Proceedings of CONF-FMCE 2026 Symposium: Smart City and Infrastructure Engineering
DOI: 10.54254/2755-2721/2026.CH38042

Green Construction Management in Offshore Wind Power Projects

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Abstract. The transformation to clean energy in the world promotes the development of offshore wind power in deep and Far Seas. The construction is greatly affected by complex sea conditions, with short effective operation time and a long ecological chain impact path. Most of the existing management methods are based on land-based construction, and no effective circular control measures have been developed for the unique marine pollution factors, which can not meet the needs of emerging industries. This paper summarizes the literature review and typical engineering project examples, summarizes the theoretical research progress and governance experience of green construction of offshore wind power, and compares the policy transmission mode and technology docking mode in different jurisdictions. The academic community has reached a conclusion that the land green construction standard can not be well applied to the marine field. Practice has shown that centralized approval and marine spatial planning are feasible, but the transnational spread of floating wind power is still controversial, mainly due to the contradiction between the requirements for stability and construction flexibility. The current research lacks a localization evaluation method combining micro and macro perspectives and the internalization path of ecological cost.

Keywords: carbon peaking and carbon neutralization target, Offshore wind power, Green construction, Management system, Policy adaptation

1. Introduction

Under the guidance of global carbon peak and carbon neutral goals, offshore wind power has become one of the main directions of new energy transformation. Such projects are rich in resources and stable in power generation. In recent years, the installed capacity has been rising, and the development area has also expanded from offshore to offshore [1, 2].

Offshore operation is greatly affected by natural conditions; the available operation window is small, and there are many uncertain factors. The main construction steps rely on large construction ships, and there are many underwater construction processes, which are easy to cause confusion regarding ecological environment impact, safety and quality problems, and duration and cost pressure [3, 4]. The traditional management mode takes cost and schedule as the main goal, and pays less attention to ecological environment protection and low-carbon construction, which can not meet the needs of offshore wind power projects operating in complex environments. The academic

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point of view is that the land-based standard is not applicable to the marine environment [5]. The dispute mainly focused on the applicability of the policy. Supporters believed that the Danish and British methods could be used for reference. Projects such as Shenquan also proved the feasibility of the responsibility of the general contractor [6]; Opponents believe that the lack of legal authorization, unclear soil conditions, and environmental costs are not included [7]. This paper integrates the relationship among process flow, literature review, and national policies to answer the question "which of the mature practices of International Shanghai wind power can be generalized and used for reference from other countries, and which must be improved because of the different laws and regulations of different countries, the particularity of Marine Geology and the impact of ecological environment", so as to provide a basis for the revision of the standard.

This paper discusses green management in the construction phase of offshore wind power construction projects, and summarizes the development characteristics and common problems of offshore wind power construction based on the comprehensive analysis of relevant literature and cases around the world, in order to provide a reference for the improvement of relevant management systems.

2. Green construction policy and adaptability of offshore wind power

2.1. Marine space control and engineering particularity

The space constraints, construction conditions, and risk transmission path of offshore wind power are different from those of onshore wind power, and many details must be determined according to the water level at that time [1].

The external wind energy resources are better. The wind speed 10 km offshore is about 25% higher than that in coastal areas. However, due to the impact of natural environmental factors such as waves and currents, the actual working time is reduced [3]. The construction period of the Guangdong wailuo project is concentrated in May to September, and the impact of a typhoon is about 7 days [8].

The underwater noise of single pile sinking and submarine cable laying has an impact on marine organisms. The noise at 1m away from the sound source during submarine cable laying is as high as 178- 188.5 dB re 1 μPa, and marine mammals may also be affected if the noise is less than 120dB at 100m [6]. Therefore, it is necessary to consider the single and cumulative sound exposure levels. The behavior of fish will change when they are 4m away from the pile [6]. Therefore, the noise impact is far beyond the scope of construction, and there must be a special control standard.

The sediment resuspension concentration caused by submarine cable laying and anchoring operations can reach several 10mg/l, and the influence range of a single fan is about 1km [6]. Pile sliding will also cause instantaneous seabed damage, while the restoration of benthic communities will take decades, reflecting the uncontrollability and far-reaching impact of pollution from offshore operations [4, 6]. The construction quality also determines the emission level during operation, and green construction runs through the whole life cycle management (Table 1).

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Table 1. Comparison of onshore and offshore wind power projects

Contrast direction	Land engineering	Offshore wind power engineering
Spatial conditions	The site boundary is fixed and can be completely enclosed	The development of sea areas may take into account waterway /fishery /protected areas
Construction conditions	All-weather operation	The window period is short, which is greatly affected by season and climate.
Risk issues	Within the site	Noise, floating objects, suspended objects, and falling objects have a long influence distance, a large range, and low controllability.
Work area	Fixed and divisible management	With the dynamic changes of the ship, frequent shutdowns
Core process	Earthwork/pouring/steel structure	Pile sinking/hoisting/submarine cable
Geological risk	Conditions are relatively controllable.	Pile sliding and puncture burst, which are difficult to predict and have great disturbance
Ecologically sensitive period	Basically no need to consider	Attention should be paid to the impact of different biological active periods and risk issues on marine organisms.
Device conditions	General instruments	Jack-up self-propelled installation ship and other special ships
Construction quality embodiment	Basically limited to the project itself	Determine operation and maintenance frequency and emission intensity

2.2. Practical application limitations of general green construction standards

At present, most of the commonly used green construction standards are formulated for onshore engineering projects, which are not fully applicable to offshore wind farm projects. In terms of control indicators, the land standard is mainly aimed at reducing dust, construction waste, and site noise, while the main pollution sources of offshore construction include underwater noise, seabed damage, and marine sewage discharge [3, 9].

The concept of construction organization, management, and control is very different. Land projects can be finely managed on closed sites, while offshore operations' surface changes with the movement of ships and is vulnerable to the impact of climatic conditions. It often stops work repeatedly. The traditional progress environmental protection linkage management method can not be simply applied. Such land-based practices as garbage partition storage cannot be realized in the limited space on board, and the secondary pollution caused by transportation back to land for treatment has not been included in the unified standard.The problem of insufficient coverage of risk management and control has become increasingly serious. The general standard ignores the link between special geological risks at sea, extreme weather emergencies, and ecological damage.

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Runaway engineering risks such as pile sliding and anchor dragging will lead to secondary ecological accidents such as oil spills and large parts falling [4, 9]. The transmission mode of "engineering risk to ecological damage" has little impact on onshore projects, but it is the key object of offshore construction management. The management regulations and ecological protection requirements of major sea areas are different, and the general standards can not meet the management specifications of different regions [10]. The expenses paid by enterprises to comply with the general provisions can not fundamentally solve the ecological and environmental problems, but squeeze the cost of ecological restoration.

3. Research and practice on green construction management of offshore wind power

3.1. Existing research progress in different countries

There are significant differences in research emphasis among countries. Chinese research focuses on the mechanism of single pile sliding, but the prediction model is mostly based on the calibration of siliceous sediments, and the adaptability to deep- and far-sea carbonate soil layers is insufficient [4]; And process optimization often ignores the ecological cost, and speed-up measures may increase carbon emissions [2]. The UK has rigidly embedded the approval of marine spatial planning and has included underwater noise in the legal requirements [8]. Ireland, as a latecomer market, has set a differentiation threshold (such as the limit of Atlantic salmon migration period) based on mature experience [1]. In general, the adaptation of the existing literature in the internalization of ecological costs and the localization of different technologies in different regions needs to be strengthened (Table 2).

Table 2. Research progress in various countries

Country/region/ Organization	Research focus	Core issues	limit
China [2, 4]	Mechanism of single pile sliding	Most of the models are calibrated based on siliceous sediments, and the carbonate rocks are not well adapted; Speeding up may increase carbon emissions.	Lack of a local exclusive model; ecological cost not included in optimization.
Britain [8]	Spatial planning+approval	Underwater noise is included in legal requirements; Design envelope mechanism to give flexibility.	Relying on improving the legal framework, late developing countries are difficult to copy
Ireland [1]	Late market policy	Differentiation threshold (Atlantic salmon migration period); Green constraints embedded in auction system	Insufficient accumulation of local empirical data

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Table 2. (continued)

EU [1]	Unified governance framework	2014/89/EU directive promotes unified Marine Spatial Planning	Large differences in implementation among Member States
European academia [6]	Floating ecological impact	Early research on the disturbance of anchor chain/cable to benthos, proposed OECM compensation.	Lack of Sinicization based on European waters
Denmark [1]	One-stop approval	Under the unified management of the energy administration, the cycle is 4-5 years.	High requirements for single department capability
Netherlands [1]	Centralized licensing	Green requirements are integrated into a single license to reduce compliance costs.	May weaken differentiated fine response

3.2. Typical engineering cases

The empirical case shows that technical potential and management loopholes coexist. Guangdong Wailuo project shortens the process handover time through flow operation, but the position deviation caused by surge needs to be corrected again, and the additional energy consumption weakens the improvement effect [11]. The theoretical window period of the project from May to September is about 153 days. Due to the coexistence of typhoons (about 7 days each time), fog, and various adverse conditions, the actual number of days that the fan foundation can be constructed is only 25 days, less than 17% [11]. The operational results of jack-up self-propelled ships in the Zhanjiang sea area show that the field effect of high-precision positioning technology is discounted, the puncture problems of clay geological pile legs are frequent, and there is no unified standard management for high-pressure grouting waste materials [3]. Large installation vessels idle at sea or spend tens of tons of fuel every day in the process of rework and positioning. The idleness and rework caused by rush work cause a large number of additional carbon emissions. The technical improvement needs to be matched with the green management system; otherwise, the increase in speed will increase the ecological risks, and the internalization of ecological costs is necessary.

4. Existing issues and lessons learned

4.1. Existing weakness of project management

At present, there is a common phenomenon of "compliance is more important than effectiveness" in the management of offshore wind power projects, which is more obvious in the subcontracting chain. The general contractor's environmental requirements are gradually decreasing after layers of subcontracting, and the grassroots front-line operators' awareness of marine ecological environmental protection is weak. "Fujing 001" incident is an example of the lack of data support

DOI: 10.54254/2755-2721/2026.CH38042

for on-site decision-making. After receiving the typhoon warning, the engineering ship did not evacuate in time, and the illegal operation caused the anchor chain of the anchor ship to break and collide with the wind turbine pile, resulting in 25 deaths and 1 missing, reflecting the failure to perform the duties of safe production and ecological protection [9]. More than 35 nautical miles offshore, the mobile phone, AIS, VHF, and other communication monitoring signals are affected. The maritime department is unable to understand the site situation in time, and the site decision depends on experience judgment rather than data support [9]. The supervision gap overlaps layers of subcontracting, concealment, and misrepresentation of the case, which makes the potential safety hazard unable to be found and stopped, resulting in tragedy. The accident may also lead to fuel leakage and secondary damage to the seabed caused by ship salvage, and secondary environmental problems can not be ignored.

The uneven quality of personnel has also hindered the implementation of green construction. The front-line operators' awareness of the hazards of scattered items (screws, packaging supplies, etc.) entering the sea is not in place, and there is a lack of corresponding assessment and reward and punishment system [5]. The cumulative damage of these small, high-frequency emissions to the marine environment should not be underestimated, which is obviously missing within the scope of the existing management system.

4.2. Comparative analysis and reference direction

International comparison shows that the decentralized approval system has the disadvantages of different standards and low efficiency. Under the system currently implemented in China, green construction requirements are scattered in various departments such as environmental protection, maritime affairs, and safety. There are still overlaps or even contradictions in the standards between various departments, which not only increases the cost of compliance, but also reduces supervision [8]. By comparing the policy documents of China and the UK, it is found that the UK policy has greater support for marine ecological construction and long-term ecological development, and China's policy lacks the green construction standard of sea area refinement [8]. The main directions that can be learned are as follows: learn from Denmark's "one-stop" examination and approval, integrate sea-related authorities, reduce links, and unify standards [1]. For emerging businesses such as floating types, it can refer to the practice of a "project design envelope" in the UK, set ecological red lines at the planning level, and give certain flexibility for scheme modification in the project [1]. Reconstruct the standard system, learn from the experience of the European Union, increase marine-specific indicators such as underwater noise and suspended solids concentration, and take differentiated management measures for special geological conditions such as carbonate rock soil layer [6]. Make good use of the economic lever, refer to the practice of Ireland, integrate the ecological threshold into the auction process, extract the ecological compensation, and include the loss caused by ecological damage into the project cost, to realize a virtuous cycle [1]. The transplantation of these experiences has its boundary conditions, and the framework assumption at the institutional level has good universality, but the technical standards and cost models need to be localized and improved according to the legal provisions of different countries, geological conditions, financial support, and other factors.

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5. Challenges and research prospects

5.1. Current core challenges

Although the floating type has no piling noise, the seabed swept area of the single mooring system is about 0.25 km². The anchor chain disturbs the benthic habitat, and the dynamic cable electromagnetic field may also affect marine organisms. Its mechanism is still under discussion.

Monitor bottleneck real-time control. Marine facilities have short endurance time, slow information transmission, and it is difficult to continuously monitor underwater noise, suspended solids diffusion, and other indicators. The current method is more based on on-site operation of ships, which is expensive and has limited coverage [7]. The long-term cumulative environmental impact of large-scale construction still lacks corresponding monitoring measures and theoretical model support [6].

The root cause of the emergency short board is not only the inadequate implementation of safety responsibilities, but also the serious neglect of the management of secondary ecological hazards. The sinking or drift of Fujing 001 is generally accompanied by hundreds of cubic meters of fuel leakage (engine room oil is about 15 m³, and the dangerous storage capacity of 10000 ton barge is about 595 m³). The oil film expands to form a large area of water pollution, and the sunken ship salvage operation will also cause a second trauma to the seabed, with a damage area of 500~1600 m², damaging the biodiversity of the seabed [9].

5.2. Future research directions

Future research should focus on interdisciplinary penetration, continue to explore and improve the green construction evaluation index system on the basis of solving problems, develop a three-level control standard in terms of floating wind power, and clarify the thresholds and monitoring methods of exclusive indicators such as anchor chain disturbance and the impact of movable cables [6]. This requires the cooperation of multiple disciplines such as marine ecology and geotechnical engineering to complete the data calibration according to the current situation of marine ecology in different countries.

Improve the cross-departmental linkage approval system, integrate the speed advantage of "one-stop" approval and the flexibility of "project design contracting", and eliminate the different standards caused by multiple approvals [1]. Research on digital twin intelligent monitoring, realize risk early warning, process optimization and real-time statistics of energy consumption, and break through the problem of offshore data acquisition and transmission [7].

Establish an ecological compensation and incentive mechanism, carry out the construction of the "marine ecological credit" system, combine environmental performance with electricity subsidies and green credit, and use economic leverage to promote enterprises from passive law-abiding to active environmental protection [6]. Internalization of ecological costs is the fundamental way to change the current unreasonable cost accounting system. It is necessary to determine the assessment methods and compensation standards of ecological damage in the process of policy formulation. Strengthen life cycle management, formulate the calculation standards of construction carbon emissions, and strengthen research on the recycling of waste such as waste concrete pile heads and construction mud [5, 12].

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6. Conclusion

The research on green construction of offshore wind power has shifted from a single process optimization to a system engineering covering policy transmission, technology adaptation, and ecological management and control. Scholars generally agree that the land green construction standard has the defect of scene adaptation, and it has become a consensus to construct an exclusive index system such as underwater noise threshold, suspended sediment concentration, and spatial avoidance of vulnerable marine ecosystems. For far-reaching sea development, international practice has verified the effectiveness of centralized approval and marine spatial planning, but there are significant differences in the governance logic under different legal systems. The differences between the rigid constraints of the EU and the risk-based hierarchical management and control in the UK form different management methods.

The controversy focuses on the applicability of the existing policy tools in the floating new business. The supporting view is that Denmark's one-stop approval and the UK's project design envelope mechanism have the characteristics of transnational migration and can solve the problem of inefficient multi head management; The opposition points out that the lack of legal authorization of different countries in the exclusive economic zone, the cognitive blind spot of deep and far sea carbonate soil mechanics mechanism, and the economic problem of ecological damage cost constitute insurmountable institutional and technical barriers. This divergence is essentially due to the policy pursuit of institutional stability, while construction needs operational flexibility in the face of adverse sea conditions, and the two have not yet found a balance.

At present, the main problems of existing research are the lack of connection between micro technology and macro policy, the technical feasibility can not be implemented into the rationality of the system, the ecological impact caused by the special geology and floating construction in the far-reaching sea has not been measured by the corresponding localization index system, the cost of ecological loss has not been included in the cost, and the green construction has remained in the state of forced compliance. Further research can be carried out from the perspective of deep-sea hierarchical management mode; multi-department linkage approval; Digital twin intelligent management; The marine ecological credit system and the recycling of construction waste are the entry points to transform the damage to the environment into economic restrictions in the whole life cycle, and promote the green construction from passive compliance to active governance.

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