

Ports Energy and Carbon Savings

Deliverable 1.5.3

Report on methodology and assessment of energy saving options in SMS ports and operating companies

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1. Introduction [use Heading 1]

The territory of the 2 SEAS interreg project is the major maritime road linking the Atlantic Ocean and the North Sea Region. Seaports there are numerous and key parts of logistic chains that provide an essential links between supply sources, industries and their markets. Some ports in that region aimed also to transport passengers with numerous ferry lines and or are used for leisure.

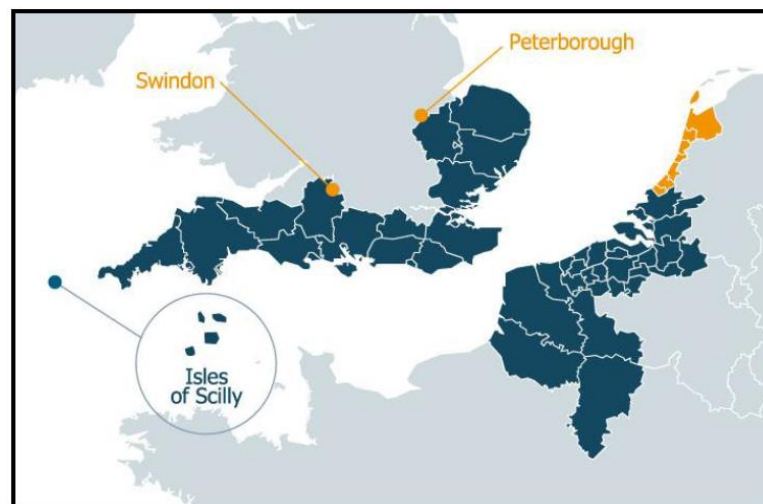


Figure 1 Territory of the 2 SEAS Interreg project

Those ports are not impervious to current major issue. As energy price have risen, energy efficiency has become more important for them and environmental regulations are putting pressure on all sectors. Energy consumption itself does not always play an important role in decision-making. However, competition for customers is hard and those new issues become an additional competitive factor in addition with energy prices. Besides, unlike most other transport sectors, EU legislation does not specifically regulate ports. There are only few directives that concerned ports: the Port Reception Facilities Directives (2000/59/EC) on port reception facilities for ship-regenerated waste and cargo residues, the directive 2005/35/EC on ship-source pollution and the Clean Power Transport Directive (2014/94/EU) which requires major port to provide LNG (Liquified Natural Gas) refuelling and if viable shore-side electricity by 2025.

Even if energy efficiency in port has not yet been fully explored, several project have gathered information on port energy efficiency. For example EcoPorts, Climeport, Green Efforts, Existing standard such as the ISO 50001 on the energy management can also be applied to ports and helps improve energy efficiency

But because ports are a multiple activities, actors and flux, the systematic approach to energy efficiency is complex and still not well explored in port areas. However, even if a large global approach remained too complicated, a thematic approach or a unit process approach allowed

ports to seize opportunities to improve their energy efficiency. This methodology aimed to describe such unit process approach.

The aim of these deliverables is to present the methodology to determine energy savings in ports.

2. Energy challenges in ports

2.1. Energy consumption

The energy use and consumption in ports depend on the type of port (commercial ports, industrial ports, leisure ports). Commercial and industrial ports accounts for the major part of the energy consumption in ports and the majority of the green house gases (GES) emitted in the sector came from those ports. Leisure and non-industrial ports emit less but are also smaller and the emissions are mainly due to passengers coming to the port and passengers going out from the port.

One of the problematic faced by port authorities when they take an interest into energy consumption, is that ports host other companies on the port territories. Often those companies on the ports have their own contracts with energy provider thus, ports authorities don't always have the total consumption of the port or any details. This is an issue because without a global view of the energy consumption, the port's authority cannot properly work on industrial ecology and energy cooperation. In this methodology, the exploration of energy savings in ports will be limited to the port's authorities own consumption with example of industrial ecology will be described.

The big part of the literature regarding energy in ports targets container terminal. As shown in figure 2 the type of consumption and the areas where energy is used are numerous and varied. Energy is used in buildings, in containers, in specific equipment such as cranes or trucks.

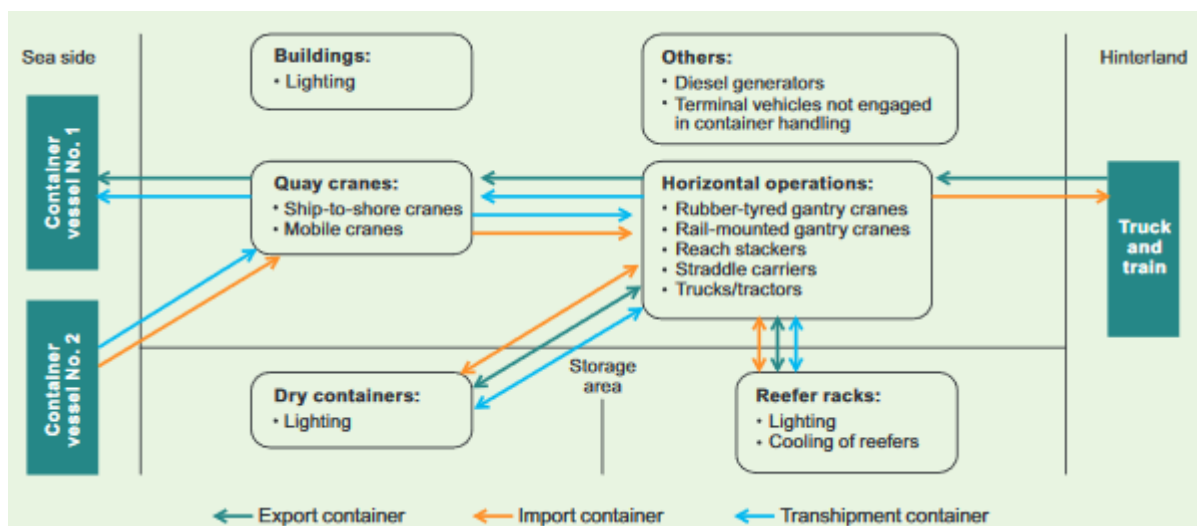


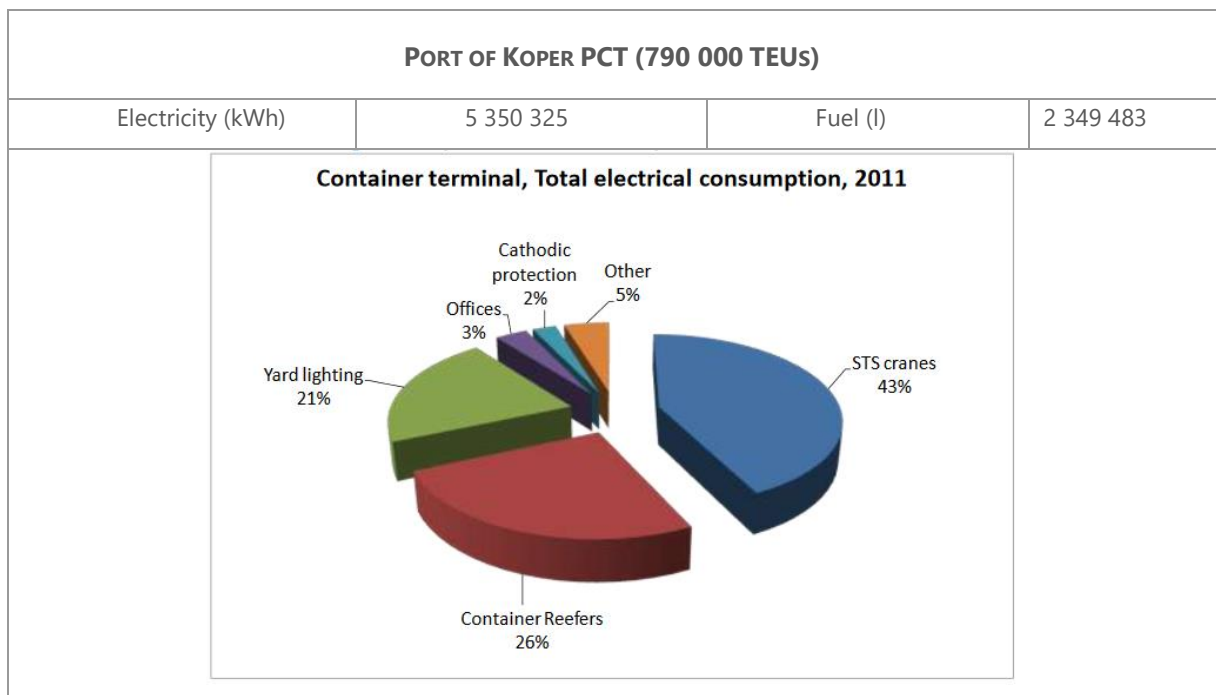
Figure 2 Energy Activity Clusters in a Container Terminal, G. Wilmsmeier

The energy in a port is also used in many forms (see figure 3). Diesel is often the main source of energy for industrial ports before electricity and gas. But most of the energy used can be replaced by another.

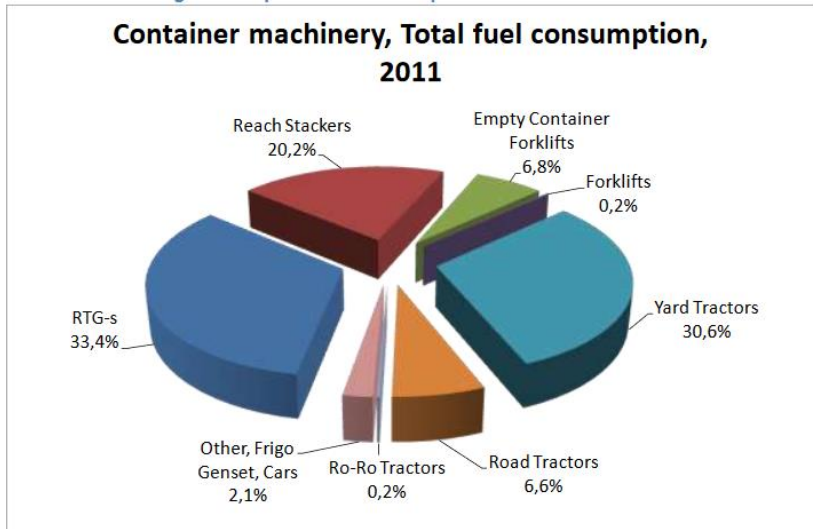
	Diesel	Petrol	Natural gas	Electricity
Ship-to-shore cranes	•			•
Mobile cranes	•			•
Rail-mounted gantry cranes	•			•
Rubber-tired gantry cranes	•			•
Reach stackers	•			•
Straddle carriers	•			•
Tractor-trailer units and lorries	•		•	•
Generators	•		•	
Buildings				•
Lighting				•
Reefer containers				•
Other port vehicles	•	•	•	•

Figure 3 Energy consumers inside a container terminal, Spengler and Wilmsmeier

Regarding the energy consumption profile of the ports, as mentioned earlier, it depends of the type of ports. The energy consumption of a medium size container terminal is usually dominated by reefer containers (40%), ship-to-shore cranes (40%) terminal lighting (12%) and administration buildings (8%)¹. The Table 1 shows example of energy consumption in port terminal. Consumption in marinas is obviously very different with a larger share of lighting and ship-to-shore power.

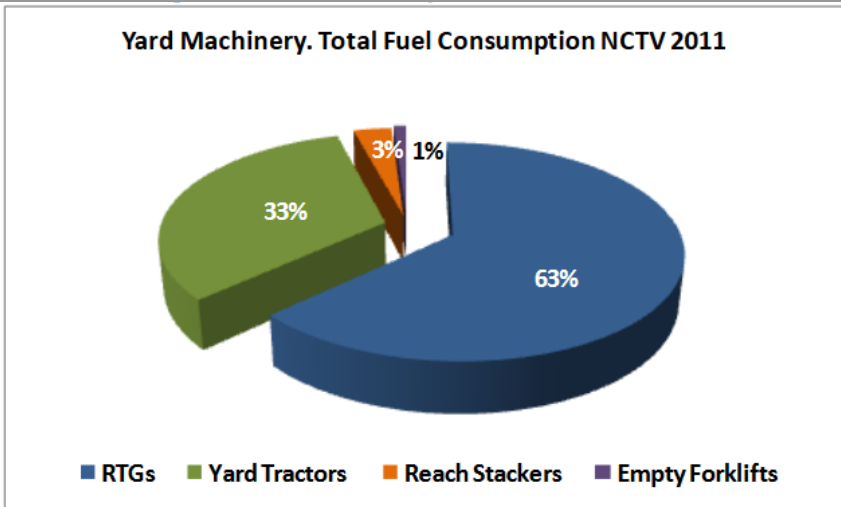
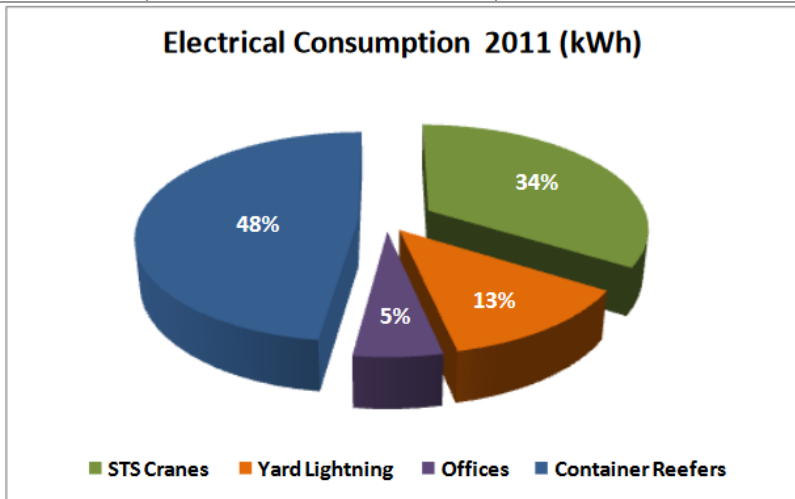


¹ Source : ECLAC/USI Energy Consumption and Efficiency Survey



PORT OF VALENCIA – NTCV (1 920 702 TEUs)

Electricity (kWh)	19 203 799	Fuel (l)	6 103 445
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PORT OF LIVORNO (LDT) (900.000 TEUS)															
Electricity (kWh)	9 151 887	Fuel (l)	1 348 571												
<p>Electrical Consumption 2011 (kWh)</p> <table border="1"> <caption>Electrical Consumption 2011 (kWh) Data</caption> <thead> <tr> <th>Category</th> <th>Percentage</th> </tr> </thead> <tbody> <tr> <td>Reefer Containers</td> <td>51%</td> </tr> <tr> <td>STS Cranes</td> <td>26%</td> </tr> <tr> <td>Terminal Lighting</td> <td>13%</td> </tr> <tr> <td>Offices</td> <td>10%</td> </tr> </tbody> </table>				Category	Percentage	Reefer Containers	51%	STS Cranes	26%	Terminal Lighting	13%	Offices	10%		
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TABLE 1 ENERGY CONSUMPTION AND ENERGY PROFILE (SOURCE: GREENCRANES - MAPPING OF PORT CONTAINER TERMINALS ENERGY PROFILE)

2.2. Energy management

Energy efficiency is a continuous process in company and the entire organisation must be committed to it. To identify the more efficient actions, ports need good monitoring and management systems with the setting of reduction targets and the investigation of the energy use. Without a true commitment and an energy management program, results might remain disappointing.

Firstly, an energy audit have to be conducted to help identifying opportunities and areas of high-energy consumption and waste. Energy Audit can estimate the potential for energy saving achieved through measures

that are economically feasible. Only good data regarding energy consumption and use can lead to an effective energy audit and efficient measures. Indeed, it is possible to improve only what you can measure. PECS WP.1 – Output 1 focuses on Energy Audit and can help ports authorities to handle this task.

Various software tools exist nowadays and enable to manage and interpret energy data. For example, there are software that can be connected to port machinery, and software that helps to operate terminals while minimizing the energy consumption (Terminal Operating System).

The main difficulty regarding those monitoring solutions and analyses is that medium and small ports lack of the presence of an energy specialist in their staff. Without forming employees to at least the understanding of how a port is charged for electricity and the total cost for each division, it might be hard to reach an ambition goal. However, national or local energy agency (or equivalent) starts to focus on ports and can bring both funds and expertise to create an energy management plan.

The ports that possess the required staff experience have still some difficulties implementing environmental management because of the numerous stakeholders and the lack of awareness of good practice. This guide aims to help ports authorities in their search for energy savings.

2.3. Where to find energy savings?

Potential energy savings are everywhere in a port, from the light to the buildings or the boats but not every action leads to the same complexity, investment, amount of energy savings and CO2 reduction. This deliverable is an overview of the different actions leading to energy savings, with when possible examples of realisation.

The potential of energy savings will be explored through different thematic:

- Lighting
- Heating and Cooling
- Fuels
- Specific Equipment
- Other considerations

3. Energy savings and lighting

3.1. Lighting in ports:

Lighting technologies are an energy efficiency issue that most of the ports are already addressing or considering. Indeed lighting represents a non-negligible share of ports' electricity consumption (more than 10%) and the principal share of energy costs in a warehouse (41%). Of course, lighting share in energy consumption depends of the activities on the port. For a container terminal the share of lighting in the electricity bill accounts for 12% on average but it can be up to 50% for marinas. In both case, the outdoor lighting is the principal cause of this consumption.

Outdoor lighting in ports is rather specific and often needs high mast lighting poles and high power lights. Indoor lighting is also a bit specific because in addition to classical tertiary buildings there are often warehouses.

Numerous and well-known solution exists thus to reduce both cost and energy regarding lighting. Light sources can be switched for more efficient one such as LEDs for indoor but also outdoor locations. It is also possible to install lightings controls to both save energy and reduce light pollution. Actions of the lighting enables energy savings of 10 to 60% depending on the choice and investments.

3.1.1. Switching technology:

For warehouses, as for most space with high ceilings metal halide, high-pressure sodium lamps (HPS) or other high-intensity discharge light sources remained common. For outdoor lighting with high masts, high-pressure sodium lights dominates the market. However, nowadays LEDs has become the standard efficient retrofit technology with 145 lumens per watt on average against 100 for metal halides and 100 for High Pressure Sodium lamps.

The cost is higher than classical solution but the LEDs consumes less energy and last two to five times longer. There are LED technologies developed for port environments (resistant to wind and salt) leads to both electricity savings (around 50%) and maintenance savings. Furthermore, LED lights come on instantly and do not require extended warm-up times. Consequently, light can be turned on and off on demand according to the need. In addition, LEDs have a better colour rendering and are more resistant to shock or vibration, which remained an important criteria for a technology installed in a coastal area. Some cranes are equipped with lights and once more LED seems to be the better choice regarding energy efficiency and cost. The retrofit of RTGs (Rubber Tyred Gantry) crane can result in 3% reduction in fuel consumption.

For indoor lighting, retrofitting can also result in substantial savings both in operational and in maintenance costs. Because it can be complex such a retrofit is usually done by an energy services company (ESCO).

Lighting retrofit are however costly and even if the payback time is usually less than 10 years, it demands an important financial investment.

3.1.2. Sensors and control devices:

For warehouses, sensors and control devices can led to easy energy savings and does not cost a huge amount of money. Once more, LEDs represents opportunities for advanced controls. To reach those savings, it is necessary to know how much light is really needed, where and when. If there is only little human activity, sensors can turn off light when no one is in the warehouse. Timers or photo-sensors can activate lamps when daylight diminished. It is also important to light only where it is needed. The floor of the warehouse might not need as much light as a workstation. For outdoor lighting, strategies such as dimming, scheduling and monitoring can help to save more than 25% of energy. In automating terminals, lighting is also less required and it is possible to reduce the proportion of light during the night to simply ensure the need for safety and security. With control devices, full lighting can be ordered from the port authority for sectors with ongoing operation.

3.1.3. De-lamping and Daylight

For warehouses as well as outdoor areas, it is important to consider de-lamping where lighting power density is higher than needed.

Indoor, windows, skylights and white walls allow to use this free energy at the maximum. Those easy solutions must be considered when a new warehouse or a new building is built or refurbished. De-lamping is also an option in offices buildings where corridors or other rooms can be too luminous.

In addition, the design of lights can also maximize the efficacy of lighting and reduce dispersion, in order to have to the same visual effect but with fewer lights.

3.1.4. How to evaluate energy savings thanks to lighting solutions

Lighting can lead to energy savings and reduction of electricity bill but to evaluate the amount of savings, data is required for each of the solutions presented above. Tools already exist in this field and required more or less input with consequently, more or less accurate results. One of the tool that can be used by Port authorities is the bhydro tool² but it required a good knowledge regarding the lighting situation and might not be easy to handle for most ports.

² <https://www.bhydro.com/powersmart/business/programs/new-construction/lighting-design.html>

The first step to evaluate energy savings and the interest of lighting retrofit is to estimate the energy used for lighting in the port and the cost of lighting (in terms of both energy and maintenance). This operation required the description of the lighting system lamp by lamp (technology, usage, controls, etc). Once the description is complete, it is rather easy to estimate the energy savings due to a switch to LEDs. The question of maintenance remained a bit more complicated because the maintenance costs depend on the contract and the country.

To estimate the energy savings due to sensors and control it is necessary to have information about the usage of the different areas. Without precise information, only a vague estimation of the energy savings can be achieved.

Lot of ESCo are specialized in lighting (either indoor or outdoor or both) and their assistance is often necessary to undertake a successful retrofit.

3.2. Examples:

Some ports have already launched a LED lighting program:

- Port of Los Angeles: 20 million for the replacement of HPS with LED for a return on investment of about 8 years.
- Port of Seattle: replacement of 680 old flood lamp fixtures with 300 more energy efficient lamps to conserve 1 200 MWh/year and save \$140 000 in maintenance and operational cost.
- Port of Bremerhaven: Reduction of the lighting consumption from 8 000MWh to less than 3 000MWh by switching to LED and reducing the number of lights (2 048 floodlights disassembled and 1 611 installed).
- Port of Valencia: world's first LED floodlit crane (in replacement of high-pressure sodium vapour lamps) with smart-controls results in more than 60% energy savings
- Port Metro Vancouver: replacement of HPS which took 20 minutes to warm-up (and lead to 24h/7d on) by LED floodlight on the quay crane trolleys, RTGs and other areas.

4. Energy savings and heating and Cooling

4.1. Heating and cooling in ports

Even if heating and cooling for office buildings, passenger terminal and warehouses is sometimes only a minor share of energy consumption in ports this aspect has the advantages to be well known and already explored by most ESCO or even government agencies. Energy efficiency in buildings is indeed a well-known areas where numerous achievements had been done for new buildings but also for refurbished ones. Heating and cooling present the first energy use of a building and numerous solutions have been studied to handle this problem. The ideal solution is obviously to build efficiently from the beginning but for existing buildings cost-effective measures can led to energy savings.

The energy consumption for heating and cooling depends on the age of the buildings and the country but literature on the subject is easily found and the average in energy consumption in offices is around 250 kWh/m² with more than 60% of it for heating and cooling.

Other buildings might however need more specific attention in port areas. Non refrigerated warehouses are only heated to prevent freezing yet, with lighting; heating is the largest part of the energy use in a warehouse. Besides, some warehouse need cooling and refrigeration system. Thus, actions on warehouses can also help to reach energy efficiency goals.

4.1.1. Insulation

Insulated roof is the most efficient measure regarding insulation right before insulation of walls. For office building, those measures are common and well known. For warehouses, it is possible to install dock seals or dock shelters to reduce outside air infiltration. Insulating the doors to the outside is also an efficient way to save energy.

For new buildings or old buildings to be refurbished, choosing high-energy standard reduces drastically the use of energy for heating. The investment is obviously higher but the ROI (Return On Investment) usually good. Port areas can have different lives in a sort time with industrial wasteland being re-used for industry or buildings. The question of building efficiency is then important.

4.1.2. Heating solution

In a warehouse, ambient interior temperature often only needs to be around 4 to 10°C to avoid freezing. In a warehouse, it is better to use radiant heating where staff are most commonly working instead of heating the entire warehouse to a chosen temperature. This solution allows the employees to work in a comfortable environment without heating the entire warehouse.

Programmable thermostats are also a great solution to save energy without costly investments. This solution only required to know precisely the need for energy use of each building and the need for heating and cooling.

Changing the heater can also improve the carbon footprint and led to energy savings. It is for example possible to use heat pump with the seawater for heating and cooling. The water temperature in harbour basins is more stable and project of district cooling or district heating in ports using seawater are starting to developed. If there is on the port an industry, which produces lot of waste heat, it can be cost efficient to create a district heating. Many ports have their own district heating and cooling system (CHP, gas boiler, Heat Pumps, etc.). This centralized system allows port authorities to have a better control over the total consumption. It is also possible to recover heat from cooling system on warehouses or from other mechanical equipment.

4.1.3. Ventilation

Free cooling, or the use of natural ventilation to let warmer air escape during the cooling season is an energy free solution. Installing wind-catchers with automated louvres for example can allow a precise control of the ventilation system.

4.1.4. Other advices

For refrigerated warehouses it is possible to program defrost cycle to run when needed rather than relying on timers.

4.2. Examples:

- Port of Portsmouth: passenger terminal is heating and cooling thanks to heat pumps using seawater as a source.
- Marseille harbour: district cooling using thermal inertia of harbour basin cools 500 000m² of buildings in the ports.
- Varta Terminal of the port of Stockholm: a building built in 2016 and based on extremely high environmental standards (energy consumption 40% lower than similar buildings in Sweden)

5. Fuel savings options

Fuel is one of the biggest post of energy consumption in ports. The problematic of fuel in port is also closely linked with air emissions and public health. As shown in figure 3, the main cause of pollution is fuel. But not only fuel used by vessels. Indeed, fuel is used for equipment such as cranes but also for vehicles and trucks on site. Ships also use fuel and even if this energy consumption is not entirely the ports responsibilities, in some cases, ports can do a lot to reduce this fuel consumption. Therefore, the different possibilities to reduce the fuel consumption of boats within the port will be explored in this part.

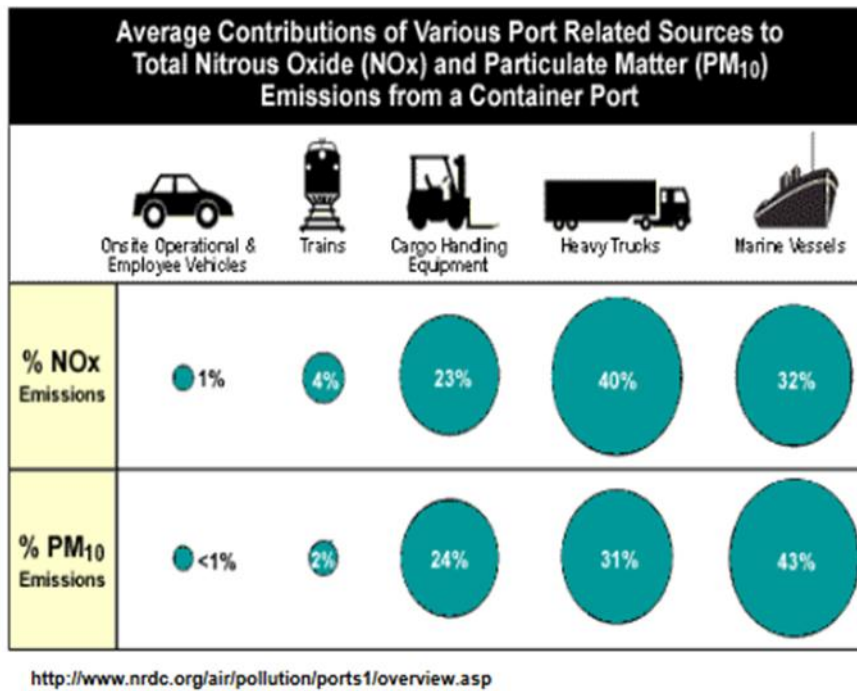


Figure 4 Port's air emissions

5.1. Cold ironing or ship to shore power

Providing ships with shore side power so vessels can turn off their engines while hoteling in port is one of the key elements to reduce the port carbon footprint. Unfortunately, port are rarely equipped to supply boats with electricity form the dockside (from a shore-based generator or if possible directly from the port's grid). The boats are rarely equipped to receive power this way neither. It is already a well-used practice in the military but more and more commercial ports are trying to switching to cold ironing. In July 2012 the IEC/ISO/IEEE 80005-1 Utility connections in port – Part 1: High Voltage Shore Connection (HVSC) Systems – General requirement was published, it is the first international standard for shore-to-ship systems. Directive 214/94/EU has also a positive impact to shore power utilization since it demands that all the member states assessed in their national policy frameworks the need for shore-side electricity.

By "plugging in" a vessel, it is possible to shut down boats generator using fuel and eliminates pollution coming from it. The direct link between PM (Sox, Nox, etc.) and certain diseases has been proven and Ports are now under pressure to reduce those PM emissions by the surrounding cities. Cold ironing allows the production transfer form dirty sources (boats generators) to cleaner power station. Besides, boat generator are not as energy efficient as power plant, so using the grid truly saves energy.

Cold ironing caused often many technical problems and some harbour might found this option too complex. It is then important to know than other solutions do exist such as connecting the ship to the harbour district heating. It is particularly interesting for ferries which, even plugged at quay, can need to heat the boat.

If most marinas and leasure ports already have ship-to-shore installations, it is still possible to save energy thank to easy measure such as "Pay what you consume". However, some costumers might prefer another port or use their engine instead. If the energy consumption during wintertime used to heat and fight humidity, it is better to propose dehumidifier since it does not consume any energy and prevents any risk of fire due to electrical issue on the boat related to the heating system.

5.2. Reducing time in port and other operational efficiencies

Port time for a ship may be assumed to be insignificant compared to overall voyage time but it actually greatly depends of the ship size, cargo type and port facilities. It can actually be more than 25% of the time for certain vessel. Marinas and leisure ports have obviously a different profile regarding this aspect.

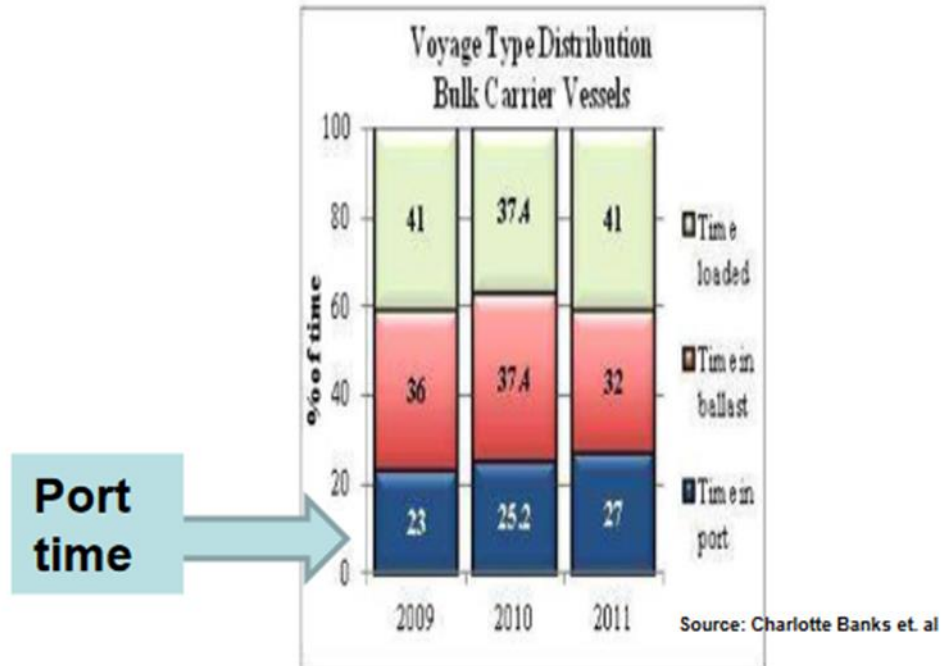


Figure 5 Port time

Time in port is divided into 5 type of operation: manoeuvring time, waiting time, berthing time with both productive time (actual time from start of cargo handling operation to end of cargo handling operation) and idle time (no cargo handling operations).

The idea of “just-in-time” port operation is to reduce the idle time in ports via minimizing the delays. It demands good early communication with port and harmonization amongst parties concerned and improvement of cargo handling. To optimize the time in ports, a good management system is an available option.

Depending on the port configuration, optimization of a ship’s movement through water can have a significant impact such as vessel speed reduction or slow steaming, optimisation of ship systems and optimization of fleet sizing to maximize vessel efficiency.

5.1. Technologies to reduce emissions:

If this is not exactly energy savings measure, it is important to underline than possibilities exist to reduce fuel pollution. Figure 5 shows the results of the study on port air quality by the International Council on Clean Transportation. The study describes the potential emissions reduction of different technologies and the potential reduction.

Type	Technology Name	Application	Potential Emissions Reduction	Cost (US\$)
General Emissions Control Technologies	Diesel Oxidative Catalysts (DOC)		PM 20-30% HC 50-90% CO 70-90%	\$1,000-2,000 (Truck, CHE) \$3,000-4,000 (Marine) Variable Cost (Locomotive)
	Closed Crankcase Ventilation (CCV)		PM 15-20%	\$700 (\$48-50 filter replacement)
	Diesel Particulate Filters (DPF)		PM up to 90% HC, CO 60-90%	\$6-18K (Truck) up to \$40K (Marine, Locomotive)
	Selective Catalytic Reduction (SCR)		NO _x 70-90%	\$36K (Truck & CHE) \$60K-120K (Marine)
	Lean NO _x Catalyst (LNC)		Moderate NO _x Reductions	\$14K (On-road) \$40K (Off-road (limited))
	Exhaust Gas Scrubbers		SO _x 90-99% PM 60-80%	\$5M (Marine)
	Shore Power		Net emissions reductions	\$1-15M
On-Engine Modification	Exhaust Gas Recirculation (EGR)		NO _x 40-50% PM 70% (with DPF)	\$12K (Truck) \$10M (Marine)
	Engine Replacement, Repower, Rebuild, Refuel		NO _x up to 90% PM up to 90%	\$0.5-1.5M
	Slide Valves		PM 10-50% NO _x 10-25%	\$1.5-16K (Marine)
Alternative Fuels	Ultra Low Sulphur Diesel (ULSD)		PM 5-15% SO _x 99%	Surcharge: \$0.05-0.15/gal
	Biodiesel Fuel (BXX)		PM 15-70% HC 10-40% CO 10-50%	Surcharge \$0.25-0.40/gal
	Emulsified Diesel Fuel (EDF)		NO _x 10-20% PM 15-60%	Surcharge \$0.25-0.40/gal
Operational Strategies	Vessel Speed Reduction (VSR)		Net reductions in NO _x , PM, and other air pollutants	Net negative cost over time (balance fuel savings and travel time increase)
	Landside Operational Improvements		Net emissions reductions	Multi-million/billion dollar improvements

Notes: = Trucks, = Cargo Handling Equipment, = Marine, and = Locomotive. 1 icon= Low or uncertain deployment, 2 icons= Emerging, 3 icons= More Widespread. The technology and operational emission reduction options are diverse, and the per cent emission reduction estimates represent the potential reduction from best practices in each area. The associated cost ranges are illustrative, based on the most common such alternatives; “K” = 1,000 USD, “M” = 1,000,000 USD. Cost estimates are based on Starcrest (2012) estimates from the *Developing Port Clean Air Programs*.

Figure 6 Technologies and air quality, 2012, (source: ICCT)

5.2. Alternative fuels measures:

Ports can help to develop alternative fuels such as LNG that is cleaner than classical fuel used by boat (less GES and less atmospheric pollution). Switching fuels does not systematically leads to energy savings but it is often a quick way to reduce the emissions in the port. Port can make LNG or other alternative fuels available for ships.

	Applicable Emission Source	Retrofittable?	Applicable Operational Modes	NOx	PM	SOx	HC	Energy Consumption
Fuels								
Low Sulfur Fuels	All	NA	All	↓ cbc	↓ cbc	↓ cbc	–	↓ cbc
Liquefied Natural Gas - gas only	All	N	All	≤88%↓	≤98%↓	100%↓	↑ cbc	↕ cbc
Liquefied Natural Gas - dual-fuel	All	Y	All	↕ cbc	≤78%↓	97%↓	↕ cbc	↕ cbc
Water in Fuel	All	Y	All	≤30%↓	–	–	–	–
Methanol	All	Y	All	↓ tbd	tbd	100%↓	tbd	↓ cbc
Biofuels	All	Y	All	↑	tbd	↓ cbc	tbd	tbd

Figure 7 Alternative fuels :↑= increase, ↓ = decrease; ↕=either increase or decrease depending on various factors (source: study of emission onctrol and energy efficiency measures for ships in the port area, IMO, 2015).

5.3. Rails or fluvial transportation and connections to the city centre

For merchandise, transport rails or fluvial transport is much more efficient than road transportation but it demands also lot of investments (form the port and the local authorities or the state). Cooperation with other actors is necessary but it helps reduce the carbon footprint of the product. More and more manufacturer or seller are trying to reduce the carbon footprint that has become a marketing aspect.

For passengers, a better connection with the city-centre (bus, boat, train, etc) can also help reducing the fuel consumption on the port. Again, this is not fuel consumed by the port authorities but only the port authorities can improve this aspect.

5.4. Eco-driving

For port personnel but also for other workers on site, training can be organized on eco-driving. Eco-driving can easily reduce the fuel consumption of more than 10% depending on the initial behaviour of the driver. But to be completely effective, this action required motived drivers and communication with important feedback

5.5. Examples:

- Port of Oslo – A new automated Cold ironing system PLUG for the ferry “Color magic” is installed, with new cable able to resist at very low temperature and to heavy charges.
- The CMA-CGM company equipped his ships with “mobile container solution” making Cold Ironing (or AMP) a modular practice and that can possibly be moved onto other ships , adapting the ship to the ports requirements.
- Port of Gothenburg – The ferry “Stena Danica” which docks several times a week in the port a cold Ironing is implemented and it is linked to the district heating for the boat in port will be connected to the district heating. Ship to shore power at quay are already available but the ferry still needed his heating equipment. Now, through the existing connection at the pier used for wastewater, a connection to the district heating network will lead to 62% of Co2 reduction (172 tonnes per year and per ship) in comparison with using the ship generators.

- Port of Saint-nazaire (project in study): production of micro-algae with the Co2 emitted by the in the industrials in the port to create biofuel and launch a new economic activity on the port. The basins used for the algae crops could be heated by the waste it of those industries.
- Harbour of Lalonde des maures (marina): the marina decided to implement the "pay what you consume" for ships and it leads to 30% of energy savings
- The Brittany ferries' "Honfleur", to be delivered in 2019 is an LNG powered ferry. It will also be more efficient with his electric propulsion powered by LNG electric generators.

6. Energy saving and specific equipment

New technologies more energy efficient technologies are available for machinery and handling equipment in ports. The main problem is that heavy machinery is rather expensive with a long lifetime. The commissioning of efficient technologies will be slow. However, when new investments are under consideration, energy efficiency must be taken into account in decision-making.

6.1. Cranes

It is possible to have power metering on cranes in order to realize how much energy those equipment cost and the effect of energy savings measures.

STS cranes (ship-to-shore), on average consume between 150 and 200 KWh/operating hour. If diesel fuelled, then switching for electric STS is one of the first action to do. Grid-fed installations with e-STs are then possible and regenerative energy from motion braking or lowering load can be reused or stored. Auxiliary power (for AC, spreader pump, floodlights etc) accounts for more than 60 kW on large modern ship-to-shore cranes so it is yet again to find energy savings options such as installing all-electric spreader or controls temperature and speed of cooling fans and AC.

RTG cranes (Rubber-tired gantry) are usually diesel fuelled and remains a major contributor to diesel emissions. However, it is possible to switch to electric rubber-tired gantry, which are much more efficient and save 86% of energy and more than 65% reduction in Co2 emissions. The expected individual payback period of e-RTG is less than 3 years. To change from a combustion engine to an electrical operation connected to the grid, the RTG has to be equipped with a cable reel or a bus-bar connection. Those two systems require crane modifications. Grid-fed installations with e-RTG are then possible and regenerative energy from motion braking or lowering load can be reused or stored.

Every other terminal vehicles such as mobile cranes, straddle carriers and trucks that could hardly be connected to the grid can be equipped with at least a diesel-electric system.

Other considerations can help a port reduce its energy consumption such as automatic mooring system or electric shore side pumps for bulks liquids

6.2. Reefer containers

Reefer containers accounts for more than 50% of the electricity consumption in container terminals Average consumption per reefer container (chilled and frozen) is 53 KWh/day according to an ECLAC survey. From simple measure to more complexes ones, numerous actions can be taken to reduce reefer containers energy consumption from installing a roof shade, to switch technology for modern reefer container or to optimise use in order to reduce peak consumption of reefer container.

However, literature is still rare regarding this topics with not enough feedbacks to properly handle the subject.

7. Energy saving and industrial ecology

The possibility to use waste heat or waste cold or even waste material from one industry to be used in another. Not only this kind of cooperation brings massive energy savings but is also cost savings. The presence of one industry can consequently attract others in need of cheap heat. But to facilitate this cooperation or initiate it, usually a third party is needed. The port authorities can play this role and try to encouragement industrial ecology at the maximum. The main difficulty usually is the risk taken by one industry to rely on one other industry exclusively and not knowing for how long this other industry will be there. Once again, the port authority can help reassuring different actors with the study of potential back-up solution.

7.1. Examples

- The Port of Dunkerque: the port of Dunkerque has a long history of industrial ecology. The steel factory has been heating the city more than 30 years and now IndaChlore , a factory which recycle waste chlorinated product will sell its waste heat to another plant which is also a client of IndaChlore.
- Port of Dover: the Port of Dover made land available to a third party which operated a CHP plan powered by used cooking oil The plan provided renewable electricity and free heating. A partnership with tenant whose operation within the ort is very energy intensive also exists.

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