Fact-finding study on opportunities to enhance the energy efficiency and environmental impacts of ports in the Baltic Sea Region

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Cover photo: The Port of Gothenburg, Sweden

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Foreword

Almost 15% of the world's maritime transportation is carried out in the Baltic Sea, where over 800 million tonnes of cargo is handled yearly. The countries in the Baltic Sea region have strong trade relations with each other. Efficient transport and logistics solutions are needed to get goods to market. Seaports are key parts of logistic chains that provide vital links between industries and their markets and supply sources. Ports are often also significant locations for industrial activities which need energy for their production processes.

Energy use, energy efficiency and environmental issues have become more important as energy prices have risen, while the operational environment is constantly changing and tougher environmental regulations are putting pressure on all industrial and commercial sectors. These issues are all also evident regarding ports. At the same time, competition for customers is harder than ever. In maritime ports and related activities, new environmental issues are constantly emerging and becoming additional competitive factors. Energy consumption and emissions in shipping and the port sector are increasingly the focus of public concern and political attention.

Several different actors operate in any port area, including the port authorities, stevedoring companies, shipping companies and logistic companies. Energy consumption is often spread among a number of different operations. Energy efficiency and environmental awareness at ports can only be enhanced with the help of advanced know-how and co-operation between different actors. Several ports have implemented energy efficiency measures, but in general ports evidently still lack a systematic approach to energy efficiency.

Compared to other more energy intensive sectors, ports still remain a less explored area concerning energy efficiency. It is clear, however, that as in all other commercial and industrial sectors systematic energy efficiency analyses will be able to find potential for further improvements in energy efficiency.

The aim of this study is to describe the current situation regarding energy efficiency at Baltic ports and examine the most important related issues. We have also aimed to analyse whether there is a need for a larger collaboration project concerning the energy efficiency of ports around the Baltic Sea. The study has been funded by the Baltic Sea Region Energy Co-operation (BASREC). The seven-month project has been led by Motiva Services Ltd. The ports included in the study were HaminaKotka, Tallinn, Riga, Klaipeda, Gothenburg and Copenhagen-Malmö. Representatives of stevedoring companies, The Finnish Port Association and The Finnish Port Operators Association were also interviewed.

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Abstract

This study aims to clarify the current state of energy efficiency at the Baltic Sea ports and examine the most important related issues. The project has been divided in to two tasks. Firstly, earlier studies and projects were examined in a literature study. Based on the findings of the literature study, the representatives of six ports at the Baltic Sea region were then interviewed about energy efficiency issues.

Energy savings can be achieved at ports with the help of new techniques and technologies, reshaped terminal layout and operations, and changes in the attitudes and behaviour of personnel. In the literature study we identified several aspects of operation that affect the energy efficiency of any port, including: energy monitoring and management systems; lighting technologies and lighting control; the energy efficiency of buildings, terminals and warehouses; the energy use and operation of machines and vehicles; the use of shore-to-ship power systems; and co-operation between different actors at the port.

The ports included in the interview study were HaminaKotka, Tallinn, Riga, Klaipeda, Gothenburg and Copenhagen-Malmö. The representatives of various stevedoring companies, The Finnish Port Association and The Finnish Port Operators Association were also interviewed.

The interviews revealed that different levels of importance are given to energy efficiency in the management of different ports. In general, energy costs only account for a relatively low share of total costs, so energy efficiency has not played an important part in operations or investments. However, with energy prices increasing and environmental friendliness becoming ever more significant, energy issues are today gaining importance.

Spreading information between ports is recommended in the report as an effective way to improve energy efficiency. This could be done by presenting the good practices compiled here. As energy efficiency is not a key business area for the companies in a port, collaboration between ports and between different actors within ports could be possible, and this would lead to a situation where all the participants will benefit.

Lighting technologies are evidently the main energy efficiency issue that ports are already considering or addressing. Light sources have been switched to LEDs especially in indoor locations, but LEDs are also in use in some outdoor applications. Lighting controls have also been developed to save energy and reduce light pollution.

Novel energy efficient technologies are available for machinery in ports. Heavy machinery is expensive, and service lifetimes are long, so these factors slow the commissioning of more efficient technologies. However, when new investments are under consideration, energy efficiency is already taken into account in decision making.

Training in eco-driving is commonly provided for port drivers. Through such training and the consequent energy efficient practices energy use can be decreased without further investments. Attention should also be paid to other potential behavioural changes among personnel: how can personnel be effectively encouraged to save energy?

It is important to develop resource efficiency monitoring and reporting systems to meet the needs of ports. It would also be important to monitor and report on both the energy effi-

ciency of port facilities, and vehicles' fuel consumption rates. Development work is needed to combine these measurements and system technologies. In addition to energy and fuel consumption follow-up, the system could be developed to monitor and report on material flows within ports. The resulting information could then help to improve the material efficiency of ports.

Contents

1 Literature study

The goal of this study has been to collect background information on best practices relating to energy efficiency and environmental issues at ports, not only in the countries around the Baltic Sea, but also in Europe in general. In this chapter we compile case studies that have been carried out in ports in order to improve their energy efficiency. Wider environmental issues are covered here only in the context of the energy consumption of actors working in the ports.

1.1 Ports in general

1.1.1 Different types of ports

A port can be defined as a harbour or an area that is able to provide shelter to numerous boats and vessels. Ports consist of the dock area, fields, quays, fairways, and land routes. Ports also include related to the port activities, infrastructure such as warehouses, cranes and terminals. The widest definitions of ports also include all the services provided by different organizations within the port. (1)

Ports are strategic geographical locations situated beside oceans, seas, rivers or lakes. The facilities provided for a port depend on the purpose for which the port is being used. The depth of the water plays a vital role in enabling various types of ships to enter and dock at the port. Today most ports, especially seaports, are well-equipped with specialized fixtures such as forklifts and gantry cranes to facilitate regular trans-shipments of cargo. Ports can be of great significance to a nation, as they promote commerce and trade. (2)

Considering factors such as location, water depth and ship sizes, ports can be classified into various types. Some of the main types are as follows (2):

- Seaports are the most common types of ports used around the world for commercial shipping activities. Numerous seaports are situated along many of the world's coastlines to actively handle cargo transactions. Seaports can be further categorized as cargo ports or cruise ports. (2)
- Inland ports are ports built on comparatively smaller water bodies such as rivers or lakes. Some inland ports have access to the sea with the help of canal systems. Ports built on inland waterways typically function like seaports except that they are not usually able to accommodate deep draft ship traffic. Some inland ports specifically created for recreational purposes may only be able to take small sized vessels, such as passenger ferries and fishing boats. (2)
- "Dry ports" are inland terminals that can be interconnected with a seaport via road or rail transportation facilities. They usually function as centers of multimodal logistics. Dry ports may prove useful for the importing and exporting of cargo where they may reduce congestion at a nearby seaport. Their functions are quite similar to those of seaports, with the difference that they are not situated on the coastline. (2)

- Cruise Home Ports specialize in catering for cruise ships, by providing a platform for passengers to enter and disembark from their cruise vessels at the beginning and the end of their journeys. (2)
- Cargo Ports function variously according to the cargo they manage, and the amenities available differ from one port to the other. Cargo ports utilise many mechanical techniques to load or unload shipments. A cargo port may be designed to deal with single or multiple types of products. Items such as liquid fuels, chemicals, grain, timber, machines and motorcars, are often transported via cargo ports. A cargo port which engages in the transfer of containerized goods is referred to as a container port. Stevedores are companies which act as terminal operators and manage the functioning of diverse operating terminals. (2)

Terminals are sets of specific facilities at ports where the loading and unloading of cargos or containers takes place. (2) Terminals may consist of marine structures, yards, cranes, building infrastructures, power infrastructure, vehicles, equipment and tenant operations. (3) Terminals can be classified on the basis of the types of cargo they can handle. Common types of terminals include container terminals, bulk cargo terminals and LNG terminals, etc. (2)

Different types of traffic require different types of ports and handling equipment. Examples of the kinds of traffic that can be handled by different port types include (4):

- Ro-ro[1] ports: trucks, cars, rail wagons
- Container ports: containers
- General cargo/break bulk ports: cargo which is bundled but not stowed in containers, e.g. project cargo (power generation plants), turbines, iron and steel products (bars, coils) and forest products
- Dry bulk ports: coal, iron ore
- Liquid bulk ports: crude oil, LNG, gasoline

1.1.2 Different actors in ports

The port concept can vary depending on approach, but when speaking of a port, the term rarely refers only to a port authority. According to most definitions, the port authority is described more as a landlord or regulator, even though other functions also exist. Commonly the port concept includes the entire port community, consisting of several companies and authorities operating in the port area. Companies that operate within the port area can include for example stevedoring companies, terminal operators, shipping companies, carriers, shipbuilding and repair companies, logistic companies, maintenance services, piloting services, tugging services, vessel traffic services, marine services, container services, packing service providers and trucking companies. Also several different authorities such as hydrographic institutes, customs, immigration, police and fire brigade may operate in facilities located within port areas. (5)

[1] RoRo ships are vessels designed to carry wheeled cargo (i.e. vehicles such as cars and trucks, or trailers) that are driven on and off the ship on their own wheels or using a platform vehicle, such as a self-propelled modular transporter.

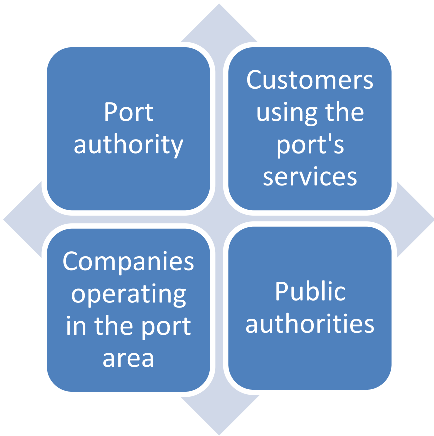

Figure 1. Different actors operating in a port area.

The set-up of port management varies considerably across Europe. In some countries ports are managed by private entities which own the land where the port is located, or have similar rights to those of an owner. In most cases ports are managed by public entities or undertakings. Within this group of public port authorities, there may be differences regarding the degree of autonomy from other public authorities, the level of government they belong to, and the range of services they provide. (6) According to the different roles of the public and private sector concerning the provision of port services and infrastructural development, four main management models can be described: (7)

- Public Service-Port model
- Tool-Port model
- Landlord model
- Private Service-Port model

In the Public Service-Port model, the port authority (a public body) invests in all kinds of infrastructures and superstructures and provides all the port services (goods handling and storage, pilotage, towage, mooring, etc.). (7)

In the Tool-Port model, the port authority invests in all kinds of infrastructures and superstructures, but private companies provide the services at the port. (7)

The Landlord model is the most representative port management model in Europe. In such ports the public port authority usually invests in maritime accessibility infrastructure and protection works (dredging, docks, etc.), whereas the private operators invest in superstructure (handling equipment, installations, etc.) and occasionally in port infrastructures (berths). (7) Finally, in the Private Service-Port model, the port authority (a private body) invests in all kinds of infrastructures and superstructures as well as providing all the goods handling and technical port services, just as they are provided by the public port authority in the Public Service-Port model. (7)

There are significant differences in terms of the objectives and functions of port authorities between different countries and ports. Their institutional frameworks and financial capabilities also differ. Port authorities furthermore differ in terms of market power, but also in terms of the knowledge, skills and competence they can utilise. Most port authorities in Europe have ambitions to go beyond a passive landlord role, but those ambitions may be limited or enabled by the diversity in governance frameworks. (6)

1.1.3 The port sector in Europe

The European Union is highly dependent on seaports for trade with the rest of the world and within its internal market. 74% of goods imported and exported and 37% of exchanges within the EU transit through seaports. Ports guarantee the territorial continuity of the EU by servicing regional and local maritime traffic to link peripheral and island areas. They are the nodes from where the multimodal logistic flows of the trans-European network can be organized, using short sea shipping, rail and inland waterways links to minimize road congestion and energy consumption. (8)

Bottlenecks in ports and their hinterlands due to the lack of high quality infrastructure or low performing port services may result in congestion and extra costs for shippers, transport operators and consumers. European ports face common challenges which will require substantial private and public investment, including: the need to adapt infrastructure to changing demands, notably the increasing size of vessels; and the need to comply with new environmental legal requirements such as the obligation to provide waste reception facilities, LNG refueling stations and shore-to-ship power. (8)

1.1.4 Baltic Sea ports

Almost 15% of the world's maritime transportation is carried out in the Baltic Sea. (5) There are approximately 250 ports in the Baltic Sea area. The total amount of cargo handled in ports bordering the Baltic Sea was 839.4 million tonnes in 2012. Measured by total cargo volume, Russia is the leading country in the Baltic Sea region, with a market share of a 25%, followed by Sweden with 21%. The three biggest ports in the Baltic Sea Region are the Russian ports Primorsk, St. Petersburg and Ust-Luga. (9)

Liquid bulk is the largest cargo type by volume (41% share) in the Baltic Sea Region, with a total volume of 319 million tonnes in 2012. Dry bulk volumes totalled 197 million tonnes, and other dry bulk than cargo totalled 258 million tonnes in 2012. The numbers of containers handled by the Baltic Sea ports amounted to 9.4 million TEUs[2]. St. Petersburg was clearly the biggest container port with approximately 2.5 million TEUs handled. (9)

1.1.5 Regulations and legislation

The main goals behind the EU's energy policy are the security of energy supply and combating climate change. The EU has created an ambitious energy strategy extending to the year 2020, aiming to reduce emissions of greenhouse gases by 20% (compared to 1990 levels), to increase the share of renewable energies to 20% of final energy consumption, and to increase energy efficiency by 20%. (6, 5)

[2] TEU: twenty-foot equivalent unit; an inexact unit of cargo capacity based on the volume of a 20-foot-long (6.1 m) intermodal container.

Unlike most other transport sectors, ports are not specifically regulated by EU legislation. In 2001 the Commission proposed to regulate market access, but the European Parliament rejected the proposal in 2003. In 2004 a second proposal was formulated, but it was again turned down. (10)

The aim of the Port Reception Facilities Directive (Directive 2000/59/EC on port reception facilities for ship-generated waste and cargo residues) is to prevent and reduce discharges of ship-generated waste and cargo residues into the sea. This can be done by making available and improving port reception facilities. (5, 11)

Another directive concerning ship-source pollution is the directive 2005/35/EC on ship-source pollution and the introduction of penalties for infringements. This directive aims to incorporate international standards for ship-source pollution into Community law and to ensure that persons responsible for discharges are subject to adequate penalties, in order to improve maritime safety and enhance the protection of the marine environment. (5)

The latest relevant EU policy documents are the White Paper on Transport and the Single Market Act II, issued in 2011 and 2012. (10)

In 2013, the European Commission put the European seaports on the political agenda of the EU and proposed a strategy to develop their competitiveness together with an action plan combining legislative and non-legislative measures. The new guidelines for the development of the trans-European transport network (TEN-T) have identified 329 key seaports along Europe's coasts that will become part of a unified network boosting growth and competitiveness in Europe's Single Market. The Connecting Europe Facility financial instrument will provide up to €26 billion to support the development of transport infrastructures, including ports and connections from ports to their hinterlands, over the period 2014–2020. (8)

One key measures will involve raising the environmental profile of the European ports by providing guidelines and promoting the exchange of good practices and innovations. In the Clean Power Transport Directive 2014/94/EU of 22 October 2014, the European Parliament and the Council agreed to include provisions which require all core ports to provide Liquefied Natural Gas refueling points and shore-side electricity (unless not economically viable) by 2025. (8)
In a future the Commission will provide financial support to ports implementing good environmental practices and investing in Liquefied Natural Gas and shore-side electricity infrastructure. The Commission will develop analytical tools and criteria that ports can use on a voluntary basis to vary port infrastructure charges according to environmental criteria in a cost effective way. The industry will be invited to assist in this in order to contribute to the greening of the shipping industry at low cost. (8)

1.1.6 Energy consumption

The profiles of terminals' energy use vary according to geography, available energy sources and port type. In Europe, for example, the typical split of diesel fuel to electricity usage is 70:30 depending on the types of equipment used. Diesel is typically used to fuel mobile equipment, while electricity is purchased to power cranes, reefers, electrically powered mobile vehicles, lighting and buildings. (1) Port container terminals are huge energy consumers, especially with regard to energy sources based on fossil fuels. Average values show a yearly fuel consumption of almost 10 million fuel liters (in form of diesel oil). This figure illustrates the true scale of the high energy intensity needed for container handling operations. Great economic, environmental and social impacts are generated by the massive use of diesel oil for developing non-stop operatives at ports. (7)

There is not really any general information available about average energy consumption and distribution. As an example, the energy consumption distribution of the port of Valencia is presented below. Figure 2 illustrates electricity consumption at Noatum Container Terminal, Valencia (ES), in 2012. Electricity consumption by function is divided into four major categories: STS cranes[3], terminal lightning, offices and reefer containers[4]. Reefer containers and STS cranes are the two main contributors to the terminal's electricity consumption. These two categories combined represent 80% of the total figure. Both of these categories are strongly influenced by the levels of traffic on a monthly basis. (7)

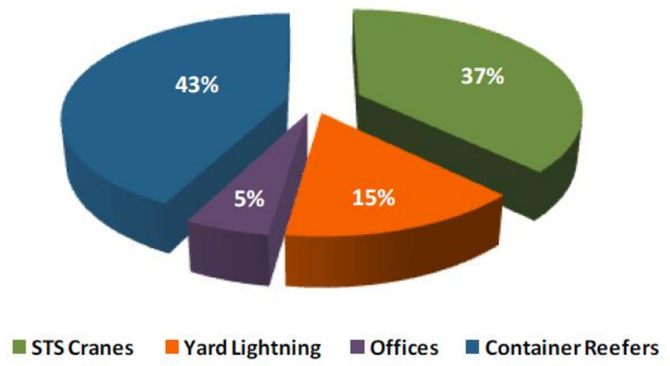

Figure 2. Electricity consumption (kWh) at Noatum Container Terminal, Valencia, 2012. (7)

The machinery used at the port mainly uses fuel (mostly diesel petrol). Fuel consumption is also a major contribution to direct greenhouse gas emissions. Figure 3 illustrates the fuel consumption shares of different types of yard equipment: RTG[5]s, yard tractors, reach stackers and empty container forklifts. (7)

[3] Ship-to-shore container cranes
[4] Refrigerated containers
[5] Rubber-tyred gantry cranes

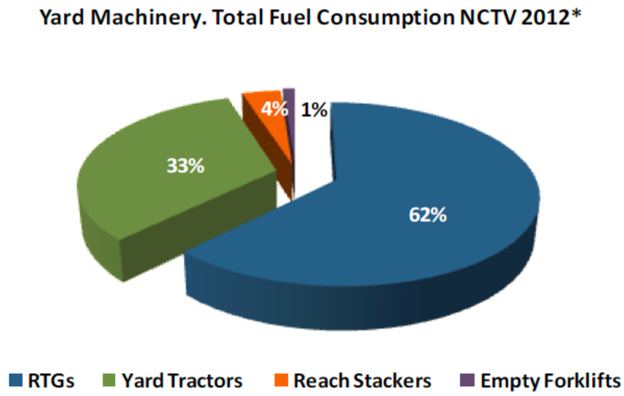

Figure 3. Yard machinery fuel consumption at Noatum Container Terminal, Valencia, 2012. (7)

In 2012, 62% of the total fuel consumption was associated with the operation of RTGs, whereas 33% was used by yard tractors. These two types of machines represent around 95% of the total fuel consumption of the terminal. The remaining 5% is divided between reach stackers (4%) and empty container forklifts (1%). (7)

1.2 Energy efficiency

This chapter presents the most common actions that can be carried out in ports to improve their energy efficiency. The whole chapter is based on publicly available literature. Our aim is to briefly introduce the most common opportunities to improve ports' energy efficiency. The interview-based study presented in chapter 3 was based on the findings of this literature study.

1.2.1 Previous projects examining the energy efficiency of ports

The ESPO Port Environmental Review 2013, published by the European Sea Ports Organisation (ESPO), identified the most significant environmental issues for EU ports. This survey highlights the progress that has been achieved over the years. 79 ports from 21[6] European Maritime States participated in this survey. (6) ESPO and EcoPorts have been monitoring the top environmental priorities of the European port sector since 1996 through regular respective surveys (Table 1). Similar surveys were made in 1996, 2004 and 2009. Interest in environmental issues has increased in recent decades, and the related priorities have also evolved. The table below summarises changes in ports' environmental priorities from 1996 to 2013. Many of these reflect prevailing political drivers. Priority issues change their ranking over time, but certain components have retained their significance for the sector. (12)

[6] The Maritime States and the number of ports represented were: Albania (11), Belgium (2), Bulgaria (1), Croatia (2), Cyprus (1), Denmark (5), Estonia (1), Finland (3), France (11), Germany (4), Greece (8), Ireland (3), Italy (5), Latvia (1), Lithuania (1), Netherlands (6), Norway (1), Portugal (2), Spain (5), Sweden (4), and United Kingdom (12).

Table 1. Evolution of environmental priorities over time (1996-2013). (12)

	1996	2004	2009	2013
1	Port Development (water)	Garbage / Port waste	Noise	Air quality
2	Water quality	Dredging operations	Air quality	Garbage / Port waste
3	Dredging disposal	Dredging disposal	Garbage / Port waste	Energy consumption
4	Dredging operations	Dust	Dredging operations	Noise
5	Dust	Noise	Dredging disposal	Ship waste
6	Port Development (land)	Air quality	Relationship with local community	Relationship with local community
7	Contaminated land	Hazardous cargo	Energy consumption	Dredging operations
8	Habitat loss /degradation	Bunkering	Dust	Dust
9	Traffic volume	Port Development (land)	Port Development (water)	Port Development (land)
10	Industrial effluent	Ship discharge (bilge)	Port Development (land)	Water quality

Some environmental issues such as dredging operations, port land development and dust have been among the top 10 priorities in Europe over the last 17 years. These highly prioritized environmental issues form a basis for environmental collaboration in the port sector.

Energy consumption made it to the list in 2009, and by 2013 it was already the third most important environmental issue. This clearly reflects new political priorities on energy efficiency and climate change. Energy consumption and efficiency can be seen as a rising topics for the port industry. (12)

According to the The ESPO/EcoPorts Port Environmental Review 2009, 33% of ports measure or estimate their carbon footprint, 51% of ports take measures to reduce their carbon footprint, 57% of ports have a programme to increase energy efficiency, and 20 % of ports produce some form of renewable energy. (6)

Several projects have striven to gather information on ports' energy efficiency. One of them is EcoPorts – an environmental project run by ESPO which publishes guides and tools to improve several environmental factors in ports, including energy efficiency. (13)

The Climeport project proposes the assessment of different methodologies in order to combat global climate change. The project takes place in several countries in the Mediterranean region. The project aims to develop and implement solutions in order to mitigate climate change by means of actions in maritime and inland transport, energy saving and efficiency, implementing the world port climate declarations, and designing an environmental indicators system as a footprint based on CO_2 emission levels. In the Climeport project 30 good practices for reducing the greenhouse gas emissions and carbon footprints of ports were identified and tested. Table 2 lists the 17 highest ranked practices. Several of these practises are similar to those identified in this study as good practices that can improve the energy efficiency of ports. (14)

Table 2. The 17 Best Practices with the highest ranking in the Climeport project. (14)

DESCRIPTION OF BEST PRACTICE (BP)	EVALUATION CRITERIA								Total BP rank
	1.- The BP reduces significantly the CO2 emissions	2.- The complexity degree of the required knowledge for the BP implementation is appropriate / affordable	3.- The local availability of resources/supply for the BP implementation is appropriate	4.- The port has the needed capacity (technical and human) to implement the BP	5.- The economical investment for the BP implementation is appropriate / affordable	6.- The investment payback of the BP implementation is appropriate	7.- The current normative does not introduce barriers for the BP implementation	8.- The current port organization does not introduce barriers for the BP implementation	
Emission reductions in fleet vehicles in Port Authorities	5,00	5,00	4,67	4,67	3,67	4,00	4,67	4,33	**4,22**
Electric Consumptions Monitoring	4,33	4,67	4,67	4,33	4,00	4,00	4,67	4,67	**4,21**
Vessels Speed reduction entering in the port	4,33	3,89	4,33	4,22	4,33	4,33	3,67	2,89	**4,13**
Improving in the consumption of exterior lighting of roads, yards and docks	4,67	4,33	4,33	4,33	4,00	4,00	4,33	3,67	**4,11**
Optimisation of indoor lighting systems in buildings	4,11	4,33	4,33	4,33	4,33	4,11	3,67	3,67	**4,06**
Energy Efficiency Renewable in Sanitary Water Production	3,83	4,33	4,67	4,17	4,17	3,67	4,83	4,67	**4,04**
Improvements in energy management of concessionaries companies.	4,33	4,00	4,00	4,00	4,00	4,00	4,00	4,00	**4,02**
Reduction of machinery fuel consumption	4,00	4,00	5,00	4,00	4,00	4,00	4,00	2,00	**3,92**
Environmental R&D in Port	3,67	4,00	4,00	4,00	4,00	3,67	3,67	3,67	**3,74**
Establishment of a gardening model for the optimization of the capture and sequestration of CO2 in the Green System of the Port of algeciras Bay	3,33	3,67	3,67	3,67	4,00	3,33	4,33	4,33	**3,67**
Clean Fuels usage for Port Mechanisation	4,67	4,33	4,33	4,33	3,00	3,67	3,67	2,33	**3,64**
Installation of transformers in accordance with the standard HD 428.1 S1.	4,00	4,50	4,00	4,00	3,00	3,50	4,00	4,00	**3,63**
Installation of Wind Energy in port facilities	4,33	4,33	3,67	3,67	3,33	3,33	4,00	4,00	**3,59**
Installation of Photovoltaic Energy in administrative buildings of APBA	4,00	4,33	4,67	4,33	4,00	3,00	3,67	4,67	**3,50**
On shore power supply (OPS)	4,67	4,00	3,33	3,33	3,33	3,00	3,67	3,33	**3,32**
Economy Software for optimised fuel compsuption for Harbour Mobile Crane	3,89	3,33	3,33	2,78	2,44	3,33	3,67	3,33	**3,28**
Use the thermal inertia in industrial cooling facilities	4,00	5,00	3,00	4,00	3,00	3,00	3,00	4,00	**3,21**

According to the Green Cranes report, the main challenge nowadays concerning energy is to improve the way that energy is used, by obtaining the same benefits from fewer resources. In this context eco-efficiency at ports is becoming more and more significant in line with other strategic sectors. The study describes the main objectives of eco-efficiency at ports as follows:

- To reduce losses within the electrical distribution network by means of monitoring and control of installations, as well as the operation in real time over the network behaviour.
- To plan the development of the different infrastructures and networks within the port attending to operational and environmental criteria.
- To increase the awareness and training of port personnel in order to promote the more efficient use of energy resources.
- Electrical energy at ports is essential to develop the great majority of activities related to cargo handling and logistics, especially with containerized cargo. The evolution of these activities and their complexity demand nowadays huge amounts of energy. (7)

Green EFFORTS, "Green and Effective Operations at Terminals and in Ports", is a collaborative research project, co-funded by the European Commission under the Seventh Framework Programme. Its goal is to investigate the current energy mix in ports and terminals while identifying activities which account for real energy savings, and investigating the range of regenerative energy sources which could be adapted to port and terminal environments, with the knowledge and project achievements transferred to stakeholders in the maritime sector through dissemination activities. (43)

For the purposes of this study, we have identified several aspects of operation that affect the energy efficiency of a port. These aspects are covered in more detail in the following chapters:

- Energy monitoring and management systems
- Lighting technologies and lighting control
- Building and warehouse energy efficiency
- Energy use and operation of the machines and vehicles
- Shore-to-ship power systems
- Co-operation between different actors at the port

1.2.2 Monitoring and management systems

Management systems

Energy efficiency should not be a one-off project, but a continuous process in company. It is crucial that the management in particular, but also the entire organization, should be committed to purposeful improvement of the efficiency of energy use. On the company's side, continuous improvement of energy efficiency demands good monitoring and management systems. Activities that needs to be included in any management system are: (15)

- the setting of reduction targets
- monitoring and analyzing the energy use of the port
- identifying opportunities to save energy, for example by carrying out an energy audit

- identifying areas of high energy consumption and waste
- identification and implementation of energy-saving measures that are techno-economically feasible
- using energy efficiency indicators and calculating carbon footprint
- consideration of energy efficiency in the company's practices, investments and procurements
- knowledge of the various options for energy procurement
- the creation and implementation of a good energy procurement strategy

The concept of port environmental management has developed in Europe over the last 15 years. Collaboration between the port sector, research institutions and specialist organizations has driven this progress. There is an increasing trend for ports to produce an environmental policy and publish an annual environmental report. Many ports have also established activities and procedures to manage their environmental risks such as designating environmental personnel, adopting an environmental management system, and monitoring environmental performance through the systematic use of environmental performance indicators. (6)

Environmental management systems enable a systematic approach to environmental issues. This should include setting up a functional organizational structure that sets respective targets, implements measures, monitors impacts, evaluates, reviews and takes corrective actions when and where necessary. In this way ports can achieve and demonstrate continuous environmental improvement. Energy efficiency can be part of a company's environmental management system. Different tools and well established environmental management standards already exist that ports may choose to implement when they build environmental management systems such as EcoPorts, ISO 14001 and EMAS. (6) The energy star system has also listed seven steps that are needed to complete a suitable energy management system (Figure 4). These steps can also be applied to ports' energy management systems (16):

- Make a Commitment: Recognize that the economic, environmental and political impacts of energy consumption are sufficient motivation to change our energy use patterns.
- Assess Performance: Make a personalized accounting of energy use and costs. Benchmark your facility by comparing its energy performance with similar sites.
- Set Goals: Review your objectives and constraints. Establish priorities and set measurable goals with target dates.
- Create an Action Plan: Define the technical steps. Apply proven methods to increase energy efficiency or get specialized guidance.
- Assign roles and resources: Consider rolling savings from earlier efforts into future, more complex initiatives.
- Implement Action Plan: Install equipment and change operational procedures. Establish a maintenance schedule. Train equipment operators and building occupants on the changes. Track and monitor conditions.
- Evaluate Progress: Compare current performance to established goals. Understand what worked well in order to identify best practices. Adjust procedures, goals, and schedule the next evaluation.

- Recognize Achievements: Provide internal recognition for the efforts and achievement of individuals, teams, and facilities. Seek external recognition from government agencies, media, or third party organizations.

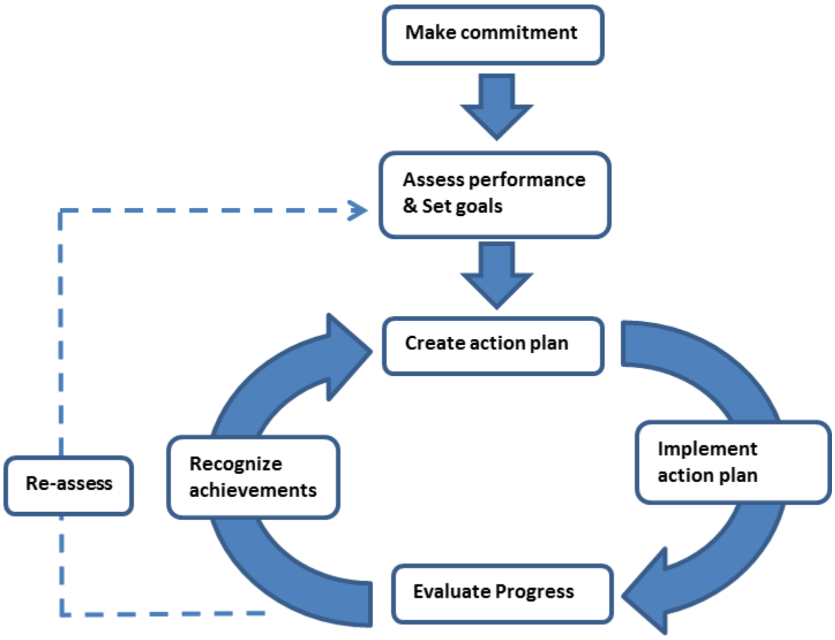

Figure 4. ENERGY STAR®'S steps for energy management (16)

The ISO 50001 energy management standard provides organizations a framework to manage and improve their energy performance. An energy management system helps an organization internalize the policies, procedures, and tools to systematically track, analyze, and improve energy efficiency. It considers maintenance practices, operational controls, and the design and procurement of renovated, modified, and new equipment, systems, processes, and facilities. (44)

Energy audits

Energy audits are a good way to identify energy-saving measures that are techno-economically feasible. The purpose of energy auditing is to analyze the energy use of the facility being audited, to work out the potential for energy savings, and to present a profitability calculation on the basis of the proposed investments and savings. (17)

An energy audit is based on data concerning output, energy consumption and use during the implementation period, though it also tries as far as possible to take account of existing information and planned alterations. The point is to link the energy audit closely with the company's other operational processes so that it can be used for monitoring and maintaining the facility's energy efficiency in the future. (17)

The Directive of the European Parliament and of the Council 2012/27/EU on energy efficiency contains measures to promote energy audits. Among other provisions, it stipulates that Member States shall develop programmes to encourage small and medium sized enterprises to undergo energy audits, and subsequently implement the recommendations resulting from these audits. (18)

Barriers

Despite the presence of environmental specialists (69% of ports have at least one) and the fact that 72% of ports have an environmental policy, less than half of the ports examined have any specific form of Environmental Management System (30% are certified under ISO 14001, and 17% by EcoPorts PERS). Concerning publicity, only 36% of ports publish factual data on their environmental performance that can be accessed by the public, even if 69% publish some sort of environmental information on their websites. (10)

Table 3. Changes over time in selected environmental indicators. (10)

Environmental Management conponents	1996 (%)	2004 (%)	2009 (%)	Change 04-09 (%)
Port authority has an environmental policy	45	58	72	+ 14
Policy information available to the public	-	59	62	+ 3
Policy improves over legal requirements	32	49	58	+ 9
Publishing of annual environmental review/report	-	31	43	+ 12
Presence of environmental specialist(s)	55	67	69	+ 2
Presence of environmental management system	-	21	48	+ 27
Presence of environmental monitoring	53	65	77	+ 12
Presence of environmental indicators for trends monitoring	-	48	60	+ 12
Presence of procedure for consulting with the local community on port's environmental programme	-	36	37	+ 1

Source: ESPO / EcoPorts 2010

According to this study, 71% of ports still experience some difficulties in implementing environmental management, due to both internal and external factors. The main challenges are: (6)

- Number of authorities/stakeholders involved
- Expense
- The lack of awareness of good practice
- Status given to environmental issues
- Identification of responsible authority
- Information and guidance related to legislation

Monitoring

To improve energy management at a port, better knowledge is needed about where and how energy is consumed. Various software tools exist that enable measured data to be managed, interpreted and distributed. After being connected to port machinery such tools are able to provide accurate measurements of voltage, current, power and energy, comprehensive logging and advanced power quality measurement and compliance verification functions. (7)

Due to the huge amount of information exchanged, it is essential to deploy information and communication technologies to assure the efficiency and reliability of operations within the container terminal as well as exchanges of information with external agents (shipping companies, port authorities, freight forwarders, shipping agencies, etc.). (7)

At internal level, the most essential information is associated with the containers themselves (identification, position and transport mode) and the machinery (operative, position, work orders, etc.). In order to manage the above-mentioned exchange of data, port container terminals need to adopt Terminal Operating Systems (TOS). TOS are software tools structured into different modules of information management and control connected to a general data base. (7)

A sophisticated TOS will help to determine optimum workflows and improve energy efficiency. In most cases, it also will increase productivity. Solutions can range from modifying the stacking layout and organization of import and export containers via the "chaotic" allocation of prime movers to cranes, i.e. with the TOS always selecting the most appropriate equipment instead of working with crane-related gangs, to the implementation of fuel-saving technologies such as start-stop automation for prime movers and RTGs to minimize idle operations. (45) Different solutions are provided in the market, so terminals are able to choose from several options according to their specific needs and business strategies. The implementation of a TOS in a terminal has the following benefits: (7)

- Planning and controlling all movements of containers within the terminal increases the efficiency of the yard machinery and equipment.
- Reductions in waiting and idle times at the container terminal gates
- Optimization of the available surface of the terminal
- Optimization of vessel planning
- Improvements in the precision of the available data
- Reduced operation costs for the terminal
- Increases in the safety and security of the installation

Significant savings have been achieved in several ports by adopting energy management systems, energy efficiency audit programmes or carbon footprint calculation systems. Four of these cases are introduced below. All of these examples are from ESPO's "Green guide; Good practice examples in line with the 5 Es" (18).

Energy management case: the Port of Dover (UK)

Energy Management has been a high profile environmental programme at the Port of Dover since it began in 2006. Reductions have been achieved year after year in the use of electricity, which is the most significant source of carbon emissions. These savings have significantly improved the efficiency and cost effectiveness of the port operations, as well as their sustainability. (18)

The monitoring data is collected by meters and a building energy management system. After the data is displayed in an online graphics package, the port's technical team can analyze the energy use of the port and more tightly control heating, ventilation and air conditioning systems to meet operational demand. Areas of high consumption and waste are identified, and operations where savings can be made are determined. The energy graphics package is used to measure the energy efficiency of the operation by comparing throughput with energy consumption. (18)

Staff and significant port tenants are encouraged to participate in the scheme, and given feedback on their performance against targets through an energy monitors scheme, regular meetings and newsletters. (18)

Energy efficiency audit programme case: the Port of Antwerp (NL)

The Antwerp Port Authority has promoted a voluntary energy efficiency audit programme. An energy efficiency expert assists the port authority in the implementation of the initiative. The port users pay a very modest sum for the energy efficiency audit. The energy audits' results include tailor-made proposals for concrete measures and estimations of the economic feasibility of these measures. The engagement of the port authority also includes co-operation and assistance regarding the follow-up of the audit results. (18)

At the same time, the Antwerp Port Authority is able to share its knowledge regarding the subsidy landscape for rational energy use, and even to provide assistance with regard to applications for possible subsidies. By developing this initiative, the port authority intends to engage and encourage private companies to invest in energy efficiency measures. (18)

Under the first energy efficiency audit scheme, launched in 2010 with a budget of €100, 000, nine companies participated and benefited from the offer. Since the audit reports tend to show clear potential for energy savings, other companies have also now shown serious interest and might follow the path. (18)

Carbon footprint case: the Port of Valencia (ES)

In partnership within the Climeport project the Port Authority of Valencia has developed a methodology to obtain an accurate estimate of the port's carbon footprint. This method distinguishes between 4 levels; the port as a whole, port activities, services, and port equipment and machinery. This distinction allows for the calculation of the carbon footprint of port activities both in total, and for each of these separate aspects. This helps to define targeted measures for reducing greenhouse gas emissions. An online tool (ECOABACUS) has been designed to facilitate the calculation of the carbon footprint of ports. (18)

CO_2 emission reductions case: the Port of Rotterdam (NL)

Since 2007, the Port of Rotterdam Authority has published a yearly footprint report regarding CO_2 emissions from its own operational activities. This footprint addresses CO_2-emissions derived from the energy use of buildings and transportation needed for daily activities and operations. In 2010 the port authority published a business plan for the period 2011-2015 with the following objectives regarding the port's carbon footprint: (18)

- a CO_2-emission reduction of 10% targeted for the business plan period 2011-2015
- reported 2010-emissions of 9.8 kilotonnes as a new baseline for ambitious reductions in the business plan

- operational activities to be CO_2-neutral as of 2011
- CO_2 emission reductions to become part of the sustainable procurement criteria used in respect investment projects such as maintenance dredging, construction quay walls and other port development projects

1.2.3 Lighting technologies and lighting control

Lighting of yards accounts for a high share of ports' electricity consumption, so installing an effective lightning system is good way to reduce total electricity consumption. (18) Lighting also represents the largest share of energy costs in warehouses (41%). Improving the lightning technology is one of the best ways to enhance a port's energy efficiency. Efficient lamps, fixtures, and controls save money and improve working conditions. By adopting these energy-saving steps, the amounts of energy needed for lighting can be reduced significantly. (16)

<u>Indoor and warehouse lighting</u>

Light sources

High-intensity discharge (HID) light sources, such as metal halide and high-pressure sodium lamps, have long dominated the market for lighting indoor spaces with high ceilings, but today other technologies have proven more efficient in many common situations. Historically, cold storage facilities have used metal halide lamps, despite their inefficiency, since fluorescent lamps did not function well in cold temperatures. With the advent of LEDs, however, cold storage spaces now have an alternative which, while expensive, is vastly more energy efficient. (19) LED lighting is the most efficient option, and prices have dropped enough for it to be cost-effective for many warehouses. (20) LEDs use a small fraction (10% or less) of the energy required for compact fluorescent or incandescent lamps, and they last at least 10 years, which saves on maintenance requirements. (16)

Sensors

With lighting, it's important to start by asking two questions: How much light is really necessary in the warehouse; and where is it needed? Automated warehouses, where there is little human activity, require much less lighting than a fully staffed facility. Work stations require a different kind of lighting than a warehouse floor. (21) It is not necessary to have each bulb in a facility turned on where lighting isn't critical. Timers or sensors can turn off lights when no one is in a particular part of the warehouse. (20) Photo-sensors activate lamps automatically when daylight diminishes, and motion sensors can be used in less busy areas. (16)

Another major advantage of LEDs is their capability to be integrated with automated systems. By using sensors, such systems allow facility managers to control when and where lighting is used within a space. Previously, a manager might have had to turn on every metal halide in a facility just to get access to a single aisle. By making it possible to use far more sophisticated controls, LEDs can save refrigerated storage spaces up to 90% of their lighting-related energy costs. Because LEDs have no warm-up time, as metal halide lamps do, LEDs can be turned on and off as needed. Moreover, the very long expected service life of LEDs promises to reduce maintenance costs.

Other methods

Lighting fixtures often have more lamps than are required for recommended lighting levels. One easy way to reduce energy consumption is to remove unnecessary lamps. (22) Another easy way to improve lighting levels while reducing energy expenses is to simply keep the lighting fixtures clean. (21) When lamps are regularly cleaned and replaced according to a fixed schedule to prevent the accumulation of dirt and dust, full-light output is ensured. (16)

Painting walls white and installing windows and skylights to let in natural light is also a good way to reduce the energy consumption of lighting. Skylights are becoming commonplace because of exhaust requirements, but the light that they let in is an extra benefit. Thermal glass in the skylights can enhance indoor climate control. (21)

<u>Outdoor lighting</u>

Light sources

The technology currently most used for high mast lighting systems is high pressure sodium lights fitted with 400W light bulbs. Depending on the height of the mast and the numbers of lights installed on the mast, the required lighting level of 20 Lux at 1 meter above ground (EN 13201) can be achieved in various ways. Usually between 10 and 30 single light bulbs are attached to a single high mast. Due to new developments, technological advances and market demand, new lighting solutions, that can further reduce power consumption – during night operations, for example – have recently entered the market. LED lights have become the new trend, with numerous applications arising. (23, 46)

The use of LED lights in ports and terminals around the world has seen a jump in popularity simply due to the huge consequent reductions in electricity consumption. The directionality of LED light is good, and properly balanced high-end LED fixtures are beginning to achieve satisfactory colour rendering indexes (CRI) and colour temperatures, although this comes at a significant premium. (23)

Heavy industrial equipment and above-ground mining equipment now often operate with LED lighting. While LED lighting is touted for reducing power consumption, ports and terminal operators will realize the greatest savings from reductions in maintenance expenses. Properly designed and manufactured LED fixtures installed on port container cranes will last, maintenance free, for 50,000 hours, all the while reducing crane electricity draw and maintenance expenses. Over the last two years, high brightness LED chips have increased the potential light output from a single fixture. (24)

Light fixtures installed on port container cranes endure constant vibration, moisture and corrosion. These factors are always significant in coastal environments. These extreme conditions often result in premature lighting fixture failure, which necessitates constant maintenance and increases material and labor costs. Installing properly designed LED fixtures on port container cranes can immediately reduce energy usage, decrease crane maintenance costs, and increase operator safety. (24)

New optic technology can distribute a very even light over a wider target area than traditional lighting options. This means that fewer lighting units are required, and exterior units can be mounted lower. Light pollution is also reduced as the light output is focused only where it is needed. The quantitative reduction in fixtures achievable by using LED technology offsets the additional costs, and allows for a reasonable two year payback period on investments. (25)

Automation

Automating terminals also presents new opportunities to reduce maintenance expenses and environmental impacts. Automated equipment lighting requirements are different than those for standard equipment. Less lighting is needed overall, through lighting must still be available on-demand for remote control and maintenance operations. Furthermore, LED lights come on instantly, as opposed to many traditional lighting options that require extended warm-up times. This means that lights only need to be turned on when they are needed. There is a strong trend to fit Automated Stacking Cranes (ASCs) with LED lighting, since this significantly reduces energy costs, minimizes downtime, and improves sustainability overall. Lighting is often perceived to be a fixed expense, but adopting LED technology can reduce the power consumption of lighting by up to 75%. (25)

Significant savings have been achieved in a several ports by updating the lighting systems at the port. Some of these cases are introduced below.

Mobile lighting control case: the Port of HaminaKotka (FI)

At the Port of HaminaKotka only one third of all lightning comes on automatically at nightfall. This ensures the basic lighting needed for safety and security. Full lighting must be ordered from the port authority for any sector where operations are ongoing. The full lighting is then on for a predetermined time, after which lighting is automatically reduced again, unless a new cycle is ordered. The next step is to arrange mobile control for the lighting of different sectors. (18)

In the future new measuring systems will be practical in order to optimize energy use. Energy use and cost savings go hand in hand here. Lower lighting levels also reduce light pollution from the port. The design of lights can also maximize the effectiveness of lighting and minimize dispersion. (18)

Focusing lighting case: the Port of Dover (UK)

Successfully implemented projects include a complete refit of high mast lighting, which subsequently delivered increased light output with much fewer lamps, by focusing the light where it is needed and reducing light loss. (18)

Lighting control case: the Port of Pori (FI)

In 2009, a new lighting control system was installed at the Port of Pori. Taking a little over a year, this project set up environmentally friendly and intelligent lighting for the Mäntyluoto harbour area. The most important objectives were to focus lighting more efficiently, to have a user-friendly system, and to save energy. The project was challenging, since the irregular working hours in the harbour area necessitate flexible lighting control. Operations are primarily conducted during the morning and evening shifts, but ships are also often loaded and unloaded during the night. The new system enables energy savings of 10–30%, depending on how the lights are used. (26)

LED lighting case: the Port of Amsterdam (NL)

Rietlanden Terminals at the Port of Amsterdam has become in 2014 the world's first terminal facility to be illuminated entirely by high-power LEDs. Using LED lighting will increase the company's sustainability, and fit in well with the Port of Amsterdam's environmental plans. The energy savings amount to around 60% compared to existing lighting solutions. The new LEDs means the light is less diffused, providing further environmental benefits, while the white light also increases safety, which in turn improves working conditions. (27)

1.2.4 Buildings, terminals and warehouses

Office buildings

Port organizations and companies operating within port areas often have office buildings at the port. The energy efficiency of these buildings can be improved in several ways. Energy use is the greatest environmental burden and cost factor during a building's lifetime. The choices made during building design and construction have an impact for decades to come, and such decisions may subsequently be impossible or very costly to alter. (17)

Passive house case: the Port of Aalborg (DK)

A 200 square meter office building constructed in the 1970s at the Port of Aalborg recently needed to be rebuilt and modernised. It was decided to use this opportunity to gain experience with passive house standards. By fitting effective insulation, energy recovery from ventilation, and state of the art windows, it was possible to reduce the building's use of energy for heating by 94%. On top of that, employees will experience a much better indoor climate and comfort inside the building. (18)

Head office building case: the Port of Ghent (BE)

The Ghent Port Company's offices are partly housed in a new office building that was taken into use in 2005. The new building project consisted of a new wing built onto the port's original head office building. As the Ghent Port Company wanted to see its attention to sustainable development reflected in its own offices, the company resolutely opted for a construction that prioritised sustainable techniques and materials. The reuse of original cobblestones from the quay flooring at the Grootdok symbolizes the sustainability aspect. The environment-friendliness of the office furniture was also crucial. (18)

Ghent Port Company's main building was the first office building in Belgium to be entirely constructed according to the "passive house" concept. This means taking advantage of advanced insulation and sophisticated heat recuperation techniques to reduce the energy consumption of the building to an absolute minimum. Thanks to this advanced insulation, airtightness, sunblinds and well-planned ventilation, the building has no need for air-conditioning installations or any conventional heating installation (although a small natural gas system – comparable to systems installed in typical family homes – has been installed for when additional heating is needed during severe winters). (18)

Warehouses

Warehouses are not always seen as a potential target for great energy savings even though they represent a significant opportunity to improve operations, lower operational costs, reduce climate impacts, and achieve a more sustainable building stock through energy management. Warehouses are often only partially heated to prevent freezing, and they are rarely cooled. (16) With a little research into new lighting, roofing and HVAC technologies, however, creative ways to reduce the costs of operating warehouses can be found. (21) The lightning of the warehouses is covered in more detail in chapter 1.2.3.

Heating and lighting are the two largest components in the energy use of warehouses, together accounting for 64% of total energy use (Figure 5). Lighting and heating are therefore priority targets for energy cost reduction measures. Adopting modern technologies for lighting, the building envelope, heating and cooling systems, and refrigeration systems, can help warehouse owners to attain their energy efficiency goals. (16)

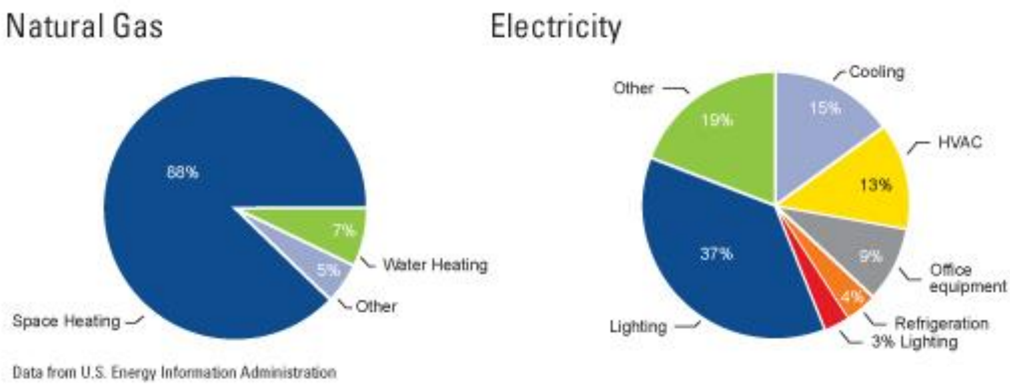

Figure 5. Typical energy use in a warehouse. (28)

Insulation

Improving insulation is a proven way to reduce both heating and cooling costs. (21) Wall and roof insulation levels vary according to needs determined by the climate zone. (16) Warehouses with older insulation typically lose energy to the environment. Traditional batt insulation can be replaced by more efficient spray foam or loose fill insulation. Spray foam insulation is the most expensive option, but it is twice as efficient as batt. Loose fill is a compromise alternative that is easy to install in existing spaces, but still provides superior insulation. (20) Doors also need to be insulated to reduce conduction losses. It is also important to properly insulate interior partition walls between semi-heated and conditioned spaces. (16)

Proper sealants are also a good way to improve the energy efficiency of a warehouse. Weather stripping and caulking need to be fitted to ensure that windows and doors are airtight. Also air seal building seams and joints (tops and bottom of walls, around windows, etc.) and penetrations (electrical wires and conduit, plumbing, flue or HVAC ducts, etc.) with site-appropriate sealing material (tape, caulk, weather stripping, grout, foam, etc.) are worth installing to create a continuous air barrier around conditioned spaces. (16)

One of the greatest sources of energy losses for heated or refrigerated warehouse spaces is air infiltration through the gaps around loading-dock doors during loading and unloading operations. Regularly checking and repairing any gaps in seals is a simple energy-saving measure. (22)

Docking shelters which enclose the entire back of a truck are more energy-efficient than roll-up dock doors, because they reduce outside air exchanges. Docking shelters are unlikely to be found in warehouse facilities built on spec, because they are more expensive than typical loading docks. However, if facility executives have the opportunity for a build-to-suit facility, this is an option to consider. (21)

Indoor temperature

In many warehouse facilities, especially in loading areas, it is costly and inefficient to maintain temperatures of 16° to 21°C to keep staff comfortable. In such situations, reflector focused gas or electric radiant heaters can be mounted above smaller areas that require heat, keeping employees comfortable with the ambient interior air temperature as low as 4° to 10°C. This reduction in overall indoor air temperature can dramatically reduce heat loss and energy consumption, sometimes by as much as 50%. The radiant heaters should be controlled by timers or occupancy sensors to minimize their operation when areas are unoccupied. (22)

HVAC systems are a huge drain on energy where they are needed. Not all areas of a building require climate control at all times, however. If a warehouse is automated or unoccupied much of the time, it is important to evaluate the level of heating and air conditioning really necessary to make the environment comfortable or store the company’s products. (21) Programmable thermostats with timeclocks, setbacks, and demand control ventilation can be used to reduce energy requirements. Installing internet thermostats on remote unit heaters will enable monitoring and control of multiple units that may sometimes get left in the heating position even during the summer. Buildings should be divided into thermal zones with separate controls based on space functions. (16)

Regular maintenance of heating, ventilation, cooling, and refrigeration systems, including changing filters, is important for good operation and to avoid wasting energy. (22) With heat recovery systems, exhaust heat from mechanical equipment can be captured and used for space heating. Heat recovery options include condenser coils or heat recovery for the hot water supply. (16)

Passenger terminals

Passenger terminal case: the Port of Portsmouth (UK)

Portsmouth International Port is experiencing a growing number of calls by cruise ships. The existing passenger terminal required replacement. From the outset one of the main considerations was to make the new terminal as efficient and environmentally friendly as reasonably possible. In particular the means of heating and cooling the building were put under scrutiny to minimize the energy demand and future running costs. As a result the terminal is the first public building in the UK to use a seawater source heat pump allowing thermal energy from the sea to heat the building in winter and cool it in summer. In addition wind-catchers have been installed on the roof and equipped with automated louvres allowing precise control of ventilation requirements. Further unusual features of the terminal include a seawater flushing system for toilet facilities. (42)

1.2.5 Machines, cranes, and vehicles

The forms of cargo-handling equipment used in a port are determined by the nature of the port and the type of cargo and packing used. (29)

Dry bulk cargoes are often handled by power-propelled conveyor belts, usually fed at the landward end by a hopper or grabs, which may be magnetic for handling ores, or fixed to a high capacity travelling crane or travelling gantries. These two types of equipment are suitable for handling coal and ores. In the case of bulk sugar, or when the grab is also used, the sugar would be discharged into a hopper, feeding by gravity a railway wagon or road vehicle below. (29)
Transfers of liquid bulk cargo, crude oil and derivatives from tankers are undertaken by means of pipelines connected to shore-based storage tanks. Oil cargo is discharged from the ship's tanks via the cargo piping system. From ship's manifold oil is transferred by means of shore-based loading arms to the shore manifold and then distributed to shore-based storage tanks within the oil terminal. (29)

With regard to general cargo (goods, merchandise, commodities), almost 90% of the total cargo volume is today containerized. General cargo is handled by cranes on the quay, floating cranes or by the ship's own cargo gear. There are numerous types of tools or loose gear that can be attached to shipboard or shore-based lifting gear. These include the sling or strop, which is probably the most common form of loose gear. (29)

A couple of types of crane may operate within a terminal. Firstly there are the ship-to-shore (STS) cranes that have to load or unload container ships. Usually multiple cranes work on a single ship. The containers then have to be transported "horizontally" to the stacking yard behind the STS cranes. This is done by much smaller vehicles like container tractors, automated guided vehicles (AGVs) or straddle carriers. Finally, the containers are stacked for the most efficient use of space and time, before they are transferred onto trucks or trains that will transport them overland. In smaller terminals, this stacking can also be done by straddle carriers, but usually this is done by larger rubber-tired gantry (RTG) or rail-mounted gantry (RMG) cranes. (30)

New technology

Rubber-tired gantry (RTG) cranes are commonly used in shipping ports around the world to move containers weighing up to 40 tonnes. These cranes are mobile and obtain the electrical power needed for their hoist motors from a diesel engine and generator set, rather than from the utility system. Container cranes, such as the RTG crane, are major contributors to port-based diesel emissions. These cranes employ conventional power trains consisting of a diesel engine coupled to an alternator that provides electrical power for a set of hoist, trolley, and gantry motors. The diesel engine prime mover allows an RTG crane to be unencumbered by a utility mains connection as it moves around the yard. When a shipping container is lifted by a conventional RTG crane, the diesel engine provides the energy demanded by the hoist motor. When the container is lowered, the container's potential energy is converted by the hoist motor into electrical form, but the conventional drive system has no means to store this regenerated energy. Consequently, this energy is typically dissipated as heat in resistor banks, resulting in a reduced overall system efficiency and increased fuel consumption and emissions. (31)

Fully electrical operation of cranes at container terminals is the most environmentally friendly means of operation compared to other power sources. Many suppliers are now offering solutions for electrification using, for example, cable reels or conductive wires to connect machines to terminals' electrical power grids. (32)

Eco-driving

Container and trailer management are fundamental activities in the operation of a port. The loading and unloading of vessels requires working machines such as straddle trucks and forklifts, reach stackers and terminal tractors. These vehicles are usually the largest direct source of CO_2 emissions within a port, and they account for approximately 70% of emissions caused by traffic on land within the port area. Eco-driving is a way of driving that contributes to reduced fuel consumption. It is also called "economical driving". Working Eco-driving is a method of driving developed specifically for working machines. (33)

Working Eco-driving involves (33):

- Driving with consideration in order to predict various events and avoid unnecessary halts. Well-planned logistics can avoid unwanted detours.
- Keeping a steady speed, as the most important way to save fuel and protect the environment.
- Keeping to a suitable revolutions per minute (rpm) range through each stage of driving and lifting.
- Avoiding high rpms, which mean higher fuel consumption and increased engine wear.
- Accelerating machines in an environmental-friendly and efficient way.

Eco-driving is a term used to describe the energy efficient use of vehicles. It is tempting to drive a little too aggressively when you move from one task to the next using a terminal tractor or a straddle carrier. But this is very hard on the vehicles and expensive on fuel. Eco-driving is all about learning to drive as economically as possible. One parallel benefit is that driving at slower speeds is also less stressful for machine operators. (34)

Route optimization

Ports can also utilize software process optimization tools to enhance equipment deployment procedures, resulting in further operating efficiencies, and reduced pollution and emissions with expected fuel savings of 5-8%. The optimization tools anticipate yard traffic and container flows, and minimize RTG moves in the yard through sophisticated planning algorithms. Global Pooling processes also eliminate unproductive driving, idling, crane delays and traffic congestion. (35)

Significant savings have been achieved in a several ports by adopting eco-driving techniques. Two of these cases are introduced below.

Eco-driving case: the Port of Copenhagen(DK) and Malmö (SWE)

For several years, machine operators at the Port of Malmö have been driving in accordance with the rules of eco-driving, and this has reduced fuel consumption by 10-15% a year on average. Combined with the lower level of wear-and-tear on the vehicles, this led to savings of around €110,000 (I million SEK) in 2009. (34)

Machine operators at the Port of Copenhagen are also learning to drive in more environmentally friendly ways when they handle containers. The port’s eco-driving programme aims to reduce the burden on the environment by promoting more economic driving, while also thereby reducing expenditure on fuel and wear-and-tear on vehicles. (34)
Eco-driving is part of the twin ports’ initiative to improve the environment. One important element in the company’s environmental policy is that gas and particle emissions from fuel consumption must be reduced, as must the consumption of diesel fuel per tonne of goods handled. Around 80 employees are to be trained in eco-driving, including the teams in the workshops who also operate all of the machinery types when they have to be serviced. The entire training course takes place down at the port in familiar surroundings, and it should be a successful experience. (34)

Eco-driving case: the Port of Gothenburg (SWE)

Previous assessments show that the Port of Gothenburg has the potential to reduce its fuel consumption by 15–20% by introducing Working Eco-driving without increasing the time required for the work. The working machines at the Port of Gothenburg use approximately 4.5 million litres of diesel each year. This means CO_2 emissions could be reduced by approximately 2,000 tonnes annually. The benefits of Working Eco-driving also include financial savings as a result of reduced fuel consumption and lower maintenance costs. It also contributes to an improved working environment for both machine operators and those working close by, as it reduces both noise and stress. (33)

The Port of Gothenburg's key environmental objective is to limit its impact on the climate. A long-term goal has therefore been set to introduce Working Eco-driving for working machines in all production areas. When purchasing new machines, these will be adapted to ensure simple installation of an onboard computer that monitors the vehicle's fuel consumption. All new machine operators will also receive training in Working Eco-driving. (33)

In order to measure the possible fuel savings achievable through Working Eco-driving the following assessment methods have been used (33):

- Onboard computers that register fuel consumption were installed on working machines.
- Working machines were operated in the normal way, and their fuel consumption rates were recorded.
- Machine operators received theoretical and practical training in Working Eco-driving.
- Working machines were operated in the new way, and their fuel consumption rates were recorded again.
- Fuel consumption rates before and after training were compared to calculate the results of the change.

1.2.6 Shore-to-ship power systems

Air quality is one of the highest priorities on the environmental and political agenda. The impacts of air pollutants such as CO_2, NOx, SO_2, hydrocarbons (HCs), volatile organic compounds (VOCs), lead and particulates vary in scale and range from locally based to regional and global effects. (6) Ports are quite often situated within or in close proximity to densely populated urban areas that are often critically affected by air pollution. In addition, being major nodes linking and bringing together international transport chains and related economic activities, port areas are often part of critical geographical areas when it comes to air quality considerations. Although port-related emissions contribute only partially to air quality problems in ports and surrounding areas, these problems can negatively affect the image of ports vis-à-vis their surrounding residential zones, and put serious pressure on port development ambitions. Air quality issues often lie at the heart of the political and societal debate about economic development plans and port development projects. The emissions of air pollutants by port operations are therefore a high priority issue for European port authorities. The main challenge that port authorities face is to apply appropriate control mechanisms in order to manage and reduce port-related air pollution. (6)

When berthed, ships require electricity to support activities like loading, unloading, heating and lighting and other onboard activities. Today, this power is generally provided by auxiliary engines that emit carbon dioxide (CO_2) and air pollutants, affecting local air quality and ultimately the health of both port workers and nearby residents. The same holds for noise nuisance. (36)

As an alternative to onboard power generation, vessels can be hooked up to an onshore power supply, i.e. connected to the local electricity grid. In this way ships' operations can proceed uninterrupted, while eliminating negative side-effects. (36)

Ports nowadays are not normally equipped to supply vessels with electricity from the dockside, nor are vessels usually equipped to receive power in this way. Around the world, though, many activities in this direction are now underway and interest in such technology is rapidly growing, spurred on by tougher environmental legislation, a greater focus on emissions in ports from shipping, and, more recently, rising fuel prices. (36)

A shore-to-ship electric power supply can help eliminate pollution problems such as emissions of carbon dioxide (CO_2), sulphur oxides (SOx), nitrogen oxide (NOx) and particles, as well as noise and vibrations generated by ships in port. With shore-to-ship power, ships can shut down their engines while berthed, and plug into an onshore power source. The ship's power load is thus seamlessly transferred to the shore-side power supply without disruption to onboard services, thereby eliminating emissions to the local environment. (36)

Shore-to-ship power supply is one of the strategies recommended by the World Port Climate Initiative for reducing the environmental impact of seagoing vessels in ports. (36) The EU's Strategy for the Baltic Sea Region also promotes measures to reduce emissions from ships and enhance the development of shore-side electricity facilities or emission treatment in all major ports around the Baltic Sea. (37)

While shore-to-ship systems eliminate onboard emissions at berth, consideration needs to be given to the emissions associated with power generation as such, as the source of this power will have a major influence on the overall emission reductions achieved. In particular, if renewable energy is used, near-zero emissions of all kinds of air pollutants can be achieved. Studies suggest that the average carbon dioxide emissions from the EU electricity mix are around 50% lower than emissions from diesel engines. While coal-fired power plants emit more CO_2, they have lower emissions of nitrogen oxides, particulate matter and sulphur oxides compared with the alternative of burning marine diesel fuel with a 0.1 sulphur content. (36)

In July 2012 the first international standard for shore-to-ship systems was published, called IEC/ISO/IEEE 80005-1 Utility connections in port – Part 1: High Voltage Shore Connection (HVSC) Systems – General requirements. This standard was jointly developed by the International Electrotechnical Commission (IEC), the International Organization for Standardization (ISO) and the Institute of Electrical and Electronics Engineers (IEEE). (36)

Shore-to-ship systems are today being installed in more and more ports around the world. Most installations can be found along the east coast of North America and in Northern Europe, due to these regions' strong environmental legislation, community pressure and social responsibility. In Asia they are an upcoming technology in the context of reducing local emissions. (36)

Some ports have already built shore-to-ship electric power systems. The first ports using such systems are listed in table 4.

Table 4. High-voltage onshore power supply (OPS) installations developed in ports worldwide. (36)

Year of introduction	Port name	Country	Capacity (MW)	Frequency (Hz)	Voltage (kV)	Ship types making use of OPS
2000-2010	Gothenburg	Sweden	1,25-2,5	50 & 60	6,6 & 11	RoRo(1, ROPAX(2
2000	Zeebrugge	Belgium	1,25	50	6,6	RoRo(1
2001	Juneau	USA	7.syys	60	6,6 & 11	Cruise
2004	Los Angeles	USA	7,5-60	60	6,6	Container, cruise
2005-2006	Seattle	USA	12,8	60	6,6 & 11	Cruise
2006	Kemi	Finland		50	6,6	ROPAX(2
2006	Kotka	Finland		50	6,6	ROPAX(2
2006	Oulu	Finland		50	6,6	ROPAX(2
2008	Antwerp	Belgium	0,8	50 & 60	6,6	Container
2008	Lubeck	Germany	2,2	50	6	ROPAX(2
2009	Vancouver	Canada	16	60	6,6 & 11	Cruise
2010	San Diego	USA	16	60	6,6 & 11	Cruise
2010	San Francisco	USA	16	60	6,6 & 11	Cruise
2010	Kariskrona	Sweden	2,5	50	11	Cruise
2011	Long beach	USA	16	60	6,6 & 11	Cruise
2011	Oslo	Norway	4,5	50	11	Cruise
2011	Prince Rupert	Canada	7,5	60	6,6	
2012	Rotterdam	Netherlands	2,8	60	11	ROPAX(2
2012	Ystad	Sweden	6,25-10	50 & 60	11	Cruise
2013	Trelleborg	Sweden	0-3,2	50	11	

1) RO-RO vessels are designed to carry wheeled cargo, such as cars and trucks that are driven on and off the ship.

2) ROPAX (roll-on/roll-off passenger) is a RO-RO vessel built for freight vehicle transport along with passenger accommodation. Technically this encompasses all ferries with both a roll-on/roll-off car deck and passenger-carrying capacities, but in practice ships with facilities for more than 500 passengers are often referred to as cruise ferries.

Shore-to-ship power case: the Port of Gothenburg

In 2000 the Port of Gothenburg became the first port to introduce a high-voltage onshore power supply (OPS) for cargo vessels. (10) That year Stora Enso connected its vessels to OPS. In 2011 Stena Line began operating a new OPS facility for the company's new ferries used on the route to Germany. What was unique about this facility was that it transforms the standard frequency of 50 hertz for alternating current in Europe to 60 hertz, which the majority of vessels use as a system frequency. (18)

At present, the passenger and freight ferries (ro-ro vessels) used in scheduled traffic within Europe use this technology. Ten vessels are equipped for the technology and five quays currently offer OPS. In total, one in every three vessels that calls at the port can use onshore power supply. The power is supplied by environmentally labeled electricity from renewable sources like wind power. (18)

This OPS connection is the result of collaboration between the Port of Gothenburg, paper and forest products suppliers Stora Enso, and the shipping companies Wagenborg and Cobelfret. The high-voltage system was initiated by Stora Enso as a way of achieving a green logistics concept via the port of Gothenburg. (36)

The aim in the short term is that all ro-ro vessels and passenger ferries will be connected to shore-side power. In the longer term, the aim is that by 2015, 40% of all vessels visiting the port will use OPS. (18)

Shore-to-ship system case: the Port of Ystad (SWE)

The Port of Ystad has installed shore-to-ship power systems at all ferry berths. This facility, which currently is the world’s largest, enables the vessels to turn off all main and auxiliary engines powered by fossil fuels during laytime in the Port. Various measurements are performed making it possible to calculate the achieved effect in terms of emissions of carbon dioxide, sulphur dioxide, nitrogen dioxide and noise. (18)

1.2.7 Co-operation between different actors

The management and improvement of port-related supply chains is challenging due to the complex and heterogeneous operations of the ports, with several actors and processes involved. For this reason the effective sharing of information is of vital importance in port contexts. However, the information exchange between different port-related actors is often challenging. (38)

Environmental considerations can be different for each port, since they depend on the specific location and characteristics of the port area. The dilemma for the port authority is that it may not necessarily be directly and legally responsible for the activities, products and services of certain components of the logistic chain, but its overarching administrative role, ownership of the estate (land and water) and permanency of operational presence, means that the port is the obvious point of contact and the readily identifiable player for any environmental issues concerning the whole port area. (6)

There is potential for further integration as seaports proactively act as facilitators of procedures and of communication between the different parties involved in the logistic chain. The concept of ports as facilitators refers to the contribution that ports can make in helping the whole port community (including partners in the logistic chain) to deliver compliance with legislation, prevent pollution, reduce and mitigate environmental impacts, promote sustainable development and provide evidence of their satisfactory performance. This has resulted in the trend within some ports to include their efforts regarding sustainability, as part of their corporate social responsibility, in their yearly audited, financial reports. (6)

Port authorities do not only work in co-operation with other companies and actors at the port area, since they may also encourage shipping companies to use cleaner flues and pay more attention to environmental issues. Quite many ports have launched projects applying the Environmental Ship Index (ESI). The ESI is a good indication of the environmental performance of vessels, and it generally helps to identify “cleaner ships”. Vessels that have good ESI while operating in the port's fairways, can for example be given financial incentives.

Quite many ports have likewise started related co-operation projects, and several examples are introduced below. All these examples are from ESPO’s “Green guide; Good practice examples in line with the 5 Es”. (18)

Network for Sustainable Development case: the Port of Aalborg

Together with a few neighbor companies the Port of Aalborg have initiated a network for companies and institutions situated in south-eastern districts of Aalborg. During the first year more than 50 companies joined the network, which is still growing. The network will contribute to the development of infrastructure, services, employment and social life within the area. Ten companies have joined forces in a focus group on environment and energy, aiming to create environmental improvements through collaboration, the sharing of knowledge and industrial symbiosis. (18)

Information sharing case: the Port of Dover

The Port of Dover recognizes the importance of its environmental responsibilities, and experience has shown that there is much value in publishing and sharing information on environmental matters. The Port of Dover website has a dedicated environmental section which provides an array of general information as well as specific environmental reports and polices. This information is easily accessible, and updated on a regular basis. (18)

An annual Environmental Bulletin is produced and published on the website, with hard copies also made available to tenants and local groups. The bulletin highlights progress against annual environmental objectives and targets, detailing the port’s work and its achievements on waste, energy, water as well as environmental incidents and environmental quality issues. (18)

Environmental issues are aired at quarterly meetings of the Port Consultative Committee. This is the main stakeholder engagement forum in which over 60 organizations participate, ranging from local residents groups through to government agencies. The Port Consultative Committee provides stakeholders with the opportunity to raise their own port-related issues, including environmental matters. (18)

Health, Safety and Environment Liaison Group meetings are held quarterly with major tenants, during which environmental issues within the port can be raised and discussed. Tenants play an important part in the port’s energy consumption, as well as regarding environmental incidents, so it is important that they are fully engaged with the port on environmental matters. (18)

Heat and power generation case: the Port of Dover

Port land has been made available to a third party which operates a combined heat and power (CHP) plant powered by used cooking oil. This plant provides the port with renewable electricity and free heating. A working partnership has been developed with a tenant whose operation within the port is very energy intensive. (18)

Environmental Ship Index case: the Port of Hamburg (GER)

Stricter air quality standards and interest from nearby residents have prompted the port authorities to take stricter measures to improve air quality. The development of an Environmental Ship Index (ESI) is a project within the World Ports Climate Initiative (WPCI). The ESI identifies seagoing ships that perform better in reducing air emissions than required by the current emission standards of the International Maritime Organization. The ESI evaluates emissions of nitrogen oxides (NOx) and sulphur oxides (SOx), and rewards ships that report on their greenhouse gas emissions. The ESI is a good indication of the environmental performance of ocean-going vessels, and assists in generally identifying cleaner ships. The index is intended to be used by ports to reward ships when they participate in the ESI, and it will thus promote clean ships, but it can also be used by shippers and ship-owners for their own promotional purposes. The ESI aims at achieving genuine reductions in emissions of NOx, SOx and particulates, as well as CO_2 in the longer term, to be achieved by initiating changes in behaviour among ship-owners/operators and ports. In Hamburg, vessels with an ESI score above 20 points are granted discounts on harbour fees of up to 10%. (18)

Environmental Ship Index case: the Ports of Bremen/Bremerhaven

The Ports of Bremen/Bremerhaven together with other European ports have applied the Environmental Ship Index (ESI) in their port charge system since January 2012. The ESI is one key project of World Port Climate Initiative where Bremen/Bremerhaven together with 54 other key ports around the world have committed themselves to reduce their greenhouse gas emissions. ESI was worked out by a group of ports in North-west Europe including Bremen /Bremerhaven. If a ship performs better than is legally required, participating ports may reward them with various incentives. In Bremen, environmentally friendly ships can be granted a discount on tonnage charges on submission of an ESI certificate. A total of 25 ships with the best ESI score will receive such a discount. (18)

Environmental Ship Index case: the Port of Gothenburg

During 2011-2012 the Port of Gothenburg organized a campaign directed at shipping companies. The vessels that opted for cleaner fuel whilst operating in the port’s fairways were compensated financially. Vessels classified as green according to an international index were also compensated. Shipping companies could also apply for financial support to convert their vessels to run on LNG or equivalent clean fuels. (18)

For several years the Port of Gothenburg has applied an environmentally differentiated port charge. Shipping lines that use fuel with a sulphur content higher than 0.5 % pay a surcharge. Income from this sulphur surcharge is then channelled into shipping lines that are investing in more environmentally friendly equipment. The reimbursement has been arranged in consultation with the Gothenburg Shipbrokers' Association, environmental organizations and a number of the port’s customers. (18)

Environmental Ship Index case: the Port of Le Havre

In 2009 the Port of Le Havre, in close partnership with the ports of Amsterdam, Antwerp, Bremen, Hamburg and Rotterdam, started to establish and implement an Environmental Ship Index (ESI). The aim of this project is to encourage shipping companies to go beyond the requirements of current regulations. (18)

The ten cleanest container or Ro-Ro shipping lines, with regard to their emissions into the air, will be granted an "environmental reward". An agreement has been signed between the Port and each shipping company wishing to join the scheme. This agreement specifies the joint commitments, terms and conditions under which the ESI is applied in Le Havre. A special fund dedicated to the ESI has been created within the port's Environment Department to finance the environmental rewards. (18)

1.3 Environmental issues

As ports are often located in sensitive environmental settings they can result in a range of environmental impacts. This chapter introduces the most typical and most important environmental issues related to port operations.

The environmental issues that ports need to take into consideration include waste management, dredging, dredging disposal, dust, noise, air quality, bunkering, hazardous cargo, the land use impacts of port development, and finally discharges from shipping (Table 5). These are issues that all ports worldwide need to cope with. (39)

Table 5. Environmental issues that ports need to take into consideration. (39)

The environmental issues considered at the ports
Waste management
Hazardous cargo
Ballast water
Dust
Dredging
Dredging disposal
Land use
Noise
Air quality
Bunkering

Ports generate large amounts of waste every year. The handling of this waste is a complex issue, because it is affected by both national and international legislation. Two different classes of waste can be defined, originating from two different sources: port-related waste and ship-related waste. Waste management procedures involve two main phases, handling and treatment.

Although international conventions are followed and accepted by the majority of shipping companies and seafaring nations, there are still too many cases of ship-generated waste being dumped in the sea and left to pollute the marine environment. (39)

Waste

Waste products generated by shipping can affect the marine environment if they are not handled properly. One example of the irresponsible handling of waste products is the disposal of garbage or contaminated bilge water directly into the sea. (40)

Ships' garbage includes all kinds of food-related, domestic and operational waste generated during the normal operation of a ship. Such wastes need to be disposed of continuously or periodically. More specifically, ships' garbage consists of ordinary household waste such as cardboard boxes, empty glass and plastic bottles, tins and other small containers, as well as food waste, together with cargo-associated wastes generated in cargo holds, such as dunnage, wire slings and covering materials (e.g. plastic sheets). (39)

Whereas general cargo and container-handling ports and terminals typically only generate small amounts of wastes, usually restricted to the waste oils from trucks and other equipment; the situation at oil terminals and tank farms is quite different. In such ports visiting ships may generate large amounts of waste oils either from operational spills or from accidental spills. Operational oil spills are predictable by their nature, although the amounts should be minimized. Accidental oil spills should primarily be prevented to ensure there are only minor problems with the handling of waste. (39)

Almost all commercial ports need to handle hazardous substances at times. This requires special care due to the related risks to the environment and the workers handling such transshipments. (40)

Ballast water

Ships make use of ballast water to control their balance and buoyancy. Intakes and releases of ballast water may occur in locations that have completely different marine ecosystems. This may result in the accidental release in ballast water of marine species alien to their new surroundings. Some of these species may thrive in their new surroundings and become problematic "invasive species". Such species can have serious impacts on the ecosystems they are released into. The Baltic Sea and the North Sea have both suffered from the negative impacts of such invasive species. To minimize the risks associated with ballast water releases, the water can for example be treated with chemical substances or filtered. (40)

Air pollution

Port-related activities are heavily dependent on energy. Large amounts of energy are used, for example, during the incoming flows of goods, various kinds of processes taking place in the port, and subsequently the outgoing flows of goods. These different processes consume vast amounts of energy, mostly derived from fossil fuels, so they result in high emissions of greenhouse gasses. (40)

The most significant sources of air pollution from port operations include combustion emissions from ships' propulsion and auxiliary engines and boilers. These emissions include sulphur dioxide (SO_2), nitrogen oxides (NOX), carbon dioxide (CO_2), carbon monoxide (CO), fine particulate matter [PM], and volatile organic compounds (VOCs). Several of these pollutants are important greenhouse gases. The next most significant emission sources are vehicles and land-based engines and boilers, whose combustion processes emit similar pollutants. (41)

Ports and port-related areas are large, and traffic flows within, into and out of ports are also huge. Ports' annual environmental permits include emissions from working machines, road transport, rail traffic and heating. In wintertime, office buildings and some warehouses must be warmed. (5)

Ships' combustion exhaust gases vary depending on the type of engine, the speed and the load at which they are run, and of course the composition of the fuel used. It is well-known that diesel exhaust contains identified mutagens and carcinogens. Diesel exhaust particles are small enough to penetrate to the alveolar region while breathing. (39)

A wide variety of initiatives have been launched to encourage port authorities to undertake to reduce air pollution through targeted measures and controls. Ideally, newly constructed ports should be located far away from cities or city centres. The latest trends worldwide are to site new terminals close to the mouth of the harbour, close to existing transportation infrastructure, and far from residential areas. Another factor that helps to limit air pollution is the development of cleaner diesel fuels. Although high-sulphur diesel is most widely available and cheaper, other more favourable options available include low-sulphur diesel (≤ 15 ppm sulphur), diesel emulsions, biodiesel and Fischer-Tropsch diesel. (39)

Fugitive dust in city ports

Problems with fugitive dust emissions in ports are similar to those related to air pollution. Dust emissions form part of the wider air pollution problem, and they are covered by the same directives, conventions and international agreements. Dust is considered as a set of particles emitted to air that may constitute visual, physical, chemical or health hazards for employees and the public. The most common sources of dust include the open storage, handling and spillages of dry bulk cargoes. Fine particles require little wind to create dust. (39)

Fugitive dust is particularly emitted from coal and iron ore storage and handling sites in ports. Even though numerous reports and research studies have focused on fugitive dust emissions from traffic on roads and in industrial areas, few attempts have been made to measure and estimate the amounts of dust emitted during port activities. (39)

Dredging and the disposal of dredged materials

Dredging activities involve the periodic removal of material from the seabed in the approach channels to ports and harbour basins, in order to maintain channel widths and depths in previously dredged areas to ensure safe access for vessels. (39)

Dredging activities have two main aspects that affect the environment. The first is the dredging process itself, and the second concerns how and where the dredged materials is disposed of. Dredging may significantly affect the environment by reducing water quality. (39)

Noise

Noise pollution is another aspect of pollution created by port activities. Noise pollution should not be underestimated. Noise can play an important role in people's lives and health. Certain types of noise, either too loud or too low frequency sounds, may become a health risk for humans. It is therefore important for the port authorities to have all the appropriate equipment needed to measure noise levels, as well as opportunities to control potential noise pollution. (39)

One aspect of the noise pollution problem in ports concerns the diesel-powered auxiliary engines used when ships approach ports and lie idle at dock. The noise levels produced by these engines can reach 80-120 dB. As port activities have expanded over the decades, the levels of noise emitted from ships and particularly from large vessels have been increasing as well. (39)

Land Use

Shortages of space and the increasing numbers of industries located in port areas may necessitate their expansion into surrounding areas. The needs of many ports are increasing, and at some point a port may need to be expanded or completely relocated. Most ports are located near cities and towns. The wastes that they generate contribute to the general environmental degradation of the nearby urban environment. The scale of their land use may generate several consequences: (39)

- Natural areas close to the port may be destroyed or degraded. In many cases ports are located next to wetlands or dune systems. Any expansion of a port towards such natural areas might increase instability and be detrimental to the species that live or feed in these habitats.
- Flora and fauna living in the area affected by expansion may be disturbed. Even if such areas are not in a natural state, they will host natural flora and fauna. The flora and fauna living in the area of the expansion will be either lost or forced to move.
- The relocation of some port installations may generate social conflicts. Certain installations might have to be moved to a residential area, for instance. The consequent social conflicts may be sizeable, and difficult for the state or the local authorities to cope with.
- The very existence of the port may result in significant landscape impacts. For instance, the port infrastructure, the related land-based traffic and the lighting used during night operations give ports the appearance of a busy industrialized district. This might affect the aesthetics of the whole environment or the urban areas neighboring the port.

2 Interviews

This study aims to find ideas for co-operation on energy efficiency and environmental issues between ports in countries involved in the Baltic Sea Region Energy Co-operation (BASREC). Representatives from six ports in the Baltic Sea Region were interviewed and surveyed for this study: HaminaKotka in Finland, Tallinn in Estonia, Riga in Latvia, Klaipeda in Lithuania, Gothenburg in Sweden, and Copenhagen-Malmö in Denmark and Sweden.

The ports were chosen as representing different Baltic Sea coastal countries and different types of ports, including both cargo and passenger ports. The list of the selected ports was presented to officials from BASREC, who made related suggestions.

The purpose of the survey was not to compare the ports to each other, but to build up a picture of the situation in general, and to identify good practices and possible means to enhance energy efficiency.

Table 5: Ports visited

	Cargo Million tonnes	Containers	Dry bulk	Liquid bulk	Gas	Cars	Number of passengers
HaminaKotka	14	y	y	y	y	y	minor
Klaipeda	60	y	y	y	LNG terminal under construction		45 000
Riga	35	y	y	y	LNG terminal in plans		838 000
Tallinn	28	y	y	y	y		9 200 000
Gothenburg	39	y	y	y		y	1 690 000
Copenhagen-Malmö	24	y	y	y		y	840 000

The port authorities were contacted before the port visits and received the study plan and the questionnaires (Annex 1) in advance. The visits took place in April-August 2014, with each visit lasting one day. Four of the visits were carried out by Mr Hippinen and Ms Federley, and two by Mr Hippinen alone. The port authorities hosted the visits, but other actors from the ports also participated in parts of visits or were able to submit information. The stevedoring companies were particularly of interest because of their important role in energy use. The hosts of the visits are listed in Table 6. Deputy Director Ms Kirsti Tarnanen-Sariola from the Finnish Port Association and Director Mr Markku Hakala from the Finnish Port Operators Association were additionally interviewed.

Table 6: The hosts of the visits

The hosts of the visits
HaminaKotka
Teppo Jokimies, Technical director
Saana Vuorinen, Maintenance engineer
Arto Sinikannas, Production Manager Steveco
Klaipeda:
Dalia Gun, Marketing specialist
Riga
Inita Luna, Director of Environmental and Development Departament
Vilis Avotins, Head of Environmental division
Vilis Uzulis, Powerman
Imants Zurins, Representative of Riga Commercial port
Vita Gerharde, Specialist of Marketing Department
Tallinn
Ellen Kaasik, Head of Quality and Environmental Management Department
Carl-Juri Piht, CEO of Green Marine
Patrick Gerber, TS Energy
Gothenburg
Jan Inganäs, Senior Advisor
Susan Dutt, Quality Manager and Sustainability Specialist
Copenhagen-Malmö
Petra König, Environmental manager, Civil Engineering Department Malmö
Hans-Olov Ivarsson, Manager, Civil Engineering Department Malmö
Other
Kirsti Tarnanen-Sariola, Deputy director, Finnish Port Association
Markku Hakala, Director, Finnish Port Operators Association

2.1 The ports visited

Basic information on the ports' types, owners and organisations are given below, together with the names of companies operating within them.

HaminaKotka (FIN)

HaminaKotka is the biggest universal, export, container and transit port in Finland, with regular connections to all major European seaports and thereby to other parts of the world. As the largest full-service universal port in Finland, the Port of HaminaKotka deals with all types of cargo: containers, Ro-ro, liquid bulk, dry bulk, LoLo, gas, project shipments and passenger traffic; and also provides versatile value-added services.

The port company is owned by the municipalities of Hamina and Kotka. The land area is owned by the municipalities; the port company has rented the land and sub-lets areas on to tenants. The tenants are responsible for the warehouses, the machinery and their energy use in their respective areas; while the port company is mainly responsible for infrastructure, such us the lighting of roads and yards.

About 200 companies operate within the port. These companies have their own contracts with power companies, and details about total power consumption are not available. District heat and natural gas are available.

Industrial production facilities also operate within the port, and these are the biggest energy user of the port. Some of these facilities have their own heat production (steam boilers).

Cranes are the biggest energy consumers within the port operations as such. They are mainly owned and operated by the stevedoring companies.

There is widespread collaboration between companies within the port, including joint purchases of oil spill response capacity and shared development work for the port area. The companies have joint meetings concerning port development, although energy issues only play a minor role in these discussions.

Tallinn (EE)

The port of Tallinn consists of five separate harbours: the Old City Harbour in Tallinn, Muuga, Paljassaare, Paldiski South and Saaremaa. The Old City Harbour mainly functions as a passenger harbour, but also handles ro-ro cargo carried between Estonia, Finland, Sweden and Russia. Muuga harbour, the biggest harbour in Estonia, is located 20 km east of Tallinn and specialises in handling transit traffic: containers, solid and liquid bulk goods, general and ro-ro cargo. Paljassaare handles break bulk, coal, oil products, timber and perishables. Paldiski South is located 45 km southwest of Tallinn, and serves Estonian foreign trade and also transit traffic via Estonia. Saaremaa serves passenger traffic, recreational vessels and cruise ships.

The port is a state-owned limited liability company, which provides infrastructure, land, quays and sea approaches, while private operators provide superstructure such as handling equipment and warehousing. The port's energy is provided by a subsidiary, and another subsidiary handles waste management. The existence of this port energy company enhances the overall planning of the port's energy use, although tenants are still responsible for energy use and energy efficiency in their respective areas.

Riga (LAT)

The Freeport of Riga lies on both banks of the River Daugava and has a total length of 15 kilomet-res. The estimated loading capacity of the terminals of the Freeport of Riga amounts to 45 million tonnes per annum. By cargo turnover Riga is Latvia's biggest port, and also the biggest port in the Baltic States (36 million tonnes and 3,956 vessels in 2012). Up to 80% of the Freeport's cargo turnover is made up of transit cargoes. 34 stevedoring companies and 28 shipping agents operate at the port. The main types of cargo handled are containers, various metals, timber, coal, mineral fertilizers, chemical cargoes, oil and food products.

The port company is owned by the State of Latvia and the City of Riga. 34 stevedoring companies work in the area. A total of 5,000 people work in the port, of whom 385 work for the port authority. Tenant companies are responsible for the warehouses, cranes and other technologies used in the port. Industrial facilities also operate in the port area, including shipbuilding yards and oil refining plants.

Klaipeda (LT)

Klaipeda State Seaport is the northernmost ice–free port on the east coast of the Baltic Sea. It is the largest and most important Lithuanian transport hub, connecting sea, land and railway routes from east to west.

Klaipeda is a multipurpose, universal, deep-water port, providing high quality services. 14 major stevedoring companies, ship repair works and shipbuilding yards operate within the port, as well as many types of marine business and cargo handling services.

The port is well connected with important industrial regions in its Eastern hinterland (in Russia, Belarus, Ukraine etc.).

The port company is state-owned. The company rents out areas to stevedoring companies. These tenants are responsible for infrastructure, including the lighting of the areas they rent. 14 stevedoring companies operating in the port, all of them Lithuanian. Information on their energy consumption is collected from these companies, but consumption is not monitored. The port reports on its annual total consumption of electricity, heat, natural gas and water.

Gothenburg (SWE)

The Port of Gothenburg is the largest port in Scandinavia, with over 11,000 vessel calling each year. Almost 30% of Swedish foreign trade passes through the port. The Port of Gothenburg offers a very wide range of routes, with traffic to over 140 destinations throughout the world, including direct routes to the USA, the Middle East, India and other parts of Asia.

The Port of Gothenburg is the only port in Sweden with the capacity to receive the very largest ocean-going container vessels.

Around 25 rail shuttles depart each day, offering companies throughout Sweden and Norway a direct, environmentally favourable link to the port, and the opportunity to utilise a broad range of routes.

The Port of Gothenburg has terminals for containers, ro-ro, cars, passengers and oil and other energy products. Since 2010 the port has been divided into a municipal Port Authority and separate terminal companies that deal with operational functions.

The port company is owned by the City of Gothenburg. The company owns the land and the infrastructure. Terminal operations are carried out by privately owned companies. The concession agreements between each terminal operator and the Port Authority oblige co-operation on common environmental issues, including climate impacts (CO_2 footprints).

Copenhagen-Malmö (CMP)

CMP is located in the heart of the Øresund Region within a short distance of almost four million consumers. The region is experiencing increasing integration between the Danish and Swedish sides of the strait. At the same time, the region is the gateway to the entire Baltic Sea Region with its population of more than 100 million people.

CMP provides access to an infrastructure that ensures goods are processed quickly and safely. The company is the major port operator in the Øresund Region, and meets demands for the transport of consumer goods, new cars, aviation fuel, building materials, passengers, etc.

CMP is one of the biggest port and terminal operators in the whole Nordic Region, and also one of the largest Northern European cruise-ship ports, also occupying a key position in the Baltic Sea Region for the distribution of cars and transit oil.

The port is situated in two cities in two countries. The port company has different owners: the Danish part is owned by the State of Denmark and the City of Copenhagen; and the Swedish part by the City of Malmö and private investors. The port company also operates the stevedoring, which makes it different to the other ports visited for this study. The port company purchases the energy used in the port, and the tenants pay for energy according to their consumption levels. The port company is responsible for all the machinery, vehicles and infrastructure, and makes decisions related to energy use.

2.2 Energy consumption

The ports were asked if they can specify how much energy is consumed, and where. The goals here were to discover the extent of knowledge of energy use, to examine how the monitoring of energy consumption is arranged, to find out where the big energy consumers are, and to identify where there may be possibilities to increase energy efficiency.

HaminaKotka

The companies have their own contracts with power companies: the total consumption of the port is not known. District heating and natural gas is also delivered, and some companies have steam boilers of their own. The stevedoring companies are the biggest energy users.

Klaipeda

The companies have their own contracts with the power companies. Figures for the total consumption of the 14 stevedoring companies are compiled, including electricity, heat, natural gas, drinking water and process water. The authority does not know the details of different partners' contracts or the prices of the energy purchased. Energy consumption itself does not play an important role in decision making, but energy prices seem to be important.

Riga

An old coal-fired power plant provides heating in the port. Electricity is purchased. The purchased electricity is from the Latvian national grid and it is both imported and produced in Latvia based on natural gas and hydropower. Energy costs account for about 10% of all the port's costs. Some cranes have their own power metering.

Tallinn

The energy subsidiary of the port supplies energy for actors within the port and tenants are billed directly by the company, based on their directly measured monthly consumption levels. End-users are responsible for controlling their own energy use. The energy company does not have production of its own. Lighting, cranes and heating were described as the biggest source of energy consumption.

Gothenburg

The Port Authority and each operating company are responsible for controlling energy use in the areas and buildings under their own responsibility. Energy consumption levels are measured through metering for electricity and heat, and by using fuel invoices.

Copenhagen-Malmö

As the port company takes care of stevedoring in the port, it also consumes most of the energy used in the port. The energy consumption of tenants is metered for charging purposes. The company is also responsible for decisions related to energy. The port's environmental permits require reporting of energy consumption levels. Fuels play an important role in energy use. The diesel fuel used by various vehicles is seen to be the most important energy usage, and it is hoped that consumption levels can be cut because of its high price. Electric and hybrid vehicles have been considered as replacements for diesel-fuelled vehicles. Electricity use is metered by more than 100 meters for the purposes of billing tenants with many separate contracts. The fuel consumption rates and CO_2 emissions of all vehicles are monitored and calculated.

2.3 Shore-to-ship systems

Shore-to-ship systems are used to improve the air quality near the port area and/or to reduce the CO_2-emissions of the port activities.

As the ports are often situated near to residential districts or city centres, air emissions from visiting ships may play an important role in local air quality conditions. Emissions can be decreased by supplying the power needed by ships in the harbour from the local grid, so that ships do not have to use their engines for power production.

If the port purchases or produces renewable energy, the CO_2-footprint will decrease when the ships use energy from the grid instead of generating their own electricity.

The Port of Gothenburg can be seen as forerunner in building shore-to-systems. Its high-voltage system since has been in use since 2000, and a low-voltage system was set up in 1989. Ships using shore-to-ship systems get a 97% reduction in their electricity taxation. The port is also collaborating with other ports along the same shipping routes to promote shore-to-ship systems.

Table 7: The shore-to-ship system in Gothenburg.

ENVIRONMENT	2011	2012	2013
Onshore power supply			
Percentage of vessels calling that can connect onshore power; %	34	34	30
Percentage of lay time when onshore power can be used; %*	19	18	12
Quantity consumed, MWh	6 230	10 340	10 520
Environmental benefits:			
Sulphur dioxide, tonnes	6	10	10
Nitric oxide, tonnes	80	130	140
Particulates tonnes	2	4	4
Carbon dioxide, tonnes	3 800	6 300	6 400

*) Excluding bunker boats.

Klaipeda and Riga have low-voltage connections for smaller vessels.

As HaminaKotka has little passenger traffic and the stevedoring is done by machinery on the berth, not by the cranes of vessels, there has been little interest in ship-to-shore systems. Moreover, there are no crowded residential areas near the port, so exhaust emissions from the vessels have not been seen as a problem.

The Port of Tallinn has a plan to establish a shore-to-ship system for ferries. This is dependent on the commitment of ferry lines and support from regulatory frameworks. In the port of Copenhagen-Malmö discussions with shipping companies concerning a possible shore-to-ship system are ongoing. As a major investment, this development is competing with planned investments for an LNG terminal.

Shore-to-ship systems are expensive investments, and commitment to use a new system is needed from ferry operators and shipping companies.

There is still lack of standardisation of such systems, which hinders their use, especially for vessels that may not visit a particular port regularly. This process may be easier for ferry lines with regularly scheduled visits.

New systems compete for financing with other investments such as LNG terminals in ports side and sulphur scrubbers on ships.

The driving forces behind investments in shore-to-ships systems may be the opportunity for ports, ferry lines and shipping companies to have a greener image, possibly under pressure from their clients.

Cruisers and ferries typically remain in harbours for relatively long periods, and their energy consumption levels in harbour are high compared to cargo vessels. These factors increase the attractiveness of using grid electricity.

2.4 Renewable energy and alternative fuels

The ports were asked if they produce or purchase renewable energy, or if alternative fuels are used in machinery or vehicles, or if there are plans to switch to such energy sources.

As stated earlier, the tenants in the ports usually have their own contracts for electricity supply, and the port company does not make decisions on the origin of the purchased electricity. Both Copenhagen-Malmö and Gothenburg purchase renewable electricity.

The ports did not have electricity production of their own. Some had plans to utilize solar energy for heating, or replace natural gas with biogas. The wide areas of warehouse roofs give good possibilities for utilizing solar energy.

As diesel fuel consumption was seen problematic in Copenhagen-Malmö, alternative energy sources for vehicles were under consideration, including electric, hybrid and gas-fuelled vehicles, which may be used when possible. Employees have access to a carpool with a gas-fuelled car that can be used for business appointments.

2.5 Energy efficiency

Questions relating to energy efficiency covered energy monitoring and management, infrastructure, machines and vehicles, and the behaviour of personnel.

2.5.1 Monitoring and management

Port representatives were asked to rate the importance of the role that energy efficiency plays in decisions made by the port, and to specify whether the port has an action plan to increase energy efficiency, either as a separate programme or part of a wider environmental programme. They were also asked how responsibilities are shared and collaboration is arranged between different actors. Targets and levels of monitoring of energy use were also discussed.

None of the ports have a specific action plan for energy efficiency. Their environmental programmes or environmental permit conditions may, however, include energy issues or demands related to the monitoring and reporting of energy consumption.

The allocation of responsibility for energy issues varied between ports. Since many different actors are present in ports, responsibilities are sometimes spread widely, and there is a lack of overall management of energy issues. Energy issues are typically one of the areas of collaboration between companies in a port, but they have not been given a high priority. Data on energy consumption in a port area is usually collected from the companies working there, but no detailed information is available on exactly where the energy is consumed or how efficiency could be increased.

In the Port of Tallinn, the port energy company is responsible for supplying energy throughout the port, but tenants are responsible for their own energy use.

As operations in Copenhagen-Malmö Port are carried mainly by the port company, energy questions are easier to review at the port level.

2.5.2 Infrastructure

This section of the interviews concentrated on lighting and storage conditions (i.e. heating, cooling etc.) Responsibility for these issues is divided between different actors within the ports. Usually the port company or authority is responsible for the lighting of the shared areas of the port, and the tenants are responsible for the lighting of the areas they rent. The situation was same regarding buildings and warehouses.

Lighting

Lighting is one of the biggest energy consumers in the ports. Thanks to the rapid development of new lighting technologies, it is also one of the areas where energy consumption can most easily be reduced This can be done by changing the light sources, or by controlling or focusing the lights better so that lights are only on when and where they are needed.

The ports are actively switching to LED technology. This technology is developing quickly, and the prices of lighting solutions are decreasing. LED lights have already been installed for indoor lighting in warehouses, offices and passenger terminals in many places. The use of LED applications outdoors for lighting roads and yards is still rare, however, and companies are still evidently seeking reliable applications for these purposes.

Lights controlled with presence detectors are especially used in indoor locations. Motion detectors switch on the lights when they are needed, and the lights are automatically switched off when they are no longer needed.

The port of HaminaKotka has in some areas installed lighting systems that can be switched on and off remotely by mobile phone.

One special area within the ports is the car terminals. In one of the visited ports an agreement of with a car importer stipulated that the lighting in the car terminal must be kept on at a certain level during the night. In another port, contrastingly, a car terminal could be left unlit, with lighting controlled by motion detectors.

Even in locations where control systems for lighting are available, their effect on energy efficiency may be limited if they are not used properly. Respondents mentioned several locations where personnel often forget to switch of lights when they are no longer needed. Here, as in many other areas for action, the training and motivation of personnel plays an important role.

Buildings: warehouses, offices, staff rooms, passenger terminals

Warehouses were not generally heated. Their heating, ventilation and insulation may however need to be taken into account in energy efficiency contexts in future.

The port authorities typically reported that the energy efficiency of their offices or other buildings where staff is based is an issue that arises whenever energy efficiency is considered. Many buildings have undergone energy audits and renovations involving improvements in their energy usage. These methods are no different to those used for buildings in other sectors, and there are no special issues related to ports in this context. However, the port companies and their tenants could be given incentives or rewards for auditing their buildings.

Relatively little information about passenger terminals was obtained from the interviewees, as the terminals are not within the responsibility of the authorities or companies interviewed, but are run by other operators or their subsidiaries. Some answers were obtained after the visits, however.

In Tallinn, over the last 5-7 years many actions designed to improve the energy efficiency of passenger terminals have been carried out in relation to lighting (replacement and automation), HVAC and general control systems. One ongoing concrete action is the implementation of a new energy concept for Passenger Terminal D. This terminal is going to be enlarged, and its heating system (currently 100% electric) will be changed, with air or seawater source heat pump solutions presently seen as the most favourable options. The insulation of the existing terminal will also be reevaluated, while the new part of the building will be so large that the whole building has to fulfil criteria in the EU building directive, so this may entail the total refurbishment of insulation. Tallinn has performed energy audits for the terminal buildings, and has plans for the continuous monitoring of their energy consumption.

2.5.3 Machines and vehicles

Another part of the questionnaire covered the energy efficiency of the machines and vehicles used in ports:

Heavy machinery

The heavy machinery used for loading and unloading ships is mainly owned by the companies who use them, though in some cases machinery is owned by the port company and rented to users.

This type of heavy machinery usually has a long service life, typically 20-25 years. Even though the energy efficiency of such machines has increased greatly, thanks for instance to the use of generators that can recover potential energy from the lifted cargo, the rate of machine replacement remains low due to the machines' long service life time and high investment costs.

The energy consumption characteristics of machinery and vehicles were in general taken into account during purchasing processes. In Copenhagen-Malmö, for example, environmental personnel participate in purchasing decisions.

On the other hand, reliability is widely seen as a much more important parameter when choosing machines or vehicles, and this may lead to the choice of a less energy efficient alternative.

Use of machines and vehicles

Training in eco-driving is commonly given in the ports visited. However, the effectiveness of work was seen as more important than energy savings. Even where fuel consumption is monitored, there are no related incentives for fuel-savings, while there may be incentives for efficient work, so for operators it is more important to work quickly than to save energy. It was also noted that since operators may not benefit from energy saving, they may not bother to turn vehicles when they are not in use. Also in some cases a less efficient older vehicle may be used instead of a newer one considered to be less comfortable or more difficult to operate.

There are two ways to affect energy consumption by routing. The first involves making the road network as efficient as possible to eliminate unnecessary kilometres. The ports are currently working to improve the efficiency of their routing and road networks. This work is more driven by considerations related to overall efficiency and safety, though such measures also save energy.

The second way is to use software optimisation tools to enhance equipment deployment procedures, resulting in further operating efficiencies. These tools are designed to optimise yard traffic and reduce unnecessary transfers and lifting of cargo, so they may also lead to considerable energy savings.

2.6 CO_2 footprints

The ports were asked if they have estimated their CO_2 footprint. A carbon footprint is defined as "the total set of greenhouse gas emissions caused by an organization, event, product or person".

Practices regarding estimates of the CO_2 footprints of port activities differed greatly between different ports. The Port of Gothenburg has set a good example by calculating its CO_2 emissions and having an action plan for decreasing greenhouse gas emissions:

- Monitoring is conducted by collecting data on energy consumption, and estimating the related CO_2 emissions.
- The development of the Carbon Footprint of the Port Authority has been based on ISO 14064–1:2006 & the Greenhouse Gas Protocol. The port's footprint has been estimated every year since 2010 (when the Port of Gothenburg was transformed into a Port Authority and Terminal Operating Companies). The CO_2 emissions of the port authority and the terminal operators are compiled for an annual report published within the port's Climate programme.
- The port is required to report emission data annually to its licensing authority.
- The port authority also compiles data for its own annual sustainability report and quarterly internal target reviews.

The other ports visited have not estimated their carbon footprints. Estimates may have been made for some aspects of operations, such as fuel consumption, but not for the whole port. However, ports acknowledged that such procedures will be necessary in the future.

2.7 Industrial parks

Industrial activities are carried out in many ports. These may involve production units where raw materials arriving at the port are refined for export or import; while other industrial activities may be present to support the port operations. These industrial operations have their own needs with regard to energy use, and they may also have surplus or waste heat or secondary material flows that can be used in other parts of the port complex.

Ports are increasingly developing new harbour areas as industrial parks, where industrial production is integrated with other port operations and industrial companies aim to take advantage of the harbour infrastructure. This will open up new opportunities to realise industrial symbioses, where energy and material flows can be utilised effectively.

2.8 Environmental factors

Various environmental issues arose during discussions (see below). These issues are not described in detail here, and the ports where specific issues were mentioned are not named.

- Noise and light pollution where a harbour is near a residential area.
- Air pollution involving volatile emissions released during the loading/unloading of oil products.
- Dust emissions from the handling of coal.
- Pollution of water with storm water, especially if sea levels increase and storms become more common due to climate change.
- Soil contamination due to dredging.
- Polluted land: during the long history of one port the ground has been polluted, and soils have to be decontaminated.
- Wastes from scrubbers: Since ships will have to clean their flue gases because of new SO_2 regulations, ports will need facilities for handling scrubber wastes.
- As many small companies operate within the port, exact sources of pollution can be hard to find and eliminate.
- The need to use land within the present port area for residential purposes, and to move harbour operations to new areas.
- It is becoming more difficult for companies to operate because environmental rules and permit conditions are getting tighter all the time.

An example of a port's environmental activities: the Port of Tallinn

The Port of Tallinn has established a subsidiary to look after waste management. The company collects and handles different waste fractions from the vessels visiting Tallinn's harbours. The company has developed methods and technologies for sorting and refining wastes including cardboard, used cooking oil, glass and wood, as well as means to handle oily water and sort hazardous wastes. Wastes are collected from ferries already sorted – and the ferries participating in the system will get discounts on their fees. Representatives reported that 90% of the wastes generated in the port are recycled.

2.9 Co-operation

Port representatives were asked about co-operation on energy and environmental issues between actors within their ports, and between their ports and other actors such as research institutes.

The different ports are in many respects competitors. However, energy efficiency and environmental issues are not major business areas for them, so it has been possible for them to build up co-operation on these areas. Since only a few people within the ports deal with these issues, networking with their counterparts in other ports can be fruitful in terms of spreading information and good practices.

Different companies and other actors working in the ports often attend common meetings about ports' operations and development.

As mentioned above, hundreds of different companies may operate within a port. Some of these companies are competitors, and co-operation can therefore be seen as problematic even in areas outside their core business areas. For example, if a company has a steam boiler, it will be unwilling to sell steam to its competitor even though this would benefit both companies.

Examples of co-operation between port actors have been presented above in this report.

As mentioned earlier, the ports are organized in different platforms, such as the European Sea Port Organisation (ESPO) and the Baltic Ports Organization (BPO), which have environmental issues in their Agenda. The ports interviewed are members in both of those organisations, and most of them are members in the Cruise Europe and the Cruise Baltic organisations, where environmental issues are also elaborated. Moreover, the ports have different bilateral or group partnerships going on (such as Tallinn with Helsinki and Stockholm). It may be useful in the future, instead of building new networks, utilise those networks on information spreading on energy efficiency issues.

3 Conclusions

Energy efficiency issues related to ports were examined both in existing literature and through visits to selected ports in countries around the Baltic Sea. In general, it seems that the energy does not play a very important role in decision-making in the ports and the companies working in them. However, even if the share of energy costs in ports' total turnover is still relatively low, energy efficiency will play a more important role in future because of increasing energy prices and the present economic situation. Increasing pressure due to environmental reasons and from ports' clients may further intensify the need for energy efficiency improvements.

Energy use can be improved in ports in different ways, including: technical improvements in infrastructure and machines; behavioural changes in the use of machines and infrastructure, including monitoring and management systems; choices of energy sources; and the comprehensive examination of the different port operations in co-operation with different users in the port. Seeing a port as industrial park or from perspectives such as process integration and industrial symbiosis may open up new ideas and opportunities for improvements.

Responsibility for energy and environmental issues in ports is typically divided among different actors within the ports, and there may be no overall vision with regard to energy use and opportunities to enhance the efficiency of port operations.

Two main driving forces may promote the increased installation of shore-to-ship power systems in ports. One is the imposition of environmental regulations or permit conditions that require such systems. Another is the willingness of ferry or cruise companies to use such systems wherever they are available.

Energy use can in many contexts be reduced through purposeful training and energy efficient practices without additional investments. Training in eco-driving is already widely used in the ports. Attention should also be paid to the behaviour of port personnel: how can personnel be encouraged to save energy? Energy efficiency incentive or award systems are not in use in ports as yet, but they might be possible tools for encouraging improvements.

Recommendations for further work

Information spreading: information about opportunities to increase energy efficiency and its benefits should be made more widely available among the port authorities and other actors in ports. This includes information on technologies as well as energy monitoring and management methods. It could be well worth producing a compilation of examples of best practices for energy efficiency in ports.

A collaboration network focusing on energy issues at ports in the Baltic Sea countries could be established to promote the exchange of information. The network should include other actors in the port sector in addition to the port authorities. Research institutes working with energy issues could also be asked to join such a network. Another possibility is, instead of new networks, utilise existing networks for information spreading.

Harbour areas could be seen more as **industrial parks** with different activities including industrial production. This opens up opportunities to use energy and materials more wisely, and to plan greener production methods and new services. As nodal points of transportation networks ports are suitable locations for different refining processes related to either the importing or exporting of goods. New tools should be developed to facilitate the examination of energy and material flows and potential synergies between different actors.

It is important to develop a resource efficiency **monitoring and reporting system** to meet the needs of ports. The existing commercial energy monitoring and reporting systems are not completely applicable to ports. In such a system it would be important to monitor and report on both the energy efficiency of port facilities, and vehicle fuel consumption. Development work is needed to combine the necessary measurement and system technologies. Such a system would enable a comprehensive environmental monitoring and reporting system to be set up for ports. Energy Performance Indicators (EnPIs) and other values and process parameters affecting environmental efficiency are important factors that should be defined and analysed during the development and definition phase of such a monitoring and reporting system. In addition to addressing energy and fuel consumption, such a system could also be developed to monitor and report on material flows within ports. The resulting information could then be used to improve the material efficiency of ports.

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ANNEX
Fact-finding study on opportunities to enhance the energy efficiency and environmental impacts of ports in the Baltic Sea Region – Port survey

The following questions have been listed to help guide discussions during port visits and to find the proper people and possible background data for the discussions. The findings from the port survey will be published in the final report of the fact-finding study. Please inform us if any of the information provide needs to be treated as confidential.
The purpose of the survey is to compile information on important features related to efforts to enhance energy efficiency at ports. The results will not be used for any kind of comparison of the ports.
If you have any questions or require further information please contact
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Basic information

- Basic information on the port
- The actors in the port
- The owner
- Tasks and responsibilities of different actors, especially in relation to energy and environmental issues
- Co-operation between different actors on energy and environmental issues (information sharing, common projects etc.)
- National and international legislation concerning energy efficiency and environmental issues

Energy consumption

- What is the total energy consumption of the whole port
- What is the share of energy costs in the total costs of the port
- How are energy costs divided between port actors?
- What are the areas/operations that use most energy in the port area, or what is distribution of the energy use in the port area?
- How do you measure energy use in the port area? What is measured, and how often? *(Port and tenant operations, facilities, vehicles, equipment, power generation, heat production and consumption, etc.)*
- Who is responsible for the control of energy use (heating, ventilation or air conditioning systems) of the buildings?
- Is secondary or waste heat used for heating purposes?

Shore-to-ship systems

- Do you have a shore-to-ship power system or are you planning to build one?
- The share of visiting ships using any shore-to-ship system
- Availability of the system for different users
- Financial compensation for ships using the shore-to-ship system
- Barriers hindering the use of shore-to-ship systems
- Other measures taken to enhance the use of any shore-to-ship system
- Experiences, need for development

Renewable energy and alternative fuels

- Do you purchase or produce renewable energy? Which kind(s)?
- Have you shifted to other sources of energy?
- Do you use or do you have plans to use alternative fuels or energy sources for vehicles or machines in the port?

Energy efficiency

- Driving forces and barriers with regard to enhancing energy efficiency

Monitoring and management system

- How important a role does energy efficiency play in the decisions of the port?
- Do you have an action plan to increase your energy efficiency or reduce energy use?
- Is it a separate programme or part of a wider scheme such as an environmental programme?
- Have you set targets for your energy consumption or energy efficiency work?
- Who is responsible for energy efficiency or environmental issues, and how is the work organised between different actors?
- Have you surveyed opportunities to improve the energy efficiency of the port?
- How do you monitor your energy efficiency (collecting data, analysing data, energy efficiency indicators, reporting results)? When did you start the monitoring?
- Do you estimate your CO_2 emissions?

Infrastructure

- Which kinds of actions have been taken to achieve improvements?
- What kind of lighting technologies do you use? How is the lighting controlled?
- Any special features of the heating of buildings (economically wise temperatures, waste heat for space heating etc.)
- How are different needs for storing conditions taken into account?
- Plans or needs for improvements?

The operation of machines and vehicles

- Energy efficiency in the procurement of machines and vehicles
- Energy efficiency practices for operators
- Training of drivers in efficient driving; optimisation of routes
- The use of renewable/alternative fuels, or any changes in energy sources
- Any other plans?

Personnel

- Have organised any training regarding energy efficiency at the port?
- Do you have instructions for employees on energy efficiency issues?
- Are personnel actively engaged in energy efficiency issues in their everyday work?
- Is there any incentive or award system for suggestions related to energy efficiency improvements?

Environmental factors

- Which are the most important environmental issues for your port? (air emissions, solid waste, wastewater, noise, dredging, light pollution, etc.)
- Are there special needs for the future?
- Is financial compensation provided for environmentally friendly vessels or ships?

Co-operation

Co-operation between different actors at the port

- Activities involving the exchange of information on energy and environmental issues
- Collaboration projects for improvements

Co-operation between ports

- Have you co-operated with any other ports regarding energy efficiency or environmental issues?

Research and development

- Are you participating in any research or development projects related to energy efficiency or environmental issues?

Other issues related to energy use and environmental issues

- Any other important issues related to energy or environmental impacts not mentioned earlier
- Future needs and barriers/challenges