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Market strategies for offshore wind in Europe: A development and diffusion perspective

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ABSTRACT

Offshore wind will contribute to the decarbonization of European power systems, but is currently costlier than many other generation technologies. We assess the adequacy of market strategies available to private actors developing offshore wind farms in Europe, by employing the development and diffusion pattern model. The model includes two earlier phases in addition to the large-scale deployment phase of other diffusion models: the innovation and the market adaptation phases. During its development and diffusion offshore wind moved from experimentation to a dominant design (monopile foundations and a permanent magnet generator). Simultaneously, wind farms shifted from an experimental to a commercial purpose and grew from 10 to 316 MW on average. The turbine and wind farm development markets kept a high concentration throughout all phases. Also, the wind farm life cycle and supply chain became more integrated and drew less from the onshore wind and oil & gas sectors.

This development and diffusion was shaped by the barriers of cost, project risk and complexity, capital requirements, and multi-disciplinarity. Wind farms developers combined three niche strategies to address these barriers: the subsidized, the geographic, and the demo, experiment and develop. The barriers make these niche strategies more adequate than strategies of mass-market (dominating a market) or wait-and-see (developing resources but waiting for uncertainty reduction before market entrance). Nonetheless, the barriers and market strategies changed during the development and diffusion pattern. Thus, cost and risk reductions decreased the importance of the subsidized niche, while the geographic niche becomes less important as offshore wind develops outside of Europe.

The study also identified an increase in cooperation for wind farm development, as development became more international and with more frequent alliances. Wind farm developers and development and diffusion models research must consider how contemporary forms of cooperation improve or hinder the market strategies.

Contents

Abbreviations: CR_2, concentration ratio for the two largest companies in the market; EPCI, Engineer-Procure-Construct-Install; LCoE, levelized cost of energy; MWh, megawatt-hour; O&G, oil & gas; O&M, operation and maintenance; PMG, permanent magnet generator

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1. Introduction

Our paper aims to analyze different market strategies available to private actors developing offshore wind farms in Europe. These market strategies are the decisions of when and how to participate in the offshore wind farms. To achieve this goal, we apply the development and diffusion pattern model to offshore wind for the first time. The model analyzes offshore wind considering an erratic, non-continuous historical development and diffusion of the technology, separated into three different phases [1]. The results allow us to define the barriers to offshore wind power technology that affect the market strategies of private wind farm developers.

The European Union has set ambitious targets for the reduction of greenhouse gases emissions of the power sector: a 40% reduction by 2030 (compared to 1990 levels) and a complete decarbonization of the sector by 2050 [2,3]. Offshore wind is a low-carbon technology, and studies consequently predict a significant deployment which will contribute strongly to the European Union's decarbonization goals [4,5]. However, offshore wind is young when compared to onshore wind or conventional generation technologies, as it was only 25 years ago that the first offshore wind turbine in the world was installed in Sweden [6]. In 2015 wind power represented 11,4% of the total European power consumption, however offshore wind accounted for only 1,5% of this total consumption while onshore wind responded for the remaining 9,9% [7]. Nonetheless, estimates forecast that offshore wind may represent up to 15% of total power consumption by 2050 [5]. At the end of 2015 the European cumulative offshore wind installed capacity was 11 GW, or 1% of the total European net generating capacity [8,9]. But yet again, offshore capacity may range from 42 to 122 GW by 2030 – up to ten times the current figure [10]. The current modesty of offshore wind is also reflected in the annual installations: in 2015 3,4 GW of offshore wind were installed worldwide, only 5,4% of the global (onshore and offshore) wind power installations [11].

Since offshore wind is poised for important future growth, a number of recent studies target it. These use the viewpoints of technological innovation systems [12–14], technical and/or economic analysis [15–19], market structure [20,21], actor analysis [22], life cycle analysis [23], or a combination of the above, possibly also addressing regulatory issues [24–27]. However, none of them applied the development and diffusion pattern in their analysis. Our methodology has three steps: application of the development and diffusion pattern, definition of the barriers to offshore wind, and analysis of their impact on the market strategies of project developers. As the first application of the development and diffusion pattern to offshore wind, our work complements the aforementioned studies and simultaneously provides recommendations to project developers. Therefore, it is of interest to developers, companies innovating in offshore wind, and to policymakers who intend to guide this innovation. Also, we contribute to case study literature on the development and diffusion pattern.

This article is structured as follows. First, we conduct a review of offshore wind technology and of its cost. Next, the development and diffusion pattern is explained in Section 2, followed by the methodology comprising the offshore wind barriers and market strategies. Section 3 presents the results of the offshore wind pattern, barriers and market strategies. We then conclude on Section 4 on these three elements.

1.1. Offshore wind technology and actors

To understand the pattern of development and diffusion, we first briefly present the advantages and disadvantages of offshore wind, as well as the components, life cycle phases and actors of an offshore wind farm. Both onshore and offshore wind power are intermittent, meaning they are variable (changing uncontrollably in time) and uncertain (wind forecasts contain an error component). Offshore wind also competes with other economic activities such as shipping and fishing, and costs increase with water depths and distance from shore, as the near-shore potential is exploited [4]. Finally, offshore wind farms face harsher environmental conditions than onshore wind, and accessing the turbines for operation & maintenance is also more difficult. On the other hand, the offshore wind in Northern Europe has higher mean speeds and is less variable than the onshore wind, which results in higher full load hours (i.e. the equivalent time the wind turbine is generating at its full capacity) [28]. Also worth noting is that offshore wind farms currently face less socio-environmental barriers, which reduces design constraints and facilitates their implementation. Moreover, many European offshore projects can be built close to consumption centers [15,28].

Fig. 1 presents the main components of a horizontal axis offshore wind turbine. These are the rotor-nacelle assembly, the tower, the transition piece and the support structure. The rotor comprises the blades, which capture the wind mechanical energy, and the hub, which transmits it to the drive train. The drive train, located in the nacelle, is composed of gearboxes, the generator group, and the power converter, and transforms the mechanical energy to electrical energy. The gearbox and/or power converter are optional and depend on the drive train configuration. The generated power is transmitted down the turbine tower. As the name indicates, the support structure fixates the turbine on the seabed through different foundation technologies, and is usually connected to the tower by a transition piece. Other terminologies than the one used here can be found, such as in DNV [29].

It is then necessary to transmit the power generated onshore. For this, the collection system connects all turbines of a wind farm to an offshore substation. The wind turbines, the collection system and the substation constitute the offshore wind farm. The transmission system then links the offshore substation to the onshore power system (Fig. 2) [30,31]. In an offshore wind farm, items other than the turbines can account for 60% of total costs, against 30% for onshore farms. This is because the foundations and the collection and transmission systems are more expensive and complex, as is the farm installation, operation & maintenance and capital costs [21,32].

The life cycle of an offshore wind farm has several phases as shown in Fig. 3 with the main private actors involved in each phase [23,33]. Despite the apparent linearity, the different phases influence each other. For example, the use of gearless drive trains