



## GREEN EFFORTS Report Summary

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### Final Report Summary - GREEN EFFORTS (Green and Effective Operations at Terminals and in Ports)

#### Executive Summary:

The GREEN EFFORTS project, co-funded by the European Commission, after 30 months was concluded end of June 2014. There were very comprehensive terms of reference which can be simplified by stating "GREEN EFFORTS aimed at making terminals and ports a better place to work and to live with" as carbon footprint mitigation was the objective specified by the European Commission.

The project was a true challenge for mainly two reasons:

- Port sustainability was and is an objective well supported by policy makers, the industry, administrations and the public but there is some fuzziness how this could be achieved in detail and ideas sometimes were quite divergent.
- There is a tremendous lack of statistical process information.

The project, however, was very lucky to find industrial partners to cooperate, not only in Europe but especially in South America. At a later project stage United Nations Economic Commission for Latin America and the Caribbean (UN ECLAC) in Santiago de Chile coordinated the support resulting in a large collection of consumption data.

As the focus of interests of ports and terminals, depending on the port model, usually is different, also involvement of ports was searched for and mainly found in Singapore, Los Angeles and the European Ports of Antwerp and Hamburg. The RoRo Port of Trelleborg and the inland navigation Port of Riesa (upper river Elbe) as consortium partners represented their special operational profile. However the majority of the project work aimed at container terminals as these are the biggest representatives of the industry with the highest energy consumption.

Carbon footprint mitigation at terminals and in ports directly depends on energy consumption. Not every port and terminal manager might be equally motivated to reduce the carbon footprint, being concerned of the costs this might cause. It is, however, much easier to find fellow campaigner for greener ports and terminals once energy savings and mitigation costs can become positively balanced. The economy of potential solutions therefore was a constant requirement during the course of the project.

The wide scope of GREEN EFFORTS did not allow for in depth research as resources were restricted. However the project was able to deliver a rather comprehensive overview of opportunities to achieve improved energy-efficiency and hence to provide a useful platform to focus further research according to industrial needs, available solutions and political objectives. In addition, it rose the awareness for both, emission problems and energy-saving opportunities. Europe does not call the tune when it comes to size of terminal operators but why not targeting to be the innovation leader?

#### Project Context and Objectives:

An increasing need for green and effective operations at terminals and in ports exist due to present and upcoming stricter air quality standards and regulations. At the same time there is an increasing awareness of the need to reduce energy consumption of ports and terminals and to focus on the carbon footprint which is dependent not only on equipment and operations, but also the energy mix and the management of energy consumption. This is an important for objective for the terminals but also for a wide variety of stakeholders, such port authorities and transport service clients.

GREEN EFFORTS aimed at identifying and quantify energy consumption in terminals without impairing the efficiency of operations but improving it. The quantification has been conducted according to the process domains defined in WP 3. Data on amount of energy consumption of selected terminals process domains is collected in order to provide a comprehensive inventory of energy consumers.

"Baseline scenarios" by relating operational objectives to processes and to exploitation of resources (equipment) and its energy consumption in nature and quantity are taken into consideration. Potential saving and reduction measurements for handling equipment that are considered in the project include hybrid technologies, energy storage and recuperation, power management and electrification of equipment.

Energy supply has been elaborated in terms of regenerative energy, both external supply of it and possibilities to produce on site. Exploitation of LNG and shore based power supply for berthed ships were also in the context.

The increasing need for information regarding terminals carbon footprint calculations as well as the lack of information on correlation between key performance indicators (KPI) and parameters / decision are the key drivers in this field of research. So far, various approaches have been applied for simulating container terminals. Those have been used to validate decisions during late stages of planning processes. The high complexity and the high computational effort of micro-simulations, in combination with the required number of simulation runs to statistically validate such analyses, prevented extensive large scale studies. Additionally, the diversity of cargo RoRo / Ferry as well as Inland Waterway terminals are facing, has to be considered in the simulation model as well.

Whilst the main focus of GREEN EFFORTS is the energy efficiency of ports and terminals, transport sector has also been investigated to enable comparison of energy management.

Current standards applicable for transport provide guidance to capture and report carbon dioxide emissions on a global level. Recent development aims at product-based allocation of emissions as described in CEN EN 16258 [CEN 16258] but restricted to carriers. In a next step transshipment centres shall become included. Therefore, GREEN EFFORTS aims at developing an appropriate methodology for sea and inland navigation terminal by considering the future step of CEN 16258.

#### Project Results:

##### Energy Consumption

##### Measures to reduce energy consumption

The following approaches push reduction of energy consumption forward divided in behavioural, technical and organizational measures:

- The awareness of staff towards an efficient use of energy needs to be strengthened. This can be done by specific training or further education.
- Generally spoken, technical measures to reduce energy consumption comprise the usage of energy-efficient equipment (lighting, engines, and generators). Also, stand-by consumption should be closely monitored and if it cannot be reduced with technical measures, should be part of the awareness training of port personnel.
- Organizational measures comprise techniques that are of organizational matter.

As a conclusion, drawn from the conducted measures, it cannot be said that all of the discussed measures are well established or easily adaptable and/or investable, but by taking into account at least the following measures a terminal can well manage its use of energy and tackle unwanted emissions:

- Better plan necessary movement on the terminal
- The intensive use of renewable energy
- Reduce the consumption of energy in total.

##### Equipment Consumption:

- Using alternative fuels. Blending biofuels can reduce the emissions of diesel fuel. But using electricity has the most potential. Electricity cannot only be generated in a more clean way, but can also be recuperated by equipment. This makes the use of electricity a more energy efficient way of operating equipment.
- It is also recommended more efficient use of equipment. This means that idle runs have to be minimized. One of the developments on this process is the use of double loading cycles of Quay Cranes.
- This brings us also to the human factor in terminal operations. Most equipment is still operated by humans and the way in which equipment is operated is directly connected to the energy consumption of equipment. Therefore, good and regular driver training can make changes in driving behaviour.
- Using energy management systems to operate load shifting and energy balancing in smart grids can balance the energy consumption throughout the terminal in a way that energy is used in an efficient way.

#### Reefer:

##### Consumption of reefers depends on

- Nature of cargo resulting in a closed cooling air system as e.g. for deep frozen cargo or an air exchange process as e.g. for fruits
- Setpoint temperature providing the required carriage temperature
- Return air temperature resulting from cargo temperature and hence governing the cooling demand to reach the carriage temperature
- Ambient temperature
- Sun radiation resulting in reefer body surface temperature higher than ambient temperature

- Reefer size, the consumption of a 40' container is about double that of a 20' container
- Reefer technology
- Reefer status including airtightness of doors and ventilation openings and clean ventilator systems.

Potential measures to reduce energy consumption

- Reefer technology, which however can only be improved by the owners of the reefers, i.e. shipping lines and leasing companies. Technical measures include
  - o Improved insulation, however insulation material must be certified for global use
  - o Compressor systems with adaptive control
  - o Air fan systems with adaptive control
- Sun protection roofs, preferably combined with photovoltaic panels, to avoid direct sun radiation
- Minimizing unplugged periods during transshipment to avoid bigger differences between setpoint temperature and return air temperature
- Not accepting "hot cargo", i.e. reefers not sufficiently pre-cooled and with cargo not yet cooled down to carriage temperature
- Opportunity to exploit regenerative energy once available
- Regenerative energies are often volatile and not available once operation would need it. For deep frozen reefers the time gap between availability and demand can become bridged by "advanced cooling" i.e. lowering the setpoint temperature by a few degrees during periods of availability and switch it back to normal once regenerative energy supply ceases. This results in no energy demand for the compressor for a longer period. The air fans will of course need to operate. This procedure requires a suitable reefer monitoring system (RMS) with the opportunity to apply computer-supported control of setpoint temperatures according to availability of regenerative energies. The ideal solution is to integrate the RMS into a terminal smart grid solution providing optimized management of all electrical energy demand and supply on site.

#### Yard Lightning

- More energy efficient lights should be used in terminals. Switching to LED lighting can make significant progresses. LED's can generate the same amount of light as conventional lights but use far less energy. A real case calculation for the inland navigation terminal Riesa conventional lighting by High Pressure Sodium (HPS) floodlight resulted in a necessary power input of 24.600 W. The LED alternative calculated for a minimum light intensity of 20 lumen at a maximum height of light posts of 37m resulted in energy savings of 57% .
- Improvements can also be made on organizational levels. Nowadays most terminals are fully illuminated which cost a lot of energy. It is recommended to make differentiations in the lighting of different areas, for instance only full illumination for areas with work activities or sensor based lighting. This recommendation may interfere with security requirements but there can be tailor made solutions like combining visible lighting with infrared lighting for monitoring.

#### Energy Supply

Regenerative energy is available in nearly all European states. What is important is that to negotiate with the power suppliers for contracts with increased amount of regenerative power which will decrease directly the emissions of the terminals. Bundling of different consumers to create a common big consumer and building up a local distribution network are the key factors to consider when it is about external supply of regenerative energy. Furthermore, there are several regenerative energies that can be produced onsite and then used in terminals and ports. Different types of regenerative energies are detailed according to technical feasibility, maturity and efficiency.

Exploitation of LNG increased significantly throughout the last decades, is highly supported by the European policy and expected to become a significant market share. Apart from being an alternative fuel for ships LNG can also be used as energy source for electric engines, running turbines, since the potential for electrification of port and terminal processes is considerably high with consideration to Methane that produces considerably lower emissions than other fossil fuels but has a global warming potential about 23 times more than of carbon dioxide. Therefore, a 100% combustion is essential which usually is only possible in gas turbines and not in piston motors.

A vision for an integrated solution of shore based power supply for berthed ships is presented: In a fully electric terminal with regenerative power generation on the terminals wherever possible and a combined cycle power plant onshore fed by LNG/Methane. The surplus of regenerative power, which cannot be utilized, will be transformed to Hydrogen and on to Methane, which can be stored and used for feeding the gas turbine when regenerative production is too weak. Therefore, the question for future is not whether LNG technique or electrical onshore power but an integrated LNG technique and electrical onshore power supply.

The research and findings on energy supply has contributed to the development of comprehensive and intelligent energy demand and supply management at terminals and in ports which shows opportunities of terminals and ports as power supply providers to other (port) industries and to ships berthed.

#### Simulation

The increasing need for information regarding terminals carbon footprint calculations as well as the lack of information on correlation between key performance indicators (KPI) and parameters / decision are the key drivers in this field of research. So far, various approaches have been applied for simulating container terminals. Those have been used to validate decisions during late stages of planning processes. The high complexity and the high computational effort of micro-simulations, in combination with the required number of simulation runs to statistically validate such analyses, prevented extensive large scale studies. Additionally, the diversity of cargo RoRo / Ferry as well as Inland Waterway terminals are facing, has to be considered in the simulation model as well.

Creating a mathematical model for complete terminal environments can be regarded as a highly complex process. In practice, such projects are usually implemented to validate strategic decisions. In order to gain applicable results those models are tailored to the specific terminal requiring a tremendous amount of data.

To facilitate the process of determining a terminals carbon footprint as well as developing measures to reduce the terminals emissions, simulation models were developed in GREEN EFFORTS.

For Simulation, the Software Enterprise Dynamics Developer was used. The reason is that ED is widely used in the industry and developing models in ED is more economic. Three micro-simulation models of port terminals were developed to answer different questions which are relevant for the industry: First, for the RoRo Port of Trelleborg, the amount of carbon dioxide emissions produced by external vehicles in ferry port was determined. Second, the best dispatching strategy for horizontal transport and respective vehicle configuration was identified weighing financial, operational and environmental criteria against each other for a non-existing example RTG Container terminal. In this case, significant saving or wasting potential was identified. Third, for an inland container terminal with restricted pre gate area the amount of container trucks that can be handled per hour was determined. For the existing ports, recommendations are provided for future port development decisions. To enhance validity, several trace analyses were conducted during the modelling processes to lower the probability of errors. Visualisation helped to track the behaviour of the simulation model during experiments.

It could be shown that with various measures energy consumption and resulting emissions can be reduced in port terminals. A very good way would be to include modules for measuring and managing energy consumption in the used Terminal Operating System (TOS).

No container terminal could operate without the support of a TOS and the systems currently in use are rather mature and offer various functionalities. However, there is still room for improvement to enhance energy efficiency and hence reduce costs and emissions.

The GREEN EFFORTS catalogue for improvement comprises the following items

- Interoperability (not integration!) with container handling equipment (CHE) tracking system to minimize traveling distances of vehicles and adjust speed of operation (“operation speed kills fuel economy”) according to actual needs
- Interoperability with berth planning system to stack containers to minimize re-stacking and movement distances over the whole box stay on the yard, continuously adjusting to changes of estimated time of arrival (ETA) of vessels
- Forecast of cost of resources (container handling equipment , staff, time)
- Real-time availability of information required for decision-making and disturbance-management
- Performance analysis to learn from conducted operation to improve yard and equipment strategy (reverse engineering).

Optimization of yard operation of course depends on working rules. When e.g. there is a “gang” system per crane in place, it is not possible to send a straddle carrier or tractor where it is required most. The enhancement of TOS and the extension of interoperability with related systems usually require early involvement of job stewards and union representatives.

## Energy Management

The potentials of energy management in harbour terminals have been discussed as a standalone issue viewed from a power system perspective, focusing primarily on the status quo and imminent electrical consumption needs of most harbour terminals in Europe. This approach has exhibited conspicuous advantages in terms of exploring detailed aspects of the (electrical) energy management topic such as reactive power compensation, load shedding, and the deployment of smart grid technologies etc. However, a major opportunity of inter-disciplinary integration of electrical energy management and port logistic management systems has been largely overlooked so far.

As the operators of modern harbours are mostly already working with a port management system that monitors and remotely controls the operations of cranes, trucks, and even berthing and departing actions of ships, the least-cost way of implementing a localized energy management system would be naturally to build the energy management functions on the basis of existing ICT architectures from the port management system. In addition to this sharing of information and communication platform, the merging of both systems can also facilitate fast transfer of measurement data and control commands between logistic and electrical sub-systems, thereby creating new prospects for optimal management of both landside and maritime processes and tasks.

Firstly, when viewed from the landside perspective, a local energy management system can potentially optimize the battery swap and charging operation patterns of a fully-automated container transportation system, in which battery-driven automated guided vehicles (AGV) completely replace the role of traditional trucks or short-distance trains for transferring containers between quay-side operational area and the terminal stacking yard. In this case, the charging process of swapped-out AGV

batteries can be potentially controlled to compensate for sudden load peaks from (power) grid-connected STS (ship-to-shore) and RTG (rubber tyred gantry) cranes, thereby fulfilling the role of an energy storage device without dedicated investment. Of course, successful implementation of this operation mode relies heavily on the timely transfer of logistic information to the energy management system, as well as a solid understanding of the operation routines of both cranes and container vehicles.

On the other hand, the sharing of logistic and electrical information can also lead to significant performance enhancements for maritime operations. For example, as STS and RTG cranes contribute to a significant proportion of instantaneous terminal load, a most economical way of minimizing this type of load spikes is to 'interleave' the operation patterns of multiple cranes, such that the next crane always starts hoisting operation as soon as the previous one begins to lower down its container unit, thereby creating a partial cancel-off effect while ensuring that no more than two cranes with opposite vertical movement directions are in operation at any time. In addition, the integration of type and size information from berthed ships into energy management system will serve as the main (electric) load estimation criteria when a shore-to-ship power connection is established to replace onboard diesel power generation units.

Finally, it should be noted that the quantitative modelling and analysis performed have been considerably simplified due to limited availability of measurement data in terms of source diversification, time resolution, and content coverage. This means more comprehensive studies could be performed in future when, for example, measurement data from a large assortment of different types of harbour terminals are made available, such that the 'typical' harbour load composition can be extended to a large number of representative cases corresponding to salient regional and geographical features. Similarly, the energy balancing study can also be extended from the current long-term scope (15-min resolution) to short-term scope (smaller than 1-s resolution) for supercap design, if load data in corresponding time frame can be obtained beforehand. Finally, the outcomes could also be collectively exemplified in one application case if a representative harbour distribution network can be built on the basis of realistic data, thereby illustrating the impacts of reactive power compensation, load shedding, and smart grid technology deployment by a series of load flow calculations. Last but not least, all these possibilities could serve as very good starting points for future research work towards developing and realizing green smart terminals & ports.

#### Context to Transport Chain

Whilst the main focus of GREEN EFFORTS is the energy efficiency of ports and terminals, transport sector has also been investigated to enable comparison of energy management. A comparison between ports and airport has shown that there are many similarities in activities undertaken as well as some differences in the consumption areas. Although every transportation mode has its specific characteristics which can lead to very specific technical solutions for each mode, some of the energy efficiency and emission saving measures are common in most modes of transportation. Prominent examples are hydrogen-powered vehicles and e-mobility, recuperation techniques, the use of electricity from renewable energy sources like wind energy and photovoltaic or the introduction of environmental zones where stricter emission regulations apply. It can be said that a broad implementation of these measures will help to effectively reduce transport-related emissions at reasonable costs

#### Standardization and Calculation of emissions

GREEN EFFORTS developed a methodology for sea and inland navigation terminals characterised by a top-down approach from total terminal emissions to product level, hence using only real data, no default data, and by integrating the management of energy-efficiency and mitigation of emissions. An example for a container terminal elucidates the approach.

Within the GREEN EFFORTS project the following requirements were formulated to develop a methodology for a standard:

- Standardization power: technical and management standards are formal documents that establish engineering or operational criteria, methods, processes and practices developed through an accredited consensus process by standardization bodies. Even if legally not binding, standards provide generally accepted references and thus allow applying uniform criteria.
- Reuse of approved standards and guidelines to support familiarization.
- Comprehensiveness: all business activities required providing the transport service, including those not directly related to the physical transport operations but being an essential part to realize required operations, must be taken into account.
- Transparency: essential to allow benchmarking upon equal assumptions.
- Consistency: distribution of the total carbon footprint to individual operations and finally shipments must follow an inherent logical principle.
- Generalization to base on average values rather than individual and often coincidental operational results. Same type of shipment transported by the same carrier under same conditions in the same transport relation must result in the same carbon footprint.
- Stringency: unambiguity of rules, recommendations and algorithms.
- Concise: following the "KISS-principle" i.e. to keep it short and simple.
- Predetermination: the carbon footprint of a product such as e.g. a shipment must already be part of the transport service offer, i.e. prior to the real process, to play a role as decision-making factor to allocate a contract.
- SME-suitability: also small and medium enterprises must be able to manage the calculation and the reporting by their organisation without extensive extra administrative effort.

- Compatible to enterprise management systems to allow for a common comprehensive approach.

An important deliverable of the GREEN EFFORTS project, D 12.2: Recommendation for Standardization gives detailed information of calculation and methodology (attached).

Consolidated report, Deliverable 12.1: Recommendations Manual for Terminals provided detailed information on results and potential impact (attached).

#### Potential Impact:

Pressure on the terminals and ports for more environmental friendly operations does not only come from the often nearby housing areas or the local, national or European policy makers. Most pressure comes from within the logistics industry, where shippers and other actors of the intermodal transport chain require distinct information about the carbon footprint of operation. The European logistics industry is becoming a pioneer for a greening industry, leading the way for a sustainable way to carry out business. Terminals and ports will have to be integrated in that trend. However, you cannot improve anything that you cannot measure. It is therefore necessary to establish a clear and transparent scheme how to measure the emissions and energy consumption in ports and terminal. To find out which operations may be optimised to have a substantial effect which has been carried out successfully by the GREEN EFFORTS.

It could be shown that with various measures energy consumption and resulting emissions can be reduced in port terminals. A very good way would be to include modules for measuring and managing energy consumption in the used Terminal Operating System (TOS).

No container terminal could operate without the support of a TOS and the systems currently in use are rather mature and offer various functionalities. However, there is still room for improvement to enhance energy efficiency and hence reduce costs and emissions.

Optimization of yard operation depends on working rules. When e.g. there is a “gang” system per crane in place, it is not possible to send a straddle carrier or tractor where it is required most. The enhancement of TOS and the extension of interoperability with related systems usually require early involvement of job stewards and union representatives.

The first steps in establishing a CO<sub>2</sub>-eq inventory and allocation scheme to product level are cumbersome and challenging because a structured energy measuring system must be developed and installed and the capturing system must be comprehensive. Details overlooked in the base year prevent from qualified comparisons in the follow-up years. Capturing the total energy consumption of a terminal and derived emissions should not be too difficult, however, for allocation on product level the devil lies in the details. Usually a terminal is more complex than it appears in the research papers and there can be subcontractors making it difficult to decide about operations and processes to be calculated or excluded.

Many detailed data will not be available at the beginning, either because there is no measure device or because lack of process tracking, therefore the GREEN EFFORTS recommends to apply a top-down approach allowing for future increase of accuracy by maintaining the overall approach and methodology.

Although the scope of GREEN EFFORTS is restricted to container terminals, for other types of terminal the energy management will be similar, only the allocation methodology must differ as the “product” differs. Instead of allocating CO<sub>2</sub>-eq to containers, it must be distributed to tons of dry cargo or barrels of oil. Only multi-purpose terminals are more challenging because there all kind of cargo is being handled. According to the nature of cargo and energy demand for handling a reference system combining weight and volume might be required.

Results that will or have the potential to be exploited are given in below table providing an overview on the results, their owner and beneficiaries.

Table 1 List of GREEN EFFORTS specific results (attached)

Table 2 List of white papers produced during the course of the project (attached).

#### List of Websites:

[www.green-efforts.eu](http://www.green-efforts.eu)

## Related information

### Documents and Publications

- [final1--green-efforts-d12-1-final.pdf](#)

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## Subjects

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[Transport](#)

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