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Transitions in the energy system: The strategies of new firms commercializing advanced renewable energy technologies

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Abstract

The paper discusses the entry strategies adopted by research-based firms introducing advanced renewable energy technologies in the electricity production sector. Because these firms operate in an environment that combines fast technological change and strong incumbent power, this provides a good setting to address the interactions between niche innovators and regime incumbents. Drawing on contributions from the literatures on sustainability transitions and on strategic management of technology we build an analytical framework to address the conditions faced by the new entrants, the strategies they adopt, the nature the relationships they establish with incumbents and the attitudes of the latter towards their technologies. This framework is applied through in-depth case studies of new firms in two energy niches that display different levels of technological maturity: wind and wave energy. The paper presents preliminary results from a first set of case studies, which provide some insights into the "commercialisation environment" prevailing in those fields. They suggest that research-based firms tend to depend on the complementary assets possessed by incumbents, but have conditions to protect their technologies; and that the technology is relevant for (at least some) incumbents, which show interest on them, or are directly involved in their development/use. This is, in most cases, conducive to "cooperation" strategies, which assume different forms, according to the stage of development of the technology and its proximity to incumbent competences and business models. The results, although still preliminary, contribute to a better understanding of how these firms act to introduce their technologies, how they relate with regime actors and how the conditions found in the particular environment where they operate influence their potentially disruptive behaviour. Thus, they adds to our knowledge about the role of entrepreneurial firms in energy transitions and provide some insights into nature of the (business-level) niche-regime interactions that take place along these processes.

Keywords: energy transitions; actor behaviour; niche-regime interaction; commercialization strategies

Transitions in the energy system: The strategies of new firms commercializing advanced renewable energy technologies

1. Introduction

This paper investigates the strategies adopted by new research-based firms to commercialise renewable energy technologies that can contribute to a sustainable transformation of the electricity production sector.

Given its scale, complexity and contribution to the functioning of modern societies, the energy system can be described as a major socio-technical system (Verbong and Geels, 2010). Transformations in the way key societal functions are fulfilled – or socio-technical transitions - are complex processes that can place along decades and involve far reaching changes not only at technological but also at institutional, organizational and social levels. These processes have been addressed by the various streams of the sustainability transitions literature (Markard et al, 2012). One of these streams – the multi-level perspective (Geels, 2002) – conceptualises transitions as the product of interrelated processes at three levels: niche, regime and landscape. Radical innovations that may come to play a role in regime transformation are developed in niches that act as protective spaces, temporarily shielding them from the selection pressures exerted by the dominant regime. Changes at the landscape level may introduce some destabilisation in the regime and create opportunities for niche innovations, which, may break through and profoundly transform or even overthrow the dominant regime.

However, previous research has shown that the way these processes unfold varies, revealing differences in the role played by niche and regime actors, in the type and extent of the interactions between them, as well as in the final outcome (Geels, 2002; Foxon et al, 2010; Kemp and Van Lente, 2011). A number of transition routes or patterns have been suggested by the literature (Geels and Shot, 2007; Smith et al, 2005) and research has increasingly focused on the actual process of niche breakthrough and on the implications, for niche development, of its interaction with the regime within which it emerges (Shot and Geels, 2007; Smith and Raven, 2012). This also called for a more detailed investigation of the micro-level behaviour of actors involved in these processes (Markard and Truffer, 2008; Farla et al, 2012), both niche innovators striving to develop, legitimise and diffuse their technologies (Avdeitchikova and Coenen, 2013; Kishna et al, 2011; Wustenhagen and Wuebker, 2010) and powerful regime actors confronted with disruptive innovations (Smink et al, 2011; Thurnheim and Geels, 2012).

The objective of this paper is exactly to contribute to this micro-level research, by addressing the strategies of entrepreneurs introducing potentially disruptive renewable energy technologies in the electricity production sector and, in particular, their relationship with powerful regime actors – the large energy production and distribution companies and the large energy equipment manufacturers that dominate the sector.

A process of transition to sustainability is already underway in the energy system. While it is not yet clear how the process will unfold, a trajectory whereby niche innovations break through, overthrow and replace the established regime is unlikely, given the infrastructural nature of the energy system. Rather a process that involves some forms of interaction and integration between regime and niche actors and their technologies and practices, potentially resulting in some basic reconfigurations in the regime architecture, appears as more probable (Verbong and Geels, 2010).

Thus, even if transitions are complex undertakings involving a wide variety of processes and actors, it still appears to be relevant to look in some detail into specific aspects of the interactions taking place, at the micro-level, between individual actors. The analysis of the strategic behaviour of a particular group of niche actors – new research-based firms exploiting emerging energy technologies - may provide us with some insights into the strategies open to radical innovators and the nature of incumbents involvement in the development and diffusion of these innovations .

For this purpose we combine contributions from the sustainability transitions literature – in particular the MLP and other recent research on niche breakthrough – with contributions from the strategic management of technology literature. The former contributes to a deeper understanding of the ongoing transformations in the energy system: the tensions in the dominant energy regime; the opportunities they generate for new entrants endowed with new technologies and attitudes and the incumbents' attitude towards them (Jacobsson and Bergek, 2004, Verbong et al, 2008; Foxon et al, 2010; Sine and David, 2003). It also provides insights into the generic mechanisms at work as part of the process of niche development and niche breakthrough (Kemp et al, 1998; Hendry et al, 2007; Raven, 2007; Schot and Geels, 2007; Smith, 2008; Smith and Raven, 2012). But, while the disruptive role of entrepreneurs and their capacity to gaining other actors – namely regime actors - to support the development and diffusion of their innovations is widely recognised (Raven, 2007), this literature still pays limited attention to their strategic behaviour (Alkemade et al, 2011). In particular, to how entrepreneurial firms effectively act/interact with powerful regime actors to introduce their potentially disruptive technologies. The strategic management of technology literature contributes to fill this gap, by providing conceptual instruments to address the conditions for exploitation of new technologies by new entrants, in industries dominated by large incumbents (Teece, 1986; Arora et al, 2001, Colombo et al, 2006) and, more specifically, to assess their strategic positioning (Gans and Stern, 2003).

Combining these contributions we develop a framework to investigate the strategies of new firms exploiting niche technologies and their interaction with regime incumbents. In this paper we present preliminary results, based on a small set of cases, where this framework is applied to the analysis of Portuguese research-based firms active in two renewable energy niches – wind and wave – in different stages of development.

2. The changing environment in the electricity sector

2.1 Conceptualising transitions in the energy system

New firms developing renewable energy technologies that have an application in the process of electricity generation and/or distribution are entering a sector that is both highly complex and undergoing profound changes.

The sector is responsible for the production and supply of a basic resource – electricity – whose availability is critical for the functioning of the economy and the society at large. It is one of the largest sectors in the economy, encompassing a wide range of activities associated with the production, transmission and distribution of electricity, which tend to be highly centralised, given the infrastructural nature of the system. Until recently the sector relied on relatively mature technologies and incremental innovation. It was controlled by large national utility operators (frequently under public monopoly) and by large equipment manufacturers (often multinational companies), being characterised by strong economies of scale (Jacobsson and Bergek, 2004).

But more recently the sector has been experiencing profound changes, driven by the liberalisation of energy markets and by pressures for reducing dependency on fossil fuels (Jager-Waldau et al, 2011; Verbong et al, 2008). The evolution of the sector and the impact of these changes on the sectoral regime have been addressed by authors drawing on a sustainability transitions conceptual framework (Verbong and Geels, 2010; Foxon et al, 2010; Jacobsson and Bergek, 2004; Hekkert and Negro, 2009). Among the various streams of the transitions literature, the multi-level perspective (Geels, 2002; Geels and Schott, 2007), provides a useful analytical framework to understand the structural rigidities that characterise this large infrastructural system, as well as the conditions in which a process of transition to a more sustainable system may unfold (Verbong and Geels, 2010).

According to this framework changes in large socio-technical systems - as the energy system - are difficult to achieve because they involve major transformations on the ways the system fulfils its functions, which are embodied in the dominant socio-technical regime, characterised by strong path dependence. The regime accounts for the stability of the system, guiding and constraining the behaviour of its actors and guaranteeing its own reproduction[1]. However, pressures originating at the landscape level may create tensions and lead to regime destabilisation, providing opportunities for the emergence of innovations with a transformative potential that are being developed in niches - such as those associated with renewable approaches in the energy case. Niches are protected spaces that shield innovations from the regime selection environment, but where processes of nurturing and empowerment may also take place, which can ultimately lead to innovations breaking out of the niche and bring about regime shifts (Kemp et al, 1998; Smith and Raven, 2012). However, these processes are far from being straightforward, requiring profound changes not only at the technological but also at the social, institutional and political level, which are resisted by regime actors and institutions. Besides, they may unfold along different paths, involving a variety of developments both internal to the niche, between competing niches and in the interplay between niche and regime (Geels, 2005; Raven, 2007) and may lead to different outcomes.

It is therefore relevant, from the standpoint of our research, to try to work out what changes are taking place, as part of the development of the renewable energy niches, in order to understand which is the space for new firms introducing emerging renewable energy technologies and whether and how these niche-level actors are interacting with regime actors.

2.2 The emerging renewable energy sector

Drawing on the above approach, it is possible to argue that the changes underway have already introduced some destabilisation in the prevailing electricity production regime, leading to alterations in the sectoral knowledge base and in the industrial structure. The liberalisation of the energy sector, that took place in the majority of European countries, brought about the extinction of public monopolies, with transmission of ownership and management to private companies operating in a competitive market (Jorgensen, 2005). It also forced the separation between energy production, transmission, distribution and commercialisation, which required established companies to reorganise their activities and reconfigure their strategies (Markard and Truffer, 2006) and made market entry comparatively easier, at least in some segments (Verbong et al, 2008).

The need to achieve a lower dependence on fossil-fuel and pressures towards cleaner production led to the introduction of policies promoting the introduction of renewable energy sources (Jager-Waldau et al, 2011). This opened new opportunities for potentially disruptive renewable technologies that were

[1] In the case of the electricity system, the socio-technical regime is characterised by the interplay between "material and technical elements" including generation plants, production resources, grid infrastructure; "networks of actors and social groups" including utilities, large industrial users, domestic consumers and government bodies with responsibility in the sector; "formal, normative and cognitive rules that guide the activities of actors (e.g. regulations, belief systems, guiding principles, search heuristics, behavioural norms)" (Verbong and Geels, 2010: 1215)

being developed in niches, given the still high technological and market uncertainty associated with their exploitation. Competing technologies based on different energy sources and on different modes of exploiting these sources were in different stages of maturity and underwent diverse development processes (Verbong et al, 2008). Some of them have now reached a stage where wider commercial exploitation became viable, especially in countries that introduced market-oriented policies. This is particularly the case of wind energy that is the most widely diffused renewable source, despite the problems associated with its intermittent nature (Kaldellis and Zafirakis, 2011).

The creation of a growing space for renewable energies drove a renewal of the industry knowledge base. There was a fast increase in the level of R&D, patenting and innovative activity, largely fuelled by government policies that sponsored research or provided incentives for the development or implementation of renewable technologies (Ayari, 2012; Johnstone et al., 2010). The emergence of technologies that substantially departed from the incumbents' knowledge base created opportunities for the new firms that developed or exploited them. The distributed nature of some of the new energy sources also favoured new entry, which was further encouraged by a variety of incentives for their production and use (Schoettl and Lehmann-Ortega, 2010).

These transformations challenged the dominant position of energy utilities (Duncan, 2010) and led to some readjustments in the actor composition and balance of power (Verbong and Geels, 2010). However, although the introduction of renewable technology may have created some internal tensions in the regime and caused some reconfigurations in its architecture it did not radically change the system basic structure or dislodged its dominant players.

First of all, in most countries renewable sources still provide only a minority of the electricity produced and the system is still largely fed by conventional sources that, together with large scale hydropower plants, still shape the electricity dominant regime (IEA, 2011). This is a centralised regime that matches the competence and assets of large regime players (Duncan, 2010). Furthermore, with some exceptions (e.g. wind is some locations), energy production from new renewable sources still did not reach cost parity with that originating from fossil fuel sources and also raises several system level problems (e.g. grid integration) (Jacobsson and Bergek, 2004; IPCC, 2011). Thus, the renewable business is strongly dependent on government policies, which may change, associated with political and economic cycles (Verbong et al, 2008). Consequently, its expansion is affected by the capacity of its promoters - companies or trade associations, research organisations, social movements - to influence the decisions of governments and other critical actors (Jacobsson and Lauber, 2006). It is also vulnerable to "capture" by powerful regime actors (Kern and Smith, 2008; Smink et al, 2011).

On the other hand, regime actors have become increasingly engaged with niche-level innovations, being able to absorb and integrate at least some of them (Bergek et al, 2013). In fact, along the process of development and diffusion of renewable energies, it was possible to observe a growing involvement of some regime actors with the more mature technologies - in particular those that were closer to their competence base, both in technological and in organisational terms. This involvement is likely to have influenced the development trajectory of some technologies and their mode of deployment (Geels and Schot, 2007), namely favouring large scale centralised systems that better match their competitive advantages. The case of wind energy is a good illustration of these effects. The configuration of the emerging sector, made it attractive to incumbent, both energy utilities or equipment manufacturers that were able to reconfigure their business, redeploying their assets and competences to enter the new field; and large firms that diversified from other sectors, attracted by favourable policies and often profiting from competences in complementary fields (e.g. metalomechanics or construction).

Thus, in more mature renewable segments where markets started to develop, regime actors ended-up joining and competing with the *de novo* entrants - firms that had pioneered the development of specific technologies and had been able to grow on the basis of innovation and first mover advantages (Dewald and Truffer, 2011).

2.3 Implications for new firms introducing advanced technologies

Which are the implications of these processes for new technology-intensive firms introducing advanced renewable technologies?

It can be argued that a renewable electricity production sub-sector has already emerged in those segments and countries where renewable technologies have reached maturity and achieved some market diffusion. This sub-sector is currently characterised by fast technological change and by an industrial structure where large established firms tend to occupy dominant positions. Moreover, it is closely interlinked – in terms of activity and actor composition - with the more global electricity production, transmission and distribution sector. Thus it can be expected that behaviour of the renewable energy actors will be influenced by the sector's operational and institutional logics.

However, the renewable energy field is diverse and heterogeneous and, as a whole, it is far from being stabilised. In fact, the promotion of energy production from renewable sources created incentives for the emergence of a variety of competing energy conversion approaches and technologies, giving rise to a diversity of trajectories. Currently we find technologies in different stages of development, market introduction and adoption, ranging from those that reached commercial stage and achieved some market diffusion (such as large scale wind conversion or first generation solar photovoltaics) to those where a dominant design is still to emerge (such as wave conversion) (Jäger-Waldau et al, 2011; IPCC, 2011). This has implications in terms of the conditions faced by technology-intensive firms operating in the respective niches, influencing the opportunities that are created and the way these can be exploited. It also influences the attitude of the firms established in the sector and of other key actors (capital providers, policy makers, consumer groups) towards new entrants and their technologies.

Regarding the opportunities open to the new firms, the positioning of powerful companies in more stabilised renewable segments, raised entry barriers and drove out entrepreneurs from the core activities. But even in these fields, there is still a variety of complex problems that require extensive technological developments (incremental innovations). These include problems associated with the operation of the actual technologies (efficiency, costs, reliability) and new system-level problems that emerged due to their distributed and intermittent nature. This creates opportunities for technology-intensive suppliers that offer established actors advanced solutions for these critical problems.

On the other hand, the still relatively unsatisfactory performance of renewable sources in terms of energy yield, costs and security of supply opens some space for the emergence of alternative designs (e.g. new modes of wind conversion or third generation photovoltaic cells) which are often being developed and tested by new firms. The same happens in the case of technologies that favour a distributed production system, as opposed to centralised or grid-connected systems. New entrepreneurial firms are also important actors in the case of emerging renewable sources that have not yet reached a commercial stage. In all these areas we observe a variety of competitive technologies being developed by different firms, often still at research or experimental stage (IPCC, 2011). The positioning of new firms in this type of activities is not unexpected. In fact, the opportunities created by technologies that depart substantially from the established knowledge base tend to be identified and exploited by new firms that originate from outside the industry (Winter, 1984). This is, namely the case of research-based spin-offs that base their competitiveness on the quick paced exploitation of knowledge originating from scientific research (Mustar et al, 2006).

Incumbent companies vary in their attitude towards less mature, fast evolving or still emerging technologies (Ansari and Krop, 2012; Bergek et al, 2013). Established companies are often reluctant to getting involved in the early exploitation of more immature technologies, given the high uncertainty and their lack of competences (Levinthal, 1997). Thus, as pointed out above, energy companies repositioning themselves in the renewable field, or companies diversifying from other sectors are more likely to invest in stabilised fields and technologies and in innovation promote projects that are closer competences and competitive advantages (Hockerts and Wüstenhagen, 2010; Duncan, 2010).

But the growing international competition in the energy area has quickened the technological pace and increased the pressure to invest in innovation, and thus the need to look for new technologies, or get involved in alternative technological paths (Hekkert and Negro, 2009). Thus incumbents may wish to keep an eye on the new developments, in order to follow-up (or even influence) their evolution and/or to guarantee an early position, once a dominant design starts to emerge (Sine and David, 2003). But they usually prefer to achieve this through collaborations that reduce the risks and costs involved (Dyerson and Pilkington, 2005). This may assume different forms, from simple technological watch, to participation in research activities (often coordinated by research organisations), to greater involvement with the firms that are developing the new technologies. The latter can include funding of entrepreneurial activities, participation in demonstration projects to test/validate the technology, alliances with firms whose technologies are perceived to have future potential, or answer to existing needs (Hockerts and Wüstenhagen, 2010; Dyerson and Pilkington, 2005; Teppo and Wüstenhagen, 2009). The presence and interest of large incumbents can be important for the development of the niches where these new technologies are exploited, since they convey resources and legitimacy and can make them attractive to other key actors, such as capital providers (Schot and Geels, 2007).

Thus, we are faced with a context that combines strong incumbent power and fast technological change and where at least some regime incumbents recognise the need to explore new trajectories and thus reveal interest in the niche technologies being developed by entrepreneurial firms. This combination creates a particular competitive environment that has implications for the interaction between the new firms exploiting niche technologies and the regime incumbents.

3. New firm strategies in conditions of incumbent dominant position

3.1 Conditions for entry of technology-intensive start-ups

The conditions faced by new entrants in an environment that combines fast technological change and strong incumbent power and the strategic opportunities open to them have been addressed by the literature on the strategic management of technology (Teece, 1986; Arora et al, 2001). According to this literature, the capacity to protect the technology and the conditions of access to a number of downstream resources or competences that are necessary to sell a complete product/service – the “complementary assets” - are basic elements in the start-up strategic decisions. In particular, it has been shown that when large incumbents control a number of key complementary assets, small technology-intensive entrants may benefit from adopting “cooperation strategies” (Gans and Stern, 2003), entering in relationships with them (Colombo et al, 2006).

Technology-intensive start-ups are typically small firms with strong knowledge competences, but limited financial resources and frequently missing market-related competences and networks (Arora et al, 2001; Mustar et al, 2006). Thus, when attempting to commercialise their technologies they have to make some strategic decisions regarding critical complementary assets. They can build (some of) them internally, can try to gain access to them, through market transactions or through alliances, or else, can focus on technology development and licensing, avoiding any involvement in downstream activities (Arora et al., 2001). The decisions made at this level are strongly influenced by the nature of the assets, in particular those that are key to capture rents from the innovation.

In fact, complementary assets can be generic and supplied by the market in competitive conditions, or co-specialised to the innovation (Teece, 1986). Co-specialised assets may not be readily available in the market, since their owners try to achieve control over them, and they may also be difficult to imitate, because they are built on the basis of a process of learning within the firm (Rothaermel and Hill, 2005). In these cases, access to these assets may require the establishment of a contractual relationship with the owner (Aggarwal and Hsu, 2009; Colombo et al, 2006; Shan et al, 1994). The problem is compound when such assets are owned by established, often powerful firms, which may not be easily gained to such relationships, or may use their position to appropriate a substantial part of the rents from the innovation (Rothaermel and Hill, 2005).

In the limit the new firm may choose to avoid engaging in the development of products/services and commercialise the technology instead (Conceição et al, 2011). However the literature describes a variety of vertical alliances where the owners of the needed assets - to whom the new firms technologies/products are particularly interesting (Rothaermel, 2002) - assume part or all the manufacturing and/or commercialisation activities (Colombo et al, 2006; Stuart et al, 2007). Indeed, in some sectors incumbents deliberately encourage the development of new and complementary technologies by research-intensive firms (Gawer and Cusumano, 2008; Orsenigo et al, 2001). These alliances also have benefits for the start-up, enabling it to access markets and supply chains; providing capital for technology development and sometimes conditions for the testing of its technologies/products and offering legitimacy (Baum et al, 2000).

But, although these alliances can be mutually favourable, they tend to be characterised by power asymmetry between partners (Shan et al, 1994; Rothaermel, 2001). This asymmetry increases the appropriability hazards, making new entrants vulnerable to the expropriation of their main (or even unique) asset (Teece, 1986). This may deter firms from establishing some types of alliances, unless they can resort to strong intellectual property protection (Katila et al, 2008). In the case of small firms, formal appropriation mechanisms, like patents, are often the only effective means of protection, being particularly important for technology suppliers (Arora and Merges, 2004). In summary, although firms run effective risks when partnering with powerful incumbents, they may need to consider that strategic option (and eventually obtain a return from it) depending on the characteristics of their innovation, the variety of potential partners and their incentive/opportunity to behave opportunistically, the value of the resources provided by the partner and the protection mechanisms available (Katila et al, 2008; Dyer and Singh, 2008).

3.2 The impact of the "commercialisation environment" on firms' strategic decisions

The strategies open to new technology-based entrants were addressed in detail by Gans and Stern (2003), who argue that the characteristics of the "commercialisation environment" constrain the choices to be made by the entrepreneurs. They define commercialisation environment along two dimensions - the extent to which innovation by the start-up precludes the incumbent's development and the relevance of incumbent complementary assets to the start-up – and devise a typology of environments and associated strategies. This framework is relevant for our purposes, since it addresses the type of conditions that may influence the attitude of incumbents towards the advanced technologies being developed by new energy firms and the nature of the relationships that may be established between both.

The environment labelled by the authors as "ideas factories" configures a set of conditions that is likely to emerge in the renewable energy sector. In this case, invention by the start-up precludes effective development by established firms, because the start-up ability to protect the technology makes its appropriation difficult; but established firms control the complementary assets required for its commercialisation. This environment is conducive to a "cooperation strategy", which may range from the licensing of the intellectual property, to the establishment of a variety of strategic alliances to, in the limit, the acquisition of the start-up. For incumbents, relationships with several innovative start-ups offer a fertile source of new ideas in fields where they have limited competences and/or where uncertainty is still too high and thus experimentation with a variety of competitive paths is still required (Raven, 2007). But, while they effectively reduce the start-up's investment in downstream assets (Arora et al, 2001) and offer advantages in terms of legitimacy building, very often they strengthen the basis for incumbents' advantage and thus their market power (Gans and Stern, 2003).

However, Gans and Stern (2003) also argue that when incumbent complementary assets are less important and the technology can be protected from appropriation - the "greenfield competition" environment - the start-up may consider the choice between collaborating and competing. The ability to control the development of platforms and standards is critical if the start-up decides to engage in product market competition. Cooperation is equally an alternative and in this case the start-up has stronger bargaining power and can define where and which conditions to cooperate.

3.3 A framework to analyse the strategic behaviour of new energy firms

In order to investigate the nature of the interactions between entrepreneurial firms and regime incumbents along the process of exploitation of the new renewable energy technologies, we developed a conceptual framework to address firms' positioning that builds on and extends Gans and Stern (2003) concept of commercialisation environment. This framework considers the interplay of three main analytical dimensions:

1) The relevance of incumbents' complementary assets for the new firm to capture the value of its technology.

   At this level we assess the start-up need for and mode of access to those assets. We distinguish, first of all, between firms that avoid engaging in the development of products/services based on the technology and thus *skip the need for those assets*; and those that at least partly engage in the activities necessary for such development and thus *require downstream assets* (Arora et al, 2001).

   In the case of those who need to gain access to some assets, we consider the established distinction between assets mostly *supplied competitively in the market* and assets co-specialised to the innovation and mostly *controlled by incumbents* (Teece, 1986).

   The need for assets is conducive to cooperation strategies, although the conditions in which assets can be accessed has implications for on the type of relation established.

2) The positioning of incumbents relatively to the technology exploited by the new firm.

   At this level we assess whether the technology is relevant for the incumbent. Three generic levels of incumbent potential involvement are considered: keep a *watch* on the activities conducted by the developers of the technology; show *interest in their development*, expressed through direct participation (investment), or through the use of the resulting IP, products or services[2]; be involved in the development and/or commercialisation of *competitor* technologies.

   The two first levels are conducive to a cooperation strategy with new entrants, while in the third there may be competition between them.

3) Whether the new firm can preclude appropriation.

   The extent to which the *need to* rely on complementary assets (in particular co-specialised assets) controlled by the incumbents and/or the *involvement of the incumbents* with the technology may bring about the threat of appropriation depends (at least partly) on the firm's c*apacity to protect the technology*. Thus we also consider the *protection mechanisms* available to the firm.

[2] Besides the mode of involvement it is also relevant to take into account the incentive and, especially, the capacity of the incumbent to use the relationship to appropriate the technology (Diestre and Rajagoplan, 2012). This capacity may be higher when there is greater technological proximity between partners (Cohen and Levinthal, 1990; Dushnitsky and Lenox, 2005), which could provide potentially more valuable alliances (but which may also entail greater risk).

This framework supports an exploratory analysis of the relational behaviour of research-based start-ups, in the process of early development and commercialisation of their technologies, with a view to answer to the following questions:

- Which is the competitive environment faced by research-based firms introducing renewable energies in the electricity production sector; and which is their strategic positioning relatively to the large incumbents and the type of relationships established with them?
- To what extent these strategies/relationships differ according to the stage of development of the technologies they exploit and niches where they operate?

4. Empirical research: setting and methodology

In order to answering to these questions, exploratory research is underway on the process of technology development and commercialisation conducted by a set Portuguese research-based spin-offs in two renewable energy fields – wind and wave energy. In both fields there is evidence of involvement by energy incumbents, but there are great differences between the wind and the wave technologies and the respective "niches" concerning the degree of maturity of the technologies, the level of market development and the structure of the supportive networks. Thus, it is expected that these differences generate variation in the competitive environment and therefore, on the behaviour of new entrants and incumbents. The empirical analysis is based on a detailed analysis of the process of creation and early development of the firms, grounded on two types of data: in-depth interviews with the founders; documentary information on the firms and on the research, business and institutional setting where they operate.

In a first stage we selected, four companies for preliminary case studies, which were the object of the analysis presented in this paper. In this first selection there was an attempt to include some variety in terms of maturity of the technology, firm age and also type of business adopted by the firms. The firms operate in the following areas, whose technological maturity can be roughly located in a scale of maturity as shown in Figure 2:

- ***Wind***: Plant optimisation; High-altitude wind; Off-shore engineering services
- ***Wave***: Engineering solutions (products & services); Conversion systems

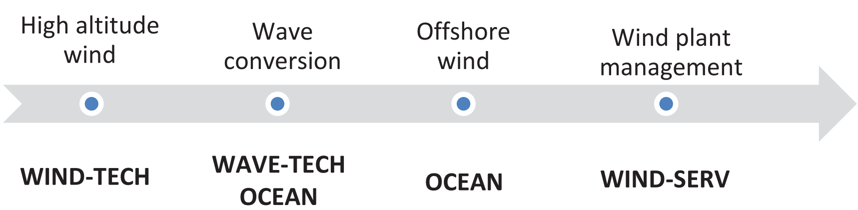

Figure 1 – Firms in case studies

In order to situate these firms in the environment where they operate, we will provide a brief overview of the Portuguese situation in what concerns the diffusion of renewable energies for electricity production, the creation of new firms exploiting advanced renewable technologies and the generic characteristics of the two niches addressed.

4.1 A brief overview of the renewable energy sector in Portugal

Portugal was regarded as providing a good empirical setting for this research given its position as one of the European countries with greater penetration of renewable energy in electricity production and also with more ambitious targets regarding its future development (MEID, 2010). In fact, in the last decade the country invested strongly in the development of renewable energies, both at the research and at the industrial level. It also introduced a very favourable incentive regime for the production and use of energy from renewable sources[3]. Policy documents presented the development of competences and industrial activities in renewable energies as a driver of the country's progress and offered a "vision" of Portugal as an exemplary case of their use, which was largely diffused by the media, creating certain hype around the field.

As a result of these efforts, the contribution of renewable energy sources to the country's gross electricity consumption reached about 50% in 2010. This amounted to an installed capacity of around 10000MW, of which about 50% correspond to hydropower (where there is a longstanding tradition) and another 40% to wind. Other sources have a smaller contribution: biomass (including co-firing) amount to 5% and solar photovoltaics to only 1%. In 2009 Portugal ranked third among the EU15 countries regarding the proportion of renewable sources in electricity production and was fourth in the ranking of countries with the highest penetration of wind power. However, the continuity of these efforts may be threatened by the economic and financial crisis. In fact the energy policy is under revision and the government announced the intention to modify the support scheme for renewable energy (DGEE, 2012). While this includes a necessary adjustment of tariffs for technologies whose costs have substantially decreased, other changes can have a considerable impact on the future evolution of the sector, in particular on the technologies whose diffusion was starting to take-off.

Turning now to situation in the two niches under analysis. **Wind energy** is now widely diffused in Portugal, its deployment taking place mostly through large scale wind plants. The maturity of the technology and extensive government incentives have attracted large investors, national and foreign (including the now privatised utility that created a joint venture specifically for the sector) that are the

[3] The main mechanism is a feed-in tariff. All renewable technologies are eligible, although the amount paid depends on the source, the technology and the system's output and capacity. Energy from renewable sources has priority of access into the grid. Other mechanisms include public financing, public competitive bidding and fiscal incentives. Among these can be mentioned a favourable regime for grid-connected micro-generation.

dominant players. It is possible to suggest that large scale wind generation has broken out of the niche and is decisively entering and competing in the mainstream market, even if its exploitation is still subsidised[4]. However, the implementation of wind systems in Portugal was based on imported technology and therefore local innovation is more likely to be incremental, focusing on organisation and operation systems rather than on core technologies. Opportunities for new technology- intensive companies emerge in the development of technologies that address efficiency, as well as plant and grid level management problems. One of the firms studied offers services in that area.

However the wind sector also presents some developing or emerging segments that are expected to address its current shortcomings (such as intermittence and environmental impacts). One is **offshore wind** that offers greater energy potential, but has a more complex in technology and higher energy costs. Several technological solutions are under experimental development in a field dominated by large international firms. The utility is currently engaged in the development of a new deep-waters offshore technology, in consortium with national and foreign companies, and intends to advance with its commercial exploitation. Since there are strong synergies with wave field (which share the ocean setting and auxiliary technologies) one of wave energy firms in the case studies provides specialised engineering services to both fields. Finally, there are some alternative wind conversion technologies being developed by small technology-intensive firms. One of these is **high altitude wind.** It is a very recent field and both the knowledge about wind behaviour at high altitude and the technologies for capturing power from it are still in a very incipient stage. However, there are a number of companies worldwide developing and testing different types of mechanisms (still at prototype stage). This is the case of one of the companies in the cases studies.

Ocean wave technologies only recently started to move from the R&D to the early stages of industrial development. Technological uncertainty is still very high, since it is not yet established which systems will be more effective in producing electricity while withstanding the ocean conditions. Thus, there are a number of competing systems, which are being tested at experimental settings in various locations (WAVEC, 2009). In this case, it is possible to argue that we are still in presence of a technological niche (Schott and Geels, 2007). A wave energy niche has been very active in Portugal, securing the involvement of some large energy companies and relatively favourable policies (Hamawi and Negro, 2012). Given the good natural conditions (large Atlantic coast and middle climate), the expertise developed by some universities and the proactiveness of local actors, Portugal has emerged as an attractive location for experimental installations promoted by local and foreign companies which, combined with the growing activity in offshore wind, provided some impulse to the niche. Two of the firms in the case studies operate in this field, although with different activities.

[4] It has namely been suggested that it possible to identify "embryonic regime dominated by three-bladed, horizontal axis megawatt-scale wind turbines operating in grid connected clusters and supported through public policy" (Smith et al, 2005).

4.2 The new research-based energy firms

The policy efforts towards the development and dissemination of renewable technologies and the expansion of the renewable energy sector created a favourable environment for the creation of new firms exploiting advanced energy or energy-related technologies, in particular firms originating from university research, whose creation registering a sudden increase in the last years (Fontes et al, 2012). An extensive search conducted by the authors permitted to identify 28 research-based spin-offs developing technologies and systems, that target renewable electricity production and distribution activities[5]. Figure 2 shows their distribution by energy fields. Firms whose technologies are applied in more than one field were assigned to the one corresponding to their main business, unless their activity is transversal. In that case they were included in the "systems and models" group, together with firms offering solutions (methods, instruments and systems) to address system level problems associated with renewable energy production.

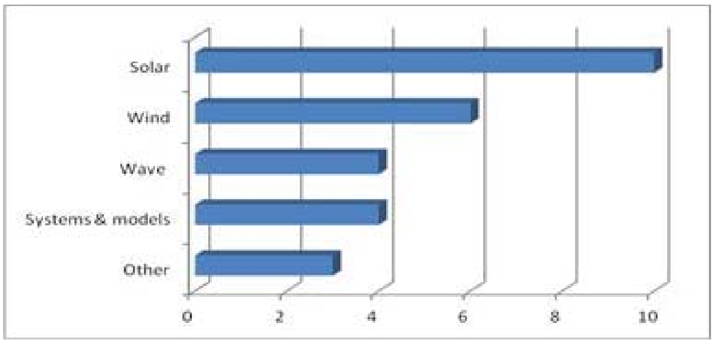

Figure 2 – Research-based spin-offs by application field

The group of firms operating in the wind field are mostly producers of intermediate technologies for the wind farming sector. As pointed out above, the niche is dominated by large companies, largely drawing on imported technologies. Thus, while we still find a small set of firms experimenting with new alternative wind technologies, spin-offs are more frequently involved in the development of technologies to improve the productivity of electricity production from wind sources (e.g. new materials, monitoring and control instrumentation and systems, sophisticated weather assessment or forecast systems). Some of these firms also operate in other areas, besides energy. This contrasts with the activity in the solar field, where most firms are involved in the development of solar systems, namely new generations of photovoltaic technologies (e.g. new types of cells, or building-integrated photovoltaic materials). However, solar spin-off creation started more recently, encouraged by the emergence of a market for grid connected distributed systems, and thus most firms are not yet in the

[5] We have also identified a similar number of new company projects, in different stages of development that were not included in this account, but that reflect the dynamics of the field.

market. Regarding the wave field, despite the preliminary stage of development of the technologies, we still find a small group of spin-offs developing and testing competing equipment and systems.

The firms analysed in this exploratory research were selected from the group of wind and wave spin-offs. The remaining firms identified in these fields will be considered in the next steps of research. Table 1 presents the main characteristics of the firms.

Table 1 – Firms* in case studies

	WIND-TECH	**OCEAN**	**WAVE-TECH**	**WIND-SERV**
Year creation	2003	2005	2009	2004
Field	High altitude wind energy conversion (& energy storage)	Solutions in wave energy conversion; Engineering services to off-shore wind	Wave energy conversion	Wind resource assessment (on-shore)
Business	IP development and licensing	Customised development (products); R&D and engineering services	Product development	Plant optimization services based on own methods
Stage of development	R&D	In market with products & services	Prototype	In market with services
Patents	Y	Y	Y	N
Market *(expected)*	Research organization *(Energy producers & distributors)*	Wave energy companies; Off-shore wind companies	*(Energy producers & distributors)*	Wind companies
Team	Young researcher in international organisation	University professors (senior) & industry engineers	Young university graduates	Senior researchers in industry oriented organisation
Incubation	International agency	University	Utility laboratories	No
Capital	Own + Subsidies (European & National RDT Programs)	Own + Subsidies (European & National RDT Programs)	Own + Prizes (Ideas Contests) *(business angels)*	Own + Subsidies National Innovation Programs

* Firms' names are fictitious to guarantee confidentiality

We will now analyse in detail the commercialisation strategies adopted by this group of firms and nature of their interaction with the established energy firms along this process.

4.2 The commercialisation strategies of research-based firms

Drawing on the analytical framework presented in section 3.3 we started by assessing the nature of the technology being introduced and the structure of the energy segment where the firm operates, in order to outline its competitive environment. We subsequently draw on the information obtained from the case studies to understand the firms' positioning concerning the framework dimensions: whether some of the key complementary assets are possessed by incumbents and in which conditions the new firm can gain access to them; whether the technology being introduced by the new firm is relevant for the incumbents and thus which is their attitude towards the technology and its supplier(s); whether the new entrants have the capacity to protect their technology from expropriation.

Regarding the capacity to protect the technology, all firms studied are, at least in principle, in a similar position. In fact, all but one have the core technology protected by patents. The one that did not patent the technology benefits from the protection afforded by the tacit and experiential nature of the knowledge base. It is therefore possible to assume that these firms had conditions to exclude others from imitating their technology. This lowers the risk of appropriation, although not excluding it, given the firms weak capacity to withstand eventual litigation. Thus, at least in principle, firms have better conditions to establish technological and/or market relationships with incumbents (or even to compete with them). We will subsequently discuss the firms' situations regarding the remaining dimensions.

OCEAN and WAVE-TECH, that operate in the wave field, are introducing technologies still in a very immature stage, which require extensive testing, first at prototype and later at pilot stage in real life conditions. These experiments involve complex infrastructures and extensive financial resources that are beyond the reach of a small firm, being often possessed by large firms or consortia that lead large scale demonstration projects. For OCEAN, access to these settings is critical, since it provides a market for its products and services and simultaneously a test bed to improve its technologies. The incumbents show interest in its technologies and are prepared to get involved in its testing and validation. Thus OCEAN has established alliances with the owners of the co-specialised assets. However, because no dominant design has emerged, there are several experimental projects underway. This provides OCEAN with opportunities of cooperation with different partners, the main challenge being to capture their interest in a context where there are several other small suppliers. The fact that OCEAN emerged within the Portuguese "wave energy community" and that its entrepreneurs were actively involved in the early development of the sector was instrumental in this process. The firm benefited from their scientific reputation, industry visibility and extensive contacts to gain access to experimental settings at national and international level. It enabled her to establish a close relationship with local energy incumbents (both the utility and an equipment manufacturer) that have a strategic interest in ocean technologies and provide it with a market for technologies and skills that can be applied both to wave energy and offshore wind. But OCEAN was equally able to establish relationships with foreign companies that lead the wave sector and to participate in consortia involving several public and private actors conducting experimental projects in various countries. Thus OCEAN capitalized on the still turbulent nature of the sector to propose its technology and extensive skills to different partners, deflecting the risks of exclusive relations.

A similar reasoning may apply to WAVE-TECH, which is still developing a prototype, in its future efforts to introduce its innovative wave technology. The main issue in this case concerns the extent to which the new technology being introduced will require the same degree of integration with incumbent assets to obtain a final product, since its system is presented as having a greater autonomy, and also a wider range of applications. In any case, the incumbents' attitude relatively to the technology is likely to be different. Contrary to OCEAN, this firm emerged outside the “wave energy community” with a technology design that departs from the one in which the local incumbents are involved. Nevertheless, we observe an interest of the utility in watching the development of a technology that deviates from its core competence, but appears to have some potential. This is materialised in some contribution to its development (seed capital, access to facilities and human resources), as well as advice and legitimacy. That is, the incumbent is offering access to some key assets that will enable the new company to complete the development of the technology. We observe a strong reliance of the new firm on the “benevolent” interest of the influential company. But its strategy is not confined to the local market. In fact, it profited from the visibility afforded by winning a series of entrepreneurship contests to gain access to an international incubator that is now providing it with a wider range of connections and business opportunities. The firm plans to manufacture its core product and eventually license the technology for other applications (including wind). Once it engages in these activities it will have to make some new decisions regarding the type of relationships to establish.

The case of WIND-TECH, that is also introducing an emerging technology, presents an interesting contrast. First of all, because WIND-TECH opted for focusing on the development of the technology and licensing the intellectual property, thus avoiding the need to build production and commercialisation assets. Second, because high-altitude wind is at an even earlier stage of development, and thus the essential of the relationships WIND-TECH established so far concern R&D activities and are taking place in the context of European RTD consortia (involving public and private organisations). However, subsequent developments may require other types of alliances or, in the limit, licensing contracts. Finally, its technology is much outside the competences of local incumbents. Indeed, the genesis of the company was an international organization in a different field (space) that remains a key partner, being a source of knowledge and contacts. However, the utility integrates the RTD consortium, denoting some interest in keeping a watch on a technology that is a potential extension - or even a competitor – to its core wind area.

Finally, the structure of relationships is clearly different in the case of WIND-SERV that operates in the onshore wind segment, dominated by large incumbents. In this case the new firm is a typical small specialised supplier of services that improve the performance of the incumbents’ core business. Thus, its activities provide value to the incumbents, but competition with them is unlikely given the different set of competences involved, and the risk of expropriation is low because imitation is difficult. Although the firm business depends on the incumbents’ activity, it sells its competences in a market populated by a variety of potential clients and thus arms’ length commercial relationships prevail. But long standing relationships exist with important clients, some of whom had a lead-user role at early stages and have consistently included the firm in their wind plant installation projects.

Table 2 – Factors shaping commercialisation strategies

		WIND-TECH	**OCEAN**	**WAVE TECH**	**WIND-SERV**
		R&D *(technology)*	**Services & products** (customised)	**Prototype** *(product)*	**Services** (plant optimisation)
Background	**Stage of development of technology / energy segment**	Emerging field: no dominant design. Early stage (prototypes)	Emerging field: no dominant design. Experimental projects.		Stabilised technology / large scale systems with efficiency and reliability problems:
Background	**Opportunities for research-based entrants**	Early development of new conversion systems (publicly funded)	Development of new conversion systems. Offer technologies/services to organisations involved in or managing experimental projects. Synergies with offshore wind (shared technologies)		Scope for suppliers of solutions (plant and system interface management & support systems)
Commercialisation environment	**Firm capacity to protect technology**	**Patented**	**Patented** (+ firm specific knowledge)	**Patented**	**Firm-specific & experiencial knowledge**
Commercialisation environment	**Relevance of CAs possessed by incumbents and firm access to these assets**	Knowledge distributed by several organisations (R&D consortia)	Complex infrastructures & financial resources required; integration in large systems: *CAs controlled by incumbents* (even more in offshore wind)	*Idem*: But new technology design, that may not require same degree of integration with incumbents assets	Specialised supplier of services that improve incumbent performance: final clients but *no dependence on co-specialised incumbent CAs*
Commercialisation environment	**Incumbents attitude to firms' technology**	Incumbents follow-up the new technology through participation in R&D project led by firm	Incumbents interested in technology: experimental projects as test-bed & market	Incumbents interested to closely watch the development of the technology (support prototype development)	Incumbents interested in using technology (incorporate in process); Scope for project-based relations in foreign market entry
Types of incumbents and their actual involvement with firm		**Utility** & **Foreign firms:** watchers	**Utility & equipment producer; Foreign firms**: partners & clients	**Utility:** watcher *(Firms is prospecting foreign markets)*	**Utility, new players, foreign firms**: clients
Strategy adopted by new firm		**Sell technology**	**Alliances required to enter market**	**Alliances may be required to enter market**	**Enter market directly with service:** arms-length market relations, some long-standing associations

WIND-SERV early expansion to foreign markets also benefited from the interest of the incumbents in the technology, since it often took place in the context of their international projects. This was instrumental for its penetration in some foreign markets. The firm also draws visibility from the consistent participation of its entrepreneurs in activities for the promotion of the industry

Table 2 summarises the above analysis, presenting the situation of each firm in terms of the factors shaping its commercialisation strategy, as proposed in the framework. This analysis enables us to uncover some sources of variation in the conditions experienced by firms, that can at least partly explain their positioning relatively to incumbents and thus the nature of the relationships established with them in the commercialisation process. Drawing on it, we can position the firms along the main dimensions of the "competitive environment", as defined by our framework (Table 3).

Table 3 – Positioning of case study firms and types of relationships established

		Relevance of complementary assets possessed by incumbents: **Firm access to complementary assets**		
		Access in market	**Controlled by incumbents**	**Skip (sell technology)**
Relevance of technology for incumbents: **Incumbent attitude**	**Watcher**		**WAVE-TECH (Wave conversion)** Alternative technology design developed outside "wave community". Support to new firm as monitoring device	**WIND-TECH (High altitude wind)** Alternative conversion technology that deviates from incumbents' core competence & operational control. R&D alliances as sources of potential clients for technology
	Interested in development		**OCEAN (Wave conversion; Offshore wind engineering)** Wave technology design developed jointly in local "wave community" Offshore: technology adds value to incumbents assets and is used by them Alliances combining technology and market elements	
			WIND-SERV (Wind plant optimization) Technology that adds value to incumbents assets and is used by them Market relations, but some longstanding alliances with lead-users	
	Competitor			

Considering the generic commercialisation environments proposed by Gans and Stern (2003), it is possible to conclude that the “ideas factory” type of competitive environment appear to prevail in the energy fields analysed, although we observe at least one emerging technology that has potential to operate outside the centralised regime favoured by incumbents (high-altitude wind) and thus offer different conditions. But the case studies also permitted to go in greater depth into the nature of the relationships that are associated with different positioning of the new firms relative to incumbents and different attitudes of the later.

In both fields, the new firms depend more or less clearly on the complementary assets possessed by large energy incumbents, although the analysis enables us to understand that this happens for different reasons and assumes different forms, depending on the nature of the niche and also on the technology. In wind, this results from a combination of incumbents’ dominant position in the industry and interest in the complementary technologies that add value to their assets. This is valid for both onshore and offshore, because despite the less mature stage of the technology in the latter, the relative position and function of the two actors is similar. Thus, new firms act as specialised technology suppliers to incumbents, establishing market relationships with them, which are more arms-length in onshore given the maturity of the technology and the larger number of customers. But we observe, in both cases, the presence of closer, longstanding relations with an important role in the early market introduction of the technology (in onshore) or in the access to service opportunities (in offshore).

In wave, where a dominant design has not yet emerged, relationships derive from the strong interest and resulting positioning of a number of incumbents in the emerging field. Thus, the new firms develop the conversion technologies, but incumbents have a dominant position in what concerns the access resources and infrastructures required for test and demonstration. They are also well positioned to influence the development trajectories of the technologies, so that they match their operational competences and knowledge base, as well as to come to control the final installations, may that require important investments. The nature of relationships depends on the degree of incumbents’ familiarity with the technology: close, longstanding relationships when they were involved in the development of a given design vs. monitoring of alternative designs, through the identification and early support of new companies introducing them. Their future involvement may nevertheless be influenced by the developments taking place in offshore wind, since competition for attention and resources between the two ocean energy technologies may end-up having a negative impact on the less mature one: wave.

Despite the small number of cases, it is possible conclude that in the energy fields being analysed there is some incumbents’ interest in the new technologies, and even some involvement in their development and use. On the other hand, the incumbents' attitude appears to be beneficial for the early activity of the new firms, providing resources, markets and legitimacy, even if this sometimes entail some deviations from the initial trajectory to adapt to incumbents' interests. It also implies a great dependency on powerful companies, which is stronger when the number of incumbents involved in the field or interested in the technology is smaller, as becomes particularly evident in the case of wave energy. Indeed, new firms operating in this field search for partnerships with foreign companies, which can offer greater scope for exploitation and limit the threat of excessive dependence on one large partner.

5. Conclusions

This paper investigated the strategies open to new research-based firms introducing advanced renewable energy technologies in the Portuguese electricity production sector. Since the sector combines a strong incumbent power with fast technological development, it emerged as particularly interesting for investigating the new firms' positioning relative to large established companies and the attitudes of the latter towards their technology, thus providing some insights into the nature of the business-level interactions between niche and regime actors.

An analytical framework was developed and tested on the basis of case studies in two niches in different stages of development, but where there is evidence of incumbents' involvement - wind and wave energy. The research presented in this paper, although still preliminary, permitted an in-depth analysis of the strategies adopted by the new firms and provided some insights into the behaviour of incumbents in these fields. These first results suggest that both fields are characterised by a competitive environment where: new research-based firms tend to depend, to a greater or lesser extent, on the downstream complementary assets possessed by large energy incumbents (unless they opt for selling the technology), but have the conditions to protect their technology from appropriation (mostly with patents); and where the new technologies are relevant for (at least some of) the incumbents, which show interest in their development, although through different levels of involvement. This is conducive to "cooperation strategies", but these can assume diverse forms, depending on the stage of development of the niche, the maturity of the actual technology being exploited by the new firms and its proximity to the incumbents' knowledge base and operational competences.

These preliminary results confirm the usefulness of the analytical framework proposed to address the strategic behaviour of niche innovators in this type of context and offer some first insights into how firms act to introduce their technologies; how they interact with one crucial element of the system to access and deploy key resources; and how the conditions faced on their particular competitive environment influence their potentially disruptive behaviour. This adds to recent research on transitions that address the micro-level analysis of the strategies of individual entrepreneurs (Alkemade et al, 2011; Avdeitchikova and Coenen, 2013) and their interaction with other elements of the system (Musiolik and Markard, 2011), extending and complementing the extensive body of research focusing on system level mechanisms and dynamics (Markard et al, 2012).

The results are consistent with the literature that discusses niche evolution as involving processes of linking-up with developments taking place within the regime and that argues that these processes assume different forms in different types of niches (Schot and Geels, 2007). They also reflect processes of hybridisation (Raven, 2007) whereby niche technologies are partly adapted to match incumbents competences and interests. Although this may preclude more radical transformations, and result in the new approaches being captured by the regime, it may also lead to some changes (albeit slower) in the regime configuration (Verbong and Geels, 2010). In fact, in the case of a complex infrastructural system such as the energy/electricity production, it can also be a strategy through which niche innovators profit from regime tensions – such as the ones already induced by renewable energy – to "infiltrate" their novel technologies and practices, translating them into ways acceptable by regime actors (Smith, 2007) and simultaneously gaining them to support niche development.

In the cases discussed, some incumbents were perceived by the new firms (and other niche actors) as an important element in the development of the niche – profiting from the favourable policies, but in any case driving some of the technological and market developments taking place. They become also critical element at a time of declining incentives, if niche actors are able to maintain their alignment with niche interests. This appears to confirm the idea that presence and interest of incumbents can bring-in resources and legitimacy and reinforce the development of supportive networks … at least up to a point. In fact, the strong involvement of incumbents that was identified in the niches analysed also raises a number of questions regarding the actual nature of their interests, as well on the impact that their "insider" intervention may have in the definition of policies, in the trajectory of the niche technologies and, more generally, on the behaviour of other niche actors (Smink et al, 2011). Since, regime interest is always likely to "provoke a niche reconfiguration closer to the regime" (Smith, 2007: 447) it may be important to investigate in greater detail the impact of regime actors´ involvement on the behaviour new firms operating in the niche and on the outcome of their innovative activities.

Thus, subsequent research will expand these results, by applying the framework to a larger number of cases along the different categories considered, in order to verify whether these preliminary results are confirmed and also to achieve a more precise understanding of the processes underway as part of the interaction between the various actors. It will also be relevant to extend the analysis to other energy niches that have so far raised a lower interest on the part of regime incumbents. This is namely the case of solar energy, that displays a less centralised development trajectory and, thus, where competitive environment may differ, leading to potentially different and strategies and modes of interaction.

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