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Article

The power of wind: An analysis of a Uruguayan dialogue regarding an energy policy

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Abstract

This article addresses a dialogue process regarding the implementation of an energy policy based on the development of wind power in Uruguay. This policy is the major component of a national strategy of diversification of the energy matrix based on renewable sources initiated by the Uruguayan government in 2005. We focus on the development of a cognitive niche regarding wind energy emphasizing a virtuous articulation between academia and government. Results are presented as a narrative of the development of wind energy engaging with the literature on technological transitions and innovation systems. The transition resembles a transformation path in three phases during which relationships among different communities evolved. The analysis addresses the importance of learning spaces on energy-related topics and the leading role of the State in the transformation.

Key words: wind energy; energy matrix; energy policy; energy transitions; Uruguay.

1. Introduction

Energy transitions to renewable sources require major transformations in processes, practices, and knowledge about energy sources, production, distribution, control, and regulations, among others. Worldwide there are diverse private initiatives, public policies, and social movements involving transformations from conventional forms of energy to cleaner ones based on renewable sources (Kamp 2008; Strachan et al. 2006). Transformations were initiated in Europe followed by large investments in research and development at specialized institutions, particularly in Germany and Denmark (Ammonit 2016). In Latin America, Brazil has led the initiatives for energy change based on a national program later followed by Chile, Uruguay, Peru, and Argentina (Aquino Juárez et al. 2014; Global Wind Energy Council 2015). Uruguay has recently developed a national energy policy (NEP), which guarantees electric energy supply while reducing dependency from foreign sources, fostering environmental protection, and promoting the development of local capacities. This energy policy is the basis for the transformation of the Uruguayan energy matrix.

Historically, the sources for the generation of electricity in Uruguay have been thermoelectric generation based on imported fossil oil and locally produced hydroelectric power. In the 1990s, an increasing energy demand coupled with the physical impossibility of augmenting hydroelectric generation capacity and the failure of a market integration strategy with Argentina, established the land mark to start working on an autonomous transformation of the electric matrix. This situation was on the basis of the initiation of the NEP 2005–30 conceived as a tool to foster development and social integration. The NEP evolved from a process of dialogue among multiple actors related to energy production and was supported by all political parties represented at the National Congress. A major goal of the NEP is the diversification of energy sources emphasizing the importance of native and renewable energies as a way to reduce dependency from fossil oil imports. The NEP thus became a national State policy with long-term goals backed up by a wide social and political support.

Still in progress, the transformation of the Uruguayan energy matrix already reduced oil imports and dependency from weather conditions for the generation of electric power for residential, industrial, and commercial sectors. Renewable sources were promoted leading to the incorporation of wind energy, biomass, and solar energy for electricity generation. Therefore, in 2015, the electric matrix was composed by 54 per cent hydropower, 12 per cent eolic, 19 per cent biomass, and 15 per cent of petroleum (Ministerio de Industria, Energía y Minería [MIEM] (a) n.d.). Eolic energy was inexistent up to 2013 when it represented 2 per cent of the electric matrix (Ministerio de Industria, Energía y Minería [MIEM] (b) n.d.). Thus, eolic energy grew and established itself as a suitable option for the transformation.[1]

This article focuses on the process of incorporation of wind power to the electric matrix in which different stakeholders played diverse roles in the dialogue regarding energy production. Different from other transitions involving wind energy with varied innovation strategies (Kamp 2010), the Uruguayan experience was not based on the development of new technology. Major components of wind parks (turbines) are imported as design and manufacturing was out of the reach for Uruguayan actors. Local entrepreneurs are mainly investors and industrial initiatives focused on low technological components such as transformers and transmission lines. The introduction of a new energy source and additional entry points into an electric grid required automated monitoring and prediction procedures to allow the shift from one source to another when needed. A technical solution was locally developed at the university as a simulation-free software (SimSEE) operated by the national energy enterprise for the command of the electric grid (Televisión Nacional de Uruguay [TNU Canal Cinco] 2016). At the core of the process there were changes in regulations regarding the use and production of energy, emergence of new actors, transformation of user practices, and generation of new expert knowledge on the subject. For instance, it was necessary to strengthen technical capacities and invigorate financial resources at the National Energy Directorate (DNE, by its Spanish acronym), the body leading the design of the energy policy since 2005 at the Ministry of Industry, Energy, and Mining. Also, the Eolic Energy Uruguayan Association (AUDEE, by its Spanish acronym) was created in 2009 clustering firms and individuals involved in the development of wind power. At the regulatory level, a complementary legal framework for the generation and distribution of energy was necessary including regulations for access to grid connections, for the construction and operation of wind parks, as well as environmental, legal, financial, and tax-related aspects.

In the following pages, the development of wind energy is presented engaging with the literature on technological transitions and innovation systems. The study is based on multiple sources of information including eight interviews with energy officials, university researchers, and private investors, analysis of technical reports, policy documents, public databases, and conference presentations. The transition is examined throughout different phases in the dialogue in which stakeholders (Dutrénit et al. 2017) played diverse roles in the construction of social, political, and technical agreements regarding energy production.

2. On technological and energy transitions

This section introduces the theoretical concepts to be used in the analysis of the development of wind energy in Uruguay as a suitable option for the transformation of the electric matrix. The concept of technological transitions guided the search for an understanding of this transformation.

Technological transitions are 'major, long-term technological changes in the way societal functions are fulfilled [by sociotechnical configurations]. TT do not only involve changes in technology, but also changes in user practices, regulation, industrial networks, infrastructure, and symbolic meaning or culture' (Geels 2002: 1257). The stability of a sociotechnical configuration therefore depends on interrelated elements of varied natures. Elements' configuration and their linkages result from the activities 'aligned to each other and coordinated' among different social groups (Geels 2002: 1259). Thus, social groups through coordinated activities can reproduce or transform established configurations.

The evolution of sociotechnical configurations will rest upon the relationships among the landscape, the sociotechnical regime involving multiple dimensions (technology, user practices and markets, symbolic meaning of technology, infrastructure, industry structure, policy, and techno-scientific knowledge) and technological niches. Niches are protective spaces where real-world experimentation and development of sustainable technologies can take place shielded from market forces during incubation (Smith 2007; Geels and Schot 2007). They 'provide the seeds for systemic change,' on the basis of social network development, learning, and articulation processes (Geels 2011: 27).

Niches are conceived as organizational fields in which different group communities interact according to shared rules (regulative, normative, cognitive) and coordinated actions. Rules tend to fluctuate as they are still in the making with communities being small and unstable. Actors create and modify rules at the same time they are shaped by them. In this sense, innovations performed at niche level can evolve to a regime 'when social networks grow larger and rules become more stable and constraining, leading to a reversal in their relation to agency' (Geels and Schot 2007: 402–3).

Rules' refinement and stabilization are achieved, among other factors, by learning processes and articulation 'to stimulate the price/performance ratio of new technologies and their alignment in broader socio-technical systems' (Geels 2005: 80). Three different learning processes expressed by concepts developed by evolutionist authors are relevant here: 'learning by doing (Arrow 1962), learning by using (Rosenberg 1976; Von Hippel 1988) and learning by interacting (Lundvall 1988)' (Geels 2005: 80). Learning processes develop throughout regime dimensions; a niche gains stability and expands as it co-evolves together with social support networks and expectations.

Positive learning experiences may strengthen the expectation, which, in turn, may attract more actors to support the niche. The expanding social basis makes the niche more stable. But the gradual alignment of socio-technical aspects also makes it more stable [..]. The emerging stability will be represented by more stability in the rule-set, which guides the actions of actors. On the other hand, if the three niche learning processes do not reinforce one another, the niche may fall apart. When learning processes and technical performance do not live up to expectations, actors may leave the support network (Geels 2005: 81).

Energy transitions, in particular, can be seen as large transitions resulting from the accumulation of minor concerted transitions, which have often been planned. Indeed, 'quick energy transitions', taking place within few years, share some traits such as the fact that they have been guided or stimulated (Sovacool 2016: 207). For 'truly transformative change', alterations at every level of the system are needed. This implies conjunct change simultaneously involving technology, policy and legal regulations, market signals, and social values (Sovacool 2016: 205).

Now, how do transitions actually occur? Geels and Schot (2007) propose a typology of four possible transition paths on the basis of time and type of interaction between niche and regime. Our study resembles the case of a *transformation path* as characterized by these authors. A transformation path occurs when there is moderate pressure from landscape on the regime and niche-innovations are still not sufficiently developed. Regime actors react reorienting the trajectory and innovation activities. Regime outsiders, involving pressure groups and social movements, scientists and engineers, and entrepreneurs, are crucial for both making moderate pressure more visible and showing alternatives to regime insiders (for instance, policy makers) who can change their perception regarding regime reorientation (Geels and Schot 2007). Far from being smooth, regime reorientation often entails conflicts and power struggles. In this context, sociotechnical dynamic predominates over prevailing techno-economic dynamic, indicating that actors negotiate rules within and among their communities. Basic regime architecture is maintained and 'new regimes grow out of old regimes through cumulative adjustments and reorientations' (Geels and Schot 2007: 406–7).

A significant trait in the energy transition carried out in Uruguay during recent years is the leading role of the State following a government change in 2005. In this sense, Pérez (2013) in the preface of 'The Entrepreneurial State' highlights Mazzucato's assertion that the green revolution will depend on the proactivity of governments for stable and committed support and that success will be reached 'by those countries that have been able to reach a strong national consensus and can therefore maintain the level of funding and sustained policy support through the ups and downs of the economy' (Pérez 2013: 12–13).

We will now turn to the analysis of the niche of wind energy, the particular learning processes that occur and the landscape pressures that were on the basis of the transition take off at the beginning of the XXI century. Following the explanation of a *transformation path*, we will present the successive changes in the dimensions of the sociotechnical regime linked with the niche in different phases: *pre-development*, *take-off*, *acceleration*, *and stabilization* (Rotmans et al. 2001; cited by van der Brugge and Rotmans 2007).

3. Landscape conditions and the emergence of the new energy policy

At the beginning of the XXI century, three sets of factors challenged the continuity of the former energy matrix in Uruguay setting a moderate to strong pressure on the regime, particularly on political decision makers: scarcity and dependency, external factors, and climate change.

a) Limitations of the former matrix: scarcity and dependency

Energy dependency to provide electric power has been structural in Uruguay. It entirely relied on imports until 1945 when the first hydroelectric dam started operating. Up to the 1970s dependency from imported sources was over 90 per cent. With the global oil crisis, a compulsory reduction of imports and substitution by biomass, wood, and new hydroelectric dams took place lowering dependency to 75 per cent at the beginning of the XXI century (Bertoni et al. 2009). Thus, starting conditions for the transformation of the energy matrix were a strong dependence from foreign sources and from climate conditions. Climate variation left the country exposed to electric power shortages during dry years (Méndez 2008). Energy was bought from Argentina during drought periods. However, starting on 2004 the Argentinean energy system weakened and stopped producing surplus for exports.

Between 1991 and 2006 there were no investments in the electric sector to increase power generation, which aggravated the situation. The Uruguayan economy continuously grew since 2004 accompanied by an increased energy demand of 6.2 per cent annual average, between 2004 and 2011 (González and Méndez 2015; Uruguay XXI 2013). The energy sector, highly vulnerable to oil prizes and climate changing conditions, was even more stressed by the combination of lack of investments and sharp rise in demand, endangering power supply to the population. In fact, an interviewee from the government indicated that during 2006 and 2007 scheduled electric cuts were considered.(b) Structural external factors

(b) Structural external factors

Particular international conditions favored the possibilities for the incorporation of wind energy in Uruguay. Interviewees from the Administration of Power Stations and Electric Transmissions (UTE, by its Spanish acronym) indicated that there were technological factors as well as particular dynamics of the international goods and financial markets favoring the attraction of investments to Uruguay.

First, technological development made possible the power increase of wind turbines and mill's height, both facilitating its set up all over the territory. At the beginning of the current century, the development of wind turbines of greater power, and able to collect energy at 100 or 120 m height, increased the Uruguayan wind potential,[2] multiplying the number of locations where wind turbines could be installed throughout the territory. This fact had a positive impact on the profitability of investments.

Second, the international goods and financial markets were deeply affected by the 2008 economic crisis with epicenter in Europe. Wind mill European manufacturers faced production surpluses as the European demand for wind turbines was significantly reduced below their installed capacity. These companies were stimulated to find new markets overseas after they had significantly improved their production capacity. Wind turbines finally installed in Uruguay were imported mainly from Denmark, Germany, and Spain with the Danish Vestas being the major provider (Asociación Uruguaya de Energía Eólica [AUDEE] 2017). Also as a consequence of the crisis, there were available funds from Germany, Spain, and the International Development Bank with very low interest rates, looking for profitable low risk projects.

(c) Climate change

The emergence of policies focused on the promotion of energy renewable sources is a worldwide phenomenon. Climate change-related topics were in the public agenda since the 1980s, but after the United Nations 1992 summit in Rio de Janeiro an international agreement was signed for the reduction of CO_2 emissions. This constituted a milestone for the advancement of the sustainable development paradigm challenging the hegemonic global policy regarding environmental issues, especially for the energy sector. Renewable energies emerged as a clean and sustainable alternative to an energy sector based on the extraction of fossil oil, which exacerbates the increased climate change.

4. The development of a network of actors and a growing niche on wind energy

In almost a decade, a State energy policy was established in Uruguay involving changes in the production, access, and use of energy. A major transformation concerns the development and consolidation of wind energy on the basis of a network of heterogeneous actors, grouped into communities: entrepreneurial, academic, public sector, and societal groups (Dutrénit et al. 2014, 2017). The development of wind energy gets stronger as different actors involved go through negotiation, articulation, and consolidate along the process. Table 1 displays the main functions performed by actors within communities engaged with wind energy.

It is worth noting that previous relationships existed among some of the actors involved. In particular, members of the academic community and several officials engaged with the public sector community had developed trust relationships based on other dialogues different from wind energy undertakings (Goñi et al. 2015). Shared knowledge and capacities favored a synergic alliance among university research teams and government actors for the development of the technical groundings of the energy policy. Other actors emerge

Table 1. Communities, actors, and contributions to wind energy.

Actors	Type	Type of participation	Main contribution
Academic community			
National Public University (UdelaR): • Electric Engineering Institute • Fluid Mechanic and Environmental Engineering Institute • - Interdisciplinary Group on Energy Studies	Public, higher education and research	Knowledge production	Wind maps First windmill for research purposes SimSEE software Energy prospective study First wind tunnel Integral diagnostic of the energy sector
Entrepreneurial community			
Eolic Energy Uruguayan Association (AUDEE)	Private association	Promotion and articulation of eolic energy projects	Technical workshops, dialogues with other communities, and firms providing materials for the construction of wind parks.
Administration of Power Stations and Electric Transmissions (UTE)	Public enterprise	Energy production, transmission, distribution, and commercialization	Construction of wind parks, expansion, and administration of the electric grid.
Uruguayan Chamber of Industry	Private association	Contribution to the development of wind parks	Construction of wind parks, wind energy sale, technical workshops, dialogues with other communities.
Private wind parks owners	Private firms	Energy production	Energy sales to the public.
Public sector community			
Administration of Power Stations and Electric Transmissions (UTE)	Public enterprise	Energy management	Public tenders for the construction of wind parks, commercial contracts with wind energy sellers, research agreements with university.
National Energy Directorate (DNE) and National Industry Directorate (DNI), Ministry of Industry, Energy and Mining (MIEM)	Government (Executive)	Participation in policy design and enforcement of regulations	Decrees on production and use of eolic energy, dialogue facilitator among communities, research agreements with university.
National Environment Directorate (DINAMA), Ministry of Housing and Environment	Government (Executive)	Policy design and enforcement of regulations	Environmental assessment of projects, presentation of projects to society, approval of construction projects.
Administrator of Electric Market (ADME)	Public non-State	Administration of the wholesale electric market	Approval of contracts with producers, distributors, and large consumers of electricity, energy dispatch on demands to the grid.
Energy Fund (FSE): National Research and Innovation Agency (ANII)	Public research funds	Allocation of research Training courses and development funds	More than 100 projects funded (2009–14).
Energy Multi-Political Party Commission	Government (legislative)	Policy design	Approval of National Energy Policy.
Uruguayan Technical University (UTU)	Public, tertiary education	New training courses	Technicians in maintenance of wind parks.
Technological University (UTEC)	Public, higher education	New training courses	Technicians in renewable energies.
National Land Institute (INC)	Public, non-State	Management of State land (some wind parks are on State lands)	Land grant contracts
Energy and Water Services Regulatory Unit (URSEA)	State	Regulation of energy services	Regulation and enforcement, specialized advice to users.
Society			
Private Users	Users	Connection to electric grid, efficient energy use	Consumption of energy
Local communities around wind parks	Users	Construction of wind parks on private land	Wind and wind park information
Workers union of UTE (AUTE)	Workers	Questioning private investment	Opinion against terms and conditions for investment

Source: Own elaboration based on collected data.

as a natural consequence of the dialogue process. This is the case of the private sector in the entrepreneurial community. The public sector contribution was instrumental for the creation of an interesting opportunity for private investment for which a new legal framework was required. In this sense, AUDEE was established in 2009 integrating for the first time entrepreneurs, financial investors, and main promoters of the eolic market. AUDEE collaborated in the search of financial instruments for the presentation of wind energy projects, promoted national and international cooperation regarding wind technology, and represented the private interest at the regulatory and government energy agencies [DNE and Energy and Water Services Regulatory Unit (URSEA), mainly]. Other specific dialogue spaces involved mechanisms such as data rooms for interactions between the government and private stakeholders regarding terms and conditions for public tenders for the installation of new wind parks.

The implementation of the NEP and the transformation of the energy matrix followed a top-down logic preserving 'in government hands the ability to drive public and private stakeholders in policy development, promoting systemic efficiency, and placing the logic of the market (competition and profit maximization) to the service of public policy' (González and Méndez 2015: 15, own translation). However, along the process, linkages among communities configured a space for dialogue (Álvarez et al. 2016; Dutrénit et al. 2017) in which strengths and weaknesses in the development of wind energy could be identified.

A cognitive space around renewable energies was silently growing under the protection of the university setting. UdelaR, as the autonomous public national university provided an environment of academic freedom and income stability for researchers at the Faculty of Engineering (FING, by its Spanish acronym) in which wind characteristics and eolic energy-related topics were studied for six decades. Undoubtedly, the accumulated expertise and interpersonal knowledge among engineers constituted advantages for the development of the transition. Articulated knowledge production among different engineering fields busted the development of diverse projects at pilot stage, products, and prototypes during that time. This cognitive space involved developments in the fields of software, fluid mechanics, and control applied to winds, including the development of a robot for the installation of a meter in a wind tunnel, the implementation of an energy efficiency laboratory for light bulbs, a windmill prototype, and a software for prediction and monitoring. In turn, this community of researchers built bridges with the team of engineers at the public energy enterprise who had studied at the same university but so far had dismissed wind-related topics as a typical 'curiosity driven' university initiative. Such communication was mainly driven by the academic community and taken in a piecemeal manner by the public sector community in a rather reticent way until years later.

Particular collaborations between the Executive branch of government and FING occurred during the period 2000–5, building a new agreement regarding the need to increase energy generation on the basis of alternative sources. Many people referred to the delicate energy situation as the 'energy blackout' emphasizing the scarcity pressure on the energy regime. In 2000, the national government requested a technological prospective study in the energy sector, which was conducted by researchers at FING analyzing the energy situation on a 2015 horizon. The study was further updated in 2004 including recommendations of several actors and experts regarding the energy crisis (Nunes and Cataldo 2005).

Further, a new national government was installed in 2005 with closer links with university groups and appointing outstanding researchers in Executive positions. The development of a common language and a circle of trust among experts who had worked together at the university setting were fundamental for the advancement of the transition on the basis of policy decisions with academic foundations. Knowledge embodied in people (Snoeck and Sutz 2013) was instrumental for policy design. Considerations regarding renewable energies, and in particular wind energy, were easily transferred from the academic community to the energy sector leading both the political orientation and the actions of energy public firms. With this political change the energy visions of different communities (academic, public sector) got in the same line further integrating the private sector.

The key factor for the involvement of private investors in the wind energy business was the development of win–win solutions, according to the opinions of several interviewees. A DNE authority suggested that private investment was possible 'on the basis of a long term policy founded on a political agreement that assures continuity regardless of government change, and that is sustainable at the environmental and economic level given the fact that is not supported by a subsidy mechanism'.

The design of the NEP was enhanced by a practical exercise of stakeholder and price check through public tenders in a clear learning by doing and interacting way. A first exploratory public tender was carried out in 2006 aiming at a 20 MW each of wind energy, biomass, and small hydropower contracted with UTE. The response from private investors was poor because returns to the investment were uncertain. On a second public tender, the stakeholders were provided with a wind map updated by FING and certified by an international agency. This tender aimed at 150 MW and received offers up to 920 MW from major international energy firms. The main attraction for the investment was the potential long-term contract with the public Uruguayan energy enterprise.[3] Public–private contracts included the obligation of the public enterprise to purchase all eolic energy produced at a fixed price in US dollars for 20 years, regardless of whether all the energy could be absorbed by the grid. Tender changes evidence positive learning experiences among the actors strengthening the expectations and attracting more actors to each new call.

A weakness of the process reveals minimum participation of societal groups along the progression of the transition. There was no organized social community representing users or local populations in the vicinity of wind parks. For this reason, information asymmetries may have operated as barriers to local empowerment or opposition to the installation of wind parks. However, during the first developments, there were opposite reactions of a 'not in my backyard' type (Oosterlaken 2015) from a couple of local populations near the sites where wind parks were projected. One particular local organization argued that the installation of a wind park on top of the highest hill in Uruguay altered the natural beauty and biodiversity of a tourist site (Trobo 2013). Local opposition was not against wind energy in general but against the installation of wind mills in that particular hill. Visual and environmental impact as the main sources of unacceptance became evident in a public hearing held in the local community and organized by the public bodies. In their website, the local organization states that local claims were unheard by the authorities.[4] Public hearings organized by environmental authorities are part of the process of installation of wind parks, but their character is merely informative and not binding (Ministerio de Vivienda, Ordenamiento Territorial y Medio Ambiente [MVOTMA-DINAMA] 2015). In any case, public demonstrations show that there is no full legitimation of the NEP by the populations close to the wind parks.

Social opposition against the process also involved the workers union at the public energy enterprise (AUTE). Against private investments in the energy sector, AUTE recently criticized the business model of the NEP considering that it will result in higher energy costs to the general population.[5] While market acceptance of wind energy is high, sociopolitical and community dimensions of acceptance (Wüstenhagena et al. 2007) are not so consensual. Although the process of transformation has not been hampered by these oppositions, they can be seen as significant weaknesses in the social acceptance of the process and sources of potential conflicts which contrasts with the consensus between academia and politics.

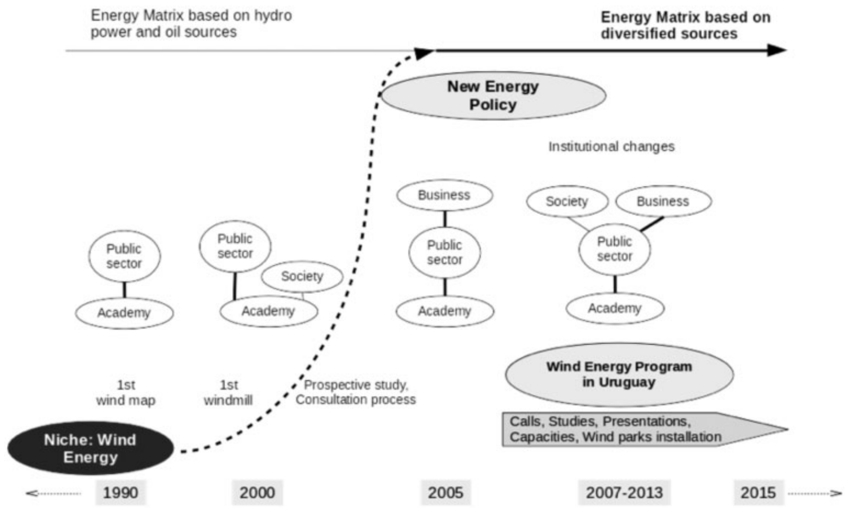

Figure 1. Incorporation of wind energy in the Uruguayan electric matrix.

In sum, the transformation of the electric matrix started as a cognitive niche, which developed in a protected university space up to the early 2000s. Such niche later evolved and became stronger transforming the sociotechnical regime, taking advantage of the window of opportunity that the political change opened in 2005. Actors in the government and academia, using a deliberate policy to stimulate private engagement, generated the conditions for further transformations allowing the regime to absorb the niche by the end of 2010. Without the development of the cognitive niche, political decisions would not have been made. A representation of the transformation is depicted in Fig. 1.

5. The transition to wind energy throughout different agreements and tensions

A continuous process of change through interactions among niche, regime, and landscape can be partitioned in different phases for analytical purposes. Rotmans et al. (2001) cited by van der Brugge and Rotmans (2007) identified four phases in transition processes: (i) pre-development, (ii) take-off, (iii) acceleration, and (iv) stabilization. The transition pace will depend upon the intensity of interactions among levels and within regime dimensions (technology, user practices and markets, symbolic meaning of technology, infrastructure, industry structure, policy, and techno-scientific knowledge) as well as on the relative ability of actors in the regime to resist and/or alter the equilibrium among dimensions. The relative importance of different actors is given by their participation in and development of collective learning processes (Huntjens et al. 2011). Niche actors can be identified as innovators, regime actors can be understood as investors, politicians, and policy makers, and external actors with lesser influence on the transition may resemble local community and labor union representatives. Learning and the intensity of the linkages among innovators, regime actors, and external actors are crucial for the advancement of the transition.

In our study, wind energy is basically a cognitive niche and the sociotechnical regime is the existing electric matrix that gets transformed into a new one with emphasis on renewable sources. The transition process takes into account the factors that contributed to the incorporation of wind energy as a stable component of the energy regime. We will look at the transition process along the phases previously mentioned.

(1) Pre-development and niche consolidation: during this phase the dynamic of the system is not visibly altered; however, actions are detected which start destabilizing system's balance.

During this phase, the wind energy niche was mobilized and consolidated. Given its main traits, the niche could be identified as a 'cognitive niche' because learning and knowledge accumulation was on the basis of its development. Also in this phase, the first steps are taken for stronger linkages between the actions of a dominant group (researchers) with actors identified with the sociotechnical regime at both a technical and political levels (UTE). A growing disagreement between researchers and regime engineers plus knowledge accumulation may have created the opportunity for the next phase.

Local knowledge development regarding wind begun in the 1950s when FING initiated a research line for measuring and characterizing wind flows. A research team on renewable energies was developing, which decades later generated a primary wind map and the first Uruguayan wind tunnel. Later, research was promoted on the basis of funding agreements with institutions outside the academic community. Formal relationships between UTE and UdelaR fluctuated until the end of the 1980s when a specific contract made possible the development of an improved wind map using available computer technology. This was the beginning of a systematic relationship among both institutions which is still in place (Rodriguez 2015).

After 2000, UTE under the technical advice of the university research team created a pilot eolic plant jointly funded by the public enterprise and the International Development Bank. From that moment, the FING became the main national reference in wind energy topics including the development of an energy prospective study, which will later inform the contents of the NEP. Other applied projects were developed to value the energy supply on the basis of wind energy for example for rural communities including the set up of autonomous systems on renewable sources (Rodriguez 2015).

(2) Take off and acceleration phases: policy takes the leading role after 2005 and the energy policy becomes a Sate policy. At take

off, the structure of the system begins to change often associated with the emergence of innovations and destabilization of the existing regime reaching its limits. Later during acceleration, changes towards transition get visible. These result from the interactions among the different levels facilitated by collective learning processes and diffusion of new practices (Rotmans et al. 2001; cited by van der Brugge and Rotmans 2007).

These two phases are considered together in our case of study because there is no discontinuity between them (Álvarez et al. 2016; Dutrénit et al. 2017). Take off and acceleration are almost simultaneous in light of the profound changes occurred at the regime level. In 2005, for the first time in Uruguay a left coalition reached the national government. Soon, researchers from FING were hired as heads of the energy public firms, and in 2008 a theoretical physicist was appointed Director at DNE, at the Ministry, which included energy transformation as a strategic point for industrial development. DNE's Director was responsible for a project, approved *in totum* by the Executive, which was seminal for the NEP, further approved and confirmed by all political parties in 2010. For the first time, Uruguay had a State energy policy aiming to overcome energy deficiencies and fostering the transformation of the energy matrix. The following are the core lines of the NEP approved in 2008 (Comisión Multipartidaria de Energía [CME] 2010):

i. Institutional: institutional roles are assigned according to a long-term vision regardless of government's political affiliation. The Executive is in charge of coordination and assessment of the energy policy, private enterprises participate in activities attributed by the Executive, the public energy firm is the main instrument for the implementation of the NEP, and control and regulation is in charge of URSEA.
ii. Demand: mathematical simulation models will provide scenarios in order to forecast socioeconomic and energetic evolutions. The goal set is to satisfy the total energy demand on the basis of responsible, efficient, and sustainable consumption.
iii. Supply: diversification of the energy matrix increasing the participation of native renewable sources, promoting both transfer of technology and development of Uruguayan knowledge capacities.
iv. Social: the energy policy is an instrument for social integration. Thus, access to the energy types that can meet the needs of the population at an affordable cost should be granted for all social sectors throughout the country.

The magnitude of NEP's strategic lines and the novelty of its goals linked to renewable energies required intense learning processes regarding environmental engineering, short-term prediction of wind energy, power electronics, wind tunnel modeling, socioeconomic impact, among several others, building upon existing capacities previously accumulated in the academic sector. New capacities were as well developed along the implementation of the NEP. The quality of learning rested upon synergies and circles of trust developed among the academic community, several public sector institutions, and the new government. Complementary, institutional embedding could only be bonded by a strong leadership played by the Sate, mainly represented by DNE for driving policy design. The role played by this body during the process was such that DNE grew from around four officers to a large multidisciplinary team articulating technical and political know how under the mentorship of a university researcher appointed as DNE's director. Further, UTE kept the monopoly for energy distribution and organized competitive tenders to private firms to develop wind parks which would supply the national grid on the basis of public private agreements. The first contracts specifically made for wind energy generation by private firms were ruled by a Decree passed in 2009 for a total potency of 150 MW. Major investments were possible because of the association of private firms with the public enterprise, turning energy into an attractive low risk and high return sector. Quality control and electricity price regulation was also retained by the public sector (at ADME) in accordance to the Executive main orientation.

A direct precedent of the NEP is the Eolic Energy Program carried out between 2007 and 2013 under the initiative of the national government. This program was funded by the UNDP with the main goal of promoting wind energy in Uruguay. In the context of this program, energy regulations begun to change including new norms for grid connection, construction and operation of wind parks, environmental regulations, financial incentives, and tax-related aspects. These undertakings gave way to the emergence of new actors such as AUDEE as well as new roles assigned to existing ones. In this sense, the Chamber of Industry was put in charge of certifying that the new private investments comply with regulations establishing a 20 per cent proportion of Uruguayan components in renewable energy projects. The development of the second wind map, that was crucial for the second public tender already mentioned, and the installations of the first two wind parks established by UTE were also accomplished during this phase.

A synthesis of the main actions and events undertaken during pre-development phase and take off and acceleration jointly considered, according to the different regime dimensions, is presented in Table 2. It is worth noting that knowledge accumulation was stronger in the first phase while increasing public and private investments, articulation and policy design are evident in the second one.

(3) Stabilization: during this phase changes slow down and a new configuration of the system dynamics is in equilibrium.

As previously seen, wind energy inclusion in the new Uruguayan energy matrix was possible on the basis of knowledge accumulation and policy development. A wind energy cognitive niche developed which in turn pushed new knowledge demands and institutional undertakings. In this last phase, the development of infrastructure has reached its limit as well as the provision of wind energy to the electric grid. The regime is rather stable and new challenges emerge. These are mainly linked to the training of local technicians for the maintenance of wind parks, the increase of higher level professionals focused on prospection and prediction of short time natural phenomena which can alter the electric grid and in power systems to guarantee stable energy flows to the grid. Also, advancements are needed in the systems for energy storage, the generation of a smart electric grid, and in the development of regional transmission lines across frontiers.

Up to present, 34 wind parks have been developed throughout the country, which contributed over 15 per cent of the electricity consumed in 2015 (Ministerio de Industria, Energía y Minería (MIEM) (c) n.d.). Figure 2 displays the evolution of electricity sources in which the rapid development of wind energy since 2009 is evident. It is expected that in 2017, 38 per cent of the electricity in Uruguay will be generated from wind on the basis of a 1.500 MW installed wind power capacity by the end of the year. According to UTE's President, the construction of wind parks will stop in 2023 since the installed capacity increased from 20 MW in 2008, and will soon exceed Uruguay's domestic needs (Global Wind Energy Council 2015). Most private companies engaged in the wind energy

Table 2. Main undertakings during pre-development and take off and acceleration phases.

Regime dimensions	Main events
Technology	*Predevelopment*: Development and update of wind maps, influenced by the use of available technology and the advancement of scientific knowledge at the niche level.
	Take off/acceleration: Taking advantage of the accelerated evolution of wind technology worldwide (increasing turbine height and amount of energy generated).
	Domestic production of low tech components of wind parks: concrete towers, electrical components, transformers, transmission lines, accessories (lifts, ladders).
	Domestic software development for prediction and monitoring of diverse energy sources in electric the grid (SimSEE).
	Call for presentation of innovative national prototypes for microgeneration.
User practices and markets	*Predevelopment*: Two contradictory circumstances. Promotion of the energy consumption (mainly imported) at the regime level aggravating dependency. Emergence of isolated practices from the niche including for instance, the development of a wind tunnel.
	Take off/acceleration: Public investment in the grid and incentives for public and private investments in eolic energy.
	AUDEE created in 2009 as a civil association for the promotion of wind energy.
Symbolic meaning of technology	*Predevelopment*: The promotion of energy consumption from the regime level contributes to the unrealistic idea of unlimited energy. Simultaneously, UdelaR created in 2003 a space for the interaction of diverse actors: academia, NGOs, productive sector, government, labor unions.
	Take off/acceleration: Energy access is considered a human right by the NEP. Efficient energy consumption habits are promoted.
Infrastructure	*Predevelopment*: Academic actors engaged in the construction of the first eolic plant in conjunction with UTE.
	Take off/acceleration: More than 30 wind parks are constructed (29 still in operation).
Policy	*Predevelopment*: No major developments nor guidelines in this phase to revert dependency. Approaches with academic community begun.
	Take off/acceleration: some members of the academic community engaged with the cognitive niche move to the political sphere.
	Energy transformation is considered an industrial strategy.
	Executive leads the development of the NEP.
	Professionalization of DNE's team.
	Incentives to private investment: 20-year contracts at a fixed price in US$, State obligation to buy all eolic energy produced, mechanisms for public–private partnerships.
	Long-term consensual policy (stability).
Industry structure	*Predevelopment*: No evident investments. Lack of activity could be an impulse to the advancement of the niche for the configuration of a new stability.
	Take off/acceleration: A specific office for eolic energy within renewable energies was created at DNE.
Scientific and technological knowledge	*Predevelopment*: Knowledge accumulation mainly carried out within the university setting and in combination with UTE.
	Take off/acceleration: R&D Competitive funds on energy. Consolidation of new research teams on energy topics.
	Professional training: graduate programs and undergraduate technical programs in energy-related topics.

Source: Own elaboration based on collected data, following Rotmans et al. (2001).

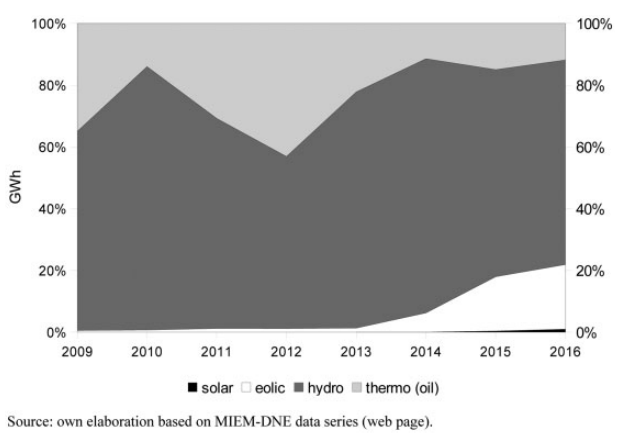

Figure 2. Evolution of electric energy by generation type in Uruguay (2009–July 2016).

business are getting ready to export their know how to other Latin American countries facing energy transitions.

6. Conclusion

The possibility of using the power of wind to transform the Uruguayan energy matrix emerges from a dialogue among peers, opened up by the appointment in Executive public offices of former academic researchers in the context of political change. This fact allowed a rather unusual process: the use of academic knowledge as the basis for policy actions. This does not imply that all knowledge involved in the transformation of the prevailing energy sociotechnical regime came from the local academic setting (in fact, knowledge from the entrepreneurial community and the public sector has been recorded). But it can be asserted that if this transformation was at all possible in a short time, it was due to the full harnessing of that knowledge to the decision-making process. Exceptionally for

Uruguay, this transition resembles a hands-on mode of articulation between research and public policy design (Snoeck and Sutz 2013) in which links and agreements can develop through people moving from academia to policy positions, working together, learning by sharing and interacting. The dialogue process can be described as a transformation throughout communities in which the creation of a network of researchers, engineers, and policy makers made cooperation and knowledge transfer effective.

Other factors contributed to the sociotechnical regime change, all including dialogues of different types. Perhaps the most outstanding relates to the building of a State policy around the transformation of the energy matrix integrating renewable resources in which public and private actors have roles to play. A central aspect for wind energy take-off was the ability of the public policy to create a set of incentives for private investment plus the operation in a captive market created by the State's commitment to buy all the energy produced by wind parks. These conditions were crucial to make investment possible but at the same time created the potential dilemma of higher energy prices in the short and medium run.

The small size of Uruguay was an advantage during the cognitive niche development, given that it allowed the consolidation of trust relationships (Goñi et al. 2015) among peers in different institutional settings. However, at present the small size constitutes a barrier during the stabilization phase. Currently, wind energy entrepreneurs demand permission to export, by themselves, energy to neighbouring countries when their production level exceeds national demands. This constitutes a totally new situation for the strongly based State policy, requiring new consensus and, thus, new and challenging dialogue processes.

Conflict of interest statement. None declared.

Notes

1. Simultaneously, transportation sector is still highly dependent on oil imports. Energy consumption for transportation has doubled between 2003 and 2015 (Ministerio de Industria, Energía y Minería-DNE Data base 2016).
2. Mostafaeipour (2010: 1050) outlines three areas of potential wind turbine improvements: 'advanced tower designs, including taller towers, new materials, and telescoping towers that are easier to install, larger rotors made from lighter materials and having improved aerodynamics, (and) more efficient gear boxes, drive trains, generators, and electronics.'
3. International investors were attracted even though the price of a MW in Uruguay was half the value paid by European countries.
4. Friends of *Aiguá* is the organization leading the opposition (available at https://amigosdeaigua.wordpress.com/).
5. AUTE's President stands against the fact that private investors are assured high returns at the expense of UTE's obligation to purchase all eolic energy they produce, regardless of whether all the energy can be absorbed by the grid. <http://970universal.com/2016/12/19/trabajadores-de-ute-rechazan-ajuste-de-tarifas-y-critican/>.

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