"Green Logistics - The concept of Zero Emissions Port"

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Ports are a key element to the supply chain and the green logistics are of primary interest. The concept of zero emissions' port is referred to a port powered mainly from renewable energies in order to fulfill its power requirements and to reduce the air emissions mainly using this concept for the emerging cold ironing regulation. Several renewable energies and their application to port operation are discussed. The concept of smart grid is used in order to facilitate the use of several renewable energies and to monitor and control all the demand and distribution.

Keywords: *Green logistics, Air emissions, Port development, Smart grid, Zero emissions concept.*

1. INTRODUCTION

Logistics is used to describe the transport, storage and handling of products as they move from raw material source, through the production system to their final point of sale or consumption. Although its core activities have been fundamental to economic development and social well-being for many years, it is only over the past 50 years that logistics has come to be regarded as a key determinant of business performance, a profession and a major field of academic study [1]. During this period the dominant paradigm for those managing and studying logistics has been commercial. The prime, and in many cases sole, objective has been to organize logistics in a way that maximizes profitability. The calculation of profitability, however, has included only the economic costs that companies directly incur. The wider environmental and social costs, traditionally excluded from the balance sheet, have been largely ignored – until recently. Over the past 10–15 years, against a background of increasing public and government concern for the environment, companies have come into consideration to reduce the environmental impact of their logistics operations. This impact is diverse, in terms of the range of externalities and the distances over which their, impact extends

Logistics is responsible for a variety of externalities, including air pollution, noise, accidents, vibration, land-take and visual intrusion [2]. As climate change is now considered to be the most serious environmental challenge facing mankind, the main focus will be on greenhouse gas (GHG) emissions from freight transport. In measuring the environmental effects of logistics it is important to distinguish first-order and second-order impacts. The first-order environmental impacts are those directly associated with freight transport, warehousing and materials handling operations. Second-order impacts result indirectly from these logistics operations and take various forms. For instance, advances in logistics have facilitated the process of globalization so that goods are now sourced from previously little-developed parts of the world. Partly to accommodate the consequent growth in freight traffic in such areas, governments have expanded transport infrastructure and this has often encroached on sensitive environments. The increase in air freight and other traffic resulting from global sourcing is a first-order effect, whereas the increase in infrastructure, such as road building in sensitive areas, is a second-order effect.

Shipping and ports are essential for international trade and commerce. More than 90% of the EU's external trade and over 40% of its internal trade is transported by sea. Europe's leadership in this global industry is unquestionable as it controls 40% of the world fleet. Every year over 3.5 billion tones of cargo and 350 million passengers pass through European seaports. Approximately 350 000 people work in ports and related services, which together generate an added value of approximately €20 billion1. Globalization, the elimination of trade barriers, the unprecedented growth of containerization and the increase in seaborne trade have had an impact on maritime transport and logistics chains. International supply chains have become more and more complex. The ability to deliver integrated supply-chain services has been a trend driven by customer demands. At the same time, technological possibilities are expanding – in particular thanks to advances in information technology. The role and strategic position of the key players in the maritime logistics chain are constantly changing. In this stage the demand for greener ports has arisen by the public and governments.

Tzannatos [3] compared the current practice of generating electricity at berth using onboard generators with the upcoming requirements of the 2005/33/EU Directive. He addressed the problem of ship exhaust emission at the Port of Piraeus and undertakes the challenge of finding a cost-effective option for its reduction, via analysis of port traffic data and the utilization of the experience gained through previous studies. Notteboom [4] demonstrated that a well-designed concession policy should also incorporate green port management targets. Terminal concession agreements thus have a role to play in the greening of

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port management. Goh [5] presented the effort of Singapore in promoting green ports and green shipping through the use of incentives, and working hand in hand with the key stakeholders of the maritime community. The examples of the PSA and Jurong Port are highlighted to put into perspective the progress of the Singapore Maritime Green Initiative using a tripartite approach.

On the other side, many contributions to green ports are tripartite arrangement where by government, respecting itself as manager of a resource in the global make-up, the relevant agencies playing their roles in promoting innovation and development of greener and cleaner more fuel efficient equipment, and industry such as the ports, shippers and shipping lines, coming together to collaboratively intertwine policies incentives engagements for the good of the collective whole [5]. This is evidenced in the case of European port governance [6] and from other research fields [7].

In this paper, the approach of zero emissions port is presented. After the introduction the emerging concept of cold ironing is discussed with its advantages and disadvantages. Next, the concept of fully powered by renewable energies port using the concept of a smart grid is presented. In order to show our concept in realistic situation a simulation exercise in the Port of Piraeus is presented including several initial calculations. Finally, the conclusions and recommendations are outlined.

2. COLD IRONING

During the ship's berthing a significant electric power is required in order to support its operations such as loading, unloading, lighting, cooling etc. So far this energy is produced by auxiliary machineries where due to low quality fuel that they are using the emissions of carbon dioxide, (CO_2), sulphur and nitrogen oxides (NOx, SOx) and Particulate Matter (PM), having consequence the degradation of air quality and noise pollution. This kind of pollution has influence on the working environment and the quality of life of the citizens living in the neighboring port's area.

Shore-to-ship electrification; also known as *Cold Ironing* ([8] and [9]), is an old expression from the shipping industry, that first came into use when all ships had coal fired iron clad engines. When a ship would tie up at port there was no need to continue to feed the fire and the iron engines would literally cool down eventually going completely cold, hence the term cold ironing. Cold ironing, in the meaning of shore to-ship electrification, has been used by the military at naval bases for many years when ships are docked for long periods. As the world's vessel fleet is increasing, vessel calls to ports are becoming more frequent. In addition, hotelling power requirements have increased, and thus the concern of onboard generator emissions during docking periods has become an important air pollution issue.

Thery are:

- Connection to electrical grid and electrical energy transfer 20-100 kV to a local station when transformed to 6-20 kV.
- The electrical energy of 6-20 kV transferred from local station to port's terminal station.
- There is a frequency conversion from 50 Hz to 60 Hz, depending ship's type.
- Next distributed to all terminal's electrical connections.
- For safety reasons special cable handling is required. The handling mechanism could be electro-hydraulic or electro-mechanic.
- On board of the ship specific adaptation for connection is required.
- Depending on ship's power the voltage is transformed to 400 V. The transformer usually is located in the engine room.
- The two systems are synchronized to work in parallel.

There are practical problems associated with the procedures some of them are:

Frequency: The electricity frequency in the European Union grid is 50 Hz. However, the frequency used onboard ships can be either 50 or 60 Hz. A ship designed for 60 Hz may be able to use 50 Hz for some equipment, such as lighting and heating, but this is a small fragment of the total power demand on the ship. Motor driven equipment, such as pumps and cranes, will not be able to run on their design speed, which will lead to damaging effects on the equipment. Therefore, a ship using 60 Hz electricity will require that the frequency in the European grid, needs to be converted to 60 Hz by a frequency converter, before connected.

Voltage (M/V on board): The difference in Voltage between shore power and ship's power voltage requires a specific onboard transformer (see Figure 1).

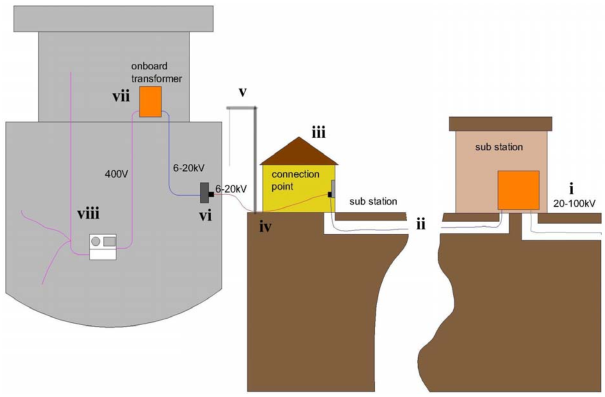

Figure 1. General arrangement of cold ironing ([3] and [10]).

Safety: By requiring direct handling of very heavy and cumbersome HV cables & connectors, cold ironing generates high risk of injuries - Health is also a drawback by requiring handling of heavy loads in awkward positions, cold ironing expose, on the long term, quay side personnel to back injuries. Non Compliance with National regulation, especially the European Directive 90/269/EEC3 is also an issue.

Several ships' types - berthing procedures: There are different onboard power demands, system voltages and system frequencies vessels for, when they are at berth. The vessel types usually are the Container vessels, Ro/Ro-and Vehicle vessels, Oil and product tankers and finally cruisers. The docking pattern of each kind of ship and the usage of cranes is also an issue.

3. GREEN PORT APPROACH

Although the cold ironing is a way to reduce ships' emission the fact that is connected with the grid is a drawback for its holistic approach to fight the climate change. The electric grid of each port is mainly powered by fossil fuel's sources so the total contribution to air emission is limited. In the zero emissions'' port approach a smart grid technology approach is used connected mainly to renewable energies sources and the usage of grid is only in emergency situations. The available energy sources, found in nature, are the wind, solar, geothermal and tidal and wave energy, while there is also energy in biomass and earthquakes. Although there are so many, the difficult task is the conversion to electricity and the efficiency of the converting systems [11]. In the next paragraphs a brief description of all renewable energies used is presented together with the smart grid approach.

Solar Energy: The sun with solar radiation is deriving the solar energy. Other than heating and cooling with solar architecture, solar hot water and daylight, there are solar powered electrical generation techniques such as photovoltaic. The mechanisms that capture, convert and distribute this energy are divided in the passive solar and active solar. Examples of active solar techniques are the photovoltaic or solar panels, which convert the energy into electricity and passive solar are orienting a building to the sun and designing spaces that naturally circulate. Today, the technology of designing photovoltaic panels is developing in a fast pace and growing rapidly. Solar panels are now more efficient, transportable and even flexible, making them capable for many applications and installations. A single solar cell does not provide enough power, but a combination of many in arrays make them able of powering medium sized applications, except for a PV park (see Figure 3) in the port area. It is proposed the main port's building to be reconstructed as green building using solar panels in the roofs or in the windows.

Figure 2. PV park
(http://www.messaritis.com/web2/images/park2.jpg)

Wind Power: The various ways to convert wind energy of the air flow to other useful form of energy, such as wind turbines to produce electricity, windmills to make mechanical work, wind pumps for pumping water or sails to propel ships. The biggest interest nowadays is the installation of wind turbines in large wind farms onshore and/or offshore. The numerous installed turbines will have the potential to produce enough electricity and supply a local transmitting system for medium communities/loads and isolated areas. Since most ports are facing problem in land expansion, the proposal is to use offshore wind turbines just outside the ports. Figure 3 depicts several wind turbines configurations while Figure 4 depicts the general arrangement of an offshore wind turbine.

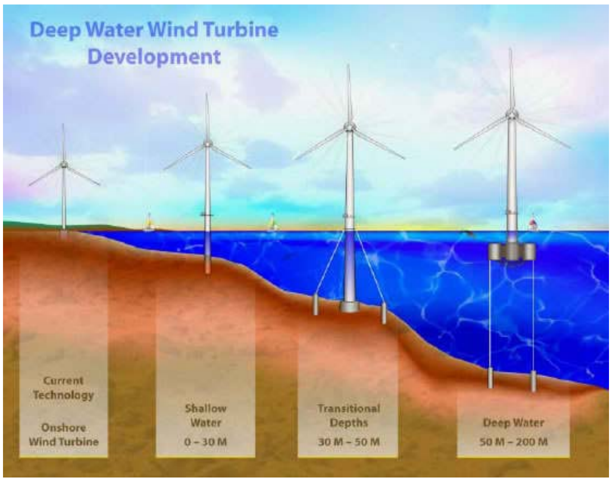

Figure 3. Windturbine developments
(http://globaloffshorewind.files.wordpress.com/2009/11/wind-turbine-technology.jpg)

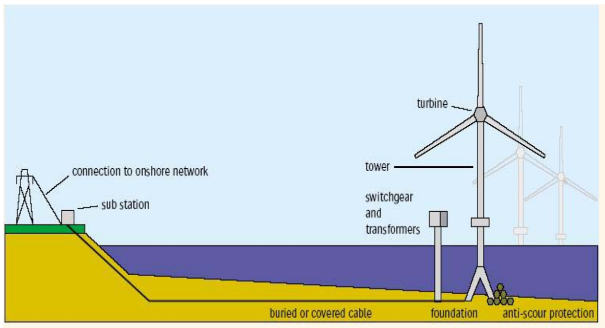

Figure 4. Offshore windturbine arrangement
(http://www.offshore-sea.org.uk/site/)

Wave Power: A form of energy, which is met at seas, is the wave power. Surface waves are the mean of transporting energy and this energy can be used in the production of electricity and desalinate water. The higher the waves are, the more energy they transport, making the application of techniques for energy conversion more interesting. The installations can be onshore or offshore, as in Figure 5 depending on the morphology of the shores and the typical waves of the area.

Tidal Power: The systems Earth-Moon, Earth-Sun and their gravitational forces are responsible for the recurrent change of the sea level, known as tide. The tide has different potential from area to area and in some cases is so strong that can create streams or elevate the sea level several meters. The kinetic energy carried from the streams and the potential energy of the elevated mass of seawater can be converted by the suitable system to electricity. In the first case, the popular mechanism is underwater stream generators similar to wind turbines and in the second, large tank near the highest level store the water, which then following the principles of hydroelectricity produce electricity. In a number of ports there are locations that fulfill the requirements for a tidal system (Figure 6).

Figure 5. Offshore wave energy converters.
[http://www.greenlivinganswers.com/archives/156]

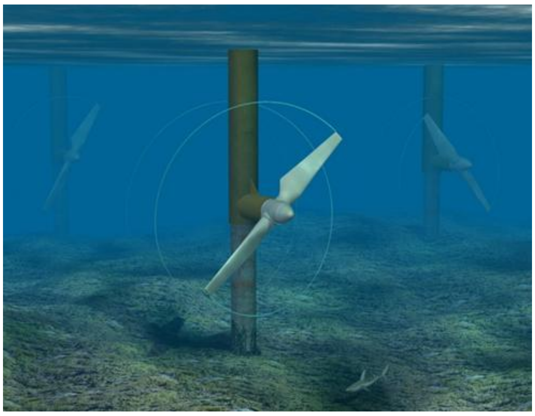

Figure 6. Under Water Stream Turbine [12].

Geothermal Energy: As capacitor store energy in an electric circuit, the ground stores thermal energy originating from the creation of the planet and the natural decay of the minerals. Today, there are small applications as a geothermal heating pump for a residential unit and large as geothermal power plants for energy production. In ports geothermal energy could be used for the port's buildings.

Hydrogen Fuel Cells: Another more advanced form of renewable energy source is the combination of fuel cells combined with electrolyzes. When the energy produced by RES is more than the needs, can be supplied to the main grid or feed electrolyzes. The electrolysis produces H_2 which is stored in an H_2 tank. In the cases when the produced energy is not enough, fuel cells can use the stored H_2 with O_2 from the air, and produce electricity and water, through inverse electrolysis. This is a free of charge, other than installation and maintenance costs, since the fuel is produces by the system. The cost of installation is high and there are no big facilities deployed, but this situation may change in the future. The use of electric cars for ports operation could be facilitated by applying this concept.

The concept of "smart grid" [13] defines a self - healing network equipped with dynamic optimization techniques that use real - time measurements to minimize network losses, maintain voltage levels, increase reliability, and improve asset management. The operational data collected by the smart grid and its sub - systems will allow system operators to rapidly identify the best strategy to secure against attacks, vulnerability, and so on, caused by various contingencies. However, the smart grid first depends upon identifying and researching key performance measures, designing and testing appropriate tools, and developing the proper education curriculum to equip current and future personnel with the knowledge and skills for deployment of this highly advanced system.

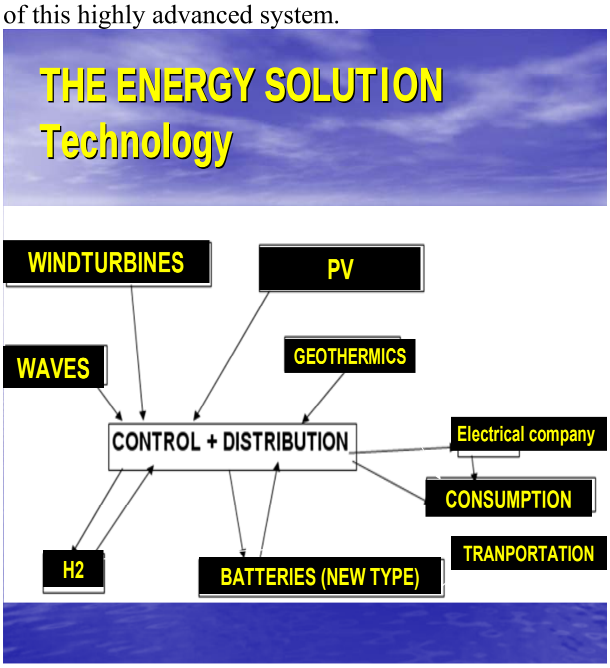

Figure 7. Smart grid for zero emission's port concept [author's research]

Figure 7 presents the approach to the concept. A control and distribution centre is fitted with a number of renewable energies namely offshore windturbines anchored outside of the port, PV power sources for the park or from the buildings, wave or tidal energy according to port potential in those sources and geothermal energy depending of ports abilities. The centre is connected with permanent electric grid used according to the needs and a digital metering system (in several areas such as docks and port's facilities) in order to monitor the port's energy demand and thus to distribute the required available electrical power. The excessive power produced from renewable energies is transformed to hydrogen or stored in new technologies high capacity batteries. The hydrogen produced used for a fleet of electric cars for port's operations

The intention is that 100% power for all port from renewable sources, and thus the power availability and the weather conditions should be carefully examined. In case of emergency the electric grid will be used or a power generation station will be in warm up conditions.

In next step an optimization of this configuration will be attempted using software tools and accessing meteorological data. An intelligent algorithm for prediction and optimum power distribution is currently under development to avoid the frequent interchange in electrical sources helping in reliability improvement of this system. Finally a business plan is carefully examined in order to identify the main financial indices of each port (i.e. NPV, ROI) taking also into account the new regulations related with emissions' reduction (ETS etc).

4. SIMULATION AND CALCULATIONS

This Section illustrates a first attempt for the simulation of the proposed configuration. In the Port of Piraeus we are using a PV park of 2 axis tracking system with nominal power 430Wp directed to the south and the total losses are in the range of 14%. Using PVGIS software we can calculate the mean annual energy production and to make reference for the particular day (see Figure 8).

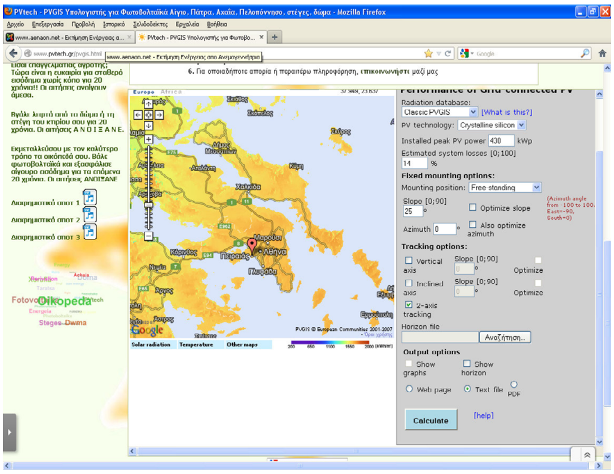

Figure 8. Calculation of PV park's energy performance in Port of Piraeus. (www.pvtech.gr/pvgis.html)

The floating wind turbines are installed in places just outside the port where the maximum air potential is observed from existing wind atlas and the average annual wind speed is observed to be 8m/s.

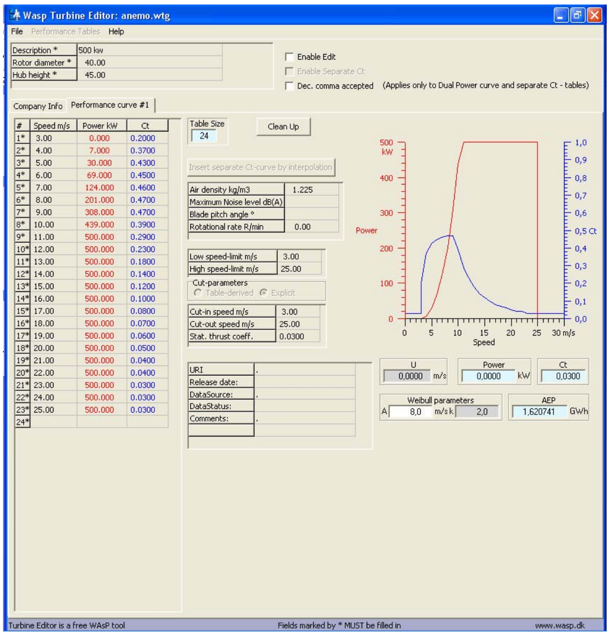

Figure 9. Calculation of wind turbine performance using wasp. (http://www.wasp.dk/Demo/TurbineEditor.asp)

In order to calculate the exact power each time we need the windturbine power curve from the manufacturer and the real time measurement of wind speed using anemometers in the area of floating windturbine (see Figure 9). For the purpose of our simulation we are using 3 wind turbines of 500 KW with rotor diameter 40 meters. The proposed floating platform appears in Figure 10.

Figure 10. Floating wind turbine configuration. [Author's research]

For our scenarios the RO-RO City of Amsterdam (see Figure 11) with calculated energy consumption of 252 kW per hour is assumed that is using the Piraeus port for 5 hour. Note that this particular ship is among the lowest in energy consumption for all similar ship's calling at port of Piraeus.

Assuming that there are batteries or fuel cells for storing the excessive energy and the smart grid is continuously connected to the electrical grid. Note that we assume that the wind turbine is a constant rate of energy production using 8 m/s wind speed. The measurements performed at day time periods, namely starting from 9 am to 9 pm, calculating the total energy needed and having the batteries to accumulate the load changes. The results appear in Table 1.

Figure 11. Ro-Ro ship (City of Amsterdam). (http://www.marinetraffic.com/ais/showallphotos.aspx?imo=9174751)

It is obvious that at night the situation becomes more difficult due to the lack of power production by PV Park. An attempt to use a second ship in our simulation namely (Ro-Ro ship *Birka Explore* with average power 377KW) shows as that it is supported by our smart grid configuration only during day time and ay night needs the electric grid support.

Table 1. Initial calculations results

Starting on 23-09-2012	PV	Wind Turbine	Batteries storing excessive power	Required energy for the ship for 5 hours
0900 am	1008	1952	(1700)	1260 (252*5 hrs)
0900 pm	0	1952	(692)	1260

5. CONCLUSION

Ocean-going marine vessels represent one of the largest, most difficult to regulate, source of air pollution in the world and are also an essential component of the international trade and goods movement process. These marine vessels are similar to floating power plants in terms of electric power, and it has been indicated that the marine vessels are growing in length and they will therefore be need of greater electric power need.

In this paper, it has been shown that shore-side power supply is a really interesting subject matter, and that today's marine vessel emission regulation needs to be stricter. Most of the ports worldwide are investigating the possibilities to use shore-side power supply. In order to create a zero emissions' port, a new concept of smart grid using renewable energies is investigated and shown its promising effects in minimizing ports' air emissions

Furthermore, using a part of Piraeus and a particular in day and time ship's hotteling period in the port an energy balance was calculated using a combination of renewable energies of selected scale. It was not possible to use wave energy devices since there are not so far adequate data for calculations. Although the initial results have shown that for a large port we need large floating windturbines for cold ironing electricity demand, the concept could be initially applied to smal ports when the energy demand is rather small. The future research will be focused on exploiting the possibility for a computer program to take into account all the particular renewable energies for this smart grid plus the facilitation of several ships' operational conditions through gold ironing. This automation will enable us to a better cold ironing management and optimal use of smart grid consisting of renewable energies.

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"ЗЕЛЕНА ЛОГИСТИКА - КОНЦЕПТ ЛУКЕ СА НУЛТИМ ЕМИСИЈАМА"

Никитас Никитакос

Луке су основи елемент у ланцу снабдевања и зелена логистика је код њих од суштинског значаја. Концепт нултих емисија односи се на оне луке које се снабдевају енергијом углавном из обновљивих извора енергије како би задовољиле своје енергетске потребе и како би смањиле емисују гасова. Разматрано је неколико извора обновљивих извора енргије и њихова примена на функционисање лука. Коришћен је концепт паметних мрежа у циљу олакшања имплементације обновљивих енергија, њиховог праћења, контроле захтева и дистрибуције.