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How the policy mix impacts innovation: Findings from company case studies on offshore wind in Germany

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ABSTRACT

Transforming the energy system to one with a greater importance of renewables requires redirecting and accelerating technological change. In this transition, so-called policy mixes play a crucial role. Yet precisely how policy mixes affect technological innovation remains poorly understood. To remedy this, in this study we choose a qualitative company case study approach to analyze the innovation impact of a comprehensive policy mix, taking offshore wind in Germany as research case. We find that the feed-in tariff level and the perceived consistency and credibility of the German offshore wind policy mix have been vital innovation drivers. Specifically, the consistent and stable policy strategy with its long-term targets, and the consistency of the instrument mix with this policy strategy appear crucial to RD&D. In contrast, adoption decisions depend on a comprehensive and consistent instrument mix. Finally, a high level of credibility can partly offset negative effects of inconsistencies in the mix.

Abbreviations: EEG, Renewable Energy Act; EnWG, Energy Economy Law; FIT, feed-in tariff; KfW, German Reconstruction Loan Corporation; LTT, long-term target; OW, offshore wind; PG, power generator; RD&D, research, development and demonstration; TP, technology provider; TSO, transmission system operator.

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1. Introduction

Given the sustainability challenges that face humankind, researchers and policy makers alike have proposed a number of routes leading to a greening of the economy (Grin et al., 2010; UNEP, 2011). One prominent example is the challenge of limiting climate change, calling for a decarbonization of the economy (IPCC, 2013, 2011). In this regard, the transition of the energy system toward renewable power generation technologies plays a key role, requiring the redirection and acceleration of technological change (IEA, 2009; Van den Bergh et al., 2011). Policies incentivizing such technological innovation and related cost reductions are crucial—particularly for emerging renewable energy technologies (Del Río, 2012; IEA, 2008).

Research analyzing the link between policies and innovation in environmental technologies has thus far mostly focused on the innovation impact of single policy instruments (Kemp and Pontoglio, 2011). These studies can be differentiated into those analyzing the innovation impact of the instrument type (e.g., Hoppmann et al., 2013; Rennings et al., 2008) and of instruments' design features (Del Río, 2012; Hascic et al., 2009). Some recent studies go beyond such a focus on instruments by considering the effects of particular policy mix aspects, such as policy coherence and long-term targets (Huttunen et al., 2014; Schmidt et al., 2012). Studies at a system level analyze the impact of policies on the performance of technological innovation systems (TIS) for selected renewable energy technologies (Foxon et al., 2005; McDowall et al., 2013). However, most of these studies either only account for policy instruments or, if they consider other policy aspects, this rarely follows a comprehensive policy mix approach.

Yet, in the broader climate and energy policy as well as innovation policy literature increasing attention is paid on the importance of analyzing policy mixes (Matthes, 2010; Nauwelaers et al., 2009; Rogge and Reichardt, 2015, 2013).[1] The rationale behind this is the multiple market, system and institutional failures in place requiring multi-faceted policy intervention (IEA, 2011a; Lehmann, 2010; OECD, 2007). In addition, policy mix concepts help to better capture the complex multi-level and multi-actor realities of 'real-world' policy mixes and their changes over time (Flanagan et al., 2011). The strength of using a policy mix concept from the outset of a study lies in its explicit and systematic recognition of aspects exceeding single instruments, such as interactions of instruments, the relevance of a policy strategy with long-term targets, and the importance of overarching policy mix characteristics such as consistency, comprehensiveness, credibility and stability (Boekholt, 2010; Del Río, 2012; Flanagan et al., 2011; Rogge and Reichardt, 2015).

However, there is a lack of empirical studies of the innovation effects of policies that use a comprehensive policy mix concept as starting point for their analyses. In this paper we take a first step in this direction by analyzing how a policy mix impacts corporate innovation activities regarding emerging renewable energy technologies, including both research, development and demonstration (RD&D) and adoption. In doing so we consider both elements and the so far understudied characteristics of the policy mix, as specified by Rogge and Reichardt (2015). That is, in our analysis we include the policy strategy with its long-term targets, interacting instruments and the consistency, credibility, comprehensiveness and stability of the policy mix (for definitions see Section 2). While we acknowledge that these elements and characteristics are shaped by policy making and implementation processes, which can also have a direct effect on innovation, we do not explicitly include policy processes in our analysis since this would exceed the scope of this paper. Instead we put a particular focus on the consistency of the elements of a policy mix and for this build upon studies analyzing interactions between policy instruments (Del Río, 2010). However, we extend these by considering the absence of contradictions and the existence of synergies at three levels: first, within the policy strategy, second, within the instrument mix, and third, between policy strategy and instrument mix. Following the literature on the determinants of eco-innovation we also consider the innovation impact of other firm-external and firm-internal factors (Del Río González, 2009;

[1] Rogge and Reichardt (2015) represents an updated and shortened version of their 2013 working paper, the 2013 version including – among others – a comprehensive annex with overviews of definitions used across different studies for defining policy mixes and their components.

Frondel et al., 2008). Overall our analysis enables a better understanding of the role of real policy mixes for innovation, thereby going beyond the existing literature on the innovation impact of single policy instruments. Based on this we derive policy recommendations providing more differentiated advice to policy makers.

To explore how policy mixes affect innovation, we study the case of offshore wind in Germany for two main reasons: First, the policy mix for offshore wind in Germany – which also encompasses some relevant EU policy mix components – represents a rich empirical case in which an ambitious long-term target and a complex instrument mix with apparent inconsistencies are present (BMWi and BMU, 2010). However, despite being the only renewable power generation technology in Germany with an explicit policy strategy and corresponding high political commitment backing it up, the actual diffusion of the technology is lagging behind, suggesting there may be important lessons to be learned for policy mix design. Second, given the large technological potentials of offshore wind (Roland Berger Strategy Consultants, 2013) and the increasing global interest in making it a key element of countries' energy transition plans (EWEA, 2011), a more thorough and systematic understanding of how to support this emerging technology is of great interest to policy makers around the world. In order to understand how the policy mix has impacted innovation in this emerging technology, we choose firms as our unit of analysis and apply a qualitative case study approach. Our main data source are interviews with several power generators and technology providers active in the German offshore wind market, supplemented with secondary data, such as company reports and public statistics. The remainder of the paper is structured as follows: we first explain the research framework (Section 2) before turning to a description of the research case (Section 3) and methodology (Section 4). Section 5 presents the main findings for firms' innovation activities regarding adoption and RD&D. Finally, in Section 6 we discuss some major findings and derive implications for policy makers.

2. Research framework

The literature that discusses factors driving environmental technological change considers a variety of innovation determinants, with environmental policy featuring as a key determinant (Del Río González, 2009). For instance, environmental policy and its stringency have been shown to be highly influential for innovation (Frondel et al., 2008; Taylor et al., 2005). Our paper contributes to this literature by studying how a broader policy mix impacts environmental innovation at a firm level. Based on the Oslo Manual (OECD, 2005) and in line with Rogge et al. (2011), we define these corporate innovation activities as consisting of adoption as well as research, development and demonstration (RD&D). That is, by adoption we refer to firms' investments in new or significantly improved technologies, and by RD&D we mean basic laboratory research, testing of the new technology in small-scale pilot projects and demonstrating its functioning by initially implementing it at a larger scale.

In contrast to many earlier studies, our policy variable does not consist of single policy instruments or specific design features only, but applies the policy mix concept proposed by Rogge and Reichardt (2015) as an analytical framework for a more comprehensive policy analysis. Fig. 1 shows a representation of this concept comprising elements and overarching policy mix characteristics.

Elements include the policy strategy and instrument mix. The policy strategy refers to policy objectives and principal plans to achieve these, while the instrument mix is the combination of interacting policy instruments characterized by their design features, such as the level of support. Characteristics describe the nature of a policy mix and may also be important determinants for policy mix performance. They may include consistency, credibility, comprehensiveness and stability. Consistency captures the alignment of policy mix elements with each other and as such contributes to achieving policy objectives. It thus comprises three levels: First-level consistency refers to the consistency of the policy strategy, second-level consistency means consistency of the instrument mix according to the nature of the instruments' interactions, and third-level consistency refers to the consistency of the policy strategy with the instrument mix. Credibility captures how believable and reliable the policy mix is, while comprehensiveness addresses how extensive and exhaustive the policy mix elements are. Finally, stability describes the long-term certainty of the policy mix.[2]

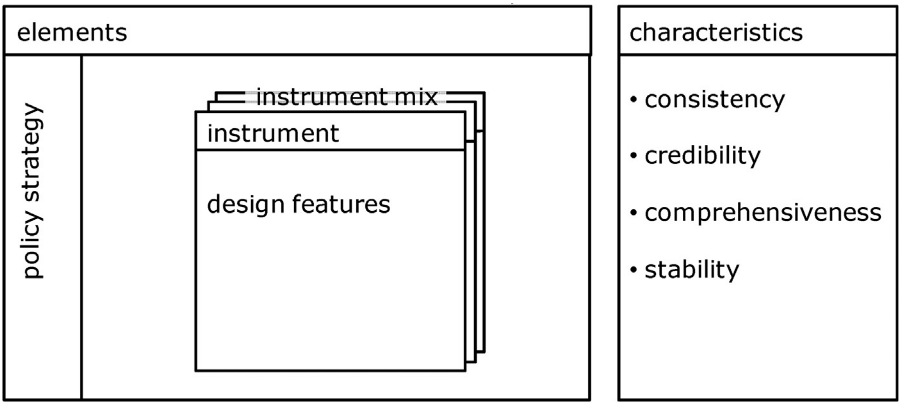

Fig. 1. Policy mix concept applied in this study (adapted from Rogge and Reichardt, 2015).

Apart from policy as one innovation determinant several other firm-external and firm-internal factors have been included in the literature, with varying effects and importance for innovation (Horbach et al., 2012). For instance, Horbach et al. (2012) conclude that different types of eco-innovation are driven by different factors which are, however, mostly firm-external, such as current and expected regulation or prices of energy and raw materials. Therefore, while focusing on the link between the policy mix and innovation, we also account for other firm-external and firm-internal innovation determinants (Rehfeld et al., 2007), namely context factors and firm characteristics.

For context factors, following other studies we distinguish between market factors, technology characteristics, and public acceptance (Rogge et al., 2011; Schmidt et al., 2012). Market factors comprise, for instance, supply and demand for resources, components and products and their prices, as well as market structure (Del Río González, 2005; Kesidou and Demirel, 2012). Furthermore, we include technology characteristics to capture the variation of techno-economic features across technologies. Examples include a technology's scale, state of development and thus its maturity, and competitiveness, or its location and necessary enabling infrastructures (Del Río González, 2009, 2005). We also incorporate public acceptance as a context factor (Schmidt et al., 2012), thereby considering the perception of the technology by society and through this its perceived legitimacy (Hekkert et al., 2007). For example, public resistance could arise owing to financial burdens imposed on consumers or taxpayers due to initial high costs or potentially negative environmental impacts associated with a technology (O'Keeffe and Haggett, 2012).

As for firm characteristics, following the literature we include four such characteristics in our research framework (Del Río González, 2009; Schmidt et al., 2012). A firm's technology portfolio, which reflects its technological capabilities, can play a role in whether a firm becomes active in a new technology or not (Christensen and Rosenbloom, 1995). A firm's strategy "defines the range of business the company is to pursue" (Andrews, 1987; p. 13) and might thus play a crucial role in guiding its innovation activities. The value chain position can influence the kind of innovation activities a firm carries out, e.g., if it conducts more RD&D or rather adopts a new technology (Mazzanti and Zoboli, 2006; Taylor, 2008). Finally, the size of a firm has been shown to affect the direction and rate of its innovation activities, although with ambiguous findings (Acs and Audretsch, 1988; Shefer and Frenkel, 2005).

[2] These definitions follow Rogge and Reichardt (2015) with the exception of stability, which was only included in Rogge and Reichardt (2013).

Fig. 2 summarizes our research framework, indicating the main link between the policy mix and corporate innovation by the thick gray arrow.[3]

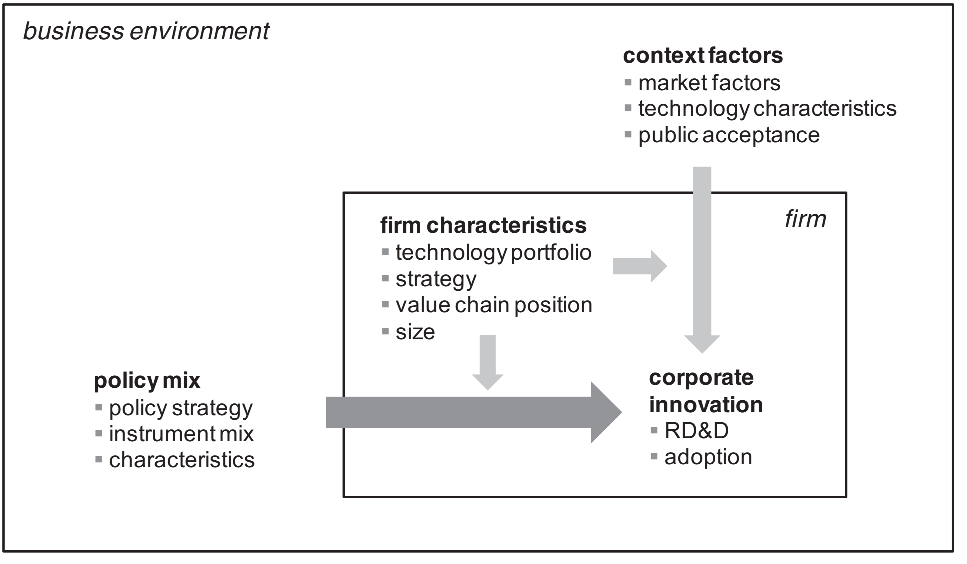

Fig. 2. Research framework for studying the role of the policy mix for corporate innovation.

3. Research case

As a research case we chose offshore wind in Germany for its multi-faceted policy mix with an ambitious policy strategy and relatively complex instrument mix. Such a policy mix provides a particularly useful example for empirically studying its impact on innovation. In addition, existing studies on offshore wind do not treat the policy mix in a systematic fashion, but either focus on costs and the investment environment in general (Praessler and Schaechtele, 2012; Van der Zwaan et al., 2012) or on specific aspects of the policy framework, such as support schemes and planning tools (Green and Vasilakos, 2011; Smit et al., 2007).

The boundaries we set for our research are summarized in Table 1. For instance, we focus on the policy mix relevant for offshore wind (technology) in Germany (geography), containing both national and relevant EU policy mix components (governance level; see Table 3). Furthermore, we analyze policy mix effects on corporate innovation focusing on the period between 2011 and 2013 (time).

3.1. The offshore wind technology

Offshore wind is a technology with large potential. Higher and steadier energy yields offshore, i.e. up to 4000 full load hours per year compared to 2000–2500 full-load hours onshore (EWEA, 2009), and limited potential for onshore growth in Europe are important reasons for its great growth prospects (Praessler and Schaechtele, 2012).[4] However, the technology is also confronted with difficulties. One

[3] This figure only depicts those links our study focuses upon. However, there may also be other possible relationships, such as effects between context factors and the policy mix. Note that the down left corner of the figure refers to the policy mix concept as depicted in Figure 1.

[4] Until 2030, between 12% and 17% of EU electricity consumption is predicted to come from offshore wind (EWEA, 2009).

Table 1
Boundaries of our empirical policy mix study.

Dimension	Specification for our study of offshore wind in Germany
Policy field	Energy, climate, RD&D
Geography	Germany
Governance level	National, EU
Technology	Offshore wind
Sector	Power
Innovation phase	RD&D, adoption
Actor	Firms (technology providers, firm characteristics)
Value chain	Turbine development & manufacturing, power generation
Time	2011–2013

Source: own elaboration (following dimensions proposed in Rogge and Reichardt, 2015)

is that offshore wind faces more challenging conditions than its onshore counterpart (IEA, 2009). For example, the marine environment with its salt water and higher wind speeds intensifies corrosion and puts higher demands on turbine materials. Thus, in view of the relatively low capacities currently installed in the EU and Germany compared to their ambitious 2020 targets (see Table 2), offshore wind is still rather immature (EWEA, 2011). Relatedly, offshore wind costs to date are comparatively high, ranging between 12.8 and 14.2 ct/kWh in Germany (Fichtner and Prognos, 2013). However, costs are expected to fall to 9 ct/kWh by 2020 (see Table 2). The offshore wind cost structure is more evenly spread across the supply chain than onshore costs, with the turbine still representing the biggest share. Key savings can be achieved not only by utilizing bigger turbines but also through improved foundation concepts, economies of scale in foundation production, and more mature operation and maintenance concepts (Roland Berger Strategy Consultants, 2013).

Table 2
Installed capacity and electricity production costs of offshore wind.

		2012	2020 (planned)
Installed capacity (in GW)	EU	5.3	40
	Germany	0.28	10
Electricity production costs (ct/ kWh)	Global average	11–18	9

Source: own compilation based on EWEA (2009, 2011), Fichtner & Prognos (2013), Roland Berger (2013).

Despite these challenges, an attractive German offshore wind market has emerged and is set to become one of the largest ones in Europe, with about nine GW of capacity being installed or in the pipeline (Fraunhofer, 2012). The number of industry players along the whole value chain that have entered this market illustrates its attractiveness; they range from operators of offshore wind ports to service providers for operation and maintenance of farms (KPMG, 2010). On the supply side, technology providers that construct offshore wind turbines represent a central actor, with currently four (mostly German) firms active in the German market (see Appendix A1). On the demand side, farm owners exhibit a high diversity with a multitude of heterogeneous, predominantly German players (see Appendix A2). In terms of capacity installed, large incumbents currently dominate the German market.

3.2. The policy mix for offshore wind in Germany

The German market is governed by a policy mix that has thus far reflected a strong political will to promote offshore wind. Table 3 gives an overview of the main components of this mix, including the policy strategy with its objectives and principal plans and the instrument mix with demand pull, technology push and systemic instruments, both at an EU and the German national level. In the following, we highlight the most important elements of this policy mix for offshore wind.

[5] However, the potential of offshore wind has been estimated to be 40 GW by 2020 (EWEA 2011).

Probably the most relevant component of the policy strategy is the German long-term target for offshore wind, an objective which aims at 10 GW of installed capacity by 2020 and 25 GW by 2030 (Bundesregierung, 2002). The core instrument of the instrument mix has been the demand pull instrument Renewable Energy Sources Act (EEG). This law specifies the levels of offshore wind-specific feed-in tariffs (FIT) (see below). Another central instrument is the Energy Economy Law (EnWG), a systemic instrument which regulates the grid access for offshore wind farms. The demand pull instrument KfW Offshore Wind Program, which grants loans at market conditions for early offshore wind farms, and technology push instruments in the form of several RD&D support programs supplement the instrument mix.

Table 3
Key policy mix elements for offshore wind in Germany as of 2013 (differentiated by governance level EU vs. Germany (DE)).

			EU	DE
Policy strategy	Objectives (long-term targets)	Offshore wind	No technology-specific target[5]	By 2020: 10 GW capacity By 2030: 25 GW capacity
		Renewables	20% renewables in energy consumption by 2020 Renewables Directive (DIR 2009/28/EC)	18% renewables in energy consumption by 2020
		Climate	20% GHG emissions reduction by 2020*	30–40% GHG emissions reduction by 2020*
	Principal plans		Energy Roadmap 2050 Strategic Energy Technology (SET) Plan	Energy Concept National Renewable Energy Action Plan (NREAP)
Instrument mix	Demand pull		EU Emission Trading System (EU ETS)	Renewable Energy Sources Act (EEG) KfW Offshore Wind Program
	Technology push		New Entrants' Reserve (NER 300) European Energy Program for Recovery (EEPR)	RD&D support programs
	Systemic			Energy Economy Law (EnWG)

Source: own compilation; *compared to 1990 levels.

One core instrument of the offshore wind policy mix is the EEG, which has been in place since 2000 and has been amended several times. The EEG version from 2012 – effective during the time of our interviews – lets investors choose between an initial remuneration of 15 ct/ kWh for twelve years and 19 ct/kWh for eight years (compression model). These and further design features of the offshore wind feed-in tariff are depicted in Table 4. It is interesting to note that installations in nature conservation areas have been excluded from these tariffs since 2004.

Another vital instrument is the Energy Economy Law (EnWG), which regulates details of the grid connection and operation for offshore wind farms and – most importantly – since 2006 has obliged transmission system operators (TSOs) to build and operate the grid connection lines for farms. Several EnWG amendments have been implemented, the latest one in 2012 addressing the problem of delayed grid access facing many of the early German farms. It changes the former provision that the grid connection be operation-ready when the farm is ready to operate by newly requiring operators to negotiate a fixed date for this with the TSO. This date becomes mandatory 30 months before its expiry. If the TSO then cannot adhere to it, a liability clause ensures that the farm operator is compensated financially for each day the farm stands idle and thus cannot feed in electricity. In addition, the EnWG 2012 obliges TSOs to put forward a yearly offshore grid development plan containing details on the location, timing and size of grid connection lines.

Table 4
Key design features of the German feed-in tariff for offshore wind (EEG 2012).

Component	Design features
Initial remuneration (since 2009)	15 ct/kWh, payable for 12 years
Elevated initial remuneration ("compression model", since 2012)	Alternative to initial remuneration for plants starting operation before 2018: 19 ct/kWh, payable for 8 years
Basic remuneration	3.5 ct/kWh, payable after initial or elevated remuneration for further 8 or 12 years (until 20 years of FIT are completed)
Remuneration extension (since 2004)	Initial remuneration is extended in time for plants: >12 nautical miles from shore: for each full additional nautical mile by 0.5 months >20 meters of water depth: for each additional meter by 1.7 months
Degression	Starting in 2018 yearly 7% degression in FIT for plants starting operation in 2013 or later

Source: own compilation based on EEG (2009, 2012)

4. Method

To answer our research question, we chose a qualitative research design involving multiple company case studies (George and Bennett, 2005; Gerring, 2007; Yin, 2009). This approach enables an in-depth study of the phenomenon and thorough exploration of its causes and consequences, thereby allowing for detailed insights into how and why the policy mix impacts firms' innovation activities. In addition, it is suitable for research settings in which only few actors are involved and which consequently do not lend themselves to a large-scale survey. In line with similar studies (Hoffmann, 2007; Hoppmann et al., 2013) our focus is on companies since they tend to be key players for innovation and addressees of many policy mix components.

In order to gain a better understanding of the offshore wind sector, we initially performed desktop research analyzing publicly available information such as magazine articles and firm websites (see Appendix A). As the policy mix concept by Rogge and Reichardt (2015) has not been empirically applied before, we then conducted exploratory interviews in order to gauge how to best operationalize the concept's key variables. That is, we tested with which vocabulary and questions the policy mix and its components could most appropriately be addressed in interviews with corporate actors. For this purpose we interviewed ten experts of companies involved in offshore wind in Germany between August and October 2011. The result of these interviews with power generators and technology providers was our semi-structured interview guide, which formed the basis for our ensuing case study interviews.

Subsequently, we started our case study research phase in which we studied six companies. We chose our firm sample in such a way as to capture major actors in the value chain who are active both in RD&D and adoption. Hence, we selected turbine technology providers (TPs) and power generators (PGs) for the following reasons: First, the turbine constitutes the single most costly technology component with the potential for cost reductions from RD&D (see Section 3). Second, power generators have thus far been crucial actors for adoption, currently responsible for constructing and operating the majority of offshore wind farms in Germany (see Appendix A). In order to allow for theoretical and literal replication and to ensure external validity, we relied on a theoretical sample which incorporates at least two firms for each of the two firm types (see Table 5). In addition, for PGs we included both large and small companies that construct and/or operate offshore wind farms in Germany.

For the case study data collection we proceeded in three steps. First, to gain deeper insights into the firms in our target group and their offshore wind activities, we conducted background research on them, analyzing their websites, annual reports and press articles in the databases Genios and Lexis Nexis starting in 2005. Second, based on this we tailored the semi-structured interview guide to the specificities of individual firms. That is we included the specific innovation activities of firms in order to be able to address specific innovation projects. As a third step we conducted our main interviews with company representatives between January and March 2013. We chose such a short interview period to control for the fast-changing policy mix for offshore wind, thereby ensuring that within the interview period no major policy mix changes occurred. With the exception of two interviews, these were jointly conducted by two interviewers and lasted around 73 min on average. Reflecting our focus on firms' innovation strategies and how they are impacted by the policy mix, we chose as interviewees firm employees with offshore wind expertise who typically held RD&D, strategy or project management functions. Depending on firm organization we thus conducted one to two telephone interviews per company, which were recorded and subsequently transcribed. In the interviews we first explored a firm's innovation activities. We then started our question block on the policy mix with an open question on the effect of the policy mix on innovation, so as to allow the interviewee to mention any target or instrument regardless of policy field or governance level.[6] Only then did we ask about the relevance of specific policy mix components for a firm's innovation activities – with a focus on consistency. Finally, we investigated the importance of context factors and firm characteristics for understanding firms' innovation activities (see Appendix B).

Table 5
Overview of the firm sample and interviews.

Category		Power generators				∑	Technology providers		∑	Total
		A	B	C	D		E	F		
Firm size	Large	x	x			2	x		1	3
	Medium/ small			x	x	2		X	1	3
Interviews	Number	1	1	2	2	6	1	2	3	9
	Interviewee functions	Head energy policy	Head business development	Head energy policy, project manager	Head renewables, member managing board		Head business development	Head OW development, R&D manager		

We analyzed our case study interviews using the qualitative data analysis software Atlas.ti and proceeded in five steps. First, we developed a code list covering all components of our research framework (as depicted in Fig. 2). We refined this list during the coding of the first interviews, which was done by two researchers to control for intercoder reliability. Second, after the code list was finalized and a common understanding of all codes ensured, one researcher coded all interview transcripts according to this list.[7] Third, based on this coding we analyzed the role of the different policy mix components, including the three levels of consistency, for corporate innovation activities. In our search for causal links between the policy mix and innovation, we also explored the role of context factors and firm characteristics for each individual firm and triangulated our interview findings with insights from our background research. Fourth, we compared our findings for single company cases among all power generators – later also proceeding in the same manner for technology providers – thereby looking for common patterns and reasons for differences among firms, such as a firm's size or technology portfolio. For instance, if a firm did not mention a certain policy mix effect, which, however, had been stressed by other firms, we tried to find an explanation based on differences in firm characteristics. Only if such an explanation could be identified did we consider this effect as unambiguous finding. Finally, we contrasted our findings for power generators with those for technology providers, searching for commonalities and differences between these two groups. Emerging patterns were cross-checked with all cases with a view for conflicting evidence, in which case we continued to search for alternative explanations. Based on this procedure we derived the main findings supported by our case studies,

[6] Interestingly, despite the open nature of the initial policy mix question respondents did not mention instruments from more general policy fields, such as general tax policies, but rather focused on policy fields directly relevant to offshore wind. This specificity was also the case when discussing perceived inconsistencies in the instrument mix.

[7] The initial coding was done by two researchers in an iterative process in which the researchers separately coded an interview passage, then contrasted and compared their coding, and based on this jointly clarified the meaning of each code and refined the code list. This procedure was repeated until a final code list emerged and coding differences were negligible. Therefore, the final coding of the interviews was performed by one researcher only.

i.e. common patterns enabling us to explain the influence of the policy mix on adoption and RD&D activities.

5. Results

In the following we present our main findings on how corporate adoption and RD&D activities were influenced by the policy mix (Sections 5.1 and 5.2, respectively). We start with the policy mix elements policy strategy and instrument mix and then turn to policy mix characteristics, also considering the interplay of these components. In addition, we point to the influence of the most important context factors and firm characteristics at the end of each subsection. We depict our main results with supporting illustrative interview quotes in Tables 6 and 7. Each subsection starts with a brief description of the main corporate adoption and RD&D activities that the interviewed firms performed.

5.1. Effects on adoption

Power generators in our sample have constructed and operate offshore wind farms in Germany. Their turbines have been developed and sold by technology providers: *"We function essentially as the operator of the farm, responsible for construction and management and the supply of electricity."* (PG)

Our interviews suggest that the **policy strategy** – in terms of the characteristics of the German long-term targets for offshore wind and renewables – played a reinforcing role in power generators' adoption activities. They perceived these targets as consistent, credible, stable over time and ambitious, and as such the targets strengthened their adoption activities in addition to other policy mix components. This is captured by one power generator: *"[The long-term targets for offshore wind and renewables] naturally motivate the decision behind every project."*

However, the **instrument mix** played a much more important role for firms' adoption activities. Both power generators and technology providers clearly perceived the EEG with its feed-in tariff for each kWh electricity fed into the grid as the most crucial policy instrument for adoption (see {1} in Table 6), as one power generator explains *"The EEG is the decisive factor in our decisions on whether to construct a wind farm."* Two main design features have been key to this realization (see {2} in Table 6): First, the feed-in tariff reached an investment-triggering level of support with the increased tariffs introduced in 2009. This was further intensified by the compression model in 2012, as illustrated by one power generator: *"The EEG amendment [2009] brought the surety of earning sufficient money from the projects. From that point on, one could say that it was possible to run financially viable projects."* The second central design feature is the feed-in tariff's long-term predictability, i.e. 20 years of guaranteed remuneration. The positive repercussions of this feed-in tariff for sales of offshore turbines (and all other associated components and services) are described by one technology provider in these terms: *"How much can be sold is very important for us as a plant manufacturer. This forecast naturally depends very strongly on feed-in revenues."*

Another central instrument in the instrument mix facilitating adoption was the EnWG's requirement that grid operators build and operate the grid connection of offshore wind farms, as this power generator states: *"From an economic perspective [the most important policy instruments] are the EEG and the grid connection [the EnWG]."* Additional instruments complement the mix, such as the KfW program which grants low-interest loans for the first ten farms in Germany. Introduced in 2011 as a response to financial bottlenecks in the aftermath of the financial crisis, it was an important instrument for project-financed farms, as explained by one technology provider: *"Startup financing is naturally extremely important for project-financed farms."*

In combination with the instrument mix and its vital importance, several **policy mix characteristics** turned out to be central determinants of firms' adoption activities. Most importantly, consistency or the fit of the instrument mix, i.e. second-level consistency, appears to have been a prerequisite for adoption (see {3} in Table 6). This is most clearly evidenced by the detrimental effect of instrument mix inconsistencies in the form of negative interactions between the EEG and the EnWG that became apparent in 2012 (see {4} in Table 6). In response to these inconsistencies power generators have put their final investment decisions for new farms in Germany on hold: *"For new building decisions [. . .] at present we have no framework that allows us to decide on new investments in construction."* (PG)

The immediate negative implications for sales and thus manufacturing of offshore wind turbines are stated by one technology provider: *"We will now [. . .] finish production according to the contract and then stop for a while".* (TP)

This inconsistency can be traced back to the ineffectiveness of the EnWG regulation in addressing the bottleneck of grid access, which simultaneously rendered the current EEG with its compression model ineffective, as illustrated by this power generator: *"For example, the compression model in the EEG is expiring. Never mind the fact that many projects are substantially behind schedule from the many changes and delays in the grid and through the awarding of grid connections. That still doesn't go together."* More specifically, although the 2012 EnWG amendment introduced significant changes for grid access (see Section 3.2), several projects would continue to face grid access delays, since this new regulation takes some time to become effective. Some offshore wind investors were thus likely to miss the temporally limited validity of the feed-in tariff compression model, which is running out in 2017 and which several of today's investors seem to require for making investment decisions for new farms. A power generator illustrates this problem: *"If you don't make the commissioning deadline [the end of the compression model in 2017], the compensation scheme is useless to you. Since the rate of remuneration is nevertheless the lower one."*

Our interviews indicate that in addition to consistency, comprehensiveness of the instrument mix, i.e. the existence of these other instruments, has been a prerequisite for adoption (see {3} in Table 6). That is, only in combination did the policy instruments appear to be able to overcome the most important market and system failures and any other bottlenecks, despite the central importance of the EEG. The significance of this comprehensiveness is illustrated by one power generator: *"It doesn't help to have a great permit if you don't have enough financing or any chance of a grid connection. These all build on each other and you need every part."*

We finally find an important role of credibility, which appears to have been key for adoption (see {5} in Table 6). That is, if power generators and technology providers perceived a credible political will in favor of offshore wind, they were very likely to start their adoption activities, as stated by one power generator: *"In view of the then relatively rudimentary state of knowledge on costs and risks, the political will to do it was naturally the deciding factor."* Yet this high credibility achieved until early 2013 was decreased by the recent political debate about how to lower soaring electricity costs for consumers, the so-called electricity price brake discussion,[8] which has been detrimental to innovation. Thus, in addition to second-level inconsistencies between the EEG and the EnWG, this discussion has further impeded adoption (and ultimately also RD&D).

The observed adoption activities were also driven by factors beyond the policy mix. First, regarding firm characteristics, the firms' growth strategies, their renewable energy goals and the propensity of large power generators to invest in large-scale power generation technologies (building on their capabilities in managing such projects) were essential drivers for adoption: *"Offshore is a very good fit for us. These are large, complex projects which we as classic power plant operators and builders know how to handle." (PG)* In addition, a firm's size helps explain which markets firms focus on: larger firms were often active in other countries, and smaller and locally rooted power generators as well as smaller technology providers seemed to focus on Germany as the home market. A further driver for adoption was the high availability of offshore wind projects and the close fit with large utilities' capabilities that are enabled by their large scale.

5.2. Effects on research, development and demonstration

Technology providers in our sample have at least one commercial offshore turbine type in their portfolio. They have been instrumental in developing, testing and improving turbines, with a current focus on improving their reliability and reducing costs, as this technology provider points out: *"Becoming more standardized, lower-priced, faster, more automated [. . .] these are areas we are working hard on."* In contrast, power generators have focused on optimizing the construction and operation of

[8] The electricity price brake discussion, initiated by former environment minister Peter Altmaier in early 2013, suggested a retrospective reduction of tariffs for renewable energy technologies (Spiegel Online, 2013).

Table 6
Key findings and illustrative quotes regarding adoption of offshore wind.

Findings on how the policy mix affects adoption of offshore wind	Exemplary quotes
{1} Feed-in law with its feed-in tariff is the most important instrument driving adoption	*"[The role of the policy mix in OW (offshore wind) innovation:] In one word: essential. Or fundamentally enabling, since without the feed-in tariffs there would be no offshore wind projects in Germany." (PG)*
{2} Investment-triggering level of support and its high predictability are the most crucial feed-in law design features driving adoption	*"They [the feed-in credits] must reach a certain level so that the investment is worthwhile. The currently announced levels are very good and enable exactly the sort of the dynamic that we now see in the German market." (TP)* *"What we see in terms of the volume of offshore wind is that we have to get far more involved with project financing than we thought. So it was important in the last EEG amendment [2012] to make further improvements. This succeeded in part because the compression model was introduced." (TP)* *"What we in the German system would point out from the perspective of a builder and operator is naturally the security that the EEG represents. That is a very big advantage." (PG)*
{3} A comprehensive and consistent instrument mix facilitates adoption	*"As stated, the grid connection is important in order to be able to feed in power at all, and naturally so that the financing, as it is currently stipulated, can work. In this respect, these two things are interdependent."(PG)* *"The EEG embedded in an appropriate policy framework is decisive." (PG)*
{4} Inconsistencies between the feed-in law and the grid access regulation hinder further adoption	*"But we now had the situation that the EEG had been solved but not the EnWG. And you can't plan a wind farm when you don't have a grid connection. And having a grid connection is useless when you don't know what the remuneration looks like. Both of these are essential." (PG)* *"So this has to do with the fact [. . .] that we don't know when we will get a grid connection. And if we are uncertain whether we will slip out of the compression model [. . .], naturally that has significant economic repercussions. And since at the moment we are not taking this risk, we have said that we will further develop the projects, but that at the present time we cannot make the investment decision." (PG)* *"We have to [. . .] reevaluate the schedule for our upcoming projects. We could say [. . .] we'll start construction on the project at such and such a time. But that doesn't help us, since we don't know whether we'll get a grid connection by then. That means we'll have to [...] wait until we get the [. . .] grid connection plan so that we can plan. At the moment we're somewhat at the mercy of this." (PG)*
{5} A credible policy mix facilitates adoption	*"Then the EEG, the EnWG with the grid access provision – these were really important instruments. But also a certain level of trust that this would not suddenly be changed." (PG)* *"Without this commitment of the government the offshore market would not exist in this form, this is very clear." (TP)*

their offshore wind farms, and in so doing they aimed for cost reductions: *"There is a lot of emphasis put on how to optimize the operation of such a wind farm [. . .] As before, our focus is on how to further lower offshore's costs." (PG)* Several actors have also jointly pursued RD&D. The most prominent example is the cooperation of early entrants in the German test farm alpha ventus, in which three power generators have been testing twelve 5 MW turbines supplied by two technology providers.

Our interviews indicate that the **policy strategy,** particularly the long-term target for offshore wind, was one factor stimulating both firm types' RD&D. The ambitiousness of this target was interpreted as a sign of a growing market, as stated by one power generator: *"[Political long-term targets] for us mean that over the next decade a market will be developed that will make it worthwhile to develop innovations."* These market expectations triggered by long-term targets then positively influenced RD&D, as explained by this technology provider: *"If [these targets] are no longer there, so to speak, or if they are not updated, then naturally the pressure to innovate is smaller."*

An important complement to the policy strategy as part of the **instrument mix** has been the German feed-in tariff – a demand pull instrument – with its sufficiently high level of support: *"[...] but without such an impulse from the EEG [...] this [that the installations would improve, run more] would not be possible." (TP)* In addition, technology push instruments, such as financial RD&D support, seem to have had an impact on RD&D activities. They appear to have been especially important for technology providers in early phases of technology development and currently seem to play a supplementary role to demand pull support by guiding or deepening some RD&D projects, as one technology provider points out: "*[R&D funding programs] support the process and can also accelerate it.*"

Regarding **policy mix characteristics**, consistency of the policy strategy, i.e. of the long-term targets for offshore wind and for renewable energies in general, has been a key driver for RD&D in offshore wind. Furthermore, the stability of the offshore wind long-term target has likely played an important role (see {1} in Table 7): *"Since we regularly check whether we're on the right track, [we look] at what has changed in the [LTT] framework, and we can say that basically it is still stable. Then naturally we stand by the decision [to be active in offshore wind]" (PG).* A further crucial RD&D driver has been the actual or expected consistency of the policy strategy with the instrument mix: Technology providers stressed that the offshore wind long-term target alone was not sufficient but needed to be operationalized in a consistent manner by policy instruments, primarily by a sufficient level of demand pull support (see {2} in Table 7). In addition the second-level inconsistency, i.e. the negative interaction between the EnWG and the EEG, which caused a decline in technology providers' sales, has been perceived as a barrier to RD&D (see {3} in Table 7): *"Naturally we want to further develop our current technology. But without knowing how long grid access delays by TSO TenneT will go on, our decisions on whether to further develop our turbines – almost all of which entail costs – will be postponed." (TP)* Yet the high credibility of the policy mix has partly compensated for the lack of consistency (see {4} in Table 7): Although these second-level inconsistencies negatively affected RD&D activities, firms continued at least some RD&D since they still perceived the overarching policy mix as credible, believing in the resolution of the inconsistencies: "*Since we now have a divergence between the EnWG and EEG rules, I'm sure that this topic will receive political attention... I think the will is there.*" (PG) Similarly, we find signs of compensation between credibility and comprehensiveness (see {4} in Table 7): Actors invested in RD&D despite the policy mix's initial lack of comprehensiveness because they trusted policy makers' commitment to solve problems. This was the case for the perceived high level of credibility that helped stimulate

Table 7
Key findings and illustrative quotes regarding RD&D in offshore wind.

Findings on how the policy mix affects RD&D in offshore wind	Exemplary quotes
{1} Consistent, credible and stable technology-specific policy strategy with ambitious long-term target stimulates firms' RD&D	*"Renewable energy targets have their place here, otherwise the policy framework is not consistent and the OW LTT [long-term target] is not credible; it would be strange to have only an OW LTT without renewable energy targets." (PG)* *"Since we regularly check whether we're on the right track, [we look] at what has changed in the [LTT] framework, and we can say that basically it is still stable. Then naturally we stand by the decision [to be active in offshore wind]" (PG)*
{2} Consistent operationalization of the policy strategy particularly by sufficiently high level of demand pull support has indirect positive effect on RD&D	*"One thing is definitely support [FIT] for our customers, since that's the only way they can build wind parks and in that way we sell wind turbines. So that's indirect support." (TP)* *"The [onshore] plants improved and more got put into operation [...] I expect the same for offshore wind in the next years, but without an impulse from the EEG [...] that would not be possible." (TP)*
{3} Inconsistencies between feed-in law and grid access regulation hinder RD&D	*"At present we can't make any large innovations, since we have a drop-off in orders. In Germany, since the first TenneT letter of 11/07/2011, there have been practically no more orders in the offshore sector." (TP)* *"We have not stopped innovating [because of TenneT's grid-access delays], but the pace has slackened somewhat" (TP)*
{4} High policy mix credibility alleviates the negative effects of inconsistencies or lack of comprehensiveness	*"The hope is there, of course. We see the willingness of the stakeholders to work on this issue – we do notice that." (TP)* *"This brings us back to the point that the national government wants to have offshore wind and will therefore find a solution to the offshore grid issue. And against this background one has a certain level of trust [...]" (PG)*

offshore wind project development activities early on in technology development even though the instrument mix lacked some important instruments, such as a technology-specific feed-in tariff. This is aptly put by one technology provider: "*Also the commitment [...] even just through statements, and even when no proper business rules have been established yet, such commitment has a huge influence on all activities, on our investments and especially the investments of our customers.*"

Besides the policy mix, several context factors and firm characteristics help explain corporate RD&D activities. For context factors, a major motivation for TPs' RD&D activities was the excellent market prospects for offshore wind, which were, however, mainly brought about by the policy mix. In this, the high demand for the offshore wind technology seems to have had a positive influence on the level and direction of RD&D activities. Furthermore, the immaturity of the technology was a strong innovation driver for both TPs and PGs. For German firms, this included the far out offshore location and related high costs, as illustrated by this technology provider: *"We are trying [...] to create a standard product, since our ultimate objective is to bring down the cost of offshore wind."*

As for firm characteristics, these high costs are reflected in PGs' cost reduction goals that drove their RD&D activities, as this PG states: *"We have identified specific measures that help us to reduce costs here as well [...] in order to be able to continue to realize wind farms in the future."* Similarly, TPs' strategies aiming at technology leadership, growth or cost reductions were key drivers for RD&D activities, as one technology provider points out *"that innovation for us is [strategically] extremely important. Our entire business is built on it."* Also, existing onshore wind technological capabilities benefited TPs' offshore wind RD&D activities.

6. Discussion and conclusion

This study has provided insights into how the policy mix has influenced corporate innovation activities in the emerging technology of offshore wind in Germany.

Summarizing our findings, we want to highlight two main points. First, the long-term target for offshore wind and its consistency with overall renewable energy targets appear particularly central to RD&D investments. In contrast, the instrument mix and the fit of policy instruments such as the EEG and the EnWG are particularly relevant for adoption. In this regard the most important policy instrument in the mix is the feed-in tariff and its sufficient level of support and high predictability. Second, we find a compensation effect of the generally high level of policy mix credibility, implying that a lack of the otherwise central characteristics consistency and comprehensiveness of the policy mix has only limited negative consequences for RD&D and the initial interest in adoption. This is exemplified by technology providers' continuation of some RD&D activities despite inconsistencies between the EEG and EnWG policy instruments.

Given the decisive roles of consistency and credibility for offshore wind innovation, we will focus our discussion on their significance. First, we find that a certain level of policy mix consistency is central for corporate innovation activities. This importance of consistency might be due to the fact that corporate actors consider the whole policy mix when thinking about investments into a technology, which they did, for instance, with the EEG and EnWG. Therefore not only single instruments need to be appropriately designed but due to interaction effects they need to fit together to provide clear investment incentives. This implies that analyzing interacting policy instruments and also the policy strategy enables crucial insights into otherwise neglected policy effects caused by interactions.

Second, the perceived high credibility of the political framework and thus the belief of actors in the political will to continue promoting the emerging offshore wind technology seems to create expectations of a favorable future policy mix. On the one hand, this is an important investment condition given the plethora of uncertainties about future developments in the offshore wind sector, including regarding the policy mix. On the other hand, such expectations might explain the aforementioned compensation effect of credibility. That is, if the policy mix is credible, it does not need to be fully consistent or address all bottlenecks – at least temporarily – since actors expect that policy makers will eventually remove these flaws.

Based on our findings on how the policy mix impacts corporate innovation in offshore wind in Germany, we propose some general lessons for other countries aiming to advance the technology.[9] First, it may be particularly useful to establish a technology-specific long-term target early on, and to ensure that it is ambitious, credible, stable and consistent with the overarching climate and renewable energy strategy. This is supported by earlier studies favoring technology-specific support over technology-neutral measures for bringing new technologies to the market (Azar and Sandén, 2011). Second, aside from introducing a predictable demand pull instrument with a sufficiently high level of support, policy makers should strive for a comprehensive instrument mix that also addresses other market failures and barriers. Third, a credible political commitment is a central characteristic of an effective policy mix for offshore wind, where trust needs to be built over time through multiple mechanisms but can also quickly be destroyed by pure political discussions.

Considering our findings for offshore wind in Germany, we recommend tackling several current challenges if the technology is to play a central role in the energy transition. The delays in grid access and associated inability of many investors to meet the 2017 deadline for the feed-in tariff compression model call for two main policy responses. First, the negative interaction between the EnWG and the EEG ought to be resolved, e.g., by extending the compression model by the grid access delay time or introducing an alternative model with comparable investment incentives, which also considers these delays.[10] Second, the effectiveness of the new EnWG addressing the grid access delays should be monitored and, if necessary, alternative solutions should be considered. The second challenge relates to the currently still relatively high costs of the offshore wind technology, which are increasingly being criticized. We argue that this debate would benefit from a more dynamic perspective that accounts for cost reductions stimulated by technological innovation. We suggest several routes that may potentially enhance long-term cost reductions. The credibility of the German offshore wind policy mix should not be prematurely put at risk, as happened through the discussions on the ‘electricity price brake’. Efforts should now be targeted at regaining trust and confirming the commitment of the German government to offshore wind. Also, the implicit cost-reduction objective could be made more explicit in the offshore wind policy strategy to provide clear guidance for companies’ innovation strategies. Finally, policy makers could also consider a more systemic policy style, so as to allow for the anticipation of required policy actions, thereby ensuring continued policy mix consistency. The resulting proactive adjustments of the policy mix could contribute to speeding up the rate of innovation and thus the materialization of cost reductions.

While our study focuses on offshore wind, our results go beyond this research case in at least two respects. On the one hand, the findings might be transferable to other emerging renewable energy technologies and potentially also other green technologies. This is because such emerging technologies have comparable characteristics such as lack of cost-competitiveness and initial high technological uncertainties (IEA, 2011b). In addition, all these technologies are confronted with multiple market, system and institutional failures (Weber & Rohracher, 2012) and as niche technologies embedded in established regimes may need an initial phase of shielding, nurturing and empowering in protective spaces (Smith and Raven, 2012). On the other hand, our research with its focus on the impact of the policy mix on technological change may contribute to a better understanding of the role of the policy mix for the envisaged energy transition, thereby supplementing studies focusing on other fundamental material, organizational, and socio-cultural changes (Markard et al., 2012).

By providing the first empirical application of the policy mix concept proposed by Rogge and Reichardt (2015), this study makes three key contributions. First, it allows for a deeper understanding of the link between the policy mix and corporate innovation activities for an exemplary emerging renewable energy technology. Second, it provides insights into innovation effects not only of policy mix elements but also of their characteristics, including their consistency and thus their interplay.

[9] An important caveat, which is however outside the scope of this paper, is the general decision about which renewable energy technologies are most suited to accomplishing the energy transition (Midttun, 2012), considering for example technology and geographical potentials and costs (Agora Energiewende, 2013).

[10] Meanwhile, this issue has been addressed by policy makers, i.e., the new grand coalition in their coalition agreement foresees an extension of the EEG compression model by two additional years.

Third, it derives more substantiated policy recommendations grounded in a better understanding of firms' strategies, which might ultimately contribute to an accelerated energy transition.

However, it is not free from limitations and thus calls for further research. First, future studies should extend our focus on corporate actors by assuming a more systemic perspective that analyzes the interplay between the policy mix and the technological innovation system, thereby also incorporating perceptions of other actors such as policy makers. Second, future policy mix research should continue to unpack the role of policy mix characteristics and also of policy mix processes for innovation, and in doing so account for the underlying politics. Finally, the effect of the policy mix on innovation in other technologies, sectors and countries should be analyzed and compared.

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Appendix A.

• *Overview of the German offshore wind market: (1) turbine developers and (2) farm owners sorted by German capacity (sum of installed and in pipeline).*

(1) Turbine developers active in the German offshore wind (OW) market.

Firm	Capacity as of December 2012 (MW)				OW turbine types (in MW)	Year of first OW turbine/ prototype	Year of market exit	Markets	Headquarters
	Germany		Worldwide						
	Installed	Pipeline	Installed	Pipeline					
Siemens Wind	48	3296	3014	6729	2.3, 3.6, 4, 6	1991	–	UK, DK, NO, DE, SE, FI, NL, CN, US, CA	Europe: Brande, DK International: Hamburg, DE
Areva Wind	30	1810	30	1810	5	2004	–	DE	Bremerhaven, DE
REpower	30	1218	405	1341	5, 6	2004	–	DE, BE, UK	Hamburg, DE
BARD	305	500	305	775	5, 6.5	2007	–	DE, NL	Bremen, DE
Enercon	4.5	0	4.5	0	4.5	2002	2004	DE	Aurich, DE
Nordex	2.5	0	4.8	0	2.3, 2.5	2003	2012	DE, DK	Hamburg, DE

(2) Offshore wind farm owners in Germany.

Firm	Firm type	Capacity as of December 2012 [MW]*				Year of first OW turbine (worldwide)	Markets	Headquarters
		Germany		Worldwide				
		Installed	Pipeline	Installed	Pipeline			
DONG Energy	Utility	0	1610	1300	4873	1991	UK, DK, DE, NL	Fredericia, DK
EnBW	Utility	48	1180	48	1180	2011	DE	Karlsruhe, DE
E.ON Climate & Renewables	Utility	60	1168	511	2391	2001	UK, DK, DE, SE	Duesseldorf, DE
BARD Holding GmbH	Technology provider and farm operator	305	500	305	500	2008	DE	Emden, DE
SWM	Utility	0	688	0	1264	2006	DE, UK	Munich, DE
Vattenfall	Utility	60	576	1018	1945	2007	UK, DK, SE, NL, DE	Stockholm, SE
RWE Innogy	Utility	0	627	869	1609	2003	UK, BE, DE, NL	Essen, DE
Blackstone Group	Financial services	0	608–672	0	608–672	–	DE	New York, US
Axpo International S.A.	Utility	0	400	0	400	2013	DE	Baden, CH
HSE AG	Utility	0	400	0	400	2012	DE	Darmstadt, DE
Iberdrola Renovables	Utility	0	400	0	400	–	DE	Bilbao, ES
Ocean Breeze Energy GmbH & Co. KG.	Power generator	0	400	0	400	–	DE	Munich, DE
Trianel	Utility & consulting	0	400	0	400	2004	DE	Aachen, DE
Windreich	Project developer	0	400	0	400	2013	DE	Wolfschlugen, DE
Erste Nordsee-Offshore-Holding	Holding	0	395–553	0	395–553	–	DE	Pressbaum, AT
Windland Energie-erzeugungs GmbH	Project developer	0	288	0	288	2013	DE	Berlin, DE
wpd offshore solutions	Project developer	0	288	0	918–953	–	FI, DE, SE	Bremen, DE
Kirkbi A/S	Holding and investment	0	277	0	277	–	DE	Billund, DK
EWE AG	Utility & telecommunication	65	108	65	108	2004	DE	Oldenburg, DE
Energiekontor AG	Project developer	0	111	0	111	–	DE	Bremen, DE

Sources: own compilation based on 4C Global Offshore Wind Farms Database, Fraunhofer (2012), firm web pages, further online sources.

Note:

- Depicted are firms that are active in the German market, i.e., that have sold turbines or operate farms there (Appendix A1).
- Due to their low ownership shares (below 20%) in offshore wind farms, ten further firms are not depicted in Appendix A2.

Legend:

*Double counting: depicted are the overall capacities of offshore wind farms a firm owns or has shares in, not the capacities a firm holds according to its shares.

Appendix B.

• *Typical interview guide as used in the company interviews on offshore wind.*

Category	Exemplary questions
Innovation activities	What are your innovation activities in the area of offshore wind? How do offshore wind innovations in your company typically come about?
Innovation effects of the policy mix	What role does the political framework play in your specific offshore wind innovation activities? (e.g., role of policy strategy, instruments, characteristics)
Innovation effects of the policy strategy and first-level consistency	What is the role of • specific political target-setting (that is, renewables, climate, offshore wind targets) • political framework concepts for your innovation activities? How consistent do you find the • targets • framework concepts? What effect does each have on your innovation activities? How consistent do you think the discussed targets are with the framework concepts? What influences the effect on your innovation activities of the positive/negative interaction of the discussed targets with the discussed framework concepts? How credible do you find the targets? What role does their credibility play in your innovation activities?
Innovation effects of the instrument mix and second-level consistency	Which policy instruments influence your innovation activities and in what way? How well do the discussed instruments go together? How does this interplay influence your innovation activities?
Innovation effects of third-level consistency	How well do the discussed instruments fit with the discussed targets (contradictions, gaps, synergies) ? What consequences does this have for your innovation activities?
Innovation effects of context factors	Apart from the discussed policy framework, are there other reasons why you are active in offshore wind (e.g., characteristics of the technology, market-related factors, social acceptance) ? How important are these reasons relative to the policy mix?
Innovation effects of firm characteristics	When you compare yourself with your competitors, how do you distinguish your innovation activities from those of your competitors? What do you think is the influence of your firm's size on your innovation activities? How does it affect your innovation activities that you have a number of technologies in your portfolio/ that you are only active in offshore wind?

Note: the questionnaire is a general one, which was tailored to the specific circumstances of a company, such as its value chain position (power generators vs. technology providers) and its offshore wind projects (firm-specific RD&D and adoption activities).

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