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Research Article

Renewable Marine Energy Generators and Integration in Commercial Ports' Infrastructure

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ABSTRACT

This paper evaluates the energy demand in seaports and identifies the main energy consumers. We analyze various options to cover this energy demand from marine renewable energy sources. A review is made of the most suitable wind, photovoltaic and wave energy converters for installation in ports. A prospective study for Valencia port is made, considering the port energy demand evolution and the port expansion plans. We conclude that ports should lead to become energy self-sufficient by the implementation of renewable marine energy integrated in their infrastructures.

Keywords: Marine renewable energy; Wind energy; Photovoltaic energy; Wave energy; Ports; Greenhouse gases

INTRODUCTION

Seaports are major energy consumers. The demand for energy in ports is currently covered using a variety of sources, depending on the type of consumer. For example, the existing yard machinery, involved in the handling of goods passing through the port terminals, generally uses fossil fuels such as gasoil or petrol; while the remaining port consumers are mostly powered by electricity supplied by the corresponding distribution company.

Energy demand at ports is mainly produced by goods and passenger terminals, since these terminals, especially those dedicated to the handling of containers, use a great deal of electrical machinery (ship-to-shore cranes, refrigerated container connections, etc.). However, energy demand also occurs in other places, such as the common areas of the ports (roads, public docks, and so on).

The trend in ports is towards an increasing level of automation and electrification of container terminals, which will bring a corresponding increase in energy demand in the coming years. Spanish port authorities, as promoters of policies aimed at reducing the impact of port activities on the environment, are encouraging the implementation of low carbon technologies. These initiatives include the generation of renewable energies, and, of course, energy sources of a marine origin are perfect candidates for use in ports. According to the data published in the 2016 Greenhouse Gas Verification Report (GHG) of the port of Valencia, energy consumption associated with auxiliary engines, generally fueled by diesel oil from ships in port, accounts for 37% (156 GWh) of the total energy consumption of the site [1].

According to the ECOFYS report 'Potential for Shore Side Electricity in Europe' published in January 2015 [2], the energy demand of all merchant ships calling European ports could reach 3,543 GWh per year in 2020. This figure represents, according to the same report, approximately 0.1% of the overall energy consumed in Europe in 2012. According to the report published by the Spanish Port System Authority (SPS) state port authority entitled: 'Measures for the provision of electrical supply to ships in the ports of general interest' in October 2016 [3], the potential demand from the SPS is around 52 GWh per year. As few ports in the SPS can meet the potential energy demand that will be required in the short term, it is necessary to explore alternative sources of generation that guarantee autonomy and feasibility through self-supply.

The objectives set out in the EU Commission communication 'Clean Power for Transport: European Strategy on Alternative Fuels', COM (2013) [4,8], should be considered when switching to cleaner generation sources and enhancing the importance of generation from renewable sources. The above leads us to look for sources of energy other than traditional fossil fuels to cope with the increase in demand that is being generated in the ports and which is expected to increase, mainly due to the regulatory imposition of reducing emissions at a global level (and therefore also in maritime transport). Moreover, the uncertainty regarding

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the evolution of energy prices, especially in relation to fossil fuels, places energy efficiency as an opportunity for ports to develop by making them less dependent on traditional energy sources. In this paper we will evaluate the potential implementation of renewable marine energy converters (wind, photovoltaic and wave) to supply energy into a commercial port such as Valencia. In Section 2 of this paper, a review is made of the port's energy consumption making special focus on those produced at the port of Valencia. In section 3 different marine renewable energies suitable for the deployment in a port infrastructure is reviewed. The simulation and estimation of installed power of different marine energy generators at the port of Valencia .

Marine renewable energies suitable for ports' infrastructures

As a primary consideration, the most suitable areas should be the ones where the distance to the final consumer is shorter. However, other considerations must be taken into account for the choice of the most suitable place, such as: Use compatibility, Environmental impact, Social impact, Neighbourhood impact.

The following is a short description of marine energy resources and a discussion of their suitability for seaport energy exploitation.

Offshore wind power

Large scale wind energy production is discarded for ports, since installation, operation, and maintenance are only justified when scaled up in offshore wind farms [5-6]. Some wind turbines can be integrated into the port facilities, but installation of a windfarm requires an amount of space not usually available in the main ports.

Ocean thermal energy conversion (OTEC)

The electricity is produced by using the temperature difference between deep cold ocean water and warm tropical surface waters. OTEC plants pump large quantities of deep cold sea water and surface sea water to run a power cycle and produce electricity. Recently, higher electricity costs, increased concerns for global warming, and a political commitment to energy security have made initial OTEC commercialization economically attractive in tropical island communities where a high percentage of electricity production is oil based [7]. However, large-scale production by using this technology is only suitable offshore.

Marine current energy

This consists on taking advantage of the kinetic energy of marine currents. This energy is captured through energy converters like wind turbines, although under water [8]. Its application to ports is very limited, because submarine currents near ports are not strong enough to run turbines.

Tidal energy

Tidal energy involves taking advantage of the tides produced by the gravitational action of the sun and moon. It is only feasible in areas where the difference between high and low tide is high. It is based on the storage of water in a reservoir with gates that allow the entrance of water for electric generation [9]. In Valencia there is no significant tide difference and therefore, its application is out of question .

Wave energy

Wave energy is the use of the movement produced by waves. It occurs irregularly since it depends on the friction between the air and the surface of the sea. This technology is under development and has not yet reached full potential [10]. According to the Intergovernmental Panel on Climate Change (IPCC) [9], there is a potential of about 32,000 TWh per year, considering all areas with energy density from waves greater than 5kW/m. A potential of 1,000 TWh/year is estimated for Europe [10]. Among the wave power converters, the so-called shoreline devices, deserve special attention, due to the possibility of coupling these to existing infrastructures in ports, with the consequent savings in deep water anchoring and long-distance wiring. This approach brings advantages for operation and maintenance costs when compared to installations far from the coast. Wind, solar and wave energy will be considered for the purpose of this paper.

Wind, photovoltaic and wave generators deployment assessment at the port of Valencia

Based on a recent assessment report for the implementation of wind energy generators at the port of Valencia, the estimated resource was around 5.5 m/s, which is in line with the estimations from [6,7], by using the corresponding extrapolation. There are several options for the deployment in terms of total installed power **Figure 2.** The annual estimated power (AEP) would be in the region of 37 GWh. This energy would cover around of 50% of the energy needs of the port of Valencia, according to could be covered.

Figure 1: Port of Valencia's future expansion project with the potential location of three wind power generators A1, A2 & A3. Source: Port Authority of Valencia.

According to the estimates from the PAV, around 12,650 panels with a total power of 5.5 MW and a net production of 8 GWh/year, could be located on the roof of a new vehicles storage silo covering almost 10% of the total consumption of the port of Valencia.

And last, there is a potential for the implementation of wave energy converters integrated into the new breakwater of the port expansion. This choice is made due to the fact that the possibility to design and built the converter at the same time that the breakwater is something that does not happen very often and it bring us the opportunity to create synergies and thus reduce the budget as if we would build the two structures separately.

Wave power generation devices can be classified according to the technology used [14 - 16]: Overtopping devices (OTD), Wave activated bodies (WAB) and Oscillating water column (OWC). Of those potentially integrable within the breakwater structure, we would choose either the Sea-wave Slot-cone Generator Type (SSG) or the Overtopping breakwater converter (OBREC), as we consider, before entering in deep detailed into its design and project, that an overtopping device could match better with the breakwater infrastructure.

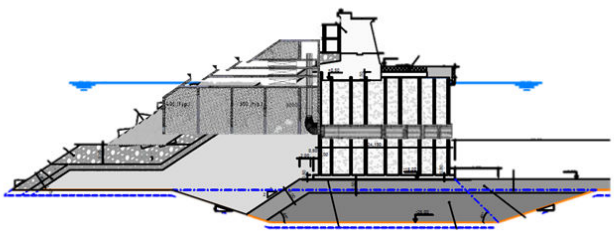

Figure 2: Simulation of OBREC integration into the new port's breakwater source: port authority of valencia.

The energy generation estimates are around 3 GWh /year. If we could get the necessary financing for the three projects, the total energy production could reach a figure between to 48 GWh/year, production enough to cover 70% of the total energy demand of the port of Valencia. With the previously mentioned three projects, we estimate that the Port of Valencia carbon footprint, could be reduced by 25%, considering the data.

CONCLUSION

The fact that the maritime transport will keep on growing in the future will lead to a huge energy consumption from different origins, likely from renewable sources. However, this energy should neither be supplied directly from the grid nor transformed into electricity from fossil fuels, we must find another way to for the self-sufficiency of the ports in terms of energy. Ports have open surfaces, walls, breakwaters, and other infrastructure where renewable energy generators could be deployed. This deployment causes little environmental impact compared to other locations, such off-shore or on-shore. If a port expansion is used as an excuse for the implementation of renewable energies in ports, the budget of the farm building could be considered as part of the infrastructure and the extra cost should not be as high as if the farm is built on an existing port infrastructure. Wave, wind and solar energy have been assessed along this paper and the preliminary results are promising as we could switch almost 70% of the total electricity from the grid into renewable energy to cover the port's energy needs. There are still some regulatory and financial constrains that should be shaved, but this is a matter of time and we will soon see our ports equipped with renewable energy generators to meet the targets set on the Paris.

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