LEGITIMACY AND GUIDANCE IN UPSCALING ENERGY TECHNOLOGY INNOVATIONS

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Legitimacy and Guidance in Upscaling Energy Technology Innovations

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Legitimacy and Guidance in Upscaling Energy Technology Innovations[1]

ABSTRACT

The paper aims to improve the understanding about the role of expectations and key innovation processes, such as legitimation and guidance, in the upscaling of low-carbon innovations. We analyze roadmaps developed for floating offshore wind energy to investigate how actors prepare for system growth. We focus on how roadmaps contribute to the formation and sharing of expectations through their influence on system acceptability (legitimacy) and attractiveness (guidance), enabling access to crucial resources. The analysis reveals that institutional and technological context affect guidance, namely a higher external openness as technology matures and governments are involved. An actors' survey finds that overpromising reduces roadmaps impact on expectations. Analyses of media coverage and Internet searches show that roadmaps affect public perceptions indirectly, through the promotion of experiments. Implications include new directions for conceptualizing legitimacy, guidance and expectations in technological innovation systems, as well as recommendations for managing key processes in systems' upscaling.

Keywords: legitimation; guidance; expectations; upscaling; roadmaps; offshore wind energy.

Highlights:

- legitimation and guidance are key processes in innovation systems upscaling
- roadmaps influence legitimation and guidance through expectations formation and sharing
- technological maturity and government involvement affect guidance
- unrealistic visions weakens roadmaps' impact on technological dynamics
- expectations need more explicit treatment

[1] This document is a significantly improved version of the working paper "Direction and legitimation in system upscalling – planification of floating offshore wind", DINÂMIA'CET-IUL Working paper n.º 2017/01.

1. INTRODUCTION

Many energy innovations in the past went through a process of intense upscaling before wide dissemination, from cars to airplanes, fossil fuels power plants to wind energy technologies (Smil, 2008). In this process they had to overcome several challenges (technological, regulatory, market, etc.) which have a similar nature than those faced by new technologies such as carbon capture and sequestration or floating offshore wind (Nemet et al., 2018). Upscaling describes the process of increase in size or performance of a technology (Luiten & Blok, 2003). It is a well-known constant characteristic of production (Winter, 2008), routed in the natural development of technological trajectories and paradigms (Nelson & Winter, 1977; Dosi, 1982). Upscaling occurs during a period in the technology life cycle when a radical innovation establishes itself as the dominant design (Frenken & Leydesdorff, 2000). It is typically motivated by the potential of economies of scale to reduce costs (Sahal, 1985; Luiten & Blok, 2003; Wilson, 2012). Non-economic factors like social acceptance are also important to mobilize the resources needed in a context of high uncertainties about both the technology and market (Bergek et al., 2008a; Kemp et al., 1998).

The creation of legitimacy (legitimation) and of guidance are important processes for accelerating energy innovations. Legitimacy has been associated in organization studies with social acceptance and conformity with current norms and values (Johnson et al., 2006; Zelditch, 2001; Suchman, 1995; Aldrich & Fiol, 1994). It has been reported as critical for the access to resources (capital, infrastructure, etc) (Deegan, 2002), and thus is a prerequisite for new systems' upscaling (Bergek et al., 2008b; Hekkert et al., 2007; Markard et al., 2016). Guidance or influence on the direction of search expresses the necessity of directing the resources of the actors (both established and new) into critical activities for technology growth[2], including experimentation of larger technologies, building of supply chains or demand articulation (Markard, 2018; Bergek et al., 2008a). Innovations emerge as a result of collective action in the context of a larger system, which is typically referred to as an "innovation system" (Hekkert et al, 2009; Carlsson & Stankiewicz, 1991). The formulation and sharing of expectations, i.e. real time representations of the future (Bakker et al., 2011), are an important element of this collective process, as they contribute to increase support and to define agendas for action (Borup et al, 2006). Both legitimacy and guidance are central processes in innovation systems development (Hekkert et al., 2007; Markard

[2] The words diffusion, adoption and growth appear interchangeably across the paper to mean the progress of the technology innovation system in terms of number and size of installations, as well as higher density actors' number and relationships.

& Hoffman, 2016) and influence collective expectations. Therefore innovation systems upscaling will entail the formation and change of collective expectations and strategies.

Legitimation and guidance have been object of a growing attention in technological innovation systems, but their content and frontiers are far from clear (Binz et al., 2016; Markard et al., 2016; Bergek et al., 2008b). Several studies assign public opinions and institution preferences to legitimation, and policy action plans and collective strategies to guidance (Miremadi et al., 2018; Borup et al., 2013; Bergek et al., 2008b), but the frontier between the two groups remains difficult to make in practice. On the other hand, the two concepts are often linked through expectations. Bergek et al. (2008b) points to the importance of expectations particularly in the initial stages of innovation systems, but the authors include them in both functions, as well as in the structural element such as the institutional base, when they refer "The shaping of expectations is part and parcel of a bottom-up strategy of system building where packs of entrepreneurs' and others work to improve legitimacy, influence the direction of search of other firms, shape institutions and form markets" (p.588). Therefore, the distinction between legitimacy and guidance remains unclear at the conceptual level, let alone for the analyst in the practice.

This paper aims to answer the question: How legitimacy, guidance and experimentation accelerate the diffusion of emerging innovation systems? We address this question by analyzing directive documents such as roadmaps as reference analytical instruments. Roadmaps are increasingly used to address the requirements of growing systems (McDowall et al, 2012; Rip, 2012). They can give a glimpse into the evolution of innovation processes such as legitimation and guidance (Borup et al., 2013). As empirical setting, we study the development of offshore wind in deepwaters, which is an emerging energy technology that could unlock huge amounts of low-carbon electricity but arguably needs to upscale to reach that potential (Rodrigues et al., 2015).

A growing literature examines the challenges associated with the development of an innovation system around offshore wind energy (e.g. Jacobsson & Karltorp, 2013; Wieczorek et al., 2013, 2015; Sovacool & Enevoldsen 2015; Andersen et al., 2018;; Normann & Hanson, 2018; Makitie et al., 2018; Makitie, 2020). However, these works focus on offshore wind in general, rather than on floating offshore wind which is less mature than in the near shore. Also, the previous works still do not address the determinants of the upscaling of an innovation system around this technology.

The analysis contributes to consolidate the definitions of legitimation, guidance and expectations and to better operationalize these two processes. Roadmaps may support the performance of these crucial innovation processes (Borup et al., 2013; Bergek et al., 2008a,b; Hekkert et al., 2007), and by this way to accelerate system upscaling. We hypothesize that this effect depends on the extent to which the two processes impact on expectations. This can be contingent on factors such as the reliability of the strategy, the participatory character of the roadmapping and the involvement of different types of stakeholders (investors, governments, users, etc.).

The remainder of the paper is structured as follows: Section 2 reviews key innovation processes in systems' upscaling. Section 3 explains the methodological approach followed to operationalize these processes. Section 4 presents the results of the analysis, including the roadmaps content analysis, the actors' survey and the trends in media coverage and Internet. The last section discusses the findings and their implications for theory and policy.

2. SYSTEM DYNAMICS, LEGITIMATION AND GUIDANCE

2.1. Upscaling technological innovation systems

In the early phases of innovation, new technologies suffer from the 'liability of newness' (Freeman et al., 1983): they are perceived as strange or unfamiliar and the opportunities for their development are still unclear. The problem is more than technological as innovations like new energy technologies often require the establishment a new set of practices and institutions to penetrate the market. The nature of these systemic challenges has been researched by technological innovation systems (TIS) studies (Markard et al, 2012, Berkek et al., 2015).

According to the TIS perspective, the successful development of a new industry relies on the capacity to establish a supportive innovation system around the new technology (Markard et al., 2012; Carlsson & Stankiewicz, 1991). In particular, it involves the establishment of structural components (technology, networks and institutions, cf. Jacobsson & Bergek, 2004) and the performance of key innovative processes or "functions" (Hekkert et al, 2007; Bergek et al, 2008a,b; Jacobsson & Bergek, 2011; Markard et al, 2012). The constituent elements are gradually built in the early years against a context of deep uncertainty about the future of the technology and the market. Over time, the focus eventually changes to enlarging both the technology and the industry as the system evolves into a more advanced stage (Bergek, 2008a).

Two processes are particularly critical in the transition to growth (Suurs et al, 2009; Hekkert & Negro, 2009; Markard et al, 2016): legitimacy and influence on the direction of search. These two system-building processes co-evolve with other system functions to accelerate energy technology innovations. For example, a typical starter of virtuous cycles is the guidance of search that is provided by leading actors such as governments. They can trigger the mobilization of resources to support entrepreneurial experimentations or knowledge development (Surana & Anadon, 2016) that in turn promotes legitimacy which further increases resource mobilization (Hekkert et al., 2007). Binz et al. (2016) shows that legitimacy and direction of the search strongly interacted between each other and with resource mobilization, entrepreneurial experimentation and market formation, in the diffusion of potable water reuse in California. These interaction effects are analyzed in more detail in subsection 2.4.

2.2. Legitimation

Legitimacy refers to the degree of acceptance by the society and of conformity with the current institutions (Johnson et al., 2006; Zelditch, 2001; Suchman, 1995). It is a process of collective acceptance of the social object, comprising a cognitive dimension about beliefs and values, and a normative dimension on what the object should be (Suchman, 1995). In these terms, legitimacy results from a socio-political process through which expectations are formed and shaped in favor of a technology (Aldrich & Fiol, 1994). Indeed, legitimacy has a prescriptive component as remembered by Zelditch (2001).

The conformity with societal expectations is also fundamental for innovation systems to ensure the access to social resources (Deegan, 2002). In the context of technological innovation systems, legitimacy has been recognized as a prerequisite for the mobilization of critical resources like personnel, capital and infrastructures (Bergek et al., 2008b; Hekkert et al., 2007). It involves a growing acceptance by the relevant stakeholders (e.g. capital goods suppliers, investors and buyers), as well as the establishment of stronger links between the system and its context (Bergek et al, 2008a; Markard et al, 2016; Markard & Hoffman, 2016). Therefore legitimacy strengthens expectations and improves the social desirability of the emerging system (Negro et al., 2007; Bergek et al., 2008b).

The creation of legitimacy (or legitimation) is a process often steered by the stakeholders. Aldrich & Fiol (1994) posits that entrepreneurs construct legitimacy gradually by building trust, reliability, reputation, and institutionalization. Rao (1994) demonstrates how important were the victories in reliability and speed contests for the survival of the early automakers in the US. In the same vein, Johnson et al. (2006) suggests that new objects gain legitimacy through a process that goes from local to general validation. To be successful, the process of legitimation must evolve and be sustained over time, as pointed by Aldrich and Fiol (1994): “a single venture's uniqueness during initial stages of an industry's development must be counterbalanced with the collective efforts of all players in the emerging industry to portray the new activity as familiar and trustworthy, if they are to survive as a group" (Aldrich & Fiol, 1994, p.664). The literature has highlighted several processes that actors use to increase legitimacy such as lobbying, coalition formation, negotiation and debate framing (Aldrich & Fiol, 1994; Geels & Verhees, 2011; Bork & Schoormans, 2015; Binz et al., 2016; Makard et al., 2016). For example, Geels & Verhees (2011) remember how decisive was the creation of positive meanings around nuclear energy to influence investments and external support in the Netherlands in the early years, in order to emphasize that legitimacy needs to be maintained in the later stages of maturity of the system.

The legitimation process is subject to the interest of actors and their agency. In particular, it can be influenced by dominant actors seeking legitimacy in the three dimensions identified by Suchman (1995): pragmatic (support for a practice); moral (values, perception of what is right, including normative and regulatory aspects); and cognitive (comprehensibility, taken-for-grantedness). Hence, dominant actors can use strategic communication to actively manipulate the general perceptions to support a certain practice, inculcate their beliefs and enhance emulation and comprehensibility around a certain direction.

Roadmaps can raise the public awareness and acceptability around emerging technological innovation systems. They enable to reach consensus and, if they have government involvement, contribute to align legislation with the needs of the innovation system. Therefore, roadmaps create conditions for the formation and sharing of collective expectations around the technology.

2.3. Guidance

Influence on the direction of search or guidance designates the mechanisms that set the direction inside the system and improve the attractiveness of the TIS to new (external) actors. It combines expectations on the technology and market potential with the actors' perceptions about the relative advantage of the technology against the incumbent or other alternatives (Bergek et al, 2008a). As pointed by Hekkert et al. (2007, p.423): "guidance of the search is not solely a matter of market or government influence; it is often an interactive and cumulative process of exchanging ideas between technology producers, technology users, and many other actors, in which the technology itself is not a constant but a variable."

Influence in the direction of search highlights the importance of the processes that lead to the articulation and sharing of expectations, including roadmaps (McDowall et al, 2012; Phaal et al., 2011). Smith et al. (2005: 1506) note that: "codified representations of technological expectations play a vital role in framing socio-technical problems, as well as motivating actors to seek to solve them…". Technology roadmaps materialize visions and guidelines for future development, being increasingly used by advocacy coalitions and governments in emerging technologies or industries, namely in the case of sustainable energies (Amer & Daim, 2010).

Roadmaps are instruments for the articulation of shared visions and expectations, as well as of strategies to reach those targets, regarding the future development of the technology. They contribute to align key actors and to guide their future behavior (McDowall, 2012). Thus, roadmapping has become "a powerful technique for supporting technology management and planning, especially for exploring and communicating the dynamic linkages between technological resources, organizational objectives and the changing environment" (Phaal et al, 2004: 5).

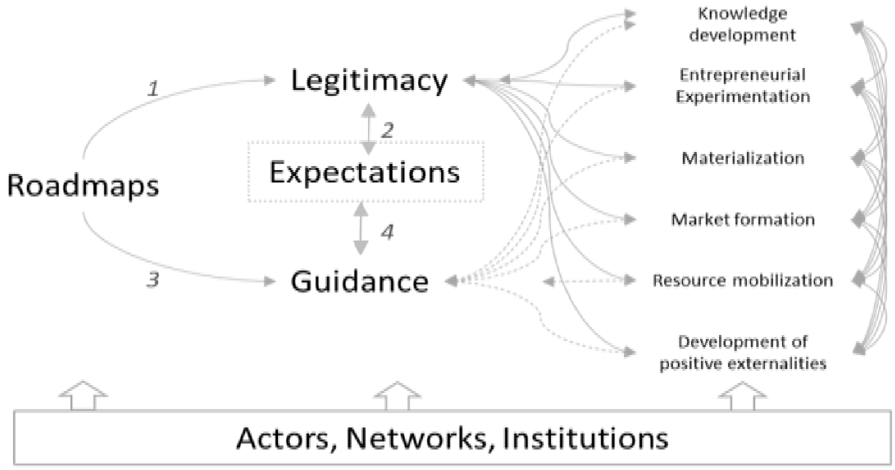
The capacity of roadmaps to guide the actors' activities is contingent on several factors. The effectiveness of roadmaps depends on the extent to which the proposals are acknowledged as being grounded in credible, good quality analysis and if they result from a participatory process involving key actors (McDowall et al, 2012). Visions are more or less powerful depending on how broad is the involvement of actors in their formulation and how inclusive is the consensus reached on the chosen path(s) (McDowall, 2012). It also means that targets set by the government are more credible when result from the initiative of specific industry or technology advocacy coalitions, where they can have an additional role of policy lobbying (Amer & Daim, 2010).

The construction of guidance is an evolutionary process that is influenced by the own system dynamics. As Jacobsson and Lauber (2006) concludes from the analysis of the diffusion of renewable energy technologies in Germany: "Legitimacy and visions are shaped in a process of cumulative causation where institutional change, market formation, entry of firms (and other organisations) and the formation and strengthening of advocacy coalitions are the constituent parts" (Jacobsson & Lauber, 2006: 272).

2.4. Relation between expectation and roadmaps

Legitimation and guidance are typically interdependent and related through expectations (see Scheme 1). While legitimation refers to the process of formation of collective expectations around the technology, guidance deals with the impact of expectations and their sharing on collective strategies. The relationship between legitimation and guidance through expectations, can run both ways. On the one hand, legitimation creates "strong expectation for what is likely to occur" (Johnson et al., 2006, p.72) and "influences expectations among managers and, by implication, their strategy (and thus the function 'influence on the direction of search')" (Bergek et al., 2008a: 417). On the other hand, guidance often triggers other processes like resource mobilization that support knowledge development and market formation, which further improve system legitimacy (Hekkert el al., 2007; Surana & Anadon, 2016).

Scheme 1 – Roadmaps' effect in technological innovation systems growth through legitimacy and guidance



Source: author inspired from Bergek et al 2008a, Hekkert et al 2017, Markard, 2018.

Expectations are real time representations of the future that can be "performative", i.e. shape action (Borup et al, 2006; Bakker et al, 2011). They can change as a result of the purposive action of early actors that engage in system building and institutional work, like in the case of potable water reuse in California (Binz et al., 2016). Expectations can also be an elusive phenomenon that temporarily attracts the general interest on a certain technology based on ambitious promises before moderating or fading away (Van Lente, 1993). The technology confronts with competitors in the process of variety and selection, and "enactors" must draw the attention of "selectors" in arenas of expectations (Bakker et al, 2011). However, inflated expectations undermine confidence on the technology leading to processes of hype and disappointment (Borup et al, 2006).

Considering the role of legitimacy and guidance in accelerating system change and sparking virtuous cycles — through their interaction with other functions (Hekkert et al., 2007; Suurs et al., 2009) — actors' purposeful actions to create legitimacy and guidance can give insights into how emerging systems prepare for growth. These actions may take the form of production of strategic documents such as roadmaps. Thus roadmaps can be a useful instrument to understand how these processes take place.

Roadmaps are the result of a negotiation process between different anticipations of the future (Rip, 2012). They articulate and convey (shared) visions and expectations on the future of the technology and translate them into broad guidelines for action. In doing so, roadmaps contribute to "institutionalize" and solidify expectations (Konrad & Alvial-Palavicino, 2017). They provide important insights about the creation and dissemination of expectations around the new technology (Borup et al., 2013). Thus, roadmaps are good analytical instruments, both concerning the legitimation of the technology and regarding the provision of guidance to actors, contributing to their alignment and guiding their behavior (McDowall et al, 2012). They have been extensively applied in various sectors such as defence (Phaal et al., 2011) and energy (Amer & Daim, 2010), but their effect in upscaling innovation systems has been little researched in the literature.

Therefore, returning to Scheme 1, the contribution of roadmaps to system upscaling takes place through the way their influence in legitimation and guidance contributes to a (positive) change in expectations (see numbers directly in the Scheme). Roadmaps influence legitimation through their capacity to improve system acceptability. Such capacity depends on the quality of the analyses conducted and the participatory character of the roadmapping process (McDowall et al., 2012) (1). Hence, roadmaps contribution to a (positive) change in expectations is greater when the visions they convey are perceived as credible and widely accepted. Conversely, overpromising reduces the trust in the technology and thus legitimacy, with negative impacts on expectations in the long run (2). Roadmaps influence guidance through their capacity to improve the attractiveness of the technology. Such capacity depends on the extent to which the visions and strategies are shared by actors, both internal and (especially) external (Bergek et al., 2008a; Hekkert et al., 2007) (3). Thus roadmaps contribute more to a (positive) change in expectations when they provide shared targets that are attractive but also perceived as achievable and when the technology is closer to maturity (Borup et al., 2006; Van Lente, 1993) (4).

In the following, we focus on how roadmaps support the processes of construction and sharing of expectations to mobilize the resources needed for technology upscaling, i.e., the "change in gears" in the transition from emerging to mature innovation systems (Markard, 2018). Thus we analyze the way that roadmaps impact on system change through their influence in: (i) the process of (re)formulation of collective strategies and their wider acceptance (legitimacy); (ii) the dissemination of these collective strategies and its effect in the direction of search; and (iii) the general expectations and ambitions. We hypothesize that legitimacy has a greater influence on the direction of search whenever visions are more realistic and there is a broader consensus among actors. In addition, the direction should contribute to the formation of the different types of legitimacy in terms of cognitive (understanding of the technology), normative (conformity with major design principles) and regulatory (sociopolitical change) legitimation (Suchman, 1995; Scott, 2001). Finally, greater legitimacy and stronger direction should create the expectations required to unlock the resources needed for upscaling the innovation system.

3. METHODOLOGY

This research seeks to understand the key processes involved in the upscale of new sustainable energy technologies, particularly: How legitimation, guidance and expectations contribute to accelerate the growth of low carbon energy technology innovation systems?

The literature points to some indicators for legitimacy and guidance. Table 1 shows the proposed measures for these two innovation processes along with some application challenges.

The empirical setting for the study is the development of offshore wind energy in deepwaters – more than 50 meters deep, where most of the resource potential is located, but whose technology is still immature.

The strategy consists of the analysis of roadmaps (and equivalent documents) and the conduction of an actors' survey to provide a comparative approach to the issues under analysis. Roadmaps are good analytical instruments of both the legitimation of the technology and the guidance for action.

We analyze the roadmaps (and equivalent documents) that have been published in the context of emerging offshore wind energy in deepwaters as they should be representative of the industry consensus (Table 2). Roadmaps were selected based on the explicit treatment of floating offshore wind (e.g. the Chinese roadmap on offshore wind do not consider floating offshore wind and for that reason was excluded from the analysis) and with the focus on the development of this technology unrelated with the administrative level (for that reason we analyze the roadmap of Northern Ireland separately from the United Kingdom).

Table 1 – Typical indicators for measuring legitimacy, guidance and expectations

System function	Indicators	Application issues & challenges
Legitimation	Recognition of societal benefits (e.g. awards, competitions, brochures). Technical assessment studies (e.g. roadmaps). Legislative debates (e.g. parliament minutes, minister speeches). Lobbying activities. Regulatory acceptance and integration, institutionalization.	Confining definition of legitimation. Quantifying social recognition, public debates or lobbying activities.
Guidance of search	Targets set by government or industry. Shared strategies (e.g. field openness) and roadmaps. Articulation of demand by leading consumers.	Assessing the credibility and impact on the direction of search of both internal and external actors.
Expectation	Opinions of stakeholders (e.g., firms, experts, NGOs). General perception on the innovation system (e.g. media analysis, Google searches). Technology promises by promotors (e.g. roadmaps).	Measuring expectations and their implications for diffusion.

Sources: Bergek et al., 2008a,b; Hekkert et al., 2007; Bakker et al., 2011; Bento and Wilson, 2016; Miremadi et al, 2018.

We conduct an in-depth assessment of these documents according to the requirements for the emergence of technological innovation systems in terms of context, structure and functions, as identified in the literature (Bergek et al., 2008b; Hekkert et al., 2007; Markard, 2018). Appendix 1 presents the questions considered for the analysis of the roadmap process, legitimacy and guidance. The analysis particularly focuses on the government involvement and openness of the strategy to foreign actors as key indicators of legitimacy and guidance, respectively. Subsequently, we further check the results through a content analysis of the roadmaps with a powerful computer software package: CorTexT Manager (application available in the CorTexT platform: www.cortext.net).

The survey confronts the actors' opinions with the expectations formulated in the roadmaps. Individual options may be aligned with the expectations enunciated in the planning documents revealing no overpromising, as well as trust (indicator of legitimacy) and shared perspectives (guidance). Conversely, misalignment reveals that visions conveyed in the roadmaps are unrealistic and untrusted, and thus may be less effective in influencing the direction of search. The survey goes along the same lines as the roadmap analysis, with questions about the expectations on technology development, main challenges and strategies pursued to overcome them (see Bento & Fontes, 2017 for more details). In addition, actors are questioned on how they perceive the role of roadmaps (i.e. asked to rate their effectiveness in a scale from 1 to 5). This question limits the generalization of the findings (close answers constrained by the *ex ante* chosen scale), but provides valuable information about the perceived influence of roadmaps in practice that would be difficult to extract otherwise.

We have identified a total of 68 entities active in the field of offshore wind energy in deepwaters worldwide. They participated in demonstration projects, reported interest in the technology in newspapers (different media), or published reports in the field. The entities comprise companies (e.g. technology providers, developers) and other organizations (e.g. research centers, government agencies, consultants). The sample is representative (not exhaustive) of the main actors that operate in this emerging technological innovation system worldwide. The survey was sent to these entities during the year of 2016. The response rate was 18% overall (12 replies), varying according to the type of actors: 7.4% for companies (5 replies on 40 contacts) and 25% for other organizations (7 replies on 28 contacts). Companies tend to be more careful to release information that could reveal their strategy in this emerging business.

More details on both the examination of each roadmap (following the analytical framework) and the survey (including all the questions and results) are available in a separate technical report (Bento & Fontes, 2017).

Table 2 – Roadmaps and equivalent documents surveyed

Document	Country	Date	Type	Initiative	Code
Target & roadmap for Japanese wind power	Japan	2014	Roadmap	Wind Power Association	JA14
Demowfloat - Demonstration of the WindFloat Technology Roadmap (Windplus)	Portugal	2014	Project report	Organizational (companies)	PO14P
Technological Roadmap by the Technological Observatory for the Offshore Energies	Portugal	2014	Roadmap	Coalition of stakeholders	PO14R
UK Renewable Energy Roadmap Update 2013	UK	2013	Roadmap	Government	UK13R
Industrial Strategy: government and industry in partnership	UK	2013	Action plan/ Strategy	Government	UK13S
Rapport de la mission d'étude sur les énergies marines renouvelables	France	2013	Strategy/ Roadmap	Government (mission report)	FR13
A National Offshore Wind Strategy: Creating an Offshore Wind Energy Industry in the US	US	2011	National plan	Government	US11
Offshore Renewable Energy Strategic Action Plan 2012-2020	Northern Ireland	2012	Action plan/ Strategy	Government	NI12
UK Renewable Energy Roadmap	UK	2011	Roadmap	Government	UK11R
Concerning an Act on Offshore Renewable Energy Production (the Offshore Energy Act)	Norway	2009	Strategy (legislative)	Government	NO09

The analysis of media coverage and of Internet searches complements the survey to understand the effect of roadmaps in the general perceptions and expectations around floating offshore wind energy. Media analysis investigates the intensity and mood of the news published on the technology in a respected newspaper (*Público*) from one of the pioneer countries in the technology (Portugal). Google searches, on the other hand, is growing mainstream as an indicator of the short-term trends in economics and society variables (Choi & Varian, 2012).

4. RESULTS

We study the elements in the roadmaps that aim to create expectations and institutions in the field (section 4.1), to set the direction inside the system and to improve the attractiveness of the TIS (section 4.2), and to influence the opinion of actors and the general perceptions about the technology (section 4.3).

4.1. Roadmaps and legitimation

We assess the impact of the roadmaps in the formation of trust and positive collective expectations around the technology. The capacity of roadmaps to improve the acceptability of the technology depends much on the process that led to the formation of visions and expectations. This primarily concerns the quality of the analysis and participatory character of the process (McDowall, 2012).

The quality of analysis varies, in the different roadmaps, with respect to the depth of study and the balance of expectations. Roadmaps present a (more or less) comprehensive diagnostic of the technology as well as of the country's strengths and weaknesses in relation to the development of the system. They resort to experts' opinion to validate projections, particularly when roadmaps are from public initiative (e.g., FR13, NI12, US11). However, roadmaps are generally optimistic and there is a risk of overpromising, which may undermine their credibility and utility (Brown, 2003). We return to this issue in subsection 4.3.

Actor inclusiveness varies in extent and nature as regards to formal recognition of involvement. Yet participatory character of the process is often difficult to assess from documental analysis. Appendix 1 presents the characteristics (origin, openness, stakeholders' involvement, etc.) taken into account in the roadmaps analysis, including the roadmapping process. The roadmaps show some preoccupation with the engagement of key actors during the formulation of strategies (at least consultation). They also attempt to reach out and involve new actors and align their activities with the goals set. Most documents define strategies for that purpose, including the promotion of specific initiatives, networks or infrastructures (e.g. setting-up demonstration sites, solving grid connection problems). But a diversity exists in terms of the level/type of actor involvement and thus on the nature of consensus achieved. Less inclusive roadmaps are more vulnerable to the interests of specific groups, constraining the capacity to influence the general expectations.

The origin of roadmaps - government led versus actors' initiative - impacts their content and the capacity to create legitimacy. Government can enact key policies and its participation ensures support to the direction set. Still the effect in expectations depends on the perception of stability of the commitment given the possibility of changes in the policies with the arrival of a new administration. The roadmaps of stakeholder initiative (cases of Japan (JA14) and Portugal (PO14R, PO14P)) signal the motivation and the willingness to implement the visions, particularly when they involve key actors in the field. These Roadmaps also stress the need for government endorsement of the preconized visions – in this sense they can work as a piece of lobbying.

Formation of technology specific institutions is crucial in system upscaling. Roadmaps recognize that standards and regulations need to be in place before the market takes-off. They often make specific recommendations, such as the implementation of maritime spatial planning that anticipate and address potential conflicts with existing activities and communities. Several roadmaps present floating offshore wind as a solution to avoid the acceptance problems associated with fixed wind turbines installation close to the coast. They sometimes resort to surveys for supporting these assertions (e.g. UK13S), in what is a clear attempt to improve the public acceptance of the technology.

Finally, the roadmaps' effects in legitimacy can be assessed through the analysis of contemporary documents, from different sources (consultants, NGOs, professional associations, etc.) technical reports and parliamentary debates (Table 3). Reports led by coalition actors set the case for very ambitious targets—to be accepted by all and integrated by the regulators—namely justified with technical analysis (e.g., historical learning rates like in the EWEA 2009 report). Conversely, the official reports develop scenarios grounded in more applied research (e.g. identification of zones, potential and capacity factors like in the NWRE 2013 report). Expert reviews typically show the circumstances for some outcome to occur (e.g. produce at competitive cost like in the Garrad Hassan 2012 report). Overall these documents reveal that floating offshore wind receives a general positive prospect from stakeholders who were also the target of the roadmaps. In particular, they show the successful integration of some of the roadmaps' conveyed ideas by the regulatory instances.

In regard to the indicators of legitimacy presented by Bergek et al (2008a,b), the roadmaps seek to raise the public (and business) awareness of floating offshore wind and align the policies and regulations with the needs of the technology. The promotors of the technology strive to increase legitimacy by convincing the governments to adopt these directive documents. However at the least, differences in respect to actor involvement impact the credibility of consensus.

Table 3 – Chronology of key publications on floating offshore wind (non-exhaustive)

Date	Type	Source	Title	Observations
June 2018	CR	WindEurope	Wind Offshore Vision Statement	Asks the countries to expand the installation of floating offshore wind from the currently expected 300 MW by 2021 in order to meet the target of 27% share of renewables in energy by 2030 in Europe.
March 2018	CR	UK's Friends of Floating Offshore Wind	Position Paper	Urges the UK government to set a target of 1GW of floating wind installed by 2025 and 5GW by 2030.
September 2017	ER	Fundação Calouste Gulbenkian	Energias Renováveis Marinhas em Portugal: Se e Quando?	Shows the positive economic value of investing in floating offshore wind what should motive public support.
Agosto 2017	ER	Prepared by NREL to the US Department of Energy (DOE)	2016 Offshore Wind Technologies Market Report	Provides quantitative information about the offshore wind market, technology, and cost trends in the US and worldwide to address technical and market barriers and opportunities.
March 2017	OR	Ministry of Energy, Utilities and Climate's Danish Energy Agency	Danish Experiences from Offshore Wind	Conveys experiences (particularly the regulation) from the 25-year long development of the Danish offshore wind industry.
February 2017	OR	Minister of the See of Portugal	Portugal Ocean Industry: a strategy for achieving sustained growth in the global economy	Suggests empowering emerging activities like ocean renewable energies to strengthen traditional ocean economic sectors.
January 2017	ER/OR	Carbon Trust and Scottish Government's backed Offshore Renewable Energy Catapult	Floating wind joint industry project - policy & regulatory appraisal	Outlines the main regulatory needs to support floating wind energy deployment with an identified potential of 90MW by 2018.
November 2016	OR	Portuguese Ministry of the See	Roadmap for an Industrial Strategy for Oceanic Renewable Energies	Identifies 260MW for offshore wind (mostly in deepwaters) to be invested up to 2030 in order to build a local cluster and defines a strategy for public support.
June 2015	ER/OR	Catapult- Prepared for the Scottish Government	Floating Offshore Wind - Market and Technology Review & Technology Assessment Interim Findings	Assess current state of the floating wind industry and the key technical barriers that need to be addressed to make it a commercial reality. Inform recommendations to the Government on how to support the industry.
March 2015	OR	US DOE	Wind Vision 2015	Provides a study scenario and baseline scenario for the development of offshore wind in the US.

March 2014	CR	European Wind Energy Technology Platform	Strategic Research Agenda & Market Deployment Strategy	Analyzes six research topics that are priority to deliver a commercial maturity technology (including floating offshore) by 2030.
March 2014	ER	OTEO	Technological Roadmap	Identifies barriers and strategies to develop an industry around offshore wind and wave energy in Portugal.
February 2014	OR	Irish DCENR	Offshore Renewable Energy Development Plan	Floating offshore wind has 25-27GW potential in Ireland by far the highest potential among foundation offshore technologies.
October 2013 (update version of 2008/09)	ER	IEA	Technology Roadmap: Wind energy	Establishes vision for the progress of wind technologies to reach the targets compatible with the 2DS scenario, discusses measures to reduce costs and improve performances, and inspires the elaboration of national action plans.
2015 (update version of 2013	OR	Portuguese Ministry of the Sea	National Strategy for the Sea	The energy cluster could help to develop and reconvert the declining activities in the maritime industry.
July 2013	CR	EWEA	Deep Water The next step for offshore wind energy report	Promotes vision for wind energy to reach 50% of electricity production in Europe with namely the development of competitive floating offshore wind.
May 2013	OR	Norwegian Water Resources and Energy Directorate	Offshore wind power in Norway: Strategic environmental assessment	Identifies 15 zones with a capacity from 4600-12600 MW and capacity factors of 36-50%.
April 2013	OR	Portuguese Research Council (FCT)	Roadmap for Renewable Energy Offshore in Portugal	Design, Monitoring and Review: Application to the Development of Marine Energies in Portugal.
May 2012	OR	Crown Estate	Offshore Wind Cost Reduction: Pathways Study	Identifies opportunities for cost reduction to reach GBP100/MWh.
2012	ER	Garrad Hassan	Cost of energy of floating wind	500MW floating wind parks could produce at a cost as lower as €128/kWh.
2012	OR	European Commission	Blue Growth: opportunities for marine and maritime sustainable growth report	Offshore wind could meet 4% of the EU electricity.
September 2011	ER	ORECCA	European Offshore Renewable Energy Roadmap	Develops a strategy to facilitate the deployment of offshore wind, wave energy and tidal stream, in order to reach the 2050 targets like 1150 GW (of which 460 GW in Europe) for offshore wind.
July 2011	CR	Windspeed	Roadmap to the deployment of offshore wind energy in the Central and Southern North Sea	Floating offshore wind will double potential of offshore wind energy but will be concentrated in the UK and Norway.

May 2011	ER	Intpow	Offshore Wind Norway	Market and Supply Chain study.
February 2011	OR	US DOE	A National Offshore Wind Strategy: Creating an Offshore Wind Energy Industry in the United States	DOE's scenario of 54 GW of offshore wind capacity by 2030 (large part in deepwaters), at a cost of energy of 7 cents per kWh, with an interim target of 10 GW by 2020, at a cost of energy of 10 cents per kWh.
November 2011	CR	European Wind Energy Association (EWEA)	Wind in our Sails – The coming of Europe's Offshore Wind	Establishes vision for European market and technology leadership in offshore wind, with new industrial supply chain to bring jobs and commercial opportunities. Recommends Europe to set ambitious targets beyond 2020, to invest in wind power R&D and to develop the grid infrastructure.
2010	ER/CR	EnergyIN and Wavec	Principles for the Development of a Roadmap	Establishes the basics and launch a Roadmap process.
August 2010	OR	ADEME	Roadmap for renewable marine energy	Vision of marine energies potential in France.
July 2009	ER/OR	French Grenelle	Le Livre Bleu des Engagements du Grenelle de la Mer	Asks the government to build demonstrators in order to accelerate the maturation of floating offshore wind technology and promote the supporting sector.
2009	CR	EWEA	Oceans of Opportunities report	Suggests that offshore wind growth is following a similar deployment rate curve as that of onshore wind plotted on a similar time scale; floating part of the plans to achieve 150GW in EU by 2030 ensuring 15% of total EU electricity demand.
October 2007	ER/OR	French Grenelle de l'Environnement	Synthèse et principales mesures proposées par le Groupe I «Lutter contre les changements climatiques et maîtriser l'énergie»	Announces the installation of 6000MW of marine technologies in France by 2020.

Type: OR – Official Report; ER – Expert Report; CR – Coalition Report

4.2. Roadmaps and guidance

The effect of roadmaps in the guidance depends on their impact on the expectations and collective strategies (Bergek et al, 2008a). It namely concerns the extent to which the actors share the same anticipations about the future of the technology. The effect also materializes in the capacity of the system to attract new actors from other sectors.

The roadmaps under analysis denote some convergence of visions and strategies. They are optimistic (and often ambitious) concerning the growth of floating offshore wind energy and preview an acceleration of development in the coming years. All countries define goals for technology development and six of them additionally set-up intermediate steps. The only exception is Norway, whose “Offshore Energy Act” refers to targets to be set later. The plans of deployment range from 27 MW in Portugal to 100 MW in Japan by 2020 and up to 4,000 MW in Japan by 2030. Intermediate steps often refer to deployment, but there are cases where it relates to a technological target such as costs reduction (e.g. GBP 100/MWh in UK or $0.10/kWh in the US) by 2020.

The roadmaps identify identical technological requirements. They refer to similar needs for the upscale and growth of the technology, e.g.: demonstration of full-scale operating systems; cost reduction and standardization; development of supply-chain. We observe a general agreement about the priority areas to address, including the need for: more “real-world” experimentation through pilot experiments and pre-commercialization projects; expansion of networks of knowledge; and the introduction of policies to create early demand and spark growth. This agreement signals a relatively shared perspective in this community on the “structuration” of the innovation system, as part of the process of upscaling and transition to the main markets.

The promotion of a new domestic industry is another feature of the roadmaps. The roadmaps often emphasize the domestic production of a substantial number of components. They present these components as complementary activities that can provide organizations from a variety of fields (e.g. offshore oil and gas in Norway, or declining sectors like metalworking in Portugal) with opportunities to broaden their markets and to increase their exports. The extreme case is Norway that focuses its strategy for growth of the offshore industry almost exclusively on exports. The national focus, nevertheless, appears to be excessive considering the highly internationalized nature of the field, leading to some neglect of the potential competition from other countries with similar goals (the UK roadmap is a rare exception). In the limit, foreign organizations are never referred to, like in the Japanese roadmap.

Targets set by industry and governments are good indicators of guidance. Table 4 compares the installations expected in the short term given the permissions already granted with the ambitions of the industry. 258 MW should come online by 2021, far from the 8,345 MW ambitioned by firms in 2025. The gap reveals a slow speed of market formation and low visibility for investments after 2021. It also shows that roadmaps have had a limited effect in general expectations and in the change of policies (proxy for legitimacy).

Table 4 – Capacity installed in 2018, expected for 2021 and ambitioned in 2025

Region/country (in MW)	Installed 2018	Expected 2021	Aimed 2025	Source: (Official/Industry Ambition)
Europe	**34**	**205**	**3045**	
UK	30	80	1000	- ambition set by Friends of Floating Offshore Wind Position Paper ('18)
France	2	98	2000	- by 2023, officially set by the « Programmation Pluriannuelle de l'Énergie » (PPE)
Norway	2	2	20	- Norwegian Minister announces (Aug'18) single unit demonstration sites
Portugal	0	25	25	- officially set in the "Industrial Strategy for Ocean Renewable Energies"
Asia	**16**	**41**	**3400**	
Japan	16	41	1400	- Japanese Wind Power Association Roadmap 2014 (sees 4GW by 2030)
China	0	0	1000	- State owned CGN Jieyang project indicative timeline
Taiwan	0	0	1000	- developers' ambition (4x Eolfi)
North America	**0**	**12**	**1900**	
USA	0	12	1900	- official plans for Morro Bay (700-1000MW) and Aqua Ventus I-II(500MW), mostly
Global	**50**	**258**	**8345**	

Sources: Carbon Trust (2018) – "installed 2018"; "expected 2021" (given the consent/permissions already granted); Bento & Fontes (2018) – cross check "expected 2021" (UK, PT, various); https://www.4coffshore.com database for latest updates on the projects).

More specific targets and strategies vary from country to country depending on the different internal conditions. These include: objectives in terms of market penetration (share of renewable energy in electricity generation), performance of other offshore sectors (e.g. offshore wind or oil & gas), industrial specialization (e.g. level and type of activity in complementary sectors along the value chain), and country's organization and resources that can be mobilized. The roadmaps attempt to propose visions and paths that are adjusted to the stage of development of the system and that might be "reasonably" pursued given the country specific conditions. This supports the hypothesis that strategies conveyed in roadmaps are determined by the technological and socio-economic context (Bergek et al., 2015).

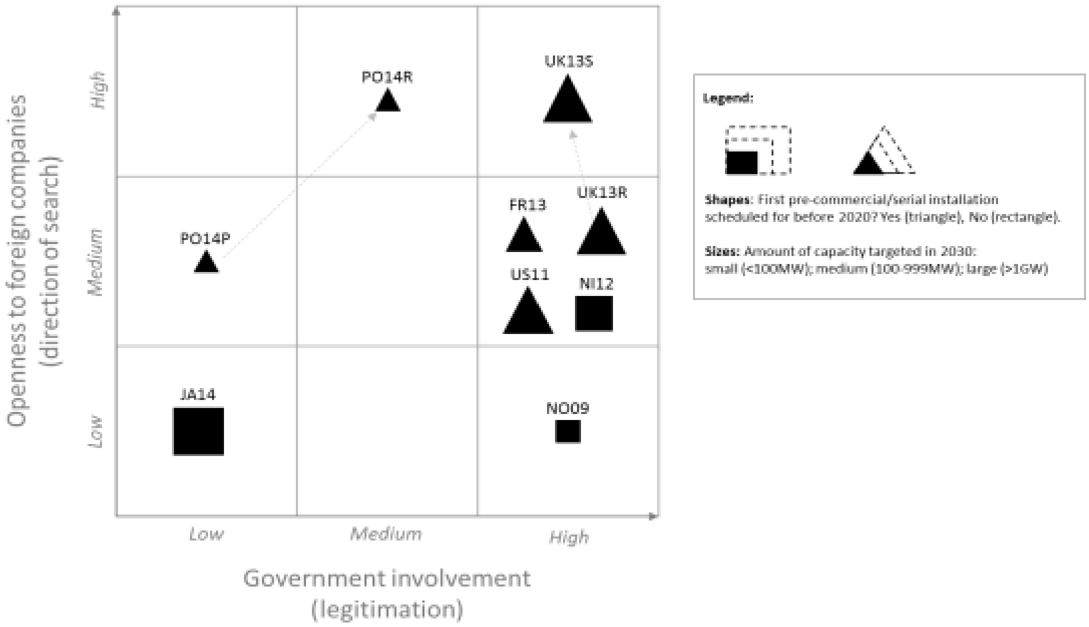
To gain additional insights into the nature of the strategies conveyed in the roadmaps, we performed a more in-depth analysis of the roadmaps with the help of a specialized software (CorTexT Manager). The automatic content analysis permits to compare with the results from the literature informed analysis through the use of a powerful and systematic methodology. It reveals three main areas of attention related to renewable energy, offshore energy and government (see

Appendix 2.). These areas globally overlap with the three main domains identified in the innovation systems literature (namely TIS), suggesting that the actors recognize the importance of creating networks around this renewable energy and institutions for the growth of the new technology. A closer analysis of the most repeated terms in the roadmaps (excluding terms like pronouns, conjunctions, etc.) finds the predominance of technology-related words (e.g. renewable energy, offshore renewable) (see Appendix 3). Despite the relevance of social aspects, the content analysis reveals that these types of issues are missing from the list of the most important terms in the roadmaps. The technology-centered perspective is consistent with the previous findings from the non-automatic analysis about the importance of technology requirements and targets. It also seems to be a robust feature of the documents, even if automatic word counting analysis can be sensible to different languages and the addition of new documents.

Therefore, the roadmaps contribute to influence the direction of search to some extent. Comparing their outcomes with the indicators suggested by Bergek et al (2008a), one can argue that they contribute to institutionalize (Konrad and Alvial-Palavicino, 2017) the expectations on offshore wind in deepwaters (beliefs in growth). Roadmaps seek to persuade policy-makers to enact favorable regulation and taxes/subsidies in order to attract more investment to the system. They also aim to articulate the interest of leading actors in the industry (even if not always the main customers, such as utilities). However, the effectiveness of the guidance will depend on whether the expectations and collective strategies are attractive enough for actors from other sectors.

Finally, we operationalize the content analysis by focusing on two indicators of guidance and legitimacy and by assessing the effect of roadmaps in these measures. We take the attractiveness of the sector to companies from other countries (openness to foreign actors) as indicator of direction of search, and the degree of government involvement as indicator of legitimation. We draw these indicators directly from the definition of the functions (cf. Borup et al., 2013; Bergek et al., 2008a). The analysis also interrelates these two innovation processes with the degree of development of the system in different contexts—here approached with the size of the plans. Figure 1 compares the roadmaps along these two dimensions and relates them to contextual information concerning the pervasivity/scale of the plans (size of the figures) and timing for deployment (shapes).

Figure 1. Stylized representation of roadmaps according to measures of guidance (openness to foreign actors) and legitimation (government involvement)



Source: roadmaps and likely documents listed in Table 2. Countries were sorted in terms of "Openness to foreign countries" according to the stated preferences for domestic manufacturing and expected development of actors & networks, reported in a separate report (Bento & Fontes, 2017). Regarding "Government involvement", roadmaps are either from government initiative ("high"), industry initiative ("low"), or industry initiative with government participation ("medium").

The results show that government involvement and proximity to deployment (triangles) tend to increase the openness to foreign companies. This trend is particularly clear when one compare, for example, JA14 with UK13R (roadmap) and UK13S (action plan/strategy). Medium and high degree of government involvement is associated to more openness to foreign actors, the only exception is Norway (NO09) that at the same time states low ambitions of offshore development (less than 100MW). Note the evolution of the UK's position from the roadmap (an updated version of the 2011 document) to the more concretely defined action plan. The degree of openness is higher with the proximity of deployment (shape of the symbols) – note there is no triangle with "low" openness. Therefore, the results reinforce the earlier conclusions about the importance of contextual structures (Bergek et al., 2015), particularly concerning the political involvement and the effect of more advanced technological contexts.

4.3. Confronting roadmaps with actors and public expectations

The expectations conveyed in the roadmaps are confronted with the opinions of the major players in the field expressed in a survey to test for the degree of alignment between the two. Misalignment, for example, would signal overinflated expectations and/or a weak roadmaps' influence in the direction of search. Figures 2-6 present the main results.

The surveyed opinions converge with the roadmaps in several aspects. According to the actors, floating offshore wind is still in the pre-commercial stage of development. The barriers to overcome are similar and mainly deal with cost reductions, access to financial capital, standardization and grid connection. The first markets should locate in Japan, United States and United Kingdom (ca. 70% of the opinions) (Figure 2). The interest in floating offshore wind has been mainly driven by the opportunities to explore areas with higher wind potential, higher capacity factor, lower production costs and less public resistance (Figure 3). However, there are substantial differences in opinion between actors and in particular among companies and (non-business) organizations.

Figure 2 – Countries were commercialization will first start

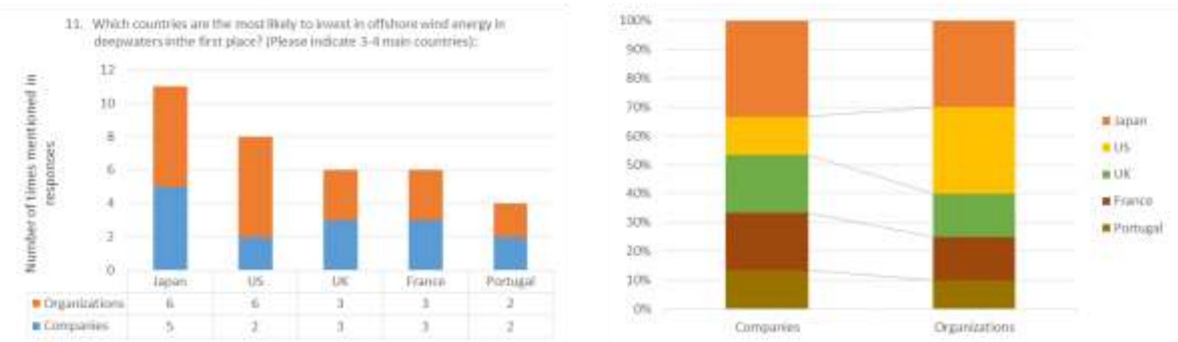
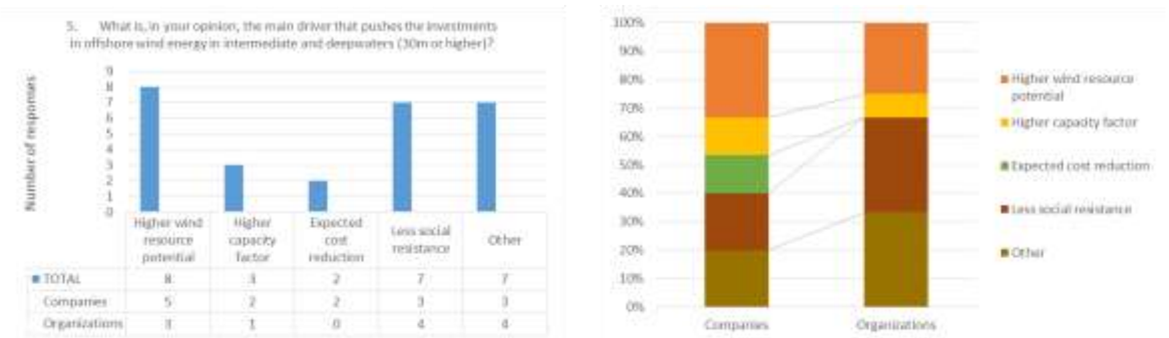


Figure 3 – Drivers of investment



Companies and other organizations differ on the prime factors that pull the investment in deeper waters. Companies underline the higher resource potential as the main driver, whereas other organizations primarily point to the lower social resistance to installations. The views also differ concerning the timings and readiness of the system to grow. Companies are more optimist than other organizations concerning the availability of system resources (Figure 4). They do not perceive a lack of core resources (e.g. knowledge, infrastructure) or of coherence in the system, and expect faster and greater cost reductions which would allow floating offshore wind to become competitive more rapidly (Figure 5). As a consequence, companies are more optimistic concerning the commercialization, which they expect to start before 2020 (Figure 6). In contrast, 70% of other organizations report that the competitiveness of floating offshore wind is very uncertain, or will never happen at all.

Figure 4 – Availability of system resources

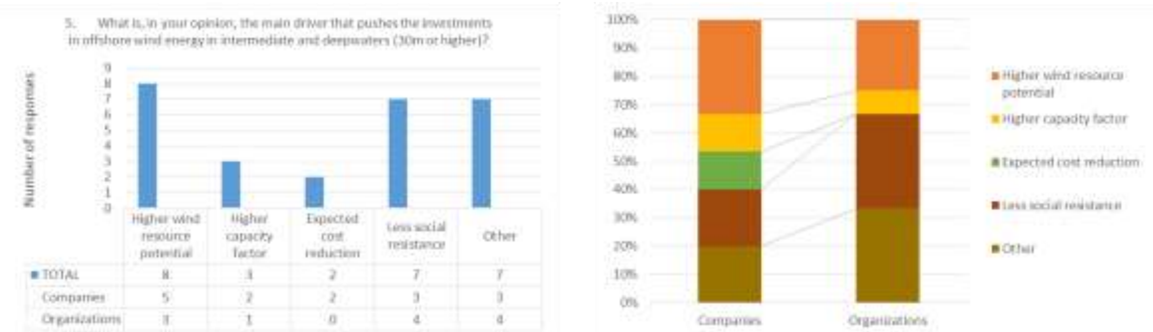


Figure 5 – Cost reductions and technology competitiveness

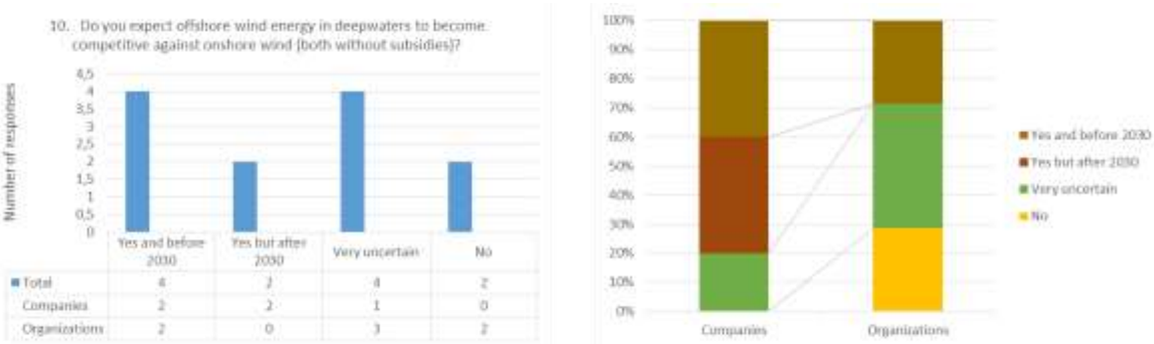
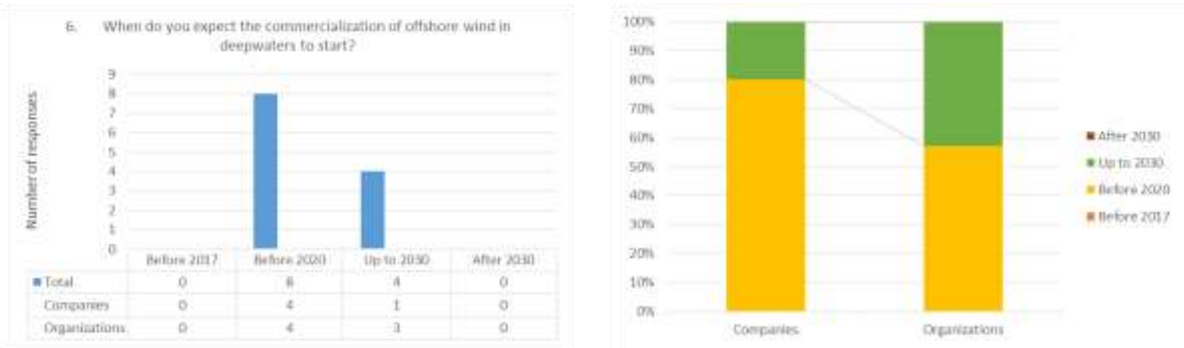
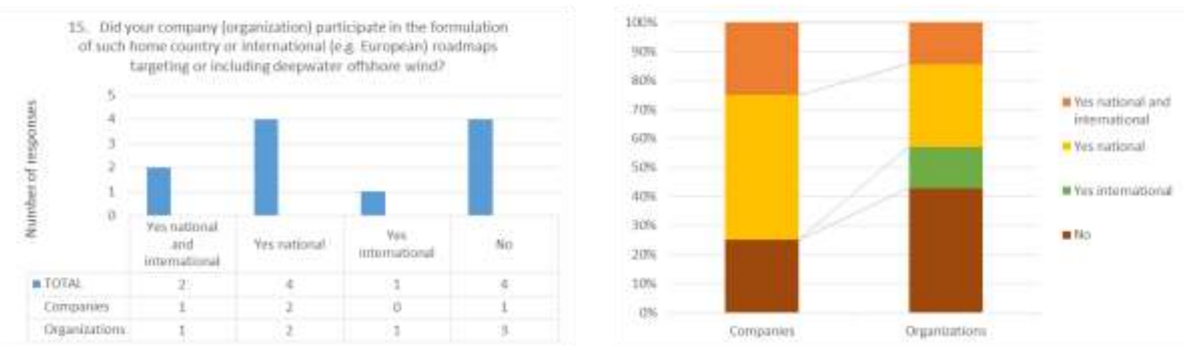


Figure 6 – Expected year of commercialization



Overall, the survey reveals that actors perceive roadmaps as having a positive, though limited, impact on both policies and system developing. The opinions of companies are more closely aligned with the visions and strategies expressed in the roadmaps. In average, companies have been more active than other organizations in the formulation of the roadmaps (Figure 7). Thus, it is possible that their positions prevailed in the final consensus that was in the basis of the roadmaps.

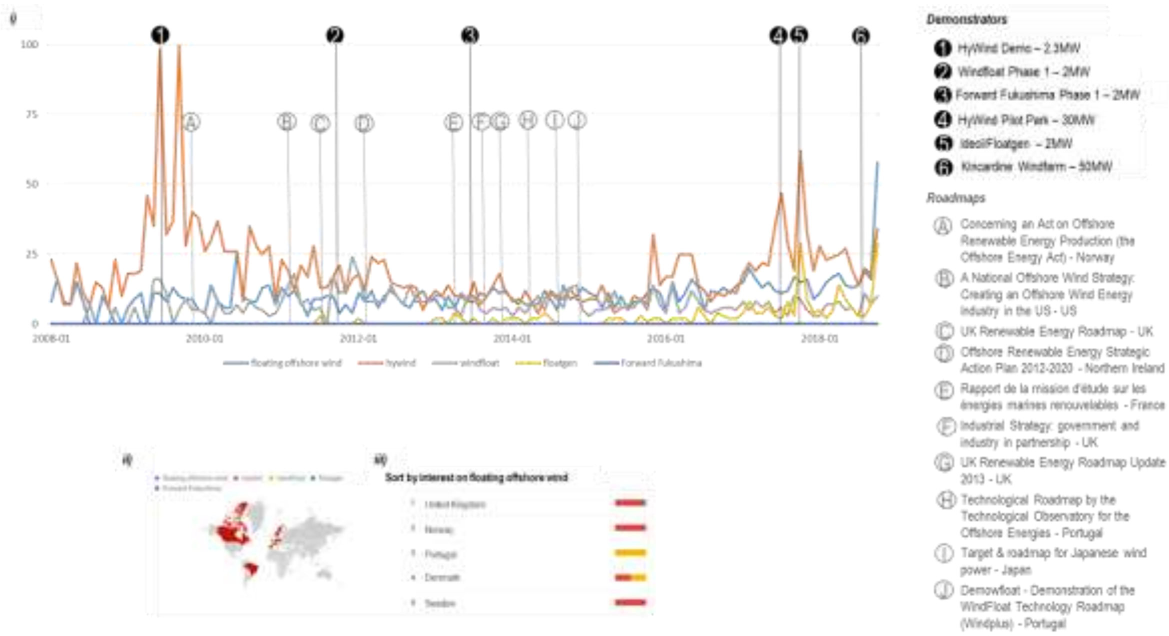
Figure 7 – Participation in roadmapping



To further comprehend the effect in expectations of the roadmaps, we analyze the trends in the search of floating offshore wind in Internet as well as the coverage in the media.

Google (search) Trends has proven helpful to identify broad society preferences and the near-term forecasting of economic indicators (Choi & Varian, 2012). Figure 8 presents the trends of search for “floating offshore wind” and for the main experiments: “Hywind”; “Windfloat”; “Floatgen”; “Forward Fukushima”. Searches have been more important for the experiments than for the generic term ("floating offshore"), pointing to the role of demonstrators for technology visibility. Particularly, HyWind is the most researched term, peaking twice around the implementation of the first demonstrator in Norway in 2009 and in Scotland in 2017. Spatial analysis reveals the prevalence of countries hosting demonstrations in searches, and the domination of the domestic experiments in these countries. The Google Trends hence suggest a low impact of the roadmaps on public interest.

Figure 8 Number of searches in Google. Index number of searches (maximum=100) for "floating offshore wind" and four key demonstrators (Hywind, Windfloat, Floatgen and Forward Fukushima) in i). Spatial distribution of searches in ii) and ranking of the countries sorted by searches of "floating offshore wind" in iii).

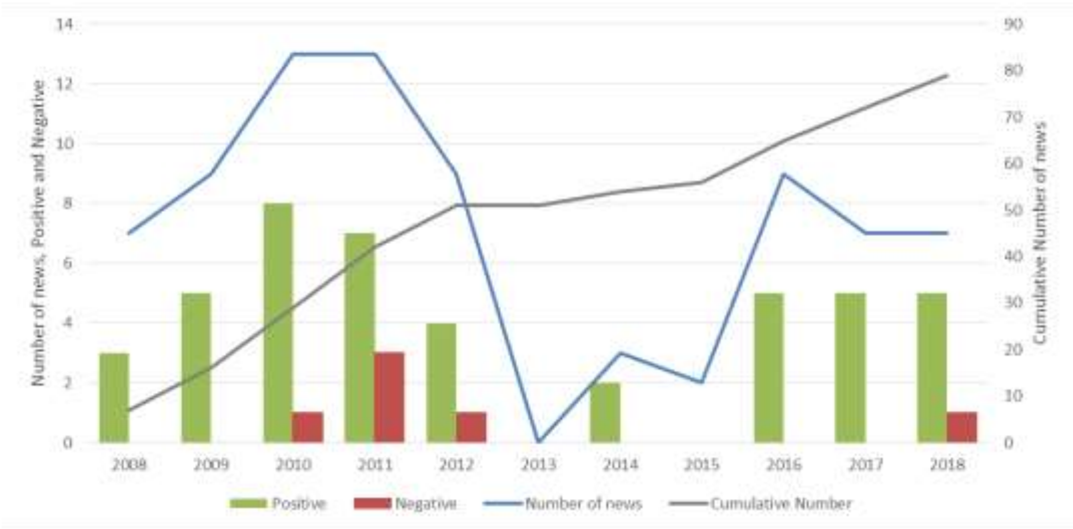


Source: Google Trends, https://trends.google.pt/trends, October 7, 2018.

A media analysis test for the importance of floating wind energy in a mass communication channel (newspaper) is also conducted. We study the press coverage in a pioneer country (Portugal) which run an influent demonstration project (Windfloat). Figure 9 shows the results from the analysis of a reference Portuguese newspaper (*Público*). There is a great reduction in media interest after the implementation of the first demonstrator in Portugal. The media interest resumes with the approach of the start of the new demonstrator expected to be operational in 2018/19. It is worthwhile noting the dominance of positive viewpoints (sign of legitimacy) on offshore wind (in Portugal only floating offshore has been considered given the ocean conditions).

But negative perceptions appear when attention declines and more recently related to some contestation of the government support to the transmission cable for grid connection. In sum, according to the media analysis the general interest has been more responsive to the prospects of large demonstrators than to the discussions around the publication of roadmaps.

Figure 9 – Number of news on floating offshore wind energy in the *Público* newspaper, in Portugal, between 2008 and October 2018



Searched terms are "energia eólica offshore" (Portuguese for offshore wind energy), "eólica offshore" (wind offshore) and "Windfloat" (local demonstrator). Table bars show positive viewpoints (green) and negative viewpoints (red), coded by the two authors separately and then unanimously agreed at the end. Blue line and gray line present the evolution of the number of news and of the cumulative number of news, respectively.

Source: Data collected from www.publico.pt in October 15, 2018.

5. DISCUSSION AND POLICY IMPLICATIONS

The paper aims to understand the role of legitimation, influence on the direction of search and expectations in innovation systems upscaling. This is important because the access to resources (labour, capital, infrastructures, etc.) that are necessary to achieve the innovation's full potential depends on the acceptance and attractiveness of the new technology. We examine the formation and sharing of collective expectations through the analysis of the roadmaps. A survey of the actor's opinion complements the analysis to compare results and to assess the effects in the public expectations around the technology.

The analysis shows that roadmaps can contribute to the performance of key processes like legitimation (acceptability) and guidance (attractiveness). However, the results point to different types of guidance depending on the technological and institutional context. That is, they reveal a tendency for higher external openness (as an indicator of guidance) when there is government involvement (as an indicator of legitimation) and with the approximation of the date expected for technology deployment (maturity of the technology).

The survey of actors' opinion confirms that roadmaps have a positive, although limited, impact on expectations and through them on technology development. It also shows that roadmaps tend to overpromise and that the optimistic vision of companies frequently prevails. The tendency to overpromise reduces the trust in the guidelines over time (Bakker et al, 2011), undermining the credibility of the plans and thus their influence in the mobilization of the resources.

The analysis of public interest and of the coverage in the media complements the survey, as ongoing public debates affect the perceived attractiveness of the technology. Search and discursive analysis is often used as an analytical instrument to unveil the process of creation of expectations and how this process can contribute to accelerate (or hinder) technology upscaling. The analysis of Google Trends and a discursive analysis of the media for a pioneer country (Portugal) found that roadmaps weakly influence public expectations. Thus their impact cannot be fully traced directly by this way. However, the analysis of the expert technical reports shows that roadmaps can impact indirectly on the opinion (and expectations) of governments or of external companies, favouring the launch of technology experiments. Since experiments were found to have a stronger impact upon public expectations, Roadmaps can be said to have only an indirect effect on public acceptance (through the promotion of technology demonstrations), their impact being more evident on business and other professional communities.

Our results have several implications for the theory. As for the operationalization of the concepts, we approach the legitimation and direction of search in terms of their impact on the change in expectations. We reconcile the indicators proposed by different authors for the functions (Bergek et al., 2008ab; Hekkert et al., 2007; Borup et al., 2013) by isolating those that directly deal with expectations (opinions of stakeholders, general interest in the media/Internet, (credible) promises of promoters).

Thus the results have implications for the treatment of expectations. Expectations can be an instrumental variable – a mediator – to study the contribution of legitimacy and guidance for the maturation of innovation systems. Legitimacy can increase (decrease) expectations with more (less) optimistic expert reports or higher (lower) integration of ambitions in regulation; guidance may increase (decrease) expectations through shared (exaggerated) promises on the future of the technology (performances, markets, etc.). Alternatively, expectations can be treated more explicitly in future works, i.e. autonomously of the other functions and structural elements. This seems a more promising development for the theory but more research is needed.

Concerning the relationship between legitimacy and guidance, we distil two main conclusions. First, the inclusiveness of the roadmapping process have an influence in the legitimacy of the conveyed visions, thus affecting the chances that the plan becomes widely accepted and attractive for actors from other sectors (McDowall et al., 2012). Second, agency and power balance influence the legitimacy of collective strategies conveyed in roadmaps. Visions and guidelines can have higher social repercussion when no particular opinion (e.g. of the incumbent) prevails in the negotiation process (Geels, 2014). Table 5 summarizes the findings on the three dimensions.

Therefore, policy makers aiming at accelerating the diffusion of low carbon technologies with roadmaps should pay attention to the process of formation and sharing of expectations. It is important to ensure a minimum representation of the stakeholders (firms, consumers, community, etc). Visions and guidelines resulting from a negotiation process that is captive o the interests of the more powerful actors are less effective to raise social support. Moreover, the ambitions should be reasonable and based on solid arguments to increase the confidence in the targets and in the recommended strategies for action.

The results have some limitations. First, roadmaps can convey the dominant positions and be so speculative about the technology that in practice they have little effect in the formation of the collective visions (expectations), affecting the direction of search (i.e. the attractiveness of the technology as perceived by the relevant actors from the other sectors) or the legitimacy (as social acceptance). Second, targets and strategies conveyed in roadmaps can change over time independently of the social perception about the technology. Third, the roadmap analysis conducted is static. In the future an examination of the investments over time would unveil possible effects of the publication of roadmaps. Similarly one could track the impact on the development of technology-specific institutions (e.g. standards folowing Markard & Hoffman, 2016). Finally, the study of more cases could deepen our resultls about the co-evolution of legitimation, guidance and expectations in the upscaling of innovation systems.

Table 5 – Synthesis table

	Summary description	**Roadmaps impacts**	**Roadmaps in Floating OWE**
Legitimacy	• aligning the innovation system with legislation, system of values in industry and society, including counteracting system resistance by constraining demand, institutions and firm behavior to improve social acceptability	• broad consensus and government involvement improve influence	• government participation signals legitimacy
Guidance	• strategic directing of investments to reduce uncertainty through promoting views on market potential, incentives, regulation or the articulation of demand from leading clients, increasing attractiveness	• materialize visions and guidelines • align key actors to guide their future behavior	• openness to foreign actors indicate direction • converging vision and plans (of roadmaps) denote clear strategy
Expectations	• perceptions orienting decisions based on collectively shared beliefs (institutions) on technology's relative advantage, where overambition leads to unstable support	• institutionalize and solidify expectations	• individual actors' expectations less ambitious than those enunciated in roadmaps • perceived limited influence of roadmaps on expectations • public expectations indirectly affected by roadmaps through the role these play in launching large experiments
Relevant section	2.1-2.3	3	4.1-4.3
Key references	Bergek et al., 2008; Borup et al., 2006; Bakker et al., 2011; Van Lente, 2011	McDowall, 2012; Amer & Daim, 2010; Konrad and Alvial-Palavicino, 2017	*(roadmaps, technical reports, survey, media analysis and Google searches*)

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7. APPENDIX

Table A1. Dimensions considered in the survey analysis for the roadmapping process, legitimacy and guidance

Process	Questions
Roadmap features	Type of document (Roadmap; National Plan…)? Focus (Floating offshore; Offshore wind; Ocean energies, etc.)? Initiative (government, stakeholders' coalitions, companies, etc.)? Indicate who participated in formulation? Date (start & publication if available)? Follow-up procedure?
Influence on the direction of search (*guidance*)	Document helps networks of actors and institutions improving the visibility of the offshore wind development? How? Set technology development goals and time frame? Define steps? (Y/N) Establish goals or milestones for different steps? Present future outlooks of offshore wind energy against competing technologies? Preference for domestic manufacturing (explicit)?
Legitimacy	Did roadmap formulation process and proposals contribute to increase legitimation? In particular, by helping in the formation of a vision and expectations? Is the regulation (e.g. codes and standards) sufficiently developed and aligned with the needs of technology upscaling? How much resistance is faced by the technology before and after receiving permit?

Figure A1. Content Analysis (Analysis performed with CorTexT Manager Application, from the CorTexT platform (www.cortext.net))

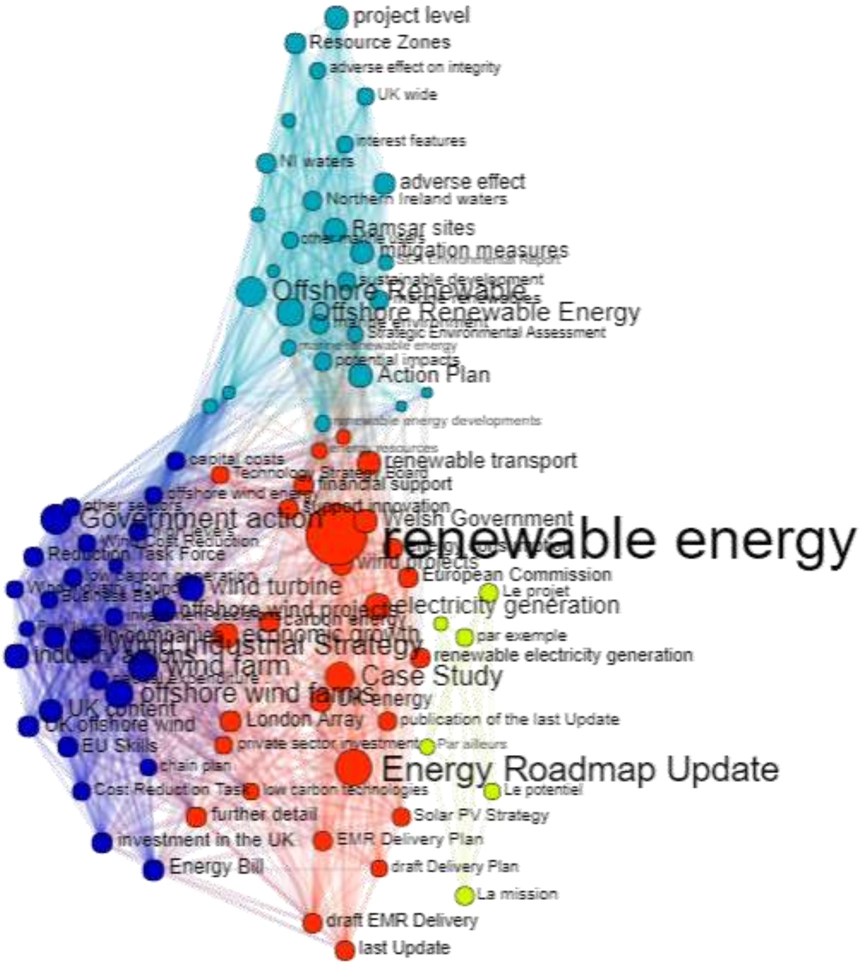

Table A2. Top 35 terms in the Roadmaps (Analysis performed with CorTexT Manager Application, from the CorTexT platform (www.cortext.net))

No.	Years	2010	2011	2012	2013	2014	Total
1	Renewable energy	11	172	22	135	1	341
2	Offshore Renewable (Energy)	10	10	50	3	3	76
3	Energy Roadmap Update	0	0	0	74	0	74
4	projet	0	0	0	37	0	37
5	Wave energy	0	0	0	0	34	34
6	Case Study	0	11	0	18	0	29
7	Ramsar sites	0	0	24	0	0	24
8	mitigation measures	0	0	24	0	0	24
9	electricity generation	1	10	3	10	0	24
10	Action Plan	1	7	9	5	0	22
11	renewable transport	0	16	1	5	0	22
12	offshore wind farms /projects	1	8	0	13	0	22
13	potential	0	0	0	21	0	21
14	adverse effect	0	1	19	0	0	20
15	wind farm	2	0	4	13	0	19
16	Welsh Government	0	12	0	7	0	19
17	wind turbine	2	8	1	8	0	19
18	Resource Zones	0	0	18	0	0	18
19	economic growth	0	7	0	9	0	16
20	wind projects	0	8	0	6	0	14
21	energy consumption	0	8	0	5	0	13
22	marine environment	0	4	9	0	0	13
23	UK energy	0	4	0	9	0	13
24	Northern Ireland waters	0	0	13	0	0	13
25	marine renewables	0	4	7	2	0	13
26	financial support	0	8	0	2	0	10
27	carbon energy	0	5	0	5	0	10
28	London Array	0	0	0	9	0	9
29	Energy Bill	0	0	3	6	0	9
30	Wind Industrial Strategy	0	0	0	5	0	5
31	investment in the UK	0	1	0	4	0	5
32	Government action	0	3	0	0	0	3
33	UK offshore wind	0	0	2	1	0	3
34	EU Skills	0	0	0	1	0	1
35	chain companies	0	0	0	1	0	1