Legitimation and Guidance in Energy Technology Upscaling – The Case of Floating Offshore Wind

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Abstract

This research studies the role of the formation of collective visions and plans in accelerating the upscaling of emerging low-carbon innovations. We analyze the national roadmaps that have been developed for offshore wind energy in deepwaters, i.e., more than 50 meters deep where there is high potential of resources but whose technology is still immature. The analysis focus on how actors create legitimacy and guidance to prepare the growth of the system. The results points to different types of guidance depending on the technological and institutional context, particularly a higher external openness with technology maturity and government involvement. A survey of actors' opinion complements the roadmaps analysis revealing the tendency for overinflating expectations. In addition, it suggests roadmaps have a positive but limited impact on technology development. Policy implications include recommendations for managing the process of formation of visions and legitimacy of new technologies entering into upscaling.

Keywords: legitimation; guidance; up-scaling; roadmaps; offshore wind energy.

Highlights:

- Legitimation and guidance are key innovation processes in technology upscaling
- We study expectations formation (legitimation) and sharing (guidance) through roadmaps analysis
- The empirical setting is floating offshore wind which enters into upscaling
- Types of guidance change with technological maturity and government involvement
- Survey indicates that roadmaps have positive but limited impact on technological dynamics

1. Introduction

Energy systems have undergone a spectacular growth over the last century and were accompanied with an increase in size and energy conversion capacity of energy technologies (Smil, 2008). The first mass manufactured car, Ransom Old's Curved Dash, featured a 10 horsepower engine in the early 20th century, while the average new vehicle in the US had 140 horsepower by 1975. Wind turbines, a typical example of an energy supply technology, saw the rated capacities growing from the tens of kilowatts in the early 1980s up to 5 MW and more today (Smil, 2008; Wilson, 2012). Many technologies went through a process of intense upscaling at some stage of their life cycle. 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 unit economies of scale to reduce costs and a further impetus to innovation processes (Sahal, 1985; Luiten & Blok, 2003; Wilson, 2012). The need to reduce emissions to implementing the Paris Agreement should increase the focus of policies and innovation efforts on upscaling alternative lower emission technologies including new methods of energy storage (Waterson, 2017) and floating offshore wind (Rodrigues et al, 2015).

Technology upscaling requires the mobilization of resources in a context surrounded by several uncertainties on technologies and markets (Bergek et al., 2008a; Kemp et al., 1998). This implies a minimum acceptance of the technology and its conformity with the current norms and values (Johnson et al., 2006; Zelditch, 2001; Suchman, 1995; Aldrich & Fiol, 1994). Legitimation is a prerequisite for the upscaling of new technologies because of the positive effects on the provision of resources by investors, policy-makers and users (Bergek et al., 2008b; Hekkert et al., 2007; Markard et al., 2016). In addition, it is necessary to direct the actors to activities aiming at the upscaling of the technology. Influence on the direction of search or guidance are terms used to express the necessity to direct the resources of both the established and new actors into critical activities for technology growth including experimentation of larger technologies, building of supply chains or demand articulation (Bergek et al., 2008a). Therefore we expect that technology upscaling involves the formulation of collective visions and expectations as well as some consensus on the strategies to follow.

The creation of legitimacy and guidance are important innovation processes in the formative and transitional phases of new technologies. Legitimation has been the object of a rising literature that examines the way early actors create legitimacy for new products, particularly in new technological innovation systems (Binz et al., 2016; Markard et al., 2016; Bergek et al., 2008b). However, the construction of guidance is still not well researched (McDowall et al, 2012), let alone its relationship with the process of legitimation.

This paper aims to answer the question: How innovation systems grounded on emerging low-carbon technologies prepare for upscaling and growth? 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).

We argue that upscaling of low-carbon energy technologies requires extra-technological factors including a collective strategy and a minimum of social acceptance of the technology. Roadmaps can help in these innovation processes, but their guidance co-evolves with the degree of maturity of the innovation and their effectiveness is contingent on the participatory character and involvement of key players (investors, governments, users and so on).

The analysis contributes to consolidate the definitions of legitimation and guidance and to a better operationalization of these processes. The theory assigns public opinions and institution preferences to legitimation, and policy action plans and collective strategies to guidance (Borup et al., 2013; Bergek et al., 2008b). However, the distinction is still unclear at the conceptual level, let alone for the analyst in the practice (Borup et al., 2013). The substance of legitimation and guidance and the relationship between them remains largely unknown in the literature and so this study aims to bring some light to these crucial innovative processes.

The remainder of the paper is structured as follows: Section 2 reviews the innovation processes in the formative years with a particular attention to legitimation and guidance. Section 3 explains the methodological approach followed to operationalize these processes as well as the empirical setting. Section 4 presents the results of the roadmaps analysis and of the survey. The last section discusses the findings and their implications for the policy and the theory.

2. Creation of legitimacy and guidance for growing innovation systems

In the early phases of innovation, new technologies suffer from the 'liability of newness' (Freeman et al., 1983) because they are perceived as strange or unfamiliar and promoters find unclear opportunities in their development.

In a technological innovation system perspective, the success 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). The emergence of such innovation systems has been conceptualized in terms of 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 the enlargement of both the technology and industry in more advanced stages (Bergek, 2008a).

Two processes are particularly critical for system development in the early years of technological innovation systems (TIS) (Suurs et al, 2009; Hekkert & Negro, 2009; Markard et al, 2016): legitimation and influence on the direction of search. These two key system building processes co-evolve with other five functions which are equally important in the formative phase of the system: knowledge creation, entrepreneurial experimentation, resource mobilization, market formation, and development of positive externalities (Bergek et al, 2008a; Hekkert et al, 2007). For instance, in the diffusion stage of potable reuse TIS in California legitimation and direction of the search strongly interacted between each other and with resource mobilization, entrepreneurial experimentation and market formation (Binz et al., 2016).

Legitimation refers to the degree of *acceptance* of the technology and its *conformity* with the current institutions (Johnson et al., 2006; Zelditch, 2001; Suchman, 1995). It is essentially 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). Legitimation results from a socio-political process by which expectations are formed and shaped in favor of the technology (Aldrich & Fiol, 1994). In the context of technological innovation systems, legitimation is a prerequisite for getting access to critical resources for the growth of new TISs (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). Legitimation is therefore the process of shaping expectations and improving the desirability of the emerging system (Negro et al., 2007; Bergek et al., 2008b).

The creation of legitimacy is a process that can be steered by the stakeholders. Legitimacy is also prescriptive as remembered by Zelditch (2001). In the original formulation, Aldrich & Fiol (1994) posits that entrepreneurs construct legitimacy gradually by increasingly building trust, reliability, reputation, and institutional legitimation. 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 & 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). Geels & Verhees (2011) show how decisive was the creation of positive meanings in the early years of nuclear energy in the Netherlands to influence investments and external support, but also that the legitimacy needed to be maintained in the later stages of growth of the new technology.

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 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 the future development, being increasingly used by advocacy coalitions and governments in emerging technologies or industries, particularly 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. Hence, they contribute to align key actors and to guide their future behavior (McDowall, 2012). 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). However, the effectiveness of roadmaps in aligning strategies depends 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 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). Targets set by the government are naturally more credible then when result from the initiative of specific industry or technology advocacy coalitions, where they can have an additional role of policy lobbying for changes in the regulation (Amer & Daim, 2010). As Jacobsson and Lauber (2006) suggests from the study 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).

Box.1 Indicators of legitimation and of influence on the direction of search (cf.Bergek et al., 2008a)

Legitimation:

- the extent to which the TIS is aligned with the current legislation and the dominant system of values in industry and society,
- the way that legitimacy constrains demand, legislation and firm behavior; and
- the determinants of legitimacy (what, who or how).

Influence on the direction of search:

- views on market potential,
- incentives and the relative advantage, e.g. subventions and taxes on energy services,
- regulatory pressures, e.g. minimum performance levels, and
- the articulation of demand from leading clients.

Legitimation and guidance are typically interdependent (see Box 1) and related through expectations. While legitimation refers to the process of formation of expectations around the technology, guidance deals with the impact of expectations on collective strategies. For example, legitimation processes create “strong expectation for what is likely to occur” (Johnson et al., 2006, p.72). Bergek et al. (2008a: 417) notes that: “Legitimacy also influences expectations among managers and, by implication, their strategy (and thus the function ‘influence on the direction of search’)”.

Expectations are real time representations of the future which 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 such as 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).

Given that system change accelerate when two or more processes interact and spark virtuous cycles (Hekkert et al., 2007; Suurs et al., 2009), the interaction between legitimation and guidance can help us understand how new TISs prepare for growth.

In the following, we focus on processes of expectation construction to mobilize resources and enable the technology upscaling, i.e., the “change in gears” in the growth of emerging technologies and industries. We analyze (i) the process of formulation and outcome of collective strategies, (ii) the effect of these collective strategies in the general formation of expectations and institutions, and (iii) the relationship between them and the impact on system change. We expect influence on the direction of search to be greater in the case of clear guidance issued from broad 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). And, finally, strong direction and higher legitimacy should relate to the maturity of the innovation systems and its preparedness to scale up.

3. Methodology

This research seeks to understand the effect of planning in the up-scale of new sustainable energy technologies in order to answer the following question: *How **legitimation** and **guidance** contribute to accelerate the growth of low carbon energy technologies?*

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 the result of negotiation processes between different anticipations of the future (Rip, 2012). They articulate and convey (shared) visions & expectations on the future of the technology and translate them into broad guidelines for action. Therefore 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).

We analyze the roadmaps (and equivalent documents) that have been published in the context of emerging offshore wind energy in deepwaters (Table 1). 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, 2016). Subsequently, to further check the results of that assessment, we perform a social network and a content analysis of the roadmaps using a powerful computer software package used in social sciences: CorTexT Manager (application available in the CorTexT platform: www.cortext.net).

The actors' survey validates the expectations formulated in the roadmaps. 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 were questioned on they perceived 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, 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. The entities comprise companies (e.g. technology providers, developers) and other organizations (e.g. research centers, government agencies, consultants). They participated in demonstration projects, reported interest in the technology in newspapers (different media), or published reports in the field. 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 1 Roadmaps and equivalent documents analyzed

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

4. Results

We study the elements in the roadmaps that aim to set the direction inside the system and to improve the attractiveness of the TIS (section 4.1), and the creation of expectations and institutions in the field (section 4.2) before confronting these insights with the results from a survey of opinions (section 4.3).

4.1 Roadmaps and Guidance

The effect of roadmaps in the guidance depends on its 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 technological requirements identified are identical across the different roadmaps. They refer to similar needs for the up-scale 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 (we develop further this point in the section 4.2). This agreement signals a relatively shared perspective (in this community) on the "structuration" of the innovation system, as part of the process of up-scaling and transition to the main markets.

The promotion of a new domestic industry is another feature of the roadmaps. All documents have a strong national flavor, frequently pointing to the interest of developing competitive capacity and achieving first-mover advantages. The roadmaps defend the need to develop or reinforce the value chain at country level, namely by profiting from the existing strengths in complementary areas that are critical for the development of an “industry” around offshore wind. 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 metallurgy in Portugal) with opportunities to broaden their markets and to increase their export prospects. 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.

More specific goals 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. These 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 proposals offered by the roadmaps, we performed a more in-depth content analysis of the roadmaps with the help of specialized software (CorTexT Manager). The analysis reveals three main areas of attention in the roadmaps, related to renewable energy, offshore energy and government (see Appendix 1.). These areas globally overlap with the three main areas identified in the TIS literature, suggesting that the actors recognize the importance of creating networks and institutions for the growth of the new technology.

Therefore, the roadmaps and equivalent documents contribute to influence the direction of search in some way or another. Comparing their outcomes with the indicators suggested by Bergek et al (2008a), it can be argued that they contribute to foster 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 have the capacity to attract actors from other sectors and stimulate them to engage in innovation activities.

4.2 Roadmap and Legitimation

We assess the impact of the roadmaps in the formation of 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 depth of study and balance of expectations. Roadmaps present a (more or less) comprehensive diagnostic of the technology as well as of the country's strengths and weakness 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).

Actor inclusiveness varies in extent and nature as regards to formal recognition of involvement, but participatory character of the process is often difficult to assess from documental analysis. Roadmaps show some preoccupation with the engagement of key actors during the formulation of strategies (at least consultation). They also attempt to achieve wide diffusion and to 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 exist in terms of level/type of actor involvement and thus on the nature of consensus achieved constraints the capacity to influence on the direction of search. Less inclusive roadmaps are more vulnerable to reflect the interests of specific groups (excluding some others).

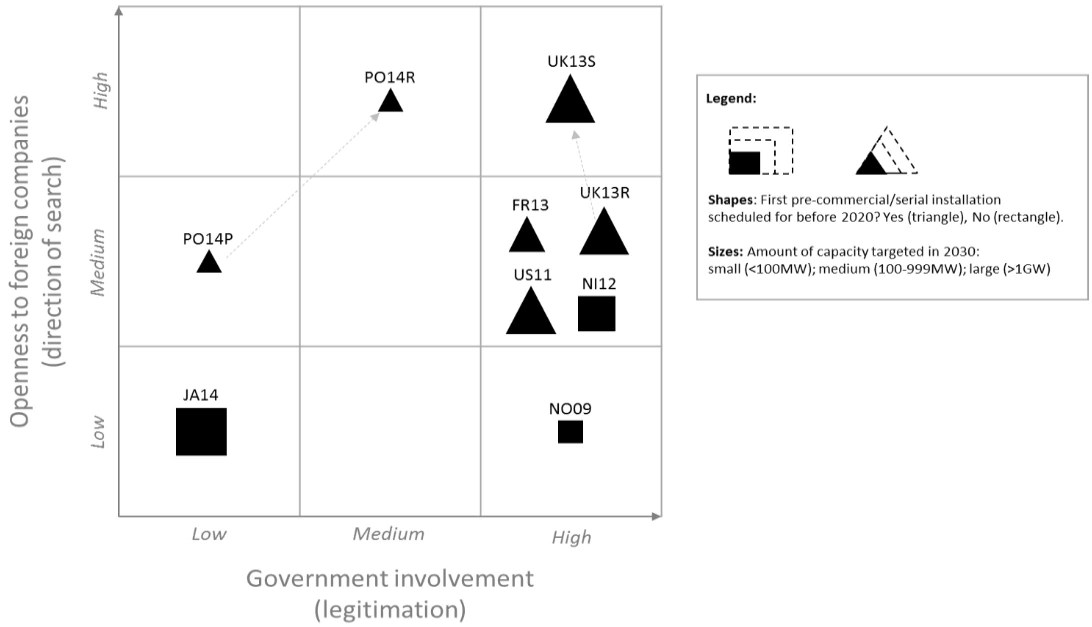
The origin of roadmaps - government led versus actors' initiative - impacts their content and capacity to create legitimacy. Government can enact key policies and its participation ensures support to the direction set. The effect on expectations depends on the perception of stability of commitment given 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 feasibility of the visions, particularly when they involve key actors in the field. They stress the need for government endorsement of the preconized visions and proposals to reinforce their legitimacy and influence on further development – in this sense they can also be regarded as a documental piece of lobbying.

Formation of technology specific institutions also emerges as a priority to raise social acceptance of the technology, in the generality of roadmaps. Standards and regulations need to be in place before market take-off. Roadmaps recognize that and often make specific recommendations, such as the implementation of maritime spatial planning, anticipating and addressing potential conflicts with existing activities and communities. Preoccupation with improving public perceptions is another important issue in the documents under review. Roadmaps often present floating offshore wind as a solution to avoid the acceptance problems associated with fixed wind turbines installation close to the coast (not to speak onshore). They sometimes point to survey results to support these assertions (e.g. UK13S), in what is a clear attempt to improve the public opinion on the technology.

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 take the initiative of these directive documents, or by using roadmaps as a lobby instrument for more active policies. However, differences in respect to actor involvement impact the credibility of consensus. Despite the relevance of social aspects, a content network analysis (Appendix 2) reveals that these types of issues are missing from the list of the most important terms in the roadmaps. This result may indicate limited strategies for enhancing public acceptability.

Additionally, we operationalize the content analysis by defining indicators of guidance and legitimacy and assessing the effect of roadmaps in these measures. This allows us to interrelate these two important innovation processes with the degree of development of the system in the different contexts. 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). We acknowledge that regulation simultaneously signals legitimation and influences the attractiveness of the sector (potential endogeneity issue), but we come back to this issue later. Figure 1 compares the roadmaps in 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 documents alike listed in Table 1. 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 separated report (Bento & Fontes, 2017). Regarding “Government involvement” in the roadmap creation, countries were sorted following the information on the “Initiative” of the roadmap.

The results show that government involvement and proximity to deployment 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 that no triangle shows “low” openness. Therefore, the results reinforce the earlier conclusions about the influence 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 survey

The expectations conveyed in the roadmaps are confronted with the opinions of the major players in the field expressed in an inquiry. 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, 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.

Figure 2 Countries were commercialization will first start

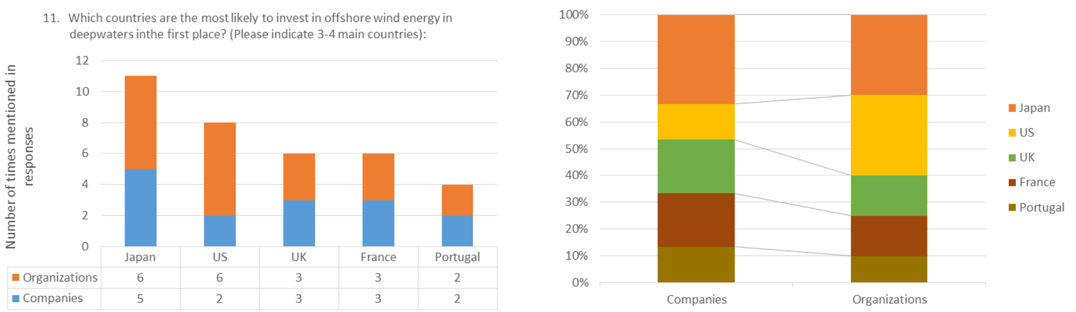
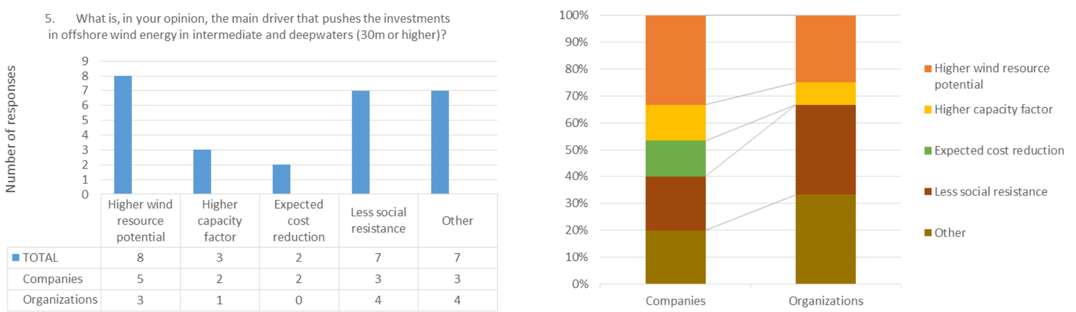


Figure 3 Drivers of investment



There are also substantial differences between companies and other organizations concerning the timings and readiness of the system to grow. Companies are clearly more optimist than organizations concerning the availability of system resources (Figure 4). Contrary to other organizations they do not perceive a lack of core resources (e.g. knowledge, infrastructure) or a lack of coherence in the system. Companies also expect relatively faster and greater cost reductions, which would allow floating offshore wind to become competitive more rapidly

(Figure 5). As a consequence, they are more optimistic concerning the commercialization, which they expect to start before 2020 (Figure 6). In contrast to companies, 70% of the 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

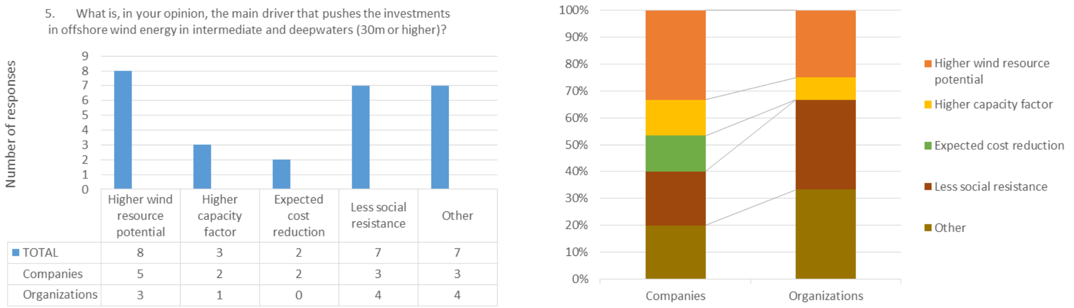


Figure 6 Cost reductions and technology competitiveness

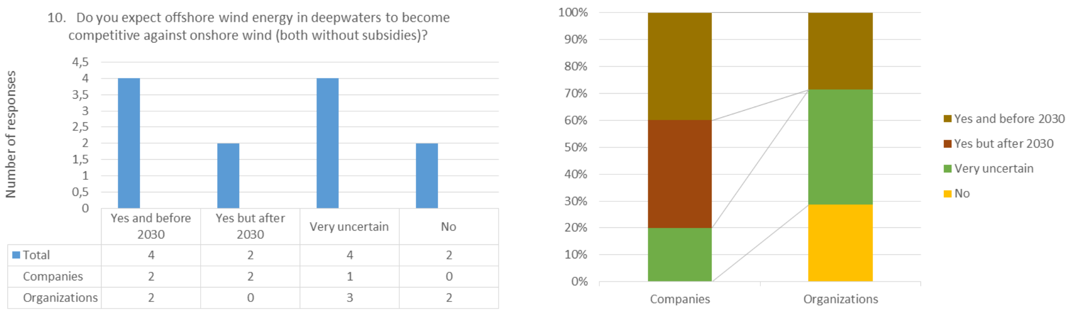
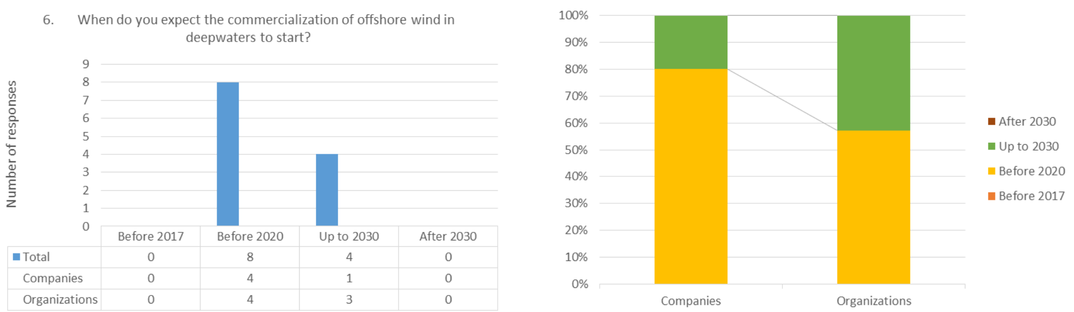
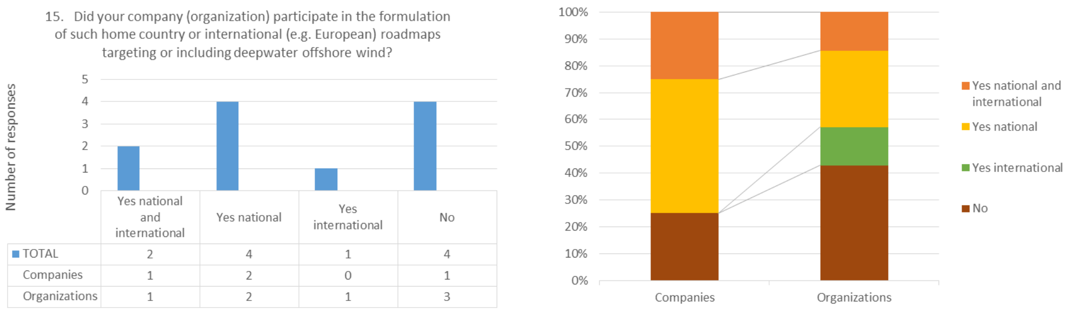


Figure 5 Expected year of commercialization



Overall, the survey reveals that actors perceive roadmaps as having a ***positive, though limited, impact*** in 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 6). Thus, it is possible that their positions prevailed in the final consensus that was in the basis of the roadmaps.

Figure 6 Participation in roadmapping



5. Discussion and policy implications

The paper aims to understand the role of legitimation and influence on the direction of search in the upscaling of emerging technologies. It studies the role of these innovation processes in the emergence of floating offshore wind energy, which is arguably undergoing a process of expansion in order to achieve its full potential in the generation of low carbon energy. We examine the formation and sharing of collective expectations and visions through the analysis of the roadmaps because of their role in promoting expectations and translating them into strategies that contribute to reinforce the acceptance and attractiveness of the new technology. A survey of the actor's opinion complement the roadmaps' analysis to compare results and discern any effects in the expectations on the technology.

The results shows that roadmaps can contribute to the performance of key processes like legitimation (acceptability) and guidance (attractiveness). However the influence of roadmaps is contingent to procedural and contextual aspects including the involvement of public actors (legitimation) in the development of floating offshore wind. The analysis points to different types of guidance depending on the technological and institutional context. For instance, the tendency for higher external openness (as an indicator of guidance) appears to be related with government involvement (as an indicator of legitimation), as well as with approximation of technology deployment (stage of technology). The survey of actors' opinion confirm that roadmaps have a positive, although limited, impact on the technology development and tend to overinflate expectations.

The analysis has implications for the theory in several ways. In terms of the operationalization of the concepts, we approach the legitimation and direction of search in terms of government involvement and openness to foreign actors, respectively. These measures are in line with the canonical definitions of the processes (Bergek et al., 2008ab; Hekkert et al., 2007; Borup et al., 2013), but have some overlaps as government involvement simultaneously signal legitimation and influence on the direction of search. In what concerns the relationship between the two processes, we distillate three dimensions at least. First, the inclusiveness of the process that leads to the roadmap affects its legitimacy and thus its chances to become more widely accepted by the actors (McDowall et al., 2012). Second, agency and power balance influence the legitimacy of roadmaps. Visions and guidelines can reach higher social repercussion when no particular opinion (e.g. of the incumbent) prevailed in the negotiation process (Geels, 2014). Third, inflated expectations may undermine the confidence in the technology. The tendency for overpromising reduce the trust in the guidelines over time (Bakker et al, 2011). In the case of floating offshore wind, for example, overoptimism on the start of diffusion undermine the credibility of the plans and thus their influence in the mobilization of the resources.

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 certain participation and inclusiveness of the process in order to enable high participation of the different actors. Visions and guidelines should be representative of the opinions of the majority of stakeholders and result from a negotiation process that is not captive from the interests of the more powerful actors. Finally, the ambitions should be reasonable and based on rational expectations to increase the confidence in the targets and in the recommended strategies for action.

The results have limitations that lay the ground for further research. First, ongoing public debates may affect the attractiveness of technologies and contribute to accelerate innovation dynamics. Discursive analysis could unveil the process of creation of legitimacy and how it affected the guidance, contributing to accelerate (or hinder) technology upscaling. Second, targets and strategies conveyed in roadmaps can change the social perception on the technology. The analysis of the investments over time would unveil possible effects of the publication of roadmaps. Or similarly one could track the impact on the development of technology-specific institutions (e.g. standards) (Markard & Hoffman, 2016). Finally, the study of more cases could deepen our results about the co-evolution of legitimation and guidance in the upscaling of technologies with the analysis of both present and historical cases.

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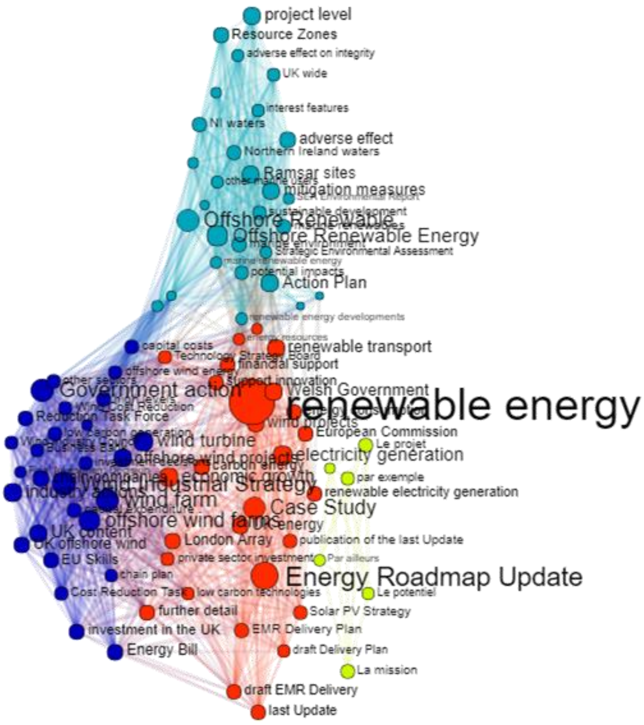
Appendix 1. Content Analysis (Analysis performed with CorTexT Manager Application, from the CorTexT platform (www.cortext.net))



Appendix 2. 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