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Identifying the Main Opportunities and Challenges from the Implementation of a Port Energy Management System: A SWOT/PESTLE Analysis

Anastasia Christodoulou *  and Kevin Cullinane

Department of Business Administration, University of Gothenburg, SE-405 30 Gothenburg, Sweden; kevin.cullinane@gu.se

* Correspondence: anastasia.christodoulou@gu.se; Tel.: +46-31-786-6437

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Abstract: Climate change is among the greatest environmental threats facing the globe today and the abatement of greenhouse gas (GHG) emissions is concerning all the industrial sectors contributing to the problem. The maritime transport sector has already implemented several measures for energy efficiency for the reduction of its GHG emissions, including both vessels and ports. This paper focuses on the prospects and challenges facing the development of a port energy management system. It analyzes the main factors which exert an impact on such a plan and that need to be taken into account for its successful implementation. A SWOT/PESTLE analysis is utilized for the identification of the political, economic, social, technological, legal and environmental factors that have a positive or negative effect on the adoption and successful implementation of a port energy management system. This analysis is based on empirical data from two leading North-European port authorities. Given the fact that ports are currently focusing on the reduction of their energy consumption, this paper's results have particular significance in that they could enlighten and inform the adoption of a port energy management plan within ports.

Keywords: ports; energy management system; sustainable development; energy efficiency; maritime transport

1. Introduction

The abatement of global greenhouse gas (GHG) emissions has been central to the work of the United Nations Framework Convention on Climate Change (UNFCCC) for the last few decades. The ultimate aim is to achieve the 'stabilization of GHG concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system' [1]. The Paris Agreement made this goal more specific by setting the target of 'keeping a global temperature rise this century well below 2 degrees Celsius above pre-industrial levels and pursuing efforts to limit the temperature increase even further to 1.5 degrees Celsius' [2]. As a consequence of this, all energy-consuming industrial sectors are expected to contribute to the reduction of these emissions and to improve the energy efficiency of their operations with the exception of international shipping and aviation which are exempt from the terms of the Paris Agreement. Because of the international nature of these sectors and the difficulty in allocating their emissions to specific countries, the regulation of their GHG emissions has been left to the International Maritime Organization (IMO) and the International Civil Aviation Organization (ICAO) respectively.

Maritime transportation is potentially the least environmentally damaging and energy efficient mode of transport but is essential for the growth of global trade, moving more than 80% of global trade in volume, while accounting for just 2.2% of global CO₂ emissions [3]. Given an expectation

of continuing growth in world trade, in 2018 the IMO's Marine Environment Protection Committee (MEPC) adopted an initial strategy for the reduction of GHG emissions from ships, setting out a vision to reduce GHG emissions from international shipping. According to this strategy, actions to reduce GHG emissions from international shipping should be implemented as soon as possible, with the specific target of achieving a reduction of at least 50% by 2050 compared to a 2008 baseline and having the long-term aim of phasing them out entirely.

While policies and measures to enhance the energy efficiency of offshore maritime activities—as applied to commercial vessels—are developed and implemented by the IMO and other regional inter-governmental institutions (such as the European Union in particular), the primary responsibility for the energy performance of port activities rests with the specific administrative authority of the country in which they are located—usually in the form of a national, regional or local port authority and/or the regional or local government authority [4]. However, due to the complicated nature of ports and their complex and varied operations, regional and international organizations have been formed (for example, the European Sea Ports Organization (ESPO) and the International Association of Ports and Harbours (IAPH)) in order to address the main challenges facing the port sector. These organizations have dealt with port environmental issues for many years and, in fact, have made an important contribution to the development of port environmental management tools and certifications. For European ports specifically, the importance of the majority of port environmental issues has remained relatively stable over the past 20 years. However, air quality and energy consumption in particular have emerged as the major priorities for European ports in seeking to improve their carbon footprint and comply with the recent relevant directives and regulations [5].

With a port's own activities accounting for only approximately 10% of total port emissions on average, it is visiting vessels in ports which constitute the main source of emissions. This implies that efforts for the reduction of GHG emissions in ports should focus on emissions from ships at berth [6]. For example, because vessels can turn off their auxiliary engines and use shore-side electricity for their activities, the installation of onshore power supply (OPS) or 'cold ironing' in ports can result in significant emission reductions, depending on the energy mix utilized in electricity supply [7–9]. In case electricity is wind or hydro generated, there is the potential for large GHG emission reductions in the port area, while the use of coal power may result in even higher emissions than electricity generated on board the ship [10]. Although the potential of OPS to reduce significantly ship emissions near ports is acknowledged by previous studies [11,12], they also mention the need for the provision of economic incentives for the installation of OPS, as the technology is quite expensive and costs for the installation should be somehow compensated for both vessels and ports. Although, to date, there has been no generally applicable international regulation aimed at the implementation of OPS in ports, the EU has unilaterally made it mandatory for the Trans-European Network (TEN-T) core ports to provide a shore-side electricity supply for ships by the end of 2025 [13]. Non-core ports within the EU are also required to comply 'unless there is no demand and the costs are disproportionate to the benefits, including environmental benefits' [13]. Apart from the installation of OPS in EU ports, the 2014/94/EU Directive obliges EU ports to provide Liquefied Natural Gas (LNG) fueling points in order to build a network of alternative fuel infrastructure and promote the use of alternative fuels like LNG. Just-In-Time (JIT) arrival of vessels at ports can also lead to reduced fuel consumption and related harmful emissions (SO_x, NO_x, CO₂) in port areas. Keeping sea-going vessels regularly informed about when their berth will become available means that they would need to wait shorter times in anchorage areas, but also that they would be able to adapt their sailing speed accordingly. Other options for the abatement of GHG emissions in ports are related to power generation from renewable energy sources or the development of the circular economy [14].

In contrast to the potential for global and regional initiatives aimed at the abatement of GHG emissions from ships in ports, the diverse nature of port governance at the local level presents a major challenge for the maritime sector, in that the wide ranging roles and responsibilities of different ports precludes their inclusion in a uniformly applied climate change regime [15,16]. Despite this, however,

by virtue of their integral role in supply chains and their engagement in the management of supply chain activities at multiple levels and scales, ports can play an important role in the development of sustainable transport services [17,18]. Indeed, sustainability management is a common concern for all ports, even smaller ones, irrespective of their governance model and the particular level and form of legislative compliance which they face. Kuznetsov et al. [19] suggests that the development of a formal Port Sustainability Management System could assist ports of whatever size in their efforts to offer sustainable services. In so doing, Acciaro et al. [20] points to the need to develop advanced conceptual frameworks which take into consideration the multiple stakeholder nature of the port industry and the resistance that organizational innovation can meet.

In their efforts to improve their carbon footprint and achieve sustainable development, ports can develop an energy efficiency management system which enables all port actors to integrate energy management within their organization or activities and to thereby reduce the energy consumption of their operations [21]. The adoption of an energy management plan is a useful tool for the continuous improvement of energy use within any type of organization and has been implemented in many industrial sectors. In the maritime sector, a Ship Energy Efficiency Management Plan (SEEMP) has been mandatory for all vessels as from January 2013, regardless of the nationality of the shipowner or the flag which they fly [22]. As developed by the International Maritime Organization (IMO), a SEEMP comprises a ship-specific plan, which aims at the improvement of the operational energy efficiency of the vessels. The SEEMP provides guidance on the way that the optimization of the operational efficiency of ships can be achieved through improved voyage planning, weather routing, just in time arrival of vessels at ports, speed optimization and other operational-based measures. In relation to the port sector, it is worth mentioning that, by 2016, the majority of EU ports (70%) had already developed a certified environmental management system. This is not only indicative of quite a high level of environmental commitment, but also means the requirements for environmental certification share some similar structural characteristics with a formal port energy management system [5].

The scope of this paper is to identify the main internal and external factors that have an impact on the successful implementation of an energy management system in ports. Having as a guide the ISO 50001 Energy Management Standard requirements of an Energy Management System, the internal parameters that play a vital role in the successful development of a port energy management plan were identified and analyzed. Given the fact that the environment in which ports operate is quite complex and encompasses various distinct parameters, a SWOT/PESTLE analysis is applied in this study to highlight the political, economic, social, technological, legal and environmental factors that have a positive or negative effect on the adoption of a port energy management plan. Since energy-related issues have only recently been receiving sufficient attention and many ports are only now integrating energy management into their overall operations, this paper's results have a special significance in potentially enlightening and even influencing some aspects of port energy management and in contributing to the discussion on the best way forward for the achievement of sustainable maritime transportation.

2. Methods and Data

In order to identify the main internal and external factors that have an impact on the successful implementation of a port energy management system, a SWOT/PESTLE analysis is applied within this study. SWOT analysis was first applied in the 1960s, 'it is widely recognized and it constitutes an important basis for learning about the situation and for designing future procedures which can be seen as necessary for thinking in a strategic way' [23,24]. According to Nikolaou and Evangelinos [25], 'SWOT analysis could be a useful tool for the strategic planning process of environmental management' as it identifies (a) the advantages for an organization from the implementation of a plan (strengths), (b) the obstacles preventing the successful implementation of the plan according to the initial goals (weaknesses), (c) the opportunities and (d) the threats from the implementation of the plan associated with external factors.

Regarding the implementation of a port energy management plan, SWOT analysis allows an assessment of the parameters influencing the application of such a plan and separates them into internal (strengths and weaknesses) and external (opportunities and threats) parameters. However, this method exhibits some disadvantages and various modifications of the analysis have been suggested, with the most popular being the SWOT/PESTLE analysis, especially in cases where the systems examined are complex and the external parameters need to be analyzed extensively [26,27]. A PESTLE Analysis is an analytical tool for strategic business planning that provides a strategic framework for understanding the external influences on a business or other form of entity. It is used by organizations for the evaluation of the impact that the external environment might have on a project. It clusters external parameters into various factor categories under the broad headings of Political, Economic, Social, Technological, Legal and Environmental (PESTLE) considerations. A PESTLE Analysis is often combined with a SWOT Analysis, as it enables the identification of internal parameters associated with a project and their classification into the various PESTLE categories. The major advantage of using a SWOT/PESTLE Analysis is related to the combined analysis of both internal and external factors that have an impact on a project, particularly since the latter are beyond the control of the organization and more difficult to identify [28].

Given the complex and multidimensional environment in which ports operate, the synergy between SWOT and PESTLE analysis offers the potential for analyzing the development of a port energy management system in relation to its internal and external environment. As proposed by Vorthman [29] and Srdjevic et al. [28], SWOT analysis is used within this study for dividing the factors that play a vital role in the successful development of a Port Energy Management System (PEMS) into two clusters—internal and external—according to the domain of their influence on the system. These factors are then further analyzed and clustered into six categories—Political, Economic, Social, Technological, Legal and Environmental—according to the type of their influence on the system through a PESTLE analysis (Figure 1).

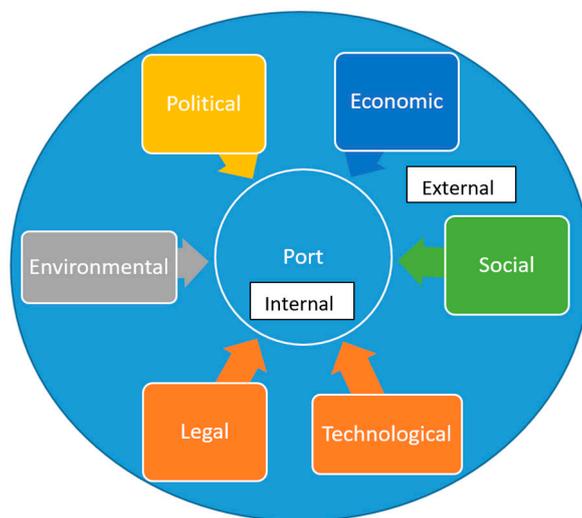


Figure 1. SWOT/PESTLE analysis of a port energy management system. Source: Own elaboration based on data from Vorthman [29] and Srdjevic et al. [28].

The method of collecting primary data for this study is through the use of structured interviews conducted with two leading North-European port authorities that acknowledge sustainability as among their core values and as an integral part of port operations as a whole. The sample selection is tightly aligned with the purpose of the research, which is the analysis of the parameters that have an impact on the implementation of a port energy management plan. Both ports are municipality-owned and represent the main national ports of the countries where they are located, offering services to a large variety of marine traffic, from RoRo vessels to dry bulkers, tankers, large containerships and

cruise vessels. They are closely connected, 'interlinked' and form part of the port city and the analysis of the port-city systems with regard to their combined carbon footprint is worthwhile investigating in both cases.

The framework of requirements that the ISO 50001 Energy Management Standard sets for the development of an energy management system was used as an underlying guideline for the interviews that were carried out in order to understand whether this framework is a useful tool for the adoption of such a system in the port sector and to shed light on the parameters that play a vital role in the successful development of a port energy management plan.

A crucial step in this research was the identification of the appropriate respondents from each port authority, with deep knowledge of their environmental and sustainability practices. From the first port authority, the environment controller was interviewed, while the second respondent was the head of environmental strategy of the other port authority. The interview protocols were sent in advance to the respondents, as it was deemed that this would help them better collect their thoughts. Additional data from the websites of the respondent ports and sustainability reports were used in order to form a concrete view of their sustainability practices [30,31].

Air quality and energy consumption are high priorities for both ports, which are certified according to the environmental standard ISO 14001. The first port authority has managed to cut its own emissions by 60% since 2010, through big investments in alternative energy sources (such as the Energy Port's pipe-heating system, alternative energy sources for buildings, the consumption of biogas and electricity from the port's production vessels), the provision of onshore connections and charging stations for cars and cycles. Both ports reward vessels with good environmental performance using environmentally differentiated port tariffs, offer vessels the opportunity to connect to onshore power supply (OPS) and provide LNG fueling stations for vessels. These environmentally differentiated port dues are offered on the basis of vessels' 'scoring' or classification in the Clean Ship Index or the Environmental Ship Index for the first port, while the second port offers discounts on the basis of the Environmental Ship Index, the Green Award or the Blue Angel standard.

Due to the limited number of port authorities that are included in the study, this research design does not permit the generalization of findings on the development of a port energy management system. The data obtained from the two port authorities cannot be considered as representative of port environmental sustainability practices in general, as the specific port authorities are located in Northern Europe, where high sustainability requirements in sea freight transport are applied and where ports generally demonstrate a very strong commitment to sustainable port operations. The results may well be different in small or medium size ports or other geographic regions of the world.

Further research is needed, therefore, to support or supplement the findings from this study, including different port categories, operated with different governance models and serving different categories of traffic. Nevertheless, the in-depth investigation of attitudes towards the adoption of a port energy management system in port authorities which have environmental sustainability high on their agenda can be justified on the basis of the valuable practical input offered in relation to the novelty of addressing energy-related issues in ports.

3. Results

3.1. *The Development of a Port Energy Management System*

Given that the ports, examined in our study, are closely connected to the port cities and form part of port-city systems, it is worth analyzing these port-city systems with regard to their combined carbon footprint. Previous research has shown a strong positive correlation between the comprehensiveness of ports' sustainability plans and the achievement of their environmental goals. According to Schipper et al. [32], the ports that develop integrated sustainability plans combining port, urban, transport network, environment and climate change dimensions are usually more successful in accomplishing these sustainability plans. The formulation of joint long-term sustainability plans

of ports and port-cities on the basis of the three main aspects of People, Planet and Prosperity can contribute to the promotion of sustainable port operations, wealth, social welfare and sustainability. In this sense, a Port Energy Management System should take into account the port-city relations and aim for combined sustainability improvements in the wider port-city area.

A port's previous experiences with environmental management systems can be valuable and form the basis for the integration of energy management into their operations. The ISO 50001 energy management standard is a recognized international standard that applies to various industrial segments and provides organizations with a structured framework for the improvement of the energy performance of their operations [33]. The standard constitutes a 'tool' that assists organizations in the implementation of an energy management system that sets and pursues specific goals for the continual improvement of their energy performance. It is based on the Plan-Do-Check-Act approach and follows an energy management cycle [34–36].

ISO 50001 provides organizations with a framework of requirements that need to be met for the development and application of an energy management system. These can be summarized as the following:

- The development of an energy policy for the organization, involving the setting of targets and objectives that could lead to the promotion of this policy
- Energy planning through the design of efficient energy policies and measures concerning energy use and consumption
- Implementation and operation of this energy plan
- Checking of the results obtained (external and internal auditing)
- Review of the effectiveness of the policy and
- Continual improvement of the energy management.

According to the ISO 50001 energy management standard requirements, ports need to form their energy management plan taking into consideration various factors [37]. First of all, their energy management goals should be set, and their energy planning should include international, national and regional energy regulations and standards. After the port energy policy has been designed, data should be gathered regarding energy needs and the potential measures for the improvement of the port's energy performance. Energy improving measures should be selected based on their potential to reduce CO₂ emissions, their cost effectiveness, their implementability, available funding opportunities and others. A similar approach to the ISO 50001 energy management standard is used for the development of port integrated environmental management systems in a wider context, including, e.g., port-city systems or targeting other kinds of pollutions, e.g., noise and micro oil spills. For example, the rationale for the design and integration of an Environmental Decision Support System (EDSS) devoted to oil spill management is similar to the ISO 50001 energy management standard requirements, including: (i) Data Gathering, (ii) Diagnosis and/or Prediction, and (iii) Decision Support in the framework's design process [38,39]. The framework of requirements that the ISO 50001 Energy Management Standard sets for the development of an energy management system was used as an underlying guideline for the development of a list of factors that may play a vital role in the successful development of a port energy management plan. The interviewees were then identified and asked to assign points to these various internal and external factors on a scale of 1 to 5 in order of importance. With the use of a SWOT/PESTLE analysis, the various factors were first divided into two groups—internal and external—according to the domain of their effects on the system. They are then clustered into the six PESTLE categories: political, economic, social, technical, legal and environmental, according to the nature of their influence on the system. The procedure followed for the identification of the factors that influence a port energy management system is graphically presented in Figure 2.

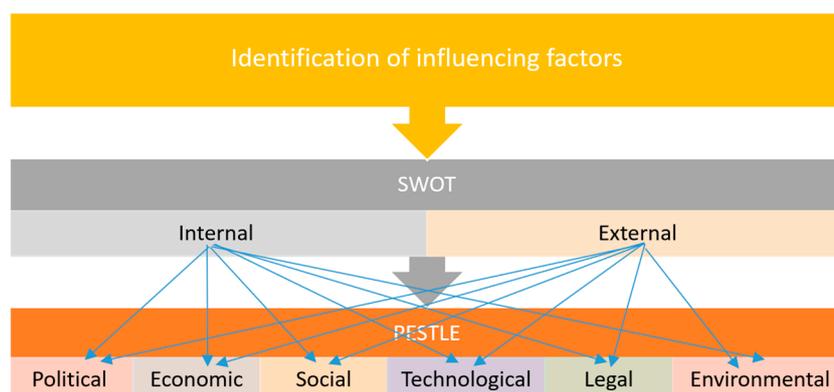


Figure 2. Identification of the factors that exert an impact on a Port Energy Management System (PEMS) using a SWOT/PESTLE analysis. Source: Own elaboration based on data from ISO 50001 [33].

3.2. Internal Factors

- *Port-specific plan:* The development of a port-specific energy management plan that addresses the energy performance of a specific port. Both interviewees argued that it is essential to take into consideration the port's main characteristics and activities, as ports can have substantial differences in size, services provided and, ultimately, energy needs.
- *Clear port energy policy, management objectives and goals:* According to the interviewees, the development of a clear port energy policy that sets specific energy management objectives and goals plays a significant role in the design of a port energy management plan. This is because the achievement of these targets will be compared with the results from the adoption of the plan and will signal its efficient implementation or otherwise.
- *Compliance with existing energy policies, regulations and standards:* Taking into consideration any international, national or regional regulations and standards is an important element in the design process of the port energy management plan, as conflicting regulations and policies may undermine it.
- *Reduction of energy consumption:* Both interviewees agreed that the most important factor in the implementation of a port energy management plan is it achieving an improvement in the port's energy performance, which reduces energy consumption and associated air emissions. The measurement of the energy performance of the ports is based on the energy efficiency of their operations and the source of energy generation. Improved energy performance implies that less energy is required for meeting the port's energy needs, while power generated from renewable energy sources can also lead to reduced GHG emissions in ports.
- *Establishment of an energy baseline:* One interviewee highlighted the importance of establishing an energy baseline by gathering data on energy consumption and current energy needs. This baseline would serve as a starting point for the evaluation of the improvement in energy performance of the port as a result of implementing its energy plan.
- *Identification of Energy Efficiency Measures:* An assessment of the energy improving measures, based on various criteria (their potential to reduce CO₂ emissions, their cost-effectiveness, their implementability, available funding opportunities and others), should be implemented in the initial phase, as the application of these measures improves the energy performance of the port.
- *Cost of the energy efficiency measures:* The cost of introducing the identified energy efficiency measures was identified by the interviewees as among the main obstacles for the successful implementation of a PEMS.

- *Need for top management commitment:* Both interviewees emphasized the importance a top management delivering a clear statement of their commitment to improving the energy performance of the port in the design of a port energy management plan. Management and staff will adopt and integrate the energy management plan into the operations of the port, if and only if the commitment of top management to the reduction of energy consumption is clearly communicated to them [40,41]. Moreover, collecting people from different sectors of a port, such as different terminals, warehouses, the hinterland, gate operations and environmental department, etc., to form an energy team appears to be difficult.
- *Need for the continuous training of staff:* The energy efficiency training of the staff was also underlined by both interviewees as a crucial factor influencing the successful adoption of a port energy management plan. Previous experience from the implementation of the International Safety and Management (ISM) Code has shown that insufficient training and involvement of the staff constituted a major problem in the implementation of a safety management plan [42,43].
- *Need for accurate performance monitoring:* According to the interviewees, a port energy management plan should include monitoring of the energy performance of the various energy efficiency measures adopted and comparison with the required energy goals that were determined in the design of the port energy policy. In this way, deviations in energy performance can be identified and reviewed by the port management.
- *Need for periodic management review:* Both interviewees drew attention to the need for a formal management review that should constitute an element within any port energy management plan, as it is crucial for the continuous improvement of energy performance within the port. It is essential for the identification of existing deficiencies and instances of non-compliance with set targets, which both provide important feedback for revising the energy policy or adjusting the targets set.

3.3. External Factors

- *Reduction of energy costs and improvement of profitability:* Reduced energy consumption from the implementation of a PEMS leads to a reduction in the cost of satisfying the port's energy needs and, ultimately, to improved port profitability.
- *Competitive advantage (commitment to sustainable development):* Both interviewees mentioned that, by adopting an energy management plan, ports demonstrate their commitment to sustainable development and gain a competitive advantage in the marketplace by presenting themselves as socially responsible organizations.
- *Influence of the stakeholders:* Given that port-city municipalities and regional authorities have a great impact on port operations, their policies on energy consumption and efficiency can influence the decision on the development of a PEMS, as stated by both interviewees. As Fenton [44] points out, the active engagement of cities in port activities which target the abatement of air emissions from shipping and port operations, as well as the systematic involvement of key stakeholders throughout the development process, could enhance a port's efforts to manage the climate and the environmental impacts of shipping and other port operations.
- *Meeting future energy-related regulations:* According to the interviewees, a port energy management plan can assist ports in meeting future international, national or regional regulations. A good example is the European Directive 2014/94/EU, which obliges all EU ports to install OPS by the end of 2025, as well as to provide LNG fueling points in order to build a network of alternative fuel infrastructure and promote the use of alternative fuels like LNG [14].

- *Reduced impact of air pollutants on human health and climate change:* As mentioned by the interviewees, reduced air emissions brought about by the implementation of the PEMS means that the negative impact of port operations on human health and climate change will be also diminished, thereby reducing the external costs of port operations. The energy policy that sets the targets and objectives of the PEMS requires the installation of OPS in ports and the provision of LNG refueling points for the promotion of the use of alternative fuels. Given that air emissions depend mainly on fuel type, building a network of alternative fuel infrastructure and generating power from renewable energy sources lead to reduced air pollutants in the port area. Coming to the abatement of Volatile Organic Compounds (VOCs) related to the cargo handling of tankers, the first port authority installed in 2017 an Odor Control Unit (OCU) to reduce VOCs and substances that generate odors when loading bunker oil, as part of the PEMS.
- *Integration of energy efficiency management in the port's activities:* According to the interviewees, if implemented correctly, a port energy management plan could help ports integrate energy management into all port activities and organizational culture, thereby engaging management and staff and making them part of this organizational change.
- *Development of new energy efficiency technologies:* The structured framework of requirements for a PEMS would assist in the monitoring and accurate performance measurement of newly introduced technologies. This may provide a stimulus to the development process for new technologies.
- *Financing opportunities:* Both interviewees agreed that the implementation of a port energy management plan can help ports better prepare for funding opportunities. For example, the EU Poseidon Med LNG Bunkering Project is an example of a European energy efficiency program. The project is funded by the EU (50% EU support) and involves designing an LNG transportation, distribution, and supply (including bunkering) network and infrastructure for its use as a marine fuel in the East Mediterranean.
- *Wrong application of the energy management plan (due to organizational culture or staff/management resistance) leading to the opposite effect:* According to both interviewees, the major threat of a port energy management plan is related to its inappropriate or erroneous implementation. The integration of energy management into an organization's operations implies an organizational change which often meets resistance from the management and the staff. The shipping industry offers various examples of management systems (ISM Code, SEEMP) that have not been efficiently implemented due to a resistance to change and the lack of adequate training and engagement of the management and staff [45].
- *Additional funds:* The energy efficiency measures selected for the adoption of a port energy management plan usually imply high initial costs and investments and require external funding that may be accompanied by high business risk, which was underlined as an additional threat by one interviewee.

The identified internal and external factors that exert an impact on the adoption of a PEMS are now clustered into their PESTLE categories. Table 1 presents the internal and external factors that affect a PEMS, as well as the categories under which they fall.

Table 1. Internal and external parameters that affect a PEMS.

SWOT/PESTLE	Internal Factors	External Factors
Political	<ul style="list-style-type: none"> • Port-specific plan • Clear port energy policy, management objectives and goals 	<ul style="list-style-type: none"> • Influence of the stakeholders • Financing opportunities
Economic	<ul style="list-style-type: none"> • Cost of energy efficiency measures 	<ul style="list-style-type: none"> • Reduction of energy costs and improvement of profitability • Competitive advantage (commitment to sustainable development) • Additional funds
Social	<ul style="list-style-type: none"> • Top management commitment • Continuous training of staff 	<ul style="list-style-type: none"> • Integration of energy efficiency management in the port's activities • Wrong application of the energy management plan (due to organizational culture or staff/management resistance) leading to the opposite effect
Technological	<ul style="list-style-type: none"> • Identification of energy efficiency measures • Accurate performance monitoring • Periodical management review 	<ul style="list-style-type: none"> • Development of new energy efficiency technologies
Legal	<ul style="list-style-type: none"> • Compliance with existing energy policies, regulations and standards 	<ul style="list-style-type: none"> • Meeting future energy-related regulations (e.g., Directive 2014/94/EU)
Environmental	<ul style="list-style-type: none"> • Reduction of energy consumption and related emissions • Establishment of an energy baseline 	<ul style="list-style-type: none"> • Reduced impact of air pollutants on human health and climate change

Source: Own elaboration based on data from the interviews.

After the identification of the various parameters that affect the adoption of a port energy management plan, the interviewees assigned points to each factor category on a scale of 1 to 5 in order of importance for the development of such a plan. According to these findings, the factor categories that have the greatest impact on the successful implementation of a port energy management system are economic, social and environmental. Both interviewees assigned five points to human-related factors: top management commitment, continuous training of the staff, erroneous application of the energy management plan and integration of energy efficiency management in the port's activities, underlining the importance of engaging management and staff and making them part of the organizational change. Reduced energy costs and improved profitability were assigned four and five points by the interviewees, while additional funds that may be accompanied by high business risk due to the high initial costs and investments of the energy efficiency measures selected for the adoption of a port energy management plan were also ranked quite high (three and four points respectively). The interviewees also ranked high environmental factors by assigning four and five points respectively to the potential of a PEMS

to reduce energy consumption and related emissions. More specifically, the most important factors, according to our interviewees, are:

1. Reduction of energy costs and improvement of profitability;
2. Additional funds;
3. Top management commitment;
4. Continuous training of staff;
5. Integration of energy efficiency management in the port's activities;
6. Reduction of energy consumption and related emissions;
7. Erroneous application of the energy management plan (due to organizational culture or staff/management resistance), leading to the opposite effect.

An analysis of these factors is included in the following section, together with some policy recommendations that could help overcome the main challenges faced when developing or implementing a port energy management plan.

4. Recommendations and Discussion

Guidelines for the successful adoption of a port energy management system include both aspects that the individual ports could improve upon and best practices that could be adopted by the port industry, its organizations and the states in which ports are located (Figure 3).

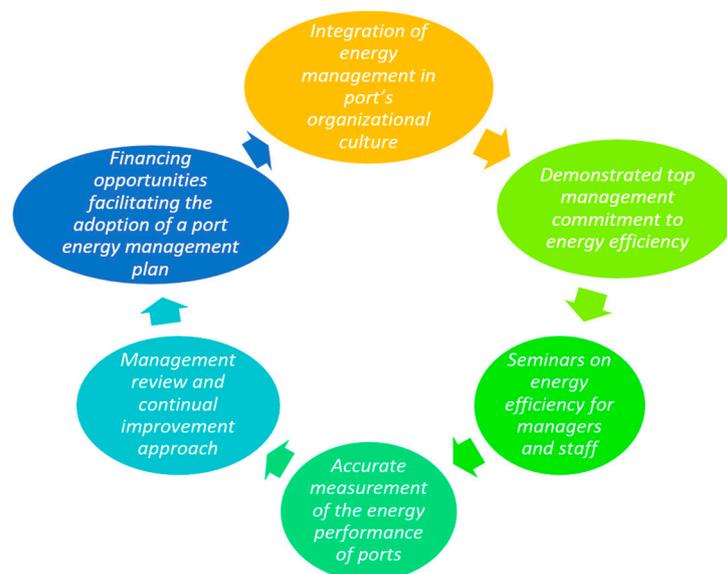


Figure 3. Guidelines and best practices for the implementation of a port energy management plan. Source: Own elaboration based on our results.

- a. *Integration of energy management into a port's organizational culture.* The greatest challenge for the successful implementation of a port energy efficiency management plan is related to the organizational change that it brings and the resistance that it may meet from the management and the staff. This could be overcome through the increased involvement in, and engagement of, the management and staff in the adoption of the port energy management plan, as well as their continuous training on energy efficiency matters.
- b. *Demonstrated top management commitment to improved energy performance of the port.* The integration of energy management in a port's culture can only be successfully achieved if the top management of the port demonstrates its commitment to the reduction of energy consumption by including energy management in its strategic policy and communicating this priority to the management

and staff. The ISO 50001 standard clearly defines the tasks of top management in a company. According to this standard, top management is responsible for: defining the area of validity of the energy management system, creating and updating the energy policy within the company, appointing an energy officer, providing the necessary resources (technical, staffing, financial, ensuring internal communication, defining the strategic energy objectives, ensuring meaningful energy performance indicators and executing the management review). Similar findings appear regarding the implementation of a shipping company energy management plan and system where special emphasis is given to the 'commitment at the highest level', energy review, energy efficiency monitoring and reporting and energy efficiency training of the staff [46].

- c. *Seminars on energy efficiency for managers and staff.* As the port energy efficiency measures are going to be implemented by port management and staff, their awareness of the energy policy of the port, as well as their continuous training and involvement in energy saving, are crucial for the successful adoption of a port energy management plan and their acceptance of energy management as part of the port's organizational culture.
- d. *Accurate measurement of the energy performance of ports.* The effectiveness of the various energy efficiency measures should be assessed through an accurate performance monitoring system that includes quantitative and measurable data, so that deviations from the initial energy goals are made apparent and reviewed by the port management.
- e. *Management review and continuous improvement approach.* The continuous improvement of the energy performance of ports can only be achieved through periodic management review. Based on the results from the adoption of the energy efficiency measures and their comparison with the required energy objectives, new energy objectives could be set targeting greater reductions in the port's energy consumption. These results are similar to those obtained by the implementation of SEEMP in vessels and indicate that effective energy management planning should include stricter requirements, like those proposed by the ISO 50001 standard [44].
- f. *Financing opportunities facilitating the adoption of a port energy management plan.* Ports should be given financial assistance for the design and development of their energy management plan, such as funding from various international or regional institutions. These recommendations are included in the possible measures for the abatement of the intra-organizational and economic barriers that lead to the energy efficiency gap in shipping [45].

These recommendations are in accordance with the requirements that ISO 50001 sets for the application of an energy management system (implementation and operation of the energy plan, checking of the results obtained, review of the effectiveness of the policy and continuous improvement of the energy management plan). Indeed, the adoption of the ISO 50001 standard could serve as a complementary tool for the design and application of a port energy management plan. Recent relevant experience regarding the implementation of the SEEMP in offshore activities has shown that several requirements necessary for its successful adoption are missing, but that many of them are actually covered by the ISO 50001 requirements [46].

5. Conclusions and Policy Implications

This paper has identified the main internal and external factors that exert an impact on the successful implementation of an energy management system in ports. Given the fact that the environment in which ports operate is quite complex and encompasses various distinct and distinguishing characteristics, a SWOT/PESTLE analysis has been applied to identify and highlight the political, economic, social, technological, legal and environmental factors that have a positive or negative effect on the adoption of a port energy management plan.

According to the findings of this analysis, the adoption of the ISO 50001 standard could serve as a complementary tool for the design and application of a port energy management plan, as it contains specific requirements (implementation and operation of the energy plan, checking of the

results obtained, review of the effectiveness of the policy and continual improvement of the energy management) that could help overcome possible inefficiencies and weaknesses of the plan. In addition, this could assist in the integration of energy management into the port's organizational culture. Given the fact that many ports are currently focusing on the reduction of their energy consumption and the development of a port energy management plan, this paper's results have particular significance in that they could enlighten and inform some aspects of port energy management and contribute to the discussion on the achievement of sustainable maritime transportation.

The major limitations of this research are that the data sources from two port authorities cannot be considered as representative of port environmental sustainability practices in general. This is particularly so as the specific port authorities are located in Northern Europe, where high sustainability requirements in sea freight transport are applied, and they demonstrate a very strong commitment to sustainable port operations. The results might be different in small or medium size ports or other regions of the world. Further research is needed, therefore, to support or supplement the findings from this study, including different port categories, operated with different governance models and serving different categories of traffic.

The study provides implications for further research. More case studies on the development of port energy management systems could be analyzed, giving some insight into the attitudes of smaller ports towards the adoption of such a plan. The case study methodology could also be supplemented with quantitative studies that could further explore the potential development of a port energy management system.

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