*European Journal of Energy Research*
*Vol 1 | Issue 1 | Month 2024*
*ISSN* 2736-5506

RESEARCH ARTICLE

# Multi-Dimensional Analysis of Offshore Wind Industry: The Case of French Wind Farms

Charles Henri Fredouet*

## *ABSTRACT*

**The development of the offshore wind industry faces a number of organizational and economic hurdles, often strong societal resistance and the instability of public policies, thus drawing interest from academics who have analyzed this process from multiple viewpoints. This body of knowledge has served as the basis for a study aiming at characterizing France's first three offshore wind farm projects, which finally reached the energy production stage after over ten years of development. Results show that although this development has been the subject of atypically strong social opposition, the projects' features are quite close to those highlighted by the literature.**

**Keywords:** Energy transition policies, French offshore wind farms, offshore wind industry, offshore wind social opposition.

**Submitted:** Month 00, 2024
**Published:** Month 00, 2024

*10.24018/ejenergy.2024.1.1.146*

*ESLI School of Logistics, France.*

****Corresponding Author:***
e-mail: cfredouet@gip-cei.com

## 1. Introduction

Many countries, particularly in Western Europe, have embarked on an energy transition strategy aimed at reducing the share of fossil fuels in their supply mix.

One of the chosen alternative sources is offshore wind energy, which has benefited over the years from significant technological improvements in terms of wind turbine power capacity and installation methods.

However, the development of this industry must face a number of organizational and economic hurdles, often strong societal resistance and the instability of public policies.

Such characteristics, comparable, for example, to those exhibited by project-based industries and global production networks, have consequently aroused the interest of academic authors. A literature review focused on the development processes of offshore wind farms has identified a body of research specifically devoted to certain aspects of these processes.

As France launched its own offshore wind development program about ten years ago, much later than its European, British, German, and Danish neighbors, it seemed interesting to study the cases of the three French wind farms recently put into operation from these same aspects, to see to what extent the results of the analysis could converge/diverge from those obtained in other contexts.

After a first part dedicated to the restitution of the literature review, this paper will therefore try in a second part to characterize the respective construction processes of three offshore wind farms with regard to some of the concerns put forward by the academic authors.

## 2. Literature Review

The reviewed sample of academic literature dealing with the development of offshore wind farms covers the period 2013–2023.

Six topics of interest to the authors have been selected: the strategic decision-making context, the project social acceptability management, the industrial and service activities localization constraints, project stakeholders' cooperation, the supplier contracting policies, and the role of ports.

### *2.1. Strategic Decision-Making Context*

The advent of offshore wind as an alternative energy source stems from converging political and economic interests [1], which created an environment all the more favorable as public authorities more actively assist related projects in their successive design and implementation phases [2].

The alignment of regional, national, and supra-national public policies is, therefore, an essential condition for the development of this industrial sector [3], with particular importance given to the cooperation between the national and the regional levels, as well as to the backing by regional public authorities of the global production network re-designs possibly undertaken by project leaders [4].

The support brought by political stakeholders to the development of the offshore wind industry can also be explained/justified by the fact that, in addition to initiating/advancing the energy transition process, this development can also contribute very significantly to job creation, particularly in the regions hosting the wind farms [5].

Leading companies in the renewable energy market, already naturally attracted by the wind energy sector, including offshore, can thus be encouraged to set up production units and R&D centers, along with their local eco-systems, not only to serve the creation of local wind farms but also likely to work for projects outside national borders [6].

Operating in hopefully favorable political and economic contexts, the consortiums carrying out projects must face at least three strategic choices: the choice of the offshore wind farm site, the choice of the component and service suppliers, and the choice of installation and maintenance ports.

#### *2.1.1. The Choice of the Offshore Wind Farm Site*

Over the course of a (very) long series of preliminary studies (geological, economic, environmental, etc.) and stakeholder consultations (users, local communities, NGOs, etc.), various selection criteria are gradually emerging: this is the case among others, of energy source relevance, technical feasibility and economic opportunity, as well as social acceptability and environmental impact.

Depending on the context, some of these criteria are considered discriminant, leading to the immediate elimination of various siting options, while others help complete the evaluation of the sites selected in the shortlist [7].

#### *2.1.2. The Choice of the Component and Service Suppliers*

In view of the high expectations of the public authorities regarding the offshore wind industry's potential contribution to local job creation, the choice of suppliers is generally subject to a strong localization requirement, probably more for foreign companies, as local leading firms are more spontaneously inclined to contract locally [8].

However, the components and services required for the construction of an offshore wind farm must be provided by highly qualified suppliers, who also contribute to the smooth running of the project [9], but not all of these suppliers are able to settle in the territory hosting the farms.

In addition, a high degree of cultural proximity and/or the experience of previous successful collaborations, with the resulting trust [10], can be incentives for leading firms to work repeatedly with the same suppliers.

Project leaders must, therefore, seek an economically, socially, and technologically acceptable compromise between these three aspects, which have a significant impact on the building of their supply networks.

#### *2.1.3. The Choice of the Installation and Maintenance Ports*

The geographical location of the port in relation to the wind farm site is a key choice criterion because of its strong impact on the process, and therefore the cost, of the installation, operation, and maintenance operations [11], [12].

Ease of access by water and land and the availability of storage areas and handling equipment adapted to the unusual volume and weight of wind farm components also play a role in the choice of ports [13].

The possibility of setting up industrial sites within or near the port for the production of wind turbines and foundations is another important decision factor to be taken into account [9].

### *2.2. Project Social Acceptability Management*

Among all the challenges that are disrupting the development of the offshore wind industry [14], social opposition holds an important place, if not the most important.

The timing of the project is recognized as a critical success factor, which makes any delay in the project launching all the more damaging as it is longer [15]. Moreover, in the search for energy justice that guarantees everyone's access to sustainable and safe sources [16], offshore wind can be of significant help.

However, wind farm construction opponents, most of them maritime site users, local communities, and NGOs, are multiplying blocking actions both in court and on the ground. Their explicit motivations are economic (e.g., coastal fishermen), environmental (e.g., biodiversity-defending NGOs), political (e.g., local authorities), or simply individual convenience (e.g., permanent or holiday residents).

The resolution of such conflicts requires the positive involvement of all stakeholders, but because of the toughness, even violence, of some of them, this involvement is most often difficult to obtain [17].

Besides, different issues and values have to be taken into account, especially for the management of risks related to the multi-use of farm sites [18], making it impossible to reach a consensus supporting a single solution on both the technical and institutional sides.

The option is rather to make specific adjustments to the different groups' requests in the hope of decreasing their respective opposition to the project [19]. For example, since the creation of offshore wind farms is part of a global approach to sustainable development, it must be avoided that it has too much impact on the environment, either in its industrial phase or in its installation phase [20]; incidentally, by minimizing the project's negative externalities, the need for financial compensations to be paid by the consortiums is at least limited [21].

This consideration of specific interests does not preclude a more general approach applicable to all external stakeholders. It is essential to communicate widely and intensively on the project's various aspects as early as in the initial phases of the opportunity and feasibility studies [18], [22], and to carry out formal and informal actions in the ultimate purpose of establishing a relationship of trust with declared and potential opponents: trust in the project leaders, trust in the processes they intend to conduct, trust in the results which will be obtained [23].

### 2.3. Industrial and Service Activities Localization Constraints

Apart from providing green electricity to businesses and residents, one of the main goals of offshore wind farm construction is the creation of local jobs.

While foreign lead firms tend to source from global markets in the absence of localization constraints, they contract locally if there are as for local lead firms, they source locally even in the absence of location constraints but do so even more if such constraints exist [8].

The public authorities, therefore, generally make the granting of subsidies to offshore wind farm projects conditional on commitments to create jobs by awarding contracts to locally established companies [24]. These may be companies already present on the national territory, but also companies that are building/acquiring industrial sites or opening service agencies to meet the localization requirements of the projects in which they wish to participate [22]; these local installations can also be requested by Tier 1 partners from their own suppliers for on-site support [25].

To encourage project leaders to sign contracts with local companies, localization constraints are not sufficient when the activities to be carried out require strong relational proximity between partners; they must be complemented by various mechanisms promoting knowledge sharing, inter-company and inter-sectoral linkages, and more generally the development of an offshore wind energy industrial sector [2], [4], [26].

### 2.4. Project Stakeholders Cooperation

The overall process of creating an offshore wind farm is made up of several sub-processes, from project design to end-of-life management of the farm, via the production, installation, and operation/maintenance phases. These sub-processes bring together activities and resources whose respectively execution and allocation require excellent cooperation between the involved actors. The overall process is also accompanied by a strong need for coordination between project leaders and their main public and private partners.

While good collaboration between actors seems easier to implement in some activities than in others [9], it must nevertheless remain a dominant concern at each stage of the project because of its impact on an essential performance criterion the final cost of the energy produced by the farm [27].

Even if mutual trust, information sharing, and the conduct of joint R&D activities can reduce their effects, various sources of uncertainty and incompatibility (geographical distance, cultural differences, etc.,) disrupt the establishment of inter-company relationships in offshore wind projects [10].

At the overall level of the farm creation process, depending on the relational context between stakeholders in production, installation, and operation/maintenance operations, the leading firms manage this complex network of stakeholders either through control and intervention or through coordination and delegation [28].

To go further in optimizing cooperation between actors, integration may be an option to consider [29]. Not having to be through mergers and/or acquisitions, it can be functional when, as is often the case, the project leaders contract with the same Tier 1 suppliers (e.g., with the same supplier of inter-array cables), which in turn subcontract with the same manufacturers or service providers (e.g., with the same shipping company for an offshore installation vessel).

In addition, cooperation between public actors and between public and private actors is a fundamental condition for the success of a wind farm project and, more generally, for the development of the offshore wind industry. In the specific case of a project, this cooperation is particularly important between public authorities and private consortiums during the design and launch phases [18], [24]. Regarding the promotion of a new industrial sector, it is mainly necessary between the local, regional, national, and supra-national public authorities [3], [26].

### 2.5. Supplier Contracting Policies

In a project-based industry such as offshore wind, the choice of the contracting strategy is of utmost importance because of the impact it will have on the design and management of the global supply network [30].

Project leaders typically adopt one or the other of two strategies: either they opt for the signing of EPCI (Engineering, Procurement, Construction & Installation) contracts, or they opt for multi-contracting. In the first case, the consortium signs a single contract for both supply and installation for each of the four main packages of the project: wind turbines, foundations, inter-array cables, and offshore substation. In the second case, it signs separate contracts, one for the supply of the components and the other for their installation [22].

Generally speaking, as the market matures, the size and experience of the project leaders influence the choice of EPCI contracts or multi-contracting: large companies, which have already successfully completed offshore wind farm projects, tend to gradually abandon EPCI contracts in favor of multi-contracting; conversely, smaller companies entering the market will seek the greater security and manageability provided by EPCI contracts [31], [32].

In the case of a given project, other factors will come into play: besides obvious financial considerations, the reputation of potential suppliers present on the market, possible past collaborations between the leading firm and a particular manufacturer or service provider, or the localization constraints imposed by public authorities which restrict the set of companies likely to intervene in the project.

### 2.6. Role of Ports

Ports play a very important role in the supply chain of offshore wind farms [11].

They are, of course, involved in transport operations to installation sites and in the operation and maintenance of wind farms [33].

But they also have their place in the production processes of various components, which, due to the handling and transport problems that their large size and/or very heavy weight entails, can be (very) difficult to produce far from a port. This is particularly true of wind turbine foundations, which weigh several hundred or even several thousand tons [9].

Ports are also the site of assembly activities for components such as wind turbine towers and jacket foundations for electrical substations, as well as pre-assembly of wind turbines before their transport to the installation site to minimize the number and complexity of operations to be carried out at sea [33].

These assembly/pre-assembly activities are accompanied by risks related to the handling of elements of non-standard size and weight; managing such risks requires careful preparation and a strong synchronization between actors during the course of execution; it is therefore impacted by the number of participants, the quality of the human resources and the relevance of the procedures [34].

It is on the basis of these six points of interest marked by the academic literature in the development of offshore wind farms that the analysis grid of the first three farms installed in France was built, the results of the study of which are presented below.

## 3. Multi-Dimensional Study of French Offshore Wind Farms

After more than ten years punctuated by lengthy administrative procedures and multiple legal actions, and finally, by construction and installation phases, the first three French offshore wind farms were commissioned within a few months of each other.

In chronological order, the first to inject electricity into the public distribution network was the Saint-Nazaire wind farm in southern Brittany (2022); it was followed by the Saint-Brieuc farm in northern Brittany (2023) and the Fecamp farm in Normandy (2024).

The project leaders were a consortium bringing together EDF Renewables (France) and EIH, a subsidiary of Enbridge (USA) and CPP Investments (Cannada) for the Saint-Nazaire wind farm; Iberdrola (Spain) for the Saint-Brieuc farm; a consortium bringing together EDF Renewables, EIH and Skyborn Renewables (Germany) for the Fecamp farm.

These three projects have been studied with regard to 1) the context in which they were designed and developed, 2) the management of their social acceptability, 3) the localization constraints to which they have been subjected, 4) the cooperation between stakeholders in the design and development phases, 5) the contracting policies adopted by their project leaders, and 6) the role of the ports involved in the production, installation, and maintenance operations.

### 3.1. *Design and Development Context*

The submission/permitting processes for the three projects were launched as part of a national policy led by the government to accelerate the country's energy transition and build a local offshore wind industry. Although they showed some divergences in approach to the subject, for example, in dealing with the opposition of external stakeholders to the creation/operation of offshore wind farms, regional and national public authorities gradually provided sufficient support to the three projects through financial aid, requirements for the localization of industrial and service activities or adjustments to education and research programs.

In addition to this convergence of interests, encouraged by the EU on the part of regional/national policymakers, the development of the projects has also benefited from the strategic eagerness and financial capacity of energy sector leaders to invest in a potentially profitable French offshore wind industry.

### 3.2. *Management of Social Acceptability*

While the suboptimal regulatory environment existing in France at the time did not significantly impede the progress of the three projects, social opposition is one of the main factors, if not the main one, explaining why the development of offshore wind farms took so long to catch up in the country.

For their part, the project leaders have been individually proactive in limiting the environmental and socio-economic impacts of their wind farms via numerous prior scientific studies and technical adjustments, such as modifying the number of wind turbines or redesigning the site outlay.

In addition, initiatives have been taken by the three owner entities and the public authorities: a wealth of information has been made available to external stakeholders, and monitoring committees have been created, welcoming all possible participants in the risk management process. However, although participation was high, the positive-minded approach of most of the groups, namely fishermen, NGOs, and local communities, to the resolution of potential usage conflicts was very weak. In the end, no optimal solution was found that would suit all external stakeholders; a form of compromise has been reached with fishermen and local authorities, mainly on the basis of financial compensations and contributions, thus buying social peace, but not with residents or NGOs.

From a more general point of view, despite multiple formal and informal actions carried out by project leaders to this end, no relationship of trust has been established with the opponents, whether it is trust in the leading companies themselves, trust in their processes and/or trust in the results of their projects.

To the extent that trust can lead to acceptance, conversely, this lack of trust may explain why, from the mention of the possible creation of an offshore wind farm until beyond the start of its operation, there has been no acceptance of projects by external stakeholders.

### 3.3. *Localization Constraints*

While in two of the three projects, the leading firm is a French company, on the other hand, only a few local companies could claim Tier 1 supplier contracts and guarantee a certain level of localization of industrial activities and service provision. Thus, since, in addition to the provision of green energy to industries and residents, one of the main socio-economic objectives of the development of offshore wind is the creation of local jobs, the localization has mainly been implemented as part of authorization prerequisites and of subsidy contracts awarded by the public authorities to the project promoters.

Of course, a significant number of activities were quite inevitably carried out abroad, in the facilities of Tier 1 suppliers or in those of their subsidiaries/subcontractors, particularly for the production of wind turbine foundations and substations.

But contractual requirements for localization led leading firms to select mainly Tier 1 suppliers who were either locals or were non-locals but had built factories on the national territory (e.g., for the production of wind turbine components) or open local subsidiaries to which contracts could be directly awarded (e.g., for offshore installation operations); in addition, project promoters and holders of global production and installation contracts worked to set up networks of local subcontractors rather than calling on their foreign partners through the establishment of advanced supplier sites.

### 3.4. *Cooperation between Actors*

Within the global supply chains of the three farms, some sub-processes have been geographically fragmented, in particular, the production of inter-array cables and electrical components for offshore substations, or also of non-gravity foundations and towers in the case of one of the wind farms. Besides, the multiplication of legal actions conducted by opponents and the length of the administrative procedures to be followed have made it difficult to set a reliable date for the start of operations, which is crucial for the synchronization of suppliers' production planning. In addition, given the large supply-demand imbalance in the provision of offshore installation services, the availability of vessels was a potential source of delays. However, despite all these operational hurdles, the collaboration between the multiple players was good enough not to generate any significant postponement of execution, probably at least in part due to the call for experienced partners holding global production and installation contracts.

Rather than formal integration, which would be a further step in structuring the cooperation of the actors, there has been a de facto integration: the project leaders have signed contracts with the same Tier 1 suppliers, for example, in two wind farms for the construction and installation of the offshore substation and in the three farms for the manufacture of inter-array cables; in turn, Tier 1 suppliers subcontracted with the same companies, for example the wind turbine suppliers of two wind farms for the final assembly and installation operations, or the substation supplier of two farms for the construction of foundations.

The fact that the same companies cooperate on at least two of the three wind farms strengthens partnerships and improves the standardization of processes, which contributes, among other benefits, to the reduction of the total cost of energy. From a more general point of view, regarding the management of their production and installation network, the leading firms have been able, in such a context, to rely on coordination and delegation rather than have to opt for control and intervention.

### 3.5. *Contracting Policies*

As in other offshore wind farms, four packages of components and services were to be supplied: production and installation of the wind turbines. Production and installation of the foundations, production, and installation of the offshore substation, and production and installation of the inter-array cables; the production and installation lot of the export cables is here handled separately by the French national distribution network operator.

Assuming that an EPCI contract covers both the production and installation operations and multi-contracting refers to situations in which the production and installation contracts are awarded separately, the procurement strategies adopted by the three project leaders are largely in favor of EPCI-type contracts. In the case of Saint-Nazaire, the multi-contracting covered only part of the wind turbine installation process, for which a contract was awarded directly by the owning consortium; in the case of Saint-Brieuc, the multi-contracting involved four suppliers in the production and two in the installation of the offshore electrical substation, but only one supplier for each of the two production phases and the installation of foundations.

Such an advantage granted to global supply contracts signed with leading suppliers in the offshore wind market may be due, at least in part, to a concern for security on the part of project promoters, for whom these three wind farm creations were their firsts in a country where the renewable energy sector was in its infancy.

### 3.6. *The Role of Ports*

The ports are involved in the three phases of development and operation of the three projects: production, installation, and operation and maintenance activities.

In the production phase, all wind turbine components (blades, nacelles, generators, towers), all wind turbine and offshore electrical substation foundations, and all substation superstructures were manufactured in or near ports, with the sole exception of the monopile foundations of the Saint-Nazaire wind farm.

In the installation phase, port pre-assembly was the rule in all three projects in order to minimize the number of components to be installed offshore and maximize the number of turbines loaded on the installation vessels; however, the pre-assembly could be carried out in a port other than the port of installation, as for example in the case of the assembly of the towers, jackets and the offshore electrical substation of the Saint-Nazaire wind farm.

In the operation and maintenance phase, activities have been/are being led out of ports chosen to be geographically and technically as close as possible to the sites; to minimize the influence of the distance between the farm and the port on operating costs, small ports were chosen, even if investment in infrastructure and/or superstructures was required, rather than larger, better equipped ports but which were further away from the farm sites; in the case of Saint-Brieuc, a large port was used at the beginning of the operation of the farm because it was immediately and easily available for this purpose, pending the completion of infrastructure and superstructure adjustments in the small port eventually selected for operation and maintenance.

Critical risk situations had to be managed at the port level during the development of the three projects: safety issues arising from actions at sea by external stakeholders aimed at slowing down/stopping the construction process; cooperation issues related to the involvement in the construction of the wind farm of multiple players, including some newcomers to the port community; resource availability issues, as handling of wind turbine components and extremely heavy/bulky foundations, require specific human/technical capabilities.

The results of this effort to characterize the first three French offshore wind farms must be put into perspective with those of the literature review that made it possible to specify the different dimensions of the analysis.

## 4. Final Remarks and Conclusion

The literature review highlighted some notable aspects of the development of the offshore wind sector: the nearly unavoidable financial help, but also the political and regulatory support needed from public authorities, whether regional, national, or supra-national; the almost general existence, albeit of varying intensity, of multiple oppositions to the construction of wind farms near the coast; the influence of economic protectionism on the localization of jobs; the preponderant role of ports, in particular in the installation and operation processes of wind farms; and finally the relevance of a good contract-based, trust-reinforced cooperation between actors.

The importance of these various aspects is reflected in the case of the three French farms.

The strong support of the government and, although more nuanced, of the regional authorities has finally made it possible to move forward with a development process that had been stalled for several years, but it came more gradually and with more procedural complexity than in other countries.

Conversely, unlike in some other places, social opposition from local fishermen, residents, and environmental NGOs has manifested itself everywhere, extremely rapidly, and often in a particularly violent way; much more than to geological, technological, or organizational reasons, the delay in the progress of the three projects is due to this strong social opposition.

This time, more in line with what is reported in the literature, the concern that the creation of jobs generated by the development of the wind farms should benefit primarily the local economy has led to the introduction of localization prerequisites in the authorization decisions and subsidy allocations; this has resulted in the local settlement of new industrial sites and new maritime service subsidiaries, as well as the development establishment of local subcontactors networks, with preference being given, as much as possible, to their local sites by Tier 1 suppliers.

In each of the three projects, the choice of ports involved in production, installation, and operation activities took into account the obvious parameter of the geographical position of the farm but also other elements that are less often identified: in the case of Saint-Brieuc, the port of Brest was selected as a production and assembly port because it had invested in advance in infrastructure and superstructures capable of storing and handling the wind turbine and foundation components; in the case of Fecamp, the port of Cherbourg was chosen as the installation port due to the availability of dedicated spaces for the storage and pre-assembly of wind turbine components; in the case of Saint-Nazaire, the port of Antwerp was integrated into the production network due to the presence nearby of the industrial site chosen for the production of part of the wind turbine foundations.

In line with the tendency of leading firms to gradually migrate from EPCI-type contracts to multi-contracting as they progressively mature on the market, the choice of the main project leaders, at the time with little experience in the field of offshore wind power, remained rather in favor of global contracts combining production and installation; in addition to reducing operational risks, this approach has made it possible to adopt a less restrictive way of managing projects, based on delegation rather than intervention; more generally, the use of a few experienced Tier 1 suppliers in the context of such contracts has facilitated cooperation between actors and the overall development of projects.

In the end, the study showed that although their development has been the subject of atypically strong social opposition, the first three French offshore wind farms have characteristics close to those highlighted by the literature. The current launch of new wind farm projects hosting floating wind turbines will give the possibility of comparing them to older projects on the assumption that, in addition to technology, the various economic, regulatory, social, and environmental contexts will have changed.

## Conflict of Interest

The author declares that he does not have any conflict of interest.

## References

[1] Kern F, Smith A, Shaw C, Raven R, Verhees B. From laggard to leader: explaining offshore wind developments in the UK. *Energy Policy*. 2014;69:635–46.

[2] Kern F, Verhees B, Raven R, Smith A. Empowering sustainable niches: comparing UK and Dutch offshore wind developments. *Technol Forecast Soc Change*. 2015;100:344–55.

[3] MacKinnon D, Dawley S, Steen M, Menzel MP, Karlsen A, Sommer P, *et al.* Path creation, global production networks and regional development: a comparative international analysis of the offshore wind sector. *Prog Plann*. 2019;130:1–32.

[4] Dawley S, MacKinnon D, Pollock R. Creating strategic couplings in global production networks: regional institutions and lead firm investment in the Humber region, UK. *J Econ Geogr*. 2019;19(4):853–72.

[5] Kahouli S, Martin JC. Can offshore wind energy be a lever for job creation in France? Some insights from a local case study. *Environ Model Assess*. 2018;23:203–27.

[6] Lacal-Arántegui R. Globalization in the wind energy industry: contribution and economic impact of European companies. *Renew Energy*. 2019;134:612–28.

[7] Vagiona DG, Kamilakis M. Sustainable site selection for offshore wind farms in the South Aegean—Greece. *Sustainability*. 2018;10(3):749.

[8] Van der Loos A, Langeveld R, Hekkert M, Negro S, Truffer B. Developing local industries and global value chains: the case of offshore wind. *Technol Forecast Soc Change*. 2022;174:121248.

[9] Poulsen T, Lema R. Is the supply chain ready for the green transformation? The case of offshore wind logistics. *Renew Sustain Energ Rev*. 2017;73:758–71.

[10] Hennelly P, Wong CY. The formation of new inter-firm relationships: a UK offshore wind sector analysis. *Int J Energy Sect Manag*. 2016;10(2):172–90.
[11] Shafiee M, Brennan F, Espinosa IA. A parametric whole life cost model for offshore wind farms. *Int J Life Cycle Assess*. 2016;21:961–75.
[12] Ren Z, Verma AS, Li Y, Teuwen JJ, Jiang Z. Offshore wind turbine operations and maintenance: a state-of-the-art review. *Renew Sustain Energ Rev*. 2021;144:110886.
[13] Akbari N, Irawan CA, Jones DF, Menachof D. A multi-criteria port suitability assessment for developments in the offshore wind industry. *Renew Energy*. 2017;102:118–33.
[14] Colmenar-Santos A, Perera-Perez J, Borge-Diez D, dePalacio-Rodríguez C. Offshore wind energy: a review of the current status, challenges and future development in Spain. *Renew Sustain Energ Rev*. 2016;64:1–18.
[15] Muhabie YT, Rigo P, Cepeda M, de Almeida D'Agosto M, Caprace JD. A discrete-event simulation approach to evaluate the effect of stochastic parameters on offshore wind farms assembly strategies. *Ocean Eng*. 2018;149:279–90.
[16] Heffron RJ, McCauley D. Achieving sustainable supply chains through energy justice. *Appl Energy*. 2014;123:435–7.
[17] Steins NA, Veraart JA, Klostermann JE, Poelman M. Combining offshore wind farms, nature conservation and seafood: lessons from a Dutch community of practice. *Mar Pol*. 2021;126:104371.
[18] Van den Burg SW, Röckmann C, Banach JL, Van Hoof L. Governing risks of multi-use: seaweed aquaculture at offshore wind farms. *Front Mar Sci*. 2020;7:60.
[19] Künneke R, Mehos DC, Hillerbrand R, Hemmes K. Understanding values embedded in offshore wind energy systems: toward a purposeful institutional and technological design. *Environ Sci Policy*. 2015;53:118–29.
[20] Soares-Ramos EP, de Oliveira-Assis L, Sarrias-Mena R, Fernández-Ramírez LM. Current status and future trends of offshore wind power in Europe. *Energy*. 2020;202:117787.
[21] Vaissière AC, Levrel H, Pioch S, Carlier A. Biodiversity offsets for offshore wind farm projects: the current situation in Europe. *Mar Pol*. 2014;48:172–83.
[22] Florian Kühn F, Liebach F, Matthey T, Schlosser A, Zivansky J. Offshore wind: procurement and construction in a changing market. client-briefing-offshore-wind-procurement-and-construction-in-a-changing-market.pdf. 2017. Available from: cliffordchance.com.
[23] Dwyer J, Bidwell D. Chains of trust: energy justice, public engagement, and the first offshore wind farm in the United States. *Energy Res Soc Sci*. 2019;47:166–76.
[24] Sooriyaarachchi TM, Tsai IT, El Khatib S, Farid AM, Mezher T. Job creation potentials and skill requirements in, PV, CSP, wind, water-to-energy and energy efficiency value chains. *Renew Sustain Energ Rev*. 2015;52:653–68.
[25] Morris M, Robbins G, Hansen U, Nygard I. The wind energy global value chain localisation and industrial policy failure in South Africa. *J Int Business Pol*. 2022;5(4):1–22.
[26] Steen M, Hansen GH. Barriers to path creation: the case of offshore wind power in Norway. *Econ Geogr*. 2018;94(2):188–210.
[27] Stentoft J, Narasimhan R, Poulsen T. Reducing cost of energy in the offshore wind energy industry: the promise and potential of supply chain management. *Int J Energy Sect Manage*. 2016;10(2):151–71.
[28] Johnsen TE, Mikkelsen OS, Wong CY. Strategies for complex supply networks: findings from the offshore wind power industry. *Supply Chain Manag: An Int J*. 2019;24(6):872–86.
[29] Martinez Neri IF. Supply chain integration opportunities for the offshore wind industry: a literature review. *Int J Energy Sect Manag*. 2016;10(2):191–220.
[30] Afewerki S, Steen M. Gaining lead firm position in an emerging industry: a global production networks analysis of two Scandinavian energy firms in offshore wind power. *Competit Change*. 2023;27(3–4):551–74.
[31] Aspelund A, Steen M, Afewerki S, Bjørgum Ø, Sæther EA, Kenzhegaliyeva A. *Conditions for Growth in the Norwegian Offshore Wind Industry*. International market developments, Norwegian firm characteristics and strategies, and policies for industry development; 2019.
[32] Dinh VN, McKeogh E. Offshore wind energy: technology opportunities and challenges. *Proceedings of the 1st Vietnam Symposium on Advances in Offshore Engineering: Energy and Geotechnics*. pp. 3–22. Springer Singapore; 2019.
[33] Vis IF, Ursavas E. Assessment approaches to logistics for offshore wind energy installation. *Sustain Energy Technol Assess*. 2016;14:80–91.
[34] Lin MSM, Lu BS. Risk assessment and management in the offshore wind power industry: a focus on component handling operations in ports. *Saf Sci*. 2023;167:106286.