Configuring floating production networks: A case study of a new offshore wind technology across two oil and gas economies

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Abstract

The authors employ global production network (GPN) approach to analyse the development of the renewable energy sector. Through a case study of the development of a Hywind floating offshore wind project (Hywind) across two oil and gas economies, namely Norway and Scotland, the paper sheds light on the key drivers and role of core GPN actors. Methodologically, the authors investigate the process from both 'inside-out' and 'outside-in' perspectives, referring to the efforts of firms expanding into overseas markets and the efforts of host countries to attract investment from outside their territories. The analysis shows how the configuration of extractive production networks is shaped by the interactions between the network development practices of firms and the market development strategies of host states. The authors conclude that the distinct materiality of floating wind power technology shapes the territorial configuration of the

production network by enabling its spatial extension across a range of locations. By contrast, existing research on other extractive sectors has emphasized the spatially constraining effects of materiality (Bridge 2008).

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Introduction

The global production network (GPN) approach is used to analyse the horizontal and vertical networks that interconnect firms and extra-firm actors, and assesses how their relationships shape both the organization of industries and the overall economic development in a region (Coe et al. 2008). The approach highlights how various important forces influence the networks of firms and extra-firm actors involved in the production of goods and services, and the distribution of power within these networks (Bridge 2008). In the case of extractive industries based on natural, due to the territorial embeddedness of natural resources, the role of states is central in shaping the production networks and the development of those industries (Bridge 2008). In the emerging renewable energy sectors, the role of states is not only based on the ownership and control of natural resources, but also involves the construction of markets through state-specific support regimes (MacKinnon et al. in press). However, the role of states and other institutional actors, and the mechanisms through which they construct markets and shape industries, remain rather underdeveloped in current GPN literature. In addition, while recent contributions highlight the network development practices of 'lead firms' and other key network actors (Murphy 2012), there is a need for further work to illuminate these practices and assess their implications for network evolution and territorial development. Furthermore, our understanding of the effects of materiality on the spatial configuration of extractive production networks remains rather partial: existing research has stressed its constraining effects (Bridge 2008) without considering whether materiality can also have an enabling effect in fostering the spatial flexibility of networks.

The aim of this article is to contribute to the sparse literature on extractive GPNs through an analysis of the key drivers and role of core actors in renewable energy industries. We do this by analysing the emergence of renewable energy production networks, focusing on offshore wind. We assess the business and sourcing practices of a lead firm, the market development strategies of the host state as well as the physical and institutional conditions that frame that process, and the territorial configuration of the resulting production network. In analysing the spatial configuration of the production network, we apply two contrasting perspectives: *inside-out*, by following firms reaching out to establish relationships with global production network actors based beyond their home territory; and *outside-in*, referring to host countries' efforts to attract investment from GPN actors outside their territory (Coe & Yeung 2015). Empirically, this article explores the development of an offshore wind production network through a case study of a floating wind power (FWP) project involving two oil and gas economies, namely, Norway and Scotland. Hywind is a first-of-its-kind floating offshore wind project, and has been developed by the Norwegian energy company, Statoil, and installed in Scotland in 2017.

Our analysis of the Hywind project is structured by the following research questions:

- What are the main drivers and roles of states and lead firms in the development of emerging renewable energy industries such as that of floating offshore wind?
- How does the materiality of floating offshore wind technologies and operations shape the spatial configuration of production networks?
- What are the theoretical implications of the role of materiality in the spatial configurations of production networks for the broader GNP literature?

Based on the GPN framework, the article shows how firm and extra-firm actors shape their assets to develop the FWP network. We identify the network actors and their network development practices, as well as the strategies and associated discourses through which host states strive to maximize the national and regional benefits of foreign direct investment (FDI) projects in emerging renewable energy sectors (Fløysand et al. 2016). We argue that the distinct materiality of FWP technology shapes the territorial configuration of the production network by enabling its spatial extension across a range of locations. By contrast, research done to date on other extractive sectors has emphasized the spatially constraining effects of materiality (Bridge 2008). Thus, we contribute to the GPN literature by using the framework to investigate the development of renewable energy industries and by assessing the role of materiality in framing key actors' strategies and practices and in shaping network configurations.

GNP and extractive industries

The GNP approach offers a broad relational framework for understanding contemporary forms of industrial organization and governance, and their relationship with local or regional development processes (Coe et al. 2008, 272). Compared with the 'new regionalism' of the 1990s, which was preoccupied with social and institutional conditions within regions (Lovering 1999), the GPN approach signals a renewed interest in extra-regional relations. Accordingly, a key contribution of GPN research has been to recast regional development in relational terms, viewing 'the region' as 'a porous territorial formation whose national boundaries are transcended by a broad range of network connections' (Coe et al. 2004, 469). Regional assets in the form of specific kinds of knowledge, skills, and expertise provide an important resource for regional development, but must be harnessed by regional institutions to 'complement the strategic needs of trans-local actors situated within global production networks' (Coe et al. 2004, 470). A global production network is the nexus of globally interconnected functions, operations, and transactions through which a specific product or service is produced, distributed, and consumed (Coe et al. 2008).

The architecture of the GPN framework is based on three principal pillars: value, power, and embeddedness (Henderson et al. 2002; Coe et al. 2008). GPN actors are constantly trying to create, enhance, and capture value through a range of strategies, including the development of capabilities, the control of technology, the harnessing of interfirm relations and branding (Henderson et al. 2002). Power relating to corporate, collective, and institutional influences upon production systems is multiscalar, is derived from local and non-local structural conditions (i.e. markets and political institutions), and is mobilized by firms and extra-firm actors who participate in GPNs (Henderson et al. 2002). Embeddedness emphasizes how economic activity becomes interwoven with social rules and networks, and concentrated in certain locations (Amin & Thrift 1995). The latter dimension of territorial embeddedness is of particular interest to us, since it draws attention to the strategies of host states and institutions to maximize the national and regional benefits of FDI projects through strategies such as local content policies (Tordo et al. 2013).

Compared with the manufacturing and service sectors, there are few studies of resource-based extractive industries in GPN research (Bridge 2008; Bridge & Bradshaw 2017). The basis of the extractive industries is the notion of the *natural resource*: materials created or produced in nature that can provide the basis for the extraction and sale of a particular commodity, such as oil or the use of wind power to generate electricity. Bridge (2008) characterizes production networks in the extractive sector in terms of two basic tensions: (1) the tension between resource-holding states and resource-seeking firms (lead firms); and (2) the tension between producers and consumers regarding the distribution of value. Additionally, Bridge (2008) outlines three characteristics of extractive production networks: (1) the nature-based character of extractive enterprises; (2) the influence that the materiality of resources has on the organization of production; and (3) the *territoriality* of resource embeddedness in the territorial structures of the nation-state.

In an analysis of the extractive GPN, accounting for these characteristics is helpful in capturing how social relations are mediated through the natural environment and the developmental outcomes of these social relations. In particular, *materiality* illuminates the functioning of the econo-natural networks through which nature is transformed into (1) resources, commodities, and conditions of production, (2) the mutual production, transformation and regulation of biophysical and socio-economic processes, and (3) the productive and generative capacities of the non-human (Bakker & Bridge 2006). Bakker & Bridge (2006) argue that 'Matter matters' because things other than humans make a difference in the way social relations unfold. They assert that it is through the socio-economic production of nature that the geographically uneven character of capitalist development takes shape. In extractive GPNs, accounting for materiality emphasizes how production networks are organized around moments of natural material production and transformation, whereby the biophysical qualities of materials shape strategies for value capture (Bridge & Bradshaw 2017). The material qualities, alongside other factors such as ownership, access, and control over resources, shape how value is created and captured (Bridge 2008).

Through his analysis of oil GPNs, Bridge (2008) finds that the locationally specific nature of resources limits the spatial flexibility and range of production networks. However, we argue that this is relative and that materiality can have an enabling effect on the spatial flexibility of GPNs, meaning that the extractive production networks also become stretched over space, paralleling the manufacturing networks, which they overlap.

Another strand of recent GPN research has been concerned with network development practices (Murphy 2012). This research has highlighted how network linkages are established, sustained, and reorganized over time and space by the power struggles and networking strategies of economic actors located in different territorialities. Network development reflects actors' common interests, familiar practices and routines, and shared identities, as well as the mutual recognition of each other's positionality in a relationship (Murphy 2012). Murphy argues that factors such as trustworthiness, social performances, adherence to mutually recognizable and appropriate behaviour patterns, and shared experiences shape whether interacting actors become relationally proximate (Murphy 2012).

Network development practices emphasize the intentions and strategies of firms and extra-firm actors, and the pattern of how they behave (Bathelt & Glückler 2003). In the context of GPN, the intentional nature of network development practices can be linked to the notion of strategic coupling, which is a dynamic process by which regional assets are matched to the strategic needs of lead firms in GPN (Coe et al. 2004; Mackinnon 2011). At the same time, strategic coupling is considered the key process that drives regional economic development (Coe & Yeung 2015). This articulation has *outside-in* and *inside-out* dimensions (Coe & Yeung 2015, 171). As such, when analysing the development of extractive industries, it is essential that analytical attention is given simultaneously to both the endogenous and exogenous aspects of strategic coupling processes (Coe et al. 2004).

The process of strategically coupling or matching regional assets to the strategic needs of GPNs requires the presence of an appropriate institutional structure that simultaneously promotes regional advantage and enhances the region's articulation in GPNs (Coe et al. 2004). Coe et al. (2004) argue that this involves three overlapping dimensions of regional development: *the creation of value* through the efforts of regional institutions to promote and attract value-added activities; *value enhancement* through knowledge and technology transfer and industrial upgrading; and ensuring *value capture* through the exercise of power and control.

In particular, value capture involves bargaining processes and power struggles between both state and lead firms and suppliers for better terms and conditions. The power that actors possess depends on their relative control of key resources and/or assets (Dicken 2015). According to Murphy (2012, 6), ‘Structurally, power is derived from an individual or firm’s positionality in relevant social and economic systems, especially the markets and institutions that regulate or govern an industry.’ In extractive GPNs, the state operates mainly as a *regulator* of the exploitation of its natural resources. Ownership of such natural resources potentially affords states enormous power over how they are exploited. However, this often implies tensions between states, lead firms, and other states, as these parties are preoccupied with capturing as much value as possible (Dicken 2015).

States strive to capture as much as possible of the value created from production (such as natural resource extraction) within their territories (Tordo et al. 2013). As a result, the primary aim of a host state is to try to embed a lead firm’s activities as strongly as possible in the local and/or national economy. Local content policy (LCP) is one mechanism through which host states strive to foster strategic coupling by establishing linkages between GPN actors and localized assets (Ovadia 2014). Local content refers to the extent to which an industry or project has further multiplier effects on the local economy beyond its direct output or employment through the development of indirect linkages to other industries (Tordo et al. 2013). LCP can also foster knowledge flows and learning between production networks and local actors (Nilsen & Jòhanneson 2016; Ivarsson 1999).

In this article, our interest is in local content or sourcing policies that aim to increase the linkages between FDI projects and local suppliers by matching the capabilities of the latter to the strategic needs and practices of investors. LCPs are often accompanied by pro-FDI discourses emphasizing the potential regional and nation economic benefits of FDI projects in terms of increased local sourcing, employment, knowledge, and technology transfer, although this may be countered by anti-FDI narratives expressing scepticism and concerns about the external ownership and control of key industries (Fløysand et al. 2016).

Based on the above discussion of key strands of GPN research, our analytical framework comprises three mutually interrelated elements: (1) the role and the network development practices of production network actors, particularly those of the lead firm, (2) the market development strategies of states, including LCPs, and (3) the role of the materiality of natural resources in the aformentioned two processes.

Methodology

This article is based on a case study of a single FWP project that is embedded in the political and institutional contexts of both Norway and Scotland (Yin 2003). Case studies of investment projects have long been used in research on GPNs and FDI (e.g. Dawley 2007). They allow an investigation to retain the holistic and meaningful characteristics of real-life events, such as organizational changes and processes, cross-border activities and relations, and maturations, changes, and evolutions of industries (Yin 2003). They offer a suitable tool to access the interplay between network relations, firms' decision-making, and territorial development processes (Yeung 1995).

As already emphasized, we analyse the Hywind case from both *inside-out* and *outside-in* perspectives. Few studies have taken a similar approach (e.g. Hansen 2008; Njøs et al. 2017). Our 'inside-out' approach follows the activities of the lead company from early demonstration phases (i.e. concept development) at home in Norway to piloting and installation in Scotland. By contrast, the 'outside-in' approach is used to analyse the project from the perspective of the host country (Scotland), focusing on how state market development strategies have shaped the production network.

Our research involved a combination of primary and secondary data collection. The primary data were collected through semi-structured interviews in 2016 and 2017 with 15 informants (Table 1). The majority of the interviews were conducted face-to-face in the meeting rooms of the organizations in Norway and Scotland. The interviews lasted c.1 hour and addressed issues mainly related to the development process of the Hywind technology from inception to pilot park phase, from the perspectives of representatives from both Statoil in Norway and national government, development agencies, and research institutions in Scotland. The interviews were complemented with analysis of secondary data, including the following: a wide range of FWP-related industry reports and publications, policy documents, company histories, project documents, market and technological appraisals, and the global offshore wind farm map and database at 4COffshore[1] and participation in a number of local and regional conferences and related industrial events. Analysis of the data involved categorizing and triangulating the data from multiple perspectives.

Developing the Hywind project: an 'inside-out' perspective

Offshore wind power (OWP) first emerged through incremental innovation from the onshore wind industry. Almost all of the current OWP is built on fixed-bottom foundations, which are restricted to waters with a depth of less than 50 m (IRENA 2016). Floating foundations, a new generation of deep-water wind power technology, are on the verge of opening the way for power generation from deeper waters to allow countries with deep water coastlines to develop domestic wind markets. The offshore wind market is national in nature, based upon the distribution of electricity from wind farms to domestic consumers through national grid systems. This can be contrasted with the global consumer markets emphasized in much GPN research (Coe & Yeung 2015). As such, the size and regulation of national markets is vital for shaping the investment decisions of OWP developers.

Hywind is a floating offshore wind concept owned by Statoil, a Norwegian multinational company that is majority owned by the Norwegian state. Driven by the current opportunities in the global energy systems, Statoil is looking for new ways to create value and gain *technological rent* (Henderson et al. 2002) by utilizing its knowledge and expertise gained from its traditional oil and gas (O&G) activity (Steen & Weaver 2017). In order to seize the new business opportunities and thereby complement its O&G portfolio with renewable energy (low carbon solutions), Statoil has been investing in new energy markets since 2006 (Nilsen 2017). In addition to its fixed-bottom offshore wind projects, Statoil is pioneering innovation in offshore wind technology through its floating wind turbine concept Hywind. For Statoil, the focus on the development of FWP is justified by the potential size of the market and relevant technology and expertise from its O&G activities.

The Hywind concept was developed in 2001 by two Norwegian experts at the new energy division of the Norwegian company Norsk Hydro. Statoil acquired the concept in 2008 as a result of its takeover of Norsk Hydro's O&G division. It subsequently invested in research and development (R&D), model testing, and demonstrations in order to bring the concept to the pre-commercial phase in 2017. The concept adapts established technologies from offshore O&G operations to a new setting and, with slight technological modifications to fit the FWP context, opens up possibilities for capturing wind energy in deep-water environments (interview with Statoil representative, February 2017).

Based on spar buoy technology, the Hywind concept has been demonstrated and verified through eight years of operation of a full-scale demonstration unit, the Hywind - Demo. After receiving a green light from the Norwegian government, the Hywind - Demo, which consisted of a standard 2.3 MW SIEMENS WTG (wind turbine generator) solution, was deployed in 2009, 10 km south-west of the island Karmøy, north-west of Stavanger and off the south-west coast of Norway. A total of 13% (NOK 59 million) of the project finance (NOK 460 million) was in the form of a grant from the Norwegian state-owned enterprise Enova. The Hywind - Demo provided validation of the Hywind technology through the collection of full-scale measurements on motion control and electrical output (interview with geophysicist, University of Bergen, March 2017).

With excellent production capacity and being well suited for serial production, the next phase for Hywind was to enter into the global OWP market. The first step in this process was finding a suitable location for the deployment of a pilot park (i.e. a pilot wind farm). According to Statoil, the selection process was influenced by factors such as wind resources, water depth, proximity to the national grid, proximity to a deep-water navigation route, and, crucially, institutional and regulatory conditions, such as the availability of financial support (Statoil 2015). Initially, Statoil identified three locations that met all or most of the physical criteria: the Gulf of Maine, Norway, and Scotland. In the Gulf of Maine, Statoil had been granted a lease but it pulled out due to uncertainty about obtaining a power purchase agreement (PPA) with the local grid operator. The Norwegian option was omitted due to insufficient political will and support for offshore wind development in Norway (interview with Statoil representative, March 2017) (Karlsen & Steen 2018).

By contrast, Scotland fulfilled all the required physical and institutional criteria for the deployment of a pilot park. The physical criteria included deep waters and abundant offshore wind resources (which total 25% of Europe's offshore wind resources) (Hansen, 2001). With regard to the institutional criteria, Scotland offered a highly attractive market support mechanism (as discussed in the following section), which amounted to an approximate value of GBP 190 per MWh (2017 price) for floating wind projects (interview with Scottish Government official, June 2017), about four times the wholesale price of electricity in October 2017 (Ofgem 2018). These conditions made Scotland an ideal location for Statoil's deployment of Hywind. Of the two sites identified in Scotland, Buchan Deep off the coast of Peterhead was selected because of its locations farther offshore, with less environmental sensitivity, and because grid connections were available (Statoil 2015).

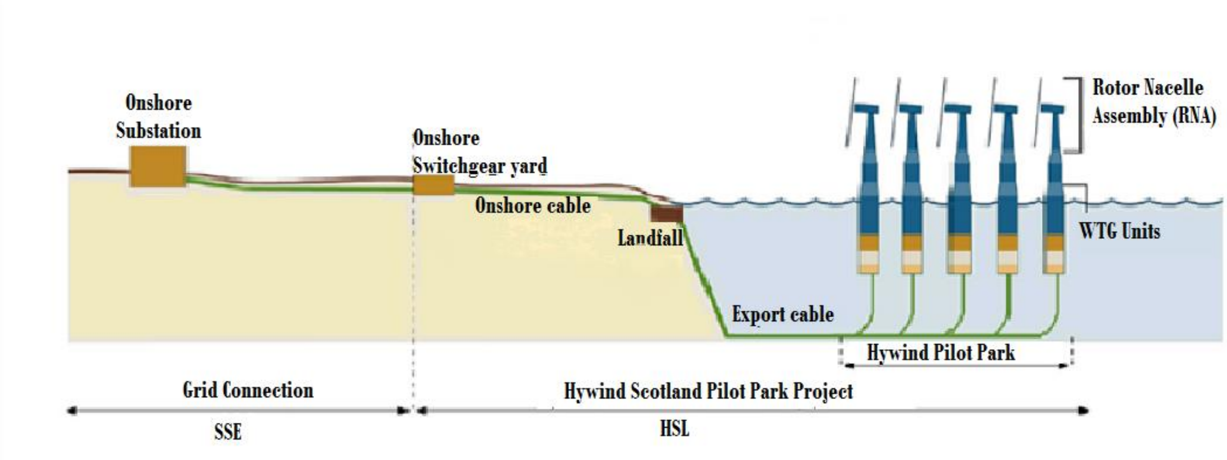

Fig. 1. Key components of the Hywind pilot park project (adapted, with permission, from Statoil 2015, 1), with the location of the pilot park indicated by the wind turbine symbol

The materiality of FWP is related to the underlying technology and infrastructure, deep water environment, wind strength, and connection to shore. Hywind comprises five 6MW turbines with a generating capacity of 135 MW of electricity per year (Fig. 1), enough to power 20,000 households. The pilot park was commissioned in October 2017, and covers c.4 km^2 at a water depth of 95–120 m.

Market development strategies in Scotland: an 'outside-in' perspective

Scottish authorities have expressed their commitment to tackling climate change through strong support for renewable energy, accompanied by a discourse of national economic and industrial development that emphasizes the anticipated economic benefits in terms of investment, output, and employment. According to one key policy statement:

> Offshore renewables, and offshore wind in the immediate term, represents the biggest opportunity for sustainable economic growth for a generation in terms of manufacturing, supply chain, job creation and training opportunities. Investment in key infrastructure with projected maximum investment in offshore wind is expected to be approximately £30bn over the next decade and the creation of upwards of 28,000 jobs by 2020. New investment on this scale offers great opportunities for Scottish based firms to support the development of this growing sector. The Scottish Government is committed to the development of offshore wind in Scotland and capturing the anticipated economic benefits. (Offshore Wind Industry Group (OWIG) 2010, 6)

The Scottish Government's commitment is reflected in the country's legislations and policies. Scotland's energy strategy stipulates that 50% of Scotland's energy consumption is to be met by renewable energy by 2032 (Scottish Government 2017). This succeeds the previous target of 100% electricity from renewables by 2020, which was instrumental to the rapid growth of onshore wind power in particular. As stipulated by the Offshore Wind Industry Group, the devolved Scottish Government, controlled by the Scottish National Party since 2007, is very keen to maximize Scottish offshore renewable resources (Offshore Wind Industry Group 2010). FWP in particular has been identified as a suitable technology given that fixed-bottom foundations have been constrained by deep waters and rough seas (interview with Scottish Government official, June 2017).

In addition, Scottish authorities have emphasized the potential of FWP to generate economic and industrial benefits. With the expected 90 MW installed capacity of FWP by 2018, Scotland has an opportunity to develop supply chain capability to exploit opportunities in the global market (Carbon Trust 2017): ‘Scotland is specifically looking to take advantage of floating developments happening around the world such as Japan, France and the US’ (interview with Scottish Enterprise official, June 2017). To realize these benefits of floating technology, there is generous support and funding for floating R&D and demonstration activity in Scotland. As part of its offshore renewables development strategy, the Scottish Government has been supporting innovation and technology development activities within Scotland (Carbon Trust 2017). Furthermore, to facilitate inward investment and foster the strategic coupling of regional assets with the strategic needs of technology developers, the Scottish and United Kingdom (UK) authorities have put key policy and regulatory conditions in place. These policies and regulatory conditions are primarily concerned with the licensing & consenting processes, subsidy and grant support mechanisms, and supply chain development strategies (Carbon Trust 2017).

Offshore wind farm development starts with a seabed lease, which has to be obtained from the Crown Estate, a UK-wide statutory organization, which owns the seabed out to the 12-mile territorial limit. In addition, a marine license is required from Marine Scotland as the planning authority for offshore renewables, demonstrating the regulatory role of the state.

These regulatory processes are necessary preconditions for the development of OWP. Nevertheless, ‘the availability of financial incentives has been vital in attracting inward investments of floating projects in Scotland’ (interview with Scottish Government official, June 2017). The main form of financial support for renewable energy in the UK prior to 2014 was the

Renewables Obligation (RO), established in 2002. The RO was banded to provide varied levels of support based on the level of maturity of the renewable technologies. In Scotland, floating wind technology qualified for an enhanced level of subsidy of 3.5 Renewables Obligation Certificates (ROCs) compared with two 2 ROCs for fixed-bottom projects. However, as part of the UK-wide process of Electricity Market Reform (EMR), the RO was replaced (effective 31 March 2017) by the Contracts for Difference (CfD) scheme (Ofgem 2017).

As indicated above, the main driver for the Scottish support for this niche market development has been the fact that it presents Scotland with a first mover advantage. To achieve this goal, Scottish authorities are actively working to embed the floating technology and other technology development projects within Scotland to facilitate knowledge and technology transfer, and the upgrading of domestic industrial capability. This *outside-in* mode of incorporation (Coe & Yeung 2015) into the floating production network signifies a transplantation approach to new industry development, which entails the importation and diffusion of radical new technologies from abroad (Martin & Sunley 2006), an approach that appears quite typical in the British context (MacKinnon et al. in press).

A key embedding mechanism in Scotland is the introduction of LCPs and tasking development agencies with duties relating to supply chain development. The UK government's strategy for the offshore wind industry established a 50% local content aspiration (HM Government 2013). As an aspirational goal, this fits into a discourse of exploiting the potential economic and industrial benefits from FDI in OWP (Fløysand et al. 2016). At the same time, Scottish Enterprise, Scotland's main economic development agency, actively supports the Scottish supply chain. The support provided by Scottish Enterprise includes issuing guides to provide domestic companies, specifically those in the O&G industry, with an understanding of diversification opportunities in the offshore wind sector. In addition to Scottish Enterprise, Scottish Development International (SDI) and the Offshore Renewable Energy (ORE) Catapult, a technology innovation and research centre for advancing wind, wave, and tidal energy, are supporting local suppliers to capture more value from their involvement in the OWP markets (interview with ORE Catapult representative, June 2017).

In the case of Hywind, both Scottish Enterprise and SDI were in continuous discussions with Statoil to inform them of the Scottish capabilities and help in identifying the Scottish suppliers capable of meeting their requirements. Scottish Enterprise in particular ensured face-to-face discussions between Statoil and local suppliers by organizing three ‘meet the buyer’ events in different regions of Scotland. Furthermore, Scottish Enterprise ‘runs Offshore Wind Expert support program, which provides the companies that are interested in OWP with a two-day free consultancy service’ (interview with Scottish Enterprise representative, June 2017). These facilitators strive to match relevant and appropriate suppliers with the lead firm and as such contribute to strategic coupling (McKinnon 2011).

Floating production network configuration: lead firms’ network development practices

The degree of the territorial embeddedness of a GPN is contingent upon the relative bargaining power of host states and lead firms (Dicken 2015), focusing attention on the interaction between their market development strategies and network development practices respectively (Murphy 2012). Such interaction will, in turn, reflect the ownership and control of key capabilities, which in turn is contingent upon the level of maturity of an industry and/or market and the domestic capabilities (i.e. the absorptive capacity of local suppliers for new knowledge, as demonstrated by FWP). These elements can give the lead firms and/or technology developers an upper hand in the relationship with the host states when configuring the production network. For an emerging market such as FWP, these actors share the concerns of bringing down costs, minimizing risks, and ensuring the feasibility of the sector, but this also coincides with host states' aims of promoting territorial embeddedness and local economic development through LCPs.

In the Hywind project, Statoil's project execution strategy was based on a multicontracting strategy as opposed to awarding engineering, procurement and construction (EPC) contracts. The multicontracting strategy involved Statoil itself choosing contractors for each element of the project. Statoil employed this approach because it provided the possibility for close interaction and monitoring of all project activities: 'For us, close interactions with the suppliers was vital as these close interactions are helpful in coming up with the optimal solutions, CAPEX [capital expenditure] minimization, increasing effectiveness and market effect maximization' (interview with Statoil middle-level manager, February 2017).

Statoil's close interactions with its suppliers was often related to the reutilization of existing supplier relations: 'Even though Statoil tried to ensure competition, the few suppliers overall in OWP sector was a challenge' (interview with Statoil project manager, March 2017). Nonetheless, familiarity and the development of trust-based relationships were vital for Statoil: 'This was an important risk minimization strategy for Statoil as it ensures that it is dealing with suppliers with a proven track-record' (interview with Statoil project manager, March 2017). Factors influencing the choice of suppliers are shared experiences, trustworthiness, and appropriate behaviour patterns (Murphy 2012).

Local content was one of the key elements that Statoil took into consideration when the company set up its supply chain: 'Even though they had not set a specific percentage, the Scottish authorities had a clear expectation that Statoil would do all it could to source things locally' (interview with Statoil project manager, March 2017). However, there were no stipulations in the contracts that Statoil signed that obliged it to achieve local content (interview with Crown Estate official, March 2017), reflecting its ownership of technology-related O&G capabilities and the limited leverage exercised by the Scottish authorities. Moreover, as Hywind was funded under the RO regime, it was not subject to the requirement to submit a supply chain plan common to the UK government that was required under the CfD scheme (interview with Scottish Development International official, June 2017). Furthermore, 'in order to prevent anti-competitive effects on the markets there exists EU legislation, state aid, which regulates government assistance to industry, and public procurement that the UK and ultimately Scotland have to abide by' (interview with Crown Estate official, March 2017). This renders the 50% local content objective more of an aspiration than a binding requirement.

Initially, Statoil had identified Kishorn, a former O&G fabrication yard on the north-west coast of Scotland, as a suitable port for assembly of its five Hywind WTGs. While Kishorn had the water depth required to assemble the spar foundation before it was towed to site, it lacked specific infrastructure: 'Scotland lacked infrastructure and a suitable port for assembly' (interview with Statoil middle-level manager, February 2017). This reflected Kishorn's lack of a track record in the offshore wind industry. Accordingly, Kishorn failed to secure the contract to to assemble the spar foundation. Instead, the contract was awarded to the NorSea Group's Stordbase at Stord, located between Stavanger and Bergen on the west coast of Norway. Once assembled at Stordbase, the turbines were towed in an upright position to the deployment area, in the marine region Buchan Deep (Carbon Trust 2017). This demonstrated that in principle, due to the materiality of FWP and the spar buoy technology, the majority of the systems for a floating wind farm could be built and assembled anywhere and be smoothly transported to site at a reasonable cost, for installation. By contrast, assembly of the fixed-bottom foundations has to take place in an operational park setting.

Thus, floating wind project developers have the opportunity to choose an assembly site or harbour that complies not only with the requirements for infrastructure and depth, but also a location with which they are familiar. This means that the lead firm can rely on suppliers close to the assembly site or harbour, not only because they have competitive advantages due to physical proximity, but also due to the relational proximity and track record.

For many of the suppliers involved in the Hywind project, it is evident that involvement in Hywind - Demo led to contracts connected to the pilot park: 'We have had long and good relations with Statoil … the NorSea Group, our parent company, has supply base agreements for all its offshore installations, which helped in us having good knowledge of Statoil and its operations' (interview with General Manager, Stordbase, November 2016). This highlights the benefits of first-mover advantage, which in turn demonstrates the importance of early involvement of suppliers not only to build the needed track record but also to cultivate the trust and relationships with the developers (interviews with Statoil representative, engineering company representative, shipping company representative, and meteorlogical institute representative, 2016 and 2017). This has in turn contributed to the very low UK content, at least in the deployment phase. In the supply chain map, the UK is represented by two first-tier Scottish firms (Fig. 2) and a second-tier firm based in England. As such, the effects of the materiality of FWP appear to outweigh the discourse on the host country's industrial development in general and local content aspirations in particular. This is particularly the case for the spar buoy technology of the Hywind project, which requires deep waters for assembling and sinking, whereas other floating technologies can be assembled and serviced from a far wider range of ports.

Fig. 2. The Hywind supply chain map (adapted, with permission, from an unpublished presentation by Statoil in 2016, titled 'Hywind- the first World's floating wind park').

The small-scale nature of the Hywind project coupled with the lack of visibility of the future offshore wind pipelines, reflecting market uncertainties associated with the transition from the RO to the CfD support regime, meant that it was difficult for the local suppliers to make huge investments in capability and infrastructure upgrading. Nevertheless, the materiality of the project enabled Statoil to utilize its Norwegian and other international suppliers. The range of suppliers selected from across Europe highlights the possibilities for developing spatially extensive sourcing strategies with floating wind technology (Fig. 2). In the deployment phase, these possibilities have very much given Statoil an upper hand in its relative bargaining process with the Scottish authorities regarding the configuration of the floating production network. As shown in Fig. 2, many of the selected contractors are suppliers with strong international track records. The involvement of suppliers from both the O&G industry and the maritime industry is evident, especially in the pre-construction phase, as well as in the construction and installation phase of the project: 'In Scotland, there were no manufacturing plants, neither for the WTGs nor for spar solutions' (interview with Statoil middle-level manager, February 2017). Accordingly, the fabrication of the Siemens turbines took place in Denmark, as Siemens had already partnered Statoil, both in the Hywind Demo and in the company's other OWP projects. Aibel was involved in the design of the spar substructures. Aibel has a proven track record in floating technology (interview with Aibel representative, January 2017). The choice of the Spanish consortium (Navantia-Windar) is justified by the companies' familiarity with the spar technology.

When compared with fixed-bottom technology, local (host region) suppliers can potentially lose their short distance advantages in floating projects due to the more flexible logistics and locational alternatives for assembly of fixed-bottom projects. As proximity to the deployment site for the floating wind park becomes less important, suppliers from elsewhere in the world will be able to compete on more or less similar conditions.

By shifting from fixed technology to floating technology, the significance of physical proximity is reduced, and relational proximity may become relatively more significant (Boschma 2005). Relational proximity is vital in the R&D phase of development (niche market development strategy, e.g. a pilot park) in which quality, risk minimization, and feasibility are more important than cost reduction through price competition, requiring close and frequent interactions between firms in the production network (Dicken 2015). Materiality plays a significant role in facilitating the relational proximity between lead firms and their suppliers. In a commercial phase with a stronger imperative for cost minimization, it should be expected that lead firms will, to a higher degree, source from low cost suppliers on a wider geographical basis. Physical and relational proximity are likely to play a less important role than in the pilot phase. The principal exception to this is operations and maintenance activities, which tend to be more locally embedded and which, for Hywind, will be carried out largely from the Scottish port of Peterhead.

In contrast to the constraining role that materiality plays in other extractive sectors such as O&G, which are unwieldy commodities (Bridge 2008), floating technology is more enabling with regard to the spatial flexibility of production networks, particularly for the spar buoy design behind the Hywind project. Furthermore, the disembedded and rootless nature of FWP technology can further promote standardization and enable the achievement of economies of scale (Karlsen 2018). A visual representation of the FWP production network is provided in Fig. 3.

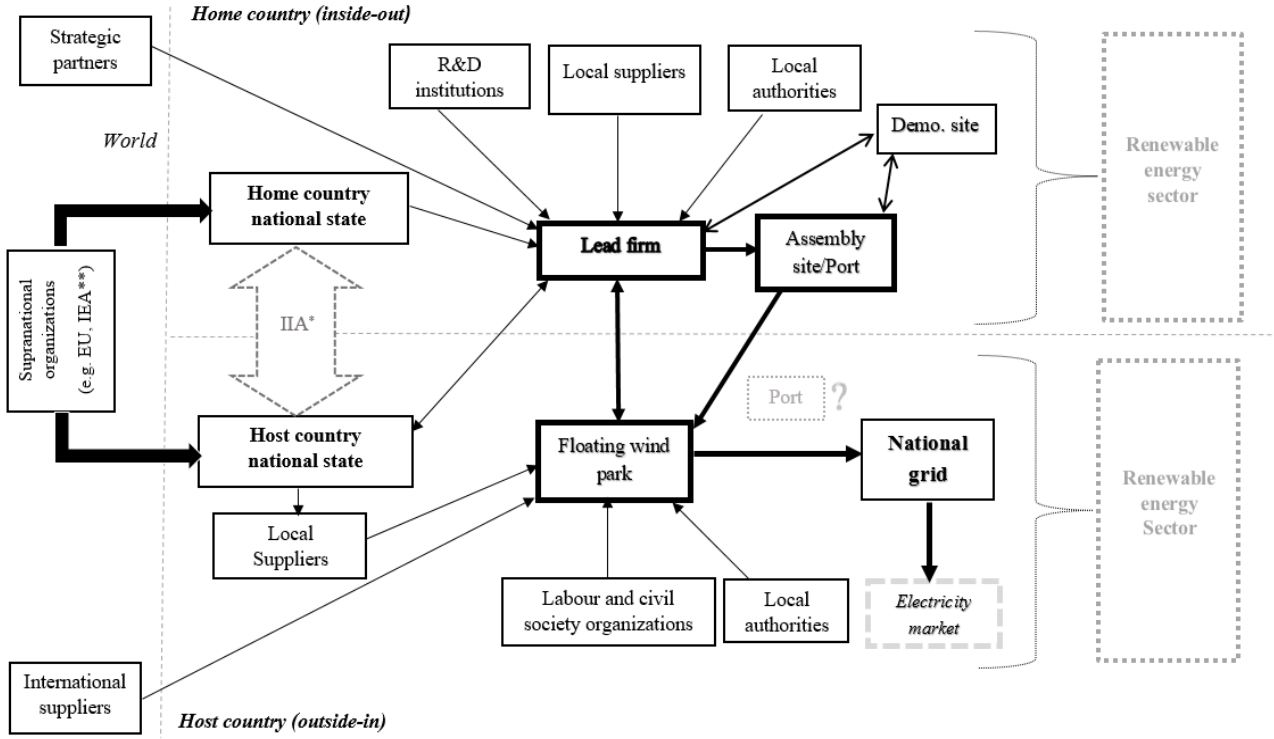

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Fig. 3. Representation of the FWP production network (losely based on Fig. 4 in Niewiadomski 2017, 7)

Conclusions

In common with other renewable energy sectors, offshore wind can be seen as particularly state dependent, as its development has been driven by policy objectives and targets, and supported by financial subsidies (Mackinnon et al. in press). In line with Murphy (2012), we recognize that network configurations reflect the interests and practices of lead firms and host states, as well as their mutual recognition of each other's position in a common GPN. Our analysis has revealed that national states, which control access to natural resources, play an important role in the development of renewable energy markets. This happens through the setting up of institutional frameworks and efforts to attract FDI and develop LCPs, framed by a discourse of maximizing the domestic economic benefits of renewable energy sectors. In this sense, host states attempt to foster strategic coupling through LCPs, which match local capabilities to the needs of lead firms and suppliers in GPNs. In the case of FWP, lead firms are driven by the need to promote and develop the technology, ensure its feasibility, access market support schemes, and investment in and coordinate the supply chain to manage costs and capabilities. For Statoil, the Hywind project is part of a diversification strategy beyond its focus on O&G, and it was attracted to Scotland by the availability of generous financial support for FWP (3.5 ROCs) and access to the national grid, as well as the deep water site in Buchan Deep. Statoil's ownership of the technology, engineering expertise, and existing supply chain relations have placed the company in a powerful position in relation to the Scottish authorities that lack domestic industrial capabilities, which thus creates dependence on incoming FDI projects. The importance of financial incentives in attracting the Hywind project to Scotland is redolent of earlier and far larger scale UK FDI projects in manufacturing (Dawley 2007).

We find that materiality plays a vital role in the spatial configuration of renewable energy production networks. In the configuration of these networks, social relations are mediated through the 'natural' environment in which the materiality of natural resources and the technology aimed at their extraction or harnessing them for energy plays an enabling role in broadening the spatial range of the network. It enables the reuse of existing suppliers from beyond the host economy, demonstrating that materiality can have a counterbalancing effect on the state's exercise of power in extractive GPNs. This, in turn, may limit the territorial embeddedness process associated with the LCPs of host states. As argued by Fløysand et al. (2016), the discursive dimensions of FDI are important in shaping actor strategies, especially those of states, when devising development policies such as financial support schemes and local content strategies. In this case, the Scottish authorities' discourse asserting the regional and national economic benefits of an FDI project in offshore renewables is outweighed by the developer's control of the technology and the materiality of the production process, based upon the use of a spar buoy design in a deep water offshore environment. As such, materiality trumped discourse in shaping the configuration of this FWP production network.

The key implication for GPN research is that, rather than solely playing a constraining role, as suggested by Bridge (2008) in his study of petroleum GPN, materiality can also play an enabling role in fostering spatially extensive production networks based on the incorporation of distant and/or trusted suppliers and in fostering and maintaining relational proximity. In addition, it is evident that the state-dependent nature of renewable energy industries does not necessarily translate into a high level of territorial embeddedness. This is contingent upon the level of domestic industrial capability in the host economy, the stage of development of a technology, the level of maturity of an industry sector, and the institutional context of the host economy. Further research is needed to study the strategies and practices of firms and extra-firm actors (i.e. states) in mature extractive industries and/or markets and well-established networks. Better insights could be gained through comparative research of developers' network development practices in more mature extractive markets such as the fixed-bottom OWP, and by comparing future projects and alternative technologies of FWP with regards to varying contexts of materiality. Moreover, different national legacies and contexts influence the market development strategies that particular states pursue. Thus, international comparative research is needed to disentangle the different strategic coupling mechanisms of states with varying institutional contexts with respect to the offshore wind power's global production network.

Note

1. The global offshore wind farm map and database were accessed via the at 4COffshore home page at https://www.4coffshore.com/windfarms/hywind-scotland-pilot-park-united-kingdom-uk76.html (accessed 1–June 2018).

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