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A proposed roadmap for delivering zero carbon fishery ports

Ateyah Alzahrani[a,b,*], Ioan Petri[a], Ali Ghoroughi[a], Yacine Rezgui[a]

[a] *School of Engineering, Cardiff University, Cardiff, United Kingdom*

[b] *School of Engineering AlQunfudah, Umm Alqura University, Makkah, Kingdom of Saudi Arabia*

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Abstract

Many seaports are facing increasing pressure to reduce their carbon footprint, while increasing their energy efficiency and global competitiveness. Moreover, energy consumption in seaports is continuously monitored to manage the increasing energy costs, these rising costs are reflected in the increased fuel demand. The fishing industry is one of the most energy intensive activity at seaports. In addition, the global human consumption of fish increased dramatically from 1950 to 2012. This paper will develop a roadmap to convert fishing ports into carbon-free ports. A number of techniques and methodologies will be used to analyze energy consumption in the port and buildings, and will include sustainability informed decision making. The overall objective of the net-zero port is to reduce energy dependence from the national grid by taking advantage of the electricity produced locally from solar energy. The roadmap that we have developed will contribute to the emergence of carbon-free fishery port ecosystem that can implement sustainable energy practices, including an assessment of the quality of the energy used in the fishery port and informed practices for promoting carbon-free societies.

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Keywords: Zero carbon port; Energy modeling; Energy auditing; Renewable energy; Decision making; Simulation; Smart grid; Roadmap

1. Introduction

The economies of many countries are based on trade through maritime transport and about 80% of the total global trade volume crosses through the seas [1]. Maritime trade in the shipping and shipping operations play a central role in addressing People demands for basic and secondary commodities [2]. However, maritime activities have contributed to adverse environmental effects, which leads to an increase in the percentage of carbon emissions in ports and coastal cities. This is directly affected by the increasing population and economic growth in developed countries, and the consequent rise in supply and demand [3,4]. It has been estimated that the percentage of emissions from marine activities is about 3% of the total global emissions and emissions from ships constitute the majority of the total emissions from marine activities [5]. In the last decade, several international alliances have been established

* Corresponding author at: School of Engineering, Cardiff University, Cardiff, United Kingdom.
E-mail addresses: Alzahraniaa2@cardiff.ac.uk (A. Alzahrani), PetriI@cardiff.ac.uk (I. Petri).

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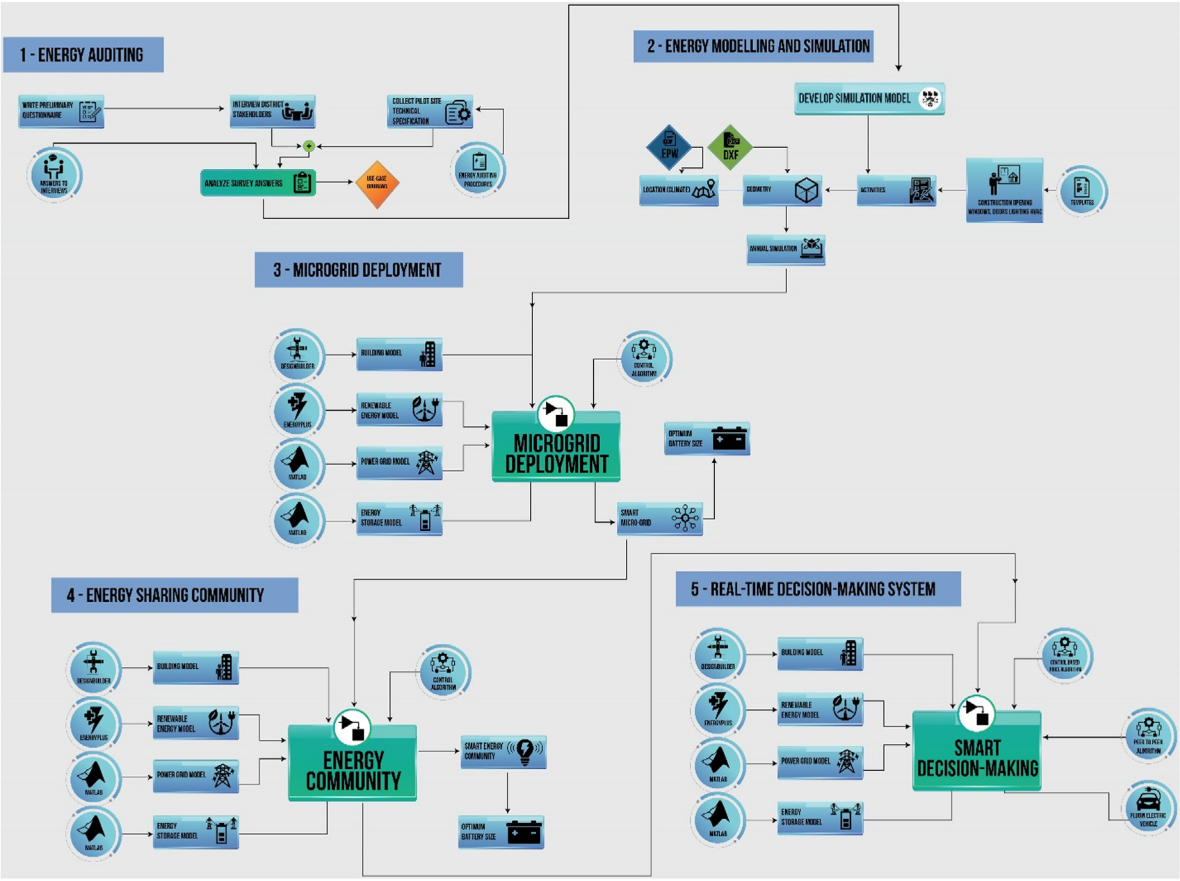

Fig. 1. Proposed roadmap to deliver zero-carbon fishery port with an energy community.

to limit carbon emissions globally through UN programmes, which directly call for carbon emissions to be dropped, and for global warming to be controlled by implementing the required policies and laws [6–8]. In addition, incentives for expanding and supporting clean energy have been implemented through funding renewable energy programmes, as well as lowering emissions of carbon in the most important sectors (e.g. in industry) [9,10]. The European Union (EU) has set ambitious objectives to address the climate agenda by: (a) decreasing greenhouse gas emissions, (b) ensuring the security of supply chains, and (c) improving the EU's competitiveness [11].

The fishing industry is one of the main activities of many seaports. In addition, the global human consumption of fish increased dramatically from 1950 to 2012. The proportion of fish processed world-wide has increased from 20 million tons to more than 136 million tons in this period. This has increased the pressure for fish processing industries to use energy from different sources to meet the demand of fishing and for fish processing operations [12–14]. Several parameters can influence the energy used by the fishing industries, such as: (i) seasonal variations, which can increase the fishing industry's demand for energy; (ii) the weather can have a significant impact on the total processed fish during a year; and (iii) the number of fisheries and boats can also affect total energy use. The energy used for fish processing industries can have two main operating modes: (i) direct use (e.g., lighting system, heating and washing machines); and (ii) indirect use, through converting the power to another form of energy (e.g., the cooling cycle and freezing equipment). However, increased energy demand from the fishing industry increases the cost and CO_2 emissions. Consequently, the fishing industry should move towards more secure, cleaner, and more sustainable energy solutions. This study argues that the new smart energy systems and techniques that have recently emerged are able to meet the requirements of the fish processing industries through increased use of renewable energy and smart energy management. Many seaports are facing increased pressures to reduce their carbon footprint, while also increasing their energy efficiency and global competitiveness [15,16]. Moreover, energy consumption in seaports must be continuously monitored to manage the increasing energy costs, these increased costs are reflected in the increased fuel demand [17]. This study proposes a roadmap that will help to address and limit carbon emissions at fishery ports. The proposed methodology has been applied by Milford Haven port authority under the piSCES research project, which aims to introduce smart grid technology that can reduce the costs and carbon impact of electricity systems in the fishery industries. As shown in Fig. 1, the proposed roadmap plan consists of five stages, starting with an energy audit, developing energy simulation models, building a micro-grid model, sharing energy with local community, and finally applying smart real time decision-making systems.

2. The key stages of the proposed roadmap

Our roadmap aims to convert fishing ports into carbon-free ports through several techniques and methodologies. It begins by understanding the nature of consumption in the port, it then builds and develops a model to simulate the energy systems. It will then develop and implement a micro-grid, and then expand the network to include the local community. Finally, a smart decision-making system will be built that helps to reduce energy dependence on the national grid and takes advantage of the electricity produced locally from solar energy. The next section will discuss this roadmap in more detail.

2.1. Conducting an audit of the fishery port's energy systems

The first part of the process of transitioning to a zero-carbon fishery port is to visit the port and understand the nature of its operations. It is essential to meet the energy manager and the staff who work permanently at the site. This step is known as a site visit in the procedure of energy auditing methodology. This action will help to gather information about energy systems and understand the behavior of energy consumption in these systems. Next, it is important to get access to the energy utility bills and analyze them over a period of at least 24-months to understand the behavior of energy consumption in different seasons. In addition, it will help to investigate operation in hot seasons that have high levels of energy consumption. Therefore, it is vital to get data for 2 to 3 years of energy consumption, which will help to build an accurate analysis for the port's activities. The port authority should provide requirement data of all appliances and the daily data sheets of operations, which will help to analyze the energy use and compare it with utility bills to determine the high energy consumption appliances and the peak times. The final stage in the energy auditing process is to analyze and recommend opportunities to save energy by replacing inefficient appliances, which will help to reduce energy consumption in the building. It is crucial during an energy audit to investigate the awareness about carbon emissions at the seaports and understand its impact in the total lifecycle. This will also help to identify the level of preparation to accept updates in the overall energy system at this seaport. In addition, it will help to introduce key workers and port's members to the importance of the transition of energy systems to become clean energy resources.

2.2. Development of a simulation model for energy systems at fishery port

The role of modeling and simulation of energy system is not only to understand the behavior of energy in period but also to save the time and money that could be spent in real-life investigation of energy usage. The new energy simulation tools help to identify the areas of high energy consumption at a specific time. In addition, it will help to model the exact geometry of real-life buildings. It will also build a similar environment for the target building. Energy simulation tools offer a smart platform that will help to propose different scenarios of energy saving without effect the overall system. It can also help to investigate different scenarios by changing the input variables to see the impact on the overall system. This will help to determine opportunities of promising areas to save energy and reduce cost and carbon emission. However, a simulation is a virtual environment, and it cannot change energy consumption in real life—it can only help to understand the nature of energy consumption in the buildings and find the main parameters that effect the overall energy system. In addition, energy simulation will help to investigate the capability of local energy demand to be meet proposed local energy supply, such as solar, wind or tidal.

The core part of this study was a simulation of an energy system at a fishery port to develop a smart energy system. The port consists of a group of buildings as seen in Fig. 2 with different functions, some of which are used for commercial purposes and some of which have been leased to companies operating in fish industry. Buildings

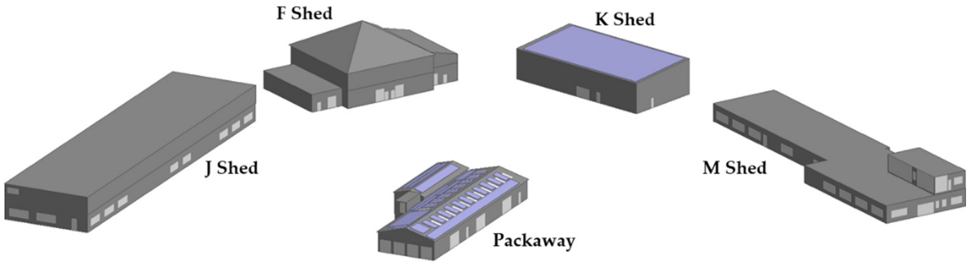

Fig. 2. Simulation models of clusters at fishery port using DesignBuilder software [18].

leased by fish factories are among the most energy-consuming buildings. The goal was to analyze and understand the amount of consumption per building. The data needed was collected to make a simulation model of buildings that leased by fish factories. It was then analyzed and compared with the monthly utility bills. Some of the buildings that provided energy-related data were compared with the results of the energy simulation modeling, and the accuracy ratio between the actual and simulated results was very high, exceeding 93%. This will contribute significantly to the design of future scenarios to raise energy efficiency, as well as to study the possibility of meeting the need for energy locally through renewable energy systems. However, one of the challenges found during data collection was the lack of sufficient data to build the simulation model, such as drawings of the building, as well as the nature of energy consumption during different time periods.

2.3. Design and implementation of a micro-grid for a fishery port

After developing a simulation model using DesignBuilder and EnergyPlus programs, the third stage investigated the deployment of a micro-grid at a fishery port. This will help to determine the capability of a micro-grid to meet local energy demand. The most robust simulation platform to develop a micro-grid is MATLAB/SIMULINK. There are many requirements to develop a micro-grid model platform, including an energy generation system, energy demand system, energy storage, energy management control and grid system. Each system has to be built separately and then tested as a standalone system. After developing a model for each component, the next step is to integrate all items in one platform as a virtual micro-grid. Graphs are then added to see the operation of energy usage. This will help to find how much power the system receives from the grid and how much power is generated in a 24-hour period. It will also help to identify the capacity of defined energy storage systems. The proposed control energy strategy will help to enhance the flow of energy, which gives a clear understanding of energy management in a 24-hour period. The grid model was considered as a finite grid model to maximize the power flow in the system and avoid blackout during operations. A finite grid can meet unlimited power demand and accept unlimited surplus power from the system. Once the proposed micro-grid model has been developed, it is important to test the micro-grid under different scenarios because this allows the system to identify the optimum amount of energy storage to build a standalone system. In addition, the system must be tested under different variables and conditions, such as seasons, maximum load, and minimum power production. This will help to build a robust model that can be expanded under different conditions. It is important to run the micro-grid model on a robust computer with a maximum amount of ram memory and smart specification to increase the model's reliability. This will lead to a model that is largely identical to the one that will be built on the ground.

2.4. Expanding the community's energy sharing around fishery port

The developed micro-grid model for the port has been expanded to include a group of five fish factories and several residential buildings from around the seaport. This will enhance the potential of the micro-grid to meet the energy needs of the port and the surrounding community by taking advantage of the port-owned solar farm, which has an estimated capacity of about 5 MWp. The expansion model was built on a prototype that had previously been built for the port's micro-grid based on only one expandable building. Electric boats have also been introduced into the grid circle and utilized as an energy storage system when needed and as a source of consumption when used. Multi-decision making systems have been developed for the extended network to determine the extent to which the network can handle the demand and save locally generated electricity from solar energy. In addition, it will help to expose the required capacity of energy storage units for the port buildings and for the residential buildings around the port. The result of the expansion of the network has greatly enhanced the effective role that the smart grid approach can play in seaports and coastal cities, and can even contribute to enhancing the role of locally generated solar energy to meet the need for electric power. This will be directly felt by the local community and the marine activities at the port. This can be called net-zero carbon community, which is an ideal model that many countries seek to reach by reducing dependence on fossil fuels. The developed model is one of the first to use solar energy in fishing ports and to have developed a smart energy community around a fishery port.

2.5. Develop a smart decision-making system to deliver a zero-carbon fishery port

After completing the study and analysis of the micro-grid system and knowing the extent of the ability of the network to achieve local energy sufficiency at the port level, the decision-making systems within the network are developed and optimized. This will help to raise the efficiency of the systems and make the most efficient utilization of locally produced solar energy. In this study, a smart decision-making system that is based on control-based pricing and P2P control strategies has been developed and implemented. Both smart decision systems achieve a nearly zero carbon fishery port. Control-based pricing is based on the total energy production of the PV panels, the battery capacity, and/or the electric boats to consider the price of electricity to decide between buying or selling energy. This will contribute to the direct interaction with energy prices in the energy market, which benefits the port directly by taking advantage of the cost of selling electricity at a high price or indirectly by supplying clean, locally produced solar energy to the local community. The P2P decision support system aims to share the surplus power that has been produced from Agent A to Agent B, to meet local power demand from clean energy. P2P energy sharing could be implemented based on price or based on sharing, which will gain more benefits to the local consumers. It will also help consumers to become prosumers and trade surplus energy inside the community. Smart decision-making systems within the micro-grid aim to increase dependence on locally produced clean energy through an energy department that allows for the benefit of both the producer and the consumer. This will directly affect the energy markets and society by increasing the production of clean energy, activating the role of the customer, as well as facilitating the customer's access to the energy markets.

3. The roles of new smart technologies in achieving a nearly zero carbon fishery port

Industry 4.0 can play a vital role in the current and future applications in industrial operations. It will also contribute to different directions to increase the competitiveness, quality, and innovation in the services, which will reflect the overall lifecycle of the industrial sector. The proposed system will help to adopt new smart technologies, such as Machine Learning (ML), Internet of Things (IoT) and Blockchain application, which will contribute to achieving a nearly net-zero fishery port under Industry 4.0 approach.

3.1. Machine learning (ML)

Artificial intelligence is a core element in the new smart energy applications. Implementing prediction and optimization tools will help to identify the optimum solution of energy while considering many variables. For example, the study by [19] used an Artificial Neural Network (ANN) model to predict energy consumption of a building in 30 min and then used a Genetic Algorithm (GA) to find the optimum amount of energy to meet energy demand in the next 30 min with high accuracy. This will help to understand the behavior of the overall system and keep the operation system in smooth mode without requiring a contingency blackout.

3.2. Internet of things (IoT)

The Internet of Things (IoT) plays a critical role in energy applications because it is responsible for utilizing and transferring real-time data via sensors to enable quick calculation for decision support systems. IoT will assist in managing the flow of large amounts of energy data and analyze the present state of energy utilization in the system [20]. In addition, it will help to reduce the energy consumption and environmental impact by monitoring and controlling energy via control, and it will reduce the waste in the overall system. IoT is key element to achieve nearly zero carbon fishery port because it will help to monitor both power supply and demand, and coordinate with an energy storage system.

3.3. Blockchain

Blockchain technology can provide the tool needed to support the decentralization of energy supplies. Energy companies can utilize intelligent contracts to transfer resource ownership and track energy the used or purchased by customers. Many people get their electricity from large power plants, but the main feature of decentralized energy generation (e.g., wind and solar) is that it has enabled more homes to create their own energy [21]. Blockchain will enhance energy trading in the fishery port, which will provide more options to deal with the surplus energy and sell it to local energy community consumers.

3.4. Industry 4.0

Industry 4.0 can emerge between the physical and digital worlds through the Cyber Physical System [CPS], which will enhance productivity and efficiency among industries. The new approach will combine among different kinds of technologies, such as CPSs, the Internet of Things [IoT], Internet of Services [IoS], Robotics, Big Data, Clou Manufacturing and Augmented Reality [AR] [22]. Digital twins [DT] are a precursor to Industry 4.0, and they are a virtual version of a rare or real-life asset, such as a service, product, or equipment, with models capable of changing behavior using real-time data and cognitive analytics [23].

4. Conclusion

The proposed roadmap aims to make fishing ports smarter, greener, sustainable, and less environmentally damaging. The following stages focused on understanding the nature of energy consumption at the fishery port and then applying smart energy technologies (e.g., smart grid and distributed generation). This will help to limit carbon emissions by making fishery ports greener through applying renewable energy resources and smart energy management systems. Our roadmap will contribute to a carbon-free fishery port, and will contribute to raising the quality of the energy used in the fishery port and the surrounding community. This will enhance access to sustainable clean energy and lead to a carbon-free society. The proposed roadmap is applicable and can be used at different port sites. In our future work, we will investigate the application of smart energy technologies (e.g., machine learning, IoT and Blockchain), which will add to the development of fishery ports and seaports.

CRediT authorship contribution statement

Ateyah Alzahrani: Investigation, Formal analysis, Validation, Writing – original draft, Writing – review & editing, Data curation, Conceptualization, Supervision, Project administration, Funding acquisition. **Ioan Petri:** Investigation, Formal analysis, Validation, Writing – original draft, Data curation, Writing – review & editing, Conceptualization, Supervision, Project administration, Funding acquisition. **Ali Ghoroughi:** Data curation, Writing – review & editing. **Yacine Rezgui:** Writing – review & editing, Data curation, Conceptualization, Supervision, Project administration, Funding acquisition.

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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