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How the policy mix and its consistency impact 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 renewable power generation technologies 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 the elements of a policy mix – its policy strategy and instrument mix – and their consistency. Taking offshore wind in Germany as research case, we find that the German offshore wind policy mix, its consistency and perceived high credibility have been vital innovation drivers. Specifically, its consistent policy strategy and the consistency of the policy strategy with the instrument mix appear crucial to research, development and demonstration. Still, for this emerging technology to be adopted the policy mix seems to require a consistent and comprehensive instrument mix.

Keywords: policy mix, policy strategy, instrument mix, consistency, innovation, offshore wind

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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 towards 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).

Yet, 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). Studies following such a rather narrow policy scope can be differentiated into those analyzing the innovation impact of the instrument type and of instruments' design features. Regarding instrument type, studies have analyzed the innovation impact of various types of policy instruments (Rennings et al., 2008). A recent example is Hoppmann et al. (2013), which studies the effects of deployment policies on innovation in the solar PV industry, concluding that this instrument type serves as an important catalyst, particularly for investments in technology exploitation and, to a lesser degree, for investments in exploration. Regarding design features, a recent study by del Rio (2012) finds that several design features of feed-in tariffs, e.g. the level and long duration of support, can have a significant – mostly positive – impact on innovation. Another typical example of the role of design features finds a positive effect of the flexibility of environmental policy on innovation (Hascic et al. 2009).

More systemic studies analyze the impact of policies on the performance of technological innovation systems (TIS) for selected renewable energy technologies (Foxon et al., 2005). However, the depth of policy considerations varies across studies, with many studies remaining at a rather general level (Bergek et al., 2008; Klein Woolthuis et al., 2005). A recent example of a more detailed consideration of policies and their impact on TIS is Kivimaa and Virkamaki (2013) who study the effects of different policy instruments on TIS functions, thereby detecting policy gaps and related system weaknesses. Similarly, McDowell et al. (2013) focus on how policies have influenced innovation system weaknesses, drawing lessons for low-carbon policy making, such as the recommendation that policies go beyond instrument types to consider a broader institutional setting. Yet, all of these studies and their policy recommendations consider several single policy instruments rather than a comprehensive policy mix.

However, in the broader climate and energy policy as well as innovation policy literature there is increasing attention on the importance of analyzing policy mixes. 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 such policy mix conceptions lies particularly in their consideration of aspects going beyond single policy instruments, namely the interactions of instruments (Boekholt, 2010; del Río, 2012), policy processes (Flanagan et al., 2011) and overarching characteristics such as consistency, credibility and stability (Rogge and Reichardt, 2013). In an effort to overcome the heterogeneity of typically rather narrow policy mix definitions applied in existing studies, Rogge and Reichardt (2013) propose a more comprehensive policy mix concept consisting of the three building blocks elements, processes and dimensions (see section 2).

However, until now there have been no empirical analyses of policies’ innovation effects that use a more comprehensive policy mix concept. In this paper we take a first step in this direction by analyzing how the elements of a policy mix, i.e. the policy strategy and instrument mix, and their consistency as a central policy mix characteristic impact corporate adoption and research, development and demonstration (RD&D) activities regarding emerging renewable energy technologies. For this purpose we apply the policy mix concept proposed by Rogge and Reichardt (2013) to study the link between policy and innovation, while we also consider the innovation impact of other firm-external and firm-internal factors. By incorporating the interplay and fit of key elements of the policy mix – and thus their consistency – our analysis sheds new light on the existing literature on the innovation impact of single policy instruments.

To explore the research question, we take the case of offshore wind in Germany and apply a qualitative case study approach, conducting interviews with several firms active in the German offshore wind market. We choose this case for two main reasons: First, the policy mix for offshore wind in Germany represents a rich empirical case in which all elements of the policy mix – including 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.

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, which is discussed in section 6. Finally, in section 7 we derive implications for policy makers and identify future research needs.

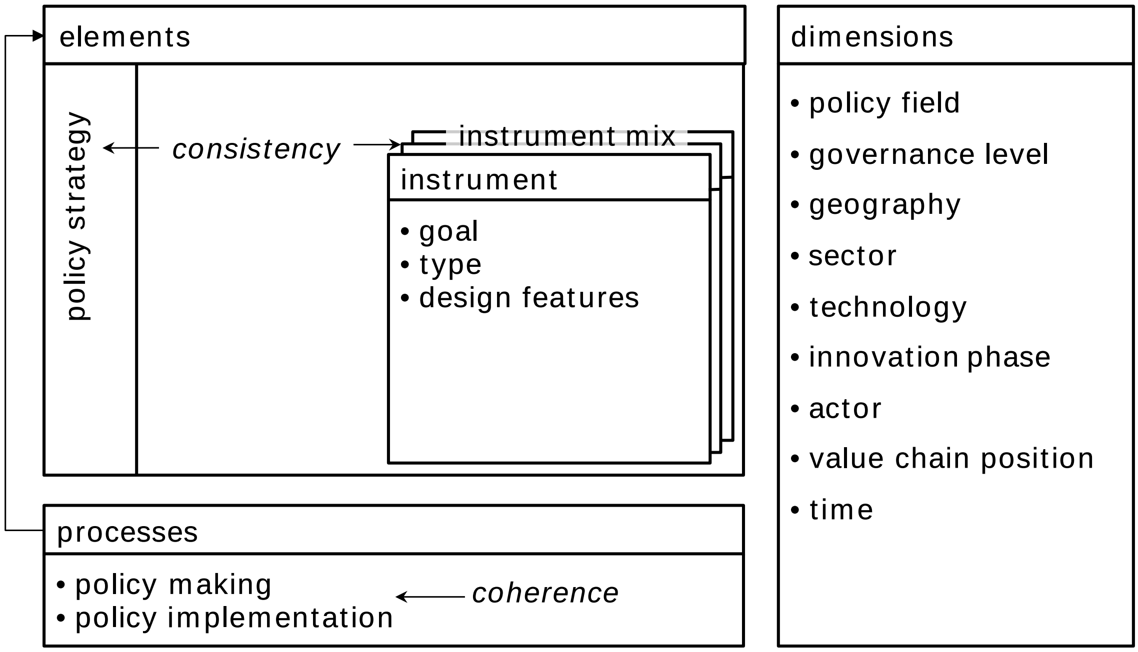
2 Research framework

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; Horbach et al., 2012). For instance, environmental policy and its stringency have been shown to be highly influential for innovation (Frondel et al., 2008; Taylor et al., 2005). Also, several other firm-external and firm-internal factors have been included in such analyses, with varying effects and importance for innovation. For instance, Griffiths and Webster (2010) find that firm-internal factors explain more corporate innovation activities (RD&D) than firm-external factors. Somewhat in contrast, 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. However, all of these studies conclude that it is a variety of factors that drive environmental innovation. Therefore, in this study we focus on the link between the policy mix and innovation, but we also account for other firm-external and firm-internal innovation determinants (Horbach et al., 2012; Rehfeld et al., 2007), namely context factors and firm characteristics.

In contrast to earlier studies, our policy variable does not consist of single policy instruments (Rogge et al., 2011) or instrument types only (Nemet 2009), but of the policy mix and its characteristics. The underlying policy mix concept (see Figure 1) has been designed as a tool for more comprehensive policy analyses. The concept comprises elements, processes and dimensions as well as overarching characteristics (Rogge and Reichardt, 2013). Elements include the policy strategy, with overarching policy objectives and principal plans as well as the instrument mix with interacting policy instruments characterized by their goals, types and design features. Policy processes comprise policy making and implementation, thereby determining the elements of the policy mix. Dimensions reflect the complex and dynamic nature of policy mixes and can serve to specify elements, processes and characteristics and thus the scope of a policy mix. Finally, characteristics are important determinants of the performance of policy mixes. They include consistency of the elements, coherence of policy processes as well as credibility, which captures the extent to which the policy mix is believable and reliable. Further characteristics are stability, which describes the long-term certainty of the policy mix, and comprehensiveness, which addresses how extensive and exhaustive the policy mix elements and processes are.

Since our study applies this concept empirically for the first time, it represents a groundbreaking effort towards its operationalization. However, given its novelty we focus only on the elements and their consistency as key constituents of the policy mix concept, thereby taking an important first step. Consistency captures the state of the policy mix with regard to the absence of contradictions or the degree of synergies within and between its elements, i.e. the policy strategy and the instrument mix. 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.

Figure 1: The policy mix concept (Rogge and Reichardt (2013))



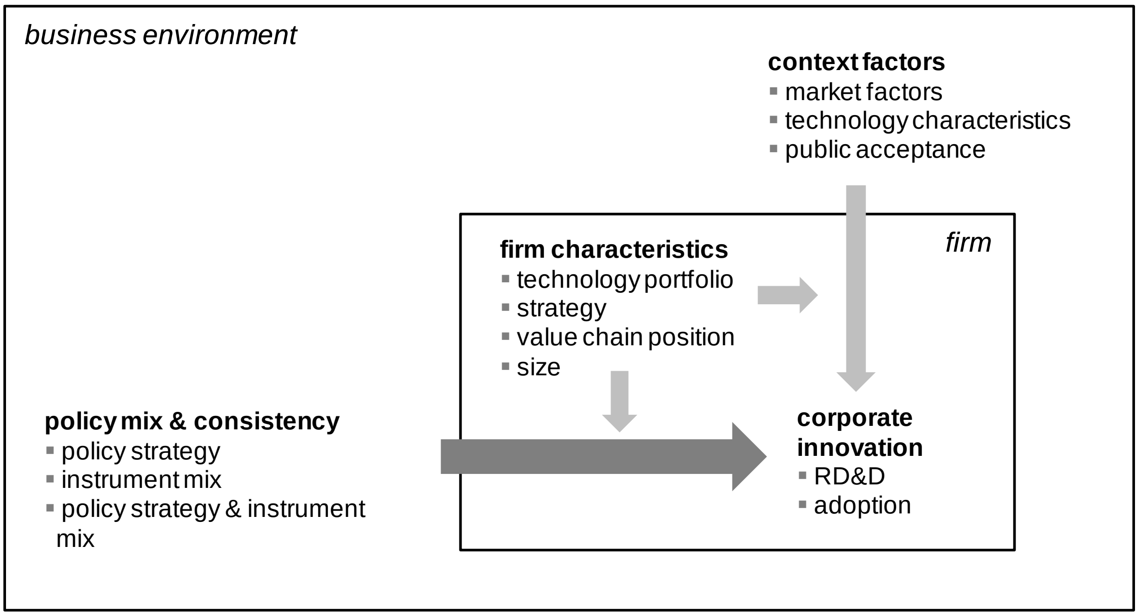
We are interested in studying how these policy mix elements and their consistency impact corporate innovation activities. Based on the Oslo Manual (OECD, 2005) and in line with Rogge et al. (2011), we define these as consisting of adoption as well as research, development and demonstration (RD&D). That 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.

Besides our main focus on the link between the policy mix and innovation (as indicated by the dark, thick arrow in Figure 2), we include context factors and firm characteristics in our research framework. 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).

Figure 2 summarizes our research framework, showing the main link between the policy mix – its elements and their consistency – and corporate innovation.

Figure 2: Research framework for studying the role of policy mix elements and their consistency 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).

3.1 The offshore wind technology

Offshore wind is a technology with large potential. Higher and steadier energy yields offshore, i.e. up to 4,000 full load hours per year compared to 2,000-2,500 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)[1]. However, the technology is also confronted with difficulties. One 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 1), offshore wind is still rather immature (EWEA, 2011). Relatedly, offshore wind costs are still 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 1). The offshore wind cost structure is more evenly spread across the supply chain than onshore costs (see Table 2), 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).

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

Table 1: 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 (2011), Fichtner & Prognos (2013), Roland Berger (2013)

Table 2: Investment cost structure of offshore wind

Component	Costs (1,000 €/ MW)	Share in total investment costs
Turbine	1,201	29%
Foundation	1,028	25%
Cable	90	2%
Substation	235	6%
Installation	684	16%
Certification/ authorization	387	9%
Reserve	544	13%
Investment costs	4,169	100%

Source: Fichtner & Prognos (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 IWES, 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. In the following, we highlight the most important features of the policy mix elements for offshore wind (see also Table 3).

Probably the most relevant component of the policy strategy is the German long-term target for offshore wind, 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 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), which regulates grid access for offshore wind farms. The KfW Offshore Wind Program, which grants loans at market conditions for early offshore wind farms, and several RD&D support programs supplement the instrument mix.

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

			EU	DE
POLICY STRATEGY	**Objectives**	**Offshore wind**	No technology-specific target[2]	By 2020: 10 GW capacity By 2030: 25 GW capacity
		Renewables	20% renewables in energy consumption by 2020	18% renewables in energy consumption by 2020
			Renewables Directive (DIR 2009/28/EC)	
		Climate	20% GHG emissions reduction by 2020*	30-40% GHG emissions reduction by 2020*
	Principal plans		Energy Roadmap 2050	Energy Concept
			Strategic Energy Technology (SET) Plan	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)	RD&D support programs
			European Energy Program for Recovery (EEPR)	
	Systemic			Energy Economy Law (EnWG)

* compared to 1990 levels

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

The EEG 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.

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)

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.

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 is particularly suited to examining how and why the policy mix impacts firms' innovation activities and has already been applied by similar studies (Hoffmann, 2007; Hoppmann et al., 2013). In line with these studies our focus is on companies since they tend to be key players for innovation and addressees of many elements of the policy mix.

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 (2013) has not been empirically applied before we then conducted exploratory interviews in order to gauge how to best operationalize the concept's key variables. For this purpose we interviewed ten experts of companies involved in offshore wind in Germany between August and October 2011. Based on these interviews with power generators and technology providers, we developed a semi-structured interview guide building on our research framework (see Appendix B).

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. As a third step we conducted telephone 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 minutes 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. All interviews were recorded and subsequently transcribed.

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 reflecting our research framework. 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. Third, based on this coding we analyzed the role of the different policy mix elements and 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, thereby looking for common patterns and reasons for differences among firms, such as a firm's size or technology portfolio. We proceeded in the same manner for technology providers. Finally, we contrasted our findings for power generators with those for technology providers, searching for commonalities and differences between these two groups. Our ultimate goal was the derivation of 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 the main corporate innovation activities regarding offshore wind in terms of adoption (section 5.1) and RD&D (section 5.2) and how these were influenced by the policy mix. We also point to the influence of the most important context factors and firm characteristics at the end of each subsection. We provide a summary table with the main findings and supporting illustrative quotes from the interviews in both subsections (Table 6 and Table 7).

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) However, most recently, since around 2012, power generators have put their final investment decisions for new farms in Germany on hold, sometimes even shifting their activities to other markets, with immediate negative implications for sales and thus manufacturing of offshore wind turbines by technology providers: *"We will now […] finish production according to the contract and then stop for a while"* (TP)

Our interviews suggest that the policy mix elements and its characteristics, particularly the instrument mix and its comprehensiveness and consistency, played a crucial role for these adoption activities. Regarding the instrument mix, both power generators and technology providers clearly perceive the EEG with its feed-in tariff for each kWh electricity fed into the grid as the most important 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 crucial 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) were 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 is 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 is an important instrument for project-financed farms, as explained by one technology provider: *“Startup financing is naturally extremely important for project-financed farms.”*

Regarding instrument mix characteristics, we find that despite the crucial role of the feed-in tariff comprehensiveness of the instrument mix, i.e. the existence of these other instruments, has probably been a prerequisite for adoption, since only together do they appear to be able to overcome the most important market and system failures and any other bottlenecks. The importance 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“* Yet, even more importantly, these instruments’ fit, i.e. their second-level consistency, appears to have been a prerequisite for adoption, as evidenced by the detrimental effect of instrument mix inconsistencies that became apparent in 2012 (see {3} in Table 6).

In fact, since around 2012, second-level inconsistency in the form of negative interactions between the EEG and the EnWG has produced negative repercussions for offshore wind adoption activities (see {4} in Table 6). This can be traced back to the ineffectiveness of the EnWG regulation in addressing the bottleneck of grid access, thereby also rendering the current EEG with its compression model ineffective, and thus impeding further adoption, 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 will continue to face grid access delays, since this new regulation takes some time to become effective. Some offshore wind investors are thus likely to miss the temporally limited validity of the feed-in tariff compression model, which is running out in 2017, as this power generator illustrates: *“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.”* It is exactly this compression model which several of today’s investors seem to require for making investment decisions for new farms. The detrimental effect of this second-level inconsistency between the EEG and EnWG is stated by this power generator: *“Building decisions we already made in the past—we are implementing those. For new building decisions […] at present we have no framework that allows us to decide on new investments in construction.”* Of course, this also results in lower sales of technology providers‘ turbines in the German market (see section 5.2). Adding to this inconsistency and thus further impeding adoption is the decreased credibility of the offshore wind policy mix caused by the debate on the so-called ‘electricity price brake’ (‘Strompreisbremse’) in Germany (see section 6).

These findings lead us to the following proposition: A more consistent and comprehensive instrument mix including a predictable demand pull instrument with a sufficiently high level of support is more likely to lead to greater levels of adoption of emerging renewable energy technologies.

Table 6: Key findings and *illustrative quotes* regarding adoption of off-shore wind

Findings on how the policy mix affects adoption of offshore wind	***Exemplary quotes***
{1} Feed-in law with its feed-in tariff is 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)* *"The EEG embedded in an appropriate policy framework is decisive."*
{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)*
{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)*

While the instrument mix and its characteristics appear crucial for adoption, power generators further report that the policy strategy also plays a role in their adoption activities. We find that they perceive the German long-term targets for offshore wind and renewables as consistent, credible, stable over time and ambitious, and that these policy strategy characteristics additionally reinforce their adoption activities. This is captured by one power generator: *“[The long-term targets for offshore wind and renewables] naturally motivate the decision behind every project.”*

The observed adoption activities are 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) are all important 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 are often active in other countries, and smaller and locally rooted power generators as well as smaller technology providers seem to focus on Germany as the home market. A further driver for adoption is 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 are 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 focus on optimizing the construction and operation of their offshore wind farms, and in so doing they aim 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 also jointly pursue RD&D. The most prominent example is the cooperation of early entrants in the German test farm alpha ventus, in which three power generators are testing twelve 5 MW turbines supplied by two technology providers.

Our interviews indicate that a consistent policy strategy and its actual or expected consistency with the instrument mix has been a key driver for corporate RD&D in offshore wind. First, a consistent and credible policy strategy that is stable and includes an ambitious offshore wind target is one factor stimulating both firm types' RD&D (see {1} in Table 7). In particular, the ambitiousness of the offshore wind target is interpreted as a sign of a growing market, as stated by this 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 influence 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."* Second, however, technology providers also stressed that the offshore wind long-term target alone is not sufficient but needs to be operationalized in a consistent manner, most importantly through a demand pull instrument such as the German feed-in tariff with a sufficiently high level of support {see 2 in Table 7}: *"but without such an impulse from the EEG [...] this [that the installations would improve, run more] would not be possible." (TP)* Third, other instruments in the mix have an impact on RD&D activities as well, most prominently technology push instruments such as financial RD&D support (see {3} in Table 7). It appears to have been especially important for technology providers in early phases of technology development and currently seems 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."*

At the time of our interviews, however, the negative interaction between the EnWG and the EEG causes a decline in technology providers' sales, which is perceived as a barrier to RD&D (see {4} 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)* Adding to this are the political discussions about the electricity price brake (see section 6.2), which are expected to lead to further drops in sales. Nevertheless, apart from these negative RD&D effects because of second-level inconsistencies of the instrument mix, technology providers still perceive the overarching policy mix as credible and thus continue at least some RD&D activities.

These aspects lead us to the following proposition: A more credible and ambitious policy strategy consistently operationalized by an instrument mix with a predictable demand-pull component of a sufficiently high level of support is more likely to lead to greater levels of RD&D for emerging renewable energy technologies.

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} Technology push instruments positively influence RD&D.	*"When there's RD&D financing, and there is […], these are naturally catalysts to accelerate a bit. Sometimes even to make possible in the first place." (TP)* *"[Our firm] profits from it and is able to put projects a bit more widely into operation, going a bit more in depth." (TP)*
{4} 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)*

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 is the excellent market prospects for offshore wind, which are, however, mainly brought about by the policy mix. In this, the high demand for the offshore wind technology seems to have a positive influence on the level and direction of RD&D activities. Furthermore, the immaturity of the technology is a strong innovation driver for both TPs and PGs. For German firms, this includes 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 drive 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 are 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 benefit TPs' offshore wind RD&D activities.

6 Extended analysis and discussion

Our findings illustrate the vital role of the policy mix elements and their consistency for adoption and RD&D for offshore wind in Germany. Yet, we also found other policy mix characteristics and policy processes to be highly relevant for offshore wind innovation activities. In this section we broaden our analysis in two ways, by reflecting on the relative importance of consistency and other policy mix characteristics and their interplay (section 6.1), and by discussing the impact of policy processes as essential building-blocks in the policy mix for corporate innovation activities.

6.1 Role of policy mix characteristics

Assuming a more comprehensive policy mix concept covering the characteristic of consistency in addition to the policy mix elements enables us to shed some light on its relevance for corporate innovation activities. As suggested by our results, policy mix consistency plays a key role in initiating and intensifying offshore wind innovation activities, albeit with varying importance of the three consistency levels for RD&D and adoption.

The consistency of the policy strategy and its fit with the instrument mix appear particularly relevant for RD&D activities. This result complements existing research that finds a positive effect of long-term targets on RD&D (Schmidt et al., 2012). One reason for this RD&D effect of consistency might be the resulting market expectations: These first-level and third-level consistencies were interpreted as indicating strong political will to support the development of a market around offshore wind and drove firms to invest in the technology. Consequently, it may enable a redirecting of technological change towards offshore wind as emerging renewable energy technology and could thus be important for achieving overarching energy transition objectives.

The consistency of the instrument mix seems to be particularly relevant for adoption. That is, second-level consistency can contribute to the speed with which the set long-term targets and ultimately the energy transition can be accomplished, thus potentially impacting the rate of technological change. This broadens existing findings of a positive effect of policy instruments on the rate of adoption (Schmidt et al., 2012). An illustration of this is the inconsistencies between the EnWG and the EEG, which currently decelerate adoption since power generators do not invest in new offshore farm projects. This also has negative implications for the development or significant improvement of new products, partly since less learning by doing takes place.

However, despite its importance we find that other policy mix characteristics besides consistency, such as credibility and comprehensiveness, also play vital roles for stimulating innovation activities. In fact, we find that credibility has an especially significant role, which mirrors economic research on government credibility (Gilardi, 2002) and management research suggesting the crucial relevance of corporate credibility for a firm's success (Newell and Goldsmith, 2001).Three points are particularly notable in this regard. First, credibility appears to be key for innovation by itself, i.e. if power generators and technology providers perceive a credible political will in favor of offshore wind, they are very likely to start innovating, 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."*

Second, we find signs of compensation between credibility and other policy mix characteristics, most strikingly comprehensiveness and consistency. Actors innovate despite the policy mix's lack of comprehensiveness or consistency because they trust policy makers' commitment to solve problems. An example of compensating for the lack of comprehensiveness is the perceived high level of credibility that helped stimulate offshore wind innovation 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."* The link between credibility and consistency can be exemplified by the current inconsistencies between the EnWG and EEG (see section 5): Although there are at present no new investment decisions in farms, actors continue some innovation activities, such as RD&D to advance the technology, because of their belief that these inconsistencies will be resolved*: "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)

Third, our analysis suggests multiple routes by which credibility may be built up or, conversely, destroyed. Perhaps the most straightforward determinant of credibility is the high stability of the German offshore wind target, having been repeatedly confirmed since its introduction in 2002. This is comparable to research arguing that the expectation of an ambitious technology development path appears more credible if a future technology performance target is in place (Bakker et al., 2012). Credibility might be further strengthened by the perceived consistency of the policy strategy, i.e. between offshore wind, renewable energy and long-term climate targets, and the characteristics of the instrument mix including the design features of the EEG. In particular, a more comprehensive instrument mix seems to provide added credibility since new or adjusted instruments, such as a higher feed-in tariff level, are interpreted as a political commitment towards offshore wind. Finally, the generally coherent policy processes for offshore wind in Germany also seem to reinforce credibility. One aspect of this is the perceived cooperative policy-making style, while another aspect concerns the constructive collaboration between firms and authorities in policy implementation.

6.2 Policy processes

While our results illustrate the significance of the policy mix elements and characteristics for fostering innovation activities in offshore wind, we also find an important role for the processes of policy making and implementation, which is in line with former research on the significance of policy processes (e.g. Majone, 1976; Sabatier and Mazmanian, 1981). Turning first to policy implementation, we find that it affected both RD&D and adoption mainly through its administrative requirements and permitting procedures, which were perceived as rather strict compared to other countries. Our findings suggest that policy implementation might have contributed to an acceleration of RD&D and to a slight deceleration of adoption. One example of the innovation impact of the regulatory strictness is the noise limit of 160 dB for pile driving of foundations set by German authorities to protect the marine environment. This ordinance, which is similar to a technology-forcing standard, was largely responsible for driving firms to develop techniques that kept them below this limit. This example demonstrates that policy implementation can also influence innovation activities – in this case positively – leading to environmentally friendlier construction of offshore wind farms.

In the area of policy making, we observe two particularly striking effects on innovation. On the one hand, policy making might have reinforced RD&D and adoption: it appeared relatively coherent until early 2013 owing to a cooperative policy style (Jänicke et al., 2000) and adaptive policy making that adjusted the instrument mix when necessary, as stated by this power generator: *"Politicians reacted to this and said we have to do something to ensure it continues. I still see the political will to continue working on the issue."* On the other hand, the recent debate about how to lower soaring electricity costs for consumers, the so-called electricity price brake discussion (Spiegel Online, 2013) has been detrimental to innovation by creating investment uncertainty and decreasing the high credibility of the policy mix for offshore wind in Germany achieved until early 2013. Thus, in addition to the second-level inconsistencies between the EEG and the EnWG, it has impeded adoption and ultimately also RD&D (see section 5.1), as one power generator explains *"[...] given the current conditions [daily discussions about the electricity price break], no finance director would approve an offshore wind farm for 1.5 billion. They would say, we'll wait until things have quieted down again."* These examples underline the importance of policy processes for innovation, despite their frequent neglect in studies of the innovation impact of environmental policy instruments.

7 Conclusion

This study has provided insights into how the policy mix stimulates innovation activities in the emerging technology of offshore wind in Germany. We find that the policy strategy appears particularly central to RD&D investments in offshore wind, although it ultimately needs to be operationalized by effective policy instruments. In contrast, the instrument mix appears especially relevant for concrete adoption activities, with the most important instrument being the feed-in tariff for its sufficient level of support and predictability. Consistency also seems to play a crucial role for offshore wind innovation activities: RD&D appears to be predominantly guided by complementary long-term targets and their operationalization by the instrument mix. In contrast, adoption is apparently most affected by the fit of instruments in the instrument mix, as exemplarily evidenced by the slow down in new adoption in the wake of recent inconsistencies between the EnWG and the EEG. In addition, credibility stands out as a fundamental policy mix characteristic, as investors need to be convinced of the existence of a strong political will supporting the emerging offshore wind technology. Finally, our results indicate that policy processes are another important – often neglected –determinant of innovation activities. Besides the policy mix, context factors including sizable market prospects and the large-scale nature of offshore wind, and firm characteristics such as firms' growth strategies and existing capabilities further explain offshore wind innovation activities.

Based on these findings, we propose some general lessons for other countries aiming to advance offshore wind.[3] First, 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. Second, it may be particularly useful to establish an offshore wind-specific long-term target early on, which should be ambitious, credible, stable and consistent with the overarching climate and renewable energy strategy. Third, 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. Fourth, while anticipation of future bottlenecks and corresponding proactive policy making may be preferable to forestall problems, the nature of offshore wind as an emerging technology may particularly require adaptive policy making to quickly address upcoming problems.

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

3 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).

investment incentives, which also considers these delays.[4] 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 (Fichtner and Prognos, 2013). 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 supplementing the adaptive and cooperative policy style by more systemic policy making, so as to allow for the anticipation of required policy actions. 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 (Rennings, 2000; Weber and 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).

4 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.

By providing the first empirical application of the policy mix concept proposed by Rogge and Reichardt (2013), 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, and of policy processes. 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. By focusing on policy mix elements and their consistency, the paper only touched upon the importance of other policy mix characteristics and policy processes. Future studies should therefore focus on the relative relevance and interplay of different characteristics, such as credibility and their effects on innovation. In addition, they should investigate in greater detail the innovation effects of policy processes and their coherence. Finally, future research should extend our focus on two corporate actors by assuming a more systemic perspective that analyzes the interplay between the policy mix and the technological innovation system.

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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	3,296	3,014	6,729	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	1,810	30	1,810	5	2004	-	DE	Bremerhaven, DE
REpower	30	1,218	405	1,341	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 (world-wide)**	**Markets**	**Headquarters**
		Germany		Worldwide				
		Installed	Pipeline	Installed	Pipeline			
DONG Energy	Utility	0	1,610	1,300	4,873	1991	UK, DK, DE, NL	Fredericia, DK
EnBW	Utility	48	1,180	48	1,180	2011	DE	Karlsruhe, DE
E.ON Climate & Renewables	Utility	60	1,168	511	2,391	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	1,264	2006	DE, UK	Munich, DE

Firm	Firm type	Capacity as of December 2012 [MW] *				Year of first OW turbine (world-wide)	Markets	Headquarters
		Germany		Worldwide				
		Installed	Pipeline	Installed	Pipeline			
Vattenfall	Utility	60	576	1,018	1,945	2007	UK, DK, SE, NL, DE	Stockholm, SE
RWE Innogy	Utility	0	627	869	1,609	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 Ener-gy 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 soluti-ons	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 IWES (2013), 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

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 – open question	What role does the political framework, that is targets AND instruments, play in your specific offshore wind innovation activities?
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?

Notes:

The questionnaire is a general one. In fact, the questions varied between power generators and technology providers as well as between individual firms and interviewees due to their different characteristics and competencies.

We asked for the offshore wind policy mix and offshore wind innovation activities, but for reasons of simplicity, here we only refer to policy mix elements and innovation activities.

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