours of utilization for group (h)*

Examples of 'fuel utilization rates' (l/h), mainly for equipment operating in container terminals, are provided by references [40, p16] and [41, table 15] in the table below:

Equipment	Fuel utilization rate	Powertrain	Source
Terminal Tractor	8 l/h	Diesel	[41, table 15]
Tractor trailer (TT)	10 l/h	Diesel	[40, p16]
Multi-Trailer System (MTS)	14 l/h	Diesel	[40, p16]
Shuttle Carrier (ShC)	22 l/h	Diesel	[40, p16]
Shuttle Carrier (ShC)	16 l/h	Diesel-electric	[40, p16]
Automated Guided Vehicle (AGV)	6–7 l/h	Diesel-electric	[40, p16]
Empty handler	8 l/h	Diesel	[41, table 15]
Reach Stacker	11 l/h	Diesel	[41, table 15]
Straddle carrier	27 l/h	Diesel	[41, table 15]
Rubber Tired Gantry Crane (RTG)	29 l/h	Diesel	[41, table 15]
Rail Mounted Gantry Crane (RMG)	140 kWh/h	Electric	[41, table 15]
Mobile Harbor Crane	40 l/h	Diesel	[41, table 15]
Ship-to-Shore crane	200 kWh/h	Electric	[41, table 15]

The 'fuel utilization rates' (l/h) can also be calculated for other port transportation- and handling equipment as Inland Vessels, Barges, Railroad Locomotives, Heavy-Duty Vehicles (trucks), Excavators, Stackers / Reclaimers, Scrapers, Reloaders, Conveyor Belts, Pumping equipment (pipeline systems), Fork-Lift Trucks, Stacking Cranes, Top handlers, Overhead Bridge Cranes, and so on. A port should take sufficient effort to estimate, or oblige manufactures to report, the 'fuel utilization rates' of equipment.

To determine **energy associated with the propulsion of (inland waterway) vessels**, the following equations can be used. [16, p32-33]

Energy consumed *(kWh) = MCR (kW) x LF (-) x Activity (h)*

MCR = maximum continuous rated engine power available (kW)
LF = load factor (%)
Activity = activity of engines at given load (h)

The load factor can be estimated with:

LF *= AS / MS*

LF = Load factor (%)
AS = average ship speed (knots)
MS = maximum ship speed (knots)

An the activity can be estimated with:

Activity *= D / AS*

Activity = activity (h)
D = distance (nautical miles)
AS = average ship speed (knots = nautical miles / h)

Emission calculation

The 'fuel utilization rate' can be used 'vice versa' to calculate the fuel that is consumed by a single type and piece of equipment [41, p211]:

> ***Fuel use*** *(l) = working hours (h) x fuel utilization rate (l/h)*

The 'fuel utilization rate' can be obtained, for example, from the table on the former page. And used to calculate the CO2 emissions for electric equipment as, for example, a Harbor Crane. [41, p161]

> ***Total CO2 emission*** *(kgCO2e) = total working hours (h) x electrical energy use (kW) x CO2 emission per kWh (kgCO2e/kWh)*

Or calculate the CO2 emissions for diesel driven equipment as, for example, a Reach Stacker. [41, p161]

> ***Total CO2 emission*** *(kgCO2e) = total working hours (h) x fuel use per hour (l/h) x CO2 emission per liter fuel (kgCO2e/l)* ***x 1,25*** *(idling factor)*

The 'fuel use per hour' (l) can be multiplied with an 'idling factor' of 1,25 to accompany for engines that are not directly turned off when idling. [41, p73] This is only applicable for fuel-powered equipment, not for electric equipment. The calculation of CO2 emissions above can also be repeated with SO2, NOx and PM emissions by interchanging the 'kg emission / liter fuel' –part with the numbers in the table on the former page. The study of Geerlings, H. and van Duin, R. [42, p4] has proposed a comparable method where all equipment is combined into one equation. It basically is a combination of the two equations above for CO2 emissions from fuel- and electrical energy use, summarized for all equipment located in the port. The 'fuel utilization rate' includes the number of rides and fixed usage per ride (e.g. lifting operations). They found that in 'reality' 15% more fuel and 3,5% more electrical energy was used in comparison with their model. This was due to the organization of internal logistic processes, which can have a determinant influence on the performance. [42, p4] The model resulting from the study of Geerlings, H. and van Duin, R. [42] is more complex, because all port operations should be monitored specifically for each type of equipment. It results in a list of CO2 emissions per TEU moved for each type of equipment (in the case of reference [42]), which can be used to optimize port operation.

Water and sediment measuring

The port of Antwerp [27] lists a number of substances that can be measured in water to check the water quality. One of them is the Nitrogen concentration (< 1,8 mg N/l). The Oxygen concentration (standard quality 30 mg O2/l) is important for the Chemical Oxygen Demand (COD), a dimension for the oxygen that is needed to decompose organic material in water. [27, p104]

According to the 'Water Framework Directive' (2000/60/EC) the following set of core parameters shall be monitored in groundwater: oxygen content, PH value, conductivity, nitrate and ammonium. The Directive sets priority to 33 hazardous substances and 8 other pollutants that should be measured in waters. It sets standards to the maximum concentrations (for good water quality) of these substances. Presenting the complete list of these substances is too extensive since many of them are rarely known. The complete list can be found on the European Commission's website, reference [99].

Besides the substances also other items are important: transparency, thermal conditions (think of the increase in temperature of cooling water that is pumped back into the harbor), oxygenation and nutrient conditions (as mentioned above) and salinity of seawaters. The parameters for 'coastal waters' include biological components (composition and abundance of: biomass of phytoplankton, other aquatic flora, benthic invertebrate fauna) and morphological conditions (depth variation, structure and substrate of coastal bed, structure of the intertidal zone).

Specific polluting substances that can be measured in sediments include: Tributyltin (TBT), Acenaphthylene, Mineral oil, Benzo(g,h,i)perylene, Nickel, PCB118, Copper, Lead, Chromium, SOM 10

PAKs, Zinc, Arsenic, SOM 7 PCBs, Cadmium, Mercury. These substances include groups of Polychlorobiphenyls (PCBs) and Polyaromatic hydrocarbons (PAHs). [27, p105-106] Many of these substances are from shipping. Tributyltin, for example, is often applied as (part of) antifouling paints at ships to prevent the growth of algae.

Items that are important to measure in waters on first basis are:
- Oxygen concentration
- Nitrogen concentration
- Ammonium content
- PH value
- Polyaromatic hydrocarbons (PAH) – (when possible)
- Polychlorobiphenyls (PCB) – (when possible)

6.4 Proposed Assessment Method

The 'Proposed Assessment Method' is presented in this section. It is based on state-of-the-art 'best practices' on sustainability as listed in Appendix 6. Many of the indicators are standardized units, and generally recognized by the port sector as 'Environmental (Key Performance) Indicators'. All indicators should be suited for use, implementation and verification. Some quantitative indicators have relative values (per unit) per throughput moved, or possibly per (10.000) TEU moved, per employee, whatever is applicable. Transshipment should be taken into account when calculating quayside operations as 'reduction factor'. [59] Absolute values (total amounts) are only included to check individual port performance, since they are dependent on the specific port's size and throughput.

The indictors are generic. For example, the use of scrubbers in an engine will not necessarily mean lower emissions compared to a cleaner engine. So the use of a 'scrubbers' cannot be judged in terms of sustainability. These aspects are engine-specific, and the total amount of emissions is the key indicator in the end.

Due to continuous changing priorities in the port sector and changing regulations it is recommended that the assessment should be updated by defining the state-of-the-art of sustainability, every few years. The red colored items define the state-of-the-art (2012), which have to be redefined and/or reconsidered every few years.

The 'Proposed Assessment Method' consists of five columns:

Unit:	The unit to measure an item, TP = throughput (ton cargo, TEU, movements over quay wall), # = number, % = percentage, ha = hectare, 'value', whatever is applicable
Target:	State-of-the-art target (2012), to be redefined every few years (in 2014, 2016, etc.), lower is better (<), higher is better (>), target value (e.g. 100%)
Performance:	Current port performance on a certain item
Evaluation:	Evaluation with respect to the 'Target' in the second column, the 'Reward' in points is noted between brackets (…), there are three types to distinguish: - 'Reward' for compliance: e.g. **(2)** means: compliance to 'Target' = 2 points, not compliant = 0 - 'Reward' for degree of compliance: e.g. **(1) per 10%** means: with 30% = 3 points, with 40% = 4 points, etc. - 'Reward' for compliance to threshold: e.g. **≥80% (1)** means: with 80% = 1 point, with 79% = 0 points
Score:	Field for listing the rewards given. At the bottom one section is reserved to summarize the total score. Also one section is reserved to estimate 'degree of sustainability' percent wise, calculated with the equation: Total (%) = 100 * (score) / (max. score)

Note that the 'evaluation' factors in the assessment method are subjective. One might give other priorities. The factors should be adapted to local 'environmental issues'. For example, when a port is located near to a dense road network (highways) it is likely that NOx and PM concentrations are critical or not compliant to applicable regulations. Some sources report that a combination of a dense road network, industrial activities and air pollution from other sources make achieving the objectives of the EU air quality standard difficult. [27] Which is the case at the West ('Randstad') in the Netherlands. For ports in these areas it is preferable to add extra weight (stricter target) to these items in the assessment since they are more critical than other items.

Some ports have determined 'target' factors, e.g. CO_2e per TEU moved. These targets can be very useful for comparison and as analysis to what extent emissions can be reduced. One of the recommendations in Chapter 7 (Conclusion) is further research to estimate what emissions can be achieved in the most ideal case. Which means a 'reference port' that can serve as leading example and target. It is recommended since this data for different types and sizes of ports is not yet available.

At the end of this Chapter a 'Quick Scan' (shortened 'Proposed Assessment Method') is presented. This compact assessment is based on 22 items that describe port sustainability in a large degree. It is based on the 'Pareto Principle', which means that 20% of the items in the general 'Proposed Assessment Method' describe 80% of the sustainability in a port. The shortened 'Quick Scan' can be used as first basis to check port sustainability, before 'diving into details' of the general version.

6.4.1 Proposed Assessment Method (general)

Item	Unit	Target	Performance	Evaluation	Score
Economics & Human Resources					
Cargo throughput (TP)	Ton	Continue		-	-
Gross added value / throughput (ratio)	Ratio (%)	Maximize		-	-
Sponsorships for local community / operating result (ratio)	Ratio (%)	≥ 5%		>5% (1) or >10% (2)	
Environmental R&D / operating result (ratio)	Ratio (%)	≥ 5%		>5% (1) or >10% (2)	
On time performance (seagoing vessels)	Ratio (%)	> 80%		(1)	
On time performance (inland vessels)	Ratio (%)	> 80%		-	-
On time performance (trains)	Ratio (%)	> 80%		-	-
On time performance (trucks)	Ratio (%)	> 80%		-	-
Employment: absolute	#	-		-	-
Employment: relative	# / TP	Maximize		-	-
Employment: social capital	# / m2	-		-	-
Personnel expenses	mi EUR	-		-	-
Average age	Year	-		-	-
Share of women	%	> 20%		(1)	
				Score =	**6**
				Total (%) = 100 * score / 6 =	**100%**

Item	Unit	Target	Performance	Evaluation	Score
Air quality – emissions					
Carbon footprint (CO_2e) [3] absolute	ton	-		-	-
Carbon footprint (CO_2e) [3] relative	kg / TEU	< 17 kg [1]		–5% (2) or –10% (4)	
Eutrophication (NOx) relative	g / TP	-		-	-
Acidification (SOx) relative	g / TP	-		-	-
Respiratory diseases ($PM_{2.5}$) relative	g / TP	-		-	-
Respiratory diseases (PM_{10}) relative	g / TP	-		-	-
Respiratory diseases (CO) relative	g / TP	-		-	-
Respiratory diseases (HC) relative	g / TP	-		-	-
Respiratory diseases (VOC) absolute	kg	-		-	-
Air quality – concentrations					
Eutrophication (NOx) content	µg/m3 (y)	< 30 µg [2]		–5% (1)	
Acidification (SOx) content	µg/m3 (y)	< 20 µg [2]		–5% (1)	
Respiratory diseases ($PM_{2.5}$) content	µg/m3 (y)	< 25 µg [2]		–5% (1)	
Respiratory diseases (PM_{10}) content	µg/m3 (y)	< 40 µg [2]		–5% (1)	
Respiratory diseases (CO) content	µg/m3 (8h)	< 10 µg [2]		–5% (1)	
Air quality – measures					
Estimating carbon footprint	-	Application		(3)	

Monitoring air quality	-	Application		(3)	
Carbon Capture and Storage (CCS)	ton/year	≥ 5% GHG		(1)	
Dust control (bulk): encapsulation	% of storage	≥ 80%		(1)	
Dust control (bulk): covering	% of storage	≥ 50%		(1)	
Modal split: road transport	% of total	≤ 50%		(1)	
Modal split: rail transport	% of total	≥ 25%		(½)	
Modal split: inland waterway transp.	% of total	≥ 25%		(½)	
Avoid rush-hour road transport	-	Application		(1)	
Driver's instructions to save fuel	% drivers	100%		(1)	
				Score =	**22**
				Total (%) = 100 * score / 22 =	**100%**

1. (www.ampterminals.com: 15,59 kgCO2e/TEU (2010), ar.dpworld.com: 18 kgCO2e/TEU (2011), van Duin, R., 17,29 kgCO2e/TEU (2006), [42,p9])
2. Standards from National Emission Ceilings
3. CO_2e is Greenhouse Gas equivalent of CO_2+N_2O+CH_4

Item	**Unit**	**Target**	**Performance**	**Evaluation**	**Score**
Materials and Waste					
Non-hazardous waste: absolute	ton	Minimize		-	-
Non-hazardous waste: relative	kg / ton cargo	Minimize		-	-
Hazardous waste: absolute	ton	Minimize		-	-
Hazardous waste: relative	kg / ton cargo	Minimize		-	-
Material demand: wood	ton	Minimize		-	-
Material demand: paper	ton	Minimize		-	-
Material demand: plastics	ton	Minimize		-	-
Material demand: metals	ton	Minimize		-	-
Separate collection of wood	-	Application		(1)	
Separate collection of paper	-	Application		(1)	
Separate collection of plastics	-	Application		(1)	
Separate collection of metals	-	Application		(1)	
Centralized collection of hazardous waste	-	Application		(3)	
Collection rate (industrial waste)	%	100%		(1) per 10%	
Collection rate (hazardous waste)	%	100%		(1) per 10%	
Oil interceptors under fuel station, maintenance facilities, parking's	-	Application		(5)	
				Score =	**32**
				Total (%) = 100 * score / 32 =	**100%**

Item	**Unit**	**Target**	**Performance**	**Evaluation**	**Score**
Water					
Water consumption: absolute	m3	Minimize		-	-
Water consumption: relative	m3 / TP	Minimize		-	-
Share of river water – other than cooling purposes	% river water	Minimize		-	-
Share of river water – cooling purposes	% river water	Maximize		-	-
Thermal conditions due cooling water	^oC	Max. + 2^oC		(2)	
Closed wastewater system in port	% of industrial area m2	Maximize		(½) per 10%	
Wastewater treatment	% treated	100%		(½) per 10%	
Ballast water treatment	% treated	100%		(½) per 10%	

Oil spillage (into water)	L / year	Minimize		-	-
Liquid substance spilling: monitoring	-	Appearance		(2)	
Liquid substance spilling: # incidents	# / year	Minimize		-	-
Water pollution monitoring (Nutrient-, Oxygenation conditions, Salinity, Pollutant substances, Algae concentration, transparency)	Critical vol. in m3	Full compliance with regulations		Monitoring (5) + Full compliance (5)	
				Score =	**29**
				Total (%) = 100 * score / 29 =	**100%**

Item	**Unit**	**Target**	**Performance**	**Evaluation**	**Score**
Local environment					
Land area occupied	ha	Minimize		-	-
Coastline occupied (width)	m	Minimize		-	-
Inventory of environmental aspects	-	Application		(2)	
Inventory of ecological situation	-	Application		(1)	
Monitoring of ecological situation	-	Application		(2)	
Monitoring biodiversity (fishes, birds, wildlife, small animals)	-	Application		(5)	
Compensation of land use	% port area	≥ 100%		(2)	
Areas designated with 'Ecological value'	% port area	≥ 10%		(2)	
Areas with protected ecosystem	% port area	≥ 10%		(2)	
Tree planting in port area	% port area	≥ 10%		(1)	
Breeding and resting areas for birds	% ecological value areas	≥ 50%		(3)	
Buffered landscaping	% landside around port	≥ 80%		(1)	
Brownfield redevelopment	-	Application		(1)	
Treatment of dredged (contaminated) sediment	% dredged sediment	100%		(3)	
Reuse released sediment for other purposes (e.g. building dikes)	% dredged sediment	100%		(2)	
Reuse released sediment in-port	% dredged sediment	100%		(1)	
Suspend bottom particles in harbor for tidal release	-	Application		(2)	
Preventive measures for release of odors (fuel stations, etc.)	-	Application		-	
Lamps with small light spectrum	% lamps	≥ 80%		(2)	
Lamps with protecting screens/covers	% lamps	≥ 80%		(2)	
Lamps dimmed when possible	% lamps	≥ 80%		(1)	
				Score =	**35**
				Total (%) = 100 * score / 35 =	**100%**

Item	**Unit**	**Target**	**Performance**	**Evaluation**	**Score**
Vessels					
Reward / decline vessels based on ESI score	-	Application		(10)	
On-shore power – vessel capability	% vessels	Maximize		(½) per 10%	
On-shore power – landside capability	% quay	Maximize		(½) per 10%	
Slow steaming in port	% vessels	100%		(½) per 10%	

Slow steaming within 20mi of coast	% vessels	Maximize		(½) per 10%	
Slow steaming within 40mi of coast	% vessels	Maximize		(½) per 10%	
Use of hybrid tugboats	% tugboats	Maximize		(2)	
				Score =	**37**
				Total (%) = 100 * score / 37 =	**100%**

Item	**Unit**	**Target**	**Performance**	**Evaluation**	**Score**
Equipment					
Kilometers driven by overall fleet	km	Minimize		-	-
Engines: on-road (trucks)	% trucks	EURO V		≥80% (1)	
Engines: off-road (port equipment)	% equipment	Stage IIIB		≥80% (1)	
Average fuel consumption per km	l/100km	Minimize		-	-
Anti-idling device installed (non-electric equipment)	% equipment	100%		≥80% (1)	
Share of hybrid powertrains	% equipment	-		(1) per 20%	
Share of fuel-cell powertrains	% equipment	-		-	-
Share of electric powertrains	% equipment	Maximize		(1) per 10%	
Lifecycle GHG calculated for equipment replacement/modification	-	Application		(1)	
Equipment capability for multiple products (e.g. different size TEUs)	% equipment capability	Maximize		(1)	
Equipment capability for automation and proactive planning/recognizing	% equipment capability	Maximize		(1)	
Lower resistance modifications*	% equipment	100%		(1)	
Lower noise source modifications*	% equipment	100%		(1)	
Light pollution modifications*	% equipment	100%		(1)	
Moderate (light-grey) color scheme	% equipment	100%		(1)	
				Score =	**20**
				Total (%) = 100 * score / 20 =	**100%**

Item	**Unit**	**Target**	**Performance**	**Evaluation**	**Score**
Resource use – energy					
Energy consumption: absolute	kWh	Minimize		-	-
Energy consumption: relative	kWh / TP	Minimize		-	-
In-port generation of renewable energy (solar, wind, biomass)	kWh	Maximize		-	-
Share of energy from natural gas	% NG	Maximize		(½) per 20%	
Share of renewable energy	% renewable	100%		(1) per 10%	
Share of in-port generated renewable energy	% in-port renewable	Maximize		(½) per 20%	
Resource use – heat					
Heating energy: absolute	MWh	Minimize		-	-
Heating energy: relative	MWh / employee	Minimize		-	-
Share of geothermal energy	% of total	Maximize		(½) per 10%	
Share of co-siting low value heat	% of total	Maximize		(½) per 10%	
Resource use – fuel					
Fossil fuel demand: absolute	L	Minimize		-	-
Fossil fuel demand: relative	L / TP	Minimize		-	-
Share of biofuel	% of total	≥ 30%		(1)	
Share of LNG / CNG	% of total	≥ 50%		(2)	
Share of USLD	% of diesel	≥ 80%		(2)	

	fuel				
Resource use – oils, paints					
Environment friendly lubricants/oils	%	≥ 80%		(1)	
Recycle lubricants/oils	%	≥ 80%		(1)	
Environment friendly paints	%	≥ 80%		(1)	
Environment friendly anti fouling	%	≥ 80%		(1)	
				Score =	**34**
				Total (%) = 100 * score / 34 =	**100%**

Item	Unit	Target	Performance	Evaluation	Score
Noise					
Noise mapping of port area (identification of noise sources)	-	Application		(5)	
Resident noise level – daytime	dB(A),16h	< 50 dB(A)[1]		–3dB (5)	
Resident noise level – nighttime	dB(A),8h	< 45 dB(A)[1]		–3dB (5)	
	dB(max),8h	< 60 dB		–3dB (5)	
Port equipment noise (average)	dB(A)	< 105 dB		(5)	
Port area enclosed by noise barriers	% landside circumference	≥ 80%		(2)	
Distance: noise sources – barriers	m	< 20m		(2)	
Distance: barriers – residential area	m	Maximize		-	-
Distance: port – residential area	km	Maximize		-	-
Average height of barriers	m	> 4m		-	-
Noise barrier as row of containers	% of barriers	-		-	-
Noise barrier as trees, nat. materials	% of barriers	Maximize		(½) per 10%	
Noise barriers as hill	% of barriers	Maximize		(½) per 10%	
				Score =	**39**
				Total (%) = 100 * score / 39 =	**100%**

[1] Noise values measured at façade-level at residential homes (chapter 4)

Item	Unit	Target	Performance	Evaluation	Score
Infrastructure					
Heavyweight area (storage)	ha	Minimize		-	-
Lightweight area (empty containers)	ha	Maximize		-	-
Covered area + electricity for reefers	% reefer stack area	Maximize		-	-
High-post lighting	% industrial area	100%		(½) per 10%	
LED lighting	% lamps	100%		(1) per 10%	
Industrial area utilization	% of total	Maximize		(1) per 10%	
Productivity per unit area	EUR / m2	Maximize		-	-
Added value per unit area	EUR / m2	Maximize		-	-
Efficient site planning	TP / m2	Maximize		-	-
				Score =	**25**
				Total (%) = 100 * score / 25 =	**100%**

Item	Unit	Target	Performance	Evaluation	Score
Buildings & Warehouses					
Sufficient isolation (double-glazed glass, high-grade isolation, etc.)	% m3 of buildings	100%		(½) per 10%	
Automated light switches	% light	100%		(1)	

	switches				
Sun-pipes (tap natural light)	-	Maximize		(1)	
Automated water taps	% water taps	100%		(1)	
Seawater flushing	% restrooms	100%		(1)	
Building climate control (summer)	°C	≥ 22 °C		(1)	
Energy efficient ICT: daytime	Wh / TP	Minimize		-	-
Energy efficient ICT: standby	Wh / TP	Minimize		-	-
Constr.: low emissions equipment (EURO V or STAGE IIIB)	% equipment	Maximize		(1)	
Constr.: clean diesel	-	Application		(1)	
Constr.: conserve materials/resources	-	Maximize		(1)	
Constr.: recycle demolition debris	% recycled	Maximize		(2)	
Constr.: use construction materials with recycled content	% recycled content avg.	≥ 30%		(2)	
Constr.: include visual quality	-	Application		(1)	
Constr.: apply for energy certification	-	Application		(2)	
Lifecycle GHG calculated for rebuilding/modification of buildings	-	Application		(2)	
				Score =	**22**
				Total (%) = 100 * score / 22 =	**100%**

Item	Unit	Target	Performance	Evaluation	Score
Environmental programs					
Implementation of EMAS	years in practice	Maximize		In use (3)	max (3)
Implementation of ISO14001	years in practice	Maximize		In use (3)	
Implementation of EMS (basic)	years in practice	Maximize		In use (2)	
Application of PERS (by ESPO)*	-	Application		(1)	
Application of SDM (by ESPO)*	-	Application		(1)	
Application of Environmentally Preferable Purchasing (EPP)	% purchases	Maximize		(½)	
Application of Sustainable Procurement	% of procurement s	Maximize		(½)	
Application of Corporate Social Responsibility (CSR)	years in practice	Maximize		(1)	
Application of other sustainable programs (*if none is applicable*)	years in practice	Application		(½)	
Oblige sustainable programs to tenants	-	Application		(½)	
Joining a (sea) 'ports organization' with environmental themes	-	Application		(2)	
Collaboration on environmental themes with other ports	# ports	Maximize		(2)	
Involvement of (local) environmental organizations	-	Maximize		(3)	
				Score =	**14,5**
				Total (%) = 100 * score / 14,5 =	**100%**

6.4.2 Proposed Assessment Method (quick-scan, shortened)

The 'quick scan' (shortened) 'Proposed Assessment Method' uses 22 items from the general 'Proposed Assessment Method' that describe port sustainability in a large degree. They are sometimes called: 'Environmental Key Performance Indicators'. They can serve as a first basis to check a port's sustainability. On relative basis a port can check sustainable performance with other ports, or compare own performance at different periods. Assessing items per throughput is the only (and accepted) way of comparing sustainability (on a limited base) between ports.

Item	**Absolute value**		**Relative value** [2]	
Carbon Footprint (CO2e)		ton CO2e		ton CO2e / TP
Monitoring Air quality (Application)	Yes / No	Application	-	-
Water Consumption		M3		M3 / TP
Monitoring water pollution (Application)	Yes / No	Application	-	-
Energy Consumption		kWh		kWh / TP
Share of renewable energy		%	-	-
Share of renewable energy (generated in-port)		%	-	-
Heating Energy		MWh		MWh / TP
Share of geothermal energy		%	-	-
Share of low-value heat (shared)		%	-	-
Fossil fuel demand		L		L / TP
Share of biofuel (of total fuel)		%	-	-
Share of USLD (of total diesel fuel)		%	-	-
Non-hazardous waste		ton		kg / TP
Collection rate (non hazardous waste)		%	-	-
Hazardous waste		ton		kg / TP
Collection rate (hazardous waste)		%	-	-
Average noise level of port equipment		dB	-	-
Land area occupied		ha		ha / TP
Coastline occupied		m		m / TP
Monitoring biodiversity	Yes / No	Application	-	-
Implementation of an EMS [1]	Yes / No	Application	-	-

1. Environmental Management System
2. TP = throughput (tons of cargo, TEU, etc.)

7. Conclusion and recommendations

7.1 Conclusion

This report has shown what measures ports could take to operate in a more sustainable way. Sustainability has gained a lot of attention in the last decades. Unfortunately, the major drivers are still cost benefits, compliance to regulations and an increasing company's image. Developments like the ongoing increase of transportation and larger sizes of equipment (for example ships up to 16,000 TEU such as the 'Marco Polo' in 2012 calling the port of Rotterdam) make sustainable efforts rather difficult. Since upward trends as increase of energy use or emissions should be prevented. Also the society continuously sets higher demands on the quality of life. While many ports are located close to or nearby residential areas, they have an influence on the local air quality, noise levels, safety and capacity of the local infrastructure. [32, p28] Scattered and diverse approaches to sustainability are evaluated, combined and presented in this report as 'best practices' in Appendix 6 and explained in Chapter 4. They show many examples of measures that could be taken to improve the sustainability of a port and/or lower the environmental impact of port operations.

A general trend in many industries is to measure the environmental impact of products, processes or services from the amount of Greenhouse Gases (GHG) emitted. It is seen as a 'first step' towards sustainability, but merely describes a small part of the environmental impact of a product or service. The European Sea Ports Organization (ESPO) has indicated that currently merely 33% of the ports measure or estimate their carbon footprint. It means that the remaining ports still should start to do that in the future. For a sustainable operation in the total chain, ports should incorporate life-cycle GHG emissions in their decision-making processes rather than looking at current and own impacts alone. Carbon Capture and Storage (CCS) is a solution in childhood with currently many (regulatory) limitations.

Many sources, as well as this report, show that ports can encourage and contribute to sustainability in the transport- and shipping sector. A higher degree of sustainability can and should be enforced beyond the port's boundaries, which are generally between quayside and gate. The modal split is a substantial part of the total supply chain and certainly needs to be taken in to account.

This report proposes an Assessment Method ('Proposed Assessment Method'), which incorporates many aspects of sustainability. It is based on 'sources' that have an environmental impact, so that sustainable measures can be checked and taken at the source (the cause of environmental impacts). This is a more preferable solution than taking measures to reduce the effects without considering the actual cause. Also a Quick Assessment ('Quick Scan') based on the 'Pareto Principle' is provided.

Comparing ports on their degree of sustainability is possible on a limited scale. Local factors might introduce different priorities and requirements for ports. For example, a dense road network, neighboring industrial activities and imported air pollution makes compliance to air quality standards difficult and tighter regulations may apply. It is recognized in the port sector that standardized methodologies are required to assess impacts to the environment. The Environmental Ship Index (ESI) is a good example of a recognized standard. This index, as well as the 'Proposed Assessment Method' in this report, is based on a state-of-the-art definition. It needs to be updated to the latest (tightened) standards, new insights and/or changed priorities every (few) year(s).

The report has shown some attractive ways to present environmental performance in such a way that they are understandable for everyone. Unfortunately, it is common practice to report reductions and targets as 'percentages' in many industries, as well as in the port sector. The difficulty here is that a baseline (benchmark) is generally defined by the port itself and does not represent a target that is valuable for, or recognized by, other ports. A high emitting port can achieve remarkable reductions and targets, but that is still no guarantee for sustainable operations. A better alternative is weighing against internationally recognized standards, for example Directives or targets set by the European Commission or MARPOL.

Communicating on environmental efforts and -performance is key to both raise goodwill of the local society as well as showing compliance with regulations to governments, stakeholders and environmental organizations. Involving stakeholders and environmental organizations in development processes and daily operations is crucial to find more comprehensive and sustainable solutions. A port should also address (environmental) consequences of solutions to problems or activities in early stages of a project, rather than focusing on fixing the problem first. Collaboration and sharing knowledge between ports can also help to limit 'unfair' competition from (non-EU) ports with less stringent social en environmental regulations.

As a general remark: ports should encourage its customers, tenants/contractors and partners to conduct their business in a more sustainable fashion, including reduction of GHG emissions. Aspects as (historical) concession agreements, subcontractors, availability of sources, port area, storage facilities, neighboring industrial activities, local regulations, etc. shouldn't be seen as limitations for doing less on sustainability. A port should take responsibilities beyond their own operations and incorporate the environmental impacts outside the port's boundaries as well. Sustainability is a topic that leads to innovation, increase of efficiency and (important!) control of costs. [21] [28]

7.2 Recommendations for further research

Some ports have reported current performance, e.g. CO2e emissions, per TEU or throughput. These numbers can be used for comparison and are very useful as analysis to what extent certain emissions can be reduced. Ideally a future research should estimate what emissions can be achieved in the most ideal case (clean equipment, limited drayage, optimal planning, limited idling, etc.), so basically a 'reference port' that can serve as leading example or guideline. Unfortunately, this data for different types and sizes of ports is not yet available.

A recommendation for further research is a state-of-the-art calculation of a 'reference port', which can be adapted to different types of products and equipment. A possibility is to make it 'interactive', so that anyone directly can observe what the influence of for example a change in emission regulation or different equipment is.

This report provides a short example of how Greenhouse Gas (GHG) emissions of the total life cycle of equipment can be used to make decisions on replacing of equipment. As second recommendation for further research, it will be useful to develop a (decision) tool that a port can use to estimate the impact of a single type of equipment. This tool should allow ports to estimate when equipment should be replaced, retrofitted or modified to lower the environmental impact by including the total life cycle. Nowadays it is still common practice to look at the Greenhouse Gas emissions of own operations ('within the boundaries of the port'). A decision to replace equipment with cleaner versions lowers the local port's emissions but might be not that sustainable when the total life cycle is considered. A tool can make this decision more 'sustainable' and transparent.

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Appendix 1: Air quality and Emission ceilings

This appendix describes the emission ceilings and maximum concentrations in more detail.

European Commission Directive 2001/81/EC (National Emission Ceilings)

	SO_2 kton	NO_x kton	VOC kton	NH_3 kton
Belgium	99	176	139	74
Germany	520	1051	995	550
Netherlands	50	260	185	128
United Kingdom	585	1167	1200	297
Sweden	67	148	241	57
Finland	110	170	130	31

European Commission Directive 2008/50/EC (Air quality / maximum concentrations)

	NO_2 µg/m3	SO_2 µg/m3	PM10 µg/m3	PM2.5 µg/m3	CO µg/m3	O_3 µg/m3
Annually (human)[3]	40	-	40	25[2]	-	-
Annually (vegetation)	30	20	-	-	-	-
1 day	-	125 max 3x[1]	50 max 35x[1]	-	-	-
8 hour	-	-	-	-	10000	120
1 hour	200 max 18x[1]	350 max 24x[1]	-	-	-	180
Alarm thresholds	400 for 3h	500 for 3h	-	-	-	240

1. The number of times this value may be exceeded annually
2. 25 µg/m3 is target value as of 2010, and ceiling as of 2015, 20 µg/m3 will be obligatory as of 2020 (this value is indicative and will be revisited in 2013)
3. Lead annual limit (human): 0,5 µg/m3

European Commission Directive 2004/107/EC (Air quality / maximum concentrations)

Substance	Limit
Arsenic	6 ng/m3 target
Cadmium	5 ng/m3 target
Nickel	20 ng/m3 target
Benzo(a)pyrene [1]	1 ng/m3 target

1. Benzo(a)pyrene should be used as a marker for the carcinogenic risk of polycyclic aromatic hydrocarbons (PAH) in ambient air.

The Dutch government has published a handbook on the implementation of their environmental policy. It gives extensive information on the national regulation and European Directives on air- and industrial emissions. The handbook explains extensively how the European Commission has developed Directives up to the current 2008/50/EC. This European Directive will be revisited in 2015. Probably, updated ceilings for 2020 will be added according to the European GHG report 2050. Reference [87] gives more information on the development of emission ceilings and national enforcement.

Appendix 2: Emission standards

This Appendix describes the emission standards for road- and non-road engines in more detail.
General note: the standard that is in force in November 2012 is marked (light-blue).

Light-duty vehicles

Stage	Validity year	Pending Directive
EURO III	2000	Directive 98/70/EC
EURO IV	2005	Directive 98/70/EC
EURO V	2009	Regulation 715/2007
EURO VI	2014	Regulation 715/2007

Motor vehicles designed and constructed for carriage of goods, category N2 (maximum mass between 3,5 – 12 tons), diesel fueled (compression ignition).

Stage	Validity year	CO	HC + NOx	NOx	PM
EURO V	2009	740 mg/km	235 mg/km	280 mg/km	5 mg/km
EURO VI	2014	740 mg/km	215 mg/km	125 mg/km	5 mg/km

(source: Regulation 715/2007)

Validity year	CO_2 emission		Fuel consumption (Petrol) (1)		Fuel consumption (Diesel) (1)	
	Cars	Vans	Cars	Vans	Cars	Vans
2007	160 g/km	203 g/km				
2010		182 g/km				
2011	136 g/km					
2015	130 g/km		5.6l/100km		4.9l/100km	
2017		175 g/km		7.5l/100km		6.6l/100km
2020	95 g/km	147 g/km	4.1l/100km	6.3l/100km	3.6l/100km	5.5l/100km

[1] Target values [71]

Heavy-duty vehicles

Stage	Validity year	Pending Directive
EURO III	2000	Directive 1999/96/EC
EURO IV	2005	Directive 1999/96/EC
	2005	Directive 2005/55/EC re-stated emission limits, due to OBD (On-Board Diagnosis system) requirements
EURO V	2009	Directive 1999/96/EC (EURO V into force as of Oct 2008)
EURO VI	2013	Regulation 582/2011, proposal made in December 2007, adopted in June 2009, info force as of January 2013

Heavy-duty vehicles, WHSC test, diesel fueled (compression ignition)

Stage	Validity year	CO	HC	NOx	PM
EURO V	2009	1,5 g/km	0,46 g/km	7,0 g/km	0,1 g/km
EURO VI	2013	1,5 g/km	0,13 g/km	0,4 g/km	0,1 g/km

(source: Directive 1999/96/EC and Regulation 582/2011)

Non-Road Mobile Machinery (NRMM)

	Validity year	Stage	Pending Directive
Diesel engines 37-560 kW	Jan. 1999	Stage I	Directive 97/68/EC + 2006/105/EC(1)
Diesel engines 37-560 kW	Jan. 2001	Stage II	Directive 97/68/EC + 2006/105/EC(1)
Diesel engines 19-560 kW	Jan. 2006	Stage III A	Directive 2004/26/EC
Diesel engines 37-560 kW	Jan. 2011	Stage III B (2)	Directive 2004/26/EC
Diesel engines 56-560 kW	Jan. 2014	Stage IV	Directive 2004/26/EC

1. Directive 2006/105/EC is a revision of Directive 97/68/EC, which introduces a modification to the numbering system of the accession of Bulgaria and Romania.
2. More stringent limits for railcars and locomotives

	Validity year	Stage	Pending Directive
Petrol engines (1)	Aug. 2004	Stage I	Directive 2002/88/EC
Petrol engines (1)	Aug. 2006	Stage II	Directive 2002/88/EC

1. Only petrol engines with a displacement > 225 cubic cm, which belong to the class SN:4, non-hand-held machinery with a net power > 19 kW are considered for this research.

(Diesel powered propulsion with net power 37 < P < 75 KW for Stage III A)
(Diesel powered propulsion with net power 56 < P < 75 kW for Stage III B and IV)

Diesel	Validity year	CO	HC	NOx	PM
Stage I (1)	1999	6,5 g/kWh	1,3 g/kWh	9,2 g/kWh	0,850 g/kWh
Stage II (1)	2001–2004	5,0 g/kWh	1,3 g/kWh	7,0 g/kWh	0,400 g/kWh
Stage III A (1)	2006	5,0 g/kWh	4,7g/kWh (HC+NOx)		0,400 g/kWh
Stage III B (1)	2011	5,0 g/kWh	0,19 g/kWh (2)	3,3 g/kWh (2)	0,025 g/kWh
Stage IV (1)	2014	5,0 g/kWh	0,19 g/kWh	0,4 g/kWh	0,025 g/kWh

(Diesel powered propulsion with net power 75 < P < 130 kW)

Diesel	Validity year	CO	HC	NOx	PM
Stage I (1)	1999	5,0 g/kWh	1,3 g/kWh	9,2 g/kWh	0,700 g/kWh
Stage II (1)	2001–2004	5,0 g/kWh	1,0 g/kWh	6,0 g/kWh	0,300 g/kWh
Stage III A (1)	2006	5,0 g/kWh	4,0g/kWh (HC+NOx)		0,300 g/kWh
Stage III B (1)	2011	5,0 g/kWh	0,19 g/kWh (2)	3,3 g/kWh (2)	0,025 g/kWh
Stage IV (1)	2014	5,0 g/kWh	0,19 g/kWh	0,4 g/kWh	0,025 g/kWh

(Diesel powered propulsion with net power 130 < P < 560 kW)

Diesel	Validity year	CO	HC	NOx	PM
Stage I (1)	1999	5,0 g/kWh	1,3 g/kWh	9,2 g/kWh	0,540 g/kWh
Stage II (1)	2001	3,5 g/kWh	1,0 g/kWh	6,0 g/kWh	0,200 g/kWh
Stage III A (1)	2006	3,5 g/kWh	4,0 g/kWh (HC+NOx)		0,200 g/kWh
Stage III B (1)	2011	3,5 g/kWh	0,19 g/kWh	2,0 g/kWh	0,025 g/kWh
Stage IV (1)	2014	3,5 g/kWh	0,19 g/kWh	0,4 g/kWh	0,025 g/kWh

1. For engines for propulsion other than of locomotives, railcars and inland waterway vessels
2. For locomotives <130kW applies a combined HC+NOx limit of 4,0 g/kWh in Stage III B

(source: Directive 97/68/EC, Amendment Directive 2006/105/EC and Directive 2004/26/EC

EPA TIER standards for diesel engines (TIER)
TIER standards set by the U.S. Environmental Protection Agency (EPA). Currently TIER 3 is into force. TIER 4 for engines with a power of 37–56 kW will be into force as of 2013. TIER 4 for engines with a power of 56–130 kW will be put gradually into force in 2012–2014, and 130–560kW will be into force in 2011–2014.

	Validity year	Stage	Pending Directive
Diesel engines	1996-2000 [(1)]	TIER 1	EPA
Diesel engines	2001-2006 [(1)]	TIER 2	EPA
Diesel engines 37-560 kW	2006-2008 [(1)]	TIER 3	EPA
Diesel engines	2008-2015 [(1)]	TIER 4	EPA

[1.] Phased-in years, depending on engine power

(Diesel powered propulsion with net power 56 < P < 130 kW)

Diesel	Validity year	CO	HC	NOx	PM
TIER 3	2008	5,0 g/kWh	4,0 / 4,7 [(1)] g/kWh (HC+NOx)		
TIER 4	2012-2014	5,0 g/kWh	0,19 g/kWh	0,40 g/kWh	0,02 g/kWh

[1] 4.0 g/kWh HC+NOx applies for 75–130kW, 4.7 g/kWh HC+NOx applies for 37–75kW

(Diesel powered propulsion with net power 130 < P < 560 kW)

Diesel	Validity year	CO	HC	NOx	PM
TIER 3	2006	3,5 g/kWh	4,0 g/kWh (HC+NOx)		-
TIER 4	2011-2014	3,5 g/kWh	0,19 g/kWh	0,40 g/kWh	0,02 g/kWh

More information on TIER4 standards can be found in references [97] (non-road vehicles) and [98] (general). (Note: compare EPA TIER 4 to the European Stage IV, maximum pollution per kWh)

Inland waterway vessels:

CCR regulations (CCR1 and CCR2) are applicable in 'Rhine States' and Belgium, and the European Stage IIIA (V1 and V2) regulations are applicable in all European inland waters. 'V2' is valid as of 21 December 2007 for engines with a swept volume of > 5 liter per cylinder.
Legislation that is currently into force (in 2012) is marked blue.

Version	**EU Stage IIIA**	Validity	CO	HC + NOx	PM
V1:1	SV < 0,9 (P >37kW)	Dec. 2005	5,0 g/kWh	7,5 g/kWh	0,40 g/kWh
V1:2	0,9 > SV > 1,2	Jun. 2005	5,0 g/kWh	7,2 g/kWh	0,30 g/kWh
V1:3	1,2 > SV > 2,5	Jun. 2005	5,0 g/kWh	7,2 g/kWh	0,20 g/kWh
V1:4	2,5 > SV > 5,0	Dec. 2006	5,0 g/kWh	7,2 g/kWh	0,20 g/kWh
V2:1	5,0 > SV > 15,0	Dec. 2007	5,0 g/kWh	7,8 g/kWh	0,27 g/kWh
V2:2	15,0 > SV > 20,0 (P < 3300kW)	Dec. 2007	5,0 g/kWh	8,7 g/kWh	0,50 g/kWh
V2:3	15,0 > SV > 20,0 (P > 3300kW)	Dec. 2007	5,0 g/kWh	9,8 g/kWh	0,50 g/kWh
V2:4	20,0 > SV > 25,0	Dec. 2007	5,0 g/kWh	9,8 g/kWh	0,50 g/kWh
V2:5	25,0 > SV > 30,0	Dec. 2007	5,0 g/kWh	11,0 g/kWh	0,50 g/kWh

Note: SV = swept volume per cylinder (liter per cylinder), P = power output of engine (kW)
(source 2004/26/EC, section 4.1.2.4)

Conventie van Mannheim voor de Rijnvaart, recognized by Centrale Commisie voor de Rijnvaart (CCR). CCR Stage 1 (CCR1) is valid until 30 June 2007. CCR Stage 2 (CCR2) is valid as of 1 July 2007.

CCNR Stage I	Validity	CO	HC	NOx	PM
37 < P < 75	Jan. 2003	6,5 g/kWh	1,3 g/kWh	9,2 g/kWh	0,85 g/kWh
75 < P < 130	Jan. 2003	5,0 g/kWh	1,3 g/kWh	9,2 g/kWh	0,70 g/kWh
P > 130	Jan. 2003	5,0 g/kWh	1,3 g/kWh	9,2 g/kWh (1)	0,54 g/kWh

Note: P = power output of engine (kW)
1. Applicable for >2800tr/min, for 500 < n < 2800 tr/min = [45 x n^(–0,2)]

CCNR Stage II	Validity	CO	HC	NOx	PM
18 < P < 37	Jul. 2007	5,5 g/kWh	1,5 g/kWh	8,0 g/kWh	0,40 g/kWh
37 < P < 75	Jul. 2007	5,0 g/kWh	1,3 g/kWh	7,0 g/kWh	0,30 g/kWh
75 < P < 130	Jul. 2007	5,0 g/kWh	1,0 g/kWh	6,0 g/kWh	0,20 g/kWh
130 < P < 560	Jul. 2007	3,5 g/kWh	1,0 g/kWh	6,0 g/kWh	0,20 g/kWh
P > 560	Jul. 2007	3,5 g/kWh	1,0 g/kWh	6,0 g/kWh (1)	0,20 g/kWh

Note: P = power output of engine (kW)
1. Applicable for >3150tr/min, for 343 < n < 3150 tr/min = [45 x n^(–0,2) – 3], for <343 tr/min = 11,0

(source 2004/26/EC, Appendix XIV and XV)

CCNR Stage IV (1)	Validity	NOx	PM
18 < P < 37	2016	4,8 – 5 g/kWh (2)	0,11 – 0,14 g/kWh (2)

1. CCNR Stage III (2012) is withdrawn; CCNR Stage IV will amend the current CCNR Stage II
2. Indicative numbers, standard is not yet defined

Appendix 3: Pollutant substances of air emissions

This Appendix summarizes the polluting substances of air emissions. The most common substances from burning fossil fuels and substances that are likely to be emitted in the port sector are listed in this Appendix, with a short description of their impact.

Particulate Matter (PM_{10} and $PM_{2.5}$)
Particulate matter is a collective term for particles from dust, soot and/or smoke. Particulate matter exists in very fine particles in solid and aerosol form. They are categorized in size as less or equal to 2.5 and 10 microns respectively. Due to the small size they can travel into sensitive parts of the lungs of people. In high concentrations there is a potential of health risks by causing or worsening respiratory diseases (reduced long function and increase chronic disease). Particulate matter is often related to carcinogenicity. Besides 'primary particles' from fuel combustion, wear of roads and tires; 'secondary particles' can form from chemical reactions of NOx, SO2 and NH3 in the air.

Diesel Particulate Matter (DPM)
Particulate matter from diesel exhaust fumes. Recognized by the government of California as a separate toxic air contaminant besides PM2.5 and PM10.

Sulphur oxides (SOx)
Oxides of sulphur are formed by combustion of fuels and burning coal. In many industrial applications and power plants sulphur oxides are emitted, but transportation is the predominant source. [88] It causes acidification, for human health respiratory diseases and is very unpleasant for asthmatics since it irritates upper airways. Emissions that lead to high concentrations of SO2 generally lead to the formation of other SOx as well. At high levels SOx leads to premature death. Research has clearly demonstrated that reducing sulphur content in fuels improves the health of people. [1] Due to strict regulation on fuel quality the concentration of SOx is decreasing.

Nitrogen oxides (NOx)
Oxides of nitrogen are formed by combustion of fuels at high temperatures. It is a highly reactive gas with a varying amount of nitrogen and oxides. High levels of nitrogen oxides can cause respiratory irritations in asthmatics and children, and lead to eutrophication in water. Oxides of nitrogen are very harmful for the environment when they bind with water, then nitric acid (HNO3) is formed.

Ozone (O3)
Ground level ozone is known as 'smog', formed by nitrogen oxides and hydrocarbons in sunlight by a photochemical reaction. It irritates eyes, nose and throat, and causes shortness of breath and coughing for people with respiratory diseases.

Hydrocarbons (HC)
Most hydrocarbons are found as fuels for equipment. Some examples of hydrocarbon fuels are the components of gasoline, diesel and natural gas. [16] Due to incomplete combustion these hydrocarbons can be emitted to the surrounding air. Since some hydrocarbons are toxic they might cause health problems but moreover contribute to the formation of ground level ozone with nitrogen oxides.

Carbon Monoxide (CO)
Carbon monoxide is a colorless toxic gas commonly formed when carbon-containing fuel is not burned completely. Most vehicles are the predominant source of carbon monoxide. [16] Carbon monoxide in very high concentrations is a health risk since it causes oxygen deficiency.

Greenhouse Gases (GHG)
These 'group' of gases are related to the contribution of global warming and climate change. GHGs trap infrared radiation in the atmosphere resulting in an increase of global temperatures. To reduce the emissions of GHG many times is referred to the 'six greenhouse gases' defined by the Kyoto protocol (which is the first major effort in reducing the GHG emissions potential):

- Carbon dioxide (CO_2)	emitted by fuel combustion, forest clearing
- Methane (CH_4)	emitted by fuel combustion, landfills (waste), fermentation
- Nitrous oxide (N_2O)	emitted by fuel combustion, fertilizers
- Sulfur Hexafluoride (SF_6)	emitted by magnesium production, electrical equipment
- Hydrofluorocarbons (HFC)	emitted by aluminum and semiconductor manufacturing
- Perfluorocarbons (PFC)	emitted by semiconductor manufacturing, refrigeration gases

The latter three are fluorinated gases (synthetic gasses and emitted from industrial processes in very small quantities). The former three gases are emitted due to human activities as combustion of fossil fuels in vehicles and industrial applications. Each of these gases has a so-called 'Global Warming Potential' (GWP), an indicator to normalize these gases in terms of their contribution to global warming. In much literature the term CO_2e (Carbon Dioxide equivalent) is used to describe the global warming potential. The GWP of the first three gases reads:

Carbon dioxide:	1 mt CO_2 = 1 mt CO_2e
Methane:	1 mt CH_4 = 21 mt CO_2e
Nitrous oxide	1 mt N_2O = 310 mt CO_2e

(mt = metric tons)

Worldwide 77% of the GHG is carbon dioxide. The majority of emitted carbon dioxide is due to combustion of fuels. A smaller part is covered by deforestation and decay of biomass. Methane and Nitrous oxide cover 14% and 8% respectively. Fluorinated gases cover the last 1% of the total GHG emitted, and because of this small amount their equivalent GWP is very high. [79]

Volatile Organic Compounds (VOC)
VOCs are substances that have a high vapor pressure at room temperatures due to a low boiling point. They immediately evaporate when exposed to surrounding air. VOCs are present as chemical components in fuels, solvents, paints, coatings and much other sources. Various health issues are concerned when humans are exposed to VOCs for a certain period. Irritation of eyes, nose and throat are modest issues, but it also can influence our central nervous system and cause loss of coordination. Some VOCs can cause cancer in animals. [80]

Heavy metals (Arsenic, Cadmium, Nickel)
These substances are carcinogenic and can influence the central nervous system in humans. High concentrations are dangerous for both human and the environment. Regulation for the allowable amounts of heavy metals is covered in EU Directive 2004/107. See Appendix 1: Emission ceilings.

Sources for description of emissions: [16] [52] [78] [79] [88]

Appendix 4: CO2 emissions from material- and energy production

CO2 emissions per kWh from electricity production [55] and [European 2012 Statistical pocketbook]:

Country	g CO2/kWh (2008-2010 avg.)(1)	Renewable energy production(2)	Renewable energy consumption in Gross(3)	Renewable energy consumption in Transport(4)
Belgium	230 g CO_2/kWh	6,2 %	5,16 %	4,33 %
Germany	468 g CO_2/kWh	17,7 %	11,00 %	5,73 %
Netherlands	425 g CO_2/kWh	9,1 %	3,76 %	3,01 %
United Kingdom	470 g CO_2/kWh	6,6 %	3,20 %	2,96 %
Sweden	22 g CO_2/kWh	58,2 %	47,94 %	7,75 %
Finland	199 g CO_2/kWh	27,2 %	32,17 %	3,90 %
European, average	342 g CO_2/kWh	19,1 %	12,50 %	4,70 %

1. Average between 2008 and 2010, source [55, p111]
2. Share of Electricity Generation from Renewable Energy Sources, 2009 [EU pocketbook 2012, p103]
3. RES in Gross Final Energy Consumption, 2010 [EU pocketbook 2012, P23]
4. RES in Transport Sector, 2010 [EU pocketbook 2012, P23]

CO2 emission from primary material production and recycled material production, data 2010-2011, total Greenhouse Gas intensity in kgCO2e per kg material [50, table 2.2 and table 2.3]:

Material	Primary production(1)	Recycled production(1)	Average production(1)(2)	Typical recycling rate (world)
Steel (flat carbon)	2,355 kg CO2	0,884 kg CO2	1,487 kg CO2	59%
Steel (cast iron)	2,005 kg CO2	0,534 kg CO2	1,137 kg CO2	59%
Aluminum	9,667 kg CO2	0,506 kg CO2	6,644 kg CO2	33%
Copper	3,810 kg CO2	0,840 kg CO2	2,711 kg CO2	37%
Zinc	4,180 kg CO2	0,520 kg CO2	3,082 kg CO2	30%
Lead	3,370 kg CO2	0,580 kg CO2	1,668 kg CO2	61%
Rubber/Elastomer	2,850 kg CO2	0,827 kg CO2	2,850 kg CO2	3
Plastics	3,310 kg CO2	1,810 kg CO2	3,310 kg CO2	3
Composites (Glass-fiber)	8,100 kg CO2	-	-	0%
Composites (Carbon-fiber)	22,000 kg CO2	-	-	0%
Wood (general)	0,310 kg CO2	-	-	-
Concrete	0,104 kg CO2	-	-	3
Concrete (reinforced)	0,163 kg CO2	-	-	3

1. kg CO2e per kg material produced
2. Average production from primary sources with average recycled content included
3. Data not available [50]

Appendix 5: Noise measurement

This appendix provides some additional explanation of the abbreviations, levels and measurements of noise. A 'Sound Pressure Level', sometimes abbreviated as SPL, is measured in decibels (dB). There is a distinction between A-weighted and C-weighted decibel scale. This is explained below, followed by some typical measurements levels (SEL, LAeq, LAmax and LAn).

A-weighting
A frequency dependent 'correction' for measured (or calculated) 'moderate sound intensity' to mimic (or adapting to) the varying sensitivity of the ear to sound for different frequencies. The unit for A-weighted SPL is dB(A). [43]

C-weighting
A frequency dependent 'correction' for measured (or calculated) 'high sound intensity' to mimic the (or adapting to) varying sensitivity of the ear to sound for different frequencies. The unit for C-weighted SPL is dB(C). [43]

LAE (SEL)
LAE is the A-weighted Single Event noise exposure Level (SEL) to quantify the noise that is generated by individual events. It is used to describe the sound pressure level of an individual source at a particular measuring point (e.g. one second). The WHO report describes that SEL measurements have been shown to be inadequate for complex impulsive sounds. [43, p22]

LAeq (LAeq,T)
LAeq is the A-weighted equivalent continuous sound pressure level (used and recognized internationally). It basically describes the constant sound pressure level equivalent to the varying sounds levels over a measurement period (up to multiple hours). It sums up the total energy over a time period T and gives a level equivalent to the average sound pressure level over that time period. The average levels are usually based on integration of A-weighted levels. [43, p22]

The time period LAeq is measured should be denoted. LAeq,8h implies a continuous measurement of 8 hours (e.g. for measuring during night between 23.00 and 7.00), LAeq,16h implies continuous measurement of 16 hours (e.g. for measuring at daytime between 7.00 and 23.00), and so on. [pdf] It is commonly used for measuring road traffic noise and industrial noise, but also for 'systems' as noise from ventilation systems. [43]

LAmax
LAmax is the A-weighted maximum sound pressure level over a certain period of time. It describes the maximum level (LAmax) of individual noise events. [43, p22] A measuring instrument should measure in a 'fast response time'-modus. [96] [43,p22] Often it is indicated as LAFmax: the maximum sound pressure level with fast (F) weighting response time of the measuring instrument. Other response time modes are slow (S) or impulse (I) which should not be used for LAmax.

Individual evens to the (general) noise, as aircraft or railway noise, should be separately measured in addition to LAeq measurements. [43, p23]

LAn
LAn is the A-weighted sound pressure level, which is exceeded for n% of the time that is measured. It is particularly used for non-steady noise to measure the level and degree of fluctuation.

LA10 (n=10) is the A-weighted sound pressure level that is exceeded for 10% of the time that is measured. This 10% is the average maximum level during the time that is measured. L10 values have been widely used to measure road-traffic noise.

L90 (n=90) or L95 (n=95) can be used as a measure of the general background sound pressure level that excludes the potentially influence of particular local noise events. [43, p23] Think of a single loud noise event that otherwise should 'increase' the average sound pressure level during a measurement period.

The figure below shows the LA10, LA90 and LAeq levels (in blue, black and green dotted lines respectively). The grey line is the non-steady sound pressure obtained during this measurement of 60 seconds.

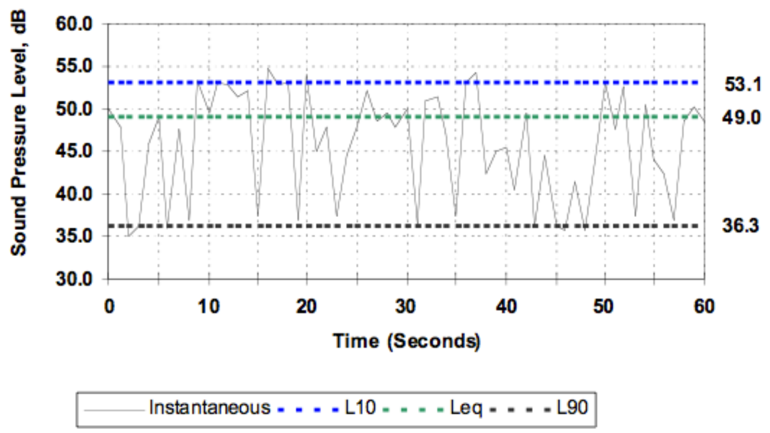

Figure 6: *Sound pressure levels L10, Leq and L90 (courtesy: [96])*

Subjective evaluation of sound pressure levels
They way noise of perceived differs for every human. Generally a 10dB(A) change in sound is accepted to correspond to an approximate doubling (or halving) in perceived loudness. A 3–5 dB(A) correspond to a noticeable change in loudness, while 1dB(A) change is difficult to detect.
The table below shows the subjective evaluation of some sound pressure levels: [96]

Sound pressure level	Subjective evaluation	Examples
110–140 dB(A)	Extremely noisy to intolerable	130dB(A) = Threshold of pain 120dB(A) = Jet take-off at 100 m dist.
90–110 dB(A)	Very noisy	110dB(A) = 'Night club dance floor' 100dB(A) = Loud car horn at 10 m. dist.
70–90 dB(A)	Loud	90dB(A) = Heavy truck at 10 m. dist. 80dB(A) = Curbside of a busy road
50–70 dB(A)	Moderate to quiet	60dB(A) = Normal conversation
30–50 dB(A)	Quiet to very quiet	50dB(A) = Office noise 30dB(A) = Inside bedroom at night
20–30 dB(A)	Almost silent	-

Measurement
The propagation of sound between sources and receivers is much more complicated than, for example, assuming that sound that propagates over absorbing materials (as grass, ground, etc.) decreases more rapidly. According to WHO, direct and ground-reflected sound can combine in a very complex way. This may result in strong cancellations at some frequencies and no cancellation at other frequencies. [43, p32] The decrease of sound is influenced by: the type of the noise source (point or line), distance, atmospheric absorption (humidity, wind-direction, wind-speed, temperature), obstacles/reflections, absorption (ground, barriers), and human perception.

For measurements it is of importance if noise is generated at a fixed location (point source or line source) or from a moving object (moving source). There are differences between the propagation of sound from both sources, as is described by [43, p32]. They report that "one cannot adequately assess the noise from a fixed source with measurements at a single location; it is essential to measure in a number of directions from the source. If the single source is moving, it is necessary to measure over a complete pass-by, to account for sound variation with direction and time". [43, p32]

Low-frequency noise (noise with a frequency range < 100Hz) is typically generated by large diesel engines in ships, trains and large equipment. Also heavy-duty vehicles (trucks) can generate low-frequency noise. All these types of equipment are commonly encountered in ports. WHO reports that: "health effects due to low-frequency components in noise are estimated to be more severe than for community noises in general". For low-frequency noise they propose to use C-weighting instead of A-weighting, since the latter 'underestimates' the sound pressure level of low frequencies. [43, p53]

As described, the measurement of noise has many implications. The measurement location is often specified in regulations. The WHO report [43] lists, for example, sound pressure levels at residential homes at façade level [43, summary p14]. The results from measurements allow for a 6dB decrease when is measured very close to a wall, since reflection of walls increase the levels. A distance of 3,5 to 4 meters is 'standard'. [96] They are specified in such regulations as:

Free-field Level = (outside) measurement at least 3,5 meters from reflecting surfaces as buildings
Façade Level = (outside) measurement 1 meters from a reflecting surface as buildings
Peak sound pressure = measured close (100mm) from the ear

The time period that is measured should be denoted. As explained; LAeq,8h implies a continuous measurement of 8 hours. To measure during daytime a time base of 16h is used (7.00-23.00). To measure during nighttime a time base of 8h is used (23.00-7.00).

Appendix 6: Best (sustainability) practices in port sector

This appendix lists the 'best practices' that ports around the world have taken on sustainability and environmental issues. The aspects/actions/measurements (items) in this 'inventory list' are similarly categorized as proposed in section 4.1 and checked on their (quantitative or qualitative) measurability. The sub-sections in Chapter 4 describe the items that are noteworthy, have lead to major improvements of sustainability in the port, or are extensively discussed and reported on. The items that are 'generic' are used in Chapter 6 for the 'Proposed Assessment Method' and made more quantitative when possible.

This 'inventory list' has been composed, especially for this research, from various environmental reports, magazines and websites of various ports worldwide. The main sources of information were: ports in China and South Korea: [1 – 5], ports in the United States, Canada and Austrilia [7 – 20], ports in Europe [22 – 27], ports specifically in the Netherlands [28 – 31], reports from the Dutch government, NGO's and ESPO [32] [33] [35] [36].

Aspect	Issue *(pollution)*	Quantitative (unit)	Qualitative (appearance)	Comments
Air quality				
Emission control / Monitoring system: existence	Air		y/n	Measuring of 'air quality' (emission concentration)
Emission control / Monitoring system: coverage of port area	Air	%		
Emission control / Monitoring system: # of substances measured	Air	%		GHG (CO2), NOx, SOx, PM2.5, PM10, O3, CO, HC, VOC
Climate Change	GHG	CO2 / TEU		Carbon dioxide
Climate Change	GHG	N2O / TEU		Nitrous oxide
Climate Change	GHG	CH4 / TEU		Methane
Air Pollution	Eutrophication	NOX / TEU		Nitrous oxides
Air Pollution	Acidification	SOX / TEU		Sulphur oxides
Air Pollution	Respiratory diseases	PM2.5 / TEU		Particulate matter <2.5um
Air Pollution	Respiratory diseases	PM10 / TEU		Particulate matter <10um
Air Pollution		HC / TEU		Hydrocarbons
Air Pollution	Toxicity	CO / TEU		Carbon monoxide
Air Pollution	Respiratory diseases	VOC / TEU		Volatile organic compounds
Decrease use of Ozone Depleting Substances (ODS)	Air		y/n	CFCs and halogens
FM200 or CO2 fire extinguishers instead of BTM / Halon	Air		y/n	
R134a refrigerants instead of R22 (in chillers)	Air		y/n	
Carbon Capture and Storage (CCS)	Air		y/n	*(Port of Rotterdam, NL)* CCS or for greenhouse growers
Dust prevention: water spray	Air	%		Requires closed port's water treatment
Dust prevention: encapsulation	Air	%		
Dust prevention: covering	Air	%		
Dust prevention: covering and air treatment	Air	%		
Prevent release of odors in vicinity of municipalities	Air		y/n	
Clean truck program (polluting trucks banned from port)	Policy		y/n	*(North Carolina Ports, USA)* based on emission standard
Modal split - obliged to tenants (reduce road traffic)	Policy	%		To reduce road transport
Modal split - barge	Policy	%		To hinterland
Modal split - rail	Policy	%		To hinterland
Traffic management; % of trucks avoiding rush-	GHG	%		*(Port of Rotterdam, NL)*

hour traffic				
Off-peak gate operations; reduce peak emissions	GHG	%		*(North Carolina ports, USA)*
Prevent paint mist on vessels / equipment	Policy		y/n	When painting a vessel with high wind speeds, etc.
Waste				
Hazardous materials surveys and removal	Waste		y/n	Asbestos, lead-based paint, PCBs in transformers, etc.
Chemical waste: collection points	Waste		y/n	
Chemical waste: centralized storage center	Waste		y/n	Preferable
Chemical waste: amount	Waste	kg / TEU		Chemical + Hazardous waste
Chemical waste: collection rate (X)	Waste	% X		
Chemical waste: treatment in port area	Waste		y/n	
Industrial waste: separated collection	Waste		y/n	
Industrial waste: separated collection rate (X)	Waste	% X		Waste that is actually collected for recycling
Industrial waste: recycling rate (Y)	Waste	% Y		Materials extracted from collected waste
Industrial waste: recovery rate (Z)	Waste	% Z		End-use material recovered from waste stream
Industrial waste: treatment in port area	Waste		y/n	Manual separation of materials and hazardous waste
Industrial waste: reuse within port area	Waste	%		Concrete, Asphalt pavement, misc. steel/scrap
Separate collection of Paper	Waste		y/n	
Separate collection of Plastics	Waste		y/n	
Separate collection of Ferrous metals	Waste		y/n	
Separate collection of Tires	Waste		y/n	*(Port of Los Angeles, USA)*
Separate collection of Rail sleepers	Waste		y/n	*(Port of Bremen, Germany)*
Monitor freq. occurring accidents of polluting the environment	Policy		y/n	
Benchmarking waste-streams	Waste		y/n	
Recycling Expansion Plan	Waste		y/n	
Cradle-to-cradle	Waste		y/n	Strive for the highest possible
Integration of more recyclable materials	Waste		y/n	% if data available
Expand/obligate recycling to tenants	Waste		y/n	*(Los Angeles, USA)*
Waste				
Water demand: fresh water use	Water	L / TEU		Drinking water
Water demand: river water use	Water	L / TEU		Processwater from river
Water demand: closed-system water use	Water	L / TEU		Processwater from closed wastewater treatment
Wastewater treatment: runoff water treatment	Soil		y/n	
Wastewater treatment: closed system in port	Water		y/n	
Wastewater treatment: no chemicals for treatment	Waste		y/n	
Wastewater treatment: dissolved air flotation (oil separation)	Waste		y/n	
Baseline characterization and monitoring: port/harbor water	Water		y/n	*(North Carolina ports, USA)*
Baseline characterization and monitoring: river water	Water		y/n	*(North Carolina ports, USA)*
Baseline characterization and monitoring: bathing water	Water		y/n	
Baseline characterization and monitoring: ground water	Water		y/n	
Monitoring: Oxygen concentration in water	Water	Δ DO (ppm)		KPI of water quality, DO = dissolved oxygen
Monitoring: Amount of nutrients	Water	Δ		*(Hong Kong port, China)*
Monitoring: Amount of depositions	Water	Δ		
Monitoring: Contaminated ground water	Water	Δ		Avoid migrating to harbor waters
Monitoring: Dredged material	Water	Δ		
Monitoring: During dredging activities to detect adverse impacts	Water	Δ		*(Long Beach, USA)*

Monitoring: Silting geometry	Water	Δ		*(North Carolina ports, USA)*
Monitoring: Oil spillage	Water	L / year		
Ballast water management	Water		y/n	
Ballast-, washing-, Bilge water receiving and processing	Water		y/n	*(Port of Qingdao, China)*
Local environment				
Protecting and conserving rural ecological and landscape resources	Policy		y/n	*(Port of Hong Kong, China)* enhanced aesthetic quality
Sustainable Program to protect port environment	Policy			
Development of core nature: areas outside the port area	Land Use		y/n	*(Port of Antwerp, Belgium)*
Development of core nature: other than Country Parks	Land Use		y/n	*(Port of Hong Kong, China)*
Brownfield redevelopment	Land Use			
Compensation of environment for land use / new facilities	Land Use		y/n	*(Bremenport, Germany)*
Shrubby grassland instead of brownfields	Biodiversity	%		
Define core areas with 'ecological value'	Biodiversity	%		*(Port of Hong Kong, China)* forest/shrublands/etc.
Extensive breeding and resting areas for birds	Biodiversity	%		*(Bremenport, Germany)*
Flora and fauna areas / bird islands / ecological infrastructure	Biodiversity	%	y/n	*(Port of Antwerp, Belgium)* > 5% special port areas
Use buffered landscaping	Biodiversity		y/n	*(North Carolina ports, USA)*
Tree planting in and around port area	Biodiversity		y/n	*(Port of Los Angeles, USA)* < emissions/GHG/smog
Tree planting as a noise barrier	Noise		y/n	*(ESPO)*
Providing passive and active leisure and recreation opportunities	Policy		y/n	
Reuse released soil for other purposes	Soil		y/n	
Contamination plan to remove and treat current contaminated soils	Soil			*(Port of Long Beach, USA)*
Sediment cleanup in harbor	Water		y/n	
Suspend particles from the harbor bottom with a dredger	Water		y/n	*(Bremenport, Germany)* Instead of sink as sediment
Treatment of contaminated sediments that is dredged from the harbor	Soil		y/n	*(Bremenport, Germany)*
Biological survey of marine organisms inhabiting harbor habitats	Biodiversity		y/n	
Collect information about the health of harbor ecosystems	Biodiversity		y/n	
Conjunction with federal and state wildlife programs	Biodiversity		y/n	Very important to raise goodwill / prevent actions
Monitoring: Biodiversity (general)	Biodiversity		y/n	
Monitoring: Fish diversity	Biodiversity		y/n	*(Port of Long Beach, USA)*
Monitoring: Bird Abundance	Biodiversity		y/n	*(Port of Long Beach, USA)*
Monitoring: Wildlife; enhancing wildlife habitat	Biodiversity		y/n	
Special lamps with small light spectrum	Light	% special		*(Bremenport, Germany)* low attraction on insects
Special screens preventing light directing into water / surroundings	Light	% covered		Prevent light pollution to surrounding environment
Vessels				
Environmental Ship Index (ESI) preference	GHG	ESI score		0 = conform requirements, 100 = zero emission
Lower rates for clean vessels / penalties for polluting vessels	Policy		y/n	*(beleidsbrief NL)*
Cleaner Ocean-Going Vessels engines	GHG	Δ emission		Limit value g/kWh - Rating g/kWh = Δ g/kWh
Diesel electric propulsion	GHG	Δ emission		Limit value g/kWh - Rating g/kWh = Δ g/kWh
Cold-ironing / onshore electricity / shore power - vessel capability	GHG		y/n	Requires adaptation to 'Infrastructure' as well
Solar power to reduce auxiliary engines	GHG		y/n	
Slow steaming in port	GHG		y/n	Vessel Speed Reduction is US term
Slow steaming (12 knots) within 20 miles of coast	GHG		y/n	*(Port of Los Angeles, USA)*
Slow steaming (12 knots) within 40 miles of coast	GHG		y/n	*(Port of Los Angeles, USA)*
Hybrid tug boats	GHG	%		*(North Carolina Ports, USA)*

Clean vessels see 'Engines', 'Fuel'				
Equipment				
Anti-idling (idling shut-off) device	GHG	% vehicles		
15-min idling limit device	GHG	% vehicles		
Harbor trams (for transporting people)	GHG		y/n	*(Port of Hamburg, Germany)*
RTG/RMG: Hybrid powertrain - replace	GHG	% RTGs		
RTG/RMG: Hybrid powertrain - retrofit	GHG	% RTGs		*(Hong Kong ports, China)*
RTG/RMG: electricity powertrain (e-RTG) - replace	GHG	% RTGs		
RTG/RMG: electricity powertrain (e-RTG) - retrofit	GHG	% RTGs		*(Port of Busan, Korea)*
Machinery & vehicles: EURO V powertrain	GHG	% vehicles		Emission standard as of 2009
Machinery & vehicles: EURO VI powertrain	GHG	% vehicles		Emission standard as of 2014
Machinery & vehicles: hybrid powertrain	GHG	% vehicles		Both straddle carriers or AGV
Machinery & vehicles: electric powertrain	GHG	% vehicles		Both straddle carriers or AGV
Frequency control capability; frequency converters	Energy		y/n	
Lighter, energy efficient equipment	Energy		y/n	
Energy recovery when lowering/idling	Energy	% recuperation		
Energy recovery: fed-back into power grid	GHG		y/n	Only for electric powertrain
Energy recovery: super capacitors	GHG		y/n	
Energy recovery: Fly wheel systems	GHG		y/n	
Energy recovery: Battery systems	GHG		y/n	
Silent exhaust pipes	Noise	% vehicles		*(ESPO)*
Tires on equipment: low resistance	GHG	% vehicles		
Tires on equipment: low noise	Noise	% vehicles		
Multiple braking disks and/or wet braking	Noise	% vehicles		*(Bremenport, Germany)*
Timers reduce volume of warning sirens during night	Noise		y/n	*(Hong Kong ports, China)*
Loud hailers are muted	Noise		y/n	*(Hong Kong ports)*
Beacon lights instead of warning sounds	Noise		y/n	
Dimming of quay crane floodlights when idling	Light		y/n	
Floodlights on crane booms auto switch-off when boom is raised	Light		y/n	
Electronic ballasts for crane floodlights	Light		y/n	*(Hong Kong ports, China)*
Clean equipment see 'Engines', 'Fuel'				
Clean locomotives see 'Engines', 'Fuel'				
Clean trucks see 'Engines', 'Fuel'				
Equipment: Engine				
Fuel efficient engines	GHG	Δ emission		Benchmark: delta to emission standard in force
Variable-speed engines	GHG / Noise	Δ emission		Benchmark: delta to emission standard in force
Waste gas treatment	GHG		y/n	
Water injection, humid-air motors (increases compression)	GHG	Δ NOx, CO		*(Port of Vancouver, Australia)*
Selective Catalytic Reactors	GHG	Δ NOx		*(Port of Gothenburg, Sweden)* 90-99% reduction
Diesel particulate filters (DPF)	GHG	Δ PM, Soot		85% reduction, typical for DPFs
Diesel oxidation catalysts (DOC) - two way	GHG	Δ HC, CO		Two-way reduces HCs, CO
Diesel oxidation catalysts (DOC) - three way	GHG	Δ HC, CO, NOx		Three way reduces HCs, CO, NOx
Scrubber	GHG	Δ emission		Reduces air pollution
Slide Fuel Valves	GHG	Δ emission		Reduces fuel consumption, Nox
Encapsulated engines, transmission units and generators	Noise		y/n	
Use water cooling instead of air cooling	Noise		y/n	*(ESPO)*
Reducing structure-borne sound radiation	Noise		y/n	*(ESPO)*
Reduce engine speed (f.e. 1800rpm to 1500 rpm)	Policy	Δ less fuel		*(Hong Kong ports, China)*
Equipment: Fuel type				
Emulsified diesel fuel	GHG	% use		(Port of Singapore) Water + diesel: up to 20% less Nox

Oxygenated fuel	GHG	% use		Oxygenate + gasoline
Promote clean fuels: biofuel (second generation)	GHG	% use		B5 (5% bio), B20 (20% bio), B100 (100% bio)
Promote clean fuels: ULSD	GHG	% use		*(Port of Singapore)* <0.5% sulphur (50ppm)
Promote clean fuels: CNG, LNG	GHG	% use		
Fuel additive to reduce diesel engine emissions	GHG	Δ emission		*(Georgia port, USA)* study: 5% less PM, NO2, CO
Dynamic oil purifiers recycle lubricant and hydraulic oil	Waste		y/n	*(Hong Kong ports, China)* lubricant consumption -46%
Environment friendly lubricants for technical operations and vessels	Waste		y/n	*(Port of Bremen, Germany)*
Environment friendly paints	Waste		y/n	Zero VOCs, water based, natural pigment, non-toxic
Operating practices				
Expected lifetime > 15 years	Efficiency	year		Part of LCA
Increase reliability	Efficiency	MTBF		Mean Time Between Failure
Increase availability	Efficiency	A		A = uptime / (uptime + downtime)
Proper equipment maintenance (to reduce fuel consumption)	Efficiency		y/n	
Eliminating Drayage	Efficiency		y/n	Drayage = transport of goods over a short distance
Calculation method for estimating amount of GHG of operations	Efficiency		y/n	GHG reduction in efficient manner *(Port of Singapore)*
Inspection of equipment (on condition)	Efficiency	interval		
Truck registration system to reduce or prevent idling	GHG	% vehicles	y/n	*(Hong Kong ports, China)*
Driving refresher courses to improve fuel efficiency	Policy	% drivers	y/n	*(Hong Kong ports, China)*
Driver instructions to save energy	Policy	% drivers		
Improve information system - vehicle status	Policy	% vehicles		*(Port of Shanhai) and others*
Automated sorting/storage	Efficiency		y/n	Eliminates human factor
Dual TEU container crane / twin RMG / tandem 40" double crane	Efficiency		y/n	
45', 48', 53' containers	Efficiency			*(Port of Shanghai, China)*
Adaptable to handle various products	Efficiency		y/n	
Reducing the speed of putting down a container and	Noise		y/n	*(ESPO)*
Reducing distance from surface of opening a bulk grab	Noise		y/n	*(ESPO)*
Automatic positioning of the spreader	Efficiency / Noise			*(ESPO)*
Proactive planning/recognizing - logically clustering of containers	Efficiency			*(Port of Rotterdam, The Netherlands)*
Proactive planning/recognizing - lower % of empty trucks	Efficiency	100 - % empty		*(Port of Rotterdam, The Netherlands)*
Proactive planning/recognizing - stimulate road trains, double trailers	Efficiency	% double		
Tires on equipment: frequently check correct pressure	GHG / Noise		y/n	
Automation: reduces need for lightning	Light			
Automation: reduces need for energy	Energy			
Energy resource				
Energy demand: use	GHG	MJ / TEU		
Energy demand: renewable energy (share in total demand)	GHG	%		
Energy resource: Power plant on natural gas	GHG	%		
Energy resource: Power plant on biomass / co-fired	GHG	%		
Energy resource: Tidal energy	GHG	%		Various pilot projects
Energy resource: Wind energy	GHG	%		
Energy resource: Solar power / photovoltaic (PV)	GHG	%		
Energy resource: Hydropower / hydrogen plant	GHG	%		*(Port of Rotterdam, NL)* R'dam Botlek ExxonMobil
Fuel demand: fossil fuel use	Natural resources	L / TEU		
Fuel demand: renewable fuel use	Natural	L / TEU		Hydrogen, bio-ethanol, green-diesel (See

	resources			'Fuel')
Heat resource: Geothermal energy	GHG	%		
Heat resource: Solar thermal collectors	GHG	%		
Heat resource: Share residual heat between (chem.) companies	GHG	%		*(Port of Rotterdam, NL)*
Heat resource: Concentrated heat supply for chemical areas	GHG		y/n	
Infrastructure				
Availability of hinterland transport: rail	GHG		y/n	Capacity itself is no benchmark, see 'Air'
Availability of hinterland transport: inland waterway	GHG		y/n	
Availability of hinterland transport: traffic congestion	GHG	100 - %		Rush hour transport or increased traffic congestion
Availability of hinterland transport: vicinity of urban areas	GHG / Noise	km		
On-dock rail / Intra-port rail system	GHG		y/n	*(Los Angeles, USA)*
On-dock rail service	GHG		y/n	
Geothermal railroad switch heating system	Energy		y/n	*(Port of Hamburg, Germany)*
Pipeline transport instead of road	GHG		y/n	Less truck, rail and barge transport
Transportation vehicles placing on flat surfaces	Noise		y/n	*(Port of Shanghai, China)*
Low-noise material (roads)	Noise		y/n	
Low noise barriers along roads	Noise		y/n	*(ESPO)*
Put noise source into a building or barriers around noise source	Noise		y/n	
Move the entrance gate away from residential areas	Noise		y/n	*(ESPO)*
Noise barriers: constructed of metal (shields / grills)	Noise		y/n	
Noise barriers: constructed of stones	Noise		y/n	
Noise barriers: constructed of natural materials (wood)	Noise		y/n	
Noise barriers: constructed as hill	Noise		y/n	
High post lamps / light masts	Light		y/n	Instead of lower lamp posts
Voltage regulating transformers	Light		y/n	Reduces energy consumption
High-pressure sodium vapor lamps (HPS)	Light	%		A more direct light beam as low pressure lamps (LPS)
LED lightning	Light	%		*(Port of Busan, Korea)*
LED light on solar cells on place dolphins	Light		y/n	*(Port of Bremen, Germany)*
Utility company in port area	GHG		y/n	Energy, LNG, water(treatment), CCS
Cold-ironing / onshore electricity / shore power - landside capability	GHG	% of quay		*(Hong Kong ports, China) and others*
Automated Mooring System	GHG	% of quay		*(Port of Busan, Korea)*
Off-side fueling of vessels	Water		y/n	*(North Carolina Ports, USA)*
Electric vehicle charging station	Energy		y/n	
Electrical plugs for refrigerated containers (no point source pollution)	Energy		y/n	
Covered areas for reefer-containers (to avoid sun radiation)	Energy		y/n	*(Rijsenbrij et al., 2011)*
Truck stop electrification	GHG		y/n	*(North Carolina Ports, USA)* Electrification + HVAC
Grade separations (in freight corridors)	Efficiency		y/n	Different grades of material: avoid degrade by mixing
Clustering of companies, or departments with same activities	Efficiency		y/n	See also share of heat at 'energy resource'
Shared transport of companies	Efficiency	%		
Shared transport equipment of companies	Efficiency	%		
Efficiency of land use: industrial area utilization	Land use	%		Excl. buffer zones, areas for nature/habitat
Efficient site planning (redevelopment or scheduling)	Land Use		y/n	
Compact facility plan	Land use		y/n	
Inward expansion: renovating older parts of the port	Land use		y/n	*(Port of Antwerp, Belgium)*
Careful (sustainable) allocation of (new) terrains	Land use		y/n	

Lightweight area (for empty containers)	Land use		y/n	Less piled area
Structured heavyweight area (for storage and HDVs)	Land use		y/n	HDV = Heavy Duty Vehicle
Pervious pavements	Soil	%		
Road surface with water permeable material	Soil	%		
Smart Irrigation System (shuts down when leaks are detected	Soil		y/n	*(San Diego, USA)*
Dedicated truck lanes	Soil		y/n	Oil spillage can be reduced by non-permeable road
Enclosed maintenance facilities	Soil		y/n	*(North Carolina ports, USA)*
Drainage system in workshop to collect emulsified grease	Soil		y/n	*(Port of Hong Kong, China)*
Underground oil interceptors beneath petrol filling station	Soil		y/n	*(Port of Hong Kong, China)*
Liquid proof floor underneath parking space for equipment	Soil		y/n	
Dedicated oil / fuel depots (covered)	Soil / Air		y/n	*(Port of Hong Kong, China)*
Sustainable development/build of infrastructure	Policy		y/n	Re-use of concrete, building materials, etc.
Redevelopment that accommodates changes in trade / logistics trends	Policy		y/n	*(Port of Los Angeles, USA)*
Buildings & Warehouses				
Double-glazed glass	GHG	%		
Promoted internal temperature >20C during summer	GHG	degr.C		
Light bricks with heat preservation and insulation	GHG		y/n	
Use noise absorbing building materials	Noise		y/n	*(ESPO)*
Tap natural lightning (sun pipes)	Energy		y/n	Extensive use of natural daylight reduces electricity use
Automatic light switches	Energy		y/n	In an entire building
Improve energy efficiency	Energy		y/n	Difficult to quantify
Energy efficient ICT equipment	Energy		y/n	
Shut-down ICT equipment when not used	Energy		y/n	During night, not in sleeping mode
Low noise electric ventilation systems in buildings	Noise		y/n	
Safeguarding water; faucet aerators	Water		y/n	
Safeguarding water; automated water taps	Water		y/n	*(Port of Hong Kong, China)*
Safeguarding water; seawater flushing	Water		y/n	
Low-emissions construction equipment	GHG		y/n	
Require contractors to use clean diesel in construction equipment	GHG		y/n	Emulsified, oxygenated, ULSD
Require contractors to use diesel exhaust controls in constr. equipment	GHG		y/n	Particulate filters, catalysts
Controlling of types of fuel used in construction equipment	GHG		y/n	
Conserving materials and resources	Natural Resources		y/n	
Recycling of demolition debris	Natural Resources	%		*(Port of Los Angeles, USA)*
Use construction material with recycled content	Natural Resources	%		
Pre-construction surveys of land, sediments and buildings	Soil		y/n	Identify and manage hazardous waste appropriately
Buildings/warehouses: prevent high-rise	Policy		y/n	
Buildings/warehouses: use 'natural' colors that absorb in surroundings	Policy		y/n	
Buildings/warehouses: visual quality of the landscape	Policy		y/n	*(Bremenport, Germany)*
Introduce a Green Building Policy (for new construction and retrofits)	Policy	type		*(Port of Los Angeles, USA), (Port of Singapore)*
LEED for new construction and retrofits	Policy		y/n	*(Port of Los Angeles, USA)*
LEED Green Building Rating System: certified, silver, gold, platinum	Policy	rating		
Sustainable Development				
Open House: showcasing green port programs, update of progress	Policy		y/n	*(Port of Long Beach, USA)*
Inform and involve stakeholders in sustainable performance	Policy		y/n	
Structured dialogue with local people	Policy		y/n	Industry <> port companies <> local authorities

Improve environmental awareness	Policy		y/n	Difficult to measure, 'what' is awareness?
Improve environmental contribution	Policy		y/n	
Community outreach	Policy		y/n	*(Port of Los Angeles, USA)*
Sponsorship policies of public or private sector	Policy	% of turnover		*(Port of Antwerp, Belgium)* culture/education/sport/etc.
Noise: subsidize sound-proof windows for residential houses nearby	Policy (noise)		y/n	*(Bremenport, Germany)* + sound-proof ventillation
Noise: subsidize sound-proof doors for residential houses nearby	Policy (noise)		y/n	*(Bremenport, Germany)*
Noise: monitor permanently	Policy (noise)		y/n	*(Bremenport, Germany)*
Noise: document permanently	Policy (noise)		y/n	*(Bremenport, Germany)*
Ensure proactive communication on changes/incidents/plans	Noise		y/n	*(ESPO)*
Promote Public transport as sustainable way of traveling	Policy		y/n	
Port restaurant: healthy food, environ.-preferable services and supplies	Policy		y/n	*(Port of Los Angeles, USA)*
Environmental Programs				
Environmental management system: EMAS	Policy		y/n	
Environmental management system: ISO 14001	Policy		y/n	
Environmental management system: (basic) EMS	Policy		y/n	Environmental Management System (policy and actions)
Environmental management system: PERS	Policy		y/n	PERS is intended for European ports
Environmental management system: SDM	Policy		y/n	SDM is intended for European ports
Other Sustainable Programs	Policy		y/n	Landscaping, water conservation, recycling/disposal
Environmental policy	Policy		y/n	
Corporate Social Responsibility (CSR) program	Policy		y/n	
Environmentally Preferable Purchasing (EPP)	Policy	% contracts		*(Port of Los Angeles, USA)* procurement and contracting
Sustainable procurement	Policy	% procurement		*(Port of Los Angeles, USA)* procurement and contracting
Sustainable purchase of products and services / Green Purchase Policy	Natural Resources	% products		*(Port of Los Angeles, USA), (Port of Rotterdam, NL)*
Task Force to promote, steer and evaluate sustainable programs	Policy		y/n	*(Port of Long Beach, USA)*
Tenant audits of activities: recommendations for improvement	Policy		y/n	*(Port of Los Angeles, USA)*
Training and outreach (port staff, management)	Policy		y/n	Measuring is difficult: content/quality/participation/nrs.
Technical R&D on environmental issues	Policy	% of turnover		
Ecological knowledge	Policy		y/n	Measuring is difficult: what is 'ecological knowledge'?
Environmental action plans on short term (1-5y)	Policy		y/n	Direct action plan
Environmental action plans on mid-term (5-10y)	Policy		y/n	Goals to achieve
Environmental action plans on long-term (>10y)	Policy		y/n	Goals to achieve
Define clear guidelines on noise levels	Noise		y/n	
Noise mapping (and measuring) of port area	Noise		y/n	
Relocation of most noisy activities	Noise		y/n	
Create economy of scale; improve efficiency	Efficiency			
Growth of internal productivity per unit area	Policy	TEU / ha		*(Port of Antwerp, Belgium)*
Carpooling (car: 2-4 pers) program	GHG	% employees		*(Port of Los Angeles, USA)* 'rideshare'
Vanpooling (van: 8-15 pers) program	GHG	% employees		*(Port of Los Angeles, USA)* 'rideshare'