The entry strategies of research-based firms in the transition to a sustainable energy system

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Abstract: The paper discusses the entry strategies adopted by research-based firms introducing advanced renewable energy technologies (RET) in the electricity production sector and their interactions with regime incumbents. Drawing on the sustainability transitions and the strategic management of technology literatures we build an analytical framework and apply it, in an exploratory way, to firms operating in two very diverse energy niches – wind and wave energy – using in depth-case studies. The results suggest that new entrants tend to depend on complementary assets possessed by incumbents, but have conditions to protect their technologies from expropriation; and that the technologies are 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 incumbents' competences and assets.

Keywords: research-based firms; entry strategies; sustainability transitions; RET; renewable energy technologies; niche regime interaction; new entrants; incumbents; disruptive innovation; commercialisation strategy; complementary assets; actor behaviour; case studies.

Reference to this paper should be made as follows: Fontes, M. and Sousa, C. (2017) 'The entry strategies of research-based firms in the transition to a sustainable energy system', *Int. J. Technoentrepreneurship*, Vol. 3, No. 4, pp.310–329.

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This paper is a revised and expanded version of a paper entitled 'Transitions in the energy system: the strategies of new firms commercializing advanced renewable energy technologies' presented at *IST 2013 – 4th International Conference on Sustainability Transitions*, Zurich, 19–21 June, 2013.

1 Introduction

This paper investigates the strategies adopted by new research-based firms to commercialise renewable energy technologies (RET) 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 societal functions are fulfilled – or socio-technical transitions – are complex processes, involving far reaching changes at the technological, institutional, organisational and social levels. These processes have been addressed by the sustainability transitions literature (Markard et al., 2012). One of the streams of this literature, the multi-level perspective (Geels, 2002), conceptualises transitions as 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 of 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.

Following this rationale, it is possible to argue that a process of transition to sustainability is already underway in the energy system, although it is not yet clear how it will unfold. But, while a variety of trajectories are possible (Geels and Schot, 2007; Geels et al., 2016), a process that involves some forms of interaction and integration between regime and niche actors and their technologies and practices, resulting in some

basic reconfigurations in the regime architecture, has been suggested as the most probable (Verbong and Geels, 2010; Foxon et al., 2013).

The objective of this paper is to contribute to an understanding of the processes underway at the micro-level, by investigating the strategic behaviour of entrepreneurs introducing potentially disruptive RET in the electricity production sector and, in particular, their relationship with the powerful regime actors that dominate the sector. This analysis is expected to provide 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 and the strategic management of technology literatures. The former contributes to a deeper understanding of the ongoing transformations in the energy system: the tensions in the dominant regime; the opportunities they generate for new entrants endowed with new technologies and modes of behaviour and the incumbents' attitude towards them (Sine and David, 2003; Jacobsson and Bergek, 2004; Verbong et al., 2008; Foxon et al., 2010; Verbong and Loorbach, 2012). It also provides insights into the process of niche development (Kemp et al., 1998; Raven, 2007; Schot and Geels, 2007; Smith, 2007; Smith and Raven, 2012; Kivimaa and Kern, 2016). But, while the disruptive role of entrepreneurs and their capacity to gaining other actors to support their efforts is recognised (Raven, 2007; Verhees et al., 2013), this literature still pays limited attention to their strategic behaviour (Alkemade et al., 2011; Farla et al., 2012). The strategic management of technology literature contributes to fill this gap, by providing conceptual instruments to address the conditions for exploitation of advanced technologies by new entrants, in industries dominated by large incumbents (Teece, 1986; Arora et al., 2001; Gans and Stern, 2003; Colombo et al., 2006; Aggarwal and Hsu, 2009).

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 results of an exploratory research, based on a small set of case studies, where this framework is applied to the analysis of Portuguese research-based firms active in two renewable energy niches – wind and wave energy – in different stages of development.

2 The changing environment in the electricity sector

2.1 Transformations in the energy system

New firms developing RET with application in the process of electricity generation and/or distribution are entering a large and highly complex sector that is undergoing a profound transformation. The structural changes taking place and their impact on the energy regime have been addressed by the sustainability transitions literature (Jacobsson and Bergek, 2004; Hekkert and Negro, 2009; Foxon et al., 2010; Verbong and Geels, 2010; Araújo, 2014; Kivimaa and Kern, 2016). According to these authors, those processes introduced some destabilisation in the prevailing regime, leading to alterations in the knowledge base and industrial structure and creating opportunities for the emergence of innovations with a transformative potential that were being developed in niches.

The liberalisation of the energy sector brought about the extinction of public monopolies and led to the separation between energy production, transmission and distribution, forcing established companies to reconfigure their activities and strategies and making entry comparatively easier (Verbong and Geels, 2010). In parallel, the creation of a growing space for RET drove a renewal of the industry knowledge base, associated with a fast increase in R&D, patenting and innovative activity (Johnstone et al., 2010; Ayari et al., 2012), and created some opportunities for new firms (Brown et al., 2007). The new RET started being developed in niches (Kemp et al., 1998; Mautz, 2007), but some have now reached a stage where wider commercial exploitation became viable, if not yet fully competitive with conventional sources (Corsatea, 2014; Ellabban et al., 2014). These processes have been (and continue to be) largely fuelled by policies that provide incentives for the development, implementation and operation of renewable energies (Lund, 2009; Jäger-Waldau et al., 2011; Verhees et al., 2015; REN21, 2016).

Those transformations challenged the dominant position of the old utilities (Duncan 2010; Richter, 2013) and led to some readjustments in the actor composition and balance of power (Verbong and Geels, 2010; Geels et al., 2016). However, the energy system retains its infrastructural and centralised nature and is still largely dominated by large companies (Hockerts and Wüstenhagen, 2010; Bergek et al., 2013; Markard and Petersen, 2009).

2.2 Implications for new firms introducing advanced technologies

As a result of those changes, it is possible to argue that a renewable electricity production sub-system has already emerged, at least in those countries where some RET have reached maturity and achieved some market diffusion. This sub-system is characterised by fast technological change and by an industrial structure where large established firms (including the utilities) increasingly occupy dominant positions.

However, the renewable energy field is diverse and heterogeneous. Thus, we can observe technologies in different stages of development, market introduction and adoption, ranging from those that reached a full commercial stage (large-scale wind energy or first generation solar photovoltaics) to those where a dominant design is still to emerge (wave energy conversion) (Jäger-Waldau et al., 2011; McDowall et al., 2013; Ellabban et al., 2014; Magagna and Uihlein, 2015). This has implications for the conditions faced by technology-intensive firms operating in the respective niches, influencing the opportunities created and the way these can be exploited. It also influences the attitude of established firms and of other key actors (capital providers, policy makers and consumer groups) towards new entrants.

The opportunities open for new firms vary. In more stabilised fields, the growing positioning of powerful companies raised entry barriers and drove entrepreneurs out of core activities. But there still is a variety of complex problems – associated with the operation of the technologies (efficiency, costs and reliability) or their system-level integration – that require extensive technological developments, creating opportunities for technology-intensive suppliers. On the other hand, the still unsatisfactory performance of renewable sources in terms of energy yield, cost and security of supply opens some space for the emergence of alternative designs, which are usually developed and tested by start-ups. New entrepreneurial firms emerge as particularly important actors in the case of renewable sources that have not yet reached a commercial stage, where we observe

a variety of competitive technologies, often still at research or experimental stage. 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 (at least in the early stages) 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).

Incumbents attitude towards renewable energies also vary. Established companies are often reluctant to getting involved in immature technologies (Ansari and Krop, 2012). Thus, energy utilities moving into the renewable field, or companies diversifying from other sectors, tend to invest in stabilised technologies and/or promote innovation projects that are closer to their competences and competitive advantages (Cohen and Levinthal, 1990; Mautz, 2007; Hockerts and Wüstenhagen, 2010). But the growing international competition in the energy field has quickened the technological pace and increased the pressure to innovate (Hekkert and Negro, 2009), forcing established companies to look for new technologies or even to get more closely involved in alternative technological paths (Penna and Geels, 2012; Bakker, 2014; Berggren et al., 2015). Incumbents may wish to keep an eye on the new developments, to follow-up their evolution or even influence it, and/or to guarantee an early position, once a dominant design starts to emerge (Sine and David, 2003); although they usually prefer to achieve this through collaborations, that reduce risks and costs (Dyerson and Pilkington, 2005). This may assume different forms, from simple technological watch, to participation in research activities, to greater involvement with firms developing radically new technologies. The presence and interest of large incumbents can be important for the development of the niches where new technologies are exploited, since they convey resources and legitimacy and can make them attractive to other key factors, such as capital providers (Schot and Geels, 2007). Indeed, the interplay between niche and regime actors has increasingly been acknowledged by niche literature as critical for niche development and breakout (Smith and Raven, 2012). However, incumbents can also try to steer the niche trajectory according to their interests (Smink et al., 2013). In the renewable energy field, regime actors have become increasingly engaged with niche innovations, being able to absorb and integrate some of them (Bergek et al., 2013; Stenzel and Frenzel, 2008).

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 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 new firms and 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; Gans and Stern, 2003).

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 product/service – the 'complementary assets' – are basic elements in the strategic decisions of technology-intensive start-ups (Arora et al., 2001). These are typically small firms with strong knowledge competences, but limited financial resources and frequently missing market-related competences and networks (Mustar et al., 2006). Thus, when engaging in the commercialisation of their technologies, they may attempt to build (some of) these assets internally, they can try to gain access to them through market transactions or through alliances (Elfring and Hulsink, 2003) or else, they may focus on technology development and licensing, avoiding involvement in downstream activities (Arora et al., 2001). The decisions made at this level are influenced by the nature of the assets, in particular those key to capture rents from the innovation (Conceição et al., 2011).

When critical assets are controlled by other firms, access often requires the establishment of contractual relationships (Colombo et al., 2006; Aggarwal and Hsu, 2009). This can become problematic when they are owned by powerful companies, which may use their position to appropriate a substantial part of the rents from the innovation (Rothaermel and Hill, 2005). Nevertheless, the literature describes a variety of vertical alliances where the owners of 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; Gawer and Cusumano, 2008). These alliances have benefits for the start-up, enabling it to access markets and supply chains; providing capital for technology development and conditions for technology/product testing; and offering legitimacy. However, they also tend to be characterised by power asymmetry (Shan et al., 1994), making new entrants vulnerable to the expropriation of their main asset (Teece, 1986). This may deter firms from establishing them, unless they can resort to strong intellectual property protection (Katila et al., 2008).

In summary, although new 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; Diestre and Rajagopalan, 2012).

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

The strategies open to new technology-based entrants are 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 types of conditions that may influence the attitude of incumbents towards advanced technologies being developed by new energy firms, and the nature of the relationships that may be established between both.

The environment labelled by these 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 expropriation 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 intellectual property, to the establishment of a variety of strategic alliances to, in the limit, 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 where uncertainty is still high and thus experimentation with a variety of paths is required. But, while they reduce the start-ups' investment in downstream assets and offer legitimacy, they may also strengthen the basis for incumbents' advantage and thus their market power.

Gans and Stern (2003) also argue that when incumbent complementary assets are less important and the technology can be protected – which they label '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 a stronger bargaining power.

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

Although there is a body of research on the conditions faced by technology-intensive start-ups entering industries dominated by large incumbents, and on the relationships they establish, there is still limited knowledge about the behaviour of start-up firms that are willing to introduce new technologies in the energy sector.

This gap reflects a more general limitation of the research on sustainability transitions: a focus on the processes occurring at the system level and a still limited understanding of micro-level aspects, such as the strategies of individual firms and their relationship with the system (Markard and Truffer, 2008; Wüstenhagen and Wuebker, 2010; Farla et al., 2012). Entrepreneurs are presented as playing an important role in the transition process, bringing-in new technologies and attitudes and contributing to set-off change (Kemp et al., 1998); and as interacting with other actors to build support to their innovative efforts (Raven, 2007). However, there is limited knowledge on how firms effectively act/interact to introduce these technologies (Hockerts and Wüstenhagen, 2010; Avdeitchikova and Coenen, 2013; Musiolik and Markard, 2011).

To address this gap, this paper conducts exploratory research at the micro-level, focusing on the relational behaviour of research-based firms along the process of development and early commercialisation of their technologies. For this purpose we developed a conceptual framework to address firms' positioning that builds on and extends Gans and Stern (2003) concept of commercialisation environment. The 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.

   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 or services based on the technology and thus *skip the need for those assets*;

and those that engage in activities necessary for such development and thus *require downstream assets* (Arora et al., 2001). In the latter case, we consider the established distinction between assets *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 have implications for the type of relation established.

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

We assess whether the technology is relevant for the incumbent (Rothaermel, 2002). Three generic levels of 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[1]; 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 The new firm's capacity to preclude expropriation.

The extent to which the firms' *need to* rely on key complementary assets controlled by the incumbents and/or the *involvement of the incumbents* with the technology may bring about the threat of expropriation depends, as pointed out, on the firm's c*apacity to protect the technology* (Katila et al., 2008). Thus we also consider the *protection mechanisms* available to the new firm.

This framework supports an in-depth analysis of the nature of the interactions between entrepreneurial firms and regime incumbents, with a view to answering 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 the niches where they operate?

4 Empirical research: setting and methodology

The empirical research uses a case study approach to gain an in-depth understanding of the technology commercialisation process followed by the firms, focusing on the role played by relationships, in particular those established with incumbents, in that process. The objective of this largely exploratory research is twofold: gaining some insights into to the processes underway in the renewable energy field; testing the framework developed, in order to understand whether it is effective in uncovering and explaining them.

The main unit of analysis are Portuguese research-based spin-offs operating 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 them concerning degree of maturity, level of market development and structure of the supportive networks. Wind energy technology is already in full commercial exploitation, despite some less developed segments[2] (Bento and Fontes, 2015). This contrasts with the case of wave energy, which only recently started to move from R&D to the early stages of industrial development, but where a dominant design has not yet emerged (Magagna and Uihlein, 2015). It is expected that these differences generate variation in the competitive environment and therefore, on the behaviour of new entrants and incumbents.

The research 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; extensive documentary information on the firms and on the research, business and institutional setting where they operate.

To situate the firms studied, we will start by providing a brief overview of the Portuguese context, in what concerns the diffusion of renewable energies for electricity production.

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 gross energy consumption (25.7% in 2014, according to EUROSTAT) and also with ambitious targets regarding its development (MEID, 2010). In the last decade, the country invested strongly in 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] As a result, in 2014 renewable sources were responsible for 59% of the country's electricity production. Of these, 37.3% corresponded to wind and 50.6% to hydropower, while biomass accounted for 7.8% and solar for 1.9%. Other renewable sources had a negligible contribution (DGEE, 2016).

The favourable environment led to an upsurge in the creation of research-based firms exploiting advanced technologies that target the renewable electricity production and distribution sector. An extensive search, conducted by the authors in 2013, permitted to identify 28 spin-offs from research organisations in operation, with particular incidence on wind, solar and bio-energy fields.

The research-based spin-offs operating in the wind field are mostly producers of intermediate technologies. Wind energy is now widely diffused in Portugal, its deployment taking place through large scale wind plants. Extensive government incentives have attracted large investors, national and foreign, that are the dominant players. However, the core technologies (e.g., turbines, blades) are licensed from international producers, even if they are produced locally (Bento and Fontes, 2015). Thus, while we find a group of firms experimenting with alternative wind conversion systems, spin-offs are more frequently developing technologies that improve the productivity of electricity production from wind (new materials, weather assessment, monitoring and control instrumentation and systems).

In the wave field, despite the preliminary stage of development of the technologies, we find a small group of spin-offs developing competing systems. A wave energy niche has been very active in Portugal, benefiting from favourable policies and securing the involvement of large energy companies (Fontes et al., 2016). The country also emerged

as an attractive location for experimental installations promoted by foreign firms, given the good natural and institutional conditions. This created opportunities for new firms, both developing new conversion systems, and providing systems or engineering services related with sea operation. This expertise also turned up to be useful for the newly developing offshore wind sector, dominated by large companies.

4.2 Firms in case studies

Four companies, two in the wind and two in the wave energy field, were selected for the case studies presented in this paper. In this selection, there was an attempt to include some variety in terms of level of maturity of the technology and firm age. The firms selected operate in the following areas: high-altitude wind; wind plant optimisation; off-shore wind engineering services; wave conversion systems and wave engineering solutions. Their activities can be roughly located along a technological maturity scale, as depicted in Figure 1. Table 1 presents the main characteristics of the firms.

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

Figure 1 Firms in case studies (see online version for colours)

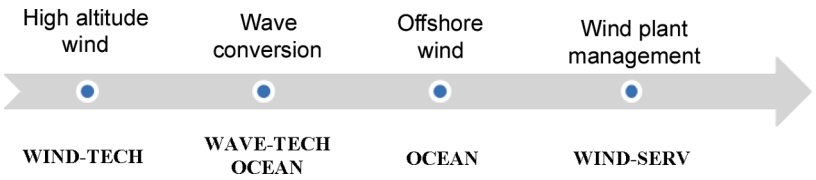


Table 1 Characterisation of firms in case studies*

	WIND-TECH	*WAVE-TECH*	*OCEAN*	*WIND-SERV*
Year creation	*2003*	*2009*	*2005*	*2004*
Field	High altitude wind	Wave energy	Solutions in wave energy; Engineering services to off-shore wind	Wind resource assessment
Business	IP development and licensing	Product development	Customised development (products); R&D and engineering services	Plant optimisation services
Stage of development	R&D	Prototype	In market with products and services	In market with services
Patents	Yes	Yes	Yes	No
Market (*expected*)	Research organisation (*Energy producers*)	(*Energy producers*)	Wave energy firms; Off-shore wind firms	Wind energy firms

*Firms' names are fictitious to guarantee confidentiality.

4.3 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 three framework dimensions:

- whether some of the key complementary assets are possessed by incumbents and in which conditions the new firm can access them
- whether the technology being introduced by the new firm is relevant for the incumbents and 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, 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, lowering the risk of expropriation. Thus, 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 sea 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 they provide a market for its products and services and a test bed to improve its technologies. Some incumbents show interest in its technologies and are prepared to get involved in its testing and validation. Thus OCEAN established alliances with the owners of the cospecialised 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 from within the Portuguese 'wave energy community' and that its entrepreneurs were actively involved in the early niche development was instrumental in this process. The firm benefited from their scientific reputation, industry visibility and contacts to gain access to experimental settings at national and international level. This enabled it to establish a close relationship with local energy incumbents that have a strategic interest in ocean technologies. They provided a market for OCEAN technologies and skills, which can be applied both to wave and offshore wind. But OCEAN was equally able to establish relationships with foreign companies, that are leaders in the sector, and to participate in consortia conducting experimental projects in various countries. Thus OCEAN capitalised on the still turbulent nature of the field to propose its technology and 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 technology being introduced will require the same degree of integration with incumbent assets to obtain a final product, since it is presented as having a greater autonomy and a wider application range. In any case, the incumbents' attitude relatively to the technology is different. Contrary to

OCEAN, WAVE-TECH emerged outside the 'wave energy community' with a technology design that departs from the one in which it has been involved. Nevertheless, we observe an interest of the main energy 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 offers access to some assets that will enable the new entrant to complete the development of the technology. Though taking advantage from the 'benevolent' interest of the influential company, WAVE-TECH strategy is not confined to the local market. In fact, it profited from the visibility afforded by winning a series of entrepreneurship contests to enter an international incubator that is 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, 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 relationships WIND-TECH established so far concern R&D activities and take place in the context of European Research and Technology Development (RTD) consortia (involving public and private organisations). However, subsequent developments may require other types of alliances or, in the limit, licensing contracts. Finally, WIND-TECH technology is much outside the competences of local incumbents. The genesis of the company was an international organisation that remains a key partner, being a source of knowledge and contacts. However, the main energy utility integrates one of the RTD consortia, denoting one again an interest in watching a technology that is a potential extension – or even a competitor – to its core onshore wind area.

The structure of relationships is different in the case of WIND-SERV that operates in the onshore wind segment, dominated by large incumbents. The firm is a typical 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. The firm business depends on the incumbents' activity, but it sells its competences in a market populated by a variety of potential clients and thus arms–length commercial relationships prevail. However, 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. This was namely the case with WIND-SERV early expansion to foreign markets. The firm also draws visibility from the consistent participation of its entrepreneurs in activities for the promotion of the industry.

This analysis enabled us to uncover some sources of variation in the conditions experienced by new 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 2).

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 offers 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, as well as different attitudes of the later.

Table 2 Positioning of case study firms and types of relationships established

		Relevance of complementary assets possessed by incumbents: **Firm access to complementary assets**		
		Controlled by incumbents	**Access in market**	**Skip (sell technology)**
Relevance of technology for incumbents: **Incumbent attitude**	**Watcher**	**WAVE-TECH** **(Wave conversion)** Alternative technology design developed outside local 'wave community'. Support to new firm, as means to monitor technology evolution		**WIND-TECH** **(High altitude wind)** Alternative conversion technology that deviates from incumbents' core competence and 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/ is used by them Alliances combining technology and market elements		
		WIND-SERV **(Wind plant optimisation)** Technology that adds value to incumbents assets and is used by them Market relations, but some longstanding alliances with lead-users		
	Competitor			

In both fields, the new entrants depend more or less clearly on the complementary assets possessed by large energy incumbents. But the analysis also enables us to understand that this happens for different reasons and assumes different forms, depending on the nature of the niche. In wind energy, 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 wind because, despite the lower maturity of offshore technology, the relative position and function of the two new entrants is similar. The new firms act as specialised technology suppliers to incumbents, establishing market relationships with them, which are more arms–length in onshore given the nature of the technology and the larger number of customers. But we observe, in both cases, the presence of close, longstanding relations, that have an important role in the early market introduction of the technology (in onshore) or in the access to service opportunities (in offshore).

In wave energy, where a dominant design has not yet emerged, relationships derive from the strong interest, and growing positioning in the field, of a number of incumbents. Thus, the new firms develop the conversion technologies, but incumbents have a dominant position in what concerns the access to resources and infrastructures required for test and demonstration, which are extremely costly. Incumbents 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 end-up controlling the final installations, which will require important investments. The nature of relationships depends on the degree of incumbents' familiarity with the technology: close 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. Future involvement may nevertheless be influenced by 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 energy.

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 start-ups, providing resources, markets and legitimacy, even if this sometimes entails 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/interested in the technology is smaller, as becomes 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 strong incumbent power with fast technological development, it emerged as particularly interesting for investigating the new firms' positioning relatively 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 renewable energy niches, in different stages of development, but where there is evidence of incumbent involvement – wind and wave energy. The research presented in this paper, although still exploratory, permitted an in-depth analysis of the strategies adopted by the new firms and provided some insights into the behaviour of regime incumbents. 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 expropriation (mostly with patents)
- where the new technologies are relevant for (at least some of) the incumbents, which show interest in their development, although with 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 technology being exploited by the new firms, and its proximity to the incumbents' knowledge base and operational competences.

These results confirm the usefulness of the analytical framework proposed to address the strategic behaviour of niche innovators in this type of context. They offer insights into the behaviour of new entrants that bring sustainable technologies into the energy sector: how they act to introduce their technologies; how they interact with one crucial element of the system – the large regime incumbents – in order to access and deploy key resources; and how the conditions faced on their particular competitive environment influence their behaviour. The results are consistent with the transitions 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 confirm the presence of processes of hybridisation (Raven, 2007), whereby niche technologies are partly adapted to match incumbents' competences and interests. These findings add to research on sustainability transitions that focuses on 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 (Hockerts and Wüstenhagen, 2010; Smink et al., 2013), thus complementing the more extensive body of research centred on system level mechanisms and dynamics.

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 in 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 the competitive environment may differ (Huijben and Verbong, 2013), leading to potentially different strategies and modes of interaction.

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Notes

[1]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 Rajagopalan, 2012). This 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).

[2]This is the case of offshore wind that in Portugal is mostly based on deepwaters technologies, which are still in a pre-commercial stage of development, as well as of emerging technologies such as altitude wind, still in the prototype stage.

[3]The main mechanism was 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 included public financing, public competitive bidding and fiscal incentives.