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The Construction of a New Technological Innovation System in a Follower Country: Wind Energy in Portugal

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Abstract

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Abstract

This article analyzes the process of construction of a new innovation system based on wind energy in a "follower" context. The technological innovation systems framework is used to analyze and explain the emergence of a new wind industry in Portugal, where this renewable energy technology knew a spectacular development in the past decade. This framework highlights the main processes or functions that intervene in the diffusion of a new technology. The evidence obtained demonstrates that the fulfillment of these functions, which were mostly studied in the context of pioneer countries, is still pertinent to explain the formation of a wind energy system in this follower country. Yet the type of resources and the nature of the activities needed to adopt the technology in the latter will often differ. This case provides new insights about the importance of functions that enhance the follower's capacity to assimilate the new technology (e.g. local knowledge development, experimentation), creating conditions for a fast move as soon as innovations become sufficiently mature in the core.

Keywords*: technological innovation systems; spatial diffusion; absorptive capacity; wind energy.*

1. Introduction

The diffusion of mature low carbon technologies like wind power and their adoption in areas where energy demand is expected to raise the most in the next decades is an important issue for global sustainability (BP, 2014; IPCC, 2013; IEA, 2012a). In this matter, the transfer of wind energy technology from "core" markets to a fast follower such as Portugal, provides an interesting case study. Portugal has no oil and natural gas resources and an historical dependence on energy imports. However, in 2011, more than 45% of electricity was already generated out of endogenous renewable energy sources (RES). This was only possible thanks to the spectacular progression of wind energy, which became the second most important RES after hydropower within a decade. It produced 17.2% of total electricity consumption in 2011, the second highest share among OECD countries, only surpassed by Denmark (EWEA, 2013; DGEG, 2013). The development of wind power benefited from the implementation of a mix of demand "pull" and supply "push" policies. A very generous feed-in tariff was implemented in the early 2000s, resulting in a strong increase on the demand for wind farm connections. Thus, in 2005 the government decided to organize public tenders and tie local production requirements of core technologies (e.g. turbines and blades) to the attribution of capacity rights (Martins et al., 2011). As a result, an industrial cluster was formed, harnessing local engineering and industrial competences, and national incorporation of inputs rose from 20% to 100%, while exports absorbed more than 60% of production, in 2011 (ENEOP, 2013; Público, 2011). Lessons can therefore be derived for countries that are considering the adoption of renewable energy technologies (e.g. wind power) with the objective of both reducing emissions and boosting their economy.

This paper draws on the literature that addresses the emergence and growth of new technologies. It combines contributions from the technological innovation systems theory (Bergek et al., 2008a; Hekkert et al., 2007) with those from the empirical historical scaling dynamics analysis (Wilson 2009; Grubler, 2012). The model of Technological of Innovation Systems (TIS) focuses on the emergence of novel technologies and the institutional and organizational change that is needed for technology development (Markard et al., 2012), providing the conceptual instruments to understand how these processes unfold. The empirical research on the spatial diffusion of several energy technologies, focusing on the effect of scaling in growth dynamics, identified some international patterns of diffusion (Wilson 2009; Wilson and Grubler, 2011). It namely uncovered an acceleration of growth as innovation penetrates into new regions (Wilson, 2012; Grubler, 1998). This was explained by the fact that subsequent markets adopt a more mature technology, taking advantage of the knowledge derived from its development and market deployment in the "core". Wind power was found to be a good example of the acceleration of international adoption (Bento, 2013; Wilson, 2012). It is the most mature renewable energy technology and the one effectively achieving a wide diffusion (IEA, 2012a; GWEC, 2013; EWEA, 2013). It therefore emerges as a relevant empirical setting to address the mechanisms of formation of a new innovation system in follower countries.

However, despite the number of studies about the development of wind power, some of them based on international comparisons, this issue is still largely underexplored. In fact, most authors have compared developments in pioneer countries (e.g. Garud and Karnøe 2003; Karnøe and Garud, 2012; Kamp et al, 2004; Bergek et al., 2003; Hendry and Harborne, 2011), but there is still a gap in the study of the organization of the innovation in other regions[1]. The objective of this paper is to address this gap. The theoretical and empirical literature discussed above permits to raise two hypotheses. Firstly, that reinforcing local innovation capacity in follower countries (e.g. knowledge development, network creation) may accelerate the formation of a local innovation system and consequently the spatial diffusion of new technologies. Secondly, that the process of construction of the innovation system is likely to differ between pioneer and follower countries, because the conditions are diverse and thus, the nature of the functions, actors and relationships they entail also differ.

Therefore, this research focuses on the diffusion of wind energy in a fast follower country and tries to answer the following question: Which were the main drivers of the transfer and adoption of wind energy in the case of Portugal? The patterns of international diffusion are investigated with the focus on

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[1] With a few exceptions, such as: McDowall et al. (2013), Sovacool (2010) and Kristinsson and Rao (2008).

technological innovation systems’ formation and industry up-scaling, in order to understand the adoption behavior in different regions. The paper is organized as follows. Section 2 presents the conceptual framework. Section 3 describes the methodology and data sources. Section 4 examines the formation of a technology innovation system in a follower market, using the case of Portugal. The paper ends with the discussion of the main findings. It is argued that a better understanding of the mechanisms at work in the process of innovation system formation in subsequent markets offers insights on the determinants of technology adoption and system building and, thus, contribute to extend our knowledge on the process of spatial diffusion of sustainable technologies.

2. The process of formation of new energy technology innovation systems

Two approaches have recently appeared in the literature that aims to understand the process of emergence and growth of new technology systems. The first is the technological innovation system (Bergek et al., 2008a; Hekkert et al., 2007), that comes from the more theoretical field of socio-technical transitions (Markard et al., 2012). The second is the recent historical scaling dynamics analysis (Wilson, 2012, 2009), which comes from the tradition of applied systems analysis (Grubler, 2012, 1998). The next two sub-sections expand more in each of these streams of literature.

2.1 Technological innovation systems

The Technological Innovation Systems (TIS) approach focuses on the emergence of novel technologies and the institutional and organizational change that is needed for technology development (Markard et al., 2012). Innovation is understood as an interactive process involving a network of actors (e.g., firms, users), who act within a particular context of institutions and policies that influence technology development, adoption behavior and performance, and who bring new products, processes and organization structures into economic use (Carlsson and Stankiewicz, 1991; Bergek et al. 2008a; Jacobsson and Bergek, 2012). This definition highlights the three main elements constituting the structure of the new innovation system: actors, networks and institutions (Bergek et al., 2008a; Jacobsson and Bergek, 2004). Actors include firms and other organizations (e.g. universities, industry associations) along the value chain. Networks are the result of links established between fragmented components to perform a particular task (e.g., learning and knowledge creation and diffusion, standardization and market formation, political and advocacy coalitions). Institutions consist of formal rules (e.g., laws and property rights) and informal norms (e.g. tradition and culture) that structure political, economic and social interactions (North, 1990, 1991). Institutions have three roles in innovation systems: reducing uncertainty by providing information; managing conflicts and promote cooperation; providing incentives for innovation (Edquist and Johnson, 1997).

The emergence of a new technological innovation system faces several challenges as actors need to get the technology ready and aligned with the relevant institutions (Jacobsson, 2008). The TIS literature focuses on the processes that are required for the new system to start, grow and gain momentum. Bergek et al. (2008a) distinguish between a formative and a growth phase. The formative phase is when "… constituent elements of the new TIS begin to be put into place, involving entry of some firms and other organizations, the beginning of an institutional alignment and formation of networks." (p.419), while in the growth phase "… the focus shifts to system expansion and large-scale technology diffusion through the formation of bridging markets and subsequently mass markets..." (p.420). The formative phase is therefore central in the emergence of the TIS. New technologies often face high uncertainties and financial needs in combination with low institutional support and small (if any) markets (Kemp et al, 1998). The early stage is crucial to build the supportive structure that allows the innovation system to move into the next stage and develop in a self-sustaining way (Hekkert et al., 2007). This process is particularly important in the case of new and radical innovations, for which almost every component must be put in place (Geels and Schot, 2007).

One of the main advantages of the TIS approach is that it highlights a number of processes or *functions* that need to be carried out for the innovation system to grow (Bergek et al., 2008b; Hekkert et al., 2007; Markard et al., 2012). The literature identified eight different key functions that need to be fulfilled for a successful maturation of the emerging innovation system (cf. Bergek et al., 2008b).

- Development of formal knowledge
- Entrepreneurial experimentation
- Materialization
- Influence on the direction of search
- Market formation
- Resource mobilization
- Legitimation
- Development of positive externalities.

The strategies and actions of some key actors play a particularly important role in the fulfillment of the functions of the innovation system. These actors - who have been referred to in the innovation literature as prime movers (Jacobsson and Johnson, 2000; Jacobsson and Bergek, 2003) or key actors (Musiolik et al, 2012; Markard et al., 2011) - may possess a very distinctive set of resources (e.g. technology and market knowledge, financial, reputation, political) that make their contribution determinant in the process of system building (Jacobsson and Bergek, 2003). They influence the development of collective resources that are needed in order to fulfill those functions, either by acting individually or through the formation of formal networks. That is, structures created to bring together firms and other actors in order to pursue a common aim, such as collective technology-related expectations (van Lente and Rip, 1998; Glynn, 2002) or legitimacy (Aldrich and Fiol, 1994), as highlighted in the studies on resource-based view of TIS formation (Musiolik et al., 2012).

However, one major limitation of the TIS approach is that it tends to focus on the national level, overlooking the interactions established between the emerging local system and those from other countries (Markard et al., 2012; Coenen et al., 2012; Binz et al., 2012, 2013). This is particularly a problem when analyzing the spatial diffusion of new technologies and the construction of a new innovation system in follower regions. The spatial dimension has been integrated in the TIS analysis in two different ways. On the one hand, through the analysis of a national TIS as a subsystem of the international TIS, which includes globally operating actors, as in the “geography of transitions” (Binz et al., 2012). On the other hand, by focusing on transnational linkages - involving technology, actors, knowledge - which allow the mobilization of local as well as international capabilities (Wieczorek et al., 2013). The comparison between these two approaches shows that the inclusion of space can be very helpful in the identification of key "prime movers" (Jacobsson and Johnson, 2000; Markard et al., 2011), who were decisive for the formation of the local TIS, namely by solving imitability and transferability issues. In this paper, the development of the local TIS is contextualized in the dynamics of global expansion of the new technology (see Section 2.2). Additionally, the specific features of the innovation system’s emergence in the follower country are highlighted through a comparative analysis with the process of formation in the core.

2.2 The dynamics of historical diffusion of energy technologies

In order to understand the process of emergence and growth of energy innovations, an empirical literature is reviewed which studies the historical diffusion of these technologies, focusing on the effect of scaling, to draw lessons about technology development (Wilson 2009; Wilson and Grubler, 2011, Grubler, 2012).

The analysis of international patterns of diffusion identified a tendency of acceleration of growth as innovation reaches new regions (Bento, 2013; Wilson, 2012; Grubler, 1998). That is, the penetration in the market tends to become faster as new technology transits from initial to subsequent markets. This acceleration may be explained by the fact that technology is more mature when enters into other regions and a significant part of the learning costs have already been supported in the initial markets (Nemet, 2009). Hence, other regions benefit from knowledge and technology spillovers created during the previous diffusion in the core (Jaffe, 2005). Keller (2010) emphasizes the role of international trade and FDI in the capture of these technology spillovers. Although the local capacity to exploit international externalities can be enhanced by importing technology, or by the physical presence of multinational firms, it is assumed that trade and FDI are not enough to explain the emergence of a new innovation system in the follower country.[2]

However, a new technology does not spread automatically from the existence of a knowledge base in the core, but requires the recipient country to have the capacity to absorb and assimilate such technology, in order to take the maximum benefit from it (Mowery and Oxley, 1995; Teixeira and Fortuna, 2010). The term “absorptive capacity” was coined by Cohen and Levinthal (1989, 1990) to

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[2] Other studies on applied diffusion (see Pulkki and Stoneman, 2014) found evidence of international spillovers driven by informational effects (positive externalities) and competition effects (negative externalities).

designate the ability of organizations (and ultimately their countries) to exploit external knowledge [3]. At the macro level, enhancing local absorptive capacity refers to the institutional and organizational changes that are needed to more rapidly adopt new technologies (Fagerberg and Godinho, 2008; Mowery and Oxley, 1995). The neoclassical approach assumes that the ability to absorb external knowledge and the efficient use of imported technology in laggard countries, such as Portugal, depends on a minimum level of human capital and local R&D efforts (Teixeira and Fortuna, 2010)[4]. Yet it is also determined by non-technological factors related with the social and institutional set-up of the country, and the way these enable or constrain the development of a coherent and integrated innovation system. The socio-technical processes are extensively dealt with by the TIS literature, as we saw above, suggesting that this literature can bring an important contribution to an understanding of the conditions in which technology diffusion takes place.

On the other hand, the historical analysis of technology diffusion can also add to the TIS analytical framework, by bringing more clarity to the link between the formative and the growth phases. In fact, the empirical researches on the patterns of technology diffusion have shown that technology development typically evolve along a three-phase sequential process (cf. Wilson, 2009):

i) a formative phase consisting of the experimentation and production of many small scale units in order to establish the first production base;
ii) an up-scaling phase by constructing ever larger units (e.g., steam turbines or wind power plants) to gather technological economies of scale at unit level;
iii) and a growth phase characterized by mass production of large-scale units, reaping economies of scale (and also learning economies) at the manufacturing level.

Combining both approaches it is therefore possible to advance that, in the formative phase, the technology and the structures of the innovation system co-evolve and prepare for the up-scaling, that is necessary in order to move into the large-scale diffusion. This perspective highlights some important mechanisms for the development of the technology such as experimentation and learning (Hendry and Harborne, 2010), but also legitimation, which usually precedes institutional alignment with the needs of the emerging innovation system (Bergek et al., 2008b; Aldrich and Fiol, 1994). It also contributes to explain the acceleration of growth in subsequent markets. In fact, the length of the formative phase is expected to be shorter, as the most important technical trade-offs were already solved in the pioneer countries.

This suggests that a complete understanding of the process of diffusion and adoption of sustainable energy technologies requires an analytical framework that combines the empirical contributions from

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[3] The concept of "adaptive capacity" in the literature of the governance of sustainability transitions (Smith et al., 2005) refers to the capacity of regime members to coordinate resources in order to adapt to selection pressures and influence those pressures exerted on the regime. This is close to the definition of "absorptive (technological) capacity" of a receiving country that is used in our paper.

[4] Caragliu and Nijkamp (2012) use the concept of "cognitive capital" which encompasses not just the stock of knowledge (technical and formalized) but also a region's attitude towards learning (e.g. networks, behavior, institutions).

the historical analysis of technology diffusion with the explanatory potential of a more “localized” technological innovation systems approach.

3. Methodological issues

This research aims to examine the construction of new innovation systems in follower countries, focusing on the case of wind energy development. Starting from the historical evidence on the acceleration of spatial growth provided by empirical diffusion studies, the paper investigates the processes at work in the case of a follower market and attempts to uncover the mechanisms associated with innovation system building that can support fast technology diffusion.

For this purpose it uses, as analytical framework, the technological innovation systems approach, extended by the actor-oriented analysis, which focuses on the key organizations and networks that play a role on the emergence of an innovation system (Markard et al., 2012; Bergek et al, 2008b; Hekkert et al., 2007; Musiolik et al., 2012). The paper addresses the case of wind development in Portugal (a “fast follower” country) and, whenever possible, compares it with the situation in a pioneer country like Denmark (representing the “core” of the innovation). Thus, instead of investigating once again the strategies pursued in core countries (e.g. Garud and Karnoe, 2003; Kamp et al., 2004; Hendry and Harborne, 2011), this paper concentrates on the conditions of rapid transfer of technology from the core to fast followers. The contrast between the growth dynamics in the two environments provides ground for a discussion on the potentially different conditions in which the emergence of an innovation system takes place and the implications for the timing and rates of diffusion.

Quantitative and qualitative data was collected from official statistics such as IEA, Danish Energy Agency, Portuguese national statistics, Portuguese Directorate-General for Energy and Geology (DGEG). Information from secondary sources (e.g., scientific articles, policy documents, laws, newspaper, documents) was also used. Interviews were conducted with key actors of the wind and energy sector in Portugal, from the industry (e.g. equipment manufacturers, developers, electricity producers), academia and policy making.

On the basis of the documentary analysis and interviews, the paper provides a short historical overview of the evolution of the wind system in Portugal, identifying the main events and key actors. Drawing on this qualitative information, the paper uses the TIS framework as an analytical structure to uncover the system building processes at work over time, and attempts to provide an explanatory account of the fast diffusion, documented by the data on wind capacity growth.

4. The development of a new TIS in a follower country: The case of Portugal

4.1 The diffusion of wind power in Portugal

This section examines the growth of wind technologies in Portugal. It starts to review the most relevant events occurred during the diffusion. The main drivers are discussed next, before comparing the rhythm of penetration of wind with other countries.

4.1.1 The early development of wind energy in Portugal

After the two oil shocks, many countries increased the investments in domestic sources of energy. Portugal was no exception, and in 1988 new legislation was introduced to support independent generation from renewable sources. This legislation was initially applied to small-hydro power projects and only half a decade later it was extended to other energy sources.[5] Consequently, a few number of small wind turbines were experimented, mainly in the Azores and Madeira islands (Castro, 2011). These early projects were undertaken by public research institutes, the public utility and foreign investors (Estanqueiro, 2013). At this point, wind power was still a technology under development. There was little experience with its deployment in Portugal and also limited knowledge of wind resource potential. Therefore, in the late 1980s and early 1990s, a large part of research activities concentrated on wind characterization and on the evaluation of the countries' resources (Matos, 2013). The situation started to change with the evolution of the international context, particularly with the technological advances made in the core over the 1980s and 1990s (Neij and Andersen, 2012) that offered new opportunities for a wider deployment of wind power systems.

4.1.2 Factors influencing the take-off of investments

The development of wind power in Portugal was driven by two main determinants: the changes occurred in the political and regulatory context; and the favorable evolution in the economics of wind power.

Firstly, the context of investment was markedly influenced by changes intervened at international level. In fact, the signing of the Kyoto Protocol and the subsequent European Directive (2001/77/CE), known as the "Renewables Directive", triggered a wave of investments in renewable energies. The directive established the overall target of 21% for electricity produced from renewable energy sources in the gross electricity consumption, by 2010. It also fixed specific targets by member-state, which was 39% for Portugal. In order to reach this objective the government launched an Energy Program (E4 - Energy Efficiency and Endogenous Energies) that aimed to double the installed capacity of renewable energies in a horizon of 10 to 15 years. This program was followed by a set of legislation that included a very attractive remuneration for electricity produced from wind.

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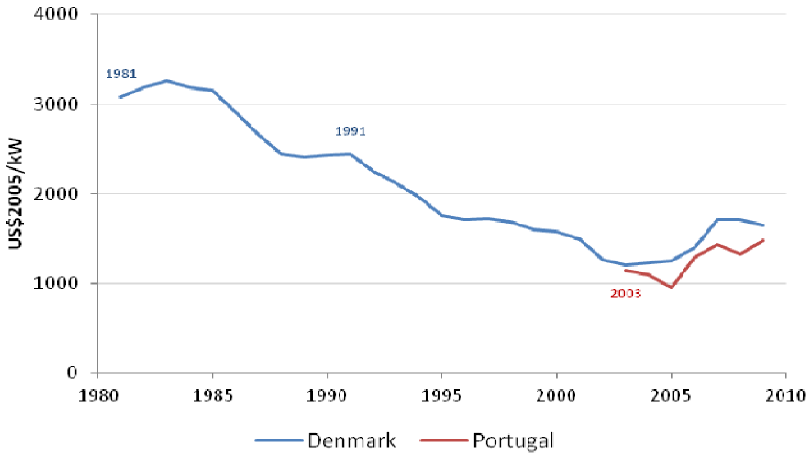
[5] In addition, the restructuration of the national electricity system in 1995 established the distinction between a public electricity system (SEP) and an independent electricity system (SEI), ending the monopoly of the Portuguese utility (EDP) and opening up the market to new investors.

Secondly, the progresses made by wind technology during the 1890s and 1990s prepared it for widespread diffusion. Danish manufacturers were already commercializing 3 MW wind turbines by the end of the 1990s. The new models had significantly improved efficiency and performances, registering important reductions in the average downtime rates (to less than 2%) and turbine noise (Neij and Andersen, 2012). At the same time, investment costs in wind turbines were cut by half between 1980 and 2000 (Fig. 1). Wind energy had finally become a mature technology, ready to supply significant amounts of energy at a competitive cost.

The favorable evolution of the economics of wind technologies was crucial for the Portuguese decision to invest in this energy source. In the late 1990s, wind technologies were much more advanced and cheaper than alternative renewable technologies, such as solar photovoltaic. The average cost of building wind capacity in Portugal was close to the one in Denmark. Figure 1 shows that investment costs are very well correlated in both countries, even if in absolute terms there are some differences between them, which may be partially explained by the different sources used to construct the graph.

Figure 1. Average costs of installed wind capacity in Denmark and Portugal between 1980 and 2010



Sources: (Portugal) IEA Annual Wind reports - various years; (Denmark) Grubler et al., 2012.

In addition, it is interesting to note that Portugal starts to deploy wind turbines when prices increase in the international market (see Figure 1). This trend contrasts with the declining cost trajectories predicted by the learning curve theory and observed in the previous decades. It was due to the joint effect of a surge in demand for wind turbines and the raise of production costs motivated by increasing labor and materials prices and profit margins (Bolinger and Wiser, 2012). The reasons that led the country to maintain the plans to adopt an increasingly expensive technology are further explored in the next points. In fact, the cost increase was more than compensated by the remuneration offered to electricity generated from wind, guaranteeing the profitability of wind farms. This strongly contributed to the rapid increase in the installed capacity of wind power.

4.1.3 Growth of the installed capacity and international comparison

The diffusion of wind power in Portugal was rapid and impressive, with most of the capacity being deployed after 2000. The growth in installed capacity kicks-off in 1999, when it was as low as 58 MW, doubling in average every other year and reaching 4,364 MW (21% of total capacity) in 2011 (DGEG, 2013). As a result, the part of wind in total electricity consumption has gradually increased to reach 18% in 2012 (DGEG, 2013). This was decisive to raise the share of renewable energies in final electricity consumption from 21.1% in 1999 to 45.3% in 2011, one of the highest in Europe (Table 1). The spectacular increase of wind power in Portugal can be further assessed by comparison with other top wind countries in Europe (Table 1). Portugal has the second highest share of wind energy in total electricity consumption and is expected to remain in the same position in 2020, according to current plans. Moreover, the Portuguese government maintains an attractive feed-in tariff (€ct. 9 per kWh in average) that is in line with the support mechanisms in practice in other countries.

Table 1. Shares and targets of renewable electricity and wind in gross final electricity consumption and support schemes for wind power in top wind countries in the EU

(in %)	Share of Renewable Electricity in Gross Final Consumption in (1999) 2011[i]	Renewable Electricity Targets in 2020[ii]	Share of Wind Electricity in Gross Final Consumption in 2011[i]	Wind Electricity Targets in 2020[ii]	Onsite Wind Power Support Scheme (Feed-in/Premium) in 2013[v]
Denmark	(13.3) 38.7	52	27.0	50[iii]	Premium above market price Guaranteed bonus of 0.25 DKK (approx. €ct 3) per kWh for 22,000 full load hours + 0,023 DKK (€ct 0,3) for covering the balancing costs. Different for plants financed by utilities
Germany	(6.7) 19.8	38.6	7.6	19	Feed-in tariff €ct 4.87 – 8.93 per kWh (according to duration of payment) + repowering bonus of €ct 0.5 per kWh and plant service bonus of €ct 0.48 per kWh
Portugal	**(21.1) 45.3**	**60**	**17.2**	**23**[iv]	**Feed-in tariff** **€ct 7.4-9.8 per kWh for 20 years**
Spain	(14.3) 30.3	40	14.8	21	Feed-in tariff[vi] €ct 8.1270 per kWh; from the 21st year onwards: €ct 6.7921 per kWh
UK	(3.4) 9.5	31	4.3	21	Feed-in tariff (GBP per kWh) 100kW - 500kW: 0.1804 500kW - 1.5MW: 0.0979 > 1.5MW: 0.0415

Sources: [i] DGEG (2013, p.12); [ii] data directly collected from the National Renewable Energy Action Plans (NREAPs) of the European Member States: Beurskens et al. (2013, Table 3 and 10a/b); [iii] Ren21 Map <http://map.ren21.net> (accessed in September 17, 2013); [iv] Plano Nacional de Acção para as Energias Renováveis (PNAER 2012); [v] RES-legal at <www.res-legal.de> (accessed in September 17, 2013), and for Portugal Peña (2013) citing ERSE; [vi] the new energy reform announced by the Spanish government in July 2013 intends to significantly reduce the remuneration of renewable energy sources, namely from wind technologies.

It is therefore important to understand the reasons that explain the spectacular increase of wind capacity in this fast follower country. Our argument is that it was possible thanks to the successful formation of a local technological innovation system based on wind technologies. The context and conditions that enabled the emergence of the TIS are studied in the next points.

4.2 The emergence of a local wind innovation system

This section analyses the emergence and growth of a local innovation system based on wind technologies in Portugal with the help of the technological innovation system approach (Bergek et al., 2008a,b; Hekkert et al., 2007, 2009). As pointed out above, this literature has identified several key processes or functions that are required for a successful maturation of the TIS. The history of wind in Portugal is examined stage by stage - formative, up-scaling and growth phase - through the presentation of the most relevant facts that influenced the fulfillment of these functions in each phase.

4.2.1 Formative phase

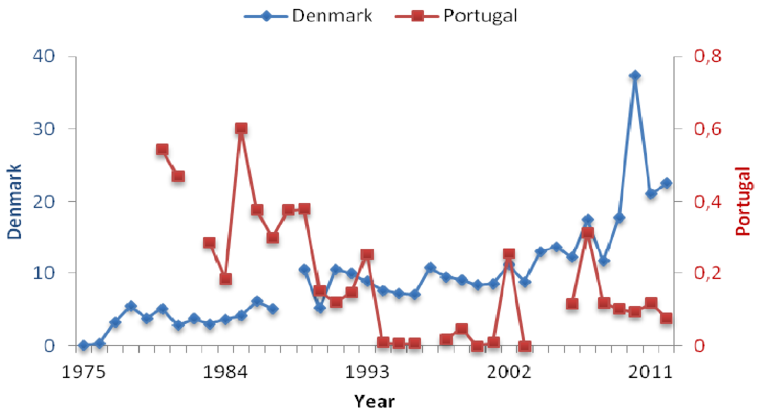
The first exploratory activities in wind technologies began in Portugal in the 1980s. Internationally, the conditions were already created to scale-up wind turbines in Denmark: in the early 1990s, the Danish industry was already preparing for the construction of turbines with capacities above 500 kW. In Portugal, this period lays down the basis for the emergence of the new technological innovation system. Two main functions of innovation system were particularly important in the embryonic and formative phase: knowledge creation from the participation in international research projects, and entrepreneurial experimentation with small wind projects.

a) Knowledge creation

The first relevant activities in the field of wind power were related with *formal knowledge development*. In the 1980s, the energy policy in Portugal is still under the influence of the two oil shocks of the previous decade. It reflects a desire of diversifying the energy sources and reducing the dependence on imports of fossil fuels. In this context a few national research groups become involved in European joint-projects, namely in the area of wind characterization (Matos, 2013). This permitted the creation of local knowledge on the assessment of wind resources and technologies, at the level of public research organizations (Estanqueiro, 2013; Matos, 2013). In the early 1990s, INETI, a public research center, publishes a detailed evaluation of the wind resource potential in Portugal (IRENA-GWEC, 2012). In the mid-1990s, studies on wind potential begin to be financed by private funds, particularly by the public utility, EDP (Costa, 2004). As a result, the installation of the first wind farms was done without the need for hiring international consultants, only the turbines were imported (Matos, 2013).

The creation of formal and applied knowledge can be assessed by the amount of investment in innovative activities over time. Figure 2 presents the total expenditure in research, development and demonstration (RD&D) activities on wind energy in Denmark and Portugal, respectively, between 1974 and 2012. Unsurprisingly, the amount of RD&D in the former is always one to two orders of magnitude larger than in the latter. However, it is more interesting to compare the evolution of the expenditures in the two countries: RD&D is steadily increasing in the case of Denmark, whereas it peaks in Portugal in the 1980s and again in the 2000s before a major raise in the installed capacity (see Figure 3). This might also be an indicator of the RD&D orientation in Portugal towards a more applied type of knowledge, directed to solve practical problems associated with the adoption of wind technology. In fact, the research activities comprised wind assessment, management of the grid penetration of intermittent renewable energy, and development of small urban wind turbines (IEA, 2012b).

Figure 2. Total expenditure in research, development and demonstration (RD&D) activities in wind energy in Denmark and Portugal 1974-2012, in Million Euros (2012 prices and exchange rates)



Source: IEA, 2013.

b) Experimentation

The second most important function in the emergence of the local innovation system based on wind technologies was *entrepreneurial experimentation*. The experimental trials took place from mid-1980s to early 1990s, allowing the first contact with early prototypes of wind turbines. The following years saw a number of small turbines (around 100 kW) being tested and experimented in different parts of the country (Table 2). The first significant capacity installation occurred in 1992, with 12 machines of 150 kW each in a total of 1.8 MW. This "exploratory" phase lasts until 1996 when the first 500kW and higher capacity turbines start being deployed in the country.

Table 2. Wind power scaling at both industry and technology levels in Portugal betwen 1985 and 1998

	1985	1986	1987	1988	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Total capacity														
Installed power (MW)	0,29	0,29	0,29	0,53	0,53	0,53	0,93	3,83	8,93	9,08	9,08	20,03	20,03	52,53
Wind turbines (no.)	10	10	10	18	18	18	22	42	76	77	77	106	106	171
Sites (no.)	2	2	2	3	3	3	4	7	11	11	11	13	13	18
Average capacity (MW)														
Farms	0,15	0,15	0,15	0,18	0,18	0,18	0,23	0,55	0,81	0,83	0,83	1,54	1,54	2,92
Aerogenerators	0,03	0,03	0,03	0,03	0,03	0,03	0,04	0,09	0,12	0,12	0,12	0,19	0,19	0,31
Aerogenerators - annual additions	0,03	-	-	0,03	-	-	0,10	0,15	0,15	0,15	-	0,53	-	0,50

Source: INEGI - APREN (2011).

The experiments contributed to the development of applied knowledge and permitted to follow the technology progresses taking place abroad. They were decisive for the main actors to acquire experience on wind technologies, reducing the uncertainty for future projects. Hence, the benefits in terms of "learning by using" for wind farm operators were similar to those previously observed in pioneer countries (Harborne and Hendry, 2009). However, the major role played by the energy utility (EDP) in the trials and in market development is a distinctive feature of this case, when compared to the situation in

Germany or Denmark (Simmie, 2012; Karnøe and Garud, 2012; Jacobsson and Lauber, 2006). The early trials in Portugal were also important to create collective resources for the TIS and promote social change (Hendry and Harborne, 2010). In that sense, they were not just able to address the problem of the “uncertain middle” between the technology transfer and early commercialization, but also the “uncertain context”, by laying down the foundations for the development of a community of firms and users that helped to legitimate the technology later on.

Other functions of innovation system were gradually fulfilled during this formative process. The government promoted renewable energy as a fundamental element of the future electricity generation mix, immediately helping to establish its *legitimacy*. It removed technical and legal barriers to the grid connection of renewable energy generators, namely by setting a "special regime" with priority dispatching (cf. DL 189/88).[6] The *financing* of early projects was supported with investment subsidies whose funds came from the public budget and from European programs (Table 3). The nature of the supported initiatives follows the expected evolution, from more basic and science-oriented research to more applied activities linked to the implementation of the technology. In addition, the relevance attributed to renewable energies, such as wind power, *influenced the direction of search* and attracted supply-side actors to the TIS. The first actors active in the field, beyond the aforementioned public research, were energy utilities (e.g. EDP, EDA-Azores) and international developers that financed several early experimental projects. Finally, the *dynamic of positive externalities* was further boosted with the creation of the network of renewable energy producers (APREN) in 1988, and the new renewable energy division of the utility EDP (Enernova) in 1993. The action of these two organizations was decisive for the implementation, in the late 1990s, of the support schemes that preceded the take-off of wind energy (IRENA-GWEC, 2012).

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[6] The national electricity system is composed by the public electricity system and the independent electricity system. The first comprises the regular activities to ensure the electricity supply in the country, including public service obligations and universal delivery. The second comprises the special regime producers and the non binding electricity system according to the legislation.

Table 3. Policies supporting the development of renewable energy positioned within the respective European & National Framework Programmes *(European programmes marked with an asterisk)*, by phase of development of the local innovation system

	RTD Framework programmes *	QCA (Country Framework Programmes)	Generic Operational Programmes at country level	Energy specific operational programmes	Support measures for energy (or including substantial number energy projects)
Formative phase	**FP1 - 1984-1987**	**Pre QCA (1982-1988)**			
	FP2 - 1987-1991				SIURE (DL.188/88) subsidized by the European VALOREN*. JOULE* Introduction of a “special regime” for renewable energies (DL 189/88)
	FP3 - 1990-1994	**QCA I (1989-93)**	PEDIP, CIENCIA		
	FP4 - 1994-1998	**QCA II (1994-1999)**	PEDIP II, PRAXIS XXI	Operational Programme for Energy (DL.195/94)	ALTENER*
Up-scaling phase	**FP5 - 1998-2002**				
Growth phase	**FP6 - 2002-2006**	**QCA III (2000-2006)**	POE / PRIME , POCTI / POCI	Programa E4, ENE2010	MAPE (DL.70B/2000)
	FP7 - 2007-2013	**QREN (2007-2013)**	COMPETE, POHP	ENE2020, PNAER,	Public tender for the attribution of rights connection (DR.144/2005), Fund to Support Innovation, SIMEI&DT, DEMTEC

4.2.2 Up-scaling and growth phases

The next stage corresponds to a period of hard market development of wind power in Portugal, encompassing both the up-scaling and growth phase. The former roughly comprises the years between the installations of the first 500 KW turbines in 1996, until the deployment of 3 MW turbines in 2003, whereas the latter starts around 2004 and coincides with the increasing pace of deployments. This took place after the introduction of incentive policies and the organization of a public tender in order to award connection rights to new wind power installations. This section examines how legitimacy was built around wind power, allowing the institutional alignment with the needs of the technology that fostered the development of the market.

At the international level, the focus of technology development in the 1990s was on up-scaling wind turbines in order to improve performances and grasp economies of scale at unit level (Wilson, 2012; Hendry and Harborne, 2011). Many economic and logistic challenges had been solved during this process, such as the availability of cranes for the erection of larger turbines (Neij and Anderson, 2013). As a consequence, the technology progressed enormously and by the end of the decade the Danish manufacturers were commercializing new models of turbines that were much larger than the previous generations and had significantly improved performances and reduced costs (Neij et al., 2003; Nemet, 2009). The technological achievements in Denmark had inspired other countries across Europe. This was the case of Germany that re-oriented the technology policy to replicate the conditions behind the Danish success. German manufacturers started to focus on smaller 3-blades turbines and benefited from the contacts with Danish companies for knowledge transfer (Neij and Anderson, 2013). Another case was Spain which took advantage from the joint venture established between the local turbines manufacturer, Gamesa, and the most important Danish manufacturer, Vestas, to start producing the latter’s technology under license for the domestic market (Lewis and Wiser, 2007). Meanwhile, Germany and Spain introduced investment and production incentives to promote market formation (Jacobsson and Lauber, 2006; del Río and Gual, 2007). The former set up a feed-in law paid by the electricity utilities to wind energy producers in 1990, while the later approved a similar law four years later.

Technology improvements in core countries opened a "window of opportunity" for the development of wind power in Portugal. In fact, the success of diffusion in Denmark, Germany and Spain, *influenced the direction of search* that led to the entry of main actors into the sector. The first wind farms were installed in 1996/97 by and EDP affiliate (Enernova) with promising results. This prepared the conditions for the intense growth of capacity installations that followed after the turn to the new millennium.

a) Legitimation and institutional alignment

The government's interest in wind power was strongly influenced by the already mentioned European Directive for Renewable Energy , which required Portugal to meet the target of 39% (later revised to 45%) of its gross national electricity consumption from renewable energy sources, by 2010. In the early 2000s the country's renewable energy production came almost exclusively from hydropower, which had a limited growth potential due to the difficulty in building new large dams[7]. At the same time, wind energy had become a more mature technology and offered a credible alternative. The maturity of the technology and the need to invest in renewable sources were crucial for the *legitimation* of wind power. They created the conditions for the fixation of objectives for capacity growth in the next years and, consequently, the implementation of a favorable regulation.

In fact, inspired by the success of wind power in other countries, in particular Spain, the Portuguese government sets up increasingly ambitious targets for capacity installation (Fig. 3). In 2003, the country planned to install 3,750 MW by 2010, raising this objective to 4,500 MW in 2006. More ambitious goals were set four years later when the government aimed to increase wind capacity to 8,500 MW by 2020. Yet the financial crisis forced the executive to lower its expectations to a more realistic 5,300 MW (PNAER 2012). In spite of the recent drawbacks, the definition of targets was decisive to create expectations about the development of the sector and profit opportunities that encouraged new entry, boosting the growth of the innovation system.

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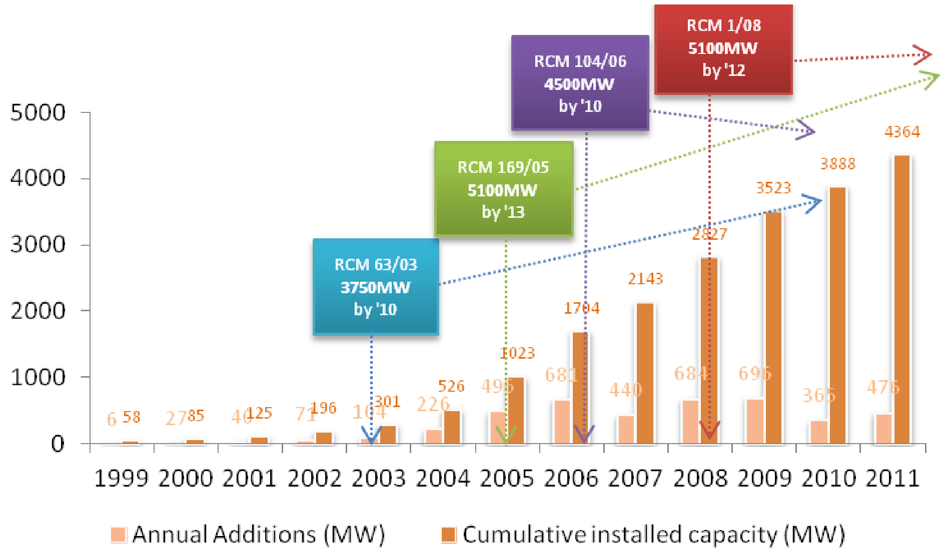
[7] Shares of energy sources estimated from the DGEG online database available at http://www.dgeg.pt/ under the title "Produção / Consumos (1994-2011)", last accessed in October 3, 2013.

Figure 3. Cumulative and annual installed capacity of wind energy and official goals (in megawatts)



Source: DGEG, 2013

The institutional alignment with the needs of technology took the form of market regulations (e.g. grid connection) and support mechanisms. A new "feed-in" tariff (FIT) was introduced in 2001 that substantially increased the remuneration of producers, encouraging the investment in wind power (Figure 4). It was equally established that 2.5% of cash flows must be paid to the municipalities where wind farms are located. This decision was effective in lowering local resistance to the installation of turbines and reinforcing legitimation (Delicado et al., 2013; Matos, 2013).[8] The FIT was further revised in 2005, 2008 and 2013, each time limiting both the value and duration of the guaranteed tariff. In 2005, for instance, its application was restricted to the first 33 GWh produced per MW installed or 15 years, whichever reached first. Nevertheless, the average tariff paid remained stable and high, as a large part of the installed capacity was approved under the most attractive tariff (IRENA-GWEC, 2013; Peña, 2013; IEA, 2009).

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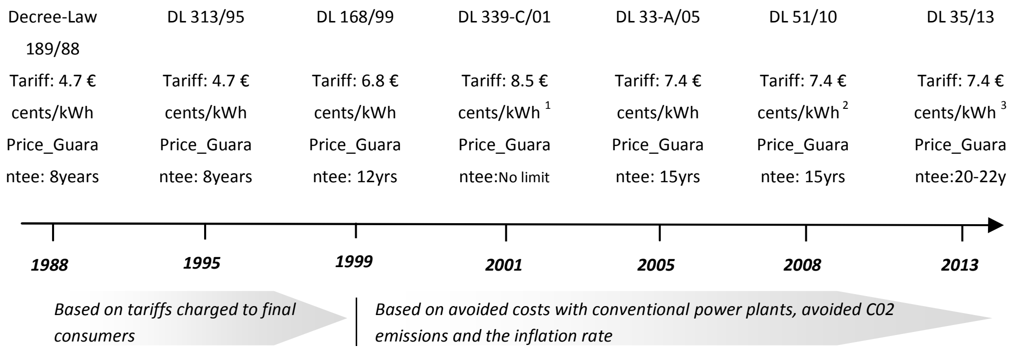
[8] Despite of fact that Portuguese public opinion has been one of the less supportive of renewable energy among the European countries according to the Eurobarometer (cf. Delicado et al., 2013).

Figure 4. Evolution of the legal framework on wind energy feed-in tariff



Assumption: 12 MW wind farm, producing in average 2,640 hours equivalent per year. The values represent the feed-in tariffs that would be expectable with wind conditions in April 2005, according to the law in force.

(1) Tariffs by output blocks: first 2,000 hours: 9.1 € cents/kWh; 2,000-2,200h: 7.8 € cents/kWh; 2,200-2,400h: 6.6 € cents/kWh; 2,400-2,600h: 5.6 € cents/kWh; beyond 2,600h: 4.7 € cents/kWh.

(2) Allows the installation of 20% more capacity, in return for a reduction on the feed-in tariff proportional to the power increase up to 2.4%.

(3) Wind independent power producers can extend the feed-in tariff period by five or seven years upon the payment of an annual compensation of 5,000 €/MW or 5,800 €/MW, respectively. In the first case, the feed-in tariff is extended by five more years and they can select either a tariff between 74 - 98 €/MWh or a guaranteed minimum of 60 €/MWh, starting 2020. In the second case, the additional period extends for seven years maintaining the alternatives as in the previous case.

Adapted from Ferreira and Araújo (2007). Other source: Peña (2013).

b) Market formation

The tariff approved in 2001 triggered hard market formation for wind in Portugal. In fact, the new attractive remuneration was followed by a strong interest in the technology. The Directorate General of Energy received applications for 7,000 MW of new wind capacity at the beginning of 2002, after the publication of the law (IEA, 2003). In addition, the size of the turbines installed in Portugal was rapidly scaling up to 1.8 MW in 2002 and 3 MW in 2003. The combination of these two factors has substantially contributed to a jump in total installed capacity, from 125 MW in 2001 to 1,023 MW by the end of 2005. The diffusion accelerated after 2004 with the installation of 500 MW per year, in average, until the end of the decade. Consequently, the part of wind in total electricity consumption passed from 2% in 2002 to 19% in 2012 (DGEG, 2013). This is almost one order of magnitude increase within a decade, which shows clearly the transformation that wind energy operated in the Portuguese electric system.

This case demonstrates how institutional alignment with the needs of the innovation can trigger the mobilization of resources for the development of a large market for a new technology.

c) Resource mobilization

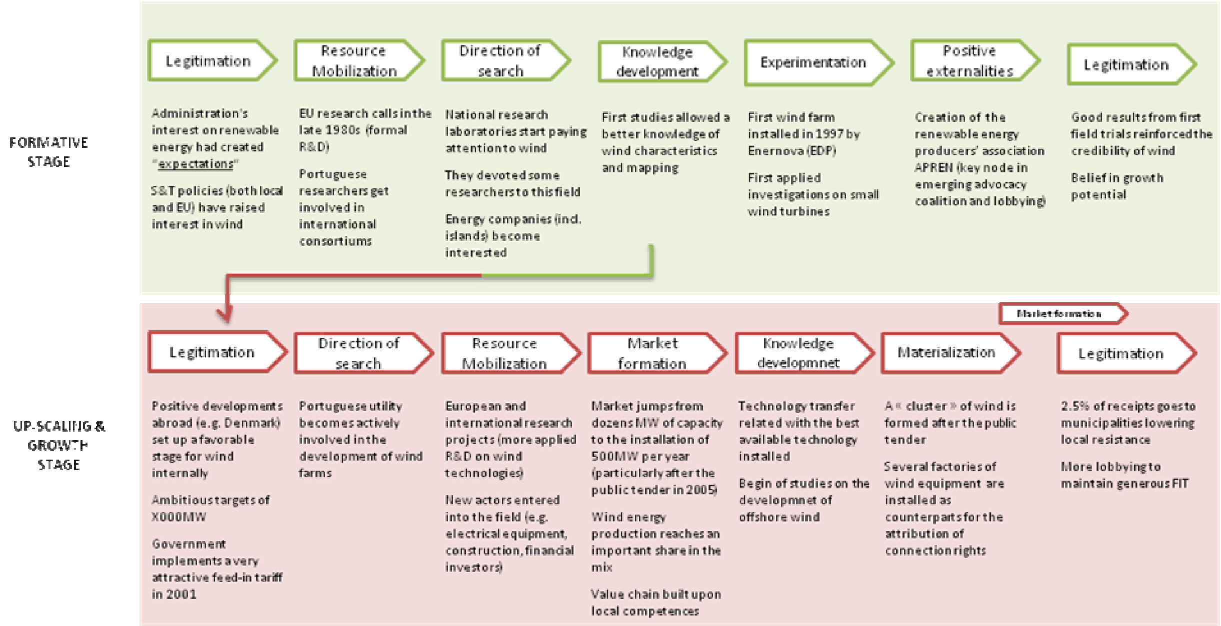
Capital became increasingly available for financing the development of new wind farms as the market for wind energy expanded. Private involvement was stimulated by a variety of government incentives, that included grants covering part of the costs with new installations. These schemes were managed by the Ministry of Industry and Energy and the funds were partly supported by the European Union under the Country Framework Programme (QCA III) (IRENA-GWEC, 2012).

The pace of investment accelerated after 2005, when the government decided to organize auctions for the attribution of connection rights to new wind power capacity, which were tied with requirements for local production of equipment. A public tender for the allocation of 1,800 MW was released in three phases in 2005. The largest one, phase (A) of 1,200 MW, was won by the ~~a~~ consortium ENEOP led by the utility EDP, in alliance with a foreign industrial partner (Enercon). This project involved the creation of an industrial cluster with a total budget of € 1.750 million (Martins et al., 2011). The second largest, phase (B) of 500 MW, was won by the consortium Ventivest formed by a national energy company (Galp), an engineering company (Martifer) and a foreign manufacturer (Repower) in which Martifer had an important share in the capital. The implementation of the wind farms was, however, delayed by the economic crisis, which made access to credit more difficult. The capacity contracted only begun deployment in 2008 and is not yet concluded. During the peak of the crisis, in 2011, the installation of new farms stopped altogether and production had to be re-orientated to exports - initially projected to start in 2013 - with more than 60% of ENEOP's production being shipped abroad (Público, 2011).

d) Development of positive externalities

Finally, the attractive remuneration and the subsequent market growth had implications for the development of other functions of innovation system. It significantly influenced the *guidance of search* and the entry of new supply-side actors from several related activities (e.g. construction, metalomechanics and engineering), in which the country already had strong competences and that had an incentive to re-deploy or extend their activities to this new sector. In the same way, the development of the market contributed to the formation of *networks and externalities*. The public tender organized in 2005 spurred the creation of an industrial cluster of wind technologies in the North region, materialized in the setting-up of blades, towers and turbines factories. This resulted in the creation of new jobs in regions where traditional industries were in decline and led to the revitalization of depressed areas. In addition, the research conducted, from early stages, on wind characterization laid down the basis for a strong local competency in a field that is critical for market development. These competencies are currently exported by specialized service providers. All these elements reinforced the local *legitimation* of wind power. Figure 5 provides a schematic overview of the processes that marked the emergence of the new innovation system in Portugal.

Figure 5. The emergence of the wind TIS in Portugal through the analysis of the most relevant functions of the innovation system by stage of development



FORMATIVE STAGE

Legitimation	Resource Mobilization	Direction of search	Knowledge development	Experimentation	Positive externalities	Legitimation
Administration's interest on renewable energy had created "expectations" S&T policies (both local and EU) have raised interest in wind	EU research calls in the late 1980s (formal R&D) Portuguese researchers get involved in international consortiums	National research laboratories start paying attention to wind They devoted some researchers to this field Energy companies (incl. islands) become interested	First studies allowed a better knowledge of wind characteristics and mapping	First wind farm installed in 1997 by Enernova (EDP) First applied investigations on small wind turbines	Creation of the renewable energy producers' association APREN (key node in emerging advocacy coalition and lobbying)	Good results from first field trials reinforced the credibility of wind Belief in growth potential

UP-SCALING & GROWTH STAGE

Legitimation	Direction of search	Resource Mobilization	Market formation	Knowledge developmnet	Materialization	Legitimation
Positive developments abroad (e.g. Denmark) set up a favorable stage for wind internally Ambitious targets of X000MW Government implements a very attractive feed-in tariff in 2001	Portuguese utility becomes actively involved in the development of wind farms	European and international research projects (more applied R&D on wind technologies) New actors entered into the field (e.g. electrical equipment, construction, financial investors)	Market jumps from dozens MW of capacity to the installation of 500MW per year (particularly after the public tender in 2005) Wind energy production reaches an important share in the mix Value chain built upon local competences	Technology transfer related with the best available technology installed Begin of studies on the developmnet of offshore wind	A « cluster » of wind is formed after the public tender Several factories of wind equipment are installed as counterparts for the attribution of connection rights	2.5% of receipts goes to municipalities lowering local resistance More lobbying to maintain generous FIT

The incentives and support mechanisms not only contributed to the development of the sector in Portugal, but also strengthened its political influence, as new players entered the field. The multiple (upward) revisions of the targets are an indicator of the increasing political strength of the coalition formed by the key TIS actors. The connections with the political sphere intensified over time, with some cases of "revolving door", whereby a number of key individuals have circulated between government positions (including minister level) and the boards of leading wind farm operators or capital investors.

Along this process, the creation of rents was ineluctable, with total funding provided by the government amounting to €3.6 billion up to 2010 ($2012 values) (Peña, 2013). This contributed to increase final residential electricity prices and led to a national electricity system deficit of over €2 million, thereby raising the opposition to wind power in the media (Delicado et al., 2013). Furthermore, the end of the "special regime" for wind energy production and the subsequent transition to the liberalized market - as the first FIT contracts were expected to expire soon - was pushed to 2020, according to new legislation approved in 2013. This new regulation gives renewable energy producers the possibility to receive the guaranteed tariff for an additional period of 5 or 7 years, in exchange for the payment of an annual compensation for the reduction of the tariff deficit. The objective of the measure was to reduce this deficit in the short term, but the benefits may be crowded out by the extra payments due in the medium term through the extension of the FIT period. This shows again the political strength of the sector, which resists any government's attempts to change the regulatory framework.

4.3 Discussion

The study of the development of a new innovation system based on wind energy in Portugal reveals some features that improve our understanding about the mechanisms which come into play when a technology moves out from the center and starts being adopted in fast follower markets.

The case analyzed shows that the diffusion of wind technology was, to some extent, the result of a policy that elected renewable energies as a priority for the country's development and, more specifically, of a political decision to promote and support the development of a wind energy sector. Yet the acceleration of the diffusion was only possible because, when this decision was made, the capacity to assimilate the technology and implement the innovation had already been created. This took place during the previous "formative" period, over which a coalition of actors was formed and engaged in a variety of learning activities, while also actively promoting the field.

The definitions of the formative phase underline that this is the period when the structure of the new TIS starts being constituted and when actors engage in early activities, such as experimentation, that are necessary not just for technology adoption but also for the establishment of a production base. Along this period these actors followed (and sometimes were involved in) the main scientific and technological advances in core countries and congregated resources and competencies - including practical knowledge derived from several local experiments - with the expectation of applying them in the future. However, these learning processes differed from those that took place in core countries (like Denmark), in what they were more constrained by the level of available resources and by the limited opportunities for an early implementation of the new technology. These were nevertheless "formative" activities that enabled the development of a strong absorptive capacity. This permitted, first of all, to identify and select the best technology options for the specific context. But it also created the conditions for quickly engaging in their implementation, as soon as the technologies became sufficiently mature to overcome the initial uncertainty and to offer an attractive return, thus encouraging a wider set of local actors to invest in wind energy.

The enactment of a policy that offered important incentives for investment in the wind sector, provided guidance for the actors' decisions. Yet the development of the innovation system was only possible thanks to the existence of enough competencies in complementary areas (e.g. metallurgy, electric equipment, systems engineering) and their alignment under a shared "vision" in order to implement the technology and expand the value chain. Unsurprisingly, there were some key actors in this process who gave a decisive contribution to legitimize wind, through the mobilization of internal resources (e.g. financial, technical and market knowledge, reputation). At this level, one distinctive mark of the diffusion of wind in Portugal is the role played by the main energy utility, which assumed the leadership during the emergence of the innovation system and was crucial to influence the policy. This process differed substantially from the one documented for the core countries, where regime incumbents delayed their entry, or assumed a less prominent role in early stages of the development of renewable energy technologies. Another feature of this case is the clear co-evolution of the institutional setting and the interests of the actors. The incentives were initially designed to attract new actors, but these have gradually acquired sufficient political strength to influence policy formulation towards the maintenance of a very favorable regulatory framework, that sustained the continued development of the system, even when questions started being raised regarding its sustainability.

These processes took place in a wider context that goes beyond the country level. External influences, in particular the interactions with the core, were important in the process of construction of the local innovation system. In fact, the absorption of the wind technology was conducted in an open system and the contact with organizations from the core was crucial for reinforcing local technological capacity. Relationships with foreign research organizations and presence in international scientific and professional networks permitted to follow knowledge developments, to gain access to state-of-the-art technology and to build international legitimacy. On the other hand, the ability to capture the interest of international manufacturers – attracted by a fast growing market – was instrumental to the formation of local production competences.

These relationships were established assuming first the form of licensing agreements, and later of production and commercial partnerships or joint-ventures, often facilitated by local competences and organizations' credibility. On the one hand, they opened the access, by local companies, to the most advanced technology and gave them the ability to produce the key equipment locally, triggering local learning processes and the construction of an integrated value chain. On the other hand, they permitted to deploy the technology timely, at a moment when industrial capacity was exhausted worldwide and there were waiting lists of several years in the international market. The creation of local production capabilities - combined with an early development of competences and experience in the set of activities required to implement and manage wind systems - also permitted local actors to quickly advance to the exploration of emerging opportunities in laggard countries, thus expanding their activities beyond the limited internal market. In other words, it allowed them to effectively assume the status of fast followers and to be competitive in new markets, at a stage when competitiveness started to depend less on "inventiveness" and when commercialization capabilities started to dominate (Lee, 2009).

All in all, this case shows that, in order to become a fast follower, Portugal needed to combine a strong political commitment to promote the creation of a wind energy sector, with the capacity to assimilate the technology developed in pioneer countries, building on the country's competences, resources and international networks. These efforts led to the development of a successful innovation system, suggesting that this can be one effective path for fast technology adoption.

Conclusions

The objective of this paper was to investigate the conditions for the development of a new innovation system in a fast follower country, centered around a new technology whose early development and first deployment took place in the technological core, but was quickly adopted by the follower. This is a relevant problem, first of all, because the follower will need to accommodate, in its socio-technological context, a new technology that was previously developed under distinct conditions. Moreover, this process of technology "absorption" - i.e. identification, assimilation and implementation of the innovation (Cohen and Levinthal, 1989, 1990; Fagerberg and Godinho, 2005) - is usually realized in contact with the core, requiring a careful consideration of the interaction implications. Hence, the emergence of the innovation system in a follower was expected to be different from that in the core, and likely to be constrained by the endogenous capacities of the subsequent market. The in-depth analysis to the process of construction of the innovation system based on wind technologies in Portugal enabled to test these hypotheses and revealed additional patterns that improve the understanding about the development of new innovations systems in next markets.

The construction process of the innovation system in the follower country differed from the one in the core in some respects. The formative stage is more focused on the development of competences and resources that will permit to absorb the technology, rather than on the development and early implementation (by trial and error efforts) of the technology, that takes place in the core. However, this formative period plays a similar constitutive role in the follower. It comprises key structural processes that enhance the capacity to assimilate the technology and implement it in ways that take advantage from the country competences in complementary areas. On the other hand, as in the core, the political decision to promote and support wind energy is decisive to create a market for the technology. Moreover, some key actors have equally played an important role in the process. Yet the involvement of large energy incumbents, in particular the leadership provided by the main energy utility, appears to be a feature of this particular case. They emerged as pivotal to create legitimacy, mobilize resources and align competences from different areas, which were instrumental to the development of the innovation system.

This research provides new insights for the TIS analysis of the construction of a new innovation system in follower countries during the periods of technology development and implementation. It shows that the approach by the functions of innovation system is still relevant in the case of followers, but there are some differences in the way they unfold. This is namely the case of formative processes, more focused on the rapid expansion of the innovation system once the technology gets mature in the core. For the future it would be interesting to compare with other follower countries in order to analyze whether the intervention of actors from the regime is a feature that accelerates the transition in subsequent markets.

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