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Research Article

ENERGY EFFICIENCY IN PORTS WITH A GREEN PORT PERSPECTIVE: A CONCEPTUAL FRAMEWORK

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ABSTRACT

Ports can be defined as the main centers of maritime transportation and trade, which provide the continuity of international trade as well as provide loading and unloading services to ships. As a result of the globalizing world, the importance of ports has continued to increase day by day because trade can be made faster and more efficiently. The fact that the ports are located at such a critical point, the increasing transaction volume, and the development of environmentally sensitive systems bring along an inevitable process of change. At this point, with increasing awareness, the concept of a green port has been developed. Green port is an approach that aims to minimize the adverse effects on the environment and ecosystem. While the ports continue their activities to achieve this goal, it aims to use systems that use energy resources efficiently and effectively while meeting energy needs and having the most negligible impact on the ecosystem. The equipment that maintains port operations, port equipment, and ships berthing in the port are energy-consuming elements. This study aims to analyze the energy efficiency in ports from a green port perspective by using the literature review method. In this context, the energy efficiency practices of two of the leading ports in Europe were examined. As a result of the qualitative analysis, it has been determined that the studies of the ports for energy efficiency have reached a critical point, and an approach compatible with the green port principles has been exhibited.

Keywords: *Green port, Energy efficiency, Sustainable energy, Maritime transportation*

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1. INTRODUCTION

With the consequences of climate change and increasing awareness, the concepts of decarbonization and energy efficiency, which have become more prevalent in recent years, make green transformation a necessity in ports. The green port is a product of the long-term commitment to the sustainable and climate-friendly development of the port's infrastructure (Pavlic et al., 2014). Green transformation in ports is addressed to express the "green port" concept in the literature. It is a policy to include environmentally friendly methods in the port's activities and operations, thus increasing efficiency and minimizing the adverse effects on the environment and ecosystem (Demir, 2021). The term "green port" was first announced at the United Nations (UN) climate conference in 2009, in other words, at the Copenhagen summit (COP15). At the conference, the importance and necessity of reducing emissions originating from ports and ships were emphasized (Demir and Arslan, 2021). It is seen that energy efficiency and green port principles and policies are directly related. In short, it is possible to say what criteria a port with a green perspective should consider, such as waste management, sustainability, water, air, and energy management, and sustainable port activities (Satır and Doğan-Sağlamtimur, 2018). In the maritime sector, it is stated that the emission generation number of ports is approximately 3%. Although it can be considered low for the port sector in maritime, it is seen that it is significant when the greenhouse gas (GHG) emission rates are considered (Alamoush et al., 2020). If we need to list the motivation and importance of decarbonization studies in ports as follows (Alamoush et al., 2022):

1. Compliance with international regulations of the International Maritime Organization (IMO) and decarbonization regulations
2. Ensuring green port practices and contributing to sustainability in ports
3. Within the scope of harmonization with the UN sustainable development goals, target 13, climate change mitigation, and target 7, implementation of renewable energy use targets
4. Contributing to the expansion of the corporate social responsibility vision of the ports and achieving cooperation and harmony with the stakeholders
5. Reducing greenhouse gas emissions from port operations
6. Contributing to the corporate image of ports with the green port concept and reduction in energy costs

This paper evaluates the green port concept in the framework of alternative energies. The main distinction of this paper from the scarce literature on Green Ports and Ecoports is that it revolves around renewable technologies.

2. DECARBONIZATION AND ENERGY EFFICIENCY APPLICATIONS IN PORTS

2.1. Alternative Fuels and Use

It is possible to obtain the energy needs of the equipment used to maintain the activities in the ports from different fuel sources such as liquefied natural gas (LNG), hydrogen, biomethanol, and biofuel obtained by recycling wastes and biomass, which are expressed as alternative energy sources. Considering the use of LNG in ports, it is seen that it is used in port internal operations and activities as well as used to power the ships in the port. While the reduction in emissions of air pollutants compared to petroleum-based fuels is seen as a positive feature, the need for extensive infrastructure for storage and bunkering points is a disadvantage (Sifakis and Tsoutsos, 2021). With the use of LNG, a significant decrease in NOx and SO2 emissions can be achieved, and an almost one-fourth reduction in CO2 emissions can be achieved (Yun et al., 2018).

Hydrogen is not a natural energy source; other energy sources are needed to ensure production. It is essential to achieve hydrogen energy by choosing and utilizing renewable energy sources to produce it since it is possible and beneficial in terms of GHG reduction (Elüstün, 2021). Although the use of biomass and biofuels in ports is very new, special equipment and hardware are required to generate and use this kind of energy. High investment costs and the requirement for complex production tools are seen as other difficulties (Sifakis and Tsoutsos, 2021).

2.2. Renewable Energy Resources and Use in Ports

Renewable energy sources in ports are the general expression of preferred energy production sources due to their positive contribution to reducing greenhouse gas emissions (Figure 2.1). It is possible to express renewable energy sources as wind, solar, wave, and geothermal energy (Acciaro et al., 2014). Solar energy is described as the radiant energy that emerges from the fusion process in the solar core because of the conversion of hydrogen gas to helium. It is a clean and renewable energy source that can meet the amount of energy needed by the world with approximately 3.9x1026 W of power emitted by the sun. Photovoltaic (PV) solar modules are the technology used to convert the solar energy source into electrical energy (Ministry of Energy and Natural Resources, 2022a). Solar energy is proposed as an energy system used in ports to reduce carbon emissions (Lam et al., 2017). Radiation originating from the sun heats the earth at different rates. As a result of this warming difference, changes occur in the temperature, humidity balance, and pressure of the air. All these changes cause air movements, and these air movements create winds. Wind energy is the name given to the use of these changes in air movements as energy. Approximately 2% of the solar energy reaching the Earth's surface is converted into wind energy. The high initial investment cost of using wind energy as an energy source, the low-capacity factor, and the variability of energy production can be expressed as disadvantages. Despite all these disadvantages, the advantages of wind energy are:

• Being an environmentally friendly and renewable energy source,

• No possibility of extinction or increase in price over time,

• Low maintenance costs of the system,

• Its technology is relatively simple to implement and operate,

• The establishment of the facility in the short term (Ministry of Energy and Natural Resources, 2022b).

The oceans, which cover 71% of the world, provide opportunities for wave energy. Wave energy is recognized as one of the most promising methods among renewable energy sources. It is estimated to produce a maximum of 2000 terawatt-hours (TWh) and at least 1 TWh annually (Li et al., 2021). According to the intergovernmental Panel on Climate Change (IPCC) (2012), geothermal resources are thermal energy stored in trapped steam and water from the Earth's interior. In geothermal energy, the power of heat is used to generate electricity. Antwerp and Hamburg Ports, which are European Union (EU) ports, generate energy from geothermal sources located close to the surface (Alamoush et al., 2020). As GHG emissions cause concerns on a global scale, the interest in renewable energy sources for energy production and transportation sectors is increasing daily. Promoting and using renewable energy is vital in tackling climate change (Yorke et al., 2022). Also, Aregall et al. (2018) identified only 76 out of 365 ports that apply the green port concept to their hinterland dimension.

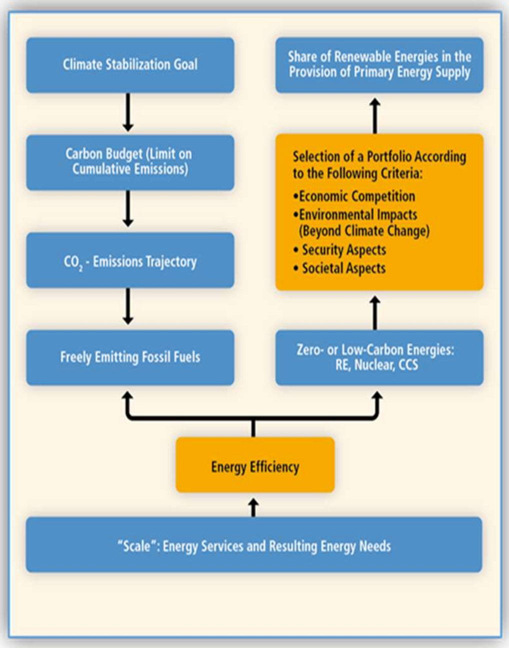

Figure 2.1: The role of renewable energies in a portfolio of zero or low carbon abatement options (IPCC, 2012).

2.3 Alternative Power Systems Used in Ports

2.3.1 Cold Ironing

Although the sources of pollution in the ports are very diverse, the ships in the ports are responsible for a large part of the air emissions in the ports. The new system that can be used instead of the fuel generators used by the ships for their energy needs during berthing and waiting at the port is expressed as "cold ironing." The definition is the transportation of energy to the vessels through the systems installed in the port rather than meeting the energy needs of the auxiliary engines of the ships waiting at berth (Ballini and Bozzo, 2015). The operation can be conveyed in different ways: land power supply, shore-to-ship power supply, and shore-to-shore power supply. Currently, it is seen as the most effective way to reduce emissions from ships waiting in berth. The cold ironing power system consists of three parts. These are the port power system, the port-ship power system, and the ship power system. The visual representation of the system is shown in Figure 2.2 (Chen et al., 2019).

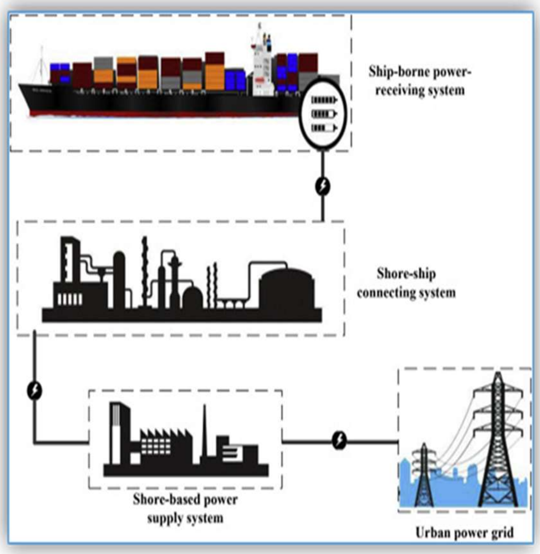

Figure 2.2: Cold ironing system (Chen et al., 2019).

It is possible to say as an advantage that the shore power supply system allows feasibility to be made in the short-term, and all the necessary components have been available for many years. The biggest obstacle to the system's applicability is the incompatibility between the port and ship connection points. While it does not pose a problem for ships that follow the same route all the time, it is not suitable for vessels operating between ports on different routes. This lack of standardization has been overcome with the standards developed by the Institute of Electrical and Electronics Engineers (IEEE). In addition, the low cost of adapting the system to newly built ships can be considered an advantage. However, the high initial investment cost of the system in ports is seen as a disadvantage (Daniel et al., 2022). 70% of the gases in the ship plume are emitted within 400 km of the shore. Besides greenhouse gas emissions, these pollutants are causing severe health and environmental problems (Eyring et al., 2010; Cullinane and Bergqvist, 2014). One of these pollutants, namely black carbon, even burns off the low marine clouds if it resides in the cloud layer, hence changing precipitation patterns (Johnson, 2004; IMO, 2022). The vast majority of oceangoing ships use fossil fuels for their auxiliary engines, which adds to maritime transportation's anthropogenic air pollution budget (Deniz and Zincir, 2016). Ships mostly use heavy fuel oil and marine distillate fuels to generate electricity for lighting, ventilation, cooling, heating, communication, and cargo operations (IMO, 2021; Seyhan et al., 2022). In Figure 2.3, on-shore power supply technologies, another name for cold ironing, whose purpose is to reduce the density of carbon-based consumption via offering electricity from the shoreside, are given.

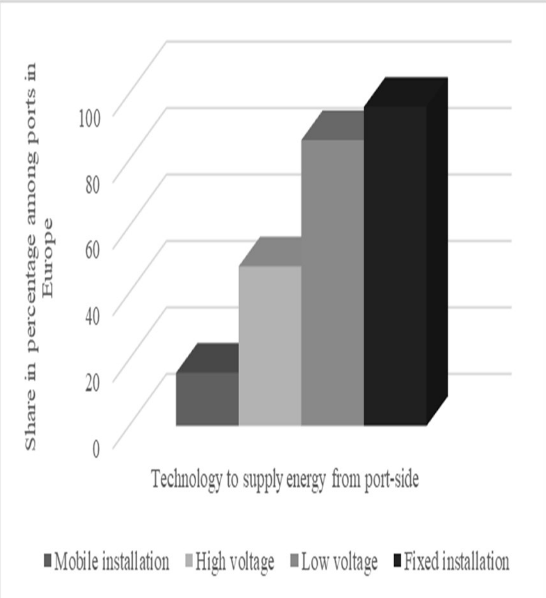

Figure 2.3 Share of ports with on-shore power supply availability in Europe by technology (ESPO, 2019).

3. USE OF RENEWABLE ENERGY IN EUROPEAN PORTS

Within the scope of the study, two ports operating in Europe were examined. These ports are the Port of Rotterdam, which is in the Netherlands and is the largest in Europe, and the Port of Antwerp, operating in Belgium.

3.1. 3.1 Port of Rotterdam

The Port of Rotterdam has a surface area of over 12,600 hectares and 70 kilometers of quayside without adding the dolphins and buoys to give a ship to ship or repair service (Port of Rotterdam, 2022a). Thanks to its hinterland connected to the Central European region, the Port of Rotterdam, which annually hosts approximately 30 thousand ships, is the busiest in Europe (Fransen and Davydenko, 2021). The findings of the review conducted within the scope of energy management for the Port of Rotterdam are as follows. It has been observed that the use of wind energy within the scope of renewable energy is done quite actively. The Port of Rotterdam can generate wind energy with a power capacity of approximately 200 MW.

Increasing the capacity by 150 MW is among the plans of the port. Another renewable energy usage area of the port is biomass. It is planned to provide hydrogen energy with biofuels, an essential step in reducing emissions. The port's most important renewable energy work is the generation of hydrogen energy, named "green hydrogen" from renewable energy sources that are also environmentally friendly. With this vision, the port continues its projects to execute its 2025 targets. It has also been seen that the port has been very successful in energy production using solar energy (Port of Rotterdam, 2022b).

3.2. Port of Antwerp

The Port of Antwerp is the second-largest port in Europe. It is idealized that emissions will be reduced by 2050, and the port will be sustainable with the energy management and vision of the port. In this context, it is seen that energy transition studies with a greener perspective gain importance, and action is taken in this direction. Using solar energy as an energy source in the port produces heat, expressed as green heat, and uses it for heat processes. Another renewable energy source used by the Antwerp port is biomass energy. In addition, more than 200 MW of energy can be produced annually with wind energy at the port. The port continues its new projects with its partnerships. One of the most important of these, the "power-to-methanol" project, aims to reduce CO2 emissions by at least eight thousand tons. In addition to all these activities, the port's work on generating energy with hydrogen continues (Port of Antwerp, 2022).

4. DISCUSSION

The main limitation of the cold ironing technology is delivering such high power to the shore. The improvements are needed by port authorities to further adapt their port to the greener approach. The incapability of powering cranes enough to carry two containers at a time with the provided electric technologies is holding back the further decarbonization process of maritime transportation.

The Port of Rotterdam is the largest seaport in Europe and the tenth-largest container port in the world. At the same time, this port is also one of the first smart and green ports in Europe. The port of Rotterdam uses environmentally friendly energy sources such as biomass, biofuel, green hydrogen, solar energy, etc. This port has especially smart applications at the container terminal. The Port of Antwerp is the second-largest port in Europe and the fourteenth container port in the world. The Port of Antwerp is using solar and biomass energy in the port area.

The European Sea Ports Organization (ESPO) established the EcoPort (Green Port) initiative in 1997. One hundred eight ports are members of this organization. If a member port has completed the requirements, ESPO also gives the Port Environmental Review System (PERS), which resembles green port certification. It is not compulsory, but 35 ports have this certification. This certificate and being a member of this organization has prestige and stands out in the competition. The Turkish Ministry of Transportation started a Green Port certification program in 2011. Twenty Turkish ports have received Green Port certificates since 2011.

Cold ironing technology is part of the Green Port but is not mandatory. For example, only one port in Turkey has this technology. Marport, a container port located North of Marmara, has a cold ironing system but is not frequently used by ships.

5. CONCLUSION

With the increasing awareness of climate change, it was seen that the use of renewable energy in ports and the transition to alternative fuels are more frequently adopted by the ports. It was found that ports are given importance in the transition from carbon-intensive sources to renewable sources, on which ports are dependent, both because of their targets of being more sustainable and because they are more efficient in terms of cost.

Operations of ports demand a relatively higher energy intake on a single move due to the many aspects of modern maritime transportation. The infancy of renewable fuels in such heavy duties critically sets drawbacks in this industry. Nonetheless, some visionary port authorities are setting examples. As seen in the ports of Rotterdam and Antwerp, which are the two ports given as examples in this study, it is seen that solar energy is utilized in the transition to renewable resources in the ports. In addition, it was seen that investments were made to meet the energy needs by using wind energy. It has been observed that replacing port equipment with electrical energy-operated equipment significantly reduces the number of emissions originating from the port. In this context, all the steps ports take to reduce fossil fuel emissions are considered necessary.

Another substantial issue is the air pollution caused by ports primarily located in dense areas. A lesser amount of fossil-based fuel used in the processes denotes minor respiratory issues. The ports should be held accountable to third parties. Therefore, aspects of a cleaner atmosphere can be ensured via renewable and alternative fuels. The technological readiness levels are vital for applying incentives or enforcements to the industry. The maritime transportation policy framework mostly limits the transportation network to a single dimension: vessels. However, if a holistic approach is adopted, market-based measurements may be applied to ports to promote electrification. Thus, such an act can be the catalyst for the much-needed link between the improvements of renewable energy and the port infrastructure.

Measurement of technological readiness of port's renewable energy investments is entitled to further discussion as well as its compatibleness to the existing situation. The debate about using alternative fuels in ports is another must-expand issue via in situ measurements. Satellite tracking of anomalies observed with and without renewable energies will most probably highlight the effectiveness as well.

DECLARATION OF COMPETING INTEREST

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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