SUSTAINABLE PORT INFRASTRUCTURE, PRACTICAL IMPLEMENTATION OF THE GREEN PORT CONCEPT

by

Bostjan PAVLIC[a*], Franka CEPAK[a], Boris SUCIC[b], Marko PECKAJ[b], and Bogomil KANDUS[c]

[a] Port of Koper, Koper, Slovenia
[b] Jozef Stefan Institute, Ljubljana, Slovenia
[c] ENEKOM, d. o. o., Energy Advisory Institute, Skofja Loka, Slovenia

Original scientific paper
DOI: 10.2289/TSCI1403935P

The overall idea and research interest related with the development of sustainable port infrastructure evolved around the core requirements of continuous reduction of negative environmental impacts without jeopardising economic growth. The growth of trade activities and need for competitiveness on the global market are forcing ports around the world to systematically and continuously evaluate all possibilities for the optimisation and related costs reduction. On the implementation level, the greatest challenge is how to empower workers, who operate machines and work on the shop floor, to achieve enduring performance improvements. Presented research work provides a methodological approach for finding realistic solutions to the problem of the future development challenges of seaports. The case study shown in this research represents a practical application of the green port concept with the emphasis on the overall energy efficiency improvement based on testing, deployment and demonstration of energy efficient solutions. Additional emphasis was placed on the state-of-the-art technologies and developing pilot initiatives based on modern energy solutions designed to improve efficiency in fuel consumption and emissions reduction in rubber tired gantry cranes.

Key words: *green port concept, sustainable port infrastructure, energy efficiency, monitoring and targeting, performance indicators, Port of Koper*

Introduction

The European Union (EU) has ambitious goals for reducing energy consumption and greenhouse gas emissions. Within the Strategy for competitive, sustainable and secure energy [1], the European Commission (EC) defined the energy priorities for the next ten years and set the actions to be taken in order to tackle the challenges of saving energy, achieving a market with competitive prices and secure supplies, boosting technological leadership, and effectively negotiate with EU's international partners. Also, at the beginning of 2013 EC announced an ambitious package of measures to ensure the build-up of alternative fuel stations across Europe with common standards for their design and use [2]. Having in mind that policy initiatives so far have been uncoordinated and insufficient, this package of measures has been the first step in direction of realistic EU clean fuel strategy.

* Corresponding author; e-mail: bostjan.pavlic@luka-kp.si

Comprehensive review of the EU energy and climate policy framework together with the instruments to tackle identified gaps can be found in [3, 4]. It is promising that EU has already demonstrated, how much can be done in reducing the energy intensity of manufacturing processes through energy efficiency and sustainable production processes. Twelve largest EU member states have achieved bigger reduction in the relative weight of energy inputs in their exports of manufactured goods than any of their external trade partners since 1995 [5]. Specific measures that have been shown to work well include efficiency targets and standards, benchmarking, energy audits, and energy management requirements, complemented by training, capacity-building, information provision and awareness raising campaigns. However, we have to be aware that further improvements are necessary, and that requires new approaches [6, 7]. Soft organisational potentials for efficiency improvements are often neglected in policies, both at the national and at the company level [7, 8]. Unfortunately, the majority of people tend not to see or feel the link between their actions (behaviour) and the companies' energy performance and impact on the environment [9]. In the current situation, especially having in mind the consequences of the economic and financial crisis, many companies are not willing to take the risk associated with energy efficiency projects.

Energy efficiency in ports is largely linked to investments in new equipment. Port activities are characterized by a number of movements of terminal cargo handling equipment including rubber tired gantry (RTG) cranes, reach stackers, yard tractors, wheel loaders and forklifts and this process is very energy (fuel) intensive. Proper analysis of the energy consumption brings additional information in ordinary business cycle from which stakeholders can obtain more reliable and accurate information about company's general performance and efficiency, not only regarding energy efficiency but also from the operational and cost perspectives [10]. Energy and environmental management systems enrich business processes with new knowledge about energy consumption and always lead to a better understanding of activities and processes, allowing stakeholders to better plan their strategies [11]. Vital element of the energy and environmental management systems is benchmarking or comparing efficiency of different processes or activities [10]. On the implementation level, the greatest challenge is how to empower workers, who operate machines and work on the shop floor, to achieve enduring performance improvements. Benefits of energy and power measurement in an industrial context can be found in [12].

The growth of trade activities and need for competitiveness on the global market are forcing ports around the world to systematically and continuously evaluate all possibilities for the optimisation and related costs reduction. The overall idea and research interest related to the development of sustainable port infrastructure evolved around the core requirements of continuous reduction of negative environmental impacts without jeopardising economic growth. The term "green port" evolved from the research activities related to the sustainability in the context of the maritime industry [13-18]. The green port is defined as a product of the long-term strategy for the sustainable and climate friendly development of port's infrastructure. The green port concept or sustainable and climate friendly development of the port's infrastructure in a broader sense means responsible behaviour of all working structures, from the port's management to each individual employee. According to [14, 15], climate change issues in combination with competitiveness of ports' operations represent a key element of future development challenges. According to [19], the future competitiveness of ports will depend on their capacity to integrate themselves into the transport routes and this capacity will in turn depend on the added value with which the port can provide the client. European port-city interfaces are considered as strategic sites for both ports and cities, but laws and regulations tend to obstruct sustainable port-city relations and projects [20]. Sustainable transformation of ports has to be based on their own strategy, developed through process of learning from own experiences and previously executed successful programmes and projects in a broader environment [21].

The research work described in this paper was inspired by the recommendations proposed by Amundsen [22] and Bunsea *et al.* [23], where the integration of energy management in environmental management system is recognised as efficient in catalysing improvement in energy conservation measures and in securing continuous improvement activities and enabling decision makers to become aware of the energy performance in real-time, facilitating more effective business decisions based on accurate and timely information. Our research interest evolved from the idea to enrich green port concept with the awareness about energy use and to better understand drivers of energy efficient behaviour in port operations. The research question that arises in this context is: "How to make green port concept alive in practice and achieve enduring energy performance improvements?" This research question is based on three hypotheses:

- H1: Current approaches to improve energy and environmental performance in port's operations and activities do not address the needs of port operators in a practical manner,
- H2: Standardization and synergies between energy and environmental management through the green port concept are important enablers for improving competitiveness of Mediterranean ports, and
- H3: To accelerate the process of change in Mediterranean ports, greater state support is needed, including strong and effective policies and regulation to promote development of the sustainable port infrastructure.

Described research work provides a methodological approach for finding realistic solutions for future development challenges of seaports based on testing, deployment and demonstration of energy efficient technologies. The case study presented in this research represents a practical application of the green port concept in the Port of Koper with emphasis on the overall energy efficiency improvement. Sustainable transformation has been enabled by the modern monitoring and targeting tool which was necessary for the performance monitoring and verification of savings. As the first concrete project in the process of sustainable transformation the greenification of the heating and hot water preparation system in the Port of Koper has been selected. Additional emphasis was placed on the state-of-the-art technologies and developing pilot initiatives based on modern energy solutions designed to provide efficiency in fuel consumption and emissions reduction in rubber tired gantry cranes.

Methodological approach for the practical implementation of the green port concept

Transition from environmentally unfriendly fossil fuelled port infrastructure to sustainable and climate-friendly development requires design and formation of policies and solutions, which must be based on excellent knowledge of other possibilities of development and especially awareness of new opportunities in exploitation of alternative fuels and renewable energy sources. Measures at the organisational and behavioural level especially in combination with environmental management are often neglected [18, 19]. According to sustainable principles, ports have to form their policies and establish an efficient system for monitoring energy and water consumption, including indicators of urban environment quality (air quality, water, energy, and water use). This highlights the fact that effective adaptation solutions are not just about physical layouts and engineering projects, but also about the need to fundamentally transform the current management and planning practices of ports [14]. The implementation of the green port concept in any organization implies the adoption of a new style of management, thus allowing the company to establish their objectives, commitments and responsibilities to the society and the environment, developing the port activity under well-defined environmental requirements which reduce the negative impacts of port activities [17]. Objective evaluations of new technologies and alternatives through various pilot schemes are very important for the success of the green port concept. The final goal is to identify the necessary decision-making criteria and recommendations for the port stakeholders and operators to take informed decisions. In the process of practical implementation of the green port concept, the first project to be implemented has a critical role and early achievement of certain visible results is a necessary precondition for the project selection and overall success. The selected project must be a logical step forward in improvement of the current energy and environmental practice and it is desired if it can be implemented without directly engaging company's financial resources. Also, implementation of the green port concept must be followed by implementation of energy and environmental management system with the aim to enable the port's management to closely follow accepted decisions, monitor performance and adapt implementation strategies. Activities and actors involved in the implementation of the green port concept are presented in tab. 1.

The first step in the implementation of the green port concept is the assessment of current operational procedures and evaluation of environmental management practice. The first action should be the self-assessment of the current energy and environmental management practices and procedures. Results of the self-assessment present valuable inputs for the definition of the scope of the following activity, energy, and environmental audit. The objective of the energy and environmental audit is to evaluate the current energy consumption patterns and environmental management practices with the aim to understand, how the efficiency can be improved. Energy and environmental audit is a periodic activity, which has to include the analysis of technical systems as well as evaluation of the role and impacts of the human factor in energy and environmental performance [10]. Vital output of the audit is the baseline for the performance monitoring. Also, based on recommendations from the audit, energy and environmental managers should prepare the energy and environmental policy and strategy. Top management is responsible for the adoption of the policy and strategy. A number of methods and tools have been designed in order to provide appropriate and accurate support for sustainable energy and environmental performance improvements in industry, but the first step in that process is an active support and commitment from the top management [24-26]. Another important step is the decentralisation of responsibilities, definition of the organisational structure necessary for the empowering of the employees on the shop floor to achieve enduring performance improvements. Integration of energy within the process flow charts is the basis for the decentralisation of responsibilities and decisions on setting up energy cost centres (ECC) [10]. Unfortunately, a comprehensive literature review did not provide any fixed rules on how to set up a model for ECC. An ECC can be any department, section or machine that uses a significant amount of energy or creates significant environmental impacts. However, the guiding principle for modelling setup is to follow the production process stages as given by the process flow chart for each industrial branch, and try to define the ECC in such a way that they coincide with the existing production quantity control boundaries [10]. Establishing a system of relevant and case specific key performance indicators (KPI) is important for monitoring the operational performance of any industrial or non-industrial activity [10, 26-28]. Properly defined KPI are necessary for monitoring progress toward a target(s) and interpreting causes of good or bad performance. According to [10], KPI for each ECC have to be expressed as the ratio of measured energy and resource amount or corresponding activity output over a defined period of time. It has to be emphasized that the information on KPI alone is not a solution of the problem, it simply serves as a tool for the management personnel to assess and improve performance efficiency. Integrated life cycle approach is included in the green port concept as a support to the strategic decision-making process and it is important to mention the Sustainable Environmental Performance Indicator which can be successfully applied to provide an overall indicator of the environmental performance of existing applications or can be used as a supporting tool in comparing competing options in a strategic decision-making process [29].

Table 1. Implementation of the green port concept, activities and actors involved

Activity	Actors involved
Self assessment of the energy and environmental management practice	Energy manager Environmental manager
Energy and environmental audit - evaluation of current operational practice and performance	Independent external expert organisation supported by energy and environmental managers
Setting a baseline for the performance monitoring	Energy manager Environmental manager
Definition of the environmental policy and strategy	Environmental manager
Definition of the energy policy and strategy	Energy manager
Adoption of the environmental policy and strategy Adoption of the energy policy and strategy	Top management
Definition of the energy and environmental action plan, set of selected projects to be implemented	Prepared by energy and environmental managers, confirmed by top management
Decentralisation (individualisation) of responsibilities, definition of organisational structure necessary for the empowering of the employees on the shop floor to achieve enduring performance improvements	Prepared by energy and environmental managers, confirmed by top management
Assigning management responsibilities on the shop floor level	Prepared by energy and environmental managers, confirmed by top management
Definition of initial targets for performance improvement on the shop floor level and on the company level – key performance indicators	Energy and environmental managers supported by the leaders on the shop floor
Motivation and training for all employees including top management	Energy manager Environmental manager Various external expert organisations
Monitoring energy and environmental performance	Energy and environmental managers supported by the leaders on the shop floor
Verification of performance improvements	Energy manager Environmental manager
Learning, continuity and communication	Energy and environmental managers supported by the leaders on the shop floor
Adaptation and redefinition of energy and environmental policy, performance targets and goals – continuous process	Energy and environmental managers supported by the leaders on the shop floor and various external expert organisations Support and confirmation by top management

Our approach evolved from the idea to enrich traditional management and control systems with the awareness about abnormal situations and to enable corrective actions to eliminate the cause of a potential abnormality in energy use. Sustainable performance improvements require continuous commitment and follow up of all performed activities and implemented measures. Verification of performance improvements is the necessary precondition in the process of learning, adaptation and redefinition of energy and environmental policy, performance targets and goals. Besides KPI, it is necessary to introduce the Energy Performance Index (EnPI) in order to enable proper management of port's activities and to provide support for corrective actions. EnPI is a ratio of actual ($E_{\rm ACT}$) to benchmark ($E_{\rm BEN}$) energy consumption for the given context of performed activity. Benchmark values are optimal values extracted from the history data for each defined context (operator, vehicle, time of the day and corresponding volume of activity). When the actual consumption is as benchmark, EnPI has a value of 1.0 which is an indication that the process is running smoothly. On the other hand, when the actual consumption is higher than benchmark, EnPI has a value higher than 1.0 which is an indication of a problem or a performance that can be improved. Information about performance is presented to the operator in a simple and straightforward way before and after each shift. Before each shift the operator is informed about his last performance and the company benchmark within the same context. Also, after each shift the operator is informed about his actual and his best performance. This new awareness about energy performance was added to the green port concept and was the necessary bridge between environmental and energy aspects of the green port concept.

Green port concept in practice – case study Port of Koper

There are 139 maritime and inland ports in the Trans-European transport (TEN-T) core network accounting for about 10% of all EU ports. Port of Koper is a TEN-T Category A Port [30] and part of the core TEN-T ports network. In the case of the Slovenian Port of Koper, future development of port's infrastructure is not only a vision, but a creative, local process of establishing a solid base for further development of the neighbouring City of Koper, a base which encompasses all fields from planning and decision making to execution of individual projects. Port of Koper is firmly anchored in its local and regional communities, and is a guarantee of social cohesion and stability. In terms of energy use and environmental impacts Port of Koper is among the most advanced ports in the Mediterranean. However, Port of Koper is special by its geographic position, universality and relative smallness, which on one side does not allow the same as to other, larger ports to achieve effects of economy of scale. At the same time and due to the same reason, Port of Koper is essentially more flexible regarding the selection of strategy for gaining support of employees and neighbouring communities for development projects, connected with the sustainable port infrastructure and climate friendly development. Also, Port of Koper provided a full support of management board for testing if the green port concept enriched with the awareness about energy use can provide additional energy savings in a challenging environment of advanced ports.

In the process of sustainable transformation, Port of Koper has already established its quality management system according to EN ISO 9001:2008 and environmental management system according to EN ISO 14001:2004. Environmental efforts were upgraded in 2010 with the implementation of EMAS certificate. In order to strengthen its environmental and energy efficiency activities, Port of Koper has decided to start with the implementation of the modern energy management system according to EN ISO 50001 standard. However, the first energy and environmental management self-assessment preformed according to the

Energy Management Guide CTG054 [31] clearly indicated significant potentials for further improvements, fig. 1.

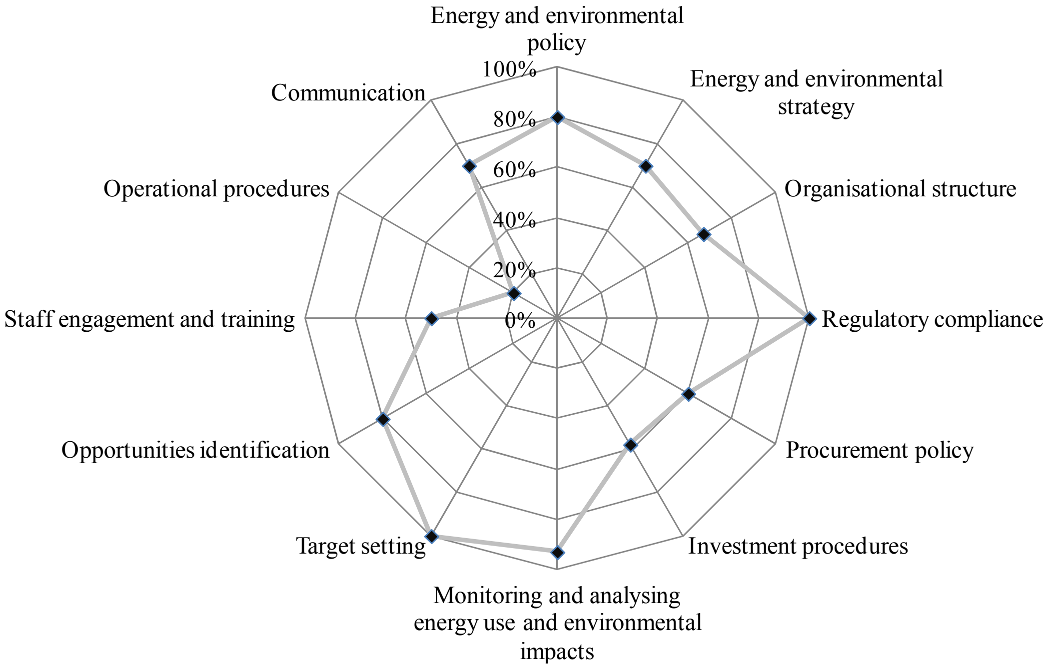


Figure 1. Port of Koper energy and environmental management self-assessment summary

One of the first activities of the energy manager was the design of the company's energy policy. Confirmed energy policy together with the previously adopted environmental policy has formed a solid base for the practical implementation of the green port concept. In its action plan, Port of Koper has taken the commitment to completely replace the extra light fuel oil for heating and hot water preparation with renewable energy sources, namely biomass and solar energy, during the next five years. Introduction of the modern energy and environmental management system has been recognised as a necessary precondition for the performance monitoring and has been included in the action plan. Also, Port of Koper has taken the commitment to actively support the introduction of the most modern and cleanest technologies that enable environmental protection at the highest achievable level. This commitment has clearly opened the door for pilot and demo projects and special emphasis has been placed on the state-of-the-art technologies and developing pilot initiatives based on efficient energy systems designed to provide efficiency in fuel consumption and emissions reduction. However, it was vitally important to start with project which can boost the confidence of management board and all employees.

Pilot activities, results and discussion

Port of Koper is at the same time port manager, investor in port infrastructure, and also terminal operator, so its actions have a direct impact on energy consumption and environmental performance. In 2011, the reference year for the green port concept implementation, Port of Koper energy consumption amounted to 68,508 MWh. Diesel fuel consumption, which amounted to 42,835 MWh or 63% represents the largest share of the port's total energy consumption. Electricity amounted to 23,389 MWh or 34% of total energy consumption. Consumption of extra light fuel oil amounted to 1,742 MWh and liquefied petrol gas to 541 MWh. Extra light fuel oil is used exclusively for the heating and hot water preparation. In its energy policy Port of Koper stated, that the improvement of the energy efficiency in all business segments is the company's strategic interest. Due to the fact that Port of Koper has a timber terminal, approximately 1,750 tonnes of wood waste is collected annually representing almost 6,000 MWh of energy, which significantly exceeds heating requirements.

Greenification of the heating and hot water preparation system

The greenification of the heating and hot water preparation system has been selected to be the first project to be executed in the process of implementation of the green port concept in the Port of Koper. The first step in the project preparation was the energy audit of exiting installations. Energy audit was conducted in a systematic and a comprehensive manner during the heating seasons 2011/12 and 2012/13. The aim of analysis was to identify opportunities for reducing cost of energy for heating and hot water preparation and introduction of renewable energy sources. During the energy audit of the heating and hot water preparation system detailed investigation of the heat and hot water demand, including detailed building simulation and heat and hot water consumption measurements, has been done. The main characteristics of the existing heating and hot water preparation system are given in tab. 2. Identified annual losses in the distribution network (pipelines) were 190 MWh.

Table 2. Main characteristics of the existing heating and hot water preparation system in the Port of Koper

Identification of the boiler house	Year of installation	Nominal capacity [kW]	Fuel consumption, heating season 2010/11 [MWh]	Hot water reservoir [m^3]
K3 – main boiler house	1984, 1999	Unit 1: 700 Unit 2: 720	1,197	Two units: 2.5 × 2.5
K17 – KT	1999	345	207	2
K7 – TL	1996	225	146	Two units: 3 × 3
K12 – INPO	2004	170	125	
K9 – TH	1997	66	74	0.3
K 19 – TP	1999	153	49	
K5	2001	63	34	
K13 – S	1995	38	26	0.3
K11 – TP	1998	63	24	
Total		2,543	1,882	13.6

During the energy audit, a comprehensive set of heat consumption and indoor temperature measurements has been done. Selected sample of measurements results is given in fig. 2.

After the evaluation of various options and discussions with the management it has been decided, that complete renovation of two largest boiler houses and fuel switch from extra light fuel oil to biomass was the only sustainable option for the Port of Koper. Project has been implemented through the energy performance contracting with local Energy Service Company. Summary of the described energy efficiency measure is given in tab. 3.

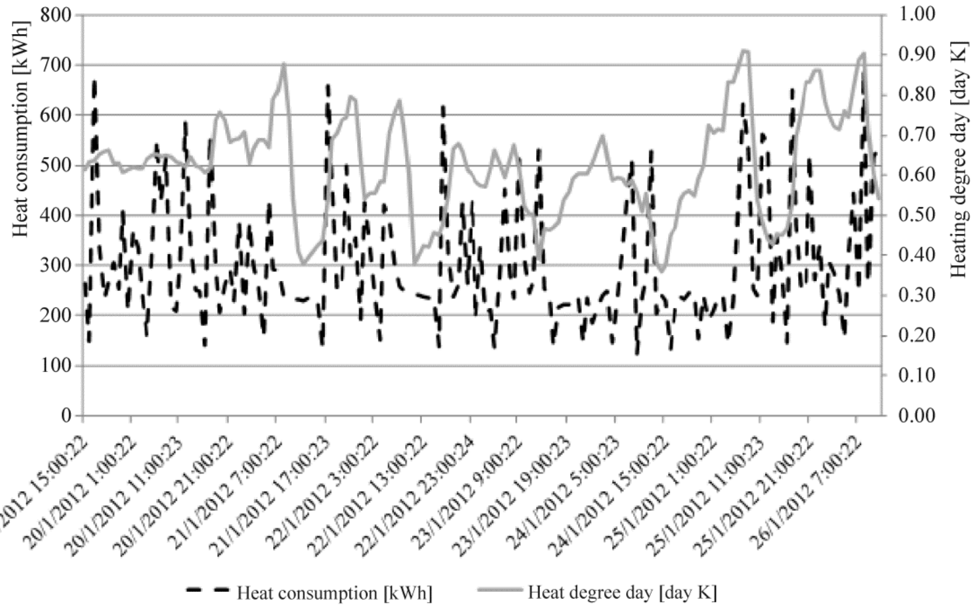


Figure 2. Selected heat consumption measurements results – boiler house K3

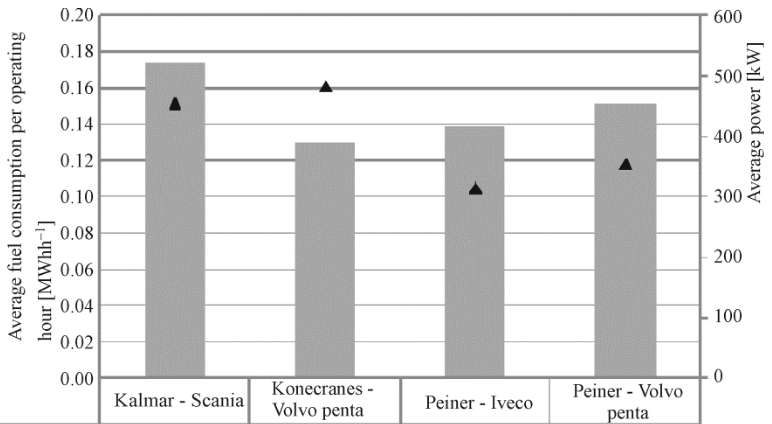
Table 3. Renovation of the Port of Koper boiler houses K3 and K17 – summary of the energy efficiency measure

Situation before refurbishment	Investment
– Three extra light fuel oil fired boilers installed with total installed capacity of 1,745 kW – Average annual consumption of 1383 MWh of extra light fuel oil – Average extra light fuel oil price per kWh 0.08 € (without VAT)	– Two biomass fired boilers installed with total capacity of 950 kW – Renovation of the boiler houses and construction of the biomass storage – SCADA system for remote control, visualisation and management of new units – Installation cost – Design, engineering and commissioning – Total investment costs: 385,000 €
Energy savings, cost and emission reduction – Primary energy savings: 202.5 MWh per year – Reduction in fossil fuel consumption: 1,383 MWh per year – CO_2 emission reduction (biomass is CO_2 neutral fuel): 369 t CO_2 per year – Cost reduction: 98,000 € per year – Payback period (static): 3.9 years – Net present value: 363,200 € (economic lifetime 15 years and discount rate 10%) – Internal Rate of Return: 25%	

Renovation of the heating and hot water preparation system was the first step in the greenification of the Port of Koper and boosted the confidence of all employees, that significant energy savings can be reached. In line with the accepted energy policy goals, by 2017 other boiler houses will be renovated on the same principle and solar collectors for the hot water preparation will be installed.

Prototype of an energy and environmental management system at the Port of Koper Container Terminal

At the Container Terminal together with the terminal operation system Tideworks, modern system for energy consumption monitoring and targeting called CSRE is in use. Combination of Tideworks and CSRE forms a solid ground for evaluation of port's operations and verification of all future energy savings measures. Improving the knowledge about the energy consumption at the Container Terminal was the necessary precondition for better understanding of actual processes of load/unload and horizontal transport. Implementation of energy and environmental management system clearly upgraded existing management procedures and enabled setting of hierarchical energy performance indicators system (10 main KPI, based on more than 50 supporting indicators). Also, new system allows proper comparison of energy performance indicators according to set target lines. Introduction of responsibility system on the ECC level (RTG level) has encouraged many additional activities and energy efficiency improvements on the shop floor level. RTG cranes are the main consumers of diesel fuel and the major contributors of diesel induced emissions in the Port of Koper. Also, RTG cranes in the Port of Koper employ conventional power trains consisting of a diesel engine coupled with an alternator that provides electricity for a set of hoist, trolley, and gantry motors. The diesel engine prime mover allows an RTG crane to be unencumbered by a utility main connection as it moves through the terminal. Figure 3 presents the relationship between fuel consumption and working hours of different RTG crane groups in the Port of Koper. The lowest specific consumption has Konecranes – Volvo group, and the highest specific consumption has Kalmar – Scania group.



	Kalmar - Scania	Konecranes - Volvo penta	Peiner - Iveco	Peiner - Volvo penta
2011	0.17	0.13	0.14	0.15
▲ Average power [kW]	455	484	315	354

Figure 3. Specific fuel consumption per type of RTG crane used in the Port of Koper in 2011 and 2012

Initial results of the energy and environmental management system implementation at the Container terminal are given in fig. 4. For the verification of performance improvements CUSUM (cumulative sum control chart) technique has been selected. This technique is typically used for change detection and is appropriate for evaluation of energy efficiency measures impact.

Detailed analysis of energy consumption for all main port activities and operational conditions clearly confirmed effects of change and verified energy savings. Analytical reasoning supported with the additional energy consumption meters have become permanent tasks of the energy and environmental team at the Container Terminal. Process of change was triggered with individualisation of responsibilities and proper motivation and training in December 2012. Results presented in fig. 4 clearly confirmed that the individualisation of responsibilities positively influence the energy performance and is necessary for the continuous improvements. Achieved energy and cost reduction boosted the confidence of participating employees and has been identified by others as key promoter and supporter of change. Summary of the achievements by implementation of this measure is given in tab. 4. Investment for the realisation of this measure included installation of additional meters, GPS and communication devices on selected machines, programming of one single unified application programming interface (API) able to receive data formatted according to a pre-defined common data model and commissioning of new system.

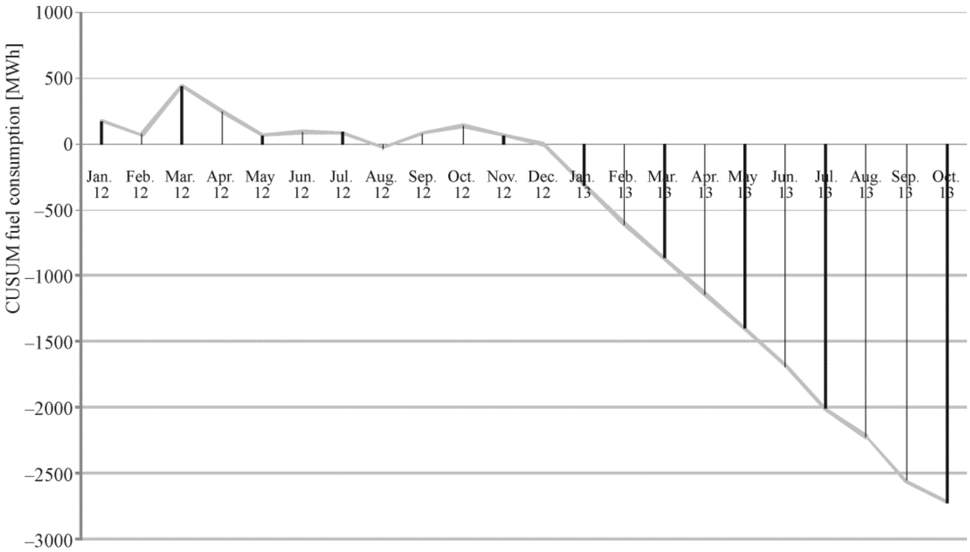


Figure 4. Evaluation and verification of fuel savings using CUSUM graph – baseline 2011

For the presented pilot activity, the benchmark values are vehicle and operator specific. Furthermore, performance indicator for each RTG crane is expressed as the ratio of consumed diesel fuel and number of movements per container block over defined period of time, one shift. RTG crane operators highly appreciated the information about their and the best operator past performance within the same context. Also, information about past performance initiated positive competitiveness between different RTG crane operators. Combination of energy awareness and support for corrective actions makes the green port concept alive and enables continuous improvement of energy and environmental performance.

Table 4. Prototype of an energy and environmental management system at the Port of Koper Container Terminal – summary of achievements

Reduction in fossil fuel consumption	2,850 MWh per year
CO_2 emission reduction	760 t CO_2 per year
Cost reduction	296,000 € per year
Payback period (static)	0.6 years
Net present value (economic lifetime 5 years and discount rate 10%)	945,100 €
Internal Rate of Return	166%

Electrification of RTG

One of the biggest potential for cost and emissions reduction in ports is the use of electricity instead of diesel in RTG cranes. Diesel fuelled RTG cranes can be found in almost all ports in the world and consume a large amount of fuel. A classic diesel generator set (genset) generates the necessary electricity for the hoist, trolley, and gantry motors, as well as for the routine demands of the crane. One of the advantages of utilizing this type of power system on a RTG cranes is, that it allows the crane to move freely through the container terminal as is required by daily port operation. The genset is sized to fulfil the requirements of the hoist motor, because the hoist requires the highest amount of electricity (both peak and idle state). Although the hoisting period lasts only a few seconds, the genset must be able to support the peak power needs. The resulting effect is excessive fuel consumption during peak power and also in idle mode. However, when a container is lowered, the regenerated energy created by controlling the hoist motor is directed to resistor banks and dissipated as heat. Compared with the electricity fuelled RTG cranes, the biggest disadvantages of diesel fuelled systems are fuel inefficiency, high fuel costs and high emissions of pollutants. An electrification project can be divided into three phases: reinforcement of the distribution network, installation of cable reel or conductor bar and machine retrofitting. Based on the prefeasibility analysis, in the case of Port of Koper electrification of RTG cranes offers a significant performance improvement compared with classical diesel fuelled RTG, and around 82% energy savings can be achieved. Simple payback period of the investment in the conversion of the diesel fuelled RTG crane into electrical (machine retrofitting) is around 2.5 year. Also, switch from diesel fuelled RTG cranes to electricity have a potential to reduce the operating noise level up to 50%. Electrification of RTG cranes will provide global CO_2 and not just on-site emission reductions if the annual and country specific electricity induced CO_2 emission factor is lower than 1.5 t of CO_2 per MWh which is the case for all European countries. In practice, in order to maximise the reduction effect it is desired that the electricity for electrified RTG cranes comes from renewable or at least low carbon energy sources. However, in the case of existing ports' installations similar to Port of Koper, electrified RTG cranes require significant modification of the existing electricity grid, which is a very expensive and relatively long lasting process. According to [32], it is necessary that governments formulate appropriate regulations or provide incentive measures in order to encourage terminal operators to upgrade their handling equipment or implement RTG electrification projects. With the proper governmental support electrification of RTG cranes should have the priority in the future greenification activities not just in the Port of Koper but also in many other European ports.

Conclusions

This paper presents a methodological approach for the implementation of the green port concept, which goes beyond investment in particular technologies. It is obvious, that the implementation of the green concept is a continuous process that should create conditions for the sustainable transformation of port's operation. The presented research work confirms that one of the basic preconditions for the successful greenification and overall energy efficiency improvement is knowledge about energy consumption and environmental impacts. Proper selection of the first projects to be implemented proved to be vitally important to make green port concept alive since the early achievement of visible results is necessary to boost the confidence of employees and management. Availability of appropriate data and knowledge which indicates where is the investment profitability threshold is a crucial factor. Due to the complexity of port operations the involvement of multi-disciplinary teams like environmental managers, energy managers, operators and maintenance staff is required. On the implementation level it is confirmed, that the implementation of the green port concept, supported by intelligent energy and environmental management system, allows a clear definition of responsibilities and empowers workers, who operate machines and work on the shop floor, to achieve enduring performance improvements. Information about past performance initiated positive competitiveness between different RTG crane operators. Efficient and effective energy and environmental management system in ports helps decision makers to become aware of the energy and environmental performance and closes the gap between theory and practice. However, having in mind the recommendations from [11], additional research work has to be done to find out, whether the described approaches can be upgraded to provide even higher savings.

Acknowledgments

The authors would like to thank the European Commission, Trans-European Transport Network Executive Agency and the partners of the European TEN-T project "Green Technologies and Eco-Efficient Alternatives for Cranes and Operation at Port Container Terminals" (www.greencranes.eu) for their support.

References

[1] ***, Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions – Addressing the Challenge of Energy Efficiency through Information and Communication Technologies, European Commission, Brussels, Belgium, 2008
[2] ***, European Commission – MEMO/13/24, Clean Power for Transport – Frequently Asked Questions, Brussels, Belgium, 2013
[3] Kanellakis, M., *et al.,* European Energy Policy – A Review, *Energy Policy, 62* (2013), C, pp. 1020-1030
[4] Helm, D., The European Framework for Energy and Climate Policies, *Energy Policy, 64* (2014), Jan, pp. 29-35
[5] ***, European Commission, European Competitiveness Report 2012: Reaping the Benefits of Globalisation, Luxembourg, 2012
[6] Thollander, P., Ottosson, M., Energy Management Practices in Swedish Energy-Intensive Industries, *Journal of Cleaner Production, 18 (*2010), 12, pp. 1125-1133
[7] Trianni, A., *et al*., Barriers to Industrial Energy Efficiency in Foundries: a European Comparison, *Journal of Cleaner Production, 40* (2013), Feb., pp. 161-176
[8] Gvozdenac, D. D., Simić, T. S., About the Serbian Energy Efficiency Problems, *Thermal Science, 16* (2012), 1, pp. 1-15
[9] Gvozdenac-Urošević, B., Energy Efficiency and Gross Domestic Product, *Thermal Science, 14* (2010), 3, pp. 799-808

[10] Morvay, Z. K., Gvozdenac, D. D., *Applied Industrial Energy and Environmental Management*, John Wiley and Sons – IEEE press, London, 2008
[11] Bergantino, A. S., *et al*., Port Management Performance and Contextual Variables: Which Relationship? Methodological and Empirical Issues, *Research in Transportation Business & Management, 8* (2013), Oct., pp. 39-49
[12] O'Driscoll, E., O'Donnell, G. E., Industrial Power and Energy Metering – a State-of-the-Art Review. *Journal of Cleaner Production, 41* (2013), Feb., pp. 53-64
[13] ***, Green Port Guidelines – Sustainable Strategies for Port Developments and Operations, Sydney Ports Corporation, http://www.sydneyports.com.au/_data/assets/pdf_file/0012/1254/gpg_guidelines.pdf
[14] Adolf, K. Y., *et al*., Climate Change and the Adaptation Strategies of Ports: The Australian Experiences, *Research in Transportation Business & Management, 8* (2013), Oct., pp. 186-194
[15] Li, J., *et al*., An Exploratory Study on Low-Carbon Ports Development Strategy in China, *The Asian Journal of Shipping and Logistics, 27* (2011), 1, pp. 91-111
[16] Esmemr, S., *et al*., O., A Simulation for Optimum Terminal Truck Number in a Turkish Port Based on Lean and Green Concept, *The Asian Journal of Shipping and Logistics, 26* (2010), 2, pp. 277-296
[17] Lam, J. S. L., van de Voorde, E., Green Port Strategy for Sustainable Growth and Development, *Proceedings,* Transport Logistics for Sustainable Growth at a New Level, International Forum on Shipping, Ports and Airports (IFSPA) 2012, Hong Kong, 2012, pp. 27-30
[18] Chang, C-C., Wang, C-M., Evaluating the Effects of Green Port Policy: Case study of Kaohsiung Harbor in Taiwan, Transportation Research Part D, *Transport and Environment, 17* (2012), 3, pp. 185-189
[19] Perez-Labajos, C., Blanco B., Competitive Policies for Commercial Sea Ports in the EU, *Marine Policy, 28* (2004), 6, pp. 553-556
[20] Daamen, T. A., Vries, I., Governing the European Port-City Interface: Institutional Impacts on Spatial Projects Between City and Port, *Journal of Transport Geography, 27* (2013), Feb., pp. 4-13
[21] Gibbs, D., *et al*., The Role of Sea Ports in End-to-End Maritime Transport Chain Emissions, *Energy Policy, 64* (2014), Jan., pp. 337-348
[22] Amundsen, A., Joint Management of Energy and Environment, *Journal of Cleaner Production, 8* (2000), 6, pp. 483-494
[23] Bunsea, K., Vodicka, *et al*., Integrating Energy Efficiency Performance in Production Management – Gap Analysis between Industrial Needs and Scientific Literature, *Journal of Cleaner Production, 19* (2011), 6-7, pp. 667-679
[24] Karapetrovic, S., Casadesus, M., Implementing Environmental with other Standardized Management Systems: Scope, Sequence, Time and Integration, *Journal of Cleaner Production, 17* (2009), 5, pp. 533-540
[25] Kastner, I., Matthies, E., Implementing web-Based Interventions to Promote Energy Efficient Behavior at Organizations – a Multi-Level Challenge, *Journal of Cleaner Production, 62* (2014), Jan., pp. 89-97
[26] Gordić, D., *et al*., Development of Energy Management System – Case Study of Serbian Car Manufacturer, *Energy Conversion and Management, 51* (2010), 12, pp. 2783-2790
[27] Herva, M., *et al*., Review of Corporate Environmental Indicators, *Journal of Cleaner Production, 19* (2011), 15, pp. 1687-1699
[28] Saygin, D., *et al*., Benchmarking the Energy Use of Energy-Intensive Industries in Industrialized and in Developing Countries, *Energy, 36* (2011), 11, pp. 6661-6673
[29] De Benedetto, L., Klemes, J., The Environmental Performance Strategy Map: an Integrated LCA Approach to Support the Strategic Decision-Making Process, *Journal of Cleaner Production, 17* (2009), 10, pp. 900-906
[30] ***, Decision No. 1692/96/EC of the European Parliament and of the Council of 23 July 1996 on Community Guidelines for the Development of the Trans-European Transport Network, 1996
[31] ***, Energy Management – A Comprehensive Guide to Controlling Energy Use (CTG054), The Carbon Trust, UK, 2011
[32] Yang, Y. C., Chang, W. B., Impacts of Electric Rubber-Tired Gantries on Green Port Performance, *Research in Transportation Business & Management, 8* (2013), Oct., pp. 67-76

Paper submitted: March 3, 2014
Paper revised: June 6, 2014
Paper accepted: June 6, 2014