DEVELOPING A PORT ENERGY MANAGEMENT PLAN: ISSUES, CHALLENGES AND PROSPECTS

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ABSTRACT

Raising the environmental profile of European ports and promoting excellence in port environmental management and performance is one of the European Ports Policy’s key priorities. The need for well-connected port infrastructure, efficient and reliable port services and transparent port funding is profound. Reducing the energy consumption in ports has also evolved, over the last few years, as a major concern of all relevant stakeholders, ranking 3rd among the top ten environmental priorities of the European ports sector for 2013. This has led 57% of the European ports to develop energy efficiency programmes and 20% of them to adopt measures for directly producing energy from renewable sources. This paper presents a structured approach for developing a port energy management plan highlighting the main issues, challenges and prospects that should be taken into account. More specifically, the role of ports in the changing energy policy framework is discussed and the value of a port energy management plan, either at a port authority or at a terminal operator level, is highlighted. Pertinent issues for developing such a plan are being described and analyzed. Valuable insights gained from the implementation of the aforementioned approach in six Mediterranean ports within the context of the GREENBERTH project are being reported, fostering the development of targeted recommendations and conclusions on how this diverse experience can contribute towards developing a robust port energy management plan.

Keywords: Ports, Energy, Energy Management Plan, Renewable sources, Clean power technologies, European port policy
INTRODUCTION

In May 2014, the European Commission (EC) released its Energy Security Strategy in which it developed a set of short- and long-term measures in order to ensure a stable and abundant supply of energy for European citizens and the economy. In October 2014, the European Council endorsed the 27% renewable energy and 30% energy efficiency improvement targets. Currently, the EU is importing more than half (53%) of all the energy it consumes. More specifically, it imports 90% of its crude oil, 66% of its natural gas and to a less extent solid (42%) and nuclear (40%) fuels. The total import bill is more than €1 billion per day. Most of these imports go through European ports. Given that approximately 40% of all commodities handled in European ports are sources of energy and that European ports are important industry clusters representing prominent energy users, it is clear that a changing energy landscape and the development of Europe’s Energy Union will be also imposing a significant impact on European ports (1).

In line with the aforementioned policy considerations, the European port sector has already recognized the importance of enhancing the ports’ energy profile and reducing the associated energy consumption of port activities. The European Sea Ports Organization (ESPO), in its 2013 report, ranked energy consumption as the 3rd of the top ten environmental priorities, rising up from the 7th place in 2009 when it was first included as a priority in the respective list (2). Other initiatives also point out the need to reduce energy consumption in ports (3, 4, 5, 6). European port authorities aim to efficiently address the environmental and energy challenges they are currently facing and have been continuously working (e.g. EcoPorts Foundation) towards improving their environmental and energy performance through focused actions structured around the following 5 pillars – 5Es (7):

- **Exemplifying**: setting a good example for the wider port community by demonstrating excellence in managing the energy and environmental performance of their own operations, equipment and assets
- **Enabling**: providing the operational and infrastructure conditions within the port area in order to facilitate port users, thus contributing towards enhancing the energy and environmental performance in the port area
- **Encouraging**: providing incentives to the port users encouraging a change of behaviour, inducing continuous improvement of their energy and environmental performance
- **Engaging**: with port users and stakeholders (e.g. SMEs) as well as competent authorities for sharing knowledge, means and skills towards joint projects targeting energy and environmental improvement in the port area and the whole logistics chain
- **Enforcing**: making use of mechanisms that enforce good environmental practice and efficient energy use by port users, where applicable, thus ensuring compliance.

Despite the fact that 72% of European ports already have an environmental policy in place and have set-up environmental departments staffed with relevant experts (69% of European ports have at least one environmental specialist), only half of them have adopted an Environmental Management System (EMS) such as the Eco-Management and Audit Scheme (EMAS), the 14001 standard of the International Organization of Standardization (ISO) (30%), and the EcoPorts Port Environmental Review System (PERS) (17%), to mention a few (8). However, this percentage will likely increase, to a significant extent, considering the focus that the EC is placing on efficiently addressing port externalities as highlighted in the European Ports Policy (9). Such a focus is currently being placed on the energy sector as well, with certification schemes such as the European Standard (EN) 16001 of the European Committee for Standardization as well as the International standard ISO 50001 paving the way towards efficient
port energy management. As a forerunner to their certification, according to the aforementioned
International and European standards, ports are starting to develop energy management plans
(EnMPs) (10), either at a port authority or at a terminal operator level, as part of their overall
“green” port policy. Within those plans, several energy efficient measures are being identified
and relevant technologies are being assessed considering the ones already in place (e.g. biomass
production, solar panels, etc.) as well as more novel concepts such as the new “Energy Island”
that is being investigated by the port of Long Beach aiming to produce clean power in order to
cover not only the port’s energy needs but city services as well (11).

Research in developing eco-efficient approaches in port operations has attracted special
interest during the last years. Several European Union projects are focusing on addressing energy
saving practices or use of alternative energy sources, including the GREENCRANES
(www.greencranes.eu) and Green EFFORTS (www.green-efforts.eu) projects.

This paper aims to provide a structured approach for supporting the development of port
EnMPs that will be in line with the existing EU energy policy framework. The paper builds upon
the activities of the “GREENBERTH - Promotion of Port Communities SMEs Role in Energy
Efficiency and Green Technologies for Berthing Operations” project, co-financed by the
European Regional Development Fund (ERDF) through the MED Programme, and reports on
the application of the proposed approach in six Mediterranean ports participating in the project
i.e. Valencia (Spain), Marseille (France), Livorno (Italy), Venice (Italy), Koper (Slovenia) and
Rijeka (Croatia), highlighting the main issues, challenges and prospects that should be taken into
consideration. The experiences gained through the development of EnMPs in each port provided
useful insights and enabled to draw some important conclusions on how the diverse
characteristics of port authorities with different challenges to face, different financial and
regulatory powers or capacities to act upon those challenges as well as with different track
records and history of environmental and energy management and performance, can contribute
towards a robust port energy management approach.

THE ROLE OF THE PORT AUTHORITY

The diversity of port authorities with significant differences being observed in terms of
objectives, functions performed, institutional frameworks, financial capabilities, market power,
knowledge, skills, competences, etc. also applies to energy and environmental considerations
which largely depend on the specific location and characteristics of each port area. From a port
authority environmental management perspective, three levels of potential intervention can be
identified with varying influence and effect potential at each level: (a) those falling under the
responsibility of the port authority (high influence, limited effect), (b) other interventions within
the port area (reasonable influence and effect) and (c) interventions at the transport and logistics
chain level (limited influence, high effect). The degree of influence a port authority can have
Towards taking actions to improve the energy and environmental performance of the port, varies
between the aforementioned three levels and depends on the institutional framework, the role and
objectives as well as the overall competence of the port authority (7).

Besides their role on port environmental management, port authorities, at least of landlord
type, are also responsible for the potential inclusion of environmental factors in the terminals’
awarding process to private operators. Making the terminals’ awarding procedures “green”
requires interventions in each of the three phases of the process i.e. the pre-bidding, the awarding
and the post-bidding phase. Port authorities may include in the concession agreement more strict
construction guidelines for port infrastructure and superstructure, modal split targets as well as
specific measures such as the use of a minimum percentage of green energy, the installation of
cold ironing or Liquefied Natural Gas (LNG) facilities, etc.

Within the awarding phase, candidates may be narrowed down according to requirements related to their financial capacity and relevant experience in operating facilities for similar cargo types in the same or at another port. The candidates’ environmental performance can be also considered as an additional requirement during this qualification process. As a result, candidates may be awarded not only for their market scale and financial potential but also for initiatives they have undertaken in the past for developing “green” policies at other terminals they have been operating.

Green elements should be also integrated into the post-bidding process. Environmental clauses are included in approximately 85% of 43 recent contracts that were reviewed across Europe (12). In most cases they dictate that the terminal operator has to comply with the local, national and European environmental legislation. In 30% of these cases, the terminal operator should have an environmental management reporting system in place and only in 18% of them emissions’ levels to be met are being specified. In a significantly smaller number of cases (9%), there is a reference to specific technical equipment that should be used for mitigating emissions in the port area. A combination of several of the aforementioned clauses is being documented in approximately 25% of all contracts.

The aforementioned considerations highlight the role that port authorities and terminal operators can play towards enhancing the environmental and energy profile of the port (13). Although port authorities provide the overall environmental framework setting the targets to be met and possibly guiding the way forward, it is in the specific interest of terminal operators not only to meet the pre-defined targets but also explore options that could lead to significant cost savings resulting from reductions in air emissions and energy consumption levels. Terminal operators, indeed, have an increased interest to enhance their social responsibility, which is being acknowledged nowadays as an important factor when evaluating a company’s profile. To this end, a EnMP at a port authority level sets the policy and the overall targets to be reached, while at a terminal level it details the specific actions (e.g. measures, technologies, etc.) that need to be undertaken for reducing existing energy consumption levels considering the specific operations and respective characteristics (e.g. equipment used, main energy sources, etc.) that fall under the responsibility of the terminal operator.

PERTINENT ISSUES IN DEVELOPING A PORT ENERGY MANAGEMENT PLAN

Within the overall framework of port environmental management, specific interest has started to be placed on enhancing the energy profile of ports. It is worth mentioning that the ESPO Annual Conference for 2015 addressed specifically this topic, engaging European port authorities in an interactive dialogue, which resulted in the identification of the energy targets to be achieved by the European port sector, considering the EU policy framework. Knowledge and experiences were exchanged during the conference on the different actions that have been undertaken by some leading ports, for enhancing their energy efficiency.

Setting up a port EnMP requires, as a first and very important step, to clearly define the port’s vision towards energy management. Considering the current business environment and market characteristics, each port has to carefully establish a future development model, with a specific time horizon, and define its mission and strategic objectives to be achieved within this time period. The port’s strategic plan besides focusing on business and financial management, improving the competitiveness of the port’s infrastructure and services, fostering innovation, etc. must also set environmental and energy sustainability targets. The overall aim is to have an economically, environmentally and socially sustainable port that is well aligned with all local,
national and European policies. Within this process, the active participation of all key port
community stakeholders proves to be an important prerequisite.

Within a port’s strategic plan, energy management objectives and goals should be set
addressing the following five energy pillars (10):

- **Resiliency**: ability to sustain business continuity during a power outage and resume
  operations after a catastrophic event
- **Availability**: access to energy sources that are required in order to meet present and future
  power demand of port operations through energy generation, transmission and distribution
- **Reliability**: availability of high quality and consistent energy able to meet predicted peaks
  in demand
- **Efficiency**: reductions in energy demand through management practices and technologies
  that maximize operational productivity and cost-effectiveness
- **Sustainability**: integration of energy management practices and renewable power
  generation to minimize the depletion of natural resources thus providing economical, social
  and environmental benefits

The aforementioned considerations provide the overall framework of a port’s energy policy
which actually presents the port’s commitment to efficiently collaborate with all key
stakeholders for implementing studies, programs and projects that will enhance energy resiliency,
availability, reliability, efficiency and sustainability in the port. It is important to point out that
the specific characteristics of each port and the services provided should be carefully taken into
account when developing the port’s energy policy.

TOWARDS A GENERIC PORT ENERGY MANAGEMENT PLAN

A generic port EnMP development framework has been created and it is presented in this
section. This framework has been used within the context of the GREENBERTH project, which
aimed to encourage the integration of SMEs in the strategic development plans of port operators
by examining in detail the improvement opportunities of energy efficiency in ports and the use of
environmentally friendly technologies to be implemented, through the exchange of best practices,
in six Mediterranean ports.

Energy mapping and consumption assessment methodology

The set-up of a port EnMP in each of the six ports required, as a basis, the detailed mapping
and assessment of the ports’ energy consumption. To this end, a generic energy mapping and
consumption assessment methodology (14) was developed following a three-level top down
approach (Figure 1).
As indicated in Figure 1, within the first level, the total energy consumption in terms of direct fuel consumption and purchased electricity is being addressed at a quarterly, semi-annual or annual basis. Understanding how a port is charged for energy and assessing the overall energy costs is an important first step (14). Within the second level, process blocks are selected and the physical processes (sub-blocks) are being mapped for the selected block (linked activities). Process blocks are being categorized into (a) operations, (b) support / maintenance functions and (c) buildings with related sub-blocks being included in each category. For each activity of a mapped process (sub-block), the energy consumption (fuel and / or electricity) is being assessed at a third level, considering among others equipment deployment and time of operation. An example of this process hierarchy is being depicted in Figure 2.
In this example, “operations” is being selected as a process block and “terminal related” operations as a sub-block. Within this sub-block, several activity levels are then selected and analyzed. In such an analysis, the energy consumption of other associated sub-blocks has also to be provided considering local specific conditions (Figure 3). For specific activities in terminals, the energy consumption should be calculated separately. However, in case equipment is being shared between terminals, the related energy consumption should be relatively allocated among those terminals.

**FIGURE 3 Level 2 sub-blocks and interrelations**

Figure 3 presents the various levels of the aforementioned analysis with emphasis on the assessment of energy consumption related to the seaside operations of a terminal. As several activities and equipment may be shared with other parts of the terminal, such as intra-terminal and landside operations, their interconnected processes need to be carefully considered.

**Process for developing a port energy management plan**

Once the generic energy consumption assessment methodology has been applied and the main results have been drawn for the selected blocks, the process depicted in Figure 4 may be followed for setting up the port’s EnMP.
FIGURE 4 Process for developing a port energy management plan

The port energy mapping and consumption assessment process provides a clear picture of the port’s energy performance and enables, through the use of Key Performance Indicators (KPIs) or a benchmarking process, to identify existing gaps that should be addressed for achieving energy efficient port operations. Preliminary recommendations for addressing those gaps can be formulated, which, as a next step, have to be communicated with all port community stakeholders in order to discuss them and gain consensus regarding the follow-up actions that should be undertaken. This process can be facilitated through focus group meetings where representatives of all port related stakeholder groups should be invited to participate, share their views and provide suggestions. Once those meetings are concluded and the actions for addressing the existing gaps are clearly defined, an energy re-engineering process should take place fostering the development of a port EnMP outlining, in detail, all actions to be undertaken for enhancing the port’s energy efficiency thoroughly describing their time frame, estimated costs, responsibilities of the different port actors, etc. The plan will also define how the port’s energy performance will be monitored and evaluated providing, for example, a set of relevant KPIs taking into account the port’s traffic, its energy requirements as well as the variation of the latter throughout the year.

Structure of a port energy management plan

Once the port’s overall vision on energy management has been defined, the strategic goals and objectives of a port or terminal EnMP should be set in accordance with the aforementioned five energy pillars and following the results of the energy mapping and consumption assessment analysis. In doing so, careful consideration should be given to the following aspects:
- Implement efficient energy policies that will contribute towards achieving the targets that have been set
- Obtain consensus from the local community
- Integrate energy saving aspects into the decision making process as an important element for reducing costs
- Improve access to relevant EU funding instruments (e.g. Connecting Europe Facility, etc.)
- Implement strategic energy management practices in: (a) purchasing / procurement procedures and specifications, (b) enhanced design and port construction practices, (c) enhanced facility port operating practices, (d) cost-effective facility upgrades and (e) active commodity management.

These goals may be achieved by following a structured approach (Figure 5), which will result in the development of a comprehensive EnMP specifying and detailing all appropriate actions that should be taken.

**FIGURE 5 Structure of a port EnMP**

Once the port’s energy management vision, goals and objectives have been set, a thorough review of energy policies at a port, local, national, European and international level should be undertaken in order to have a clear understanding of all regulations that should be respected along with the specific targets those are entailing.

The next section of the EnMP will build upon the energy mapping, consumption assessment and gap analysis, which would have been undertaken at an earlier stage, pointing out the main energy consumers in the port area, according to its specific characteristics, and the potential areas for improvement. Indicatively, in many ports, cold storage facilities prove to be large energy consumers especially during summer months. To this end, several European ports are currently investigating appropriate solutions (e.g. solar panels) for covering the energy requirements of those facilities. It should be noted that areas for energy improvement in each port largely depend on the port’s location, type of cargo handled as well as other specific characteristics.

The identification of the aforementioned areas enables the port operator to clearly identify its
major needs and start investigating possible solutions / technologies that can be adopted for addressing them. Within this process, great emphasis is being placed on further exploitation of renewable energy sources and the wider implementation of clean technologies.

The solutions / technologies that prove to best fit the port’s energy needs are being evaluated, as a next step, against a set of criteria enabling also their prioritization into short, medium and long-term ones. The criteria that were used in the GREENBERTH approach are being presented in Table 1.

TABLE 1 Criteria for evaluating energy efficient solutions / technologies

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Timeframe (timing frequency, duration)</td>
<td>The criterion aims at evaluating the time schedule and sequence of activities required for the implementation of specific actions. The actions’ timing, frequency and duration, within the overall framework of related activities, are being considered.</td>
</tr>
<tr>
<td>CO₂ emissions reduction potential</td>
<td>The criterion focuses on the potential of CO₂ emissions reduction as a result of the implementation of a specific action. It considers the difference in the emissions’ level before and after the action has been implemented. The total contribution of the action under consideration with respect to the specific topic / field / sector being addressed is being taken into account.</td>
</tr>
<tr>
<td>Cost</td>
<td>This criterion considers the overall costs required for the implementation of a specific action. It focuses on the identification of payments and the delivery of the action’s different implementation phases as well as on the initial investments that are required and the sustainability of the implementation plan.</td>
</tr>
<tr>
<td>Cost-effectiveness</td>
<td>Cost-effectiveness is evaluated according to the relationship between monetary inputs and the desired outcome i.e. the expenditure allocated for an action with respect to its emission reduction potential. Values are assigned by the stakeholders involved in the elaboration of the strategy, according to their preferences.</td>
</tr>
<tr>
<td>Technical feasibility</td>
<td>Technical feasibility considers on one hand the technical aspects of the action, and on the other hand the contextual conditions of the area and of the stakeholders involved in the action’s implementation.</td>
</tr>
<tr>
<td>Implementability</td>
<td>This criterion refers to the capacity of the stakeholders involved in the action’s implementation. It considers potential difficulties, conflicts and barriers encountered during the action’s management and implementation between key actors and stakeholders as well as with local communities.</td>
</tr>
<tr>
<td>Measureable results</td>
<td>In order to establish the consistency of an action, it is necessary to be able to measure its performance. To this end, this criterion considers (i) the advancement in the time of implementation, (ii) the results that can contribute to reducing emissions - as external efficiency, (iii) measures complying with the established targets - as internal efficiency. This criterion is closely connected with the criterion no. 2 “CO₂ emissions reduction potential”.</td>
</tr>
<tr>
<td>Co-benefits</td>
<td>Co-benefits are the additional, to the direct target of the action, benefits. Those can be: (i) social, addressing social aspects related to local communities or groups; (ii) economical, as indirect (positive) effects, for example, addressing working activities or specific sectors and (iii) environmental, as indirect effects on the ecosystems, biodiversity or on other environmental dynamics.</td>
</tr>
<tr>
<td>Funding opportunities</td>
<td>The criterion aims at considering the potential of funding opportunities for the implementation of the action. The availability of different types of funds is being evaluated: (i) external sources, such as EU funds, private funds, etc. (ii) internal sources, as funding opportunities deriving from stakeholders involved in the action’s implementation.</td>
</tr>
</tbody>
</table>
| Enforceability                    | The criterion reflects on the legal basis for the enforcement of the action. It aims to evaluate (a) if the action is supported by an existing legal framework, (b) if there is an
Different weights may be used by different ports and/or stakeholders in this evaluation process, according to their priorities. Various techniques are available for decision making and consensus building, which may be used within the context of a focus group meeting. The evaluation results lead to the identification of those solutions/technologies that best fit a port’s characteristics and needs. For the implementation of the selected energy efficient solutions/technologies, a more detailed analysis should be conducted including also a timeline for the specific actions to be undertaken as well as the role and responsibilities of all stakeholders that will be involved in the process.

EXPERIENCES FROM THE APPLICATION OF THE METHODOLOGY TO ENERGY MANAGEMENT PLAN DEVELOPMENT IN SIX MEDITERRANEAN PORTS

The methodological approach that was described in the previous sections was applied in the case of the six Mediterranean ports that participated in the GREENBERTH project.

The energy mapping and consumption assessment process indicated that commercial terminals are the main fuel and electricity consumers in all six ports. Container terminals presented the largest energy requirements both in terms of fuel and electricity, while cold storage facilities (e.g. the Fruit Terminal at the port of Koper) accounted for a significant part of the ports’ total electricity consumption. In some cases, such as in the ports of Venice and Livorno, passenger terminals also presented important energy requirements, although not to an extent similar to that of commercial terminals. Energy consumption levels in all six cases were provided for the level 2 sub-blocks considered in each port, indicating respective areas for energy efficient improvement.

At this point, it is important to point out that the data provided by the six ports were of different detail, consequently leading to a different level of application of the methodology in each case. This is mainly attributed to the energy consumption monitoring process followed by each port, improvement of which was actually highlighted as a major priority for most of the six ports.

All six ports were able to identify their major energy needs and potential areas for improvement and thus evaluate appropriate solutions/technologies that could efficiently address the identified needs thus meeting the targets set by each port’s energy policy. The solutions/technologies that were considered in each port are being summarized in Table 2.

<table>
<thead>
<tr>
<th>TABLE 2</th>
<th>Ports’ energy needs and measures for improvement – evaluated solutions / technologies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Port</td>
<td>Energy needs and potential measures for improvement</td>
</tr>
<tr>
<td>Valencia</td>
<td>1. Improvement of the lighting system in the port area</td>
</tr>
<tr>
<td></td>
<td>2. Electric mobility in the port area</td>
</tr>
<tr>
<td></td>
<td>3. Green power production</td>
</tr>
<tr>
<td></td>
<td>4. Alternative fuel use</td>
</tr>
</tbody>
</table>
6. Facility systems’ upgrade | green energy
5. Cold ironing system
6. Hybridization of diesel engines (LNG, Liquefied Petroleum Gas - LPG) of tugboats, Rubber tyred gantry cranes - RTGs (also electric motors)
7. Real-time monitoring of the energy consumption of port activities
8. New technologies for refrigerated engines

<table>
<thead>
<tr>
<th>Marseille</th>
<th>Livorno</th>
<th>Venice</th>
<th>Koper</th>
<th>Rijeka</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Type:</strong> Landlord port</td>
<td><strong>Type:</strong> Landlord port</td>
<td><strong>Type:</strong> Landlord port</td>
<td><strong>Type:</strong> Private Service port</td>
<td><strong>Type:</strong> Medium</td>
</tr>
<tr>
<td><strong>Size:</strong> Large</td>
<td><strong>Size:</strong> Medium</td>
<td><strong>Size:</strong> Medium</td>
<td><strong>Size:</strong> Medium</td>
<td><strong>Size:</strong> Medium</td>
</tr>
<tr>
<td>1. Improvement of the lighting system in the port area</td>
<td>1. Implementation of a LED lighting system</td>
<td>1. Improvement of the lighting system in the port area</td>
<td>1. Improvement of the lighting system in the port area</td>
<td>1. Improvement of the lighting</td>
</tr>
<tr>
<td>2. Electric mobility in the port area</td>
<td>2. Goods lifting equipment (crane) with energy saving system</td>
<td>2. Electric mobility in the port area</td>
<td>2. Electric mobility in the port area</td>
<td>1. Implementation of a LED lighting system</td>
</tr>
<tr>
<td>3. Alternative fuel use</td>
<td>3. Use of electric passenger and freight vehicles in the port (shuttle buses, trucks, etc.)</td>
<td>3. Green power production</td>
<td>3. Green power production</td>
<td>1. Improvement of the lighting</td>
</tr>
<tr>
<td></td>
<td></td>
<td>8. Idle reduction programs and road system optimization (timing and paths)</td>
<td></td>
<td>6. Process cooling and refrigeration systems storage facilities upgrade</td>
</tr>
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<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>
Table 2 clearly indicates the numerous common priorities of the six Mediterranean ports participating in the GREENBERTH project. Efficient and real-time monitoring of the energy consumption of port activities proves to be a major concern for most ports as they have realized that such a system will provide them with the opportunity to identify in detail areas where further energy improvements can be realized thus evaluate the energy performance of already implemented solutions / technologies.

The use of alternative fuels (e.g. LNG, LPG, CNG, etc.) as well as electricity in a variety of vehicles (e.g. trucks, shuttle buses, etc.), vessels (e.g. tugs, pilot boats, etc.) and port equipment (e.g. yard tractors, RTGs, cranes, etc.) is also being carefully considered by all ports as the benefits that can be realized from this process prove to be substantial in terms of cost, energy and environmental savings. Furthermore, the transition towards more clean fuels is also being heavily promoted by the European legislation.

Further exploitation of alternative energy sources (such as solar, wind, tidal power, biomass, biogas, etc.) is also an important issue for all ports as the energy to be produced could potentially cover the energy requirements of specific port sections. Especially for the Mediterranean region, where all the six ports are located, great focus has been placed on the exploitation of solar energy. Several studies have been conducted on the efficient implementation of photovoltaic systems (e.g. on the roof of port warehouses, buildings, etc.).

All ports also consider that the lighting sector in the port area presents significant energy improvement potential, leading to significant cost and energy savings. The implementation of LED technology and the efficient management of the lighting system are being investigated in all cases as they present two solutions / technologies with a relatively small implementation cost and a significant cost and energy reduction potential.

The evaluated solutions / technologies for each port, as presented in Table 1, were then prioritized according to the following set of eight criteria:

1. The technology reduces significantly Greenhouse Gas (GHG) emissions and increases energy efficiency
2. There is sufficient knowledge / know-how for the technology implementation
3. Local resources / supplies are available for the technology implementation
4. The port has the required technical and human capacity to implement the technology
5. The economic investment for implementing the technology is appropriate / affordable
6. The investment’s payback period is appropriate
7. Existing policies do not introduce any barriers for the technology implementation
8. The current port organization does not introduce any barriers for the technology implementation

The aforementioned process enabled the six ports to identify and pilot test solutions / technologies that fit best their needs thus presenting the greatest cost and energy reduction potential. The pilot projects undertaken by each port are being summarized below:
- **Port of Valencia**: Development of a blueprint for the **use of LNG in the port area** (charging station for vehicles and engine retrofitting for tugboats)

- **Port of Marseille**: **Static hydrogen injection** system for tugboats’ engines

- **Port of Livorno**: **Cold ironing** i.e. shore connection plant to power cruise ships and ferries with a maximum power of 10 MW

- **Port of Venice**: **Passenger electric mobility** – energy charging stations aiming to reduce the use of fossil fuel within the Venice lagoon

- **Port of Koper**: Implementation of an **energy management system** at the port’s Fruit Terminal

- **Port of Rijeka**: Installation of a **photovoltaic system** on the roof of the cold storage warehouse

The estimated costs as well as the expected benefits from the implementation of the aforementioned solutions / technologies for each port are being summarized in Table 3.

### TABLE 3 Estimated costs and expected benefits from the implementation of selected solutions / technologies in each of the six ports under consideration

<table>
<thead>
<tr>
<th>Port</th>
<th>Pilot project</th>
<th>Estimated implementation cost</th>
<th>Expected benefits</th>
</tr>
</thead>
</table>
| Valencia        | LNG supply facility for vehicles in the port area                             | • LNG supply station: 509,320 €  
                  |                                                                                | • LNG transformation of trucks: 35,000 € / truck  
                  |                                                                                | • LNG transformation of reachstackers: 80 - 120,000 € / unit  
                  | Project design for the conversion of the engines of the Valencia Harbor’s fleet to use LNG as fuel | • Feasibility study and engine retrofit project: 100,000 €  
                  |                                                                                | • For all other tasks required for the engine’s retrofit: 4,041,000 €  
                  |                                                                                | • 70% reduction of GHG emissions  
                  |                                                                                | • NOx and particulate matter approaching zero levels  
                  |                                                                                | • 3 dB reduction of noise  
| Marseille       | Static hydrogen injection system for tugboats’ engines                       | • Costs largely depend on the engine’s size  
                  |                                                                                | • Payback period estimated to less than 1 year considering the expected cost savings  
                  |                                                                                | • 20% reduction of CO₂ emissions  
                  |                                                                                | • 80% reduction of NOₓ  
                  |                                                                                | • 99% reduction of SOₓ  
                  |                                                                                | • 95% reduction of particulate matter  
| Livorno         | Cold ironing system                                                           | • Ships’ adaptation and infrastructure: 200 – 900,000 €  
                  |                                                                                | • Payback period estimated to less than 4 years considering the expected cost savings  
                  |                                                                                | • 30% reduction of CO₂ emissions  
                  |                                                                                | • 95% reduction of NOₓ and particulate matter  
| Venice          | On shore power supply (charging stations) for passenger service vessels        | 20,935 € for the installation of two charging points  
                  |                                                                                | • CO₂ emissions’ reduction of 90.77 ton / year  
                  |                                                                                | • 82% annual cost savings  
| Koper           | Energy management system at the Fruit                                         | • Installation costs: 65,000 € (including also monitoring  
                  |                                                                                | • 250 MWh annual energy savings  

As indicated in Table 3, the different solutions / technologies that were pilot-tested in each port, present a significant potential regarding energy consumption and environmental emissions’ reduction while the estimated annual cost savings result in short payback periods. Of course, the selected solutions / technologies are of different scale, require investments of different magnitude thus lead to diverse benefits. The appropriate solution / technology for a port should be carefully selected considering the port’s characteristics, its strategic goals and investment potential vis-à-vis the estimated cost and expected benefits of the solution / technology under consideration.

**CONCLUSIONS - RECOMMENDATIONS**

Energy consumption in ports is a major overhead cost for port operators, which can be reduced significantly, in many cases with minimal capital investment.

Raising the environmental profile of ports and promoting innovation in sustainability and energy efficiency are key issues facing major ports around the world. Addressing these issues may be a choice of port operators wishing to improve the competitive position of their ports. In many cases, however, addressing such issues may be a requirement. As indicated in the Clean Power Transport Directive, for example, the European Parliament and the Council require that all core European ports, in which it is economically viable, should provide LNG refueling points and shoreside electricity by 2025.

Methodological tools and criteria may be used to assist ports in selecting and prioritizing measures aiming to improve their energy efficiency now and into the future. Along this line, the methodological approach presented in this paper supports the development of port EnMPs. A generic framework has been presented, which follows a step-by-step approach, intended to guide interested ports into assessing in detail their current energy performance, based on the monitoring procedures and equipment used, and identify energy improving measures best fitting the port’s energy needs and specific characteristics.

The methodology has been applied to the case of six Mediterranean ports. As a result, specific measures have been selected for implementation. The level of implementation varies by port and by specific measure. It is important to note that the amount and detail of data that were available or that were collected in each port varied significantly. Data availability depends on the procedures followed in each port, the effort allocated in relevant activities and the energy management team that is in place in each port. The methodology presented in this paper proved to be efficient in all cases, despite the great variation in data availability and in dedicated expert personnel in each port.

This diverse experience shows that the presented methodology may support and contribute to
the adoption of a robust energy management approach, selecting, prioritizing and setting a path for the implementation of short, medium and long-term actions that will assist in achieving a port’s strategic energy efficiency goals and objectives.

Furthermore, sharing of experiences and lessons learnt from this process may facilitate the transferability of the approach to other ports that are interested to enhance their energy profile.

The proposed methodology provides the basis for the development of a port energy review system, along the line of the ESPO PERS, and a relevant self-diagnosis method.

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