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Review Article

Green Port Strategies in Developed Coastal Countries as Useful Lessons for the Path of Sustainable Development: A Case study in Vietnam

Hoang Phuong Nguyen[a*], Phuoc Quy Phong Nguyen[b], Thanh Phuong Nguyen[c†]

[a]Academy of Political Regional II, Ho Chi Minh City, Ho Chi Minh, Vietnam
[b]PATET Research Group, Ho Chi Minh city University of Transport, Ho Chi Minh, Vietnam
[c]Institute of Engineering, HUTECH University, Ho Chi Minh, Vietnam

Abstract. The global shipping industry has been contributing more than four-fifths of the volume of goods transported internationally. However, shipping is facing pressure from strict policies on combating climate change from the International Maritime Organization (IMO). Seaports are an essential component of shipping and are also having to change their development strategies to be more sustainable and smarter. The concept of a green port was born as an inevitable part of the green economic development path. Green port system development policies and strategies have been discussed and studied in recent literature reviews, and have revealed the limited reach of developing countries. This work focuses on evaluating successful green port policies and concepts in developed countries to highlight the distinctive features of green ports. Moreover, the experiences from the effective green port models of developed countries can be valuable lessons for developing countries like Vietnam. More interestingly, the core features of green ports, when piloted at several international ports in Vietnam, promote port efficiency and environmental friendliness. On the way to implementing the national green port strategy, Vietnam has been establishing legal and infrastructure corridors to realize the strategy of sustainable marine economic development by 2045.

Keywords: Green port strategies; Clean energy; Renewables; Sustainable development; Developed coastal countries; Vietnam

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1. Introduction

The flat world's cargo economy has strongly promoted many modes of freight transport between countries, especially the shipping industry (Prokopenko & Miśkiewicz, 2020). Two-thirds of the earth is water, so water transport is not inferior to air transport, and the volume of transportation by water is the largest (Sardain *et al.*, 2019). Therefore, marine shipping has become the most important mode of transport for the exchange of goods between countries. Shipping has been making many important contributions to the process of international economic development. With the advancement of science and technology, maritime transportation is making great strides. Types of goods transported today are very diverse, also, the cost of transporting goods by sea is low (Vakili *et al.*, 2022). Moreover, shipping by sea can reduce transit time to the shortest. The seaport system has been handling over 80% of the total volume of traded goods over the world (Gucma, 2019). As a consequence, in the context of comprehensive international integration, seaports play a very important and backbone role in the circulation of import and export goods of any economy (Anh Tuan *et al.*, 2022).

Along with the process of formation and development of maritime transport, the concept of seaport was born as an indispensable part of the trading economy. According to traditional theories, a seaport is defined as a place with essential infrastructure to carry out the loading and unloading of goods in the transport chain of ocean and land transport. (Hlali & Hammami, 2017). The initial basic operation of the port is loading and unloading goods, supporting transport, import and export, so the port's logistics are very limited. The concept of a seaport was perfected with the development of production methods and productive forces in the shipping industry. The initial basic operation of the port is loading and unloading goods, supporting transport, import and export, so the port's logistics are very limited. Along with the development of shipping and the deepening division of labor, the closer labor cooperation, the concept of a seaport is increasingly supplemented and improved (Duc Bui *et al.*, 2021). The

* Corresponding author:
Email: nghoangphuong11@gmail.com (H.P. Nguyen)
† Corresponding author:
Email: nt.phuong@hutech.edu.vn (T.P.Nguyen)

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seaport area includes the port land area and the port water area, with infrastructure built and equipment installed for ships entering and leaving to operate to load and unload goods, pick up and drop off passengers and perform other services (Nguyen & Pham, 2019). It is an important and indispensable part of the operation of open economic zones, free trade zones, industrial parks, and export processing zones. Seaports are also the link of multimodal transport, through which means of sea transport, railway transport, river transport, or air transport pass through (Papadopoulos *et al*., 2021). Moreover, it is the place where goods are changed from one means of ocean transport to another and vice versa, so the logistics of the port are often extensive. A study conducted by Lee *et al.* (Lee *et al*., 2018) has revealed that fifth generation seaports are a strategic target of Asia's main seaport system. That study also showed that port service and port operations are already the two main pillars of the third-generation seaport concept. More interestingly, the information services and flexibility of ports in global supply chains where the integrated relationship of shipping alliances and port associations are emphasized in the fourth generation of seaports. Even better, the fifth generation port has combined the typical features of the third and fourth generation ports (Shi, 2015). Moreover, the latest generation seaport services and operations are always closely linked to the environmental protection policy based on the most advanced and smartest technology platforms (Yap & Loh, 2019). In short, the fifth generation of ports has been adapting to new concepts of green and smart ports. Besides establishing green port concepts, studies on regulations and laws on establishing green port strategy play a very important role. A study by Canbulat (Canbulat, 2014) compiled international green port law over 50 years, as depicted in Figure 1. It has demonstrated the evolution over time of environmental sustainability regulations in seaports.

Although about 90% of world trade is conducted through shipping, the shipping sector currently accounts for about 3% of global CO_2 emissions (Zhang *et al*., 2017). Transport activities at seaports have seriously polluted the environment from loads of gases, wastewater and solid waste. The statistics of the International Seaport Association have confirmed that the activities of ships at the port have emitted about 70% of the total emissions of the journey (Cullinane & Cullinane, 2019)(Bakır *et al*., 2022). Furthermore, port operations, ships, and dredging activities can have negative impacts on the environment. It is estimated that the services related to transporting passengers and goods at seaports are transporting about 20% of the global waste dumped into the sea (Nižetić *et al*., 2022)(Gössling *et al*., 2021). The more active ports are, the higher the risk of pollution in those ports, creating a negative impact on the environment. Waste is mainly generated from port activities such as Infrastructure construction activities; Operating in the process of trading and exploiting seaports (Chen *et al*., 2022); Operation of ships (Drosińska-Komor *et al*., 2022), and equipment to support the operation of ships (Pham *et al*., 2020); Activities of dredging, maintenance of navigational channels, anchorage and transshipment areas, storm shelter, dredging of wharf hydropower plants (Y. Chen *et al*., 2020). Such activities negatively affect the air environment, water environment, and marine ecosystem (Hoang, Kumar, *et al*., 2022). Therefore, preventing environmental pollution and building a green seaport is one of the goals to balance environmental protection and economic development needs (Darbra *et al*., 2005). In general, the study of emerging smart port exploitation technologies and keeping abreast of the port's green development trend to build a green, smart port operation method is an important direction for port development today (Zhen *et al*., 2019). In summary, it has contributed greatly to improving the efficiency of port operations as well as being more environmentally friendly for more sustainable development

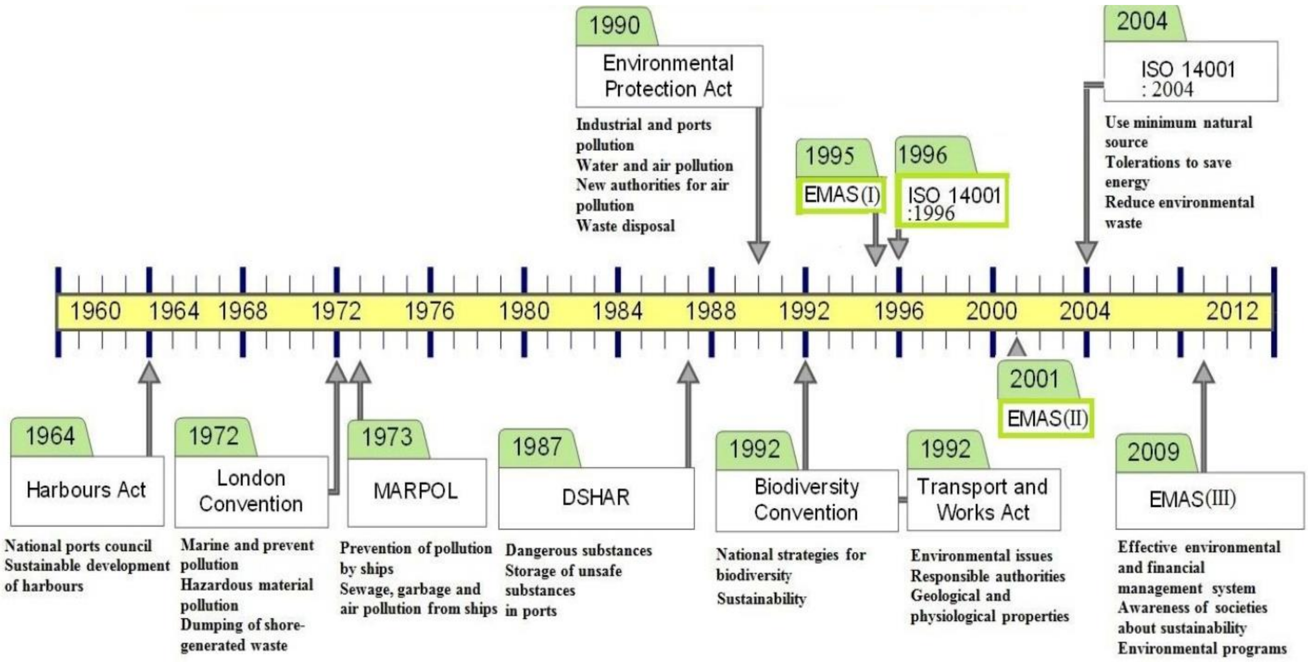

Fig. 1 The historical path of green port legislation (Canbulat, 2014)

The literature reviews in recent years have focused mainly on reflecting on the reality and challenges of emissions reduction at seaports (Hoang, Foley, *et al.*, 2022). Emission reduction strategies at ports are implemented based on IMO regulations on cleaner fuel use for fleets and port facilities (Gonzalez Aregall *et al.*, 2018). To improve ship design and reduce fossil fuel consumption, some methods have been promoted to reduce emissions from ships at ports (Hoang & Pham, 2018). In addition, green port models were born to meet sustainable development goals (Azarkamand *et al.*, 2020). The combination of modern technologies, environmentally friendly equipment, and appropriate management policies are creating a modern and adaptive green port model (Hoang & Pham, 2019). Emissions control in the shipping industry has been included in IMO's global sustainable development strategy (H. P. Nguyen, Hoang, *et al.*, 2021). Many policies and regulations have been continuously adapted and implemented for IMO members. On November 1, 2021, the United States, Denmark, and 12 other countries voiced support for the goal of reducing global maritime emissions to zero by 2050, which is expected to be discussed in detail during negotiations at the United Nations shipping agency (Joung *et al.*, 2020). At the same time, the IMO sets rules for shipping by sea through its 175 member countries, with decisions being made by consensus. A tougher climate target would require a majority of member states to agree, thus posing political challenges. Shipping decarbonization requires major investments to scale up green fuel production and ship clean energy ships this decade (Lindstad *et al.*, 2021)(Hoang & Pham, 2018). The world's largest container shipping line Maersk (Denmark) intends to operate the first carbon-neutral ship in 2023 using green methanol fuel produced from renewable sources. Green are fuels produced from biomass sources such as biodiesel (Hoang *et al.*, 2021)(Hoang, Sirohi, *et al.*, 2022), bioethanol (Nguyen *et al.*, 2020)(Truong *et al.*, 2021), furan-based fuels (Hoang & Pham, 2021)(Hoang *et al.*, 2022), and hydrogen (Murugesan *et al.*, 2021)(Hoang, Huang, *et al.*, 2022), microbial fuel cell (Hoang, Nižetić, *et al.*, 2022)(Hadiyanto *et al.*, 2022) are considered clean and sustainable fuels for the shipping industry shortly. Faced with the environmental problems posed by seaport exploitation and implementation of the United Nations' Millennium Development Goals, seaport operations in the world are being "green" according to a model that balances environmental fluctuations and economic development needs.

Building a green port according to a model that balances environmental fluctuations and the needs of economic development is a strategic trend in the development of seaports in the world (Deng *et al.*, 2022). A green port is a port that focuses on developing based on the criteria of green economic growth according to a long-term plan, meeting current and future needs (Bergqvist & Monios, 2019). Several major hub ports in Europe and America have adopted their green port strategies (Lawer *et al.*, 2019). However, a "one size for all" approach is not feasible when studying the green port concept models of developed countries. Indeed, each country has different geographical and social conditions, moreover, different environmental objectives, different equipment and port facilities. More importantly, the inconsistency between economic development and environmental protection in developing countries is deepening. Therefore, the transformation of the green port strategic framework from developed countries to developing countries requires an appropriate methodology, and it is a research question that needs to be addressed. Vietnam is a developing country, a maritime country, so establishing a green port system in Vietnam in an environmentally friendly direction not only meets the requirements of environmental protection but also helps seaports to integrate with the world.

In this work, a methodology for literature reviews was established based on the synthesis, filtering, selection, and comparison of recently published literature in prestigious Scopus and ISI journals. Data collection focuses on open databases from Web of Science and Scopus. Green port development concepts, models, and strategies are discussed to clarify the role and lessons learned from global green port development strategies for Vietnam. For the case study, over 10 ports of class I in Vietnam were selected to identify the case studies. Green port development policies and strategies of typical ports are selected as a basis for assessing and analyzing the greening situation at class I ports in Vietnam. Tan Cang - Cai Mep International Port (TCIT) and Dinh Vu Port (Hai Phong) were selected as 2 typical ports for 2 different geographical areas but capable of meeting the highest green port criteria in Vietnam. Green port goals include controlling emissions from ships, port operations, and inland transportation. The green port strategies presented in this study are based on relevant literature reviews. In addition, weaknesses and challenges are also revealed to seek solutions in the future when Vietnam's blue sea economic strategy is implemented at all class I ports by 2045.

2. Literature Review

2.1 Concepts and characteristics of green port

In the context of the sustainable development strategy of the shipping industry, the term "green port" has been proposed and developed from research activities related to sustainability (Wang *et al.*, 2020). Green ports are identified as the product of a long-term strategy to develop sustainable and environmentally friendly port infrastructure (Dinwoodie *et al.*, 2012). The concept of a green port or the sustainable and environmentally friendly development of a scalable port's infrastructure is the responsible behavior of all involved, from the port management to individual employees (Satır & Doğan-Sağlamtimur, 2018). Key challenges for future sustainable development include port competitiveness and climate change. The ability to self-integrate into shipping lanes and the added value that ports can accommodate customers can have a major impact on the future competitiveness of ports (Xia & Lindsey, 2021). In the last decade, many initiatives on establishing international green port models have been provided by international associations and organizations aiming at a greener shipping industry. The new models are tied to the mechanisms that support ports against climate change (Lasserre & Faury, 2019). By 2020, various green solutions have been pursued by 55 international ports around the world to meet the world port climate initiative with indicators of reducing ship prices and being more environmentally friendly (Lam & Li, 2019).

Green ports are often combined and integrated with many components including economic, social, environmental, cultural, and other factors. In which economic, social, and cultural factors must be closely linked with environmental requirements to ensure sustainable development (Okada *et al.*, 2021). By the principles of sustainability, ports must develop policies and establish effective energy and water consumption monitoring systems, including environmental quality indicators (Zagan *et al.*, 2021). Effective adaptation solutions are not only about the physical layout and technical projects but also about the need to fundamentally transform the current method of port planning and management (Sodiq *et al.*, 2019). The implementation of the green port concept in any organization implies adopting a new management style, thereby allowing the company to set its goals, commitments, and responsibilities towards society and the environment. In addition, it is necessary to clearly define the negative impacts of port operations to specify the objectives of port operation development by environmental requirements (Oniszczuk-Jastrząbek *et al.*, 2018). The adoption of the green port concept became possible through pilot programs to objectively evaluate new technologies (IoT and Smart port), alternative fuels, alternative energy sources, and waste management. Designing renewable energy conversion models from solar (Le *et al.*, 2021)(Nižetić *et al.*, 2021) and wind power (W.-H. Chen, Wang, *et al.*, 2022)(W.-H. Chen *et al.*, 2021) with efficient energy storage (Xuan Phuong Nguyen & Hoang, 2020) is believed to be key in powering electric vehicles at ports in the future. These components are tightly coupled as shown in Figure 2.

The starting point of the process of applying the green port concept is an assessment of the current state of operating procedures and an assessment of environmental management practices. Accordingly, a self-assessment of energy and environmental management practices and procedures is the first action. The key audit output is the basis for performance monitoring. In addition, based on the recommendations from the audit, energy, and environment managers should prepare an energy and environment policy and strategy (J. Chen, Zheng, *et al.*, 2019). Another important step is decentralizing responsibilities, defining the organizational structure needed to empower store-floor employees to achieve lasting improvements in performance. An integrated lifecycle approach is incorporated into the green port concept as a support for strategic decision-making (Chu *et al.*, 2021)(Rodriguez *et al.*, 2021). Furthermore, the sustainability index capability can be successfully applied to provide an overall indicator of the environmental performance of existing applications. That index can allow the above application to support the comparison of competitive options in the strategic decision-making process (Esmaeili Shayan *et al.*, 2022)(Niklas & Bera, 2021).

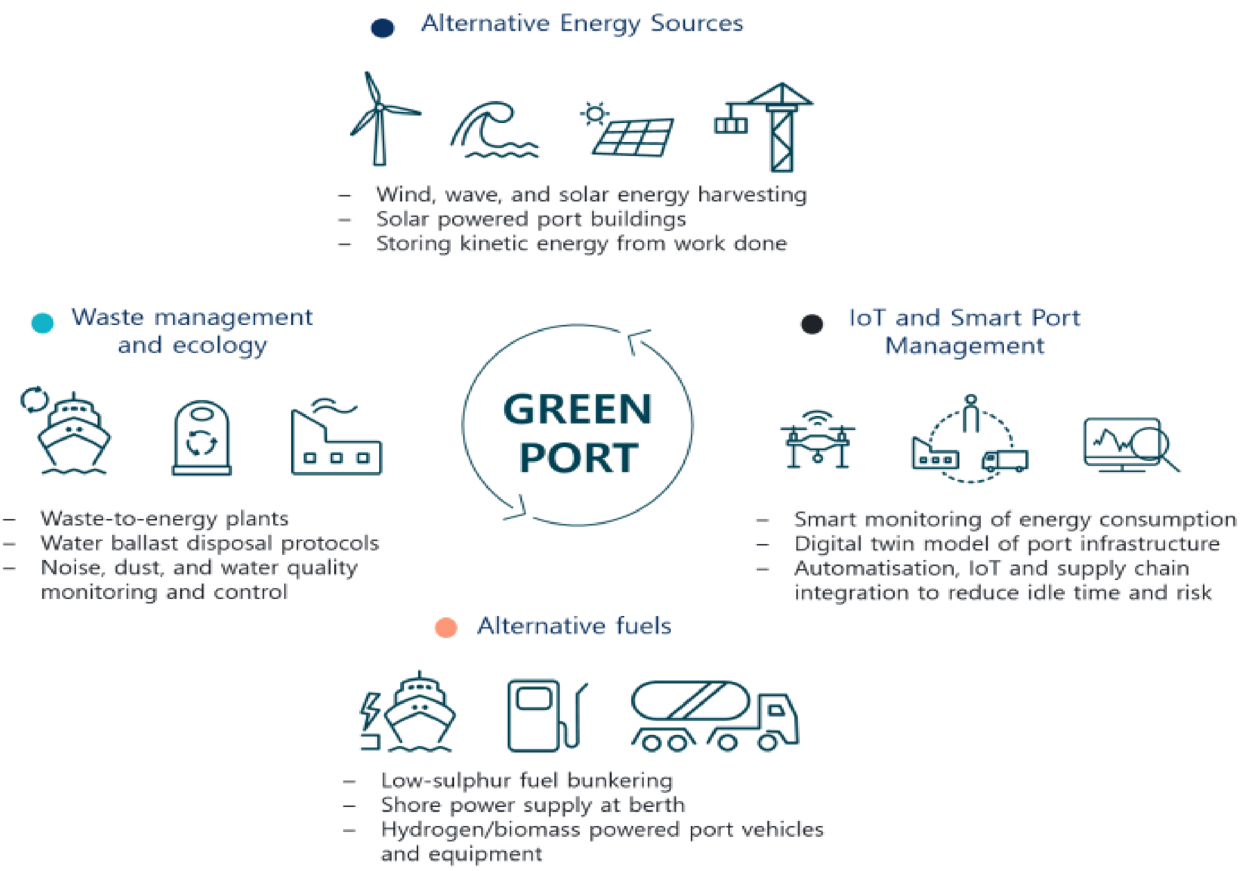

Fig. 2 Strong relationships are mapped across the core components of the green port concept (Naveiro, 2021)

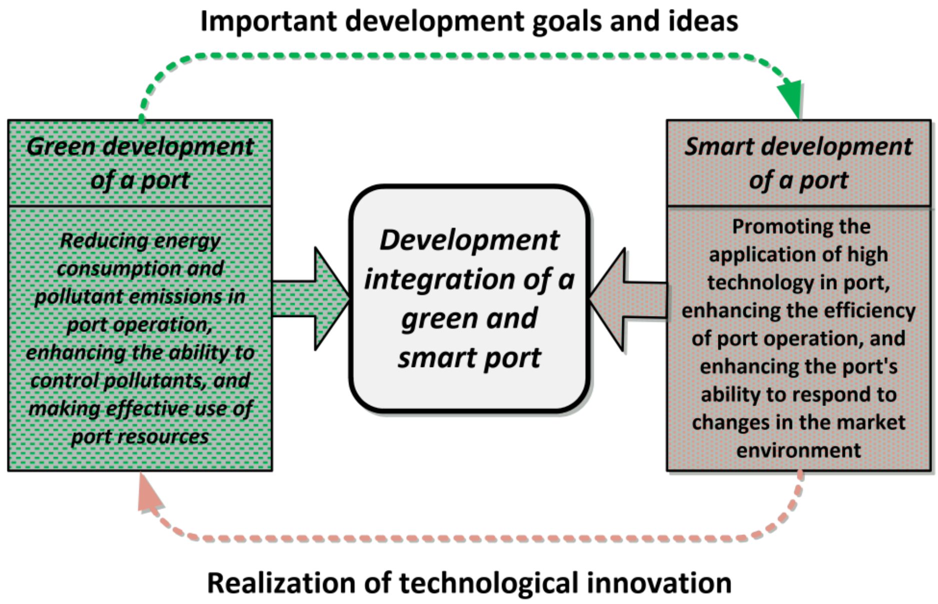

Fig. 3 The relationship between green ports and smart ports in sustainable development (J. Chen, Huang, *et al.*, 2019)

According to modern perspectives from recent literature, the dialectical and tightly integrated relationship between the concept of green port and smart port is very clear. In the operation and development strategy of ports, green ports and smart ports always go hand in hand and integrate into each other (Philipp *et al.*, 2021). The main goals of sustainable development in a port are the unification of green development goals with smart methods and infrastructure. Green development is reflected in the development process that consumes less energy, generates fewer emissions, and pollutes the environment (Yan *et al.*, 2021). In addition, in terms of smart goals, smart and state-of-the-art technology infrastructures help improve the comprehensive efficiency and competitiveness of port operations (Molavi *et al.*, 2020). Smart technologies such as the Internet of Things, artificial intelligence, and Big Data play an indispensable role in the path of green development, while smart development is always associated with green development (Vo *et al.*, 2021). Without the concept of green development, the sustainable and smart development of a port would be difficult to achieve (Kamolov & Park, 2018)(Lisowski, 2021). In general, green development is an important concept of the smart gateway. More importantly, the application of technological innovation of smart gates is an important means to realize the green port goal. In summary, the concept of green and smart ports are two sides of an organic whole system, depicted in **Figure 3** (J. Chen, Huang, *et al.*, 2019). The integrated development of green and smart ports will be an inevitable direction to achieve the sustainable development of the port in the future.

2.2 Typical green port strategies from developed countries

Various green policies and programs at ports can guide the establishment of effective technical solutions to reduce emissions from port operations. Green towing and dredging operations, and the use of green and clean electricity networks produced from renewable energy (Łącki, 2021). Moreover, encouraging port staff and tenants to participate in the green work program is also realizing green port policies (Tseng & Pilcher, 2019). Green mobility activities of port human resources include carpooling services, using public transport and cycling, and even construction of bicycle parking and parking spaces has been doing very well in green ports. Furthermore, ports establish policies to reduce the idling time of trucks and port vehicles through eco-driving and reducing vessel idling time by arranging faster berths for green ships, e.g. Panama Canal green berth allocation (Anser *et al.*, 2020). In the recent decade, ports have become an important player in carbon stores. Ports develop green buffers in addition to improving the landscape, for example, POLB planting trees to maximize carbon sequestration (Agbelade & Onyekwelu, 2020). Through carbon capture and utilization, the resulting carbon can be used as a source for other products. In the United Kingdom, for example, the British Ports Association has partnered with Siemens to launch a green port system that integrates decarbonization tools toward zero-emission port operations (Siemens, 2022). **Figure 4** depicts Siemens' zero-emissions green port model at UK ports with six decarbonization including TIP, SSP, CMS, digital twin, renewables, and green hydrogen. The integration of renewable and clean energy forms into the energy system of the smart port city's infrastructure architecture is considered an effective model to move towards a green city in the future *(Hoang et al.*, 2021).

EcoPort model is built and managed by the European Seaport Organization (ESPO) (Satır & Doğan-Sağlamtimur, 2018). Seaports recognized as "EcoPort" must meet the criteria set forth by ESPO, in which the environment is the most important criterion. Currently, many European and China ports have joined the EcoPorts Association and have been granted a valid "EcoPort" certificate (Lu *et al.*, 2021). The certification has confirmed that the environmental management programs are in line with the requirements prescribed by EcoPort, to harmonize the relationship between economic development and environmental protection, energysaving, and resource conservation, toward the sustainable development of ports (Nicea & Dănuţ, 2018). For the past 15 years, EcoPorts has focused on developing and refining tools (including self-diagnostics, and port environmental assessment systems) to support environmental management. Major ports in Europe such as Port of Rotterdam, Hamburg Port, Port of Ambarlı, and AsyaPort have obtained certificates of EcoPort and Green Port. These ports all lead Europe in terms of efficiency and sustainability in port operations associated with industrial complexes. These are great models for developing countries to learn while building a green port strategy (Nguyen *et al.*, 2021b).

Long Beach is one of the top seaports in the United States. This is also a pioneer port in the field of freight transport and environmental protection in the world, with an estimated total value of goods each year reaching more than 100 billion USD. In early 2005, the Port's Board of Directors adopted the Green Port Policy. This policy has been and is serving as an official and comprehensive guide for decision-making and establishing the framework for eco sports operations (Gonzalez Aregall *et al.*, 2018). The Port of Long Beach has applied a green port policy, thereby contributing to minimizing and eliminating negative impacts on the environment and developing environmental initiatives. The main objectives of the green port policy include: Protecting the community from negative environmental impacts arising from the port operation; Clearly defining the port's role as a leader in environmental harmonization and management; Promoting sustainability; Using advanced technology to combat or reduce negative environmental impacts (Wu *et al.*, 2020).

Taiwan's "Green Ports Action Plan" aims to improve the quality of the port environment and enhance the quality of passenger travel experiences and the efficiency of freight operations through various measures. In the long term, the goal is to stimulate and promote sustainable local development through improving the optimal port environment and greener surrounding infrastructure (Tseng & Pilcher, 2019). With the above goals, the plan has been implemented synchronously on 4 main pillars including Cargo Operations, Marinas, Community Outreach, and Port Environment. The functions of each pillar and the benefits arising from this action plan are illustrated in Figure 5 (Taiwan International Ports Corporation, 2022). The action plan covers all of Taiwan's seven international trading ports (Keelung, Taichung, Kaohsiung, Hualien, Taipei, Suao, and Anping) as a single and integrated business complex. With the outlining of short, medium, and long-term green port strategies to realize the concept of a green port complex (Tseng & Ng, 2020). Through the transformation into green ports, Taiwan International Port Corporation hopes to successfully establish a green economy that increases profits while pursuing social and environmental sustainability.

In summary, the experiences of developing green port policies and strategies from developed countries can bring many valuable lessons for Vietnam in green sea economic development strategy as well as green port development.

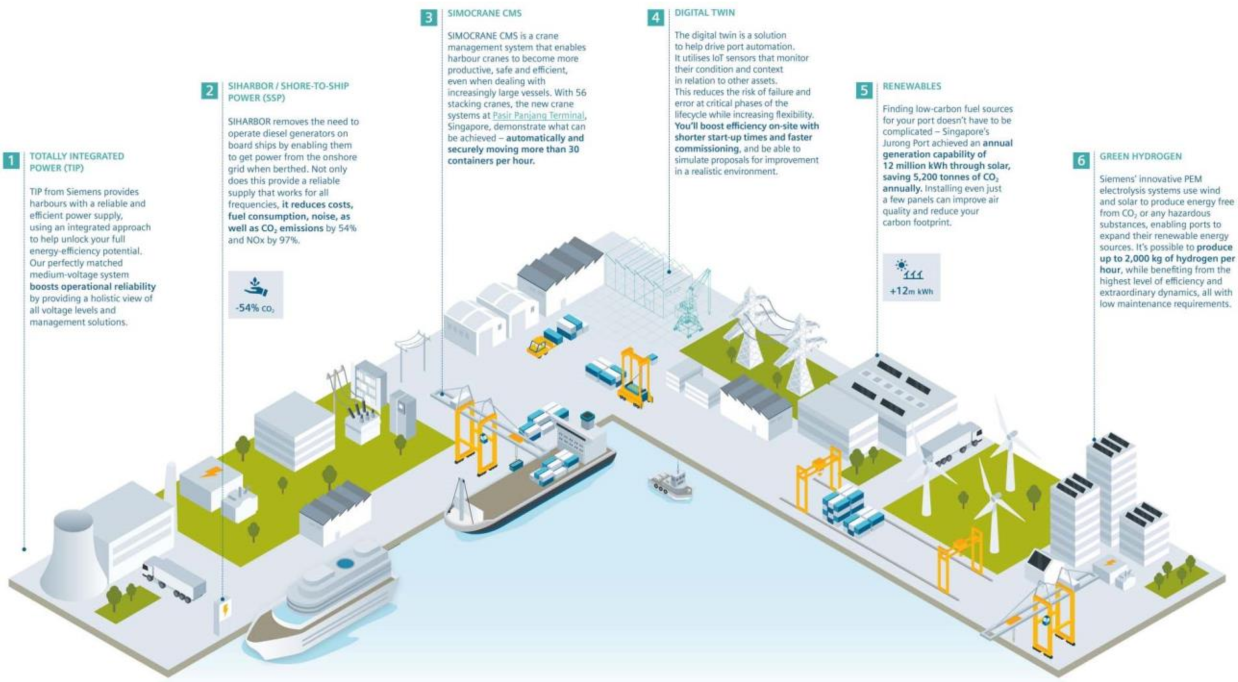

Fig. 4 A green port model with 6 decarbonization tools piloted in UK ports (Siemens, 2022)

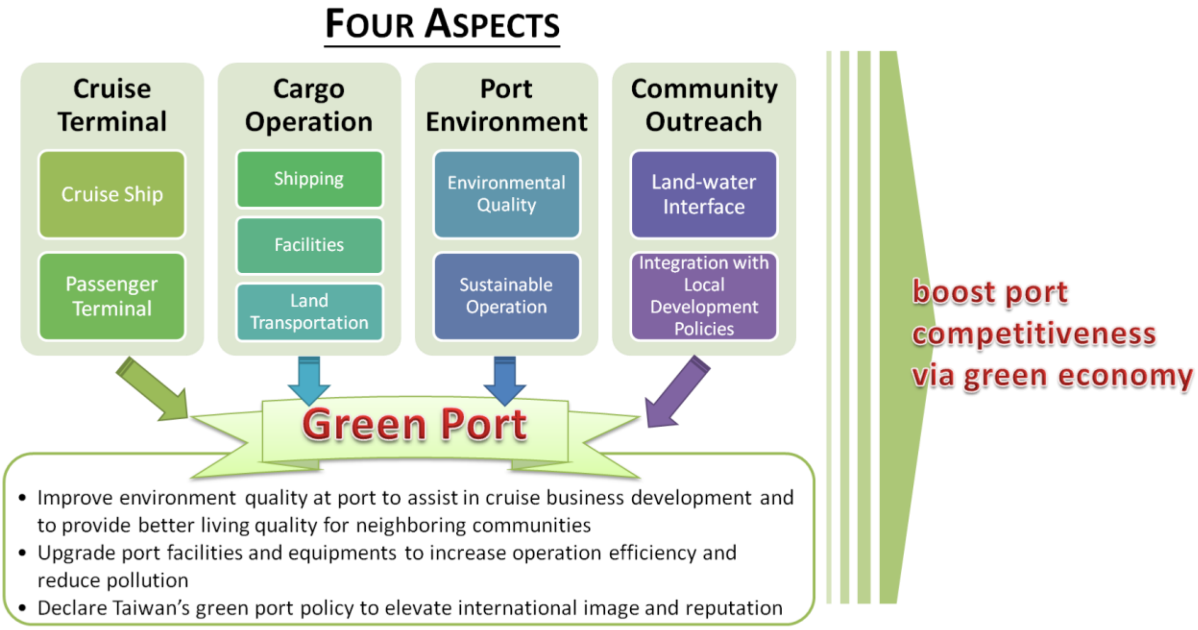

Fig. 5 Four key aspects of Taiwan's green ports action plan (Taiwan International Ports Corporation, 2022)

3. Green port strategies in Vietnam

3.1. Opportunities to develop Vietnam's green sea economy

These are favorable conditions for Vietnam to develop the maritime industry, shipbuilding industry, logistics, and seaports. On the other hand, the location is convenient for traffic and the bays have great depth, and large space in the coastal area, which is very convenient for the seaport and the development of coastal economic zones. Vietnam is considered a country with potential and advantages in the sea, for every 100 km^2 of territory, Vietnam has nearly 1km of coastline. This is the highest index in the world, contributing to affirming that Vietnam is a maritime country and has many potentials and advantages from the sea. Although the green sea economy has been mentioned in Vietnam, it is still a new field in both content and approach, especially in assessing the current status and potential for developing Vietnam's green sea economy. Building and developing a green sea economy is a new, emerging and popular economic development model, focusing mainly on the goal of creating green jobs, promoting high and sustainable economic growth, preventing environmental degradation and global warming, depletion of natural resources, and destruction of ecosystems. Along with the available potential to develop the green sea economy, Vietnam also has the following favorable conditions: *(i)* Vietnam has gradually issued many strategies and policies to shift the economy from "brown" to "green", such as a National strategy on green growth to 2020; Strategy for exploitation and sustainable use of natural resources and marine environment protection to 2020, vision to 2030; International commitments on environment and development. *(ii)* Vietnam has approved several laws and planning and plans to implement green growth-related tasks, including the National Action Plan on green growth for the period 2014-2020, Law of the Sea of Vietnam 2012, Resource Law, Sea and island environment in 2015, but the "National Marine Spatial Planning" into the Law on Planning 2017. *(iii)* Resources to support building a fast, efficient, and sustainable marine economy of Vietnam are diverse and substantial, including human, financial, material, and intellectual resources; material-technical facilities and infrastructure for marine economic development, as well as environmental protection and marine nature conservation in our country, have been paid attention and initially brought into play. *(iv)* Vietnam is determined to reform the economy and restructure the economy, in which the marine economy continues to be interested; strengthen international economic integration in the field of marine economy.

3.2 Seaport system in Vietnam

Vietnam's 28 coastal provinces and cities have about 268 large and small seaports, more than 120 floating berths, and tens of thousands of square meters of warehouses and yards. According to the master plan for the development of Vietnam's seaport system to 2020, orientation to 2020 of the Prime Minister in Decision No. 2190/QD-TTG dated December 24, 2009, according to territories, Vietnam's seaport system consists of 6 groups.

Group of seaports in the North: Including 7 seaports, the total berth length is 8097 m, of which there are 3 ports of grade I (Hon Gai, Hai Phong, Cam Pha ports) and 4 ports of grade II (Van Gia port, Mui Chua port, Diem Dien, Hai Thinh), Hai Ha port (Quang Ninh) are being invested and built (T. Y. Pham *et al.*, 2016). Cai Lan port (belonging to Hon Gai port) can receive the largest vessel down to 45,000 DWT and similarly Cam Pha coal port can receive ships up to 70,000 DWT. Other ports only accept ships from 1,000 – to 10,000 DWT (Xuan Phuong Nguyen & Pham, 2019). In the North, with specialized ports meeting typical characteristics of synchronous factory infrastructure for coal and electricity industry development. Therefore, the loading and unloading capacity is high, receiving many large ships into the berth.

Group of seaports in the South: The South has 13 seaports, with a total length of 27,774 m of wharves and berths, in which: 4 ports of grade I and 9 ports of grade II, goods through the port are mainly agricultural products, fertilizers, motorcycle parts, ores, and products from industrial zones (Nguyen *et al.*, 2019). Among the 13 seaports in the South, there are currently 39 general and 48 specialized berths. There is a huge difference in vessel reception capacity between seaports in the Mekong Delta and ports in Ho Chi Minh City - Ba Ria Vung Tau - Dong Nai port clusters (Viet, 2015). Seaports in the Mekong Delta can only receive ships with a tonnage of over 10,000 DWT while ports in HCMC - Ba Ria Vung Tau - Dong Nai can receive ships with a tonnage of up to 30,000 DWT - 50,000 DWT - 100,000 DWT (Mohamed-Chérif & Ducruet, 2016). Large-scale general and container terminals, invested with modern specialized equipment, and an electronic exploitation management system have been put into common operation, creating a new look and competitiveness with seaports in Southeast Asia.

There are some ports such as Tan Cang Cat Lai, VICT, Chua Ve (Hai Phong), Cai Lan (Quang Ninh), and Tien Sa (Da Nang) that are equipped with specialized container handling equipment. In 2021, Tan Cang - Cai Mep International Port (TCIT) was awarded the Green Port Award 2020 by the APEC Port Service Network Council (APSN) and became the second port of Vietnam after Tan Cang Cat Lai to receive this award (in 2017)(McGuire & Findlay, 2005). The Green Port System Program is a system to evaluate the criteria for environmental protection commitment and clean energy use for ports developed by the APEC Port Service Network (APSN), and designed to fit all ports in the APEC region. To achieve that achievement, TCIT has invested in a system of equipment that is operated entirely by electricity such as shore cranes, and yard cranes, which help to reduce CO_2 emissions instead of diesel-powered equipment (V. V Pham & Hoang, 2020). In addition, TCIT is constantly innovating equipment using clean energy and natural energy to further improve operational efficiency and protect the environment. More interestingly, this port has been replaced, using LED lights on the entire system of shore cranes and yard cranes; develop a harmonic filter system to ensure a stable grid power system, take advantage of excess power from shore cranes to use as energy for offices, container yards, and yard electricity systems. Although "late birth", to build a modern green port, TCIT has invested in modern equipment including 8 STS cranes, 18 RTG cranes, feeder cranes, forklifts, and other state-of-the-art cargo handling equipment. The generation of E-RTG cranes uses 100% electricity from the grid, operated semi-automatically, integrating flexible load control technology and intelligent control cabin with the DGPS system combined with modern CATOS port management software. As a result, TCIT is one of the destinations that attract shipping lines because of green development criteria, minimizing the impact on the environment in operations.

In the plan to develop the green port system in the North, Lach Huyen-Hai Phong international port will be built as a pilot green port model. Accordingly, the port authority together with port operators focuses on developing based on the criteria of green economic growth according to a long-term plan which able to meet the needs of the present without compromising the ability of future generations to meet their own needs. To build Lach Huyen green port according to green criteria, first of all, it is necessary to control smoke and dust at the port by promoting the application of science and technology (Nguyen *et al.*, 2021). Next, it is necessary to limit the old vehicles transporting goods in and out of the port and encourage ships to apply new technology to the port. Water management is also a matter of concern because seaports use a large amount of freshwater for production activities (Chen *et al.*, 2022). Studies on optimizing the transport of water resources at seaports have attracted more interest as green and smart port policies are promoted. A study by Fang *et al.* (Fang *et al.*, 2021) was carried out at Huanghua Port with 8 scenarios based on multi-objective programming models to establish the optimal plan for water purchase costs and energy consumption. Economic and environmental benefits were also revealed in the household's research on the efficient and scientific management of water resources transport in the port areas. Therefore, it is necessary to develop an overall water management plan at the port, using a water source monitoring system. Controlling wastewater to avoid environmental pollution is carried out from ships, applying science and technology to determine ballast water samples, building waste receiving facilities, organize daily garbage collection when the ship is at the port (Nguyen *et al.*, 2021)(Lai *et al.*, 2021). Dredging and maintaining the channel must also control waste, and encourage the use of new means and modern technology. In addition, noise control at the port must be strictly enforced (X. T. Nguyen, 2019). The policies outlined by the port government aim to successfully build a green port by 2025.

In general, Vietnam has built a green port system in the northern and southern regions, basically ensuring for ships operate 24/7, reducing the time that ships wait for the wharf to be very small. While many major ports in the world are congested, Vietnam's seaport system is still operating efficiently. Vietnam's seaport system has been synchronously invested in infrastructure, so cargo volume and shipping could be a bright spot in 2021 despite the COVID-19 pandemic (Huynh *et al.*, 2021). In 2021, goods through Vietnam's seaports reached more than 706 million tons, up 2% compared to 2020, of which the volume of container cargo reached 24 million TEUs, up 7%. However, policies on the environmental friendliness and smartness of Vietnam's port system need to be improved with long-term strategies to meet the global goals of combating climate change.

3.3 Green port criteria in Vietnam

Among the three main pillars including investment in the construction and operation of seaports - shipping - maritime services, the seaport is identified as an important cape that plays a leading role, spreading to the remaining two tripods (Cong *et al.*, 2020). Therefore, during the review process, the management agency can study and propose to develop a separate Law on Seaports so that the key areas can be promoted and create a driving force for the development of the maritime economy.

The Vietnamese Government has always paid great attention to the protection of the marine environment and green seaports, which is part of the strategy of sustainable economic development according to the general guidelines and trends. Green port development in Vietnam's terms is a long-term process with many advantages and challenges that require specific consideration and assessment to get the plan and the implementation schedule with the most synchronous and effective solutions. Therefore, since July 2018, the Vietnam Maritime Administration, and the Ministry of Transport have studied and developed the Project "Development of green seaports in Vietnam".

The Vietnamese government has determined the green port criteria and organized the pilot implementation of the green port model suitable to Vietnam's conditions. Moreover, it is necessary to strive for the compulsory application of green port criteria in Vietnam from 2030. During the pilot process, focus on the following aspects: (1) Raising awareness of compliance with Vietnamese laws and international conventions on environmental protection; (2) Strengthening the effectiveness of environmental management in seaport operating business; (3) Promoting Vietnam's seaports to join the Association of Ecological Seaports in the region and the world; (4) Completing the policy and legal framework in planning, investment, construction, business and exploitation of seaports.

Green ports in Vietnam are built on 6 main criteria groups (focusing mainly on general ports and container ports) with a specific scale, including *(i)* Perception of green ports (maximum score of 5 points); *(ii)* Resource usage (maximum 15 points); *(iii)* Environmental quality management (maximum score of 50 points); *(iv)* Energy Usage (maximum 15 points); *(v)* Information technology application (maximum score of 5 points); *(vi)* Reducing emissions, responding to climate change, sea-level rise (maximum score 10 points). According to the regulations of the International Green Port Association, to be considered for recognition of a green port, a seaport must achieve at least 60% of the points of the criteria (minimum total score of 60/100 points). Finally, enterprises must have documents proving the implementation of each criterion.

4. Perspectives

According to the roadmap, from 2020 to 2025, Figure 6 shows the issues that need to be implemented including (1) Developing and promulgating basic standards on green port criteria; (2) Pilot green port model at some Vietnamese seaports and evaluating the implementation results; (3) Propagating, disseminating and communicating to raise awareness and capacity to apply green port criteria in Vietnam to all levels, sectors, and enterprises operating in seaports; (4) To step up the inspection, examination, and urge, to ensure the compliance with legal regulations on environmental protection, use energy economically and efficiently, respond to climate change in investment, construction, business and exploitation of seaports; (5) Strictly handle violations.

Research and propose amendments and supplements to regulations related to planning management, investment, construction, and business and exploitation of seaports to suit the criteria of green ports in Vietnam. Research and propose mechanisms and policies to encourage and support businesses to implement the process of developing green seaports in Vietnam. Research, application, and transfer of clean, low-carbon, environment-friendly technologies in seaport operation business to reduce emissions, use energy economically and efficiently, and protect the environment as a basis for applying the green port model in Vietnam. Strengthen international cooperation with other countries and non-governmental organizations to learn from experience and enlist the help of international friends in green port development in Vietnam.

From 2025 to 2030, the green port plan focuses on the following tasks: (1) Developing and promulgating national technical standards on green port criteria; (2) Implementing voluntary application of green port criteria at Vietnamese seaports. Accordingly, specific objectives include formulating and promulgating mechanisms and policies, and reviewing, amending, and supplementing regulations related to planning, investment, management, construction, and operation of seaports by the criteria of green ports in Vietnam. (3) Continue to carry out propaganda, dissemination, and training to raise awareness and capacity to apply green port criteria in Vietnam; (4) Promote the application and transfer of clean, low-carbon, environment-friendly technologies in seaport operation; (5) Evaluation of the results of the voluntary application of green port criteria at seaports; (6) Proposing the development and promulgation of regulations on mandatory application of green port criteria to the seaport system in Vietnam. Finally, the period after 2030: Compulsory application of green port criteria in planning, investment, construction, and operation of seaports in Vietnam. In the path of transforming green seaports in Vietnam, some directions are suggested below:

First, supply chain integration: Improvements in transport links promise to improve efficiency and reduce congestion in the port area. Real-time truck positioning, barge loading scheduling systems, and digitization of processes allow operators to interact with the supply chain in real-time.

Second is the opportunity for automation: Processes can be automated from an early stage including Port access control using optical identification (OCR), radio frequency identification (RFID), or automatic weighing scales; Online digital services for calculating or paying commercial bills; Tools such as automated timekeepers or digitizing cargo manifests to reduce manual data entry.

Third, the application of appropriate technologies: After the Vietnamese Government focuses on investing in 5G technology, ports with jumping potential can skip many development stages according to the roadmap while still ensuring fast and reliable bandwidth.

Fourth, the conversion using energy sources: The first step in converting the necessary energy sources for ports in Vietnam is to conduct an emissions assessment related to port operations. From here, a strategy will be developed that will allow a step-by-step transition to zero emissions while remaining consistent with established programs.

Fifth, adaptation to climate change: To reduce risks from natural disasters, operators in Vietnam need to assess risks from climate and port resilience. This helps in decision-making regarding adaptation to disaster hazards. Ports that seize this opportunity, change and integrate digital and smart technologies promise to own a leading edge when the port and maritime industry enters a period of rapid development.

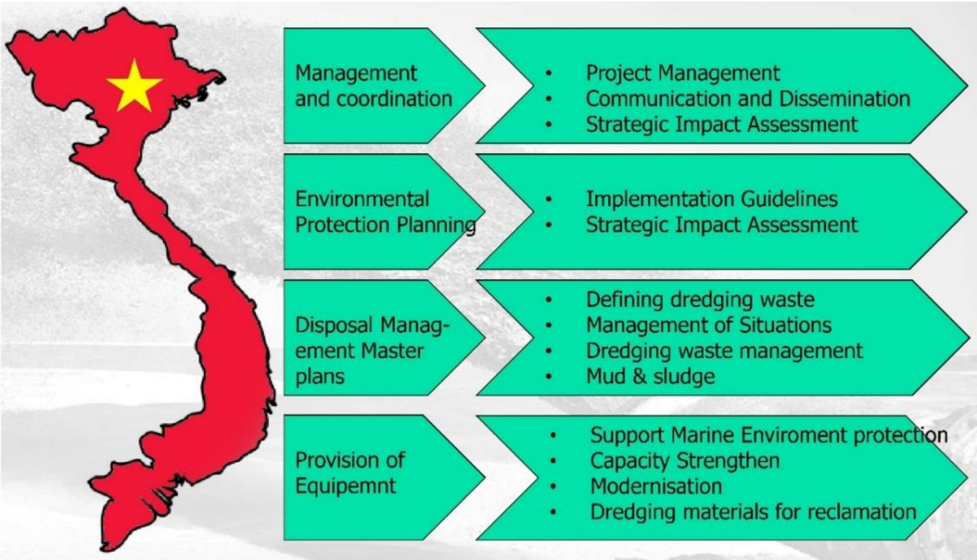

Fig. 6 The process of a green port development proposal in Vietnam from 2020 to 2025 (X. T. Nguyen, 2019)

5. Conclusion

This work aims to understand the gap between developed and developing countries in adopting green port strategy by analyzing ports in Vietnam. Green port strategies that can be applied in developed countries have been summarized in the literature. It has been shown that, although not all ports in the developed world are adopting such strategies, in practice many ports are still reluctant to increase costs for themselves or their customers. The results show that there is little research on developing countries, but the literature reviewed shows that developing countries are taking the first steps toward a green port management strategy, but progress is still slow, including Vietnam. Analysis and discussion of green port development strategies of developed countries have provided Vietnam with useful lessons on the path of sustainable port system development.

With the characteristics of seaport operations, the current operating status, and legal regulations for seaports, so the development of green port criteria for Vietnam's seaports mainly focuses on environmental criteria, environmental incident prevention, and response, and energy use requirements will be incorporated into other criteria. Green port standards for Vietnam's seaports will help build a professional and synchronous environmental management apparatus and raise the awareness of environmental protection for seaport management units. Seaports comply with regulations on environmental protection of Vietnamese law and international conventions. Moreover, ports can join the Association of Eco-Seaports in the region and the world, enhancing the image of Vietnam's seaports.

To fulfill commitments and plans for environmental and energy management, seaports need to build an environmental management apparatus, and energy, mainly using relevant part-time human resources, limiting the use of full-time staff. Ports must complete legal documents on environmental and energy management by current regulations of laws, regulations of localities, and industries. More importantly, seaports will identify environmental issues that need to be improved to be highly efficient. These solutions should be arranged in order of priority for implementation, depending on the problem to be improved, and the port's responsive resources.

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