The emergence of innovation systems in new locations:

theoretical explorations and an in-depth case study of wind energy technologies in Ireland, 1990-2014

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Submitted in partial fulfilment for
the degree of Doctor of Philosophy
SPRU – Science Policy Research Unit
University of Sussex
November 2016

UNIVERSITY OF SUSSEX

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Summary

This thesis is about the processes of creating renewable electricity systems in new locations. Specifically it addresses the challenges and drivers of building-up renewable energy system in a 'fast follower' country, Ireland. With increasing scientific, political, civil society and private sector agreement on the need to reduce green-house gas emissions from the provision of electricity, the rolling out of complex, renewable electricity systems from countries in which initial system building activities have taken place to others is an important issue. The primary research question posed is 'what explains the growth of the wind electricity system in Ireland?' This question is reflected upon by asking 'what does the Irish experience tell us about why and how these systems spread to new locations?'

The thesis addresses an innovation studies audience, making a theoretical contribution to the field of sustainability transitions. It contributes to recent research integrating theories from human geography by offering new insights on how location influences building of large scale renewable electricity systems in new jurisdictions. It contributes findings about the rapid development of the Irish wind system that challenge two dominant perspectives; roll-out in Ireland has been driven by EU policy push and the development of the industry is fundamentally about the extent of national subsidies. We find both perspectives are partial; what they omit is likely to be essential to reproducing the Irish experience.

This thesis takes as its unit of analysis the wind energy system itself, and using a 'technological innovation system' framework, examines and evaluates the structure of the system; the complex arrangement of institutions, actors and technologies; and the dynamic innovation processes or 'functions' of the system. An inquiry into the substantive historical contexts of the development of the system make possible insights into the locational characteristics and relations within and between the system; drivers, barriers and influences of direction of the system processes; and the contexts in which decisions are made and technological change takes place. The thesis finds the development of a renewable electricity system in new locations is simultaneously heavily influenced by transnational dimensions of system actors relations and institutions, and shows that while the direction of the emergent technological pathway is influenced at multiple spatial and governance levels, legitimation of the technology is highly localised.

Acknowledgements

'Acknowledgements' is insufficient as a title under which to thank my doctoral supervisors, Adrian Smith and Ed Steinmueller, for their assistance. To borrow Heaney's words, *"I've no spade to follow men like them"*[1]. I hope only that my squat pen has reflected their guidance, given freely and generously in formal and informal settings, through example as well as word. Thank you. To Frank who helped set me on my way, and Jake who came through the same departure lounge, special thanks also. It has been a privilege to study and work at SPRU. It has also been hugely enjoyable, made doubly so by Rob, Roberto, Phil and Sabine in Room 325. This thesis has benefited from conversations with Karoline, Lucy, Ralitsa, Tomás and others. And I have benefited from discussion, debates and dinners with Edwin, Ruth, Diego, Puay, Rose, Nikki, Pip, Jim, Hamed, Claire, Sandra, Paula, Saurabh, Maria, Tommaso, Andy, Tim, Mariana, Annie, Caetano and Nicola. I gained enormously from teaching, thank you to Florian, Adrian Ely, Gordon and many students for the opportunity. Thank you to Johan to Janet, Joy and other colleagues in the School, and to John and Grace at the DTC for the help along the way. I am also grateful to the people of the United Kingdom and the Economic and Social Research Council for the award of funding[2], again it is a privilege. I gained greatly from interactions, critique and conversations with those outside of SPRU also. In particular, interactions with colleagues in Zurich were invaluable, Volker, Joern and Jochen and via ETH, conversations with Raghu.

In Ireland, I am extremely grateful for everyone who took time to talk or email with me. Special thanks to John, Brian and the staff at SEAI who provided me with guidance and access to some of their data. Also to Eleanor and John who opened up their contact books to me at an important stage. Along the way, two organisations provided me with welcome distraction. Special thanks to David and the staff and members at 38 Degrees for holding on as long as you did, and then letting go. To Siobhán and Hannah and all my colleagues at Uplift who I'm still trying to keep up with. Your work is an inspiration. To Ron and Ona in St. Jean, for the food and debate.

Huge thanks to my sisters, Méadhbh, Fionnuala and Sinead for explicit and implicit support along the way (the distractions were useful). And to my mother and father, for the press cuttings, links, opinions, the numerous welcome homes and the underlying support. Finally, to Olivia, for whom ideas are so central, I hope there are some useful ones here. Thanks for coming to the seaside and for everything else.

[1] From *'Digging'* by Heaney (1966)

[2] *ESRC reference 1093315*

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Abbreviations and acronyms

AER	Alternative Energy Requirement
AIB	Allied Irish Bank
BGE	Bord Gáis Energy
BnM	Bord na Móna
DCENR	Department of Communications, Energy and National Resources
DECC	Department of Energy and Climate Change
DG	Directorate Générale
DSO	Distribution service operator
EC	European Commission
EEC	European Economic Community
ESB	Electricity Supply Board
ESBNG	ESB National Grid
ESRI	Economic and Social Research Institute
EU	European Union
EWEA	European Wind Energy Association
GW	Gigawatt, 1,000 mega watts
IEA	International Energy Agency
IWEA	The Irish Wind Energy Association
MLP	Multi level perspective
MnaG	Meithel na Gaoithe
MW	Megawatt
REDG	Renewable Energy Development Group
REFIT	Renewable energy feed-in tariff
RESG	Renewable Energy Strategy Group

SEAI	Sustainable Energy Agency Ireland
TIS	Technological innovation system
Toe	Tonnes of oil equivalent
TSO	Transmission service operator
UNFCCC	United Nations Framework Convention on Climate Change

Chapter 1

Introduction

This thesis is about the emergence of renewable electricity systems (RES) in new locations. Specifically it addresses the challenges and drivers of constructing an onshore wind-based electricity system in a 'fast follower' country, Ireland. The topic is relevant to societal debates on transitions to low-carbon electricity generation such as the consequences of making major social investments in renewable energy technology in advance of other nations even when that investment will not transform the 'latecomer' into a leader in the production of that renewable technology. Research pertaining to the innovative activity that forms a large part of constructing a RES may lead to new insights to better direct the transformation of energy systems and infrastructures. In turn we might expect these to contribute to climate change mitigation agendas and a greater understanding of firm, policy and society dynamics in the area of energy policy. The topic is also relevant to contemporary academic debates about the processes by which new technologies come into widespread use within the innovation studies and sustainability transitions literature, where the emergence of novel energy and electricity systems has been a major focus of investigation. The processes by which established RES emerge in new countries has received considerably less attention than the generation of novelty and change. In summary, this thesis contributes to that debate by outlining the innovation processes that were produced to support and develop the wind electricity system, both in Ireland and trans-nationally.

1.1 Background motivations

In recent years there has been increasing scientific, political, civil society and private sector agreement on the need to reduce greenhouse-gas emissions from processes such as the generation of electricity. This was exemplified at global level by the multilateral Paris Agreement signed at the 21st UNFCCC Conference of the Parties in 2015 (United Nations, 2015). The mitigation of climate change together with concerns for the security of national energy supply have been dominant rhetorics employed in calls for the 'transitioning' or 'transformation' to renewably generated energy at global, European, national and sub-national levels. Two aspects of this problem are relevant to this thesis. First, this potential transformation is not one of only technical plant and infrastructure, but also of political interests and culture (Giddens, 2009). In short, this presents societal challenges that extend beyond the relatively narrow domain of national energy policy. These challenges necessarily involve changes to policy, infrastructure, end-user behaviour and supplier practices and the re-orientation of social, economic and technological systems in more sustainable directions (Hughes, 1983; Unruh, 2002). Second, the climate is a public good. According to Stern (2007, p. 25) *"those who fail to pay for it cannot be excluded from enjoying its benefits and one person's enjoyment of the climate does not diminish the capacity of others to enjoy it too."* This 'market failure' argument is based on a strand of work in economics stretching back to Sidgwick (1883) through Pigou (1920), and has profound implications for responses to the problem of climate change. Stern suggests *'markets for relevant goods and services (energy, land use, innovation, etc.) do not reflect the consequences of different consumption and investment choices for the climate"* (*ibid.*). Simply put, if firms will not pay for a 'clean' climate, government must, often through subsidising 'clean' technologies or green practices. These problems have stimulated public intervention at several different governance levels.

European Union energy policy over the past two decades has been influenced by the dual agendas of the Single Market project and EU environmental and climate changes directives. The EU has committed to creating a policy regime to encourage member states to 'decarbonise' electricity generation. Financial resources have been mobilised by the EU and national governments to subsidise emerging renewable technologies against 'cheaper' incumbent fossil fuel based electricity generation. Directives have focussed on targets for renewable electricity generation at EU and member state level. Three interrelated issues are relevant to the thesis. I) Targets such as the EU 2030 Framework are relatively blunt instruments, concerned with acceleration in a pre-determined direction, that is how fast (e.g. by 2030) rather than by whom or for whom. This becomes a salient point when the distribution of benefits is discussed. II) The implicit technological focus of these targets has been predominantly on the rapid diffusion of generation technologies such as turbines and photovoltaic arrays, subsidised through feed-in tariffs, tradable green certificates or other instruments, the implementation of which occurs at national level, often through contested political processes. Rather less attention has been paid to managing systemic infrastructure and regulatory changes (Hiteva, 2014). III) EU energy frameworks and target models tend to underplay the influence of national context, including issues of regulatory change, significant infrastructure changes in the shift from centralised to distributed generation, political confrontations with often powerful incumbent interests and in the later stages of development, the appropriation of subsidy as rents.

Much of the detailed, political work in rolling-out RES and meeting European targets is devolved to member state level. Member states have considerable leeway, within frameworks set by targets and state aid rules. Thus it is appropriate for this thesis in its investigation of the emergence of renewable electricity systems in new locations, to take note of developments at the EU level and also between the EU and the roll out in Ireland of policy and technology. In a small number of countries the roll out of renewable electricity systems has been rapid. Germany, Denmark and Spain for example have been much studied as 'leaders' or 'early movers' in the deployment of technologies such as onshore wind and solar photovoltaics to national centralised grids and in distributed configurations. Influential factors and processes have been the gaining of legitimacy and the setting of future directions of technology pathways through policy or societal rhetorics, new economic actors such as farmers and neighbourhood coops entering energy systems, the creation of markets for renewable technologies and the availability of capital finance and subsidy for the production of electricity. However, a single explanatory technological deployment pathway has not emerged (Stenzel and Frenzel, 2008), and the reasons for slow diffusion have been numerous (Negro, Alkemade, et al., 2011). This thesis however, is about developments in countries that come next, of which Ireland is one. The thesis is concerned not only with the re-production in new countries of legitimacy, direction and the creation of markets, but also the processes by which RES emerge in new locations[1]. It is thus highly relevant to the debate on sustainability transitions and transformations to examine the transfer of knowledge, flows of technology, and access to extra-jurisdictional resources which are implicated in the construction of renewable electricity systems in new

[1]'Location' and 'locally' are on some occasions used as synonyms for country in the thesis. Any geographic level or scale other than country is made explicit.

locations. This thesis contributes to this debate by focussing on what is re-produced; which aspects of energy system construction are built-up in new countries, which are accessed of transferred from abroad, and how local energy system and institutional structures influence processes of reproduction.

1.2 Academic relevance and audience

The processes of creating renewable electricity systems in new locations is also a topic that is relevant to numerous contemporary academic debates. This thesis addresses primarily an innovation studies audience, making a theoretical contribution to debates within the developing field of sustainability transitions. Transitions scholars are concerned with long-term changes in the configurations of 'socio-technical systems', at least in theory, privileging neither technological or sociological deterministic explanations of change. A major sub-field within the transitions field has been the development of the technological innovation systems framework, drawing heavily on the innovation systems literature. Innovation systems are sets of public and private sector institutions and actors whose activities and interactions initiate, import, modify and diffuse new technologies (Freeman, 1987; Lundvall, 1992). Freeman and Lundvall's concept of National Systems of Innovation has had significant policy impact since its formulation in the 1980s and 1990s and a number of its core tenets have been adapted to focus on regions, industrial sectors, and on technology systems (Martin, 2012). The technological (innovation) systems framework initially was developed as an approach to investigate the emergence of novel technological systems through explanations based on the systemic interplay of firm actors, and their institutional settings (Carlsson and Stankiewicz, 1991; Bergek, Jacobsson, Carlsson, Lindmark, et al., 2008; Hekkert, Suurs, et al., 2007). The adaptation of many of the analytic concepts and protocols of NSI to TIS means a reorientation of focus from technological innovation as a driver of national economic growth, to a focus of often radical technologies as a generative component of fully fledged socio-technical transitions (Markard et al., 2012a). The framework has been applied extensively to energy systems and developed accordingly. Strongly orientated towards policy advice, the framework supplements the concept of market failure with system failure and suggests that market failure cannot be fixed through the simplistic heuristic of 'getting the price (incentives) right'. Contributions have focussed on failure of infrastructure, poorly aligned institutions, deficiencies of actor networks and insufficient financing (Jacobsson and Johnson, 2000; Weber and Rohracher, 2012a; Bergek, Jacobsson, Carlsson, Lindmark, et al., 2008; Karltorp, 2014). Using an innovation systems approach, the thesis takes as its unit of analysis the wind renewable electricity system of production, distribution and innovation, in short the Irish wind RES. The thesis contributes an analysis, evaluation and discussion of the structure of the Irish wind RES – that is the complex arrangement of institutions, actors and technologies – and the dynamic innovation processes or 'TIS functions' which influence the emergence and growth of the RES.

In recent years, scholars have sought to develop greater attention to location, place and space[2] within the transitions literature (Hansen and Coenen, 2014; Markard et al., 2012b; Coenen, Benneworth, et al., 2012). This has allowed national-level diversity, variations, interpretations and institutional contexts to be brought into explanations of why systems emerge in one country and not another (Raven, Schot, et al., 2012). Of course, attention to the emergence of technologies in new countries is not new. The literature on diffusion, technology transfer and internationalisation, has made significant contributions in this regard. However the socio-technical and systems approach has integrated concepts which allow us us to simultaneously address the market failure and systemic aspects of change in a complex technology as a distributed renewable energy system. This point is further elaborated upon in Section 3.1.

As part of the geographic turn in the sustainability transitions literature, some scholars have sought to extend the theoretical and analytic capabilities of the TIS framework by integrating ideas from human geography. Broadly, these ideas fall into two modes of inquiry relevant to this thesis: investigating the territoriality of emergent innovation processes and systems; and exploring the often transnational inter-organisational links and relations between actors (Hansen and Coenen, 2014).
These ideas include perspectives on institutional influences at international levels (Gosens et al., 2015), how global developments in a specific field effect innovation system developments in national contexts (Binz, Truffer, and Coenen, 2014), multi- governance-level nested system structures (Wieczorek et al., 2013) and the territorial embedding of systems

[2]Location is used in a positivistic sense to indicate a specific bounded geographic space. Space is used in positivistic or Newtonian sense, as an empty geographic container waiting to be filled with (economic) activity. A broad definition of place is used after (Devine Wright, 2009, p. 427) who writes place is the "physical aspects of a specific location as well as the variety of meanings and emotions associated with that location by individuals or groups." In the relational or Leibnizian view, according to Agnew, "space is relational, in the sense that it has no powers independent of objects and events but can be construed only from the relations between them" (Agnew and Livingstone, 1995, p. 320). Relational concepts of space are explicitly clarified when invoked in the thesis.

(Coenen and Truffer, 2012). There are two significant implications for this thesis. First, it necessitates the focus of inquiry is extended beyond the initial emergence of novel technologies to explicitly include the formation of RES in new locations. Second, this focus of inquiry follows that of innovation systems in context (e.g. national, regional, global and multi-scale) (Bergek, Hekkert, et al., 2014).

This thesis engages in and builds on these discussions and contributions. It acknowledges the national (empirical) bounding of the Irish wind RES where appropriate (e.g. national policy domains, island based material infrastructures), but does not reify or inappropriately background national structure and context. Rather than delimiting system boundaries ex ante, we start with a technological boundary (analytically) and then reconstruct whether sufficiently coherent sub-systems overlap with specific regional or national boundaries. This is achieved with a custom '*build-up* and *touchdown*' heuristic which seeks to avoid privileging explanation based on endogenous system activity, or innovation processes at a national level, with those taking place transnationally.

Furthermore, the framework of analysis deliberately seeks to challenge uni-directional framings of races, leaders, laggards, and catching-up. On the one hand the metaphor of a 'race' is being run against climate catastrophe is a certainly of some value. On the other, being amongst a small number of winners – in the sense of a country that is able to gain from its investments in this race – is rather less important than trying to avoid a large number of losers. This is a situation that that will not only lead to technological opportunities being missed, but will also have much more dramatic consequences for future human welfare. Given the contested and political nature of climate and energy targets at EU and national level, we argue the success or failure to meet these targets is not a clear indicator of success in addressing the greater societal challenges introduced in the proceeding passages. In other words, the thesis rejects uni-directional framings as assuming a common and uncontested goal to which all actors are committed so that all deviation from efficient paths to attainment are viewed as barriers or blockages and all initiatives that are not 'in the plan' are viewed as diversions. Guarding against tendencies to equate success and failure against such targets, the thesis employs a heuristic and research framework that is attentive to the direction of technological pathways that may be set at EU level, while also being sensitive to national and sub-national processes. The intention is to avoid undue analytic attention on whether an arbitrary race is being won, and focus instead on local emergence. Given this focus, the attention shifts to being about how a RES is built up from resources to hand, and taking advantage of resources from afar.

1.3 Research questions

Bringing together the background motivations and the chosen analytic approach highlight three specific tensions, or core problems, each of which are addressed explicitly by the research questions, and implicitly within the analytic framework (collectively referred to here as the research framework). First, the research framework addresses why wind innovation happened in Ireland. Simply put, the framework addresses why the analytic decision to categorise the Irish wind sector as an innovation system rather than attempting to explain the take up of renewable electricity technology in Ireland as a case of technological diffusion. Second, through narrative analysis, the research framework addresses why the political, firm and societal support in Ireland for wind energy existed. In addressing these tensions the framework explains indigenous RES emergence and associated levels of societal support relevant to the RES. Finally, the framework identifies relations within and between indigenous and transnational innovation sub-systems, processes and actors, and provides a foundation for explaining these dynamics. Considering these tensions, the thesis answers the following question:

> **RQ1.What explains the emergence and growth of the wind electricity system in Ireland and what does this tell us about why and how renewable electricity systems emerge in new locations?**

This question starts with a clear problem orientation but it also indicates the aspiration to a generalisable contribution as one of the main aims of the thesis, the explanation of why new renewable electricity systems emerge in new locations. As discussed in the previous section, this broad question has been addressed using several analytic approaches. Question two takes into account the discussion on academic relevance and audience and engages directly the technological innovation system framework, without privileging an overtly functional or structural explanation.

> **RQ2. How can the emergence of a wind-based renewable electricity system in Ireland be explained by the formation and development of technological innovation system functions?**

In order to address the background motivations and further elaborate on locationally specific policy issues, we pose two further questions.:

RQ3. Why are certain aspects of the RES re-produced in the new location and why?

RQ4. What is the balance of influence on the RES of indigenous versus overseas structure and TIS functions in the Irish context?

Questions three and four set out to establish the influence location plays on the emergent system, its components and functions.

1.4 Contributions of the thesis

This thesis contributes an understanding of why and how the the Irish wind RES emerged and who participated in crucial episodes that influenced its relatively rapid growth. In explaining this story, the research extends our knowledge of why and how renewable energy systems emerge in new locations. The findings supports and extends prior findings in the literature that the emergent system functions may be distributed across space, and specifically that the direction of the search is a crucial early function and may be fulfilled at multiple levels. And crucially, not all TIS system functions are required to be reproduced at a national level. The findings contribute directly to the ongoing efforts to understand innovation systems in context. We interpret the process of take up or diffusion through a heuristic that opposes, on the one hand, localised and customised building-up and accumulation processes with, on the other hand, the idea of 'touchdown' by which external, incumbent, and previously developed approaches, capabilities, and actors enter into a localised RES. This opposition is designed to assess the processes and the flows of resources that are fundamental to the global proliferation of renewable technology systems. Indeed we find that the direction of the search for new technologies is influenced at multiple levels such as the EU, global technology networks, and at national and sub-national levels.

The thesis makes two methodological contributions. The *build-up* and *touchdown* heuristic itself is a novel approach to analysing distributed system functions. In analysing the evidence, we propose a novel analytical approach, in order to appropriately assess system processes in context. We do this by focussing analytic attention on the generative aspect of narratives. This attention on the generative aspects of narratives is a complement to an event history. Finally the empirical findings in this study contribute a new explanation of how and why the Irish wind energy system has developed in the manner it has. This takes the form of a systemic, socio-technical history of a small island grid system, and its integration of a wind generated electricity. The findings address two explanatory narratives found amongst actors in the system, that 'Europe drives everything', and that the development of wind can be explained through the distribution of subsidy, specifically the Renewable Energy Feed-In Tariff. We find both of these explanations tell only part of the story, which has been elaborated significantly in this thesis.

1.5 Overview of the thesis

The thesis is set out across eight chapters. In Chapter 2 the context for the research is established by introducing and discussing aspects of the Irish wind electricity system and notable historic decisions that have influenced its development.

In the third and fourth chapters the theoretical framework and scheme of analysis are introduced and discussed. The conceptual building blocks upon which the framework is constructed are introduced through a review of the literature. Data collection, methodology and the strategy for operationalising the theoretical framework are then outlined.

Chapter 5 contains an extended account of the case narrative, organised in a periodised chronology. The narrative systematically introduces the reader to theoretically relevant case details and contexts while organising the evidence and components of the system in chronological order. Chapter 6, presents appropriate findings of the structure analysis and discuss implications for the theory. The structural analysis provides a foundation for the discussion of the function analysis, significant findings from which are presented in Chapter 7. The contribution to the Irish wind energy system of each TIS function is discussed individually before elaborating upon enlarging and attenuating mechanisms both endogenous and exogenous to the RES. The mapping and fulfilment of system functions over space and time is graphically illustrated in a series of function maps, and two virtuous cycles of functions identified in the analysis are introduced.

Chapter 8 synthesises the results of the function analysis, and discusses findings with regard to the thesis hypothesis and observations from similar research found in the literature. The research questions are directly answered before contributions of the thesis are addressed. Finally, a brief set of recommendations for policy makers and other relevant actors in industry and wider society are offered.

Chapter 2

Research context and background

This chapter establishes the research context ahead of the discussion on theory and method in Chapter 3[1]. The chapter describes case-appropriate aspects of the Irish wind RES, introducing the relevant technologies, actors and institutions. The chapter establishes a logical path for narrowing the context of the thesis. Its focus is on questions of what and who; for example, what are the notable characteristics of the Irish wind RES in 2014, the final year of the period of this study, and who are influential actors. Questions of how and why suggested by this introductory context are are addressed in later chapters. Section 2.1 discusses national and international wind electricity statistics and introduces the generation technology, infrastructure and indigenous research base. Section 2.2 introduces players within the wind industry and relevant non-firm actors and networks as well as discussing finance in the sector. Section 2.3 discusses the wider electricity industry, markets, governance structures and incentives. It describes the mix of national and regional policies and technology support available to wind actors. I then reflect on the contemporary wind RES by considering historic decisions, innovation processes and contingencies in order to discuss the support available and the challenges to maintaining and further developing the industry and its technologies. By doing so the aims are to offer an understanding of the extent to which the wind RES in Ireland is influenced by government policies, and national and transnational firms, research professionals and other actors.

[1]An extended analytically focussed narrative history of wind technologies in Ireland is presented in Chapter 5.

2.1 Ireland, turnkey technologies and the grid

"Wind Energy Meets 50% of Ireland's Weekend Electricity "[2]

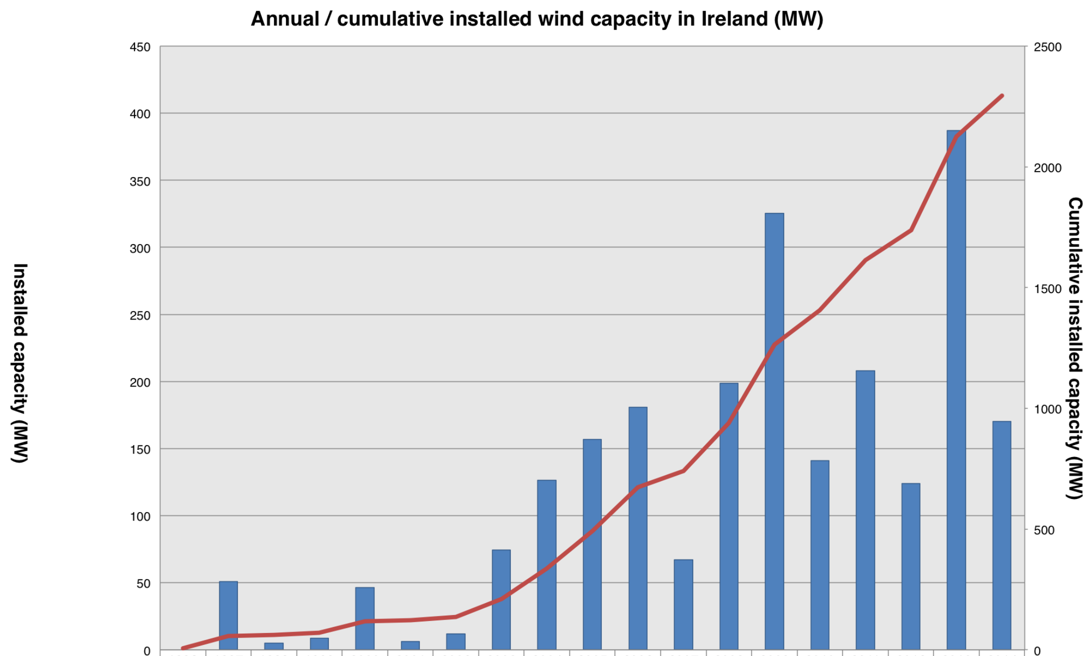
This statement headlined a press release from the Irish Wind Energy Association following Hurricane Gonzalo's landfall in Ireland over the weekend of October 18th and 19th 2014. The weather it brought was energetic, wet, and most significantly, windy, supplying notable contributions of renewable electricity to Ireland's grid. Record breaking wind generation that weekend is illustrative of the contribution wind technologies now make to Ireland's energy system, at the time or writing peaking on 23rd February 2015 when wind turbines supplied 1,969 MW of electricity to the grid (ERC, 2015). A decade previously, Ireland had only a handful of operating wind farms, illustrated in Figure 2.1. The pace of roll out of these technologies is remarkable, all the more so when we consider the European context. By the end of 2014 in the Republic of Ireland, wind had become a significant source of electricity (see wind statistic highlights for 2013 in Table 2.1).

Table 2.1 Wind statistics 2013. Source: IEA (2013); Howley et al. (2014)

Total installed wind capacity	1,991 MW
Total electrical output from wind	4.5TWh
Wind generation as % of national electric demand	16.30%
Average capacity factor	30.50%
Operational wind farms	166
National EU Renewable Energy Directive target	32% of Ireland's electricity requirements by 2020 (∼3,566 MW)

Wind power is playing a significant role in electricity supply in an increasing number of countries. By 2013 Ireland was one of 24 countries globally which had at least 1,000MW of installed wind capacity and world wide wind capacity reached 282 GW, just under half of which was in Europe (GWEC, 2012). Within the EU, the share of wind in the mix of fuels used in the generation of electricity was about 7.5% in 2014 with several countries having met significantly higher shares of their electricity demand supplied by wind. These included Denmark (39.1%), Portugal (27%), Spain (over 20%) and Ireland (19%) (IEA, 2013). Relative to the population of the county, Ireland's installed wind capacity is amongst a group of nations after Denmark. This roll-out across a select group

[2] IWEA (2014)



	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Added capacity (MW)	0	51	5	9	46	6	12	74	126	157	181	67	199	325	141	208	124	387	170
Total capacity (MW)	6.5	57	62	71	117	124	135	210	336	493	674	741	940	1,265	1,406	1,614	1,738	2,125	2,295

Figure 2.1. Installed wind generating capacity Ireland. Annual installed capacity is shown via the vertical blue bars, Ireland's growing cumulative installed capacity via the red line. Source author's compiled data

of European countries is illustrated in Figure 2.2. Here we see wind installation per capita growth over time, with Germany and Spain first to 'follow' Denmark's roll-out, then Ireland, Portugal with Sweden starting later but accelerating growth faster, a group of 'fast followers'. Other EU nations, including those not shown, are bunched in the third group which include the UK, France, Italy and Poland. This is a remarkable achievement, for although Ireland has amongst the best onshore wind resources in the EU (see wind map Figure 2.3),[3] it is faced with a number of technological limitations associated with integrating wind onto a low density small island grid (as discussed below). Supporting current generation and future goals is a complex system of technology, infrastructure, firms, a wider energy industry, skilled workers, innovation processes, finance and support policies at multiple governance levels. For example, the EU Renewable Energy Directive (2009/28/EC) set a target for Ireland to meet 16% of the country's total energy consumption from renewable energy sources by 2020. In order to achieve this, the Government set a 10% renewable transport target, a 12% renewable heat target and a 40% renewable electricity target, 32% by wind. In the remainder of this chapter we introduce these features by way of a snapshot of the contemporary Irish wind industry and relevant energy sector details

[3]The selection criteria was the top nine countries by cumulative installed capacity plus Ireland.

as of the end of 2014.

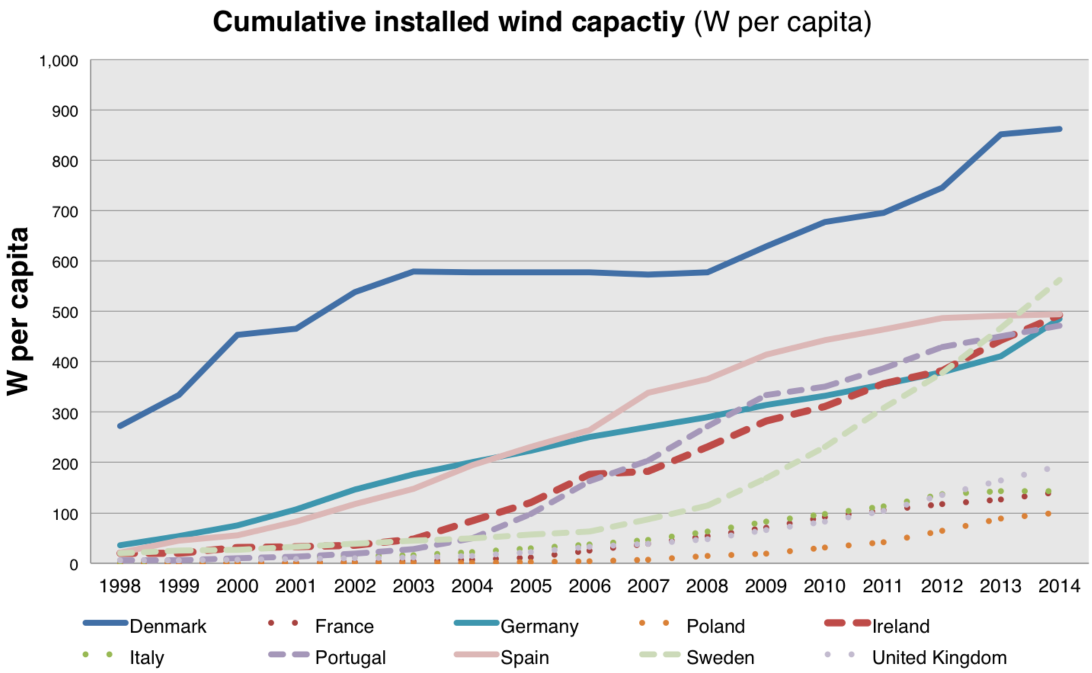


Figure 2.2. Cumulative installed wind capacity for selected EU nations, 1998 to 2014. Source Pineda and Wilkes (2015); Eurostat (2015)

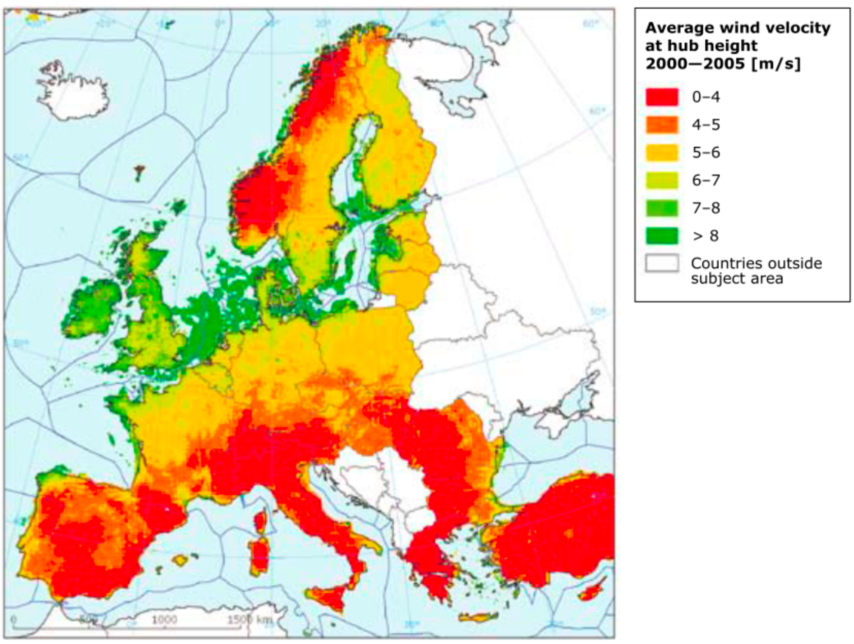


Figure 2.3. Wind field data after correction for orography and local roughness (80 m onshore, 120 m offshore) Source: EEA (2009)

Ireland's wind generated electricity is produced on approximately 190 wind farms. These have been developed predominantly on the western seaboard, utilising prevailing

North Atlantic winds coming from the southwest. The quality of wind resource although strong throughout the county generally declines from west, eastward (see Figure 2.4 which shows the geographic dispersal of current and planned wind farms), with western locations typically having an average annual wind speed of 9 m/s at 75 m hub height compared to 7 m/s on the east coast (SEI, 2003b). However in recent years, more developments have taken place in Eastern counties, as prime western locations have been occupied and generation technology improvements have meant commercially competitive returns can be made from plant at a wider range of locations (Duffy and Cleary, 2015). Typically turbines operate at 30.5% capacity factor - the electricity generated as a percentage of the maximum possible under optimal wind speeds and grid export conditions. This is a high capacity factor by international standards (IEA, 2013) and indicative of Ireland's well-endowed wind resources (Vitina et al., 2015). Wind farms range in production size from single turbine installations with less than one mega-watt capacity, to sites with tens of turbines and cumulative capacities over 50 MW. The average size of a wind farm completed in 2013, was 13 MW[4]. Ireland's wind industry is onshore, only a single 25 MW installation lies offshore, in the Irish Sea off the coast of County Wicklow. Onshore projects in Ireland, are generally in the form of clusters of turbines locally referred to most commonly as wind farms. While Ireland has a very low population density by European standards, the highly dispersed nature of rural settlement coupled with planning restrictions devolved to regional level limit the land that can be used for individual wind project development in Ireland presenting a significant challenge to developers.

The supply of electricity from wind at utility scale relies on two distinct but interrelated sets of technologies, the generating plant and the electricity system infrastructure.We can examine the former by considering Tursillagh wind farm in County Kerry. It is typical of the wind farms built in the early 2000s, consisting of 23 Danish-built Vestas V47 turbines, each capable of generating 0.66MW of power with 47m rotors[5]. Each standalone unit includes the turbines, blades, towers, gearboxes, generators and transformers. These are shown on the right hand bar in Figure 2.5 which illustrates typical capital costs and activities of a wind farm build. In 2013 capital expenditure on turbine technology averaged

[4]This figure is around the European average. However it is useful to consider strikingly different average plant sizes throughout Europe (Vitina et al., 2015). For example, Germany has predominantly smaller sized wind farms (∼7–10 MW), often owned by local firms or communities. Spain on the other hand has bigger developments (23–29 MW) with a significantly higher ownership by utility firms. Ownership models in Ireland are discussed in the next section.

[5]By 2013 the average size of onshore wind turbines for new projects had risen to 2.16 MW (IEA, 2013).

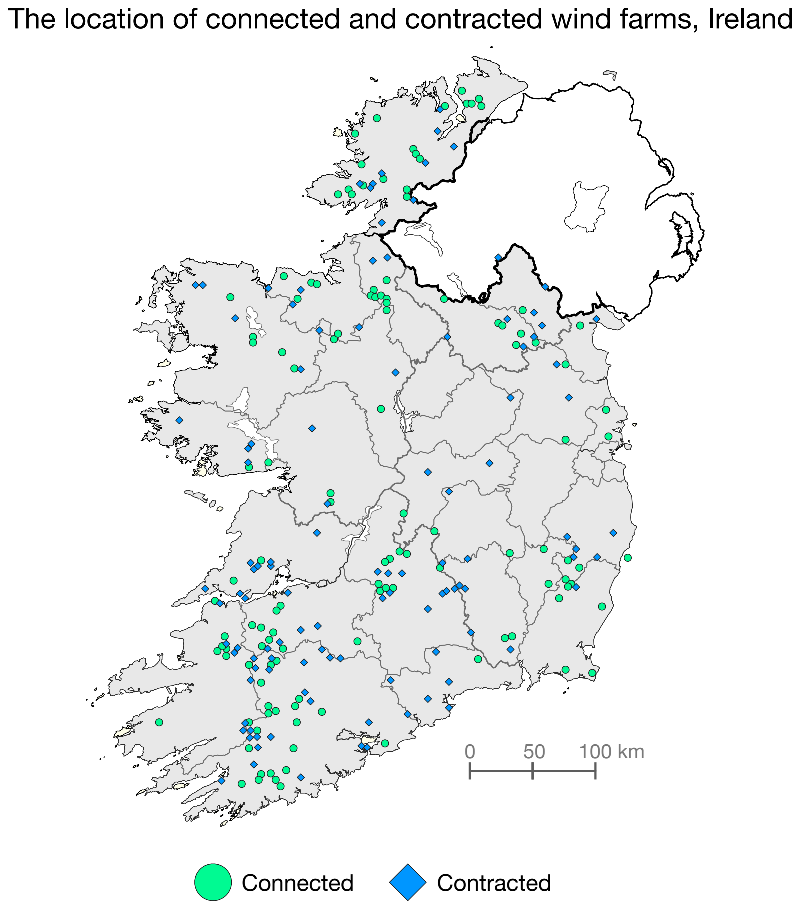


Figure 2.4. The location of grid-connected and (future) contracted wind farms in Ireland. County and municipality boundaries shown. Sources: EirGrid, IWEA, Meithel na Gaoithe.

in the range of € 0.8m to €1m per installed MW[6] for medium-to-large projects involving multiple turbines with total development costs in the order of €1.5m per installed MW (IEA, 2013).

There are two notable characteristics of this plant common to almost all installations in Ireland. First, generating technology is imported. Due to lack of heavy engineering infrastructure and small market size, no manufacturing of utility scale (greater than 100kW) wind turbines, or any major components takes place in Ireland. Second, the technology is turnkey in nature meaning a Vestas V47 operating in Kerry is not notably different a version of the same model deployed in Jutland, Denmark. As can be seen in Figure 2.5, the turnkey components represent an average of two-thirds of the capital investment

[6]There is a continuing downward trend in the price per installed MW of wind turbines towards the lower end of the price range, however newer large-rotor, low-specific-power models, which represent the upper end of the cited cost range

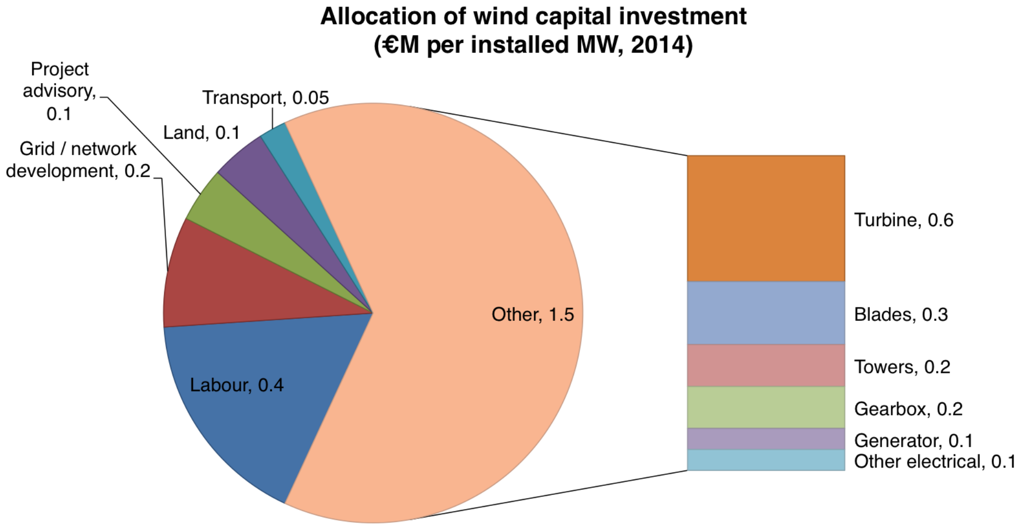


Figure 2.5. Allocation of wind capital investment in millions of Euros. Imported turnkey components make up right hand side bar. Source FitzGerald et al. (2014); IEA (2013).

required for a wind farm development[7]. Between them, Vestas, ENERCON, General Electric, Nordex and Siemens models account for over 90% of the turbines deployed in Ireland (Figure 2.6). These firms typically have sales and engineering services offices in Dublin and often ancillary offices on the west coast employing staff for operations and maintenance contracts as well as installations. Given the capital intense nature of renewable energy technologies (where marginal production costs approach zero and capital costs represent a large percentage of total cost of generation), Irish investment or subsidising of wind generation represents a considerable national outward bound flow of finance.

In addition to the imported turnkey technologies, the development of a wind farms requires connection to the national transmission system, the 'grid'. Wind energy is intermittent, output generation fluctuates with wind and other climactic factors. In other words, it cannot be easily turned on to meet surges in demand[8]. Because of this, adding high levels of electricity generated by renewable sources to the grid creates a number of technical challenges including the ability of generators to operate through periods of low voltage and controlling the balance between grid generation and load (Bazilian et al., 2004). This situation is exacerbated by the relatively small size of Ireland's grid[9] as the

[7]IWEA's The Value of Wind Energy to Ireland report lists the import intensity of wind developments as 66%, a figure derived from Irish I-O tables (Billington and Mohr, 2014).

[8]This is termed non-dispatchable generation. Fossil fuel generation on the other hand is generally dispatchable, a combined cycle gas turbine plant may be turned on specifically to handle peak loads on the network, usually when the population is making dinner between 17:00 and 19:00 hours.

[9]To put this into international perspective, Ireland's power system is nine times smaller that that of

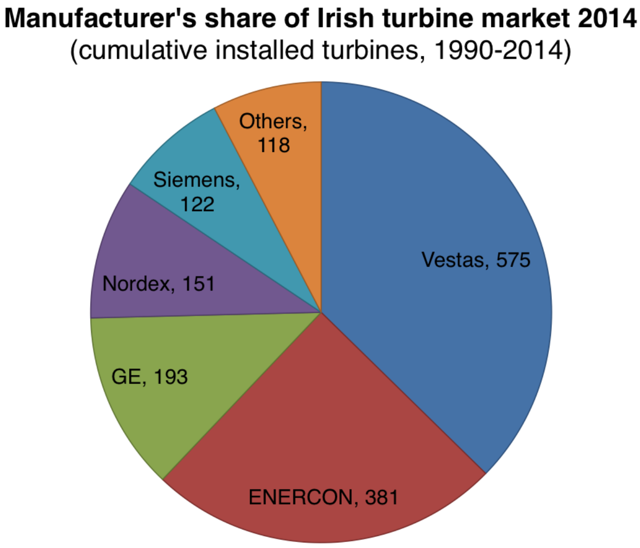


Figure 2.6. Cumulative installed turbines per manufacturer. Source: author's collated data.

cost of the balancing and back-up is linked to the flexibility of the existing system (Foley, Ó Gallachóir, et al., 2013). While there is no theoretical upper limit to wind power levels on Ireland's grid according to Gardner et al. (2003), transmission reinforcement, other technical system constraints and operating costs are limiting factors in practice. As levels of integrated wind capacity on the grid increase in Ireland, integration at the margin becomes more challenging than is the case with other larger systems due to technical constraints arising from intermittency. This is further exacerbated by low levels of interconnection between Ireland and neighbouring grids (Holttinen et al., 2009).

In Ireland, the systemic mitigation of a number of technological constraints are the responsibility of the system operators who are responsible for the transmission and distribution of electricity from generators such as wind farms and coal plants to end-users such as homes and businesses. The physical grid connection is carried out by EirGrid the transmission system operator (TSO) and ESB Networks, the distribution system operator (DSO). These operators have attempted to address these constraints first by means of specific grid codes (sets of rules) for manufacturers and generators, second by setting out access rules and processes for grid access applicants, and third through research and development aimed at finding technological solutions to constraints. The grid codes specify robust wind power prediction requirements that are needed to integrate the current levels of wind power (EirGrid, 2015). Grid access by new generators is determined centrally

Great Britain, which in turn is 30% of the Nordel system in the Nordics. Significantly larger than Nordel is the UCTE system which covers much of the remainder of continental Europe. (Foley, Ó Gallachóir, et al., 2013).

in Ireland by way of a Group Processing Approach, in which applicant projects for grid connection are batched together and offers made in series of 'gates'. By December 2013, the total amount of wind capacity contracted for connection in upcoming years under the latest round, Gate 3, was 1,230 MW with 534 MW of remaining live offers to wind projects not yet accepted. This brought the total wind capacity contracted for future connection at the beginning of 2014 to 3,293 MW—almost double the additional capacity required to deliver the EU 2020 target.

Funding for wind related technology research is less than that for ocean energy, solar and bioenergy[10]; research into wind generation technologies is not a stated priority area for government funding[11]. However, despite national policy, bibliographic analysis[12] of research outputs (as well as strong anecdotal evidence from interviews conducted by this author) shows that system integration became a significant research focus during the early 2000s, at the same time as roll out of generation technology accelerated. These data also suggests strong links between industry and university research at this time. In particular, EirGrid played a role in collaborative research aimed at increasing renewable penetration on the grid and is a significant employer of graduates of Ireland's small number of energy research groups. Focal research areas within this domain include work on increased grid interconnection (Vestergaard et al., 2010), mitigation strategies for system security issues associated with frequency response (O'Sullivan et al., 2011; Dudurych et al., 2006) better forecasting models (Foley, Ó Gallachóir, et al., 2013) and mitigating grid curtailment (Mc Garrigle et al., 2013). Research on wind energy systems in Ireland has implicitly

[10] This compares with funding for ocean energy (e.g. marine or wave based generation technologies), a stated research priority area, of €5.2 million. Solar, bioenergy and geothermal energy research received funding totalling €1.3 million, €2.2 million and €9,500 respectively. Energy efficiency funding accounts for the majority of annual energy research budget. In 2012 this totalled €30.7 million. All budget data sourced from SEAI (2013).

[11] Aggregate research, development and demonstration spending on energy in 2012 was approximately €46 million. In terms of Euros per gross domestic product, this figure is similar in scale to recent aggregate UK energy RD&D budgets. Of this, funding for renewable energy sources was €9.9 million and specifically wind €887,020 while power and storage technologies and other cross-cutting research received funding totally €5.6 million (SEAI, 2013). This compares with funding for ocean energy (e.g. marine or wave based generation technologies), a stated research priority area, of €5.2 million. Solar, bioenergy and geothermal energy research received funding totalling €1.3 million, €2.2 million and €9,500 respectively. Energy efficiency funding accounts for the majority of annual energy research budget. In 2012 this totalled €30.7 million. All budget data sourced from SEAI (2013).

[12] Bibliographic database Scopus was queried for outputs such as journal papers and conference proceedings by analysts at Irish universities and firms. Research methods, data sources and collection techniques are described in detail in Chapter 4.

addressed the dominant national characteristics of the industry, those being that turnkey generation technology is manufactured overseas and that integration onto the grid is the major challenge. Indeed, little evidence has been found of Irish-based research into generation technology itself.

Already we have identified a number of intriguing aspects of the case. We note that the turnkey nature of the technology imported and installed contrasted with the place specific nature of the technological integration required to maintain growth rates. These technological characteristics underpin the rapid integration of wind technologies onto a small island grid. Furthermore, the rate of installation itself has been been remarkable in international terms. Consider that in terms of scale, the all island grid is one ninth the size of Great Britain's, which in turn is 75% the size of the Nordic network, Nordel while the UCTE system which covers continental Europe is larger again (Ó Gallachóir, Guidi, et al., 2007). This indicates the scale and also relatively unique aspect of the integration issues faced by Irish system operators, where learning from other small island integrations was not possible because few, if any, existed. Furthermore, given the relatively small size of the Irish electricity market, Irish actors did not to have large leverage with overseas manufacturers to create bespoke technology variants.

2.2 Industry, firms and finance

Ireland's wind farms are owned in a roughly equal distribution of energy utilities and small wind farm operators. The four largest electricity utilities own approximately 38% of installations (Figure 2.7 (a)) however the installed capacity of their wind farms are typically larger. Thus, these utilities account for 58% of the country's wind generating capacity (Figure 2.7 (b)). Of these utility actors, Airtricity, Bord Gáis Energy (BGE) and Energia are owned or controlled by parent firms outside of the republic (by SSE plc, Brookfield Renewable Energy Partners L.P. and Viridian Group plc respectively). Only one of these firms, Hibernian Wind Power, remains a majority Irish owned enterprise (a wholly owned subsidy of ESB, the state owned electricity supplier). The small firms are a heterogeneous collection of small and medium businesses, farmers and investor developers.

Until the recession of 2008, the funding of developments in Ireland involved 'project financing' models. This involved debt funding by banks of up to 70% to 80% of the capital costs over 15 year payback periods, with the remainder met by equity finance from a range

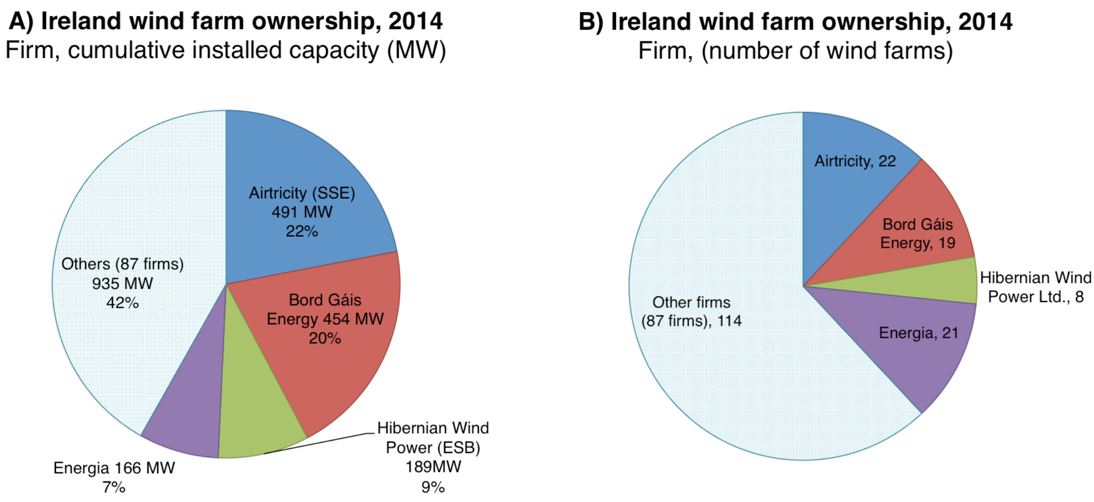


Figure 2.7. A) Wind farm ownership in Ireland, total wind farms by firm. Source: author's collated data. B) Wind farm ownership in Ireland, cumulative installed capacity by firm. Source: author's collated data from IWEA, SEI.

of actors and institutional lenders. Duffy and Cleary (2015) estimate return on equity and debt interest rates across the sector to be 14% and 6% respectively. Following the recession of 2007 and subsequent financial crises, both the number of Irish lenders and the capital they were willing to lend declined significantly. According to one interview participant:

> "...the Irish Republic banks certainly up to very recently have not been open to this sort of investment for about four or five years. They basically shut down. People like ehm Deutsche Bank, Nord LB, BNP . . . they have been open for business and then other companies like ESB, Bord Gáis, SSE have been able to do it off the balance sheet they go, they can issue their own debt for cheaper, when they take that down they build. So in terms of our exposure, if you are project financing you are slightly more exposed to the current crisis, if you are a very large multi national utility such as SSE you can raise money relatively cheaply yourself. If you are someone like ESB or Bord Gáis I think recently their credit rating has been slightly better in the States and they look to do it off balance sheet, which, is effectively a concession from the government."[13]

Evidence gathered from interview participants suggests financing projects disproportionately for smaller firms in Ireland who are less integrated into transitional finance networks, while those with or able to develop relationships with international financiers have had access to overseas investment or alternative funding models. Furthermore, utility

[13]Interview 130103

players are less reliant on financing from Irish banks as they may also have the option of funding capital expenditure from their balance sheet. Even if this option is not pursued, the availability of balance sheet funding can influence perceive risk and accordingly lower interest rates from lenders. Indeed, over recent years, a number of European investment and development banks have entered the Irish sector. For example, ESB acquired long term project finance from Bank of Ireland for a development at Garranereagh, and from Norddeutsche Landesbank Girozentrale, London Branch (Nord/LB) and KFW Ipex-Bank for Monaincha wind farm. In addition, Bord Gáis Energy and ESB Networks secured large scale finance from the European Investment Bank (EIB, 2012; Windpower, 2015).

Despite a relatively even historic distribution between utility and small firm project ownership, construction and connection of wind farms since 2011 been by larger firms, at capacities tending towards the utility scale[14]. This situation is illustrated in Table 2.2, a comprehensive list of wind farms newly connected to the grid over the 24 months to the end of 2014. New entrants to the sector in Ireland have tended to be overseas firms entering the market through acquisition of indigenous firms (purchasing fixed assets at either completed or late pipeline stage)[15]. For example ABO Wind Ireland, promote themselves as a 'one-stop-shop' who can take a project from development stage to operation, maintenance and management, in which they manage "all technical and business planning, arrange international bank financing and deliver turnkey wind farms[16]". Similarly Invis Energy are a joint venture between a UK based private equity partnership and an engineering consultancy, again promoting their financial expertise and ability to project manage. BlackRock[17], on the other hand is an "institutional investor", who purchased near-to-completion projects from Irish developer Element Power to add to an emergent global wind power and solar PV investment asset portfolio (Doom, 2015).

[14]I differentiate here between scales of technological installations. Small operators have less than three wind farms, utilities have a larger number, by wind farm and cumulative installed capacity, while medium operators may have several wind farms.

[15]We also note two relatively anomalies in 2013. First the completion of the Ireland's only community wind farm, Templederry Wind Farm, comprising of two 2.3-MW wind turbines. Despite a number of earlier successes in other countries, Irish groups employing community-owned models had not successfully launched a wind farm previously in Ireland (Comhar, 2011; Seyfang et al., 2014). Second was the initiation of work to install three 3-MW wind turbines by adjacent transnational pharmaceutical firms to supply their operations in the Lower Harbour area of Cork City. While not a major contribution to the national electricity resource, "merchant plant" developed for local industrial utilisation has enjoyed some success.

[16]Source: ABO (2015).

[17]BlackRock are one of the world's largest asset management firms, by capital.

Table 2.2 Firm ownership of wind farms launched over 24 months to December 2014

Firm	**Windfarms deployed 2013-14**	**Cumulative capacity 2013-14 (MW)**	**Scale of operations**	**Firm ownership**
Bord Gáis Energy / Brookfield Renewables	7	199	Utility scale	Foreign parent firm
Invis Energy	3	85	Utility scale	Significant foreign ownership stake
BlackRock	3	45	Utility scale	Foreign parent firm
Bord na Móna	1	42	Utility scale	State-owned utility
Airtricity	1	34	Utility scale	Foreign parent firm
ABO Wind Ireland Ltd.	1	15	Utility scale	Significant foreign ownership stake
Energia	3	13	Utility scale	Foreign parent firm
Knocknalour Wind Farm Ltd	2	9	Small wind operator	Irish
Gaelectric	1	6	Small to medium operator	Irish
Wind Source	1	5	Small wind operator	Irish
Ballynancoran Wind Farm Ltd	1	4	Small wind operator	Irish
Templederry Wind Farm Ltd	1	4	Community energy	Irish
DePuy Cork Harbour	1	3	Merchant plant	Irish
Janssen Cork Harbour	1	2	Merchant plant	Irish
Sheeragh Wind Ltd	1	0.4	Small wind operator	Irish

Whilst historical data gathered is insufficient to indicate a trend, evidence from other regions suggests BlackRock's entry into the market may be the vanguard of a sectoral shift towards a 'yieldco'[18] model of asset management and ownership. This model is based on

[18] According to (NC Economy, 2014, p. 219), yieldcos are firms "which own portfolios of low-risk, long-term projects are equity vehicles that can go a step further than infrastructure bonds by effectively

the predictable cash flows that energy generation in general, and guaranteed renewable technology support schemes such as feed-in tariffs specifically may offer (NREL, 2014). Changes to wind farm finance models in Ireland took place at a time when finance models across Europe were changing. Longer-term institutional investors such as such as pension funds, insurance companies and wealth managers have increased investment in renewable generation assets. Underlying factors for the entry into the wind sector by these new actor groups include the increasing stability and predictability of project yields at around 6% compared with relatively low government bond yields of 2 to 3% coupled with some protection against inflation and regulatory guarantee (FS-UNEP, 2014). Bloomberg New Energy Finance reports that in 2013, these firms had invested approximately €3 billion in renewable energy private equity and infrastructure funds, project bonds, or directly into equity or debt in specific development projects, a three-fold increase from 2008 (2014). This evidence correlates with case evidence which suggests a number of new business models emerging in the Irish wind sector which have evolved with this changing global landscape. Two Irish firms, Element Power and Mainstream Renewable Power, have emerged from Ireland as global players, capable of developing projects, raising finance, and creating diverse revenue streams. For example, Mainstream Renewable Power led the development of the $70 million, 33MW Negrete Cuel wind farm, financed in 2013 with debt from China Development Bank and equity from Mainstream[19] (FS-UNEP, 2014).

These developments in the financing of the industry point to a number of intriguing insights analysis of the Irish case offers. As the industry has developed, the risk-adjusted return has shifted from relatively high levels associated with private equity towards relatively lower, long-term, stable infrastructure type returns, indicating a maturing of the wind sector and something of a legitimising effect having taken place in the offices of investment professionals assessing the cost of risk. This suggests that from the perspective of an institutional portfolio manager, wind investment is now a 'reliable' investment. Second, the evidence presented so far suggests that the characteristics and composition of actors in the industry is dependent on a complex set of historical and contemporary factors, both within and outside of the country. Third, we can see that not only do fin-

bundling equity and debt together in one package. By bundling projects together, the project finance premium for single projects can be avoided. Moreover, for a portfolio of projects with risks comparable to corporate bonds, the result for investors can be a higher-yielding, bond- like instrument that nevertheless reduces the overall financing cost for the projects in question."

[19]Furthermore, this has occurred without subsidy support or power purchase agreement. Instead, Mainstream has relied on revenue through merchant power sales, indicating a strong belief in what they have called 'underlying financial fundamentals'.

ancial players enter a territory, but financial innovation that occurs by actors within the territory may then be diffused elsewhere. While wind generation technology is not an export commodity for Ireland, financial models have been developed in Ireland, or by Irish actors, are being diffused transnationally. Yet while a small number Irish firms develop and exploit discrete links in the global wind technology supply chain, in Ireland we have seen that overseas firms own, operate and maintain an increasing percentage of generation plant. The trans-national inter-penetration of ownership is a feature of modern capitalism, however it brings with it some background questions for policy makers in Ireland. First, is it societally better to divert domestic capital formation from projects where more local knowledge is needed – e.g. housing and office buildings to the 'utility' sector? Second, do Irish investors benefit from access to international markets, i.e. do they have returns abroad? (e.g. The Netherlands has a lot of income from overseas investment while also having similar patterns of international capital investment inflows (Belderbos, 1992)).

2.3 The electricity market and energy policies

Many of the disparate actors, technologies and fuels of the wind RES are brought together in Ireland's electricity market (see the energy flow for the electricity system in 2013, illustrated in Figure 2.8.[20] The market fulfils a number of roles beyond simply 'supplying' electricity from generators to consumers. First, the market serves as a location for transactions between actors, in this case generators, market suppliers or wholesalers and end-use consumers. Several 'vertically integrated' actors fulfil numerous roles in the market. For example, Airtricity (owned by SSE plc) own and operate generator plant, they supply that electricity to the market itself, and they then act as a distributer managing individual commercial relationships with households and businesses. On the other hand, many smaller wind farm operators contract with single suppliers who in turn manage market arrangements. Second, the market may be understood as a political arena, in which regulative priorities are exercised. For example, the Renewable Energy Directive requires the system operators to prioritise renewable energy generation over fossil fuels. This prioritisation is enacted through market mechanisations and dispatch-down rules[21] (EirGrid

[20]Despite the growth of indigenous wind generation, Ireland is highly dependent on imported fuels, in 2013 importing 89% of its overall energy requirements (Howley et al., 2014). Ireland has approximately 7,500 MW of grid-connected installed electricity generation capacity in addition to wind plant (EirGrid, 2015).

[21]Where measures are taken to turn-off or "dispatch-down" renewable energy for system security reasons, EirGrid must report to the regulator (CER) on those measures and indicate which corrective measures

and Soni, 2014). Third, market rules and arrangements ensure the continuous operation of the system and constant supply of electricity is maintained. As discussed in the previous section, the characteristics of a given fuel source impacts the grid structure and thus the economic architecture of the market. In other words, the operation of the grid is somewhat contingent and interdependent on the fuel sources consumed and the structure of the market and, this thesis will argue, the market exerts a core technological, and social influence on the Irish wind RES.

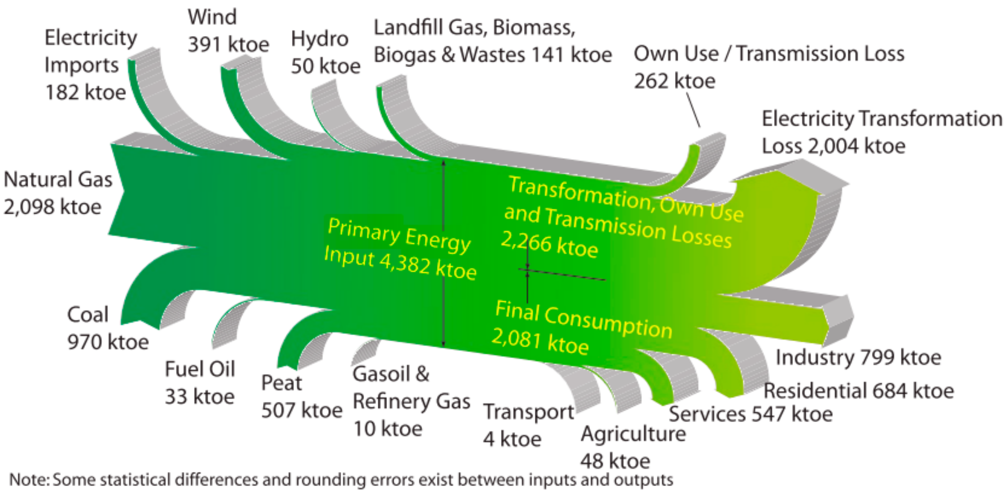


Figure 2.8. Energy flow, electricity generation, kilotonnes oil equivalent. 2013. Source SEAI (Howley et al., 2014)

All electricity generated or imported onto the island of Ireland (the Republic and Northern Ireland), must be sold into a common pool, the Single Electricity Market (SEM), operational since 2007. All electricity for consumption within Ireland, or export is purchased from the pool. The electricity market prices are set by the Single Market Operator (SEM-O) and published on half-hourly basis, calculated after the event, with all generators receive and all suppliers pay the same System Marginal Price (Leahy and Tol, 2011). The price is based on many different factors, however the predominant influence is the cost of the energy used for that period. In theory, 'market forces' ensure sufficient capacity is built up for demand at any time and that this mechanism will lower prices over time (Kee, 2004). Suppliers of wind generated electricity receive a number of special incentive payments. Capacity payments are made to all generators in order to ensure capacity is available when required. Capacity payments are fixed annually by the regulator (CER) and are intended to encourage investment and mitigate risk of uncertain revenue. The benefit for generators is that if they make plant available when capacity margins are tight,

they intend to take in order to prevent future inappropriate dispatching down (EirGrid and Soni, 2014) revenues can be earned, which are greater than the short run costs (Leahy and Tol, 2011). Curtailment payments are made to wind generators to compensate for wind power produced which cannot be taken on to the grid due to network system issues. These issues occur predominantly in situations where there is a surplus of wind power with regard to the demand on the grid. The aim of such payments is to increase certainty of revenues, encourage investment and ensure that capacity is made available when it is required. The SEM, along with major actors and flows of payments and electricity are illustrated in Figure 2.9. This diagram illustrates the central position the system operators and market suppliers have intermediating flows of electricity and finance between generators and consumers respectively.

According to Di Cosmo and Malaguzzi Valeri (2014), the decision to add generation capacity in a deregulated market such as that of Ireland's rests with individual firms and investors. This suggests that the government is naïve with regard to the effect of these deals on capacity. Yet clearly if the government believes more capacity is needed, they can stimulate its creation by signing deals or introducing incentives that will be attractive to individual firms and investors. In this regard the Irish government incentivises firms to add wind capacity primarily through the Renewable Energy Feed-in Tariff. The first REFIT instrument was introduced in 2006 and REFIT 2 in 2012. The REFIT is the primary instrument by which the government, on behalf of the people of Ireland, incentivises the production of renewably generated electricity over 'lower cost' fossil fuel which is deemed less socially desirable. It does this by guaranteeing generators (via market suppliers) 15 years power purchase agreements, with a specified fixed payment for the period of the term. In effect, this transfers some quantum of risk associated with uncertain future demand, from the wind farm investor to the bill payer, on which the Public Service Obligation (PSO) is levied. The effect of wind on the cost of electricity generation is illustrated in Figure 2.9. In this figure, Clifford and Clancy (2011, p. 4) show graphically that by 2011, wind generation was expected to reduce Ireland's wholesale market cost of electricity by around €74 million. They argue that this "reduction in the wholesale market cost of electricity is approximately equivalent to the sum of PSO costs, estimated as €50 million, and the increased constraint costs incurred, due to wind in 2011." In other words, the net electricity cost does not increase with the addition of wind capacity on the grid in 2011 when compared with a model scenario of a 'no-wind' market. What is not clear from these figures is whether the comparative cost of renewable energy technology electricity relative to combustion based electricity is only possible through subsidy. If so, there is

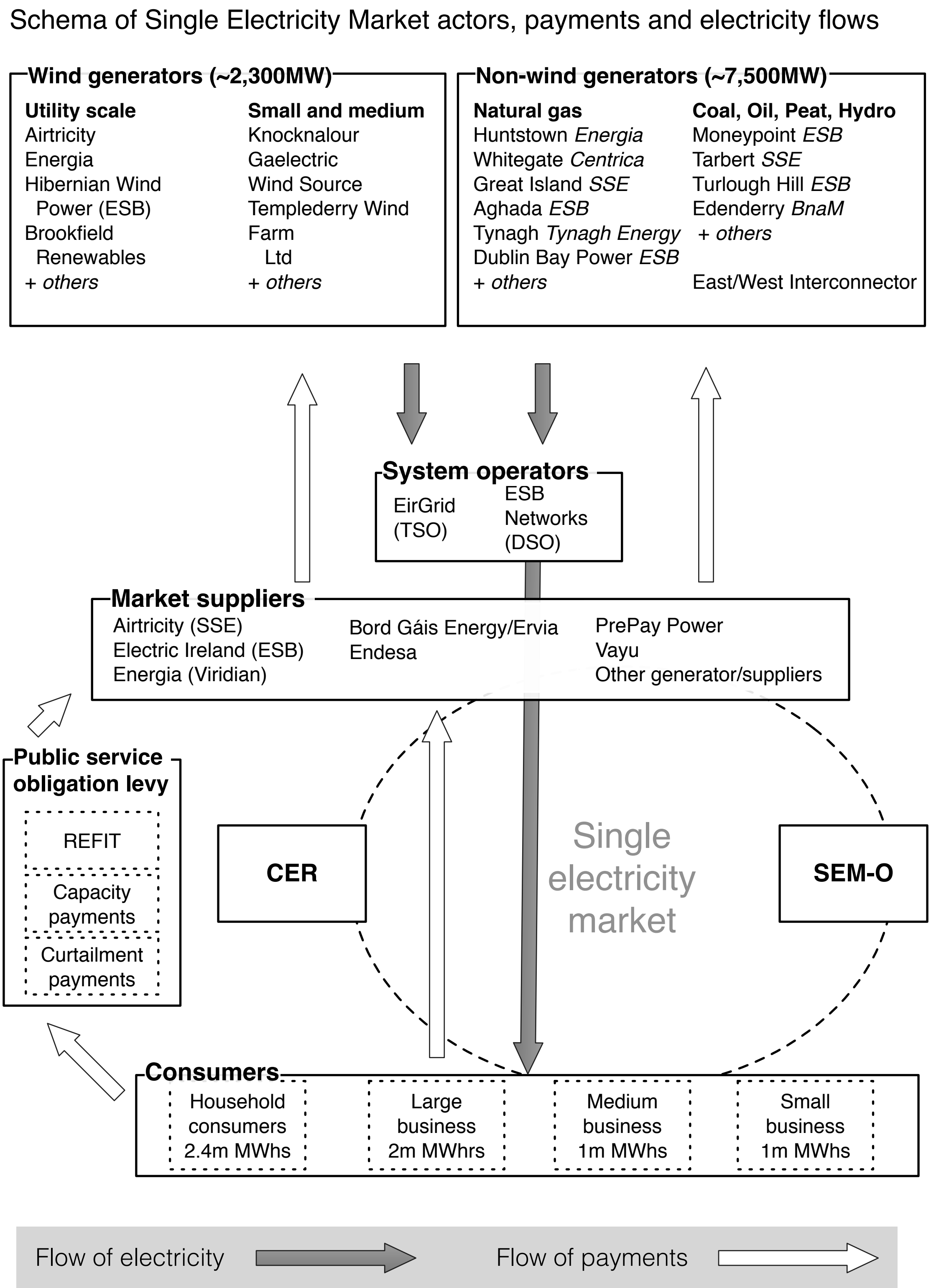


Figure 2.9. Schema of the Single Electricity Market

another investment risk factor to add to those discussed in the previous subsection, that is the ongoing government commitment to the subsidy level.

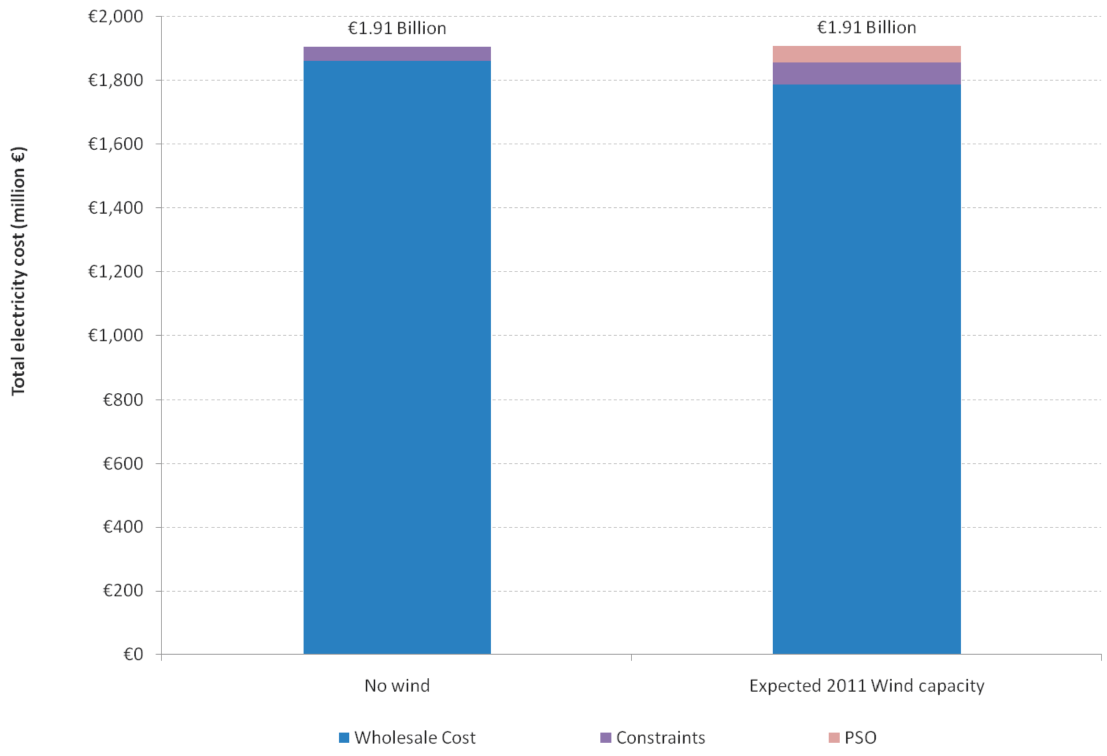


Figure 2.10. Projected Cost of Electricity Generation in 2011. Source: Clifford and Clancy (2011, p. 4)

Electricity market suppliers take payments, including subsidies, from the SEM and aggregate delivery of electricity supply though individual supply contracts with wholesalers. The average wholesale market price during 2013 was €107/MWh, as compared to the REFIT tariff of €69.235/MWh for wind farms larger than 5 MW and €71.664 /MWh for wind farms smaller than 5 MW, as calculated from the annual sum of 2013 half hourly single electricity market transactions, plus generation capacity payments, plus dispatch balancing costs, divided by the total generated electricity in 2013 (Duffy and Cleary, 2015). Electricity suppliers then (e.g. the wholesalers rather than the generators) are afforded strong positions by the architecture of the Single Electricity Market.

A number of structural, market and technological challenges remain in the Irish system with regard to increasing the penetration of wind though 2020 and beyond. Here, several commentaries on the implications of the discussion in this section are summarised. First, the age profile of thermal generating plant is old (Valeri and Tol, 2006) and substitution of new for old thermal plant has been delayed by the recession of 2007 in addition to permitting issues. This is problematic for the wind industry as high wind penetration requires parallel investment in fast-dispatchable generation technologies, such as open cycle or combined cycle gas turbine. Second, current policies, targets and infrastructure plans have been guided by research built on techno-economic based models.[22] These studies were carried out before the recession of 2008, and none, at the time of writing, account for the drop in electricity demand in the years following 2008[23]. Third, because of wider economic conditions and forecasts, the current market structure is failing to sufficiently encourage competition or new entrants with suitable generating technology (Foley, Ó Gallachóir, et al., 2013). This contrasts with the situation of traditional generators, including renewables, who entered the market in the early 2000s. It is in the interest of these incumbents to retain the current status quo of guaranteed payments of the current SEM/PSO settlement. As discussed by Lyons et al. (2007, p. 77):

> "to achieve the best long-run outcome, the SEM's regulators need to ensure that the capacity mechanism accommodates a set of strategies by all players (incumbents, entrants, government) that will lead to the highest possible societal welfare."

Foley, Ó Gallachóir, et al. (2013) suggest that if in the long term, CER and SEM-O allow the current status quo of market suppliers and generators to continue, the marginal price paid by either the government (and by extension citizens) or electricity consumers will be expensive technical fixes such as heavy grid reinforcement and further interconnection. Here then is something of a conundrum. On the one hand the government has latitude in encouraging such entry or competition by the structuring of long-term supply agreements, as discussed in the previous paragraph. Yet Foley et al. explicitly draw attention to the the powerful position of market suppliers and system operators and implicitly the relatively weak position of that of the government (see also Hunt (2012)). Fourth and finally, addressing this issue Foley et al. remark on the relatively narrow basis of policy interventions to date in 'supporting' wind technology roll-out. In particular the role of the retail electricity market and modernisation of the distribution system has been neglected, and have been little discussed in studies. These commentaries indicates a relatively narrow or focussed research and policy agenda, influenced by system operators and suppliers resistant to deviate from established sectoral operating norms.

[22] Perhaps the most influential of these is the All Island Grid Study (Department of Communications Energy and Natural Resources, 2008)

[23] A drop in overall demand, coupled with increasing penetration of intermittent electricity exacerbates systemic grid integration issues we have already discussed.

2.4 Historic decisions, processes, and contingencies

Already in this brief description of the contemporary Irish wind energy sector, we have encountered a number of different technologies, governance rules, institutions, instruments, resources and activities which collectively make up a the Irish wind sector. These include the generating and infrastructure technologies and technological constraints contingent on Irish gird dynamics and wind resources. The actors, typically firms, in industry, but also the finance, legal, regulatory and government ministers and civil servants. Many of these actors have formal roles in the electricity market, which is a site of transactions, relations and rules, including the REFIT and other subsidies. Two underlying tensions are worth noting. The first tension is locational in nature, it should now be clear that this Irish wind RES contains components from within Ireland, and from overseas.

The previous development of the technological innovation systems literature has, in a similar fashion to national innovation system literature, primarily focused on innovation systems developed and operating in single countries[24]. It is therefore not only necessary but useful to extend this framework by taking into account elements of the TIS that are not nationally located. How this is done has implications for the nature and units of analysis. The perspective taken in this thesis is centred on a national view so international elements of the TIS are taken as external elements that 'touch down' and become integrated in processes that are considered in this thesis. An alternative, which is not pursued here, is to treat the 'foreign' elements in a more comprehensive analysis which would consider how they involve internationalisation and their own dynamics of development. This approach would clearly preclude the depth of attention devoted here to the national elements of the wind RES[25]. Thus, here we introduce an heuristic concept of *build-up* and *touchdown*. Respectively these are the activities resources, technologies and institutions of the Irish wind RES originating (generally) outside Ireland and within the country. In Figure 2.11 we illustrate some of the activities, resources, technologies and regulations relevant to the contemporary Irish wind RES. The thesis will account for the *build-up* and *touchdown* of the Irish wind RES, and use the heuristic as a container for locationally explicit explanations.

The second tension in this is what may appear as a narrow policy focus of wind

[24] The history and evolution of this literature is expanded upon in Subsection 3.1.3.

[25] The thesis explicitly avoids using the nomenclature 'TIS' to refer to the system of renewable electricity production and delivery in Ireland. Rather the TIS framework is employed to analyse the structure and innovation processes within Ireland and transnationally. The analytic framework is described in some detail in Chapter 3.

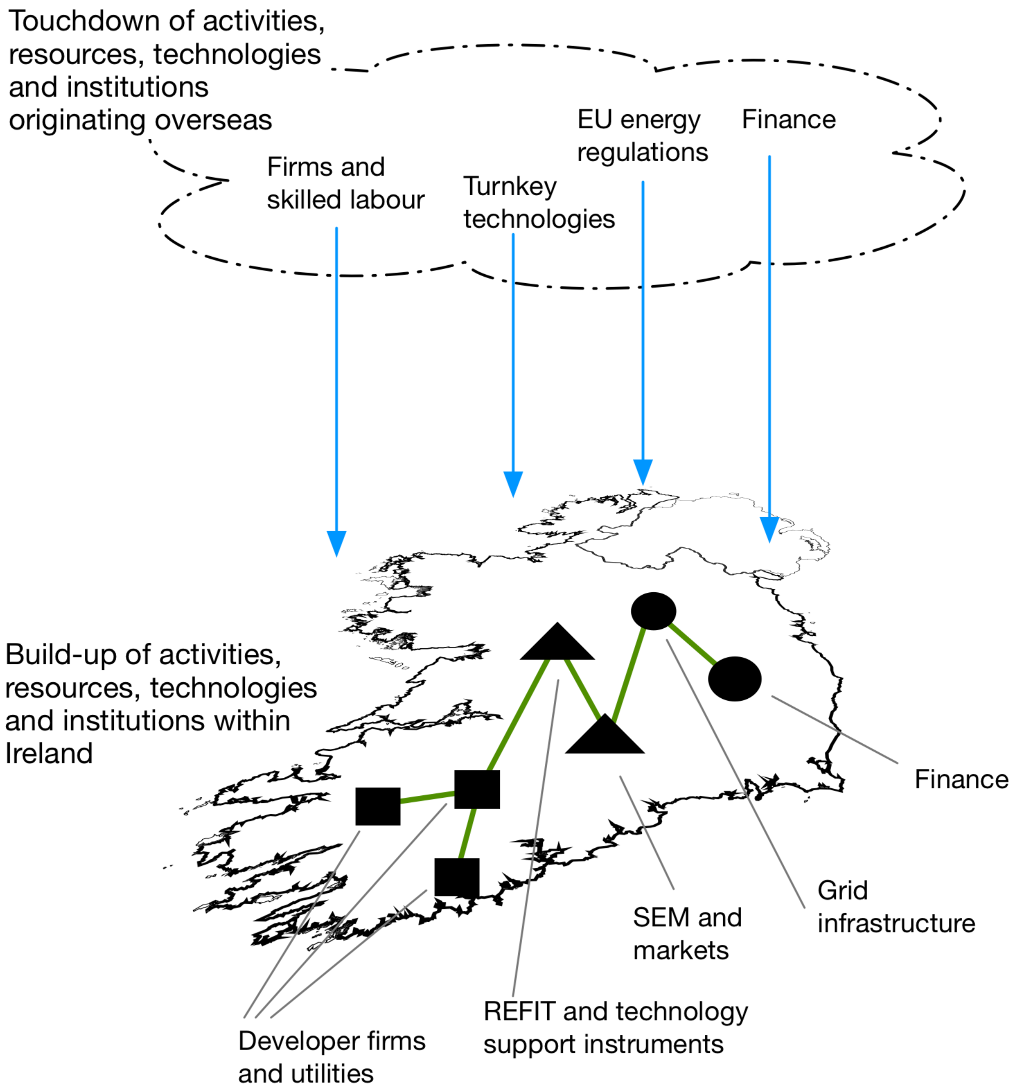


Figure 2.11. A basic scheme of build-up and touchdown

electricity in Ireland. We can think of the development of the technologies and relations as innovation processes. For example, we might ask how sectoral operating norms established, and why deviance from these norms is not common. What is unclear from this snapshot is where decisions that affect the material nature of the wind RES are made. On the one hand low emissions energy production contributes has public good characteristics, keeping greenhouse gasses out of the atmosphere. Some of the rhetorics of Ireland's wind developers have emphasised these, and other societal benefits, differentiating themselves from new combined cycle gas turbine technology for example. On the other hand metered electricity is a homogenous good. From the prospective of the end user, the quality of a 'flow' of electricity into a home or office does not notably differ according to whether the electricity is generated from spinning steam turbines (through the burning of fossil fuels) or rotating wind turbines. At one extreme, decisions about which generator to draw electricity from are made within the SEM every 30 minutes based on a 24 hour ahead market. Often, the consumer does not have a direct choice of which generation technology is supported. Politicians are elected and run energy department, and sign off on policies design by civil servants and lobbied for by NGOs or actors in firms. We have been introduced to policy at European and national level working on multi-year target models. So who decides? This is a choice, often made on the basis of previous, historical decisions, advances in technology, or because (relatively) powerful actors say it has to be made. We have already discussed the powerful role market suppliers occupy in the system, we might ask how they got where they are, and how they sustain their position. Furthermore what are the stories and how do these work with the processes of innovation.

Finally, the aim of this thesis is to explain the development of the wind energy system in Ireland. By it's very nature, that research task demands we examine the historical decisions, processes, and contingencies that have led to the contemporary situation. A fundamental part of this research is about changes over time, therefore we place the heuristic in a dynamic historical context. In doing so we reject an a priori leader - follower metaphor for the roll-out of the Irish wind RES. This allows us to build the case for indigenous processes of innovation, regulation and system building, if and when supported by data, evidence and findings in the analysis. This has already been backed up in areas introduced in this chapters such as power systems research in Ireland and the innovation and outward diffusion of new financial models. In what sense then are the builders of a wind RES in Ireland following a template laid out by others and in what sense does there exist the autonomy to create a path of their own? What role does sequencing play in this? Certainly this brief exploration of the contemporary wind RES, and historic decisions and processes indicates that there is more to the story than the acquisition of turnkey kit, imposition of a consumer levy and the granting of subsidies.

Wrapping up

In this chapter we discussed aspects of the Irish wind RES appropriate to the case, introducing the relevant technologies, actors and institutions. We found that wind power has become a significant component of the national electricity generation mix despite a number of barriers: technologies being constrained by an island grid infrastructure, no significant indigenous manufacturing capabilities, and a relatively small research and development sector. While turnkey technology was readily available for import, challenges of integration were highly location specific. Yet rate of installation of plant has been been remarkable in international terms given these technological challenges. In assessing the actors in the sector, we found that characteristics and composition of actors is dependent on a complex set of historical and contemporary factors, within and outside of the country. With regard to industry, firms and finance, we found that wind investment is now classed as 'reliable' or bankable investment. While the manufacturers and suppliers of turnkey technologies have historically come from overseas, increasingly the firms at the generation end of the supply chain are also transnational companies. Furthermore, Ireland is an exporter of some wind business innovations Alongside the diffusion of turnkey plant, significant regulatory change has taken place and new markets have been constructed within Ireland. Finally, evidence in the literature has suggested a new status quo of electricity suppliers has emerged, in which the feed-in tariff and other support payments have been, according to some scholars, appropriated as rents. This evidence from the literature indicates a relatively narrow or focussed policy agenda, influenced by system operators and suppliers resistant to deviate from (relatively recently) established sectoral operating norms.

This characterisation of the historic and contemporary Irish wind RES has clarified and focussed the research context and is used to inform research framework decisions. The relevance of location, the need for a research framework that aids our inquiry into dynamic processes should now be clear. In Chapter 3 we address the issues of location by introducing a number of conceptual building blocks derived from human geography. In Chapter 4 we discuss a process theory approach to explaining technical change, well suited to unpacking the institutional and actor strategy issues we have discussed here. Chapter 5 organises an extended case narrative using a periodisation scheme. Finally, in Chapter 8 the thesis will account for the *build-up* and *touchdown* of the Irish wind RES, and use the heuristic as a container for locationally explicit explanations. With this we address the pace and scale of technological roll-out as well as levels of support attained by the industry, why innovation happened in Ireland and the balance between indigenous and overseas development.

Chapter 3

Relevant research literature

This chapter contains a review of the literature, which is employed to construct an analytical framework with which to address the research questions. The focus of this review is on identifying relevant prior published research in order to evaluate and synthesise existing theory for innovation systems, and identify the concepts required to explain wind developments in Ireland. This is achieved through the application of existing theory to new contexts and by bridge building between concepts (Randolph, 2009). I build on the research context identified in the previous chapter, adapting theory and findings to the purpose of studying wind energy innovation in Ireland.

The chapter shows that the research questions can be addressed using a technological innovation systems approach. In Section 3.1 I introduce concepts with which to consider renewable energy technologies and means of production. Concepts of technological change are examined to explore the process of 'rolling-out' of these technologies across space and time, including diffusion, technology transfer and internationalisation. In section 3.2 I introduce the core framework, scheme of analysis and state why it is appropriate for this thesis. As noted previously, systems approaches, such as TIS, often privilege systems in a situated space and, with some limited exceptions, do not consider plural spaces[1]. Having

[1] Some attention in the TIS approach is given to the localised nature of knowledge which becomes a systemic impediment that needs to be overcome in order to improve on system performance. At least two further ideas come from this perspective. First, constraint — some impediments arising from the localisation of knowledge will remain regardless of efforts to mitigate these impediments. The second possibility is a bit more alarming — efficient mitigation of these constraints removes constraints to the expansion of a system and creates the possibility of a totalising and all-consuming innovation system which subordinates all activities in the technological area. The first rather than the second perspective is more

introduced a systems perspective, I mobilise geographic perspectives for applying it to Ireland; the formation of a complex innovation system that is not new to the world, but that is new to a given country or location. I then discuss the reasons for analytically bounding the system by a focus on a specific location, and introduce the structural analysis. In Section 3.3 I introduce each system function in turn, summarising the theoretic basis for its inclusion, its applicability to the case and explain the indicators used to identify evidence of the function in the case data. Finally, in Section 3.4 I explain how the structural and functional analyses are brought together to account for system level change. I then present the specific theoretic framework and drawing on the literature reviews, offer a number of hypotheses for the formation of the wind RES in Ireland.

3.1 Explaining technical change

3.1.1 Renewable energy technologies and systems

The threat of climate change, concerns about the security of supply of fossils fuels, and the increased perception of risk following disasters such as Fukushima have contributed to increased attention to radical innovation in energy systems (Truffer, Markard, et al., 2013). Over recent decades, considerable public and government effort and funding have been invested in developing, implementing and diffusing renewable energy technologies (RETs). However, experiences in many countries show that this is often a slow and uncertain process (Foxon and Pearson, 2008; Johnson and Jacobsson, 2000; Negro, Alkemade, et al., 2011; Raven, 2004). Despite this, as discussed in the previous chapter, in a number of countries including Ireland, technologies that were considered niche at the turn of the millennium now play a significant role in the electricity supply mix. How are we to understand the uneven roll-out of RETs and how their use is adopted across space and time?

We start with the technology itself. We have discussed that wind turbines are comprised of many interactive parts that work together to convert kinetic wind energy to electromagnetic energy (Garud and Karnøe, 2003). The design and deployment of wind turbines requires knowledge of electronics, mechanics, hydraulics, advanced materials and aerodynamics. These technologies not generally based on new or dramatic inventions or recent scientific discoveries (Golding, 1955; Shepherd, 1990), rather they embody the steady accumulation of inputs from many actors. Furthermore, turbines and towers form

common in the literature.

only one part of a wider socio-technical assemblage of artefacts, infrastructures, knowledge, rules, regulations and actors that turn wind flows into electricity services for consumers (Rip and Kemp, 1998).

Let us consider the systemic nature of an onshore wind development, again returning to the example used in Chapter 2, the Tursillagh onshore wind farm in County Kerry, which went into production in November, 2000. The installation consists of 23 0.66MW Danish-built Vestas turbines with 47m rotors. The project was originally operated and developed by a Kerry-based firm, Saorgus Energy Ltd, in partnership with Wind Prospect, a United Kingdom based consultancy and development firm with global experience of wind farm installations[2]. Finance was acquired from private funding and a national government technology support scheme, the Alternative Energy Requirement III. Development of the wind farm required the construction of access roads for plant installation and ongoing maintenance work. Further project elements included accessible land with requisite wind conditions and planning permission, skilled workers, experienced project management, new grid infrastructure and access to the existing transmission grid and electricity market as well as the long-term terms of trade, such as regulated pricing mechanisms.We can understand these different rules, regulations, actors and resources as part of the socio-technical system (Geels, 2004), of which the Irish wind renewable electricity system (RES) is an example, and the unit of analysis of this thesis.

The field of sustainability transitions has emerged in recent years to analyse and explain the historical transformation processes of socio-technical systems such as energy supply and transportation (Bergh et al., 2011; Markard et al., 2012a). A number of approaches to explaining these transformation processes have been outlined by innovation scholars, typically taking one of two approaches (Markard and Truffer, 2008a). In the 'sustainability transitions' approach, change is accounted for through the substitution of the established technologies and a change of socio-technical structures. This is investigated the level of the overall electricity sector and society. Rooted in the historical analysis of technological change, the multi-level perspective addresses interactions between structure and agency across levels (niches, regimes, landscapes) of societies (Geels, 2005; Geels and Schot, 2007; Raven, Schot, et al., 2012). Strategic niche management has focussed on how

[2]'Location' is used in a positivistic sense to indicate a specific bounded geographic space where 'space' is also used in a positivistic or Newtonian sense, as an empty geographic container waiting to be filled with (economic) activity. A broad definition of 'place' is used in the thesis, after Devine Wright (2009, p. 427) who says place is the "physical aspects of a specific location as well as the variety of meanings and emotions associated with that location by individuals or groups."

emergent technologies survive and scale-up over time (Kemp et al., 1998; Raven and Geels, 2010; Smith, 2007) and transition management, a policy model which aims at structural interventions in socio-technical systems (Rotmans et al., 2001; Kern and Smith, 2008). An alternative approach focuses inquiry on the dynamics of a particular innovation or technological innovation system, such as fuel cell or wind generation technology (Carlsson and Stankiewicz, 1991). This perspective is concerned with identifying influential drivers and barriers of diffusion and production of a technology, typically one that has elements of novelty and that can be called emerging.

3.1.2 From socio-technical systems to innovation systems

The technological innovation system according to Carlsson and Stankiewicz (1991, p. 93) in their classic definition, is a

> "dynamic network of agents interacting in a specific economic/industrial area under a particular institutional infrastructure and involved in the generation, diffusion, and utilisation of technology".

An approach based on this definition would appear readily applicable to the research problem at hand; a dynamic set of actors in Ireland and internationally, working in a sector of the electricity industry, attempting to generate, diffuse and utilise wind technologies. The technological innovation system framework is amongst a number of approaches built upon 'innovation systems' theories which hold that relationships between actors such as governments, firms and researchers suppliers and customers or users, under institutional conditions influence how technologies are created and diffused. Innovation system analysts focus on the economic and innovation processes of firms and on the systemic contexts which act as barriers or drivers to their innovation activities or capabilities (Weber and Rohracher, 2012b). Freeman's book on the innovation[3] processes and characteristics of Japan (Freeman, 1987) is credited with being the first to introduce the concept of national systems of innovation (Lundvall, 1992; Nelson, 1994; Edquist, 1997). These are the systems of institutions used to create and store the knowledge and artefacts which make up

[3]Innovation consists of the practice of developing and implementing new ideas (Freeman and Soete, 1997) or according to Dosi "concerns the search for, and the discovery, experimentation, development, imitation, and adoption of new products, new production processes and new organizational set-ups" (Dosi et al., 1988, p. 222). As Freeman (1994, p. 479) suggested, "innovation should not be viewed as a linear process, whether led by market demand or by technology development, but as a complex interaction linking potential users with new developments in science and technology".

new technologies (Carlsson, 2006, p. 58). Other innovation systems approaches have focussed on a range of analytic and geographic levels including regional (Cooke et al., 2004) and sectoral (Malerba, 2002; Dolata, 2009). Rather than a priori bounding of the focal system at a specific geographic level, TIS analyses bound the analytic system with regard to a specific technology[4]. These perspectives break with neoclassical economic theories in several different ways including the the rejection of perfect information assumptions, the existence of non-market relationships between actors and the role of government policy which is not necessarily based upon a rational public choice framework. Economic theory, even when treating technology as endogenous, has little to say about the origins of innovation or the role of organisational change beyond the idea of market based selection of those arrangements that are most fit.

The technological innovation system is a meso-level framework. The framework takes account of both the technologies and the application contexts. We have seen from the case a number of situations in which the application context matters, such as the role of national resource endowments and capabilities of firm and research actors. This level of analytic aggregation is capable of examining technology generation and diffusion at the level of a specific territory where – relevant to this case – we have geographic overlap of technological infrastructure, market architecture and national and sub-national institutions. Contrary to a prospective analysis using the MLP, we are concerned with how imported generation technologies are integrated into the infrastructures and markets of the production location rather than with a niche selection environment or niche-regime interactions.

According to Markard and Truffer (2008a) the TIS framework has utility in this regard by allowing us deal more explicitly (e.g. vis a vis the MLP) with firm strategies and agency. Thus we avoid teleological tendencies in which advances in the technologies or system are taken to be self-evident in retrospect and countervailing forces that might deflect or stall the process in the Irish or other contexts are somewhat obscured (Shove and Walker, 2010). Findings from the case context discussion indicated an intriguing mix of strategies were relevant, and did not apparently easily align with fuel type or generation technology used, two possible niche-regime types. Indeed, a technological innovation system may be regarded as encompassing several niches and for these reasons the TIS framework is well suited to the analysis of nationally specific innovation, diffusion and production processes and with respect to this thesis offers a number of advantages over MLP or strategic niche

[4]In practise, we will see that an analytic agnosticism of national borders, in practise, many, if not most, analysts have carried out case studies of particular technologies in a certain country, such as the fuel cell innovation systems of Austria.

management approaches.

3.1.3 The geography of innovation systems

The technological innovation systems framework was initially developed to conceptualise systems ex ante without considering territorial borders, instead focusing on knowledge or products which existed in a globalised innovation system (Carlsson, Jacobsson, et al., 2002). One motive for this was to address critiques that the NSI and regional innovation systems literature paid insufficient attention to transnational processes of knowledge or technology creation[5] (Bergek, Hekkert, et al., 2014; Carlsson and Stankiewicz, 1991; Hekkert, Suurs, et al., 2007). In practice however, many empirical cases have implicitly bounded their focal system at a national scale (Carlsson, 2006; Coenen, Benneworth, et al., 2012; Truffer and Coenen, 2012). Location has often been treated as a passive background variable providing little causal explanation or theoretical weight (Coenen and Truffer, 2012). The implicit focus on the national level may be justified in some of these cases as the focal technologies were predominantly produced and diffused in a national context or were fundamentally influenced by policy support applying within national jurisdictions. Often these studies were oriented towards national policy audiences. However, this is not an appropriate approach in the case of the Irish wind RES, where an explicit focus on transnational flows is required.

Recent contributions have sought to add geographic explanatory power to the sustainability transitions literature through dialogue with the field of human geography, and in particular economic geography (Bulkeley et al., 2010; Coenen and Truffer, 2012; Cooke, 2013; Hodson and Marvin, 2009; Truffer, Voß, et al., 2008). A subset of this work has specifically addressed the geography of technological innovation systems. Two broad classifications of categories can be made; first the consideration of the territoriality of innovation, and second, the geography of inter-organisational linkages in order to understand socio-economic and environmental relations (Hansen and Coenen, 2014). An example of the former approach to analysing geographic aspects of technological innovation systems has been to strengthen the analysis of system context within the framework itself. Bergek, Hekkert, et al. (2014) suggest that analysis of function strength reflects structural components which are external as well as internal to a system. Hence the analysis of functions they

[5] The early National Systems of Innovation work was itself a response to earlier models of technical change such as those proposed by Arrow (1962), which according to proponents of NSI, failed to account for explanations of why the global diffusion of technology was neither automatic nor easy (Bell and Pavitt, 1993).

argue "involves understanding not only the incentives for entry at the industry and sector level, but also the structural features of (for example) capital markets and the university sector at the national systems of innovation level" (p. 5). These findings support the inclusion of locational characteristics in the structural and functional indicators utilised.

With regard to inter-organisational linkages, analysts have conceptualised the formation and expansion of relations and processes between systems and across geographic levels[6]. Binz, Truffer, Li, et al. (2012); Binz, Truffer, and Coenen (2014) show how regionally bounded systems in China are connected by knowledge networks of researchers and universities to components of global systems. In examining the Dutch national offshore wind sector, Wieczorek et al. (2013) propose a set of nested innovation system structures in which the national system is heavily influenced by higher-order policies associated with a European system and weaknesses in Dutch market formation activities were in part offset by transnational linkages with UK actors. Institutional influence has been shown to act not only at national levels, but increasingly at international levels through global trade tariffs and environmental regulations (Gosens et al., 2015). These studies share a common theoretic perspective that emergent nationally specific innovation systems are often dependent on distributed system formation processes (see also Fornahl et al. (2012); Lovio and Kivimaa (2012)).

Before beginning detailed discussion of how the TIS framework might account for the emergence and growth of the wind RES in Ireland, I consider a number of theoretical approaches that have specifically analysed technical change of renewable energy technologies or systems. These can be broadly categorised as diffusion, internationalisation, technology transfer and catch-up. Each of these brief overviews could be extended, however, the discussion here is sufficient to convey the sense that none is suitable on its own to address the aim of this thesis, to account for the rapid emergence of a RES in a fast follower context.

[6] In the literature the terms "scales" and "levels" are used interchangeably to refer to spatial containers such as region, nation and the EU. For clarity, I use the word "level". It follows that where some authors such as Binz et. al. may use the term multi-scale to refer to processes which cut across levels, I translate to multi-level. Scale I reserve for discussions on technology, such as scaling-up wind farms. For the avoidance of doubt, multi-level does not refer to levels of structuration, as per the "multi-level perspective", which of course is concerned with changes to structure over time and is somewhat geographically naive despite its spatially influenced terminology.

3.1.4 Diffusion of renewable energy technologies

Diffusion is the process by which an innovation is communicated through certain channels over time among members of a social system (Rogers, 1983, p. 5). It is only through diffusion that inventive and innovative potentials are translated into actual changes in social practice, artefacts and infrastructures. Diffusion phenomena are at the heart of all changes in society and its material structures (Grübler, 1998). Diffusion, or the rate of diffusion, of renewable energy technologies (RETs) is often tracked in terms of aggregate deployment of the given technology, or cumulative technology output, over time. For example, the IEA produce annual reports tracking the global diffusion of wind generating technologies, e.g. IEA (2013).

In a review of the literature on the diffusion energy technologies, Wilson (2012) discusses two approaches to explaining the diffusion of RETs; learning and up-scaling. Addressing technological change in the energy system at the industry level, growth is characterised by falling units costs associated with increasing experience, a relationship described by learning phenomena. Learning, originally associated with doing (Arrow, 1962), is a descriptive label for processes of knowledge generation, application and exchange. As firms acquire development and production experience, the cost per unit of a given technology decreases. However, learning is not merely an outcome of increasing production, but rather is contingent a range of innovation processes and efforts (Grübler, 2010). If these efforts and processes have influence, then the predictive content of learning based only on cumulative production experience will be limited or misleading. Up-scaling is a second prominent characteristic of technological diffusion in the energy sector. Many electricity generating technologies have increased in size and energy conversion capacity over the past decades (Smil, 2008). While the number of generators may increase or decrease depending on characteristics of the energy fuel and generation technology (e.g. we can compare the characteristics of highly centralised nuclear generation with those of wind), typically the size, or scale of the generating technology increases per unit cost. By capturing available scale economies, up-scaling can lead to reductions in average unit costs and may encourage substitution of incumbent technologies. The upscaling perspective adds an additional dimension to diffusion analysis that requires explanations of the influences affecting scaling that may or may not be consistent with the conception of diffusion as a process of successive adoption or theories concerning what determines adoption.

Recent analysis by Duffy and Cleary (2015) show up-scaling effects of wind generation technologies in Ireland. The upscaling of turbine capacity rating is shown in Figure 3.1.

The authors show evidence of similar upward trend with regard to newly installed turbine hub height yet a downward trend with regard to average wind speed attained at these hub heights[7]. While this is fascinating research and contributes to explaining cost and revenue related questions such as historic expected rates of return on investment, it illustrates a problem with regard to how diffusion can account for the research questions posed in this thesis. Our concern is not in the diffusion of homogenous (or nearly homogenous) artefacts such a mobile phones or even wind generation plant. Rather, we seek to explain the rapid increase in installed wind capacity per capita in Ireland which, as we discussed in the previous chapter, involved a complex set of technologies, innovations and institutional change. While some disaggregation of individual learning and scaling may be possible, it would be difficult to distinguish what portion of this diffusion is attributable to scale effects and what should be attributed to learning and, perhaps most important, how each of these effects have contributed to overcoming integration problems. In short, adopting a diffusion approach would reduce the complexity of the learning process which is connected with the 'building-up' of a capacity or capability to achieve growth in the wind RES. Of course, one can index cumulative production or time, but in so doing the advance of the technology is taken to be self-evident in retrospect and the forces that might deflect or stall the process in the Irish or in other context will be obscured.

Innovation studies on the other hand offer an alternative approach to identifying drivers and barriers of diffusion, from an institutional and systemic perspective (Edquist, 1997; Jacobsson and Lauber, 2006). Rather than disaggregating scale and learning effects, we examine the set of distinct institutions and system components and processes which cumulatively and discretely contribute to the development and diffusion of new technologies. These institutions and processes in turn provide, and are shaped by, the institutional framework within which governments and industries form and implement policies to influence the innovation process.

[7]This is an interesting counter intuitive finding. Ceteris paribus, we would expect greater windspeed at higher hub positions. Duffy and Cleary interpreted the finding as an indication that more wind farms are being sited at locations with poorer wind resources, either at lower altitudes or more easterly locations. Intriguingly, average capacity factors for new wind farms installed in the same period are increasing year on year. Given capacity factors are a function of both technological variables (e.g. rotor diameter and hub height) and wind conditions, Duffy and Cleary suggest that the larger wind turbines with increased rotor diameters and hub heights are successful in achieving a viable energy yield from newer locations and that technological advances are staying ahead of the supply of viable installation locations.

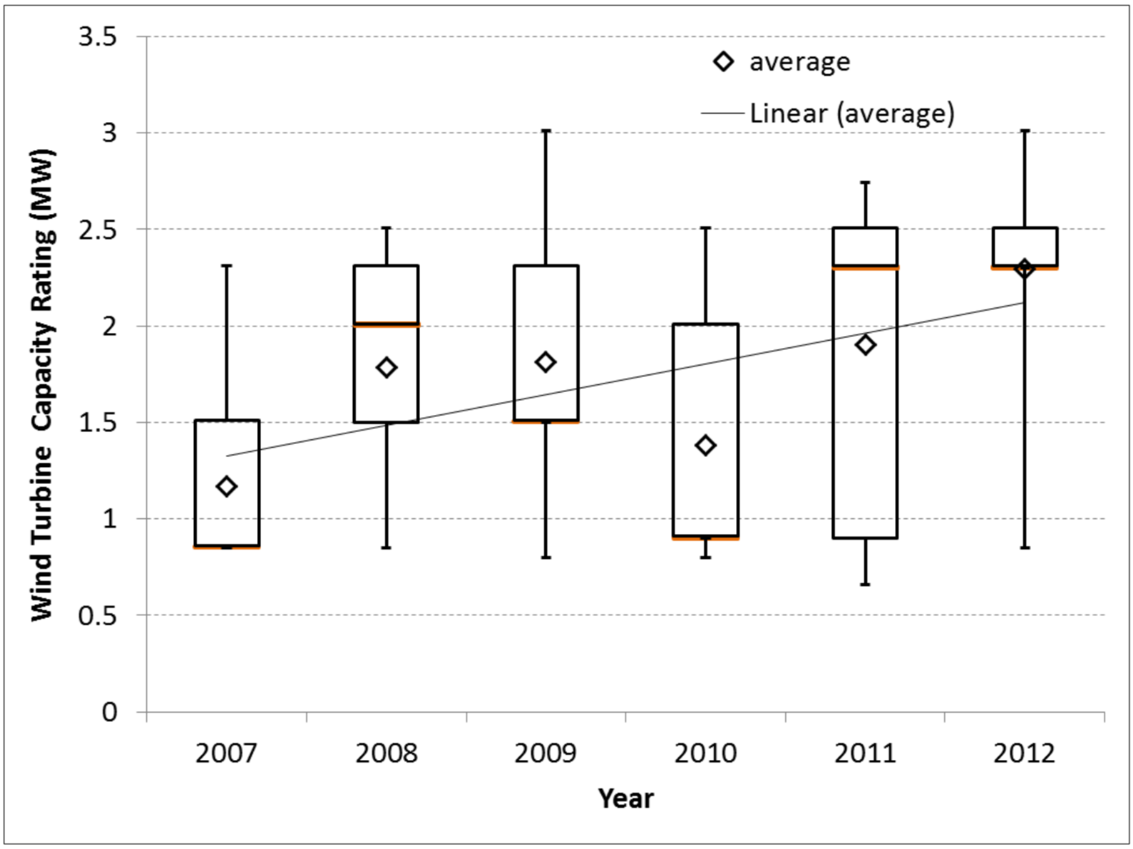


Figure 3.1. Wind turbine nameplate capacity trends in Ireland, 2007 to 2012. Source Duffy and Cleary (2015, p. 81). A box and whiskers format is used to represent the capacity of installed turbines in a given year including the median (red horizontal line), average (diamond), 25th to 75th percentile (box), and minimum and maximum (whiskers).

3.1.5 Technology transfer and internationalisation

Technology transfer and internationalisation approaches differ from diffusion in the level of analysis and the type of questions posed and analytic perspective taken by analysts. These fields share a number of foundational concepts inherited from the national systems of innovation literature. The focus in these domains is on the accumulation of technological capabilities by firms in recipient countries. Technology transfer analysts are typically concerned with recipient firms in developing country contexts (Reddy and Zhao, 1990; Bell and Pavitt, 1993) while with internationalisation studies the focus is on the degree to which transnational firms 'internationalise' research and development activities (Carlsson, 2006).

The process of technology transfer occurs between technology suppliers and technology recipients, with the role and modes of technology transfer in this process subject to many studies (Bell and Pavitt, 1993; Correa, 1994; Radosevic, 1999). A principal focus of the body of literature relates to the relationship between technological capabilities and industrialisation (Lall, 1992; Cimoli et al., 2009) and how wider economic industrialisation and development occurs through the accumulation of technological capabilities (see Bell 1990; Cimoli et al. 2009, in Byrne, 2009) and the absorptive capacity of firms (Cohen and Levinthal, 1990). Technological catch-up studies discuss the narrowing (or widening) of gaps between the technological capabilities of firms and economies from one country to another (Bell and Figueiredo, 2012). According to Fagerberg and Godinho (2005) catch-up relates to "the ability of a single country to narrow the gap in productivity and income vis-à-vis a leader country" (Majidpour, 2011, p. 514). The analytic focus is on the flows of technology between a recipient catch-up region or country and a lead industrial country. The ability of the recipient country to generate indigenous innovation is an important measure of success.

Location and proximity are important concepts in technology transfer and internationalisation approaches; technological knowledge is inherently difficult to move across space due to the importance of tacit knowledge built up in cumulative and path dependent ways (Lema and Lema, 2012; Madsen et al., 2008). Perhaps most usefully with regards to this thesis, the literature underlines the accessibility of foreign technology and international technology flows from early adoptors to followers, moving beyond recipient accumulation. But while useful in the manner discussed, these studies do not in general address the nature and the details of dynamics of innovation processes (Majidpour, 2011). Rather than following flows of knowledge, whether they be from the prospective of the recipient country or innovating firm, this thesis aims to examine amongst other things, the processes by which actors in given locations go about drawing down these flows and turning them into material and institutionalised activities, such converting wind into electricity and moving that to users across grids. For example, in the case of wind technology manufacture, we are less concerned about the internationalisation of R&D in the global turbine industry, and more concerned with how actors in Ireland access finance and knowledge sources in order to bring this plant to Ireland. Because firms are key actors in technology development, diffusion and transfer, the micro-level focus accorded by technology transfer and internationalisation is useful, particularly as we examine processes of knowledge creation and diffusion. However this understanding is better situated in a locational and sectoral context, including policies and other institutions (Lema and Lema, 2012). Therefore questions of what, how, when and why actors get access to these flows are better addressed, in this instance, within a systems perspective.

3.2 Technological innovation systems

3.2.1 The TIS framework

Having made the case for examining the development of RETs in Ireland from the technological innovation system (TIS) perspective, it is now useful to consider how the elements of this perspective can be assembled into a framework (the subject of this chapter) that can be implemented as a research design (the subject of the next chapter, Chapter 4). The development of a renewable energy innovation system is influenced by competition with both incumbent energy technologies and other emerging systems (Bergek, Hekkert, et al., 2014). Jacobsson and Johnson (2000) suggest there are a multitude of forces which favour an incumbent energy system, which are likely to reinforce one another in a process of cumulative causation (p. 638). (Carlsson, 1997, p. 303) accounts for these forces as the result of strong inertia in a number of dimension as

> "firms, institutions and networks become 'locked in' to 'old' technologies, thus, the cumulativeness and path dependence of innovation lead to risks of lock-in into technological, institutional and networking cul-de- sacs."

The TIS framework explains dynamic system change through analysis of these structural components (the actors, networks and institutions), both endogenous and exogenous to the focal system. The utility of the framework with regards this thesis is in specifying historic, current or potential contributions of actors such as firms and intermediaries, to evolving innovation system dynamics (Markard and Truffer, 2008a).

The unit of analysis in the framework is the focal system, i.e. the wind-based renewable electricity system in Ireland – the Irish wind RES. Innovation with regard to the system is understood as a set of complex evolving processes involving actors, often acting in networks, influenced by institutional contexts. Innovation and diffusion processes are both an individual (firm) and collective act (Jacobsson and Johnson, 2000; Saxenian, 1994). Because of this, our search for explanations of technology choice should look not only at individual firms, but also at actors and processes distributed throughout the system and common identities and cultures. We have encountered examples of these actors and other system components in our discussion in the previous chapter (e.g. actors include wind farm developers and manufacturers, relevant institutions are technology support mechanisms and networks include industry associations such as the Irish Wind Energy Association).

We can explain the emergence and evolution of the wind RES in Ireland by analysing interactions within and between these actors and other system components. The analysis of these interactions begins with the structure of the innovation system, the actors, actor networks, and institutions. As a new technology first emerges many of these structural components are not yet in place. These elements evolve and agglomerate in a formative phase which involves the formation of networks, alignment of actors and system institutions as well as the entry of firms and other actors into the system (Bergek, Jacobsson, and Sandén, 2008). These processes of system formation are cumulative, contain many small changes and virtuous cycles, and may last for decades. The dynamic interactions between structural components may be delineated by focussing on specific system functions.

Assessment of micro-meso processes, or functions, in the industrialisation of new systems is a core analytic approach in the field (Bergek, Jacobsson, Carlsson, and Lindmarki, 2005; Johnson and Jacobsson, 2000). Functions are influenced through the system level activity[8] of actors, and by the structural components of the system. For example, the *resource mobilisation* function identifies the process of strengthening actors' capabilities to access financial or human resources. In the Irish case, the resource mobilisation function was 'strengthened' as banks in Ireland became increasingly confident in the ability of wind farm developers to meet pay back criteria and therefore made conditions of lending easier to meet. Functions can be seen as emergent properties of the system rather than merely aggregates of system level activity. A list of generic functions has been developed by researchers located primarily in two schools, Chalmers University of Technology and Utrecht University (Johnson and Jacobsson, 2000; Bergek, 2002; Hekkert, Suurs, et al., 2007; Bergek, Jacobsson, Carlsson, Lindmark, et al., 2008). Originally Johnson proposed six functions which was built upon by Hekkert, Suurs, et al. (2007) who after empirical testing suggested the seven employed in this thesis (see 3.1). Bergek, Jacobsson, Carlsson, Lindmark, et al. (2008) also list seven system functions which though slightly different in naming, overlap significantly[9]. The functional approach has been developed into a tool to assess barriers and inducements or drivers of the system as it evolves. It allows us to scan and identify 'bottlenecks' that hinder the progression of an emergent Irish wind industry towards a fully functioning innovation system (Johnson and Jacobsson, 2000; Smits and Kuhlmann, 2002; Bergek, Jacobsson, Carlsson, Lindmark, et al., 2008; Jacobsson and

[8] In other words, the sum of all system level activity (Markard and Truffer, 2008a)

[9] The Chalmers functions aggregate knowledge development and diffusion and add a "creation of positive externalities" function. Given the analytic focus of this thesis on processes of diffusion, I utilise the Utrecht set in the analysis.

Bergek, 2011). By mapping the functions, we can identify how systems co-evolved over time and why system components were influenced by endogenous and exogenous elements and contexts. Explanation then rests in accounting for why these functions developed in the ways that they did and the ways in which development bottlenecks were overcome, or not.

Table 3.1 Functions of the TIS, adapted from Bergek, Hekkert, et al. (2014)

Function...	**...is the process of**
Knowledge creation	technological learning by actors in the system and the breadth and depth of the knowledge base
Knowledge diffusion	the distribution of the knowledge base and how that knowledge is utilised in the system
Influence on the direction of the search	the incentives and/or pressures for actors to enter the system. These may come in the form of visions, expectations of growth potential, regulation, articulation of demand from leading customers, crises in current business, etc.
Entrepreneurial activity	the performance by actors of commercial activities or experimental projects around a new technology or in a new location.
Market formation	the factors driving the formation of new markets or new market segments. Factors include the articulation of demand from customers, institutional change, changes in price/performance.
Legitimation	the acceptance and compliance with relevant institutions. Legitimacy is not given but is formed through conscious actions by organisations and individuals
Resource mobilisation	the extent to which actors within the system are able to mobilize human and financial capital as well as complementary assets such as network infrastructure.

3.2.2 The scheme of analysis

Having introduced the structural and functional aspects of the framework, we now consider the general scheme of analysis. A basic scheme for this analysis has been documented in the literature and is illustrated in figure 3.2 (Bergek, Jacobsson, Carlsson, Lindmark, et al., 2008; Hekkert, Suurs, et al., 2007). This approach has been developed into a scheme of analysis aimed at goal-orientated[10] policy advice (Hekkert, Negro, et al., 2011). A TIS policy analysis aims to suggest innovation process improvements rather than specifying end-point goals such as, in the case of wind power, annual cumulative installed capacity targets or total investment figures. Indeed, according to Hekkert et al., "the whole purpose of using the concept of functions of innovation systems is to understand processes of technological change and innovation" (Hekkert, Suurs, et al., 2007, p. 427). This is particularly useful when a socio-technical endpoint is uncertain or cannot be known, as in cases of the roll-out of emergent renewable energy technologies. In these situations, it is often the case that societal pressures call for the utilisation of technologies before these have matured into stable socio-technical systems. It is somewhat inevitable, given the explicit orientation of many TIS analyses towards pragmatic policy advice, that the discussion of the framework begins to address some issues of research design. The framework aims to produce conclusions regarding innovation system development and performance and it cannot be made apparent how this will happen without providing some information about implementation. In providing this information (in this subsection, in Subsection 3.2.4, 3.2.5 and in Section 3.3) I am raising issues that will be dealt with in greater detail in Chapter 4 on research design, where I will justify how the specific project design involves a robust plan for implementing the framework for the case.

This assessment of 'system needs' is useful in historical analysis, whereby we can trace systemic development over time. Again, rather than specific system end-points, we analyse how barriers to system development were overcome (or not) and how innovation processes were accelerated (again, or not). Two sets of tasks are essential to this this analysis. First, given the unit of analysis is the RES, to account for change in wind energy development, the analyst must examine influential system components, which may be endogenous or exogenous to the system. Structural and contextual perspectives are gained by assessing the influence and alignments of the system's actors, networks and institutions as well as exogenous factors at levels such as national or sectoral innovation systems (Bergek, Jacobsson, and Sandén, 2008).

The second major task is the mapping of the 'strength' of individual functions followed by a system level analysis of how the system functions interact, with the purpose of using this to explain the evolving state of wind energy development and deployment and its characteristics (i.e. The Irish wind energy system can be explained by the analysis functions and their interaction). An assessment of the strength of each function is achieved

[10]The goal of the policy advice being the successful implementation of the system. This should not be confused with any assumed goal-orientation within the system itself (Jacobsson and Jacobsson, 2014).

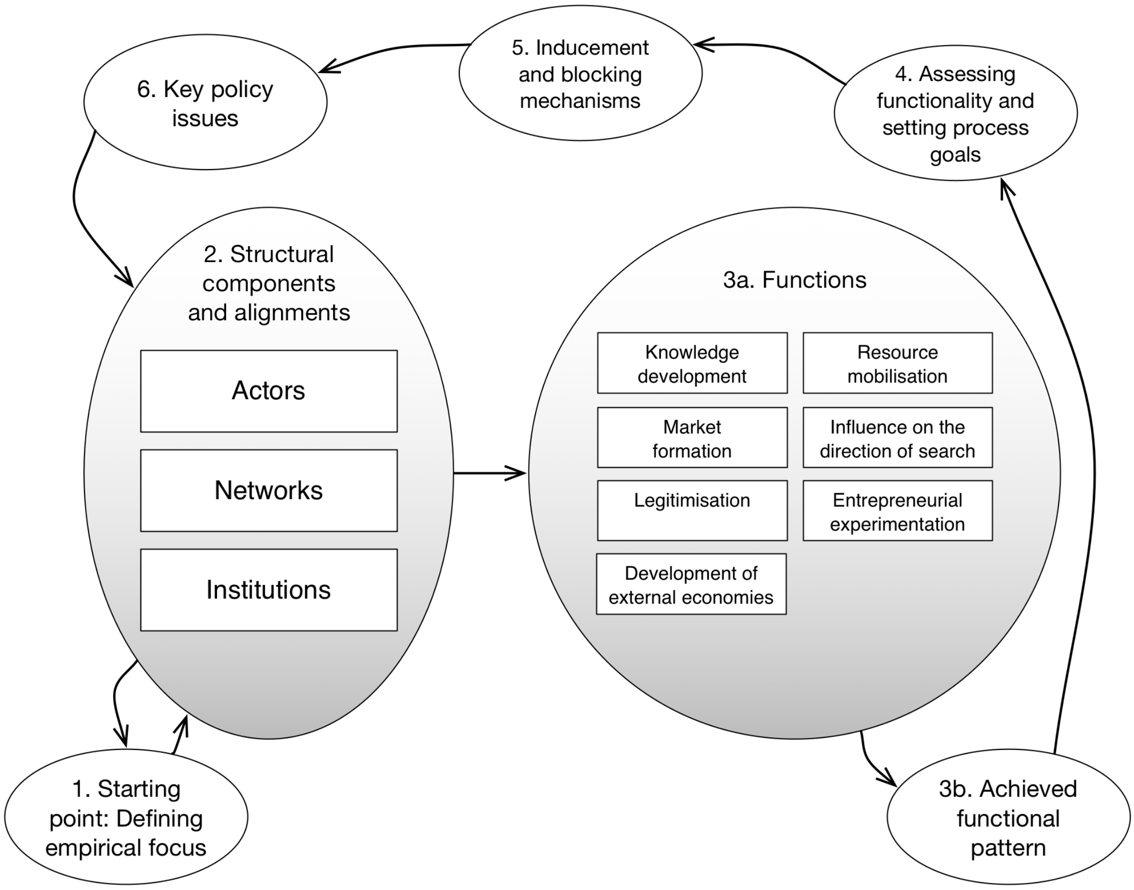


Figure 3.2. The basic scheme of analysis. Based on Bergek, Jacobsson, Carlsson, Lindmark, et al. (2008)

by explicitly relating actor level characteristics such as innovation strategies and resource endowments to system level dynamics such as actor configurations and overall system processes. System level patterns of functions may be mapped for evolving phases of development in a periodisation scheme. These patterns may then be compared across time and with TIS in other locations or other technologies. The analysis takes place over the course of six steps:

1. First the system is defined by the analyst, bounding the technology and often geography of the system.

2. The structural components and alignments between actor goals and institutions are assessed.

3. The functions of the system are mapped, and system level functional patterns are delineated

4. Consideration is made of the evolution of functional patterns.

5. System level inducement and blocking mechanisms are identified

6. Where policy recommendations are required, guidance for matching process goals with enhancing inducement mechanisms and overcoming blocking mechanisms are made.

For each of these steps, the underlying theory and suitability of application to the case is considered over the course of the remainder of this chapter[11].

3.2.3 Structure analysis: actors and networks

Actors and actor groups within the focal system are identified. Actors include but are not limited to firms, researchers and research institutes, policy makers, lobbyists, engineers, financiers, and civil society organisations. Collaboration amongst actors is common and firms often 'run in packs' (Van de Ven, 1993), forming industry associations, interest groups and networks with collective strategic goals such as gaining influence over institutions or other actors. The creation of these organisations often leads to non-commercial institutions which in turn may influence expectations and confidence in new technologies (or technologies in new places) and may facilitate the emergence of societal norms and customs (Jacobsson, Sandén, et al., 2004). The creation of such internal institutions which are internal to the focal system is a key process in the formation of a technological innovation system (Markard and Truffer, 2008a).

Clarity here is required; according to Jacobsson and Jacobsson (2014, p. 5), "in an abstract sense, such a system has a goal" e.g. the generation and diffusion of a technology. Thus are we to consider the technological innovation system, sui generis, a thing to be explained, or rather as discussed so far, an analytic framework? To be clear, in this thesis the TIS is used specifically as an analytic construct to explain a process of historical development. In other words, the task at hand is not to explain *the* TIS, but to use the TIS framework to explain the development of the wind-based renewable electricity system in Ireland. However, only in the broadest sense can this system be said to have a goal. Actors in the system then do not necessarily share specific goals and we expect that whilst agency is distributed through the system, this distribution will be uneven (a point Jacobsson and Jacobsson highlight, 2014). Thus in the analysis we pay particular attention to 'prime movers' or 'system builders' (Hughes, 1983; Jacobsson, Sandén, et al., 2004). These are firms or other actors that are technically, financially and/or politically powerful, so that they can strongly influence the development and diffusion process, often

[11] The 'consideration' and 'identification' processes by which these tasks are carried out are elaborated in Section 4.3.

fulfilling a number of tasks in the system.

Networks are the results of relations between actors. Networks facilitate the exchange of information and knowledge. In an innovation system, this information according to (Gosens et al., 2015, p. 383) is "not limited to purely technical aspects, but includes exchanges between actors from industry, government, advocacy coalitions etc., amongst others, on the current phase of development of the technology and the best way forward". In a spectrum from informal links to dense configurations, different types of actor networks have been examined and characterised (Musiolik and Markard, 2011). Learning networks, for example, link suppliers and users, universities, industry, etc., and constitute important modes for the sharing and transfer of knowledge (Carlsson and Stankiewicz, 1991; Weber, 2002). Political networks consist of actors who share certain norms, beliefs and share an agenda to influence the institutional architecture of the system (Bergek, Jacobsson, and Sandén, 2008; Weber, 2002).

An approximate distinction can be made between formal and informal networks. Formal networks have been shown to create system resources such as user-supplier linkages that are crucial for maturation and diffusion of new technologies (Musiolik and Markard, 2011). Often formal networks adopt the political agendas of their constituent actors, influencing actors and the institutional settings (Bergek, Jacobsson, and Sandén, 2008; Sabatier, 1998; Suchman, 1995). Formal networks such as industry associations are easily identified. Members of the network are identified through interviews, membership lists, and conference proceedings. The innovation systems perspective stresses also the role of informal networks (Musiolik and Markard, 2011). In this study, the linking of actors and the exchange of knowledge and information rather than the execution of specific tasks at the system level are the focus. While these linkages and exchanges are challenging to identify, bibliographic research identifying public-private research partnerships as well as interview questions are a means to uncover them. For example in the Irish case we see evidence in the bibliographic data of informal networks between the system operators and university research departments[12]. We might expect that an innovation network would form in a location before the necessary components are in place for a more complete innovation system, as such network activity may also be a precursor to learning and evidence of this network activity may indicate the early stages of an emergent innovation system (Hekkert, Suurs, et al., 2007).

Actors and networks are influenced by geographic factors. Geographic proximity often

[12]This evidence is discussed in section 4.2. and in Chapter 5.

aids the formation and rapid growth of networks, all the more so within a small island country. Furthermore, relational proximity (e.g. closeness attained through professional ties) also influences network formation. For example, we would expect workers in the legal or accountancy professions to more readily network with other actors within the professions than outside them. Knowledge of national geographies and cultures gives nationally established actors certain advantages over actors new to the country or specific location. Thus in some cases we expect indigenous actors to have certain structural advantages over overseas actors through, for example, knowledge of the political institutions and the ability to lobby them. In other cases, we might expect geographic factors to explain differences in the intensity of motivation of actors. Furthermore, some overseas actors bring with them knowledge gained from learning in lead system context. For example, in Ireland we might expect Danish or German engineering firms to have greater relevant tacit knowledge compared with Irish firms during emergent stages of the wind RES. Transnational networks can help actors in national systems overcome problems of geographic distance the diffusion of knowledge. Associations such as the European Wind Energy Association, the Global Wind Energy Association, or non-governmental organisations such as Greenpeace can enhance processes of transnational diffusion of knowledge of technological possibilities and ways to legitimise them (Gosens et al., 2015, p. 383). They may do so by exchanging insights and building advocacy based on experiences developed elsewhere. This can include information on suitable targets, best (policy) practices and regulatory design. For example, Binz, Truffer, and Coenen (2014) suggest that the increase in technological capabilities in the field of water membrane bioreactors in China was accelerated by Chinese academics accessing global knowledge networks during a period of rapidly growing international cooperation. It follows that gaining access to international networks becomes an important step towards the establishment of a well-functioning system.

A number of recent studies have shown how aspects of network formation can influence the emergent system. Vasseur et al. (2013, p. 208) show:

> "in the Japanese PV TIS a great variety of actors are present that form strong networks. Both learning networks, which build up and exchange knowledge, and political networks that formulate uniform messages to the government and put PV on the political agenda play an important role in the Japanese PV TIS."

On the other hand in a comparative study of a Dutch innovation system the authors found:

> "national and international learning networks are present but the build-up

> of strong political networks is missing, and because of the lack of unanimity between the actors, lobbying activities have little impact on the political agenda."

These findings suggest that the composition of actors in the system, as well as the nature of the networks they form influences system development. Binz, Truffer, and Coenen (2014) argue that the location of the system's underlying actor networks can shift considerably and that innovation processes in national (sub-)systems might be more strongly interconnected and influenced by a 'global TIS' level than could be assumed from existing studies. Furthermore, Binz et al, claim:

> "knowledge created in networks spanning transnational companies and their research partners (as in the nursing phase of membrane bioreactor technology) is clearly of a different quality than knowledge created in small world networks connecting different trans-disciplinary subsystems in a multi-scalar setup (as in the consolidation phase of MBR technology)."

In other words, the location where knowledge is created may influence characteristics of the subsequent innovation system. This suggests that aggregation and geographic location of actors and networks underpins, and is in certain circumstances a crucial factor for the institutional structural analysis and the functional analysis in the study.

3.2.4 Structure analysis: institutions and alignment

The institutions of an innovation system are the 'rules of the game', the cultures, norms, regulations and routines associated with a technology (North, 1990). Institutions play a crucial role the creation and diffusion of knowledge through networks by codifying, stabilising and transmitting tacit knowledge (Truffer, 2008). Institutions shape actor and firm behaviours by influencing opportunity structures, (Carlsson, 1994), influencing resource access and thus influencing profitability and research and development behaviour (Breznitz, 2007). Incentives may be institutionally set to influence whether and how actors perform certain activities and avoid others (Markard and Truffer, 2008b). Thus in the analysis, we consider these rules as 'signposts' which guide system building actors towards possible technological futures. These signposts, directing actors towards certain technological outcomes, can aid, or hinder, the diffusion processes by de-risking firm activities or enhancing certainty of future market conditions, important for investors or research funders.

Institutional alignment is at the heart of large-scale transformation processes (Freeman and Louçã, 2001) and includes alterations in norms, beliefs and regulations (Fuenfschilling and Truffer, 2013). Institutional conditions may or may not be 'aligned' to facilitate the realisation of the goals of system actors (Negro et al., 2008). For example, technology support payments in the form of feed-in tariffs may be considered well-aligned to the needs of wind farm operators as they facilitate a competitive advantage over non-wind electricity generators. Innovation system functions strengthen as a result of alignment between institutions and the aim or goals of system actors. The shaping of institutions and institutional alignment is often a strategic act by firms competing not only in a market, but also for political or regulatory influence (Jacobsson and Lauber, 2006; Van de Ven, 1993). This process involves actors at multiple geographic levels across multiple technological domains. For example, the actors in a wind innovation system may lobby for regulatory advantage over a competing generation technology, such as fossil fuels. In the analytic framework, we begin by delineating this competition along jurisdictional lines, following indigenous actors vying against overseas competitors. The evidence of these institutional contexts can be found in records of policy process, lobbying of and by policy actors, and through historical accounts. Analysing this alignment of institutions and system actors is a core analytic task within the structural analysis which involves an examination of the co-evolution of institutional structure and technological development (Coenen, Benneworth, et al., 2012).

Incorporating geographic factors into the analysis of institutions, according to Coenen and Díaz López, provides "a forceful explanation for the uneven distribution of innovation across countries and regions" (Coenen and Díaz López, 2010, p. 1153). Institutions relevant to the Irish wind RES are situated at and between a number of geographic levels such as the European Union, transitional energy markets, national energy policy and regulations and regional rules. For example, policy objectives and visions promoting future renewable energy systems have for many years been a part of policy frameworks in the European Union and throughout its member states (Helm, 2014; Lauber, 2007; Mitchell, 2008; Szarka, 2007). Conversely, despite increasing internationalisation of innovation activities, national and regional characteristics of innovation remain essential (Carlsson, 2006). The influence of education systems, industrial relations, scientific institutions, government and sub-national policies, cultural traditions and many other national institutions are fundamental to systems of innovation (Freeman, 1994). According to Carlsson (2006), these institutions are what make each system unique, many change only very gradually and provide strong path dependence. Recent work has explored the influence on innovation systems of informal territorial institutions (Wirth et al., 2013a). Institutions such as nationally situated professional culture, finance culture, attitudes to entrepreneurship and risk influence (or not) industry support schemes and policy instruments such as those discussed in this chapter. The authors show the influence of geographical differences in professional culture among Austrian farmers on the extent and character of biogas technology diffusion. Their findings suggest that endogenous territorial norms and values have important influences on the uneven geographic distribution of innovation system development, in particular where new technologies are transferred to follower countries (Wirth et al., 2013a).

The challenge of the institutional analysis is to explain the cumulative influence of these institutions on the speed and nature of the formation of the wind RES in Ireland. To accomplish this we gather (analytically) an 'ensemble' of relevant institutional forms, situated at different spatial and governance levels[13] (Martin, 2000), with which to assess alignment against the goals of actors in the Irish wind RES. Our focus is on the one hand territorially specific, taking as the starting point political institutions that influence the system in Ireland, then broadening the analysis beyond policy and regulations to include what Asheim and Coenen (2006, p. 166) calls "dynamic ensembles of mutually reinforcing sets of institutions", to include national informal institutions such as culture and behaviours. This ensemble, and the Irish wind RES is illustrated in Figure 3.3. Here we observe our two heuristic components, the global (*touchdown*) and , national formal institutions and national, regional and sectoral informal institutions (*build-up* in Ireland). These levels are useful during identification of evidence and in geographically focussing the evidence. Whilst potentially a complex task involving a wide variety of institutional forms, the geographic bounding focusses on alignment of system actors and institutions as central, ensuring adequate analytic focus. This approach accounts for influencing factors on the innovation system such as lending practices by financial organisations, attitudes to risk by entrepreneurs and lenders, and the nature of the market economy with respect to

[13] In an abstractly similar fashion, the Varieties of Capitalism literature attempts to aggregate configurations of institutions and address implications for innovative performance (Nooteboom, 2001). However, as Asheim and Coenen (2006) point out succinctly that "despite the emphasis on institutional complementarities, it takes predominantly institutions at the national level into consideration leaving 'the multi-scaled set of institutional forms' Martin (2000, p. 89) relatively unaddressed". To be clear, my ambition is not to address this critique of the varieties of capitalism literature. Instead I simply acknowledge the idea of assembling institutional influence, although in doing so in this case, I seek to offer no generalised claims with regard to aggregated institutional influence and national economic or innovation characteristics

industrial development and provides a systems-appropriate explanation of the nature of Irish specific innovation processes, not achievable by, for example, by an exclusive analysis of policy specifications.

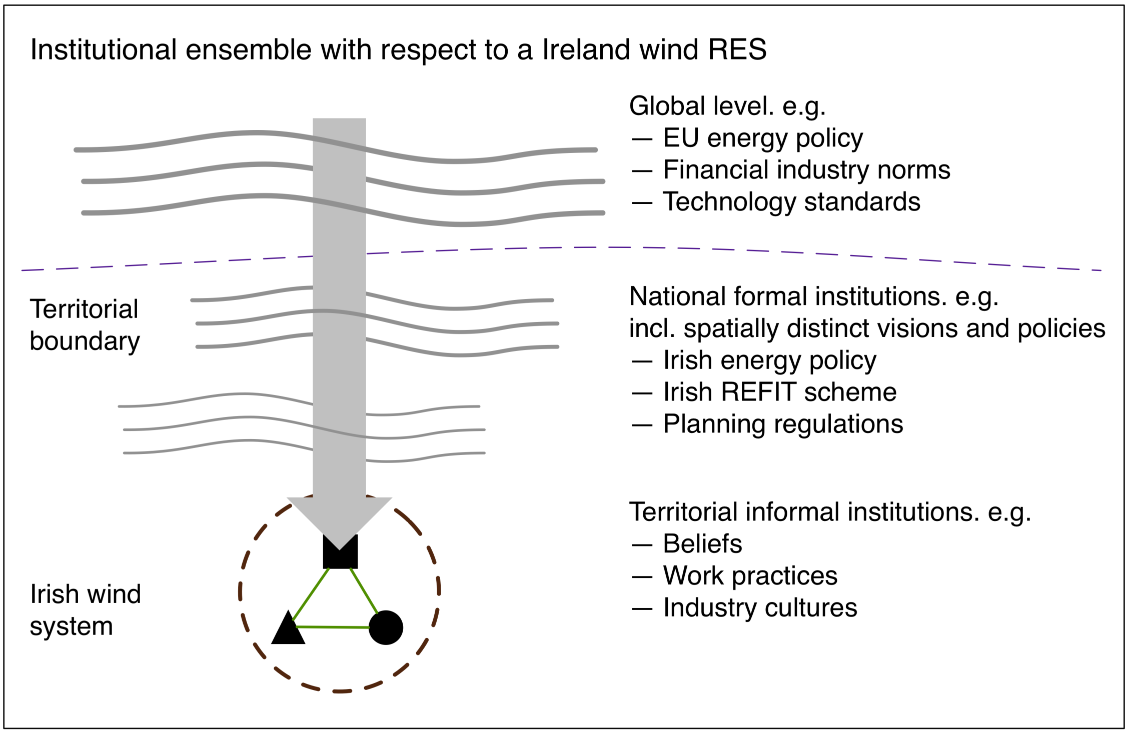


Figure 3.3. Ensemble of multi-level institutions with regard to a focal system

The synthesis of theoretical discussions in the literature, and empirical institutional studies of industry in Ireland suggest a number of explanations for the evolution of the institutional structure in Ireland's wind RES (see Table 3.2 for a list of relevant institutional, indicators and examples). First, we expect some actors will be able to influence and alter institutions through lobbying and processes of institutional entrepreneurialism[14]. Furthermore, we expect these processes to be influenced by the location of the actor and actor groups involved. Second, in situations where we observe rapid system growth, we would expect some degree of pre-existing institutional alignment, or relatively fast institutional change processes. One explanation for sudden change is exogenous system shocks. In Ireland over the period of study, two examples of rapid institutional change relevant to this study have been observed. First the marketisation and privatisation of state owned energy firms and assets. Second the economic crash and subsequent recession of 2007 and

[14]Institutional entrepreneurialism is action performed by "actors who have an interest in particular institutional arrangements and who leverage resources to create new institutions or to transform existing ones" (Maguire et al., 2004, p. 657).

2008. These are cases of general disruptions that throw up opportunities and problems for different energy actors in different ways. We address these disruptions by assessing whether and how they assist wind energy developments. Mapping the institutional alignment over time and space is on its own of limited explanatory value with regard to the research aims of this thesis. However, it is a crucial foundation for the functional analysis which follows contributing rich locational explanation for a number of system processes.

3.3 System function analysis

3.3.1 Mapping patterns of system functions

The initial step of the functional analysis is detailing the 'functional pattern' of the system (Bergek, Jacobsson, Carlsson, Lindmark, et al., 2008). In other words, describing how the system is behaving in terms of overall set of functions. This involves first assessing the 'strength' or 'performance' of each function within the system (see 3a, Figure 3.4) by examining an associated set of indicators in the case evidence. Qualitative and quantitate indicators are employed and have been arrived at through insights gained from the synthesis of theory, previous cases and emergent findings. For example, by tracking the number and geographic character of investors and lenders in the system, we can investigate how the resource mobilisation function is influenced by Irish actors in the early phases of the national RES development, but becomes influenced by overseas investors later on. The functions used in the analysis are detailed in the following subsections. For each, the relevant indicators are listed and methods of assessment explicitly stated.

Having assessed the strength of each function at given periods of wind development, we account for the achieved functional pattern in the innovation system. That is, how the functions are influencing each other, co-evolving, and cumulatively influencing the wind energy system (this is represented by step 3b in figure 2.33.4). Hekkert, Suurs, et al. (2007) argue "that acceleration in system change may occur when functions interact and lead to virtuous cycles. System change only takes place when certain thresholds of function fulfilment are reached".

We illustrate this proposition by returning to the hypothetical example of the mobilisation of financial resources in the Irish wind RES. An increase in financial resources in the system leads to a virtuous cycle by further legitimising development activities within the system, leading to more actors entering the system seeking commercial opportunities who in turn bring with them finance raising capabilities and networks. The functional pattern

Table 3.2 Alignment of relevant institutions with Irish wind system actors

Institutional level	Examples of relevant institutions	Indicators and location of evidence of influence on Irish wind system	The theory suggests we might expect...	Relevant literature
Global formal	Energy policy (inc. state aid rules)	Policy analysis of relevant European domains (e.g. energy, environment)	EU/EC influences national renewable energy targets	Helm (2014); Szarka (2010); Jacobsson, Bergek, et al. (2009); Stone Sweet et al. (2001))
	Market liberalisation agendas	Policy analysis of relevant domain and secondary literature. Evidence of privatisation and marketisation in Irish energy sector	Ownership and market structure rules change presenting opportunities for new entrants into national markets.	European Commission (1996); European Commission (2003); European Commission (2009); Adshead (2005); Jacquot and Woll (2003); Markard and Truffer (2006); O'Brien and Penna (1994)
	Climate and environmental policies	Policy analysis of relevant European and UN domains.	Global, EU and national climate change mitigation targets influnce local policy, legitimise RE technologies, may be diffused, adapted by NGOs and other non-firm actors	Fitz Gerald (2011); Giddens (2009); Laffan and O'Mahony (2008); Newell and Paterson (2010); Ó Gallachóir, Guidi, et al. (2007)
Local formal	Technology support schemes	Applications and awards of grants. Studies of relevant policy processes Evidence of lobbying activity	Support schemes may offer capital grants or market incentives to specific technologies giving wind generators relative competitive advantage over other generators	Foley, Ó Gallachóir, et al. (2013); Ó Gallachóir, Guidi, et al. (2007); Ó Gallachóir, Bazilian, et al. (2010)
	Grid allocation rules	Analysis of market creation policies. Analysis of correspondence between firms and the regulator	Rules for acquiring access to national grid create winners and losers.	Ó Gallachóir, Bazilian, et al. (2010); EirGrid (2013)
	National and sub-national planning regulations	Historical planning application data Policy analysis	National and sub-national planning regulations may affect speed of industry growth as well as other development characteristics such as firm size or plant size.	Government of Ireland (2000); McCarthy (2003)
	Electricity market structure	Analysis of market creation policies. Analysis of correspondence between firms and the regulator	Market participants may be granted relative competitive advantage based on generation technology (e.g. renewables given priority access over fossil fuels).	Doherty and O'Malley (2011); Foley, Ó Gallachóir, et al. (2013); Kee (2004)
Local informal	Professional culture	Industrial relations studies, evidence from NSI studies	Attitudes to risk or entrepreneurial activity may have national characteristics	Breznitz (2007); Duffy and Cleary (2015)
	Attitudes to investment	Global and national industry reports. Financial media Lending data and flow of investment	Lending conditions vary across countries, influence investment decisions in new technologies versus alternative opportunities Ireland is the recipient of large volumes of foreign direct investment.	Deloitte (2009); Duffy and Cleary (2015); Karltorp (2014)
	Corporatist modal of industrial relations	Secondary literature and grey literature on Industrial relations in Ireland	Nature of relationship between government and industry actors	Breznitz (2007); Byrne (2012); Culliton (1992); Hastings (2003)

is often illustrated as maps which when used in combination with a periodisation scheme can visually represent the evolution of functions in the system over time (an example of mapping over time is illustrated in fig. 3.4 and 3.5). However., mapping in itself does not hold generalisable theoretically robust explanation, instead we need to move to the level of system explanation which offers an evaluative perspective on the system and is discussed in section 3.4.

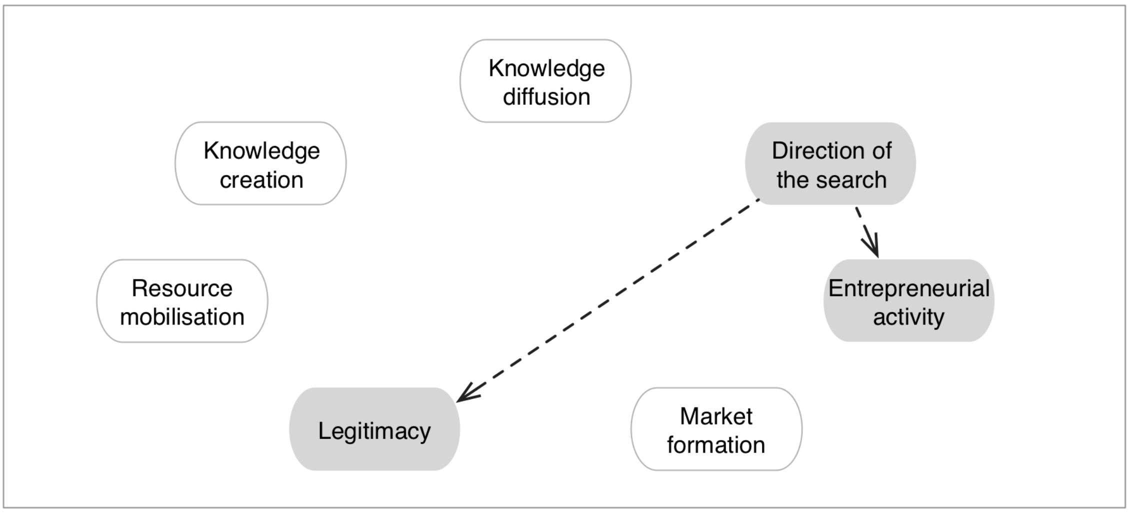


Figure 3.4. Phase 1. Illustrated example of system function mapping for early emergent phase of development. In this example the direction of the search function is shown influencing legitimation and entrepreneurial activity

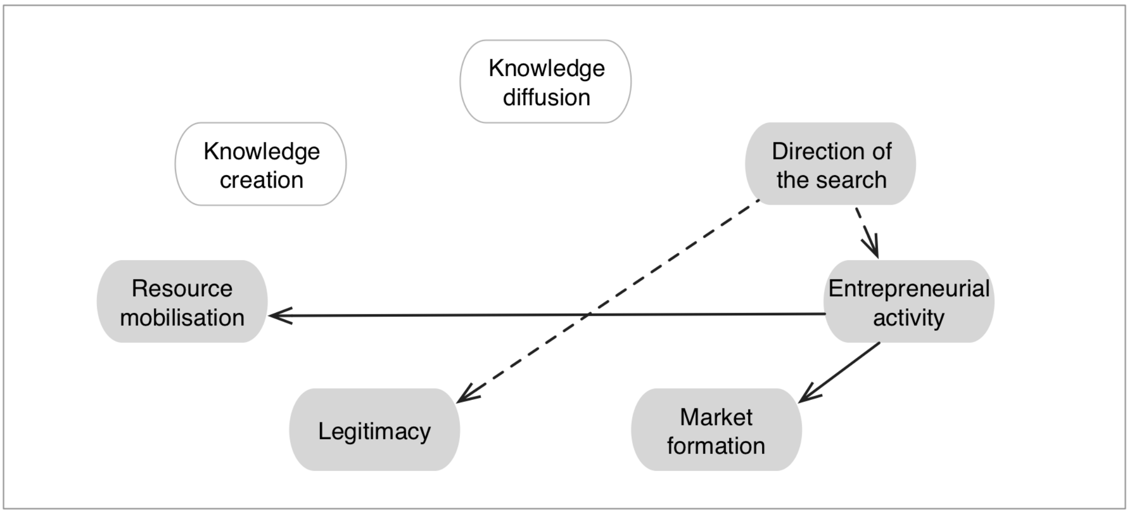


Figure 3.5. Illustrated example of system function mapping for take-off phase. In this example the direction of the search function still strongly influences the formation of markets and entrepreneurial activities such as firm creation. New firms are founded by new actors to the system, who bring with them ability to raise venture capital, strengthening the resource mobilisation function.

The literature suggests that a well-functioning system is one in which all system functions are contributing to the system when required. Recent studies integrating ideas from geography into the TIS framework have examined distributed system functions, that is, cases in which system functions operating at distinct geographic levels contribute to a nationally specified system. Bento and Fontes (2014, p. 176) found that in the case of Portugal, the knowledge diffusion from a transnational wind RES during the (national) formative phase allowed the fulfilment of functions that strengthened absorptive capacity. Binz, Truffer, and Coenen (2014) show how transnational research networks facilitate distributed knowledge functions in a number of membrane bioreactor system in China. These studies suggest not all functions are required to be operating in the same jurisdiction. Synthesising these results and integrating with evidence from the Irish case, we assess locational and geographic aspects of system functional patterns by integrating geographic characteristics into the function indicators. Rather than the focus being on how transnational system components and functions affect the national, the point of this research is to determine the causes, activities and processes of rapid system emergence and growth in a given country. For the purpose of this thesis, the analysis of RES components and innovation system functions is expanded to incorporate and differentiate Ireland-specific and transnational aspects of RES formation. Geographic indicators and relevant theory is discussed with regard to each TIS function below.

3.3.2 Creating knowledge

As we have already discussed, learning is at the heart of process of innovation system development and diffusion[15]. The function of knowledge creation is the process of strengthening technological learning by actors in the system. The creation of knowledge in the system generally is necessary to encourage and facilitate the entrepreneurial activity by firms and to assess how technologies can be optimally configured for a given market, the later is of specific relevance in the case of Ireland's import of turnkey technologies (Vasseur et al., 2013). Studies have shown how different knowledge development activities have focussed on various aspects of the value chain. For example, Jacobsson, Sandén, et al. (2004) showed that in the emerging innovation system for solar cells in Germany, initial knowledge development was limited to research and design of cell technology. Later, knowledge creation activities were broadened as firms experimented down-stream with new application design concepts (Bergek, Jacobsson, Carlsson, Lindmark, et al., 2008). Thus, we

[15] Given the focus on geography and location, developmental and diffusion aspects of this function are presented separately, as per Hekkert et al's list of TIS functions (2007).

would expect that the nature of the knowledge development activities of a system are related to the aspects of the value chain. Given the role of turnkey technologies in the case, our interest is particularly focussed on national and context setting learning.

We have seen that transnational firms operate in Ireland throughout the value chain. However, even in the case of very large corporations, studies of internationalisation suggest that that knowledge development that give firms competitive advantage is less internationalised than other aspects of corporate activity, Carlsson (2006) suggests that all things being equal, even large firms tend to perform R&D activities at home. Hence in the Irish case, we would not expect to find significant upstream R&D activities situated in Ireland. Indeed, Carlsson points out that smaller countries are at one end of the spectrum, with high levels of flows of scientific and technological knowledge and embodied technology crossing their borders, while larger countries are more self-sufficient and thus less affected by international technological and scientific flows. This resonates with our observation of the Irish wind RES is highly reliant on imported turnkey technologies which can be understood in system function terms as the acquisition of codified or explicit knowledge. On the other hand, the creation of tacit knowledge (that is, learning by doing) is strongly context dependent and difficult to move across space (Lema and Lema, 2012; Madsen et al., 2008). Therefore, where there is the system requirement for tacit knowledge generation, we might expect this to take place within Ireland. Furthermore, given the NSI perspective that the distinctive national character of innovation systems is influenced by the country's economic development and the composition of its economic and social activities, we might expect this development of tacit knowledge to take on a nationally specific character.

The strength of this function within Ireland can be assessed by mapping knowledge indicators[16] such as national innovation reports, bibliometrics analysis of the field and other activities (see table 3.3). For transnational activity, we analyse technology imports, movement of skilled personnel and transnational networks and programmes.

3.3.3 Diffusing knowledge

The diffusion of knowledge in an innovation system is closely related to the presence and nature of actor networks. The learning process often involves multiple actors and therefore knowledge exchange or the diffusion of knowledge through systems or networks is a key process. Indeed, the primary function of networks in the innovation system

[16]The geographic and locational aspects of these indicators, and the indicators listed in subsequent subsections follow contributions made by Bento and Fontes (2014), Binz, Truffer, and Coenen (2014), Gosens et al. (2015), Vasseur et al. (2013).

Table 3.3 Knowledge creation

Locational relevance and implication from the literature	**Indicators of system activity in Ireland**	**Indicators of transnational activity influencing Irish wind system**
Local institutional context influences knowledge development of local firms. Codified or explicit knowledge can be easily transferred. E.g. public goods created in the scientific system. Tacit knowledge is strongly context dependent and more likely to be generated in Ireland.	National innovation reports Bibliometrics (citations, volume of publications, orientation) R&D projects (orientation, number, other characteristics) Patents (in different competing designs, applications and along the whole value chain) National knowledge exchange (e.g. workshops, conferences, joint projects)	Imports of knowledge embedded technology International scientific cooperation Global mobility of skilled personnel Transnational corporations Global technology markets Institutional transfer programmes

is the exchange of knowledge and information (Carlsson and Stankiewicz, 1991). This is especially relevant in an innovation system context where knowledge creation activities such as research and development meet policy decisions relating to national energy targets. According to Hekkert et al. these should be “consistent with the latest technological insights and, at the same time, R&D agendas should be affected by changing norms and values” (2007:423). In this manner knowledge diffusion through network activity can be regarded as a precondition to ‘learning by interacting’ and ‘learning by using’ in the case of user producer networks, both relevant to the fast follower context (ibid.). In this way we expect the knowledge diffusion function to have a strong co-influence on the network structure of the wind RES.

For many small countries, processes of diffusion are more relevant than other aspects of innovation (Edquist and Hommen, 2008) as smaller nations have less capacity, capabilities and resources with which to develop wider range of industries, research expertise and networks. Hence in Ireland we might expect processes of diffusion of knowledge to play a more significant role than in either larger territories or lead markets. Bento and Fontes (2014, p. 176) found that the development of wind power in Portugal took advantage of the assimilation of knowledge spillovers from lead nations such as Denmark. In the case of Portugal, firms were able to take advantage of national production capabilities and through joint ventures allowed local firms to access best available global technologies whilst developing Portuguese production capabilities. Furthermore, capacity building activities such as education and general R&D expenditure are likely to improve absorptive capacity, and thus the of new innovation system, in functional terms, thus improving the ability of system actors to diffuse overseas technologies into Portugal. Given these findings, we expect a close interaction between knowledge creation nationally and transnational diffusion.

Indicators of system knowledge diffusion activity within Ireland and across its national borders are listed in table 3.4. The function can be assessed by mapping the number of workshops and conferences related to the field, and by mapping network activities and size over time (Hekkert, Suurs, et al., 2007). The import of turnkey technologies gives an indication of transnational activity as as well as accumulated codified knowledge in the system.

Table 3.4 Knowledge development

Locational relevance and implication from the literature	**Indicators of system activity in Ireland**	**Indicators of transnational activity influencing Irish wind system**
Codified or explicit knowledge can be easily transferred. E.g. public goods created in the scientific system or turnkey technologies. Tacit knowledge is strongly context dependent	Assessments by managers and others Workshops Conferences Network size and intensity	Stocks of imported turnkey plant International knowledge exchange (e.g. workshops, conferences, joint projects) Trade in equipment, licenses, patents, technical consulting

3.3.4 Influencing the direction of the search

The ‘influencing the direction of the search’ function relates to the clarity with which actors articulate demand and shape expectations for the future development of technologies within the innovation system. The function can be fulfilled by a number of components such as the government, firms, or in aggregate through markets. From an evolutionary perspective, while knowledge creation performs as a variation mechanism in the system, the guidance of the search function is akin to a selection mechanism (Hekkert, Suurs, et al., 2007). This selection is typically encapsulated in visions of actors in the system regarding desired future, often influencing regulation and policies. Visions reduce uncertainty whilst stimulating focus on a technological future (Vasseur et al., 2013). Whilst it has often assumed that national level policy and visions are best suited to articulating technology goals and futures, this remains largely unproven (Binz, Truffer, Li, et al., 2012). Visions are also set at super-national levels such as those in UN treaties and EC directives. Articulation of demand from leading customers may also be influenced by higher order societal or economic concepts such as climate change or recession. Similarly, we would expect industry trends such as marketisation or privatisation to influence the direction of the search for technologies which are compatible with such signposts.

Expectations often are influenced by development in systems in other countries. Bergek and Jacobsson (2003) show how direction of the search in the emergent German wind power system was influenced by developments in Denmark and the USA. A number of recent studies give examples of how national policy influences renewable technology innovation systems. In a study of the German solar PV TIS, Hoppmann et al. (2014) show that the PV feed-in tariff (FIT) has evolved in a highly iterative manner, with policy makers adjusting the design of the FIT over time. The authors show that while some of the policy changes were influenced by powerful actors with vested interests, policy makers correcting perceived flaws in previously legislation also played a significant role. However, they also found that the evolution of the German FIT for PV was strongly driven by technology developments such as efficiency improvements indicating that policy analysis told only part of the story. Vasseur et al. (2013) show that in the Dutch solar PV TIS, inconsistent and short-term policies confuse and discourage investors. Meanwhile, their findings with regard to a Japan study show that a longterm roadmap triggered investment and the entry of researchers into the national system. While these findings indicate that national policy or institutional context influences the direction of the search, it is less clear how the function may be influenced by factors outside the country of the focal system. Bento and Fontes address this in their study of Portugal showing that the increasing profitability of investments in the Portuguese wind industry caused a virtuous cycle in the system, whereby further investment flowed into the system from both national and international firms. Thus we expect national and international finance and lending environments to be influenced by the direction of the search function, and in turn influence the mobilisation of resources. In a similar fashion, Binz, Truffer, and Coenen (2014) conclude that the geographic influence of this function is far from restricted to a specific level.

The examples discussed provide useful indicators of how nationally specific policy may evolve with technological progress which can be turnkey or highly place specific. Specific indicators of system activity within Ireland and across its national borders are listed in Table 3.5.

Table 3.5 Influence on the direction of search

Locational relevance and implication from the literature	**Indicators of system activity in Ireland**	**Indicators of transnational activity influencing Irish wind system**
Regulation and long term goals set by government assumed but not often verified that national institutions are the best context for policy interventions (e.g. EU, UN, UNFCCC). Creation of vision and expectations by system actors who may be influenced by developments in systems in other countries. Therefore the spatiality of this function is not restricted to a specific spatial scale	Visions and beliefs that raise expectations Targets set by the government The extent of regulatory pressures, e.g. regulations on minimum level of adoption ('green' electricity certificates etc) and tax regimes (study of regulatory frameworks, secondary data) Incorporation of guidance in county level plans Belief in growth potential (interviews) Incentives from factor/product prices, e.g. taxes and prices in the energy sector (secondary data) The articulation of interest by leading customers Press articles that raise expectations Perspectives of profits in the future for the new technology vs. conventional New entrants in the market	EU renewable energy production targets Technological standards and certification Global industry platforms and environmental groups Selection of foreign technologies that better fits domestic needs Degree of preference for foreign or domestic manufacture

3.3.5 Entrepreneurial activity

This function is variously referred to as entrepreneurial 'experimentation' and 'activity', redolent of the initial focus many TIS studies had on the emergent phase of radical technology development. In this regard, entrepreneurial activities are another form of technological variety creation mechanism, in this instance by means of experimenting with and producing new configurations of technology (Vasseur et al., 2013). For Hekkert et al. entrepreneurs, while not the only actor in the innovation system, are the most central to its functioning; 'there is no such thing as an innovation system without entrepreneurs' they claim (2007:421). Entrepreneurs they suggest 'turn the potential of new knowledge, networks and markets into concrete actions' (ibid, 2007:421) and by carrying out experiments, carry much of the burden of societal risk associated with new and uncertain technologies. Indeed, 'the presence of active entrepreneurs is a first and prime indication of the performance of an innovation system' (ibid, 2007:421).

The focus on entrepreneurial activity and business formation adds a useful aspect to the study of the diffusion of innovations, which has traditionally focussed on supply side dynamics (Carlsson, 2006). However, the pertinent challenge with regard to this study is, accounting for how entrepreneurial activity matters in a follower country context. We would expect certain proximity advantages (and disadvantages) to be present in relation to the difficulty of transferring tacit knowledge, the learning by doing part of developing the TIS (Binz, Truffer, and Coenen, 2014). First, from our discussion on Ireland's small island grid we know that integrating turnkey technologies there offered unique challenges when compared with renewables integration on other European networks. These challenges may somewhat negate advantages overseas firms enjoyed due to experience built up in first mover locations. Second, we might expect indigenous new entrant firms, through spatial and network proximity to national first mover firms to have certain advantages over overseas firms. Third, entrepreneurs may go about deliberately altering the composition and structure of the innovation system (Hekkert, Suurs, et al., 2007), for example, they may lobby the government for regulatory support, or invite new actors such as investors into system networks. It follows that Irish actors, familiar with political systems and cultures may have some advantages in this regard.

The research focus on location demands that in collating this data, we go beyond quantitive measures of how much entrepreneurial activity is taking place to. In addition, we examine who is performing these activities and what access they have to indigenous and overseas resources and networks. Further indicators of these activities are listed in Table 3.6.

3.3.6 Forming markets

Market structures play a decisive role in the long term growth and success of innovation systems (Dewald and Truffer, 2011). Markets according to Fligstein "imply social spaces where repeated exchanges occur between buyers and sellers under a set of formal and informal rules governing relations between competitors, suppliers, and customers" (Fligstein and Dauter, 2007, p. 113). Supportive social spaces and rules are necessary as the initial competitive advantages of emergent technologies tend to be slight, with low margins and technological imperfections (Vasseur et al., 2013). Markets of new renewable technologies usually develop in different phases (Bergek, Jacobsson, Carlsson, Lindmark, et al., 2008).

Table 3.6 Entrepreneurial activity

Locational relevance and implication from the literature	Indicators of system activity in Ireland	Indicators of transnational activity influencing Irish wind system
This function is inherently social and spatial as the social ties of entrepreneurs are relevant and likely to be localised	Quantity, capabilities and characteristics of new entrants Diversification activities of incumbents Certain planning applications Breadth of technologies used Local merger and acquisition activity Studies, demonstration, field trials Classifications of national characteristics of entrepreneurial behaviour such as NSI based comparative case studies	Global equipment markets and market competition Global technology markets Transferability and imitability of foreign technology Shortcutting typical experimentation times with mature technology

In early phases, learning spaces and feedback loops between manufacturers and users of the technology are important (Garud and Karnøe, 2003). However, we have discussed in the previous chapter the relatively insignificant developmental role manufacturers have played in Ireland where turnkey generation technology is prevalent and little evidence of strong feedback learning loops is found. In later 'bridging' or 'mass-market' stages, producers and users have less requirement to be co-located as manufacturers develop global production networks (Coe et al., 2004). The acquisition of significant US and European solar PV market share by Chinese manufacturers is a case in point (Tour et al., 2011), showing that at least in the supply of turnkey RETs, dominant global market positions may be attained at a distance from many markets. This literature suggests that in fast follower contexts, the formation of national markets does not play a significant role in the development of the national RES.

On the other hand, we have noted the existence of electricity market, with high penetration of wind technology, which because of the nature of the electricity network, have been territorially embedded[17]. Dewald and Truffer (2011); Dewald and Truffer (2012)

[17]Embeddedness in this instance refers to a condition where system actors interact and relate to each other in a context that has a specific historical origin and development, as well as precise spatial coordinates. In other words, firms' embeddedness refers to their belonging to a certain place. The territorial embedding of electricity networks is pronounced in the provision of electricity in Europe, which is highly

argue that in order to sustain market dynamics for new technologies, system actors rely on critical resources that often are co-located in specific spatial contexts, predominantly at the sub-national level. New market segments will emerge when the following are in place:

1. The institutional context is conducive for the establishment of these markets.
2. Consumer groups are available and accepting of new technologies
3. Actors with appropriate capabilities and access to resources
4. Networks supporting innovative actors and their activities exist

The issue of concern according to Möllering is how the market is constructed by the government and others (2009). Turning to the Irish market we focus on how upstream and downstream actors have constructed the national market which at one end of the supply chain features turnkey renewable technology, and at the other - the point of metered delivery - the homogenous 'flow of electrons'. Neither of these facets of the supply chain offer significant scope for market differentiation within the wind sector. The evidence found in the literature leads us to expect that significant aspects of the market in generating technologies are formed outside of Ireland. However, electricity supply markets are also important arenas to study, and how these are constructed by the government and other actors will influence the functioning of the Irish wind RES.

Empirically we map the creation of national markets through installed capacity and unit numbers as well as supporting institutional regimes and regulations as outlined in Table 3.7. Development of the global market for wind plant is mapped through global investment and technology reports and quantitive assessments of the internal markets of lead country wind systems are assessed through existing studies.

3.3.7 Legitimising activities

Legitimising functions are complex processes of expectation shaping and institutional change and are highly inter-related with the system structure and other functions of the TIS. Legitimisation in the TIS framework is a socio-political process in which the most commonly described strategy for industry legitimation is to conform to – or 'align' with

territorially bound to national markets and more so in the case of island nations and island networks such as those of Great Britain and Ireland, each of which have relatively low levels of interconnection with external transmission or delivery networks, significant infrastructural characteristics when adding intermittent electricity generation such as wind.

Table 3.7 Market formation

Locational relevance and implication from the literature	Indicators of system activity in Ireland	Indicators of transnational activity influencing Irish wind system
'Producers and users do not have to be located nearby. The formation of market transactions relates to the exchange relationship between supply and demand for the end-products. Markets imply social spaces where 'repeated exchanges' occur between buyers and sellers under a set of formal and informal rules governing relations between competitors, suppliers, and customers	Development of new market segments Specific tax regimes and regulations Environmental standards Activities of lead users and customer groups Installed capacity and unit numbers	Global equipment markets and market competition reports Global technology markets Institutional transfer programmes Share of domestic and foreign companies in the market

– established institutions (Bergek, Jacobsson, and Sandén, 2008). Firms compete not only in the market, but also to influence the institutional structure of the system, by, for example lobbying for feed-in tariffs (Jacobsson and Lauber, 2006). Given the highly regulated nature of the electricity market and sector, this competition for influence over the regulatory framework is a fundamental aspect of the function, which often take the form of collective expectation shaping. Collective expectations, or supporting visions, motivate actors to engage in new technologic fields, they guide technology development and contribute to the coordination of actors by providing a common reference point or by implicitly or explicitly ascribing roles for different actors (Konrad et al., 2012). Collective expectations are usually purposefully and strategically set or challenged by actors in order to mobilise funds or improve the public perception of a technology. Furthermore, a significant aspect of expectation setting is the framing of opportunities. Wind generation for example has been framed in terms of resource exploitation and commercialisation to be profited from, as well as in terms of a "solution" to problems associated with climate change mitigation.

Policy objectives and visions promoting future renewable energy systems play an integral role in European Union energy policy frameworks, as well as those of individual member states (Helm, 2014; Lauber, 2007; Mitchell, 2008). As such, we would expect that changes in the legitimacy of a technology system at one geographic level may affect the legitimacy of a system at another. For example, the German solar PV sector was legitimised by actors distributed across the country including activists and special interest organisations. Jacobsson and Lauber (2006) showed that many processes of legitimacy change emanated from subnational level and subsequently influenced the federal political agenda. Meelen and Farla (2013) emphasise that both legitimation and influence on the direction of search functions have strong co-dependencies and are strongly oriented towards the context of the TIS. With regards to this research, the strength of these two functions, and how they influence and are influenced by the structure and context of the system structure are a signifier of why actors, both based in Ireland and from overseas, are attracted to enter the system (Bergek, Hekkert, et al., 2014).

Mapping these dynamics involves on the one hand assessing the evolution of the legitimacy of the Irish wind RES from the perspective of relevant actors (e.g. investors, capital goods suppliers, government). We purposefully consider the perspectives of RES actors and acknowledge these are not homogenous, and may differ from other stakeholders such as incumbent electricity firms and publics. On the other hand, we must account for the activities within the system which may increase (or decrease) this legitimacy. These activities include lobbying and the formation of coalitions and advocacy groups (see Table 3.8). Policy documents and historic studies of policy processes at European level and in lead European wind markets provide evidence to assess transnational activity.

Table 3.8 Legitimisation activities

Locational relevance and implication from the literature	**Indicators of system activity in Ireland**	**Indicators of transnational activity influencing Irish wind system**
Similar to direction of the search function, the performance of this function is closely related to the emergence of coalitions, interest groups, networks and intermediaries. These actor groups may be restricted in their spatial reach or other may aim at international or national scales	Rise of interest groups, advocacy coalition and their lobbying activity for or against technology Quantity and characteristics of media coverage The appearance of framings in new arenas, such as parliamentary proceedings Recognition of societal benefits of the technology Direction of science and technology policy Regulatory and fiscal instruments (e.g. REFIT)	International environmental regimes Global industry platforms and environmental groups Domestic policy vs. international trade regimes (WTO, EU) International technology growth and legitimation

3.3.8 Mobilising resources

Financial, human and physical capital resources are necessary inputs for innovation processes. Mobilising, attaining and putting to use these resource within an innovation system is an important function. Karltorp (2014) outlines three major resource constraints technological innovation systems face in up-scaling from an early development phase to maturity. First with regard to financial resources, emerging technologies are often linked to high-risk and long pay back periods. Second, infrastructure resources are often a significant barrier in the way of development. We have already seen that this has been a major issue in the Irish wind RES with regard to issues of constraint and curtailment on the grid. Third, competences and human resources are a major issue. For specific technologies, the allocation of resources is necessary to create or enhance knowledge production functions (Hekkert, Suurs, et al., 2007). As such, resource mobilisation is an important antecedent to the knowledge creation function. Furthermore, there is often a time lag between when these resource needs are recognised and when suitable staff come into the systems creating delays and bottlenecks. These perspectives suggest that fast followers may have some advantages over early emerging nations if lessons can be learned and resources mobilised for lead systems are accessible.

We have discussed the geographic constraints on knowledge and learning. With regard to geography and lending conditions Vasseur et al. (2013, p. 208) show how locational characteristics of actors in the Dutch solar PV industry affected their ability to mobilise resources. Aside from a small number of financially robust equipment suppliers, the solar PV sector at the time of the study consisted of a small number of SMEs. The limited industrial base of the industry was highly vulnerable to changes in investment and subsidy policy regimes which significantly hampered their ability to raise needed capital. The authors compare this situation with Japan, in which the dominant actors are multi-national firms, less dependent on exogenous investment environments and so able to raise funds in a more predictable manner. These studies see also Gosens et al., 2015 suggest that while the banking and investment industries are highly internationalised, the conditions under which they lend are influenced by national factors. We have discussed how knowledge creation capabilities are influenced by location. Where knowledge cannot be generated locally, a firm or sector may attract specialised professionals from overseas (Saxenian, 2007). However, in Ireland, the literature on national systems of innovation and foreign direct investment suggests this phenomena is mostly limited to information technology, pharmacy and the finance sectors, with little national industrial development agency support for the electricity sector (Barry and Bradley, 1997; Breznitz, 2007; Carlsson, 2006). Where the acquisition of human resources is not possible, the capabilities to access extra-territorial resources becomes crucial. In the 1980s for example, EEC community funding was acquired for early wind projects in Portugal, and while these helped kick start a national wind innovation system, resource mobilisation was not fully functioning until new actors entered the system in the 2000s, bringing with them new capabilities and access to funding networks (Bento and Fontes, 2014).

Analysing this function involves understanding not only the incentives for entry at the industry and sectoral level, but also the structural features of the capital market and the university sector at the NIS level (Bergek, Hekkert, et al., 2014). Furthermore, it requires knowledge of capabilities of the actors in and entering the system regarding finance and other resource mobilisation. Mobilisation of financial resources may be measured by volume of capital and increasing levels of seed and venture capital, where this data is available. Where not, and additionally, the difficulty of attaining finance is ascertained through interview methods (see Table 3.9).

Table 3.9 Resource mobilisation

Locational relevance and implication from the literature	**Indicators of system activity in Ireland**	**Indicators of transnational activity influencing Irish wind system**
Human capital is likely to come from local labour markets or education institutes though forging entrepreneurs and specialised professionals may also play a role. Financial resources may be raised locally or through the global financial system (Avdeitchikova, 2012). Small local firms may be more vulnerable to changes in investment environments.	Availability of competence/human capital Availability and accessibility of financial capital Changing characteristics of financial capital and lending requirements Complementary assets for key actors (Binz, Truffer, Li, et al., 2012).	Transnational corporations Private and institutional financiers Institutional transfer programmes Global mobility of skilled personnel Foreign direct investment, venture capital, international banking sector Access to European investment or demonstration funds

3.4 System level analysis

3.4.1 Evaluative perspectives on system functionality

The relative strength, or weakness of a TIS function does not on its own account for system-level change. Rather it is the cumulative and systemic interaction of the functions that enhances or impedes innovative activity and according to Hekkert et al., creates virtuous or vicious cycles of functional patterns (2007). This is the core analytic step in evaluating overall system functionality (step 4 in Figure 3.2). Mapping the configuration of functions through phases of system development, the 'functionality' of the innovation system is assessed in terms of how it supports firm entry, variety and the formation of niche markets in the early phases of development, and market expansion and the supply of resources to exploit that market in the later phases. Bergek (2002) identified two phases of system development, first a formative phase, perhaps lasting decades, followed by a growth phase characterised by positive feedback loops and increasing returns to adoption. Subsequent studies have further refined these concepts and suggested further phases such as a take-off phase and an acceleration phase which correspond, approximately, to later stages of diffusion of the system (Suurs and Hekkert, 2012). This step is central to the explanatory power of the TIS functions approach which posits that through processes of cumulative causation, combinations of functions reinforce each other positively fulfilling innovation processes within a developing system.

Based on analysis of multiple cases, Suurs and Hekkert (2012) have proposed a small typology of reinforcing dynamics, or 'motors of innovation[18]' (Ven et al., 2000; Poole et al., 2000): A *science and technology push motor* in which knowledge creation and diffusion functions are dominant; an *entrepreneurial motor* in which opportunities increasingly influence system change; a *system building motor* in which structural conditions attract exogenous actors into the system; and finally a *market motor* – the formation of the market. Suurs and Hekkert (ibid.) are careful to note that while these motors are not predictive, they contribute to our understanding of possible mechanisms that underlie long term system development. A number of similar functional patterns have been found in case studies relevant to this thesis. The case of wind energy in Portugal was characterised by two dynamic cycles; a knowledge development cycle and an implementation cycle (Bento and Fontes, 2014, p. 171). The knowledge development cycle was triggered by legitimisation which influenced the direction of search, in turn influencing the mobilising

[18]The underlying causal explanation of these 'motors' is in turn based on finding from the influential Minnesota Innovation Research Program (Poole et al., 2000).

of resources for the research and development of nationally contextualised knowledge and entrepreneurial experimentation. The implementation cycle began in parallel, and was triggered by regulatory changes that established a goal-orientated feed-in tariff (legitimation and direction of the search) which attracted new actors and brought more resources to the industry resulting in new internal markets and exports. This in turn strengthened the ability of wind actors to influence policy debates. These findings share characteristics with findings of wind in Denmark (Kamp, 2008a) and solar PV in Japan (Vasseur et al., 2013). Furthermore, whilst not detailing functional cycles in depth, Tigabu et al. (2013) found that in Kenya and Rwanda, the accumulation of bio-digestion system functions was triggered by the direction of the search function. These findings suggest some degree of consistency in the empirical literature, albeit from an extremely limited sample of cases. However, they provide a useful evaluative context from which to progress our analysis.

We assess the overall system functionality for insight into what societal and policy support the Irish wind RES attained and explanations for what innovation activities happened within Ireland, and how they were supported. First, for each period identified we analyse the functional pattern against analytically assessed system goals. That is, what structurally and functionally the Irish wind RES required during a specific period, for further development. Our knowledge of the TIS function activity for each period is based on information synthesised from the literature is explicitly labelled in the analysis. We then compare how each functional pattern gets close to this (that is, how the functions are performed and strengthened, can be analysed with respect to the requirements of each period.)

The second task is the internal comparison between transnational and Irish influenced functions. We have added geographic indicators to both structural and function analysis. This allows us, for each period of development, to assess the relative contribution of the domestic RES and links to exogenous systems. This is a crucial step in assessing why innovation happened in Ireland. For further analytic robustness, we compare the results from the analysis of the Irish wind RES to TIS functionality observed in different locations. In this case, we have used findings from historic studies of the renewable energy systems. Because of sometimes substantial differences in methodology, system boundary definitions and data sources, the comparison of system patterns is of limited value, however, general findings were contextualised and utilised to test internal robustness.

3.4.2 Locating inducement and blocking mechanisms

The final set of analytic tasks is to identify inducement and blocking mechanisms. These may be the result of actor strategies, exogenous or endogenous to the focal system. For example, there are numerous reasons why exogenous interests would seek to block the development of an emergent innovation system. These may include competition for markets, resources or political favour. A common trigger for virtuous cycles can be found in the analysis of the *direction of the search* and the *legitimation* functions where, for example, we examine evidence of proponents of the innovation system lobbying powerful actors for institutional support (Hekkert, Suurs, et al., 2007), provided for through legislation or technology support instruments. Conversely, experimentation may lead to vicious cycles; failures of public trials for example may lead to collective disappointment in technologies which may negatively impact further research activities or the availability of financial capital from lenders or investors. Similarly, with regard to the Irish wind RES, we have already discussed how the recession impacted investment from Irish lending institutions. A simplistic mapping of this exogenous event would suggest that the crash, a geographically proximate but exogenous event to the Irish wind RES, may have triggered a vicious cycle of decreased resource mobilisation. Using the geographically specified indicators, we can identify locational factors in the inducement and blocking of system level function patterns.

It is the evaluation of cycles – or motors – of functions that allows us assess the overall system. This functional pattern is likely to differ from innovation system to system, or location to location, and will change over time as the system develops. Given there are seven functions defined, many patterns of interaction are theoretically possible, however evidence from historic case studies suggest that there may be some common starting points, in particular guidance of the search function has been shown to be central to positively influencing other system functions (*ibid.*). Furthermore, the literature has shown some consistency in the temporal ordering of cycles in a number of cases as outlined in the preceding section. However, it may be the case that in a fast follower context, an emergent follower system may skip certain functional patterns of development, or have its own unique starting point, which might in part explain the rapid nature of some fast follower roll-outs activity.

Empirical cases aimed at policy makers have often sought to first identify and then make efforts to mitigate against blocking mechanisms, whilst at the same time enhancing inducement mechanisms. In this case we focus on producing an historic analysis of the development of the wind RES, rather than a policy orientated guide for future interventions. Whilst not strictly a goal of this thesis, producing policy recommendations for each period of the wind RES allows us to 'test' research findings against policy proscriptions that were, in fact, made as that period transpired in reality, during the development of the system. This is useful in testing counterfactual explanations of industry development against the technological innovation system framework.

We now return to the *build-up* and *touchdown* heuristic introduced in Section 2.4. *Build-up* is concerned with context in Ireland, the consideration of the territoriality of technological development and change. As such, this is an umbrella term which groups together the RES components which have originated from Irish contexts, and TIS functions which are enacted or influenced by Irish actors and institutions. *Touchdown* on the other hand places a great explanatory emphasis on the geography of trans-national inter-organisational linkages in order to understand the emergence of the Irish wind RES. The heuristic construct encompasses the TIS functions, flows of resources and other RES components which have substantive transnational aspects. These include coalitions and industry associations, the turnkey technology and finance organisations and overseas developers as well as European policy agendas. This locational heuristic is a useful discursive and descriptive device as it indicates not only the locational origin of a system component or function, but also allow us to consider the systemic and contextual influences. For example, we may expect that Irish informal institutions such as attitudes to industrial development strategies to influence build-up in a manner different to how it might influence *touchdown*. To be clear, heuristically, *build-up* and *touchdown* are umbrella terms bringing together the activities and processes of 'doing'. In summary, we have drawn from the literature approaches to assessing the influence and location of distributed functions and the structural context of the RES.

3.4.3 A framework for research and thesis hypotheses

We have integrated into the core TIS framework a number of analytic approaches with which to explain the speed and nature of the emergence of a wind renewable energy system in Ireland.

First the framework was underpinned with a robust and geographically focussed structural analysis. The nature and geographic location of actors and networks were important inputs for both the institutional analysis and the functional analysis. Second, a framework for geographic, institutional explanation was presented. This incorporated institutions endogenous and exogenous to the focal system and accounted for how these institutions were aligned and re-aligned with the goals of the Irish wind RES. Third we accounted for system functions focussed on the Irish case but distributed transnationally, describing and adding explanatory power to transnational function mapping.

Although the definition of functions is static, their operation is not. Changes in functions such as articulation and elaboration are referred to generically as ‘function activity.’ Indicators of function activity have been identified which explicitly account for system-build up in Ireland as well as transnational activity and flows of resources. I summarise the framework and relate it to the case in Table 3.10.

The framework has explicitly drawn on work examining other technological innovation systems and previous studies of Irish actors, institutions and networks. Critically drawing on these perspectives, and the introduction to the case discussed in Chapter 2, we make a number of hypotheses with which to explain the emergence of the system and fast roll-out of wind technology in Ireland.

This discussion may be summarised in terms of a series of hypotheses. Ireland has been able to rapidly roll-out its wind energy system because, in this fast-follower context, institutional alignment happens relatively quickly. The reasons for this become the hypotheses:

H1a: Not all TIS functions needed to be re-produced in Ireland, some system functions originate in overseas renewable electricity systems, or are produced through transnational innovation activity.

H1b: TIS Function strength reflects structural components which are exogenous as well as endogenous to the wind RES at national and European levels.

H1c: Changes in the contextual institutional environment due to market liberalisation and European climate targets were sufficient for the formation of new electricity sub-sectors including the wind RES.

H2a: Increases in legitimacy of the technology system, attained through the production of visions, policies and regulations at a national level, are powerful drivers of RES emergence.

H2b: Rapid roll-out of a technology within a RES or an implementation cycle of TIS functions is preceded by a local cycle of knowledge development functions.

H3: Despite the import of turnkey technologies, national innovation activities were an important factor in the rapid integration of wind technologies.

Table 3.10 Summary of the analytic framework and scheme of analysis

Framework stage of analysis	**Mode of analysis**	**Relevant conceptual perspectives on locational build-up of Irish wind RES**	**Prior art in the literature suggests we will find:**
System building	Structure analysis (Chapter 5)	Explaining the rapid roll out of technology in Ireland entails also of the analysis of flows of knowledge and resources between Ireland and other countries.	Characteristics of component location will influence the nature and strength of TIS function
Actors and networks	Structure analysis (Chapter 6)	Actors have relationships at different spatial levels which affect their access to resources Transnational networks facilitate exchanging insights and building advocacy based on experiences developed elsewhere The composition and access to exogenous systems, such as the political sphere influences the development of the wind RES. The location where knowledge is created counts	Proximity in Ireland enhances network building Access to transnational networks influences development of the Irish wind RES Ability of actors to perform in the RES is spatially mediated The capability of actors in a national RES to access, interact and 'capture' knowledge, information, ideas or any form of tangible and intangible asset from other places or other firms
Institutions	Structure analysis (Chapter 6)	Regional and national visions are central to actor dynamics in the emerging RES. Local policy may combine environmental aims with economic growth goals. In given situations, particular policy (spatial) levels are advantaged. Industrial development often important policy driver. Policies need to encompass multiple policy areas, contested by multiple interests. Multi-level interaction and relationship between policies and European and national level. Institutions may territorially embed knowledge from a RES. Exogenous shocks. Development and diffusion are conditioned by formal and informal institutions	Institutional alignment changes through lobbying and exogenous shock. Changes in the institutional environment due to market liberalisation and European climate targets were sufficient for the formation of new electricity sub-sectors including wind power. Actors with local knowledge and capabilities required by the RES perceive opportunity in the emergent wind RES.
Function mapping	Function analysis Chapter 7)	Assessing the locational dynamic of functions can improve the understanding of innovation processes in an innovation system. In order to sustain market dynamics for new technologies, system actors rely on critical resources that often are co-located in specific locational contexts	That the nature of the knowledge development activities in the wind system are are related to the aspects of the value chain re-produced in Ireland. A combination of local legitimacy and transnationally influenced direction of the search influenced the volume and characteristics of actor entering the systems. Irish actors have limited ability to influence direction of the search at EU level. We expect the knowledge diffusion function to have a strong co-influence on the network structure of the system.
Achieved functional pattern	System level analysis (Chapter 7)	Emergent locally specific RES are often dependent on distributed TIS functions	This step provides some indication of why RES emergence in one location may proceed in a different direction or speed to others

Wrapping up

Summarising, this thesis is based around a claim that wind energy in Ireland, for all its ostensible utilisation of imported turnkey technologies, required considerable local innovation. This claim is tested and explored using a geographically-sensitised technological innovation system analytical framework.

This is used for two related tasks, on the one hand to analyse relations between local and distant processes and elements in the emergence of an Irish wind RES. And on the other, to identify why and how innovation activities relating to the wind RES happened in Ireland.

In the next chapter I discuss how the framework is operationalised and introduce supporting data and evidence. The plausibility of this framework is assessed against empirical evidence presented in Chapter 5 and analysis presented in chapters six and seven. Results are discussed in Chapter 8, in which I derive more general findings and reflect on the theoretical perspective.

Chapter 4

Research design and analytic strategy

This chapter outlines how the conceptual perspectives in the research framework are mobilised. This analytic strategy incorporates a research design and scheme of analysis with which to operationalise the concepts. Rationales for the selection of the case method are discussed and we outline a specific narrative approach constructed for this thesis. We discuss how the narrative analysis forms the basis for producing analytic understanding of the actors and institutions of the Irish wind RES, from which the structural and functional analysis follows. The research design in Section 4.1, introducing a novel methodological approach which though built from process theory, foregrounds narrative over events in its operationalisation. This is a departure from many studies in which TIS is employed, which utilise an event history analysis approach. The evidence in introduced in Section 4.2, and we discuss how the data was arrived at and the evidence mobilised using the narrative methods. Section 4.3 outlines the how the theoretical framework is operationalised concluding with an overview of the specific scheme of analysis and details how the analysis is laid out over the remaining chapters of the thesis.

4.1 Research design and method

4.1.1 The case method

The main objective of this thesis is to understand the emergence of the Irish wind RES. Fundamental to this goal is the explanation of the processes of interaction between indigenous and overseas actors, institutions and technologies in the development of the wind electricity sector in Ireland. This includes identifying and analysing firm and other actor groups. The case study method, by going into great depth enables us to understand complex dynamics in one setting (Eisenhardt, 1989). Case studies are an appropriate method of analysis using the TIS framework (Bergek, Jacobsson, Carlsson, Lindmark, et al., 2008). The historical case method meets the research aims of this thesis in facilitating rigorous discussion on substantive contexts in which technological developments emerged in the Irish wind industry. The nature of the case study is explanatory, and the core empirical issue to explain the comparatively rapid rise of wind generation per capita in Ireland. In Chapter 3 we elaborated why it is appropriate to understand this as a case of innovation system emergence and growth in a new location. However, we also seek instrumental explanation, that is we seek explanations of the Irish case that may be generalisable to other cases, such as other fast-follower countries. According to George and Bennett (2005, p. 5) the case study approach is suitable for this purpose as a "detailed examination of an aspect of a historical episode to develop or test historical explanations that may be generalisable to other events".

This is a problem focussed research agenda, we started with the requirement to explain the empirical case of wind technology growth in Ireland. Through reviewing the literature discussed in Chapter 3 we 'diagnosed' the empirical case as that of a fast-follower emergent wind technological innovation system. Furthermore, this is a 'most likely' to case (Flyvbjerg, 2006), where given Ireland's natural resource endowments, open market economy and global flows of knowledge and finance, we might expect global and localised innovation system activity to take place under the right conditions.[1]

The case is defined as 'a phenomenon of some sort occurring in a bounded context' (Miles and Huberman, 1994, p. 25). The case is, they state, 'your unit of analysis' (ibid.). According to the TIS framework, the unit of analysis is the system. The framework incorporates instrumental explanation through explaining systemic change in terms of system functions and structure, and the empirical wind RES gives us a template with which to

[1] Of course, this 'most-likely' perspective is somewhat limited and does not account for why Ireland did not earlier lead in development when similar sized country (e.g. Denmark) did, so the thesis is tested.

bind the case temporally, sectorally and geographically. In order to understand the system, and how change happens in the system we must account for the components and processes. This we do in terms of time, 1990 to 2014[2], and geography, we have already specified our focal system is that of Ireland[3]. We also bind the case in terms of industry sector, electricity, and political level, in this case subnational, national and European policy relating to the Irish wind RES.

4.1.2 Process theory and narrative methods

Analysis using the TIS framework is accomplished using process theory[4]. Process theories according to (Poole et al., 2000, p. 12) "indicate how the process unfolds over time". Reality is not assumed to be a steady state (Pettigrew, 1997, p. 338) rather, it consists a developmental event sequence, in other words, a 'process' (Sminia, 2009; Langley, 1999). According to (Pedriana, 2005, p. 352), "causality, process, and explanation are located in the timing and sequential ordering of actions and events". Thus process theories account for historical influences and explanations of change in context and are useful when examining ongoing processes in which no end-point is clear, such as the roll-out of new and still-developing technological systems. In process theory typical patterns of events, which we can understand as variation and selective retention, are core theoretical constructs (Van De Ven and Poole, 1995). According to Van de Ven and Poole (2005:1384):

> "process theories may incorporate several different types of effects into their explanations, including critical events and turning points, contextual influence, formative patterns that give overall direction to the change, and causal factors that influence the sequencing of events."

[2] In practise this boundary work is achieved recursively as findings emerge from data gathering.

[3] While the unit of analysis is the Irish wind RES, as indicated in the discussion of relational geography in Chapter 3, the distribution spatially and temporally extends beyond the jurisdictional limits of the Irish border.

[4] Process theories are one of two fundamental models of explanation which have emerged in the social sciences. The other, variance theories, typically explain why change happens through methods employing assumptions of deterministic causation using statistical significance (Poole et al., 2000, p. 29). For example, the diffusion of wind generation technologies can be explained by capturing available scale economies such as increased returns to adoption based on increases in size and energy conversion capacity, where sufficient data is available. As discussed in the previous chapter however, this approach is less suited to explaining system change, where disaggregating explanations is more difficult in complex systems where there are not clear outcomes, issues that mitigate against their use in this case.

Analysis using these theories relies on event sequences, often located in longitudinal data (Ragin 1997, George and Bennett 2004, Eisenhardt and Graebner 2007). A number of event-based methodological approaches have been developed, including the analysis of event chains, narratives, analytical chronology, statistical analysis of event data (Turnheim, 2012; Pettigrew, 1997; Langley, 1999; Sminia, 2009).

The analysis of narratives is a suitable process method with which to investigate both structural and functional aspects of the Irish wind energy system. Narrative analysis allows us to identify the generative structures that enable and constrain system processes, or functions, by which we can account for explanatory factors that sequencing events on their own cannot (Pentland, 1999, p. 722). Process explanations that draw on narrative data are particularly "close" to the phenomena they purport to explain, according to Pentland (1999, p. 721) who suggest that *"actors do not just observe events, they focalise them and create stories to explain them"*. Narratives are versions of underlying 'analytic stories' told from a specific point of view (Pedriana, 2005). These analytic stories are generic descriptions of an event or set of events and their relationships. Narratives are not simply aggregations of one event after another, but consist of subplots of themes which guide the narrative. Narratives then are both stories – with a beginning, middle and end with often recognisable styles of storytelling – and patterns of events; they are both data and analytic constructs (Roe, 1994). In other words, narratives are the representation of social action, created and promoted by actors networks and institutions to reshape future patterns of social action (Smith and Raven, 2012).

We locate narratives in 'texts' which include written documents such as policies, green papers and newspaper reports. Of course, texts such as policy papers or research articles both incorporate narrative and in turn may be incorporated into future narratives in the domain or industry. Take for example an energy policy document which outlines renewable energy production targets to be met by the year 2020. The text of the policy may incorporate narratives such as the dangers of the effects of climate change. In turn, this policy may become part of a future narrative giving confidence to investors in renewable technologies. By analysing narratives, we gain insight into the structure and functions of the Irish wind energy system in a number of ways. We identify narrative voice, evaluative context and other indicators of locational context in the narratives and underlying analytic story. Often these occur acts of framing and reframing, where individual actors or coalitions evoke common "schemata of interpretation" (Goffman, 1974, p. 21) in order to strategically render certain meanings to events or occurrences (Benford and Snow, 2000).

These in turn, and in aggregate, give us a rich qualitative perspective of generating mechanisms. These levels of analysis are summarised with examples in Table 4.1. Furthermore, narratives aid our inquiry into the locational characteristics of the system. Narratives are created by actors in locations using a societal and often sectoral repository of language and myth with which society exercises consensus understood by other actors (Roe, 1994). One aspect of the analysis then is identifying how narratives are created, re-framed and performed to suit the emergent location of the system. Thus our analysis begins with the identification of relevant texts, in which narratives are located.

Table 4.1 Levels of narrative analysis

Level	**Definition**	**Example**	**Locational and other relevant narrative characteristics**
Text	Particular telling of a story by a specific narrator.	"Well put it like this the reason why wind has become so important is because private developers are driving it. If the private developers could drive private heat or transport I bet you it would be a lot further along but they are much more reliant on government policy to some extent or other. There was a big district heating project turned down by An Bord Pleanála recently just down the road here..." -Interview 130503	The actor and their location is identified. Wind framed as a sector driven by private developer.
Narrative	Version of an analytic story from a specific point of view	Private developers are the primary actor-group responsible for the growth of the wind industry	National government policy is and has negatively influenced the growth of wind technologies. Local planning decisions are preventing technological growth and diffusion
Analytic Story	Generic description of a particular set of events and their relationships.	Different actor groups influence to the emergence and growth of the wind RES in Ireland.	Events and relations are often located in a specific place
Generating mechanisms	Underlying structures that enable or constrain the analytic story.	The entrepreneurial activity function contributes to the emergence of the wind system in Ireland	National and local government, firms, publics influence system processes

4.1.3 Narratives and system activity

Through narrative analysis we gain analytic insight on how actors and networks influence and are influenced by events, from which the structural and functional analysis can then proceed. The goal of the narrative method is to identify the underlying generative mechanisms which produce the analytic stories of which the narratives are representative. In this task we follow (Pentland, 1999, p. 721) who suggests:

> "First, we need to pay attention to all aspects of narrative-not just sequence. Although event-sequence data are central to process, they are insufficient to tell a whole story. Other aspects of narrative, such as focal actors, narrative voice, evaluative context, and other indicators of context, are needed. Second, we need to be aware of the fact that stories may be their own best explanation. That is, agents may be actively attempting to reproduce particular templates of action that arise from their culture, their education, or their own experience. "

Actors and networks or coalitions of actors produced narratives for different audiences in different contexts for different purposes (Smith and Raven, 2012, p. 15). In other words, narratives are not objective representations of sequences of events; actors produce different narratives based on competing interests, in different locations and for specific purposes. Through the analysis of narratives and their characteristics, created or diffused by relevant actors, we generate insight on the aspects of the wind energy system located in Ireland that the actors themselves consider important and endogenous (Garud, Gehman, and Giuliani, 2014, p. 1185).

Narrative analysis also provides the basis for assessing the institutions of the wind energy system. Narratives often incorporate a particular framing of a system and its dynamics, and suggest particular ways in which these should progress to bring about a desired set of outcomes (Leach et al., 2010, p. 371). According to Smith and Raven (2012)

> "discursive strategies for institutional reforms are more likely to involve broader issues and problem frames, and relating (simplified) representations of the innovation in relation to them, as a part of a solution to broader social, environmental and economic challenges."

Thus narratives may be deployed by actors to criticise and reframe arguments away from historical associations. In short to align or dis-align goals, behaviours and attitudes with the interests of actors in the wind RES. Again, conflicting interests can often be evidenced in competing narratives[5], located in texts at industry conferences, academic journals, government consultations other events and in policy documents. We pay special attention to policy narratives, which make claims to tell what will happen if a policy prescription is followed (Roe, 1994). Accordingly, narrative certainty is often independent of representational certainty. This means a policy narrative is not debunked through truth, but rather, through the consideration of a plurality of policy narratives in the analytic story[6].

Thus we view policies and policy changes as a succession of new stories which actors interpret and re-interpret and through narrative analysis of the policy positions we seek to identify the underlying structures of belief, perception and appreciation which according to Schön and Rein (1995) are usually tacit and outside of the conscious thought of actors engaged in policy debates. Following the locating in the texts of narratives relative to the Irish wind RES, the analysis proceeds with the construction of the case narrative. This is a form of meta-narrative from which succeeding analysis and evaluation is done (Roe, 1994). The purpose of the narrative explanation is not to explain everything possible, but rather to distil and capture the explanatory content of the narrative, drawing on points that are relevant and sidelining those that are not. The case narrative clarifies sequences of events across geographic levels of analysis and is used to identify causal linkages between levels. (Pettigrew, 1990, p. 280). Furthermore, the case narrative facilitates analytic focussing on specific aspects of the case.

The narrative method used in this thesis is summarised in Table 4.2, where it is contrasted with event history analysis. Event history analysis is often used by TIS analysts (Negro et al., 2007; Suurs, 2009), and differs in a number of ways from the approach to narrative analysis outlined above. First, the unit of analysis is the event, rather than the narrative, where an event is an instance of rapid change with respect to actors, institutions and/or technology; which is the work of one or more actors; and which carries some public importance with respect to the system under investigation. Taking this approach results in some deviations in methodological process and output. For example, in this thesis, the

[5]Care must be taken with this assessment. Narratives are sometimes powerful when they can incorporate or accommodate different interests e.g. narratives of nationalism in relation to labour and capital for example.

[6]A critical realist stance is taken in the thesis, which asserts the existence of a reality independent of our knowing of it (Bhaskar, 1979). The need to convincingly interpret the material reality of others comes into the analysis. However, following Roe, the causality of interest to our analysis is that of a 'proximate nature', namely the parties to a given controversy take as a given the uncertain and complex nature of the topics they are debating (1994:10). A 'better' analytic story then is one which from the perspective of the analyst is deliberately methodologically tolerant of a plurality of narratives.

strength of functions are assessed based on the qualitative nature of the events and how they are framed in the narrative, rather than through aggregate counts of classified events[7]. This approach specifically enables an attribution of causal links across geographic levels where is may be inappropriate to compare aggregates of events in a lead jurisdiction with that of a fast follower. Furthermore, events may feature in more than one narrative, and the cause – as well as the interpretation of its causes and consequences – of these events may be contested. Indeed, the narratives employed in contesting the events provide useful information on the actors involved. Crucially for this specific case, event history analysis backgrounds the role of institutions in the system (Suurs, 2009), whereas the approach taken in this thesis specifically sets out to investigate the narratives that actors employ to institutionalise and deinstitutionalise knowledge and activities in the Irish wind RES. Institutions are at the heart of this analysis.

4.2 The case evidence

4.2.1 Sources and collection of data

The most powerful tool to assess narratives and processes are in-depth interviews and qualitative context analysis (Sydow et al., 2012; Yin, 2012). Both were employed in this research[8]. Initial studies in global wind technology development, the Irish energy sector and previous studies using the technological innovation system literature led to the creation of an initial historical timeline, the identification of significant sub-national, national and transnational events and influential or powerful actors. These acted as initial core data sets from which we strategically and iteratively accumulated further data. Narratives were located in texts in, for example, press releases, policy papers, mainstream and industry media articles and parliamentary records. These sources are summarised in Table 4.3.

Influential or powerful actors do not always commit to text, stories about themselves or their role in innovation processes. Therefore, semi-structured interviews were conducted with experts from appropriate wind RES stakeholder groups, with the exception of the current government whose role was assessed through interviews with policy experts, retired civil servants, retired politicians and evidence in the academic literature. Interviews were in-depth and ascertained personal histories and roles in the development of the wind RES as well as specific questions about actor strategies and institutional influences. Interview participants are listed in Table 4.4. Interviews were semi-structured, with core

[7] See Subsection 4.2.2 for details of how this was achieved.

[8] See Subsection 4.2.2 for details of how this was achieved.

Table 4.2 Comparison of event history analysis and case narrative analysis

	TIS Event history analysis	**Case narrative analysis**	**Application of case narrative to Irish wind case**
Unit of analysis	The event, an instance of rapid change with respect to actors, institutions and/or technology, which is the work of one or more actors and which carries some public importance with respect to the system under investigation	The narrative in which the event features.	Narratives are analysed in texts located in, but not limited to, policy documents, industry conferences, industry and mainstream media, interviews.
Core analytic practice	Identification, classification and sequencing of events. Events are used to indicate the presence of system functions.	Identification of narratives, their underlying analytic stories and characteristics such as frames, narrative voice and indicators of context. The narration of events are used to assess structural and functional aspects of system.	The characteristics of the narratives are well suited to analysing locational aspects of the system.
Analytic role within the TIS scheme of analysis	Identification and sequencing of events, which in turn allow the assessment of function 'strength'	Identification and qualitative assessment of events and the actors who narrate these	Characteristics of the narratives indicate actor strategies of institutional aligning, the emergence of powerful actors in the system, the formation of advocacy coalitions
Purpose of case narrative	Data organisation and validation tool.	The case narrative clarifies sequences of events across geographic levels of analysis and is used to identify causal linkages between levels	E.g. the case narrative allows us to assess EU and national policy narratives in parallel
Research design implications	Suitable for cross-case analysis, low number of case studies may result in 'loose' mappings	Suited to single in-depth case	Assessing the characteristics of narrative framing and re-framing is complex iterative work, requiring contextual knowledge of the system contexts thus is unlikely to scale well to multiple case comparison analysis
Examples in the literature	Negro et al. (2007), Suurs and Hekkert (2012)	Novel approach	—

Table 4.3 Primary and secondary sources of evidence

Evidence	**Nature of data**	**Sources**
Interviews	In-depth, semi structured interviews	–
Submissions to regulatory processes	Written submissions to consultations and other regulatory processes from TIS stakeholders and other actors	CER website, personal correspondence
Planning data	Comprehensive time series data of planning applications made by wind farm developers	SEAI Statistical Unit
Policy documents	Policy documents such as bills, directives, regulations and consultation process papers	Irish government, European Commission
Dáil records	Full text of relevant parliamentary proceedings in which wind and electricity sector feature in discussions	Irish parliamentary database
Newspaper reports	Full newspaper articles	LexisNexis database
Industry websites and magazines	Industry news, events, workshops, issues and press releases.	LexisNexis database, industry yearbooks
Conference proceedings and agenda	Notable speakers, thematic programming, agendas, industry news and workshop titles	Industry associations and websites
Industry reports	Attitudes to industry issues, proposed solutions, relevant actors listed	Industry associations and websites
Operational wind farm data	Time series data on wind farms, including location, activation data, owner, developer, turbine specifications, installed generation capacity	EirGrid, ESB Networks, IWEA, internet searches
Academic journal articles	Academic articles	Bibliographic search using Scopus

sets of thematic questions addressed to interviewees based on their geographic and sectoral location. These were transcribed and analysed using qualitative analysis software. Subsequent narrative based analytic tasks were carried out on the interview data as further themes emerged. Case interviews were conducted over the course of numbers trips to Ireland and Brussels and further telephone and email conversations took place with a number of interview participants, the purpose of which was elaboration or clarification of certain details. The database of interview text was the primary source from which narratives were analysed. These were checked against the periodicals and other media sources for additional, confounding or amplifying evidence.

A rich collection of narrative texts was gathered. Research on Irish wind generation has increased significantly since the first half of the 2000s. Because of this, a rich repository of secondary data is available for the second half of the study[9]. However, while policy,

[9]Essentially a collection of narratives about narratives,

Table 4.4 List of case interviewees

Code	**Role**
121201	Energy economist in a university
130102	Senior executive, domestic utility
130103	Senior executive, non-domestic utility
130104	Senior executive, domestic utility
130201	Policy strategist, government quango
130202	Former civil servant
130203	Engineer / practitioner, private practice
130204	Head of Ireland division, turbine manufacturer
130205	Energy consultant
130206	Energy economist in a university
130207	Academic
130208	Engineer / practitioner
130501	Economist in social policy think tank
120502	Energy academic, statistician
130522	Energy academic, engineer
130503	Developer and long-term owner of wind farm firm
130504	Chair / co-founder wind industry association
130701	CEO system operator
130717	Consultant wind farm developer
130703	Former senior civil servant
130722	CEO indigenous wind farm developer
130705	Planning consultant, academic at a university
130706	Former minister
130707	Energy academic
140714	System operator executive
140801	Energy policy advisor, private consultancy
140802	Energy policy advisor, civil society organisation, Brussels
150101	CEO, energy market services firm

economic and electrical engineering analysis is prevalent, the evidence suggests that rather less innovation studies literature exists on the topic. A systematic review of this literature was carried out. 215 relevant journal papers were identified using Scopus[10]. Results

[10]The following is one example of the type of query used: "TITLE-ABS-KEY("wind" NEAR "ireland"

were then exported to a local database and analysed for narratives, concepts, empirical setting, findings and so on. Furthermore, metadata such as academic affiliation and collaborations contributed to our knowledge of research networks and partnerships. These searches precluded books and book chapters, however, the snowballing method ensured a sufficient breadth of discovery. Policy documents in addition to formal bills and laws from the European Union, the Irish government and county councils were integrated into the case database. These were useful for chronological facts and cross checking, but susceptible to selective deposit and survival. Submissions to regulatory consultations run by the regulator, the CER, provided useful lists of actor networks and publicly stated positions. Finally, a full-text database of Irish and international periodicals for the period 1990 - 2013 was assembled using the search tool Lexis Nexis. A list of publications returned is detailed in Table 4.5.

Table 4.5 Data searches of the Lexis Nexis database

Publication type	Date	Texts returned
FT, Platts Renewables, newsletters	1990 - 2013	418
Irish mainstream media publications e.g. National newspapers, business and finance magazines, news websites.	1990 - 1999	488
Industry reports, Windpower Monthly	1990 - 2007	86
Industry reports, Windpower Monthly	2008 - 2013 17/11	498
Irish mainstream media publications	1990 - 1999	230
Irish mainstream media publications	1990 - 11/11/2013	208

Two sets of non-narrative data was integrated into the analysis. First a database of operational wind farm data was constructed, sourced from IWEA, SEAI, EirGrid and ESB Networks. This was a comprehensive ownership and developer information, technical specifications and connection dates for ~188 wind farms. Second, a dataset of 983 wind farm planning applications from 1990 to 2013 was used to assess actor activity at the wind farm planning stage. Each application contained data on the wind farm developer, the application date, and the planning decision. In all, an archive of over 900 digital artefacts

AND "electricity") AND (PUBYEAR = 2005 OR PUBYEAR = 2006 OR PUBYEAR = 2007 OR PUBYEAR = 2008 OR PUBYEAR = 2009 OR PUBYEAR = 2010 OR PUBYEAR = 2011 OR PUBYEAR = 2012 OR PUBYEAR = 2013 OR PUBYEAR = 2014)".

was assembled, including maps, photographs, conference proceedings, technical specifications, newspaper data, and other miscellany. Validation of this data was iteratively carried out throughout the research process, triangulating through the case narrative, actor narratives, secondary sources and data.

4.2.2 Locating and constructing narrative

The analysis of the evidence proceeded through steps of textual (or content) analysis, contextual analysis and through the function analysis of the TIS framework, interpretive sociological explanation[11]. The content of the evidentiary texts was assessed for what was said, the events and actors that were referred to and their relevance to the story of Irish wind. The analysis of context was pragmatic, the goal was to inquire as to why and also how (i.e. by what social processes) the narrative text has been produced and for what purpose (with regard to the Irish wind RES). Texts were interpreted on the basis of author and focal actor characteristics such as the framing of events, positions, intended audiences, and the contexts of the text production (or interview situation). Within the narrative analysis, it was not only important to account for subject positions and intended audiences, but also for structure positions, whereby the analysis of the narratives revealed which structural elements were 'in play', and what institutions remained fixed (Hajer, 1995, p. 55). Finally, the emergence of new narratives at points in the study may indicate social or political change.

The findings were assessed for both within-case validity and in comparison with findings in the literature. Points of uncertainty were returned to and the evidence interrogated afresh, or new evidence gathered, until we achieved stability in the historical account of the development of wind generation in the Ireland. Points of departure from expected findings were returned to for further in-depth analysis. Coding of the texts took two forms, first open-ended, in which emergent narratives were identified. In parallel, a number of pre-defined codes were utilised in order to identify theoretical concerns such as system functions, locations and actor relations. A database of case narratives was constructed from the analysis. Examples of typical texts and narrative coding are given in Table 4.6.

[11] In practise, these steps of textual analysis, contextual analysis and interpretation took place simultaneously with analysis going back and forth between levels rather than in a linear step-wise pattern.

Table 4.6 Example of narrative coding and analysis

Source	**Text**	**Narrative**	**Analytic story**	**Relevant contextual features of the narrative (Location, voice, actors, frames)**	**Relevant system observations**
Interview 130705	Well, [EU policy] has a big impact. You could argue that we don't do national spatial planning really in Ireland, in the sense, we have a national spatial strategy but it doesn't say you can't do this here you can't do that there, it's not the zoning map or anything. At the same time, we have spatial planning to the extent of protecting certain areas, or designated areas through the SAC and SPA directives. So special areas of conservation are very stringent and they come directly from Europe	1. A wide range of European policy strongly influences the development of the Irish wind system 2. The nature of Irish planning is project led rather than plan led and this influences how decisions are made at local county level.	1. The influence of European policy in Irish energy domains 2. The influence of Irish planning policy on the wind energy system	Expert opinion, based in Ireland with knowledge of European contexts. Narrator is not a government or firm actor, but has some (relatively neutral) professional take in the system.	Notable informal institutional effect of attitudes to planning European directives on habitats and wildlife influence the energy domain.
The Irish Times, May 8th 1999	Treasury Holdings owns large wind farms in Spain and Italy and has two smaller ones in Co. Donegal and Arigna, Co. Roscommon. It is planning two more in Co. Cork. The company will be able to avail of a tax break for investing in wind farms introduced in a recent Finance Act. Speaking to The Irish Times last night, Mr Richard Barrett, a director of Treasury Holdings, said the company would "devote a lot of capital" to its plans. "Most experts agree that demand for electricity will far outstrip supply in the next few years and there have been suggestions of a 700 megawatt gap in supply terms, we are undertaking our activities against that background," he said.	Narrative 1 (Mr. Barrett): The conditions and expectations for the future of Irish wind generation have given us the confidence to further invest. Narrative 2 (author of the article): Finance regulation changes is contributing to further investment in the wind sector in Ireland	1. How investment in the wind sector is influenced (by positive expectations of future returns). 2. How investment in the wind sector is influenced (by tax incentives).	Mr. Barrett evokes frames of economic growth and the positive associations of entrepreneurial investment. The author of the article presents the quoted text as fact and does not challenge the veracity of the statement. The development of the wind industry in Ireland is presented as part of a wider European industry.	Mr Barrett, a nationally known property developer is legitimising the wind industry with his public involvement and supportive comments. There is also weak evidence of resource mobilisation and positive institutional changes which support the Irish wind system

4.3 Operationalising the framework

4.3.1 Focusing the analysis

Given the substantial available data, and considerable scope for analysis afforded by the TIS framework, it is appropriate to focus the analysis on specific aspects of the problem. Three aspects of the research already discussed inform the focussing strategy. First, actors in the Irish wind RES in aggregate focalise many of the issue areas we need to analyse via narratives they construct and re-produce. We have discussed how actors themselves draw attention to aspects of the system they think important. As such, an important indicator of analytic depth required is gained from evidence in the narratives of what actors themselves think is significant. Second, the case narrative consists of empirically intriguing perspectives which are examined. These perspectives have been introduced in Chapter 2 and are explicitly stated and discussed further following the detailed narrative history presented in Chapter 5. Third, the literature review has shown us where documentation of system development is appropriate, and where there may be contested areas in which further analytic work is required. These approaches are further informed by the overarching aims of the thesis, to explain the rapid emergence of the wind RES in Ireland.

In combination, these approaches offer a robust assessment scheme to focus the analytical efforts. Furthermore, the combinatorial nature of these three approaches allows assumptions be tested along the way. Thus the analytic requirements of the framework are met in some cases by documenting aspects of the system development, whilst other more contentious aspects are analysed in greater detail.

4.3.2 Structural analysis

The core task in analysing the (TIS) structure is evaluating the alignment of institutions with actors in the Irish wind RES. This entails three tasks, the first of which is constructing the ensemble of institutions. The components of the system are identified in the evidence and an analytic ensemble of institutions is built. To assemble this ensemble, we compile policies, regulations, values, norms, beliefs relevant to the RES and disaggregated by geographic levels, in Ireland and Europe. These are mapped over time from 1990 to 2014 and ordered according to geographic level and institutional type, so that we have three discernible groupings, European regulatory, Irish regulatory and Irish informal institutions. Second, the shared system goals (or needs) of actors are assessed from narratives, the underlying analytic stories, and analysis of the case narrative for each phase of development. Third, we assess the influence of the institutional ensemble on actor goals in order to assess alignment and changes to alignment over time. This analysis gives us a perspectives on the nature of change in the system structure over time, including the speed of institutional change, and a whether that change was endogenously or exogenously directed and influenced by which actors and events. Ultimately this allows us assess the consistency and inconsistency of institutions at different phases of the history, something we do not a priori assume to be constant over time and space.

The evidence required for the institutional analysis is found in texts created by actors, of lobbying of and by policy actors and other policy processes, and through other historical accounts. As we have discussed, the actors in the Irish wind RES are not a homogenous group. The required level of institutional analysis necessitates the gathering of details from the evidence of who these actors are, their capabilities and opportunities they perceive in the system. In the analysis we delineate this evidence along both sectoral (i.e the wind industry) and geographic lines; we expect that knowledge of local geographies, cultures and institutions create certain advantages. Special attention is paid to formal networks such as industry associations and advocacy coalitions which often have political agendas and again, indigenous and transnational networks are identified. In summary, the structural analysis builds on the rich description of the development of the wind RES given in the case narrative to explain how the institutions of the system changed over time, and how they aligned with the goals and needs of actors who make up the system.

A set of core analytic stories – the generic description of events and their relationships – were (analytically) constructed[12] as part of the process of analysing the actor narratives These are summarised in Table 4.7.

Table 4.7 Analytic stories of Ireland's wind system

Ref.	Analytic story	Exemplary narrative/text
A-01	The interpretation of Ireland's wind resource endowment	ESB research suggests 2.5GW RET possible on Irish grid (S1-315)

[12]This followed a process of mapping and analysing approximately 150 narratives found in the interview text and in the database of documentary sources.

A-02	The influence of EU technology demonstration and support schemes	"[The minister] was actually out here. He stood up and he was promoting how Irish developers should apply for THERMIE grants and there was money available from EU for these developments and I stood up then and said "Well, what's the point of applying for these grants", I said "We have these grants now" I said "but we still can't build, we can't get a PPA so what's the point? It's just ended up a waste of our time and the money and stuff going back to the EU." (Interview 130717)
A-03	The informal processes of access to the grid	"The company has accused the state-owned Electricity Supply Board (ESB) of restricting the development of renewable energy because of high costs to use its network." (S1-276)
A-04	The role of turnkey technologies and the influence of manufacturers	"The farm was built by the German company Thyssen Rheinstalh Technik, under a turnkey arrangement, with Elsamprojekt as project managers." (S1-403)
A-05	Joint ventures with overseas firms	Irish Thermie winners are JVs (S1-305)
A-06	The construction of the story of what the Irish wind industry is	"The reason why wind has become so important is because private developers are driving it. If the private developers could drive private heat or transport I bet you it would be a lot further along but they are much more reliant on government policy to some extent or other." (Interview 130503)
A-07	IWEA's role in the wind industry	"Developer firms shout the loudest at IWEA meetings, have the most influence, bang fists on tables" (Interview 130204).
A-08	Planning regulations (as barriers)	"At the same time, we have spatial planning to the extent of protecting certain areas, or designated areas through the SAC and SPA directives. So special areas of conservation are very stringent and they come directly from Europe." (Interview 130705)
A-09	National technology support mechanisms	Airtricity announce they are to start domestic development work again following the introduction of the REFIT (S1-215)
A-10	The EU market liberalisation agenda	"We [DCENR] turned the ESB around, we turned its strategic direction around. It was easier to do that because they were kind of reading it in a, from a variety of different streams [referring to the EU]." (Interview 130706)
A-11	The influence of macro economic growth	"Most experts agree that demand for electricity will far outstrip supply in the next few years and there have been suggestions of a 700 megawatt gap in supply terms, we are undertaking our activities against that background." (S4-37)
A-12	The influence of the RESG	"...policy-wise that was the most significant development that took place and everything that happened derived from that." (Interview 130501)
A-13	The influence of the moratorium on the Irish wind sector	"The commission introduced a moratorium on new connection offers to renewable energy projects in December 2003 following exponential growth in applications for connections to the national grid, in particular from wind farm projects." (s1-221)
A-14	The influence of the CER's regulation of industry	"The CER was saying 'Look, I'm not responsible for the law. I'm following the law here.' (Interview 130703)

A-15	The influence of Irish research	The influence of the younger people and in particular the PhD. students who would have been those of Mark O' Malley's, they started to have a big influence in EirGrid and even though ESB was less positive [the graduates] were very significant in terms of 'look at what's happening, this thing has real potential'..." (Interview)
A-16	European energy policy and processes	"...but ultimately the evolution of the sector is being driven by Europe and European target." (Interview 130103)
A-17	The grid allocation process	Gate 1 selection criteria straightforward, and fair (Leahy, 2010)
A-18	The role of the SEM	"The single energy market, there was a political and other commitment and, well, I suppose what began to happen then is that forced the issue around the different approach to renewable in Ireland and the UK." (Interview 130703)
A-19	The impact of the recession	"that was pure financial cost of money for banks was just too expensive and there was no long term money out there or whatever. Which again, introduced an additional risk factor into the project finance in that nobody knew what's going to be there in ten years" (interview 130722)
A-20	Industry consolidation	Headline: "Big boys lead development pack". (reNews Ireland Focus, 20 June, 2013)
A-21	Wind as export commodity	Wind for export will create jobs according to Mainstream
A-22	The impact of increased interconnection	"It's critical for our delivery of targets on wind energy ... the levels of curtailment that ehm would occur to meet our 2020 targets without the East West Interconnector would be unacceptably high and it would be infeasible to finance wind farms." (Interview 130201)

4.3.3 Summarising the analytic strategy

A number of analytic tasks have been discussed in this chapter, the aggregate goal of which is to produce an understanding of the systemic dynamics of the emergent wind RES within and between Ireland and transnational players. We bring these together here in summarising the overall process of analysis employed in the thesis. First, evidence containing narrative texts is gathered from sources. Narratives within the text, which frame processes relevant to the wind RES in Ireland, are analysed and a range of characteristics recorded. The narratives contribute to a case database of analytic stories, narratives and characteristics. Narrative evidence of these processes are collated into a case narrative history. We now have two analytically constructed sources for our analysis of the structure and functions of the innovation system. The analysis of the structure of the Irish wind RES proceeds through the documenting of the activities and goals of the actors and actor networks and the construction of an analytic ensemble of institutions. I identify when and under what circumstances and actor strategies the ensemble of institutions is aligned (or misaligned) to the goals of wind RES actors. The function analysis follows. The strength of the functions are assessed through qualitative analysis of the actors' accounts of system events. The Irish and transnational re-production of the functions is dis-aggregated and the system function mapping is done though following the individual functions in the narrative history along with other ancillary evidence where required. This functional pattern is internally compared though the phases of development of the system, and is externally compared against other studies which have used the technological innovation system framework. The system level assessment of system functionality, and inducement and blocking mechanisms is made.

Based on the extended theoretical framework, I present my overarching scheme of analysis (Figure 4.1). Relevant findings from this analysis are discussed over the course of the next three chapters. In Chapter 5 we introduce the case narrative, focussing on aspects of the development of the wind RES in Ireland. In Chapter 6 the actors, networks and institutions are analysed, focussing on the causes and impacts of institutional alignment between the wind RES actors and structural and contextual institutions. In Chapter 7 I discuss the function analysis, assessing the distributed nature of the functions and the result this has on the pace and nature of the development of the wind RES. Throughout the analysis I make use of the rich case narrative (indicated in the Figure 4.1 by the circular flow of some processes within the analysis), though this analysis is discussed in a linear manner to accommodate the material nature of the thesis.

4.3.4 Function analysis and narrative performance

The function analysis builds on the detailed structure analysis. It follows closely the scheme of analysis presented in the review of the literature. In describing the operationalising of the framework we therefore focus on aspects of geography and narrative that are novel to this research. The first task is identifying and assessing the strength of the system functions. Evidence for this task is found primarily in the narratives of the actors. Where this is insufficient, the case narrative is used to draw insight on how a particular function is performing. I consider the assessment of function strength in detail. The identification of system processes or related activities in the case narrative or other evidence analytically guide us to system functions (see the tables presented for each system function in Chapter 3). It is not only the quantity and scale of given events that allow us to assess the strength of functions in the system but how these events are framed in the narrative. Take for example the mobilisation of resources function. A exemplary event indicating the presence or strengthening of this function is a bank loan. The cumulative number of loans made

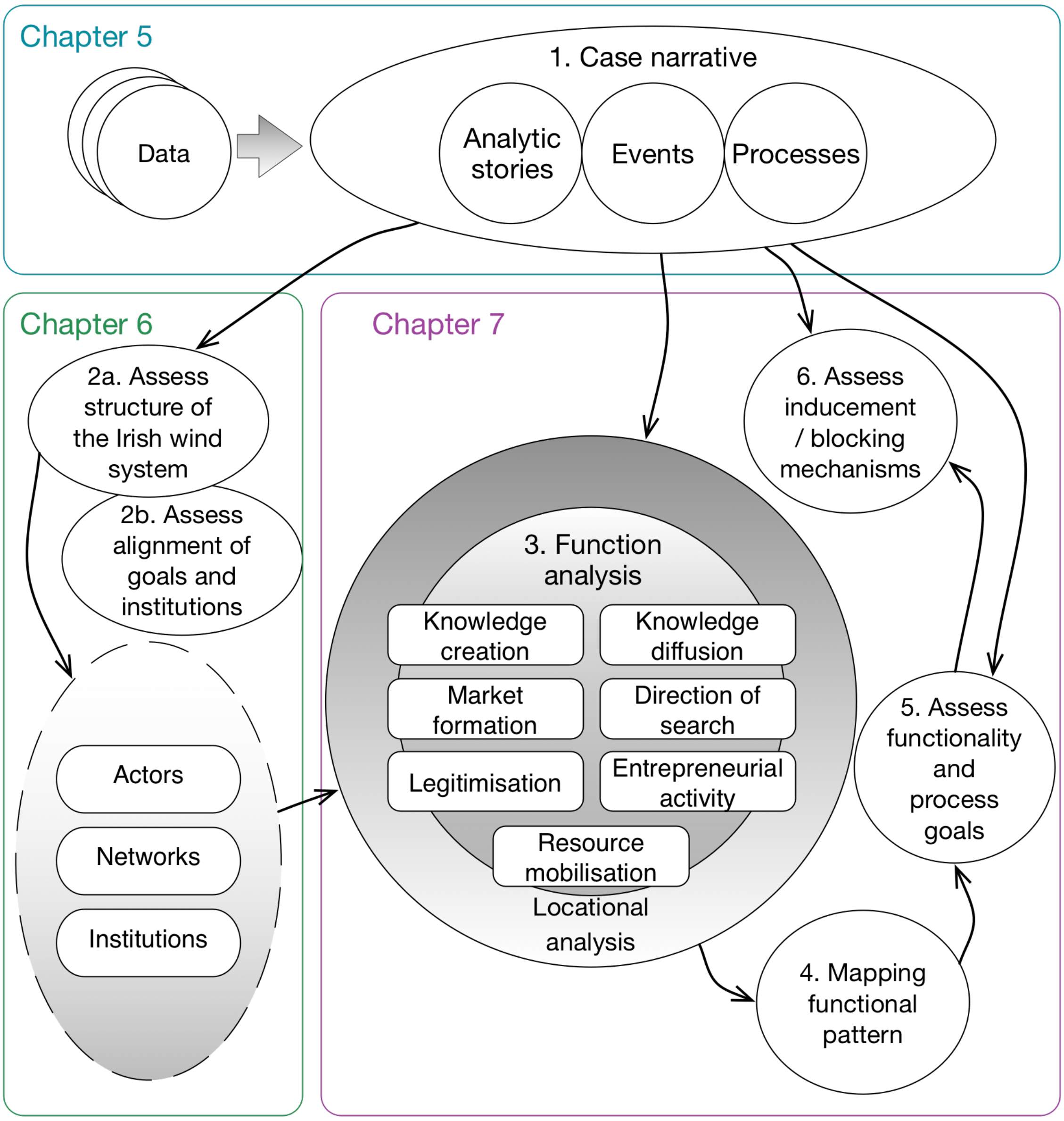


Figure 4.1. The case-specific scheme of analysis

during a given period is therefore an indication of the strength of this function. Qualitative characteristics of this event also matter. For example, which financial organisations lent these loans, the conditions of repayment, favourable or negative attitudes of developers to these loans, characteristics of developers who received loans and those that did not are all relevant details of the function we might find in the narratives. To determine the strength of the function, we use an assessment of the framing in the narrative, arrived at in an iterative and abductive manner. This approach allows for both the documentation and in-depth analysis of functions where required.

The literature has strongly suggested that emergent locally specific TIS are often dependent on distributed system formation processes. Therefore the geographic distribution of the functions are mapped using locational detail produced during the narrative analysis of the functions and emergent structural analysis. We carry out an internal comparison between Irish and transnational functions, in turn addressing the role of location in functions and assess which functions are produced locally and which functions must be produced locally. We also compare function mapping derived from this case with others TIS-based analysis in the literature in order to provide some indication of why system development in one location may proceed at a different pace and with different system characteristics to others. Finally inducement and blocking mechanisms are analysed. The structural analysis has identified relevant actors and institutions. From the evidence we identify strategies and motivations for how and why actors engage in these mechanisms and assess the impact of these mechanisms against the performance of the Irish wind RES.

Finally, since the function analysis is based on narrative analysis, the methodology can be strengthened by pointing out how narrative matters and performs. The starting point here is that coalitions form around analytic storylines, bringing with them their own narratives (Hajer, 1995). If specific narratives mobilised by actors or coalitions consider a TIS function to be weak, then this may indicate mobilization and activity to address that function, either to strengthen it, or if the coalition is in opposition, to weaken the function. By working with the narrative evidence mobilised, we can trace that activity and see who is doing this. This provides valuable insight into coalition composition, and crucially, how that composition changes over time. This is useful for example in identifying when incumbent actors shift, sometimes slowly and in a piecemeal fashion, from positions of opposition to support Indeed, this is something that an event analysis misses entirely.

Wrapping up

This chapter has explained how how the conceptual perspectives discussed in the research framework are mobilised in order to address the research task. Process theory is an appropriate approach to take, and we discussed at length a suitable form of narrative analysis with which to carry this out. Indeed, with greater emphasis on actor narratives, the case-specific methodology proposed brings with it certain advantages over an alternative event history analysis approach common in many technological innovation system studies, particularly in studies of later stage innovation processes, such as this. The case evidence was introduced, locations to find and identify relevant texts, in which narratives are located. The thesis offered a robust and practical scheme to focus the analytical efforts, in which the analytic requirements of the framework are met in some cases by documenting aspects of the system development, whilst other more contentious aspects are analysed in greater detail. Approaches to structural analysis and functional analysis were Finally, we documented the core analytic stories – the generic description of events and their relationships – which were (analytically) constructed as part of the the process of analysing the actor narratives.

The scheme of analysis presented here underpins the entire thesis. As discussed above, the process of discover and analysis was iterative rather than linear. However, for the purpose of clarity, the processes and findings of these analyses are set out in clear sequential order over the next three chapters. The narrative history of Chapter 5 highlights actor narratives and conveys to the reader the salient features of the Irish wind electricity system. Chapter 6 organises and discusses the structural analysis and Chapter 7 does the same with the functional analysis. We briefly remark on the utility of the scheme, and the research framework, when wrapping up in Chapter 8.

Chapter 5

A narrative history of Ireland's wind energy system

This chapter is a narrative historical account of the development of the Irish wind sector. Through the narrative we discuss the actors, institutions and technology which influenced the establishment of the wind industry in the 1990s and the rapid roll-out of technologies through the 2000s. In short, it tells the story of who did what to whom in relation to the emergence of Irish wind energy system. The focus in telling this story is on the actors, institutions and technologies *in* Ireland and influential flows of actors, resources and knowledge across its borders. Wider social and economic contexts are introduced and discussed where appropriate. The stories of the case narrative are organised using a periodisation scheme. This theory-driven periodisation technique is methodologically common to many innovation systems studies and to narrative histories more generally (e.g. Hekkert, Suurs, et al. (2007)). I have defined four periods in the study (see Figure 5.1) through reflexive interpretation of the historical data, and guided by previous empirical studies and the wider literature.[1] This periodisation scheme is further utilised in the analysis chapters, six and seven, as an heuristic tool with which differentiate phases of system development, primarily from a structural perspective (i.e. reflecting the actors, institutions and technologies within the system, rather than system processes), to address evidence and narratives in historical context.

[1] Ó Gallachóir, Bazilian, et al. (2010) have provided a useful template in this regard. Their comprehensive treatment of early policy instruments aligns with the first three phases of development in this thesis.

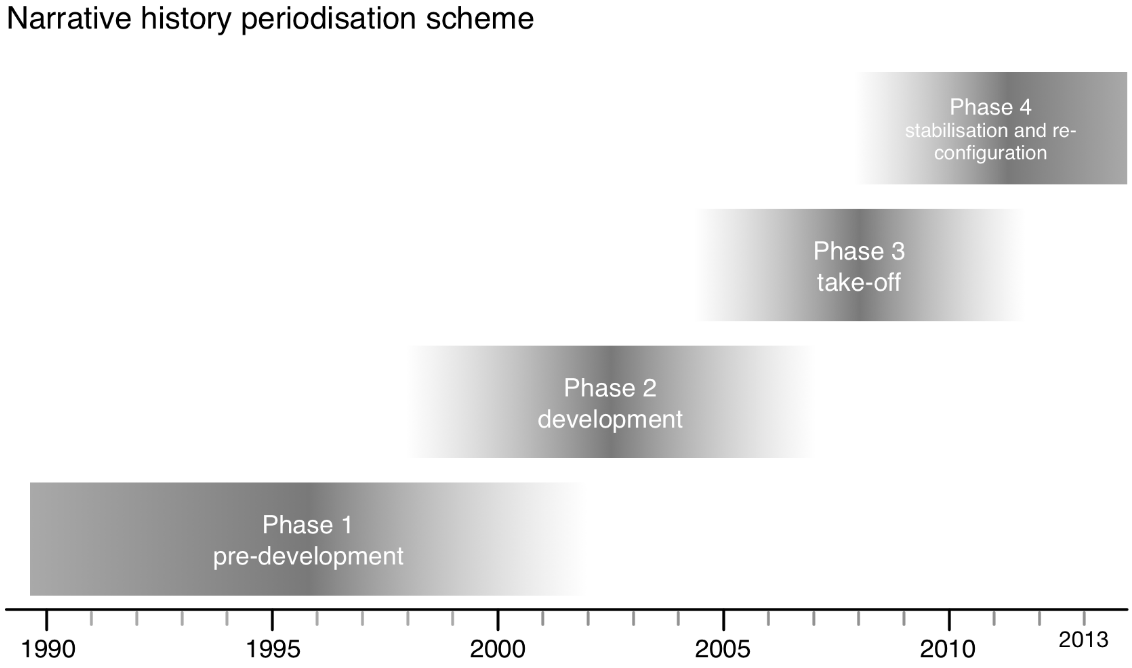


Figure 5.1. Periods of development used to organise the narrative history of the Irish wind industry.

The case narrative is made up of collated stories located in evidentiary texts and interviews. From these we identified the premises and beliefs of actors which in turn provides analytic evidence about the underlying innovation processes and causal relations within and influencing the wind sector. Narratives featuring renewable technologies in Ireland have been located in studies of demonstration projects and nuclear debates of the 1980s (Staudt, 2000; Hurley Staudt Associates, 1988), the oil crises of the 1970s, and as far back as Siemens' work on damming the Shannon river in the 1920s (Shiel, 1984). This research picks up those narrative strands in the 1990s as Irish actors begin the commercial exploitation of wind. We lead-off each chapter section with a graphic illustrating the plant diffused during that period. The intention is not to privilege the material over other aspects of the innovation system, but rather to set the scene before showing the other components and activities that were brought together.

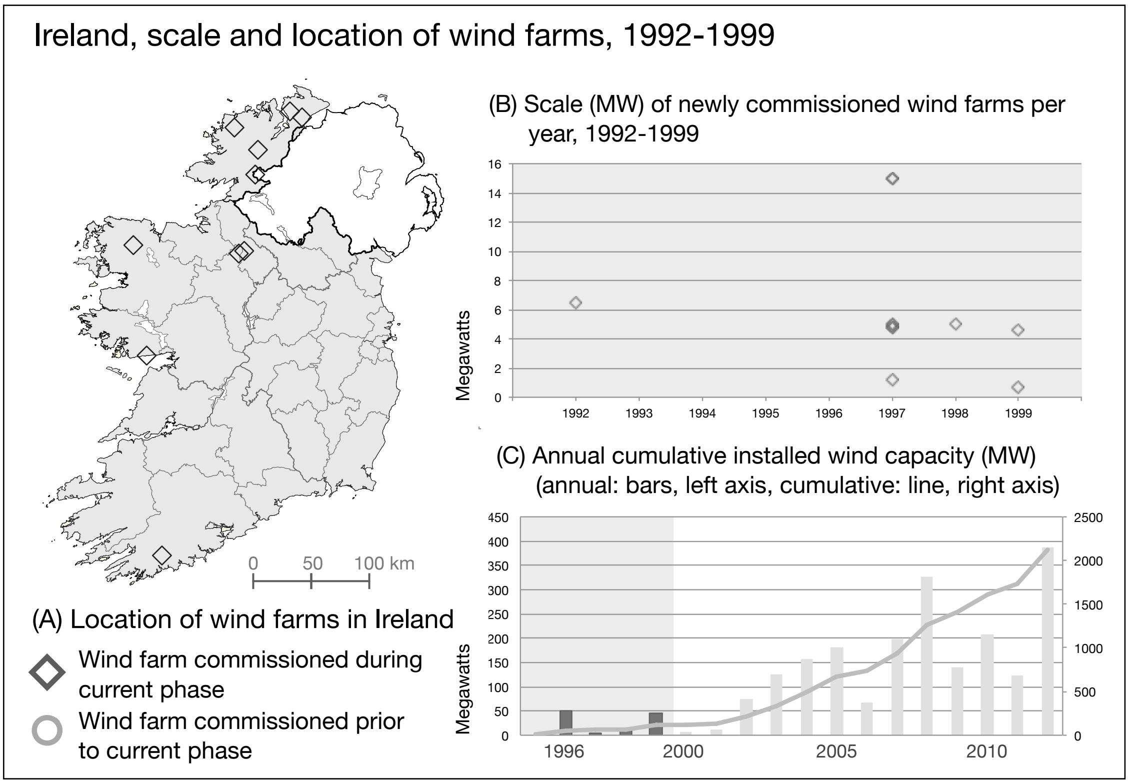


Figure 5.2. Scale and location of wind farms built 1992-1999. Source: EirGrid, IWEA, Meithel na Gaoithe, SEAI.

5.1 Period 1: 1990 - 1999

5.1.1 Demonstration and development

Bellacorrick, Ireland's first modern wind farm, was connected to the national grid in 1992.[2] The project was built on land owned by the state peat utility Bord na Móna located close to an existing thermal plant in the north west of Ireland (illustrated by the most westerly diamond in Figure 5.2(A). It consisted consisted 20 turbines totalling 6.45MW generating capacity. The surrounding topography was ideally suited to the construction of masts, wind speed was excellent and existing network infrastructure made connection to the national grid affordable[3]. As both a demonstration and commercial project, Bellacorrick was regarded as a success by many of the actors in the nascent sector and it forms part

[2]Source: S1–420

[3]Existing grid infrastructure was critical to the success of early projects and in this case the site was co-located with a peat-burning thermal power station which meant connecting to the Transmission Service Operator (TSO), ESB National Grid, was more straightforward than many subsequent builds, an issue which was later to become a significant barrier to industry development.

of a creation story that continues to be told[4].

Bellacorrick is noteworthy because it was the first wind farm, and also because within its narrative we can observe the disparate actors, relations and institutional influences of a formative innovation network. The project was managed by a trans-national consortium led by Danish power utility Elsam. The technical and commercial 'know-how' for the project came from Denmark and Germany; construction was carried out by the German firm Thyssen Rheinstalh Technik, with Elsam subsidiary Elsamprojekt as project managers. Danish manufacturer Nordtank supplied the turbines under a turnkey arrangement and also took an equity stake. Project costs were IR£7.1 million, 55% of which came from the European Community, which included a VALOREN[5] energy demonstration programme grant (Burke, 1989). The wind farm was originally operated by Renewable Energy Ireland Ltd, in which Nordtank and Elsamprojekt were the main shareholders with Bord na Móna also taking IR£250,000 of preference shares in the project. Finally, the location of the project at Bellacorrick was influenced by Ireland's energy minister Bobby Molloy, who was perceived by some actors[6] as favouring a region close to his own nearby constituency, East Galway[7] (Byrne, 2012; Laffan, 1996). Aspects of the project were explicitly and implicitly replicated over the course of the decade that followed. Notably joint ventures with European engineering and wind consultancy firms were common during this time, and European funding featured in the majority of projects built in the 1990s. Furthermore, in 1994 Nordtank sold their stake in Renewable Energy Ireland – at a profit – to US developer New Wind Power. In doing so they implicitly demonstrated a development model of project construction followed by the sale of the fixed asset which a number of actors attempted to replicate.

The establishment of wind as a significant source of electricity in Ireland had been the goal of a small number of actors stretching back through the 1970s and 1980s. Amongst long-time actors in the sector the oil crises of the 1970s was a common reference point for spurring interest in new low-carbon technologies, as in other locations where formative re-

[4] In interviews and secondary historical accounts of the industry, Bellacorrick is the single most cited wind event in the first half of the 1990s, and continues to be used as a narrative event by actors throughout the study.

[5] Council Regulation EEC No. 3301/86 27 October 1986. The cumulative European Commission funding allocated to Ireland under the VALOREN programme (Council Regulation (EEC) No. 3301/86) was 25 Million European Currency Units (MECU). Ireland's share represents 6.25% of the total programme (Burke, 1989).

[6] Interview 130717.

[7] It is a characteristic of Irish political culture that localism and clientelism is often perceived in decision making, whether intended by the political actor or not (Byrne, 2012; Laffan, 1996).

newable technologies have emerged (Est, 1999). Actors in Ireland were further motivated by a belief that Ireland's wind resources were amongst the world's best (Gibbons, 1979; IDA, 1978), a powerful analytic story, evidence for which was found throughout the period of study (an early study of Ireland's wind resources was presented in a 1978 conference on renewable resources, page 1 and 27 of the conference programme is shown in 5.3). At the end of the 1980s a small informal network of renewable energy enthusiasts were active in Ireland (Comhar, 2011). This included a number of US and Danish nationals who had migrated to Ireland and brought with them formal knowledge of wind technologies and industry contacts in their home nations[8]. These were engineers and lay-enthusiasts some of whom were inspired by ideas such as those of Amory Lovins (1977), and believed small scale distributed electricity could play a role in Irish industry and society heavily dependent on imported fossil fuels. Others meanwhile were inspired by commercial and community level exploitation of wind resources in Denmark.

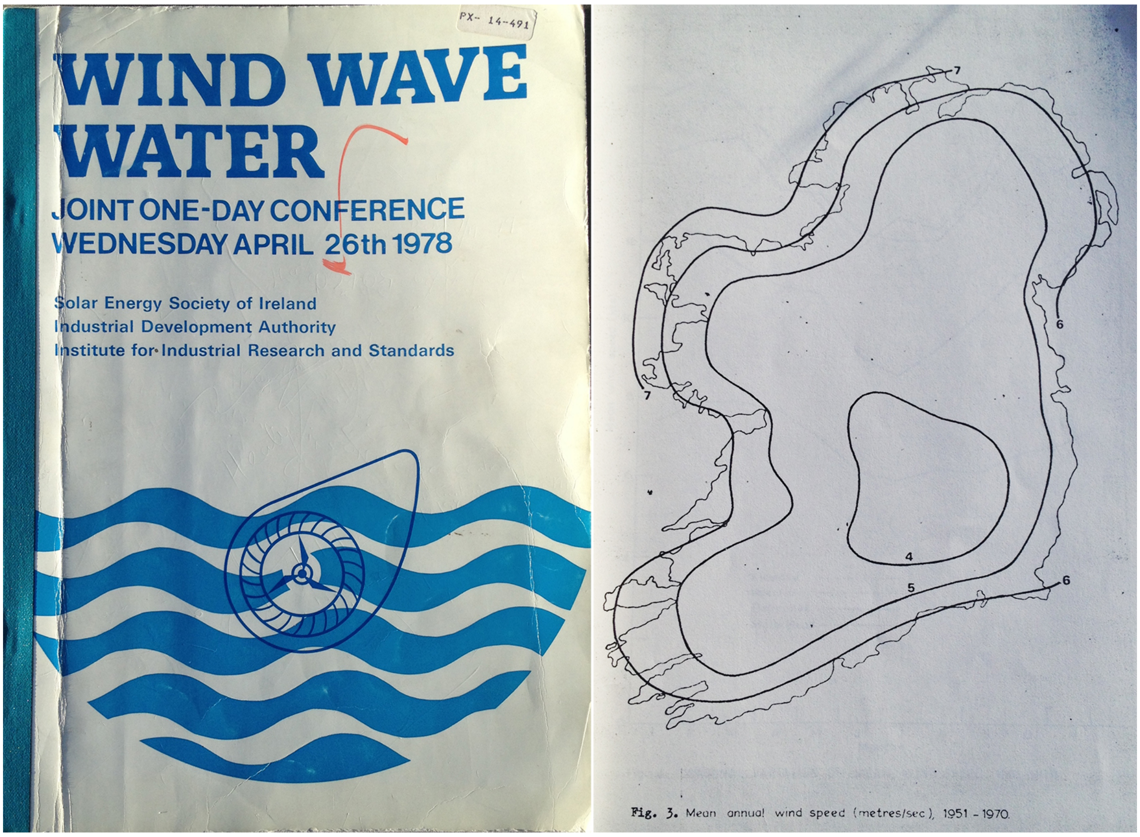


Figure 5.3. Wind water wave Conference programme. Solar Energy Society of Ireland 1978. Page 1: front cover. Page 27: mean annual wind speed per second, 1951-1979.

While Bellacorrick was the first commercial scale plant to be built, there were other

[8]Interview 130707, 130717

projects in development, also bidding for limited European and domestic demonstration grants such as ALTENER, VALOREN and THERMIE. Through the early 1990s, these projects led to an influx of new actors allowed a small informal network to evolve into, what one interviewee called, a 'cottage industry'[9], with specialisation of roles and specialised knowledge such as engineering and grant application writing. While long-time wind advocates continued to mobilise narratives based on sustainability and Ireland's wind resources, Bellacorrick was at the heart of new narratives about commercial opportunity which mirrored contemporary expectations about wider industrial growth in Ireland.

At this time Ireland had little manufacturing base and no energy generation sector apart from state owned utilities. Wind farm developers came from a variety of sectors and brought with them a range of capabilities and access to professional networks. For example, agricultural services firms such as South Western Services (SWS) brought with them experience and knowledge of generating non-agricultural income from farmland[10]. Property development firms such as Treasury Holdings sought opportunity where land availability and tax incentives could be combined to generate returns.[11] Furthermore, they were capable of lobbying for changes to regulatory arrangements favourable to their interests. Individually and often in partnership, actors contributed to the developing sector by travelling between ancillary sectors such as finance, politics and technology in efforts to acquire the knowledge and finance required for successful projects. Commercial ambition was a common motivation across the sector, but some actors were also driven by a motivations of "doing the right thing[12]". A report in 1994 accounts for this entrepreneurial development activity thus:

> "An entrepreneur will typically get an option on a wind site, prove sufficient wind capacity, get planning permission, at least in outline form which is simple and cheap, interest a local group, probably an agricultural co-op, and a foreign wind company, probably Nordtank or Vestas, and then sell out the interest."[13]

While many actors entering the industry took a long term investment view, shorter term speculation was also common, referred to in a derogatory manner by one interviewee as a

[9]Interview 130202

[10]Interview 130722

[11]Interview

[12]Interviewee 120202 made a point that despite reputations as tough deal makers focussed on commercial success, for some property speculators wind investments were made in part because of environmental or social concerns.

[13]Financial Times Energy Newsletters, 12 August 1994

'land-grab'[14].

The Bellacorrick development model also served as a beacon to other overseas firms that Ireland's wind resource endowment was capable of being exploited. The project team that developed the Tursillagh wind farm in Kerry is illustrative of an emerging transnational partnership model. Tursillagh was a 50/50 joint venture between Kerry-based start-up firm Saorgus and UK utility Power Gen Renewables. In this case, Saorgus already had a site located and knew the county planning application process. They required Power Gen to bring in the project construction and financing knowledge in order to win an Irish government-backed capital grant. Power Gen also supplied an engineering consultant[15] and equity finance as well as bridging finance which was required under some Irish grant schemes. However experience acquired developing wind farms in other countries did not guarantee success in Ireland as the following example shows:

> "One particular example was a company who were based in the States and had absolutely no local knowledge so they proposed a wind farm and it got offered one of these contracts on Slieve na mBan on the mountain in Tipperary, there were songs written about that mountain, there was no way in hell it was gonna have a chance. They withdrew the planning application rather than waiting for the rejection, so it was an interesting dynamic where you had a project that had secured a contract if you like, if it could get off the ground, but the planning process happened afterwards you know and this was another thing that was characteristic of wind energy."[16]

This narrative text illustrates the speculative nature of the industry in Ireland. Evidence of prospective commercial activity at this time has been documented in planning application records.[17] In total throughout the 1990s, 48 individual actor groups submitted planning applications to county councils for 68 wind farms[18] (see 5.4). Motivations and drivers of actor behaviour were the perception of successful business models, a favour-

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[14] Interview 130203

[15] UK firm Wind Prospect were employed as engineering consultants in 47 Irish wind projects through 2014, approximately 25% of all developments.

[16] Interview 130522a

[17] A planning application dataset compiled by Sustainable Energy Ireland Statistical Unit was used in this case.

[18] The low level of refused applications is notable. County planning boards were reluctant to outright refuse planning permission, in part because during this time they had no formal guidance as to how to address wind applications. However stringent conditions of approval were often enough to ensure projects were financially untenable.

able economic investment landscape and the belief that there was national and European funding available to augment or substitute personal investments. Activity was enhanced by two factors. First, feasibility studies could be funded by the EU's Leader Programme,[19] allowing landowners to explore the commercial viability of projects at a low cost. Second, the cost of planning applications in many counties was negligible, and in the 1990s, many councils did not have formal guidelines on where wind could, or could not, be built. However, by the turn of the millennium, only ten wind farms were operational. Three dominant barriers to development were found in the evidence; problems attaining planning permission in sufficient time to enable commercial development, access to the national transmission grid, and the lack of availability of power purchase agreements.

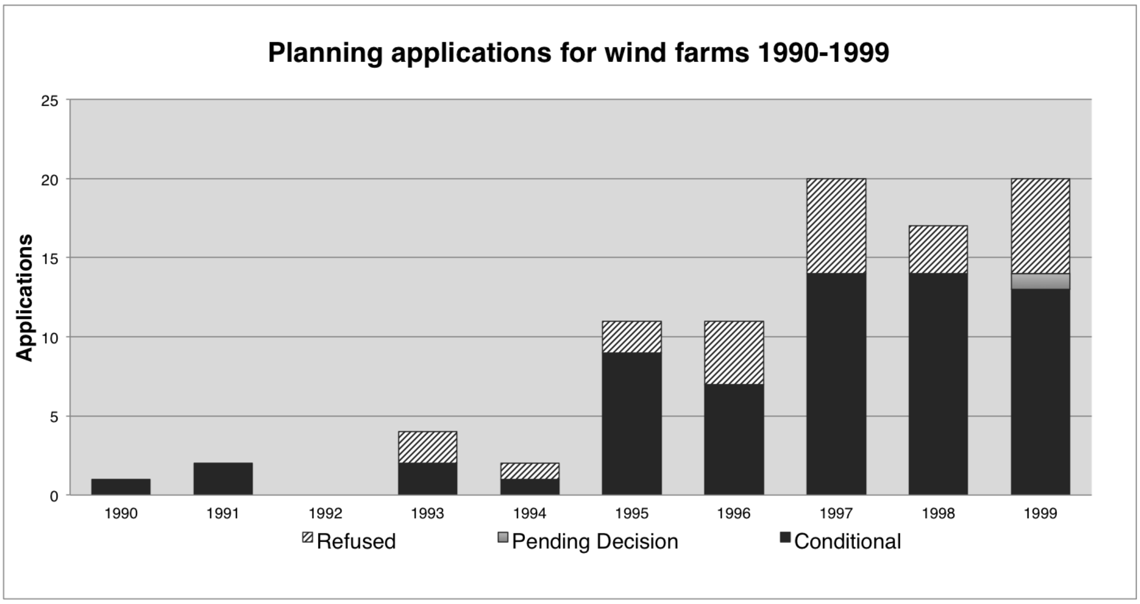

Figure 5.4. Planning applications submitted to county councils throughout Ireland from 1990 to 1999. Typically permission for development was not granted outright, but rather "conditional" on given constraints or requirements. Source SEAI 2013.

5.1.2 Interests, incumbents and institutions

Developments at the firm level in Ireland took place against a backdrop of large-scale energy industry and institutional change in Ireland and throughout the European Community. Liberalisation in the United Kingdom's energy sector in the late 1980s was observed by Ireland's state owned monopoly enterprises (Hunt, 2012). They saw aspects of

[19] LEADER ("Liaison Entre Actions de Développement de l'Économie Rurale", meaning 'Links between the rural economy and development actions') is a local development method which allows local actors to develop an area by using its endogenous development potential (European Commission, 2007b).

the UK's 'free market' agenda adopted and integrated into the EC's single market project, culminating in 1996 with the Electricity Directive (European Commission, 1996) which set minimum requirements to open national markets to competition. The rationale for open national markets was threefold; a) more competitors in a market would result in greater competition, b) there was a presumption that all new entry to the market by new firms was beneficial for users and c) the introduction of competition was the best means of removing economic rents and to achieve real reductions in cost or economic efficiency (Shuttleworth, 2000). Irish incumbent utilities such as the Electricity Supply Board (ESB) perceived both threat and opportunity from coming market liberalisation[20]. Opportunities came in the form of foreign expansion into Northern Ireland, and ultimately overseas into markets in Spain and Poland. Threats came from new competitors at home, from renewable based generators on one hand and from new combined cycle gas turbine plant operators on the other.

This competitive context and the liberalisation agenda forms the backdrop of formal and informal negotiation[21] between the Department for Communications, Energy and Natural Resources[22] (DCENR) and the ESB in the mid–1990s. For historical reasons linked to their role and one of the state's largest employers and monopoly position in an industry without independent regulation, the ESB exerted, according to Hastings, "a collaborative leverage against the political system" (Hastings, 2003, p. 39). In discussions on Ireland's energy future, the ESB – both management and unions – asserted a level of capture over the department, countering calls for increased wind generation in the early 1990s. The utility asserted a high level of influence over both price setting and the course that market liberalisation processes would take in Ireland. The ESB was a powerful incumbent actor, who perceived little strategic advantage to be gained from emergent generation technologies. As such, strategically addressing threats or opportunities from advocates of wind energy was not a priority of the ESB senior management. However, significant levels of wind development could not proceed without some level of buy-in from the ESB. In a vertically integrated industry where they managed the distribution

[20]This view was substantiated in a number of interviews and informal conversations.

[21]Following a 1992 McKinsey report commissioned by themselves, the ESB consolidated internal operations into five distinct, wholly owned business units. This was followed by a contested three year cost and competitiveness review from 1996 to 1999. This forms part of a wider national narrative of state sector renegotiation as the wider economy went through unprecedented growth.

[22]The government department charged with responsibility for energy has had a number of name changes throughout the period of study. For clarity and consistency, I refer throughout to the department name at the end of 2013, the Department for Communications, Energy and Natural Resources (DCENR).

and transmission networks and customer relationships, the ESB were responsible for all new grid connections and power purchase agreements, two of the three significant barriers faced by the industry.

The ESB's reticence to connect new generators was manifested in contestation over wind integration targets between the DCENR and the utility. These arguments were a feature of policy debate over the course of the decade[23] as the ESB mobilised narrative frames suggesting the integration of commercial levels of wind power was a 'technological impossibility[24]' (E.O'Dwyer et al., 1990). The DCENR persisted in challenging these narratives, driven by three factors. First, increasing economic growth through the 1990s drove electricity demand. Second, the European market, energy and environmental policy all pointed to a need to increase the share of renewably generated electricity in the national energy mix. Third, the Irish wind lobby, which was growing in size and voice, presented wind as an indigenous solution to these policy problems.

A group of wind farm developers founded the Irish Wind Energy Association (IWEA) in 1992, encouraged by the material existence of Bellacorrick, but frustrated by the slow progress of their own projects. Through the 1990s the association was run from the homes of members, initially on a voluntary basis and became a location for knowledge sharing, coalition building and political lobbying[25]. IWEA was also a conduit for network activity between Ireland and other European countries. In 1994 they joined the European Wind Energy Association (EWEA), and in 1997 hosted the EWEA annual conference in Dublin Castle, generating political and media interest at the time. IWEA welcomed new actors into the sector and their annual conferences became a location the public declaration of ambitions by developers, and announcement platform for policy by successive energy ministers.

In 1993, at IWEA's inaugural annual meeting[26], energy minister Noel Tracey announced the Alternative Energy Requirement (AER), the first in a series of competitive

[23] Interview 130522

[24] The ESB utilised their own expert engineering knowledge to contest optimistic wind visions and delegitimise the actor groups in favour of wind technology expansion - Interview 150101 and E.O'Dwyer et al. (1990).

[25] IWEA have successfully cultivated their own history (IWEA, 2013) which has become part of their lobbying work. I have paid particular attention to triangulating this through the interview process.

[26] This took place in Hayden's Hotel, Ballinasloe.

grant schemes[27] similar to the UK's Non-Fossil Fuel Obligation[28] (Huber et al., 2007; Pearson et al., 2010; Mitchell and Connor, 2004). The first AER scheme was effective as a signal from the DCENR to the ESB that renewable energy technologies were going to be a part of Ireland's future electricity generation mix. However, although 70MW of a targeted 75MW was eventually delivered under AER I, the scheme, and subsequent capital grant schemes were criticised by IWEA and other proponents of wind technology. The nature of these criticisms focussed on the perceived advantage given to overseas firms, who had experience writing technical briefs and demonstrable project experience were successful in winning the majority of AER I bids (seven of ten), but in order to win, they bid low and subsequently could not deliver commercial projects. Only half of the ten AER I projects were built, all of them delayed significantly. AER III[29] was launched in 1997 with increased targets, yet only 38MW of 90MW was installed by the end of the programme, the deadline of which was extended a year because of slow delivery[30] (Ó Gallachóir, Bazilian, et al., 2010). Despite the perception of failure that continues to exist, the AER schemes influenced the subsequent nature of development in the industry rather than the early pace of technological deployment. First, they influenced who got to build wind farms in Ireland. By initially imposing a minimum project scale at one megawatt, developers of small scale projects were not supported. Second, the AER competitions encouraged formative development activities such as the undertaking of assessments and planning applications[31], which increased indigenous knowledge in the industry, even amongst actor-groups who did not win grants. Although increased industry activity did not result in a significant rise in completed projects at this time, crucially, the AER process demonstrated the commercial potential of the Irish wind industry to the DCENR and the ESB.

This demonstration of activity and potential in turn explains the considerable scaling

[27] The AER's emphasis on capital grants was related to €19m available through the European Regional Development Fund for renewable energy projects under Ireland's Economic Infrastructure Operational Programme 1994–1999 (Ó Gallachóir, Bazilian, et al., 2010).

[28] Developers taking part in the AER bid for a variable capital grant and a guaranteed fixed price (IR£0.04) 15-year power purchase agreement from ESB Customer Supply (Huber et al., 2007). The structure of the NFFO was critiqued for its unsuccessful diffusion of renewable technology (Pearson et al., 2010; Mitchell and Connor, 2004).

[29] AER II was exclusively for biofuels

[30] Further industry support was granted in the 1998 Finance Act made provision for capital gains tax relief on wind farm investments (Government of Ireland, 1998) yet problems with planning applications, the availability of grid connections and acquiring power purchase agreements remained unresolved.

[31] While it has not been possible to comprehensively identify failed project bids, evidence from interviews suggest that there were approximately 100 applications under AER I and 140 applications under AER III.

up in targets (see Figure 5.5) outlined in the 1999 Sustainable Energy Green Paper (Ó Gallachóir, Bazilian, et al., 2010; Government of Ireland, 1999). Despite low numbers of successful installation, DCENR used the nascent sectoral activity to negotiate with the ESB and defend a large increase in targets, an additional 500MW of installed capacity to be delivered over five years. This indigenous activity was further supported by European policies at the time. As part of the Kyoto Protocol, signed in 1997, EU members were instructed to write and implement a National Climate Change Strategy (Department of Communications Energy and Natural Resources, 2000; FitzGerald, 2004). The government's plan had two main parts, the closure of Moneypoint, a coal-fired power plant in favour of natural gas and an additional 500MW of wind generated capacity (Ó Gallachóir, Guidi, et al., 2007). Here the interests and ambitions of wind developers came up against the incumbent barriers and institutionally framed targets. The ESB had previous conceded installing 50MW of wind annually on the grid over a decade was feasible[32]. The DCENR's did not have the technical knowledge to argue the cumulative ambition, but they did have the negotiating skills to convince the ESB halve the delivery timeframe. Furthermore, the DCENR estimated from the level of development activity[33] prompted by AER III in 1997, that collectively, the private sector had the commercial ambition and capabilities to develop the requisite plant.

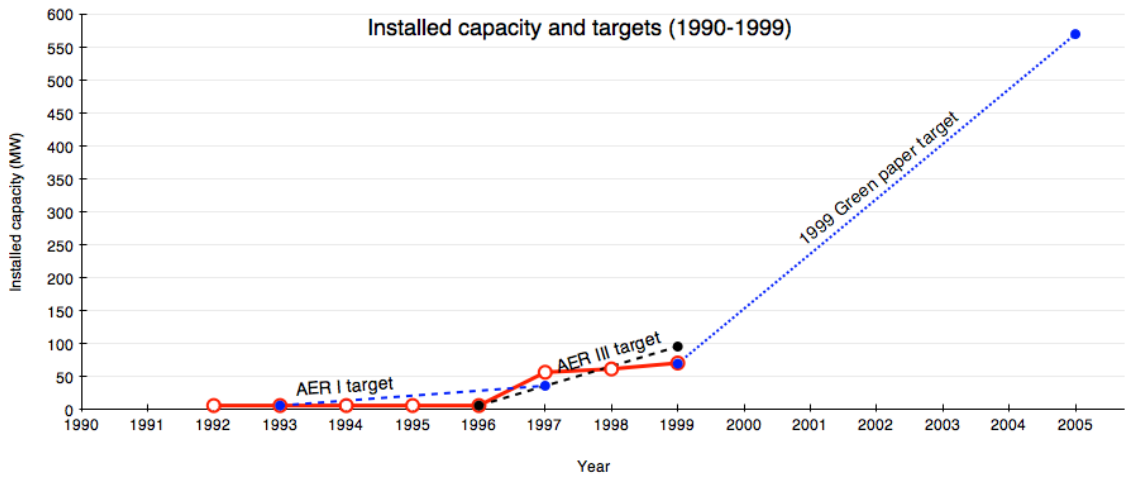

Figure 5.5. Installed capacity of wind farms (solid red line) and policy targets (dashed blue line) 1990 to 1999 in cumulative installed capacity (MW). Source: author's combined data.

[32]Interviews 130501, 130522

[33]The submission process received 279 expressions of interest representing a potential if improbable 1,680 MW of installed capacity. Projects totalling 155 MW had planning permission, a further 167 MW had applications within the planning process and 217 MW declared themselves at an advanced stage of preparation for a planning application.

By the end of the 1990s, Ireland had 71MW installed capacity nationally and 10 wind farms were supplying electricity to the national grid. The DCENR faced a considerable challenge in establishing the conditions under which the country's 500MW wind target could be met by 2005. It did not have the technical staff or resources to internally create and drive a sectoral strategy to meet its own regulatory targets. However, a combination of the submissions to AER III, the large number of planning applications, and internal ESB research[34] made a strong case that there was sufficient levels of interest and activity in the sector to support the government targets. IWEA was active in advancing positive claims of the capability of its members, framing demand increases as a problem for which its members had answers[35]. Policy makers gained confidence that developers already had or could put in place the project pipelines in place[36] to meet these targets. Faced with privatisation and marketisation, internal advocates for renewable technologies, and its own research, the ESB had begun to soften its stance toward wind, and engaged in several joint ventures with smaller firms to explore both onshore and offshore developments. The barrier was deployment of plant. To get the wind generation technologies on the hills, developers required a power purchase agreement, a grid connection offer and planning permission. The ESB were the gatekeepers of the first two barriers, the complexity of Ireland's planning regime the third. The department's solution was to convene a cross-industry stakeholder forum, the Renewable Energy Strategy Group which convened for the first time at the end of 1999.

[34] The Irish Times of Wednesday, June 3, 1998 reported the delayed release of a report commissioned by ESB International, which concluded that Ireland had had sufficient renewable resources to operate 2,500 MW of installed capacity.

[35] For example, a 1998 report in the Financial Times Energy Newsletter (December 11th 1998) reports IWEA's opinion that "the Irish government could alleviate the Electricity Supply Board's (ESB) urgent need for more power by giving the green light to a series of wind farms which already have planning permission".

[36] Interview 130522

5.2 Period 2: 2000 - 2004

5.2.1 The Renewable Energy Strategy Group

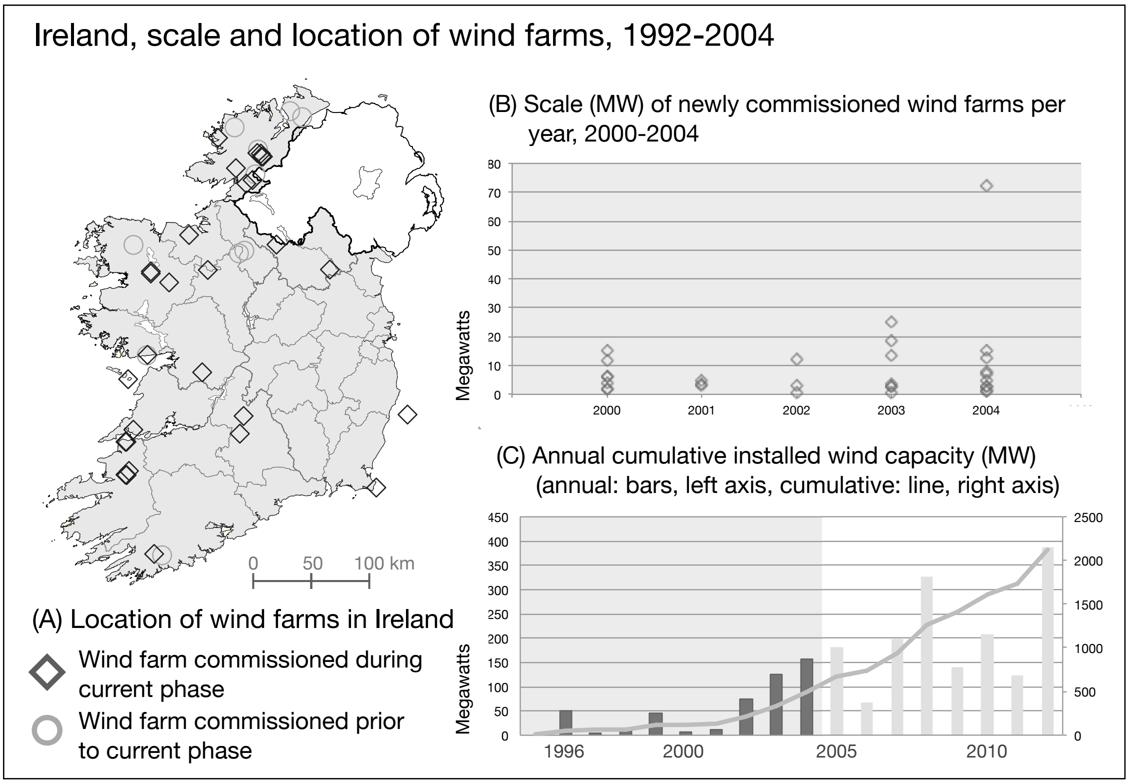

Figure 5.6. Scale and location of wind farms built 1992-2004. Source: EirGrid, IWEA, Meithel na Gaoithe, SEAI

> "To me that was the turning point . . . because at that, there was an increased understanding of the problems and there was a collective sense that ok we are going for this, this is real and that was quite, as I would say, policy-wise that was the most significant development that took place and everything that happened derived from that."

— Interviewee discusses the impact of the RESG[37].

Given the relatively weak position of the DCENR within the wider energy industry[38], the minister could not mandate action on wind development unilaterally. Instead a stakeholder approach was taken, convening a cross-industry group charged with collaboratively authoring a strategy to deliver significantly increased installed renewable capacity to the national grid. The Renewable Energy Strategy Group group was chaired by John Fitz

[37]Interview 130501
[38]Interview 130703

Gerald of the Economic and Social Research Institute (ESRI), a stakeholder from outside the three key stakeholder groups, the ESB, the government and private industry. The Group brought together many of the actor-groups already discussed, with a stated goal to address barriers to further diffusion of wind technology in Ireland[39] (Fitz Gerald, 2000). The format of the group was designed to facilitate participant's understanding of sectoral issues which in turn were identified collectively. Systemic barriers to wind roll-out were identified, and then a series of meetings were held. Topics included market mechanisms, trading issues, grid connection, capacity acceptance, spatial planning (ibid.). Over six months, report chapters on each of these barriers were written up and tested at following meetings, quickly triangulating and consolidating knowledge developed.[40] The process by which the RESG operated was an important aspect of its success[41], which was the creation and diffusion of solution orientated knowledge relevant to specific sectoral barriers. New wind farms commissioned during this period are illustrated in 5.6.

This example of how the RESG addressed planning regulations is illustrative of barriers and solutions the RESG discussed. Planning applications for wind farm construction were considered at the level of county councils[42]. Planning controversies at county level can be seen in contemporary reports of opposition to wind farm developments. In refusing planning permission to two wind farms in 2001, Clare County Council reiterated concerns of resident groups stating:

> "The proposed development would be seriously injurious to the amenities and depreciate the value of properties in the vicinity of the wind farm and would be contrary to the proper planning and development of the area."[43]

In responding to the decision the developer's consultant for the promoters of the Kilmaley plan, one of those effected, drew attention to the role of county level policy:

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[39]Three of the ESB's five business units were represented, three government departments, the Irish Planning Institute and the City and County Managers Association. Private firms were represented and IWEA was also invited to contribute (Fitz Gerald, 2000)

[40]Interview 130501, 130522

[41]Interview 130501, 130522

[42]The Republic of Ireland is made up of 26 counties. The planning regime at county level can be classed as discretionary, were an application's success is dependant on a series of guidelines as well at the contextual interpretation of the local planner. This contrasts with regulatory regimes in Denmark and much of Germany where an application, if it meets set requirements, has a high likelihood of being granted permission.

[43]Media source S1-271

> "It would seem on the basis of policies contained within the County Development Plan that the council does not want wind farms in the country."[44]

This is an example of how planners were confronted with novel challenges in assessing landscape character in areas which had never been considered for industrial use previously. Guidelines published by the Department of Environment and Local Government in 1996 were not uniformly adapted at the county level and many county planners had neither the tools nor training required to implement these[45] plans. However, despite sometimes strong opposition to specific developments at county level, throughout the evolution of the industry, the attitudes of the public to wind farms and the wind industry had been generally positive (Comhar, 2011). Anecdotal evidence gathered in interviews suggests that formally organised opposition movements were rare, though events such as the bog burst and collapse of installed plant at Derrybrien and the siting of wind the wind farm at Slievenamon led to localised opposition to individual projects[46] (SEI, 2003a). Indeed, in a major survey of attitudes to wind power in Ireland, little evidence of a 'Not In My Back Yard' effect was found, while there was a clear preference for larger turbines in smaller numbers over smaller turbines in larger numbers[47] (ibid.).

As a result of the rapid growth of development in the industry, coupled with this discretion related uncertainty, backlogs of applications were building up in country council offices. The RESG did not have the mandate or the political capital required to implement a regulatory planning change. However, they suggested a three phase 'traffic light' guidance system to guide developers but leave discretionary decision making powers with county planners. According to an Irish planning expert familiar with the process,

> "this is really Irish, the zoning system of red, orange and green doesn't actually mean definitely yes or no, it just gives a clue to the developer"[48]

These 'clues' for the first time linked national electricity targets to county planning processes in a decision making framework that could be used by both developers and planners. Ultimately planners in the group took this guidance and diffused it through the Irish Planning Institute and County Planners associations and through the subsequent Planning Act (Government of Ireland, 2000).

[44] Media source S1-271

[45] Interiview 130705

[46] Interview 130503

[47] These findings were endorsed by (Warren et al., 2005); who found that in location in Ireland studied, local people become more favourable towards windfarms after construction and that the NIMBY effect did not adequately explain variations in public attitudes.

[48] Interview 130705

The Renewable Energy Strategy Group overcame disagreement and barriers, building consensus where it could and distributing new knowledge and processes through existing institutional structures, of which participants were already a part. The group presented its conclusions and recommendations in 2000, which suggested: "three key elements, Electricity Market, Electricity Network and Spatial Planning, need to be integrated into a plan led approach to wind energy deployment" (Fitz Gerald, 2000, p. 5). The group favoured large scale developments over micro scale wind and stand-alone turbine installations (unsurprising given the dominance of utilities and larger developers in the group) and suggested an iterative process for identifying suitable development areas to take place at county level. In addition, it suggested investor uncertainty be addressed with guidance to offer 15 year power purchase agreements to all development projects which met a set of minimum requirements. However, despite some progress on individual barriers to industry development such as planning, and its recommendations on the formation of a new national electricity market, the suggestion of an integrated long-term plan-led approach was not enacted in the years that followed.

Through the RESG process the 1999 Green Paper targets were endorsed by actors across the energy industry, further legitimising the activity of those developers already active and giving some assurance to investors through policy recommendations and legitimising and normalising industry targets. This activity took place within a broader institutional context of rapid regulatory change in the Irish energy domain (see Figure 5.7 for an illustrated timeline of relevant European and Irish policies and policy instruments). The 1999 Electricity Regulation Act transposed the 1996 EC Directive on internal energy markets into Irish law liberalising the energy sector in Ireland. Marketisation was the dominant form of liberalisation and the act established an independent regulator, the CER who over-saw a four-year consultancy and design[49] process from which the Single Electricity Market (SEM) would eventually emerge[50]. Further to the creation of the SEM, the operation of the transmission system was unbundled from the ESB and independent ESB National Grid was ultimately rebranded EirGrid. The Sustainable Energy Act of 2002 transposed to national law the EC Renewable Energy Directive (2001/77/EC), which set a 13.2% target for renewable contribution to gross energy production by 2010[51],

[49]See discussion on SEM design in Chapter 2.

[50]The design of the SEM bore some consideration for wind generators in deliberately not reproducing the UK's NETA market structure, because suggests (Kee, 2004, p. 55) "it may not provide timely incentives for new generation in a shortage situation; it has separate spill and top-up prices that are seen as a disincentive to renewables and small generators".

[51]This equates to approximately 1,400 MW installed capacity of wind generation, a target that was

in line with the aim of the RESG's recommendations.

The influence of the ESB decreased somewhat throughout this time as new players emerged in the electricity domain. For example, under the status quo prior to the creation of the Single Electricity Market, potential generators had to strike bilateral contracts and agree to a balancing process that depended heavily on buy-in from the ESB. Following the launch of the SEM this was no longer the case, as a new market role was created, that of supplier to the centralised market. Yet despite changes in the power structure in the industry, and influenced by uncertainty created by them, the ESB prompted a regulator enforced moratorium on further grid connection in the industry in 2003.

5.2.2 A moratorium on development

On December 1st 2003, ESB National Grid, wrote to the CER expressing concern regarding levels of wind generation connecting to the Irish grid[52]. ESBNG explicitly stated concern for the stability of the transmission and distribution systems (Leahy, 2010), they had significant engineering issues to overcome in order to maintain security of supply, and they recommended a moratorium on all new grid connection applications from wind farms. The regulator agreed and no further consideration was given to new applications until the end of 2004. Many of the concerns[53] raised by ESBNG were not new, indeed, some had been subject to discussion at the RESG. The challenge was not that the total wind capacity committed to was large by European standards[54] (see Table 5.1), rather it was the capacity related to the power system that must accommodate it (Ó Gallachóir and McKeogh, 2005). However, if the legislative targets endorsed by participants in the RESG were to be met, by 2005, 7% of Ireland's electricity would be produced by wind, up from 1% in 2000. These numbers significantly exceeded the British and NORDEL systems with

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met.

[52] Commission for Energy Regulation (2003) 'ESB national grid request to CER regarding wind generation security issues', CER/03/281

[53] The most significant technological problem was the absence of dynamic models of wind turbines to facilitate the assessment of wind power on dynamic performance of the overall system (Ó Gallachóir and McKeogh, 2005). In other words, adding extra wind capacity to a grid dynamically affects the existing performance of the grid. The system operator needed models for both existing wind turbines and proposed turbines which would dynamically account for this situation. These did not exist at the start of the moratorium.

[54] At this time leading European countries had significantly higher wind capacity than Ireland's 166MW: Germany (16,628 MW), Spain (8,263 MW) or Denmark (3,118 MW). Windpower Monthly 2005 Operating Wind Power Capacity Vol 21 No. 4

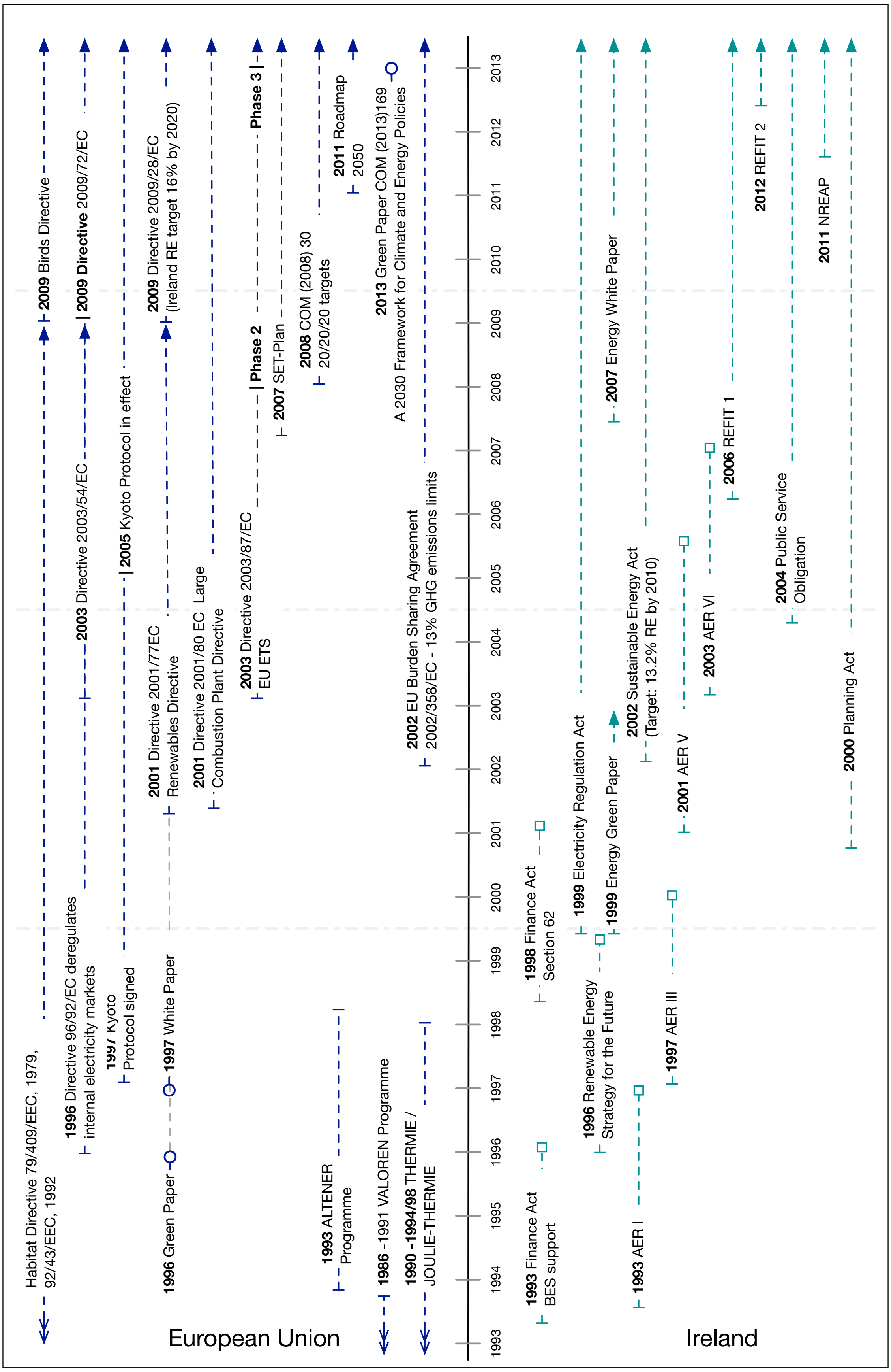

Figure 5.7. Timeline of European Union and Ireland policies, policy processes and instruments relevant to Ireland's wind sector, 1993-2014.

which developers and manufacturers were most familiar. In terms of the percentage of wind integrated onto a grid, future targets had committed Ireland to being amongst the most integrated networks in the world.

Table 5.1 Wind connections, offers of connection and applications for connection in Ireland at the start of the moratorium. Source Bazilian et al. (2004)

	Total (MW)	**Cumulative (MW)**
Connected	166	166
Signed offers	534	700
Live agreements	75	775
Applications in process	422	1197
Applications being checked	98	1295

ESBNG had legitimate technological reasons for their concern (Ó Gallachóir and McKeogh, 2005). Specific grid codes from wind generators which dynamically model turbine generation under given climatic conditions are important for reliable generation forecasting, in turn vital in "day-ahead" centralised markets such as the SEM. In part these issues arose from a global standardisation of turbine technology which did not take account of specific characteristics of the host electricity system. Some responsibility can be apportioned here to the manufacturers who ultimately did create the dynamic models required by their end-users in Ireland. However, ESBNG were criticised for not engaging manufacturers earlier and not committing enough resources to solve the substantive issues quickly (Ó Gallachóir, Guidi, et al., 2007). A number of interviewees spoke of the moratorium as a blunt strategy which created lasting damage by reducing trust at a time of rapid institutional and commercial change in the industry[55].

The impact of these activities is visible in records of planning applications, which rose year-on-year and peaked with over 100 applications in 2003, four times the number of projects as 1999. Firms were entering the sector at an increased rate and the composition of the successful applicants for AER V and VI was majority Irish firms. Developers by now had over a decade of Irish case studies to draw on, and expertise and capabilities in negotiating and building projects had been built-up by domestic consultancies and developers. Irish firms Saorgus, Hibernian Wind Power (ESB), Eco Wind Power and Ecopower estab-

[55] Interview 130103, 130503

lished operational wind farms and used revenues to finance further applications[56]. The work of these developers was aided by the creation or strengthening of intermediaries such as the Sustainable Energy Ireland, formed following the Sustainable Energy Act 2002.

Ireland's wider economy at this time continued its rapid annual growth which was coupled with a rapid increase in energy demand. The ESB estimated 1,000MW of additional generation capacity (an increase of approximately 15%) would be required in the six years to 2006.[57] 'Keeping the lights on' at the high-tech manufacturing plants of foreign direct investment firms such as Intel and Pfizer became powerful narrative drivers for the government and DCENR and in turn a source of further opportunities for investors.[58] The investment environment was further influenced by readily available credit and a growing culture of property based speculation[59]. This wave of activity, combined with technical constraints, a shifting market, institutional uncertainty as the SEM was being designed, enhanced the pressure on ESBNG and CER. On the one hand they had to deliver more generating plant, but on the other, their responsibility was keep the generators that were already operational spinning.

5.2.3 Research and innovation in Ireland

The majority of research, development and design activities had until the mid–2000s taken place outside of Ireland. Generation plant had been turnkey and Ireland's small market size resulted in Irish actors having relatively little influence in the R&D process of foreign manufacturers such as Vestas and Siemens[60]. Despite this, a number of innovation activities emerged in Ireland during this period. Three significant national studies were conducted. The first national wind atlas of Ireland was produced in 2003 (SEI, 2003b). The same year, (Gardner et al., 2003) concluded that there was no technical limit on the wind penetration feasible on the island of Ireland, rather costs are the limiting factor for increased penetration. And in 2007, Meibom et al. (2008) modelled the Irish electricity grid identifying the effects of large wind-penetrations on the island of Ireland in relation to overall operation, costs and emissions (Connolly et al., 2011). They concluded that a wind

[56] Interview 130503

[57] FT Energy Newsletters, April 7, 2000

[58] Interview 130104

[59] Property developer Joe Tiernan described the frenzied activity of Irish lending institutions at the time as being "like drink at closing time they just wanted more of it... There were all sorts of characters being financed ... It was a race to the end by the banks to give out money". Source: The Irish Times, 16th July, 2014

[60] Interview 130204

penetration of 42% was feasible on the island of Ireland by 2020 and under that scenario, overall operation costs would be reduced compared to a status quo scenario (Department of Communications Energy and Natural Resources, 2008). This 'All Island Grid Study' was a significant influence on the imposition of Ireland's 2020 EU renewable energy targets which set a 40% renewable electricity goal which in turn drove EirGrid's 'Facilitation of Renewables' and 'DS3' series of grid studies (Mccann, 2014).

Research programmes were developed in Irish universities focussed on nationally contextualised aspects of the wind industry and wind technology value chains (IEA, 2013). Examples of this research include the challenges faced by high wind energy penetration systems (Bazilian et al., 2004), proposed solutions to these challenges (González et al., 2004) and reserve demand analysis of these systems (Doherty and O'Malley, 2005). The Electricity Research Centre at University College Dublin and the Sustainable Energy Research Group at University College Cork established themselves at this time as Ireland's two significant wind systems and power systems integration groups. As well as primary research, these research groups provided a secondary function, training and educating the future staff of utilities and system operators. In particular their influence on EirGrid was noted where according to one interviewee, not only did they bring new skills and competencies to a conservative former utility, but also a new problem solving approach[61]. The net result of the feasibility studies and focussed primary research was not only solutions to technological problems, but the increasing of positive expectations across the wind sector.

Innovation also took the form of new business models and the deliberate engineering of new institutional forms, activities exemplified by wind firm, Airtricity. After failing to win bids in AER I and III, Airtricity, shifted its strategic focus from winning capital support grants to searching for and creating market opportunities both within Ireland, and overseas. Airtricity's management took advantage as the EU Electricity Directive that was being transposed to Irish law and successfully lobbied for favourable clauses. This created a situation where in a newly liberalised market, suppliers of renewable electricity would have a time-limited privileged and protected position allowing them to sell electricity to small and medium enterprises before non-renewable new entrants (Kjaer, 2008). Furthermore, Airtricity pioneered a direct route to market in Ireland, becoming a supplier as well as a generator in the industry. In an interview in 2001, Eddie O'Connor claimed

> "the regulatory regime allows us to build our own connections to the grid; ESB only has to do the final connecting in. We have pushed for this; at every step

[61] Interview 130202

Eirtricity is the innovative force."[62]

By the end of 2004, Airtricity[63], now rebranded, were the dominant player in the renewables market, accounting for 127MW of 336 MW total installed in the country. They achieved this largely without the capital grants offered by the AER schemes, or earlier direct EU support, instead raising venture capital and project finance from institutional investors based on their ability to access the market directly. Other firms followed this merchant plant model, and by the end of 2006, 338MW of wind plant had been commissioned without assistance from the AER schemes, 49% of total capacity (Ó Gallachóir, Bazilian, et al., 2010).

Throughout the period of the moratorium, indigenous commercial, research and innovation activity continued to build. The moratorium ended in 2004 when dynamic grid codes were supplied by overseas manufacturers, and mechanisms for addressing the now substantial queue for grid connectivity had been proposed[64]. The moratorium undermined levels of confidence that had built up in the industry at the time of the RESG, although the nature of long term harm sustained by the industry, aside from an increase in negative attitudes towards the ESB, is not clear. Whereas in the previous decade, transnational flows of turnkey technology and tacit knowledge were features of an emergent industry, by 2004 we see indigenous research and innovation activities emerging, against a background of changing regulatory and economic institutions.

[62] Source: Financial Times Energy Newsletters January 26 2001

[63] The brand name Eirtricity was anglicised to Airtricity, which although negating the pun on the word Éire, or Ireland, made for a more pronounceable name in English speaking countries.

[64] Over the course of the moratorium, applications representing over 1,300MW of installed wind capacity had been submitted to the system operators

5.3 Period 3: 2005 - 2009

5.3.1 Take-off and the grid allocation processes

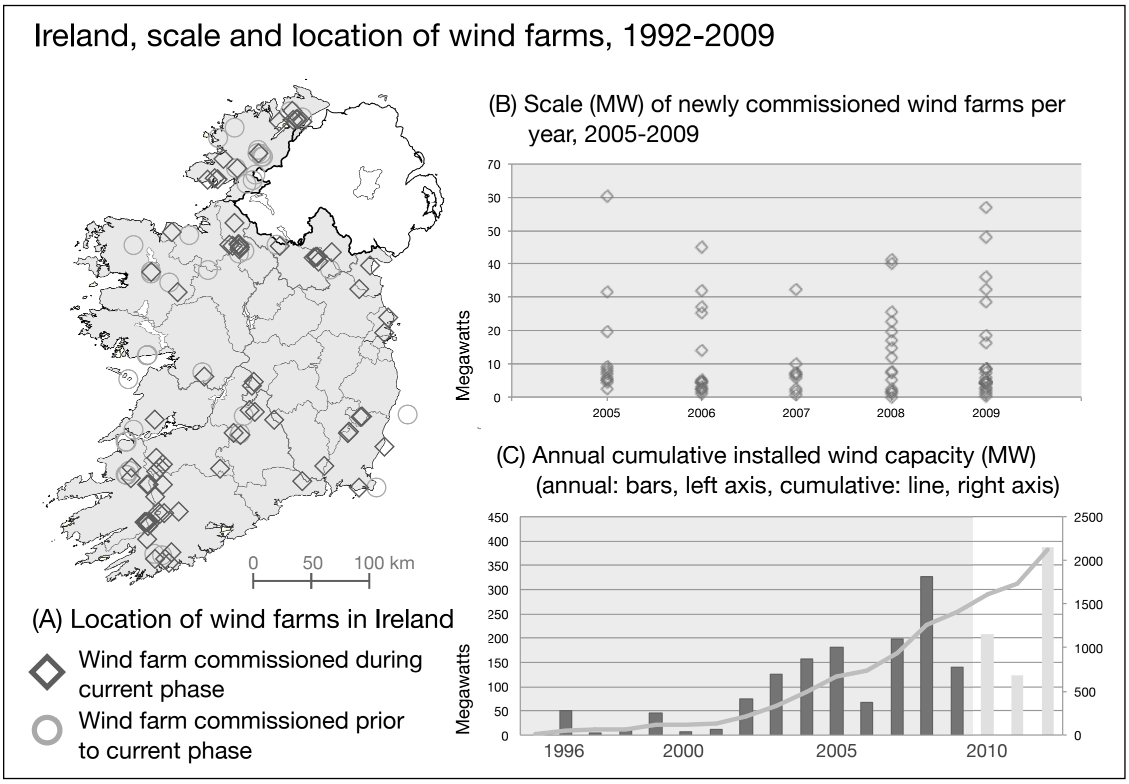

Figure 5.8. Scale and location of wind farms built 1992-2009. Source: EirGrid, IWEA, Meithel na Gaoithe, SEAI.

Processing the backlog of grid connection applications following the moratorium in 2004 and 2005 was a significant challenge for the regulator. It established the Renewable Energy Development Group (REDG), based on the RESG, in order to develop a strategy to accommodate this backlog and simultaneously devise a strategy to meet the state's 2010 renewable energy targets. The solution proposed was a group allocation process. Applications for grid connection were collated into a series of groups, each pre-determined by the size of an upcoming processing 'gate' (by cumulative installed capacity). Once the group capacity had reached the size of the gate, processing would begin and successful applicants within the gate were guaranteed grid connection in a sequence best suited to fulfilling a second set of criteria as determined by the regulator.[65] For Gate 1, CER accepted projects cumulatively totalling 370MW of generating capacity, date-ordered by application. This consisted of all the applications deemed complete by December 2003,

[65]Interview 140714

the date of the start of the moratorium (Commission for Energy Regulation, 2004). A second Gate was opened in 2005 and implemented the following year. This time 1, 687MW of wind projects were selected on an application date ordered basis beginning December 3rd 2003 (Commission for Energy Regulation, 2005; Commission for Energy Regulation, 2006). However, for Gate 2 a second entry criteria was introduced. Projects totalling a further 661MW were selected based on "system optimisation" criteria which selected projects based on geographic location and grid node infrastructure, regardless of when the application was lodged with the CER (O'Donoghue, 2006). At the end of 2006 system operators made Gate 2 connection offers to 121 projects totalling 1,348MW, leaving 76 projects (1,668MW) remaining in the queue, outside the allocation processes. New wind farms commissioned during this period are illustrated in Figure 5.8.

An outcome of this process was to give developers (and their investors and selected original equipment manufacturers) guarantees backed by the regulator, that projects in the Gates would at some time in the future be provided grid connections. The allocation criteria implemented in Gate 2 is the closest the regulator or DCENR came to implementing a long-term plan-led national strategy to wind development, first suggested in 2000 by the RESG. Furthermore, by implementing a system optimisation criteria, EirGrid[66] was given scope to select development projects based on technical constraints such as existing grid infrastructure and the position of development relative to grid nodes. However, this system optimisation approach was short-lived. The group allocation process continued with Gate 3 which was finalised in 2008 and incorporated step-up in capacity building ambition. The CER reverted to a simple date allocation criteria (up to 16th November 2007) selected on the basis of a cap of 3,900 MW capacity (see table 5.2). Evidence suggests the return to this more straightforward selection criteria was predicated by the long-standing the project-led development[67] approach, which while easy to understand and communicate, did not lead to project delivery outcomes optimised to reduce cost or technological complexity. Because of the increased scale of technological ambition, further criteria internal to the Gate 3 process were implemented in order to determine the sequencing of new grid nodes which geographically selected project groups would connect to for each year between 2010 and 2025.

The narratives of the gate processes reveals a number of premises and beliefs of actors in the wind sector at the time. First, over time the system operators maintained a powerful

[66]ESB National Grid has been renamed EirGrid by this time and been unbundled from the ESB's vertical integration structure.

[67]Interview 140714

Table 5.2 Group allocation scheme, Gates 1, 2 and 3. Source CER.

Gate	Year	Critera	Cut-off date	Projects	Additional capacity
Gate 1	2004	Application date order	13th Dec. 2003	34	370MW
Gate 2	2006	Application date order plus system optemisation	17th Oct. 2005	121	1,348MW
Gate 3	2008	Application date order	16th Nov. 2007	158	3,900 MW

gatekeeping position on grid connection, but they could not unilaterally decide the rules of the game. Through the Gate 2, the SOs had been given remit to process offers in an order best suited to connecting applications based on existing and planned network infrastructure. Yet, in returning to a date-ordered group processing criteria in Gate 3, EirGrid and the CER favoured developers at the expense of optimising grid expansion along technological and, or, cost criteria (Burke and O'Malley, 2008).

Second, a confluence of economic demand and European and national renewable energy targets continued to positively influence progress. The speculation was further enhanced by European policy processes (European Commission, 2007a). As part of the process which led to the EU's 2020 targets, the government of Ireland negotiated a national target of 40% reduction in carbon dioxide (or equivalent) emissions 2020. This became a national target in the 2007 Energy Strategy White Paper, the national government anticipating EU regulation ahead of the relevant directives. The influence of these target setting processes was illustrated at the end of criteria creation process for Gate 3 when the 3,000MW capacity was increased by 900MW in order to accommodate new emissions targets.

Third, in the context of the project-led culture of infrastructure development we have discussed already, the rules of the group allocation process were a compromise between two approaches. On one hand a centralised planning approach, which neither the DCENR nor the regulator had the agency to conduct. On the other hand a market based solution, in which the ability of each firm to financially sustain a project through to completion (between two and fifteen years) acted as a selection mechanism. The Gate process communicated to actors in the wind industry that over the next two decades, over 4,000MW of wind generation was likely to be deployed and as such gave some assurance to those developers with projects in the queue. Utility players and larger developers who already had revenue from installed developments were better positioned to wait out the Gate 3 process than smaller players who could choose not to proceed, or attempt to sell their project whilst still at the development stage.

Thus, the terms of the group allocation process positively influenced the pace of initial speculative project development. The advantage for the CER and DCENR were a large number of potential wind generation projects and sites were identified, and potential developers incentivised by opportunities in Ireland. The downside of this for both the system operators, and the citizens of the country who underwrote the process through taxes, was less certainty for the system operators that projects were viable. This in turn meant that even though there was now an ordered queue, there remained a significant scheduling process within the Gate. Furthermore, we see a diversity of applicants decrease as firms less-able to wait out the processing period were relatively disadvantaged once inside the Gate 3 process. Indeed, one early, and commercially successful developer noted the change in characteristics of industry players over time:

> "If we were starting off now we would find it much more difficult I think that is fair to say. As time goes on and it is inexorable since the early 90s it has become more and more of a big boys game. It is a huge money game, why wouldn't it be."[68]

So while the structure of the Grid Allocation Process gave long term certainty to some developers, investors and manufacturers, this was achieved at a cost to some development firms and consumers.

Gate 3 institutionalised grid allocation processes. However, the problems of alignment between accessing grid, acquiring power purchase agreements and planning permission were not yet resolved. IWEA at this time focussed most of its lobbying efforts on calling for the introduction of a feed-in tariff. In 2005, the AER schemes were scrapped and the DCENR announced they would be succeeded by a renewable energy feed-in tariff (REFIT). The tariff came into effect on May 1st 2006 with the goal of supporting 400MW of renewable generation to fulfil a 1450MW target by 2010. For wind developers, and IWEA in particular, REFIT has been claimed by themselves as one of their most significant policy achievements (IWEA, 2013). For the first time, a modern, widely accessible feed-in tariff was available to Irish developers. It was argued that deficiencies in the support scheme did not minimise costs to end-use consumers (Doherty and O'Malley, 2011). However the architecture of a feed in tariff was understood by actors domestically and throughout the

[68] Interview 130503

global industry. This further reduced investment risk domestically while in an international context Ireland was now perceived as a country with serious commitment to renewable technologies. According to an interviewee:

> "it became a serious contender, it deserved serious attention, the policy decisions had been made to... invest heavily in renewables, in renewable technology."[69]

5.3.2 Recession and industry consolidation

Throughout the 1990s Irish wind developers and associations played a role informing banks in Ireland about wind technology and finance through special investor conferences and face to face meetings. By 2007, the investment arms of Irish banks (e.g. Bank of Ireland, AIB) had learned to assess risk and the wind developers had learned how to negotiate as this text illustrates:

> "Say if we have a 10 megawatt wind farm you need about 150 million, you just go to the bank you put together your model, you have to back it up with a FIT and ehm, that will go in and on top of that you have to include projections on constraints based on whatever projected, you have to include projections on any number of different things. You run your model, you have obviously studies that show the wind factor of the site and then ultimately it comes down to negotiation."[70]

In short, lenders required a 15 year cash flow guidance plan and project costings were required for each project[71] and if they decided to lend, financiers provided letters of credit and funding for the construction phase. The economic crash of 2008 dramatically changed this investment landscape. The subsequent recession was severe, long lasting and impacted every industrial sector in Ireland (O'Hearn, 2014; Leonard and Botetzagias, 2011). In the context of Irish economic history it was a major event which has had profound implications for Irish politics, society and the economy (the timing and scale of the crash is illustrated in using GDP growth percentages in Figure 5.9) (Allen, 2014). With regard to the Irish wind RES, we consider it a large scale exogenous shock, which affected demand in Ireland for energy consumption, demand in global industry, and it raised the risk premium attached to investing in Ireland. Furthermore, according to Fitz Gerald (2011) economic

[69]Interview 130204
[70]Interview 130103
[71]Interview 130717, 130503

recovery necessitated a substantial reduction in domestic prices relative to international competitors which in turn meant that environmentally based electricity price premiums became harder for the government to justify.

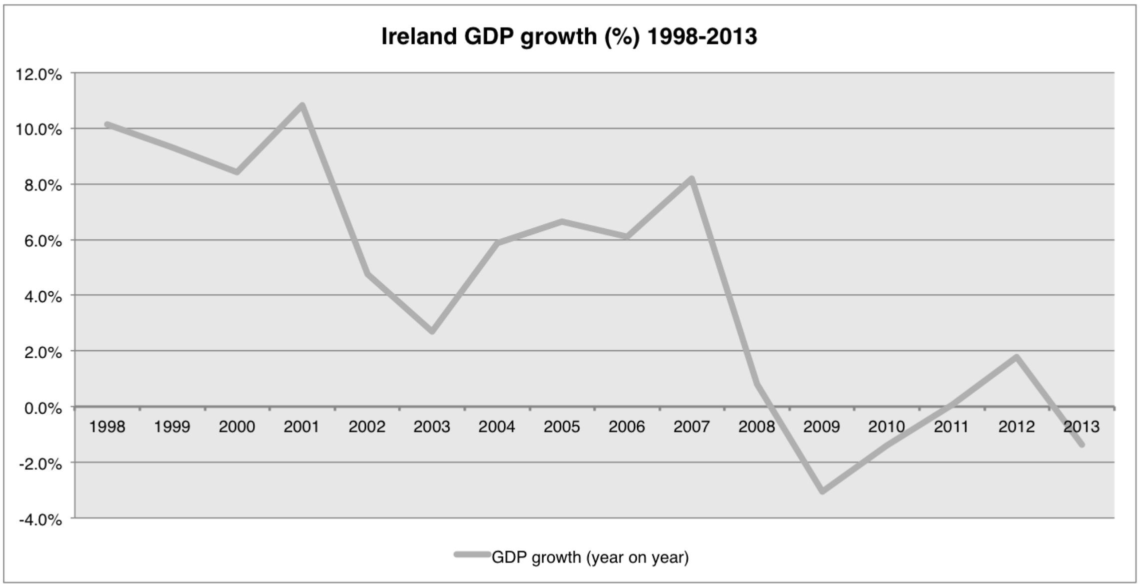

Figure 5.9. Ireland annual year-on-year gross domestic product growth rate (%). Source: Irish Central Statistics Office

With the onset of the recession, the availability of finance decreased. Project debt financing of up to 85% had been available before the crash, this dropped to 70% afterwards, and the sourcing of the finance itself became more difficult[72]. The sources of funding most affected were Irish banks which "basically shut down" according to evidence introduced in Section 2.2 . So while the basics of financing a wind project remained constant through the recession, the ability of actors to access financial resources depended on who they were, and where the financial institution was located. Equity funding and venture capital were options for actors who had access to overseas finance networks, or to overseas finance actors based in Ireland. Utility firms had the option of funding projects from balance sheets, though for semi-state enterprises this was a controversial strategy due to the nature of the risk and public service obligations of the firms.

Within two years of the recession, Ireland's two largest wind developers (by installed capacity) had exited the industry through sale. Airtricity's shareholders concluded a deal with SSE plc for €1.9 billion in January 2008 (Airtricity, 2008) and SWS was acquired by Bord Gáis Energy (BGE) in 2009 for €500 million.[73] By the end of 2007

[72]Interview 130503, 130722, 130104
[73]Source: Irish Examiner December 5th 2009

on the grid there was cumulative installed capacity of 750 MW, yet we see from the group allocation scheme there was over 4,000 MW of project applications. To get these projects to market, developers would require financing in the order of €5-€10 billion in a difficult financial environment. Utilities were handed an advantage with regard to resource mobilising according to one interviewee:

> "that was pure financial... cost of money for banks [that] was just too expensive and there was no long term money out there or whatever. Which again introduced an additional risk factor into the project finance in that nobody knew what's going to be there in ten years.[74]"

This rationale is supported by investors in Airtricity at the time. Ecofin, a fund management services firm who held 16% of Airtricity's share capital when it was sold claim that project finance was becoming an issue in 2007:

> "the majority shareholders of Airtricity decided to sell the remaining business of the company in light of the premium valuations being paid by strategic buyers at the time and deteriorating conditions in the project finance market upon which Airtricity depended."[75]

The utilities had developed small portfolios of wind farms over the previous decade, but this represented a dramatic shift in industry ownership, between them, Airtricity (SSE), BGE and Hibernian Wind Power (ESB) now owned over 60% of cumulative installed capacity (see Figure 5.10). Ireland's wind industry was now a sector dominated by utilities. While there is some evidence to suggest the recession affected the pace of development in Ireland, it is almost certain that events had an influence on the composition of the sector.

Through the early years of the recession there was record installation activity. A lag effect due to construction contracts in the industry meant that the rate of new wind farm building continued to increase through 2008 and 2009 as 199MW and 325MW of installed capacity were added to the grid. Growth in the industry was further buffered by the number of connection offers made in the group allocation processes. One further explanatory factor for this is the increased confidence developers had in the ability to deliver and the future value of assets. With a REFIT offering a price guarantee in a new market arrangement and the gate processes signalling an ordered grid expansion and connection scheme, development pipelines became clearer for those who could afford to

[74] Interview 130722

[75] Ecofin (2015)

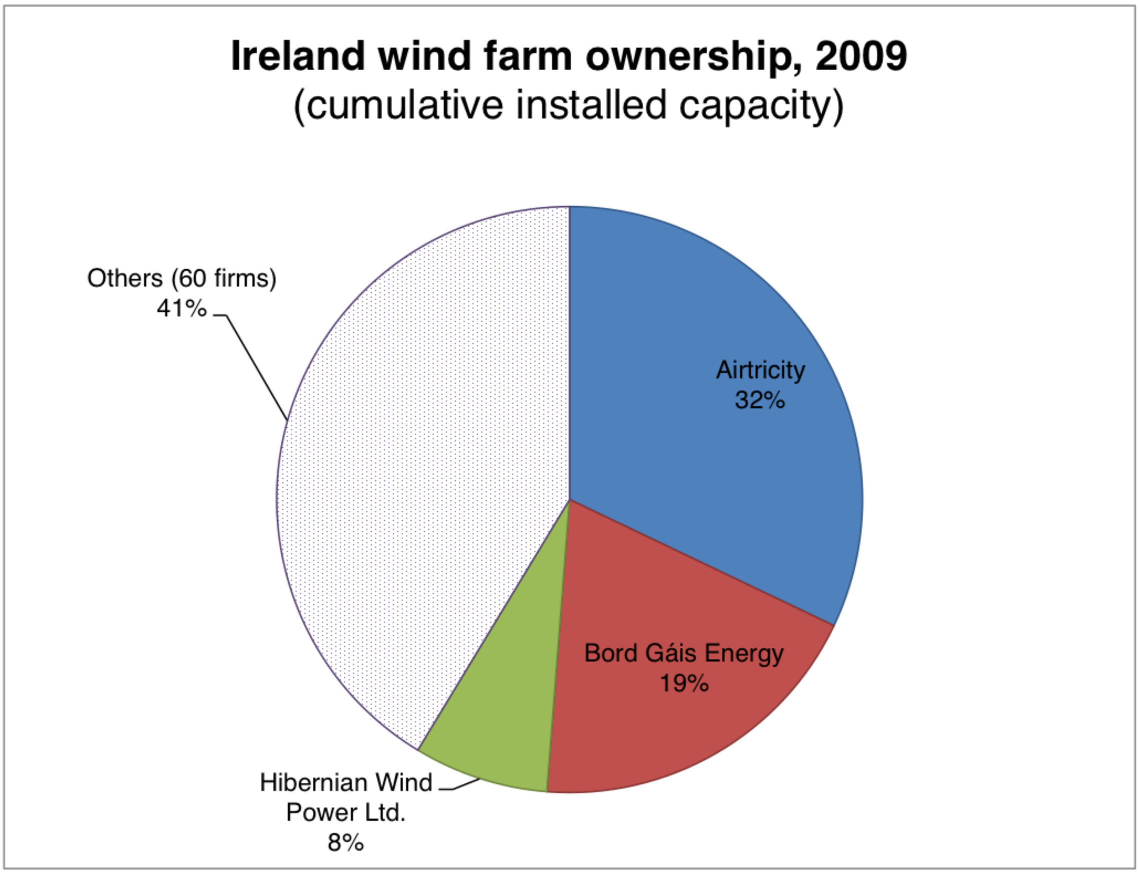

Figure 5.10. Cumulative installed capacity of Irish wind farms at the end of 2009. Source: authors data.

finance them. Indeed, the value of development pipelines (in addition to fixed assets already built) and expected worth of future wind farms was an important aspect in the sales of firms. This clarity of these pipelines and the demand for wind generation resulted in manufacturing firms such as Siemens and Gamesa expanding operations and opening offices in Ireland. An executive for one manufacturer suggested at this time a combination of Irish and European policy and research created an investment tipping point for their firm.

> "primarily it was the sign posting that happened in the mid-2000's and 2007, 2008 that had indicated at REFIT 2 and the 2020 policy in Ireland to have 40% renewable electricity generation was going to come down the road ... all the reports that had been done, all the studies had been done, the policymakers had agreed that we'd need to have an additional four gigawatts of wind in order to achieve that."...
>
> "So when when that statement [to expand operation in Ireland] was made Ireland became an important player in a European context because up until

> that [we] were quite strong across all northern Europe ... [we had] about two gigawatts in operation well two and a half gigawatts in operation in wind in the UK in GB. And they said we could get nearly the same again out of Ireland if we put our minds to it. So it became a serious contender, it deserved serious attention."[76]

This evidence suggests that despite a recession, manufacturers were confident Ireland's wind resources would continue to be exploited, and were now actively competing in the Irish market to win equipment contracts.

[76] Interview 130204

5.4 Period 4: 2010 - 2014

5.4.1 New actors, new visions, new opportunities

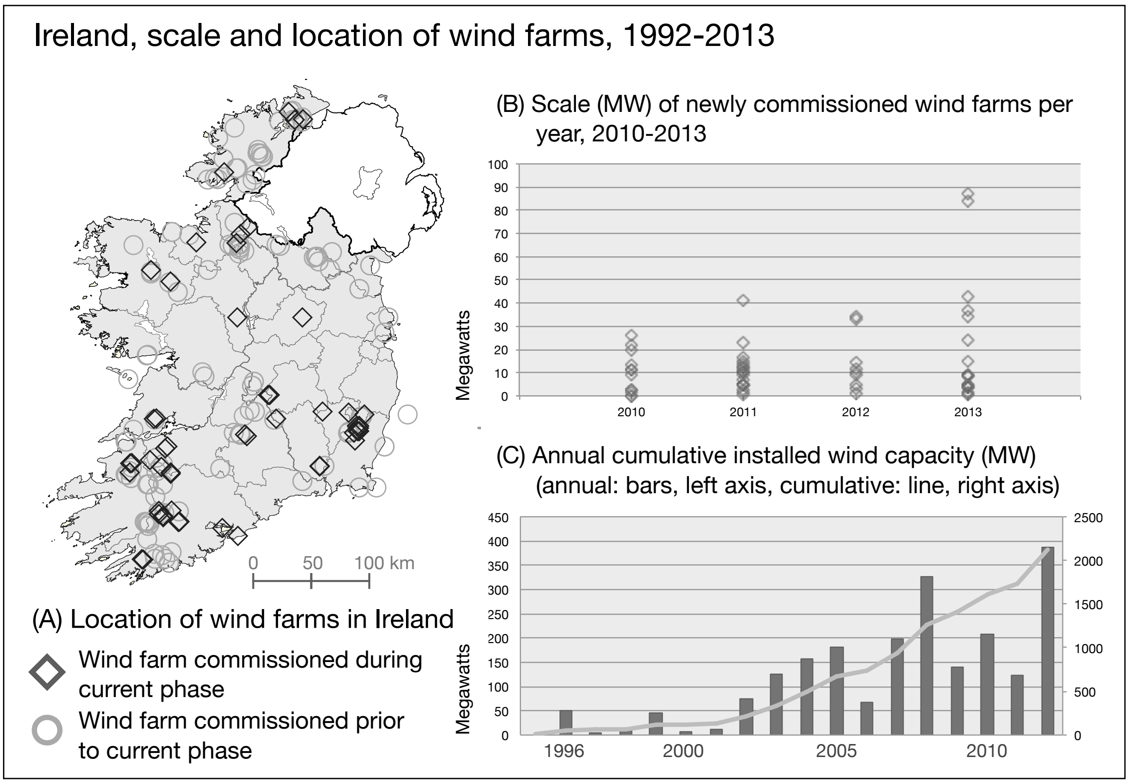

Figure 5.11. Scale and location of wind farms built 1992-2013. Source: EirGrid, IWEA, Meithel na Gaoithe, SEAI.

In 2010, Christopher Knowles, head of climate change and environment at the European Investment Bank addressed IWEA's Autumn conference with a straightforward message: Ireland's resources are good, the ambitions of the industry are positive and that combination is very attractive to international investors in renewable energy (IWEA, 2013). In an industry report the following year, Valerie Lawlor from law firm McCann FitzGerald reiterated the sentiment that the investment environment for wind developers remained attractive:

> "The only real risks for an investor are regulatory risks; that a scheme such as REFIT would either be withdrawn or delayed or would be poorly administered in some way, or sovereign risk, ie, that the entity backing the REFIT scheme – Ireland in this instance – would itself not be able to perform its obligations. But those regulatory risks in Ireland are manageable."[77]

[77] From The Green Economy: An Irish Director Report. As reported in Platts Renewable Energy

The basis for this optimism was the institutional stability, provided by the Single Electricity Market, and the regulator, the CER, who administered the REFIT. Mr. Knowles and Ms. Lawlor's messages was prescient. The ongoing expansion of the industry in the years that followed is notable for the entry of new European and North American firms into the sector. New wind farms commissioned during this period are illustrated in Figure 5.11.

New actors in the industry included ABO-Wind, global asset management firm BlackRock, and in 2014 Canadian firm Brookfield Renewables who purchased the renewable assets of Bord Gáis Energy as part of the financing of the utility's sale to UK utility Centrica Plc. These new actors performed a range of activities. BlackRock Renewable Power Fund was managed from Dublin and headed by the former chief executive of NTR, Airtricity's largest shareholder. In 2012 it was reported that it closed its first round of funding having taken in approximately \$400 million[78], to be invested in Ireland and overseas. This is indicative of the nature of the finance capabilities and skills which had built up in the industry in Ireland. ABO-Wind meanwhile took a hands-on approach. In 2009 the Gortahile project they were contracted to provide turnkey construction on failed because of financing difficulties. ABO purchased the project assets outright and arranged financing with German banks Commerzbank and NordLB[79]. ABO subsequently sold the completed development to an investment fund managed by BNP Paribas Clean Energy Partners. In this case, we note the role of transnational commercial relations take place without significant financial involvement of firms in Ireland.

Two Irish firms, Mainstream Renewable Power and Element Power were established to innovate and take advantage of new revenue models in the Irish and global wind sectors. They were founded by Airtricity's Eddie O'Connor and Tim Cowhig of SWS Energy respectively, who brought with them senior staff, investors and experience from their former firms. Element business model was identifying wind projects at various stages of development, acquiring them and 'tidying them up', which consisted of activities such as acquiring 15 year finance, planning permission and grid access[80]. They completed their first two projects and sold them on to equity investors over the course of 2012. Mainstream Renewables also considered institutional investors as an integral aspect of their commercial strategy and in 2013 announced plans for a €3 billion investment fund aimed at pension funds[81]. These firms now had four distinct revenue streams:

Report, July 11 2011.

[78] Source: The Sunday Business Post, August 5 2012

[79] Source: Platts Renewable Energy Report: January 11 2010

[80] Interview 130722

[81] Bloomberg http://www.naturalcapitalnews.com/mainstream-plans-new-fund-to-access-cheaper-

- the project management of the construction phase
- ongoing operation and maintenance
- the sale of fixed assets to equity investors
- negotiated a share of ongoing generational revenue

The market for these services was global, Irish firms were venturing further afield. While the Mainstream management had experience in overseas development activity from their time at Airtricity[82], both Mainstream and Element took a more globally orientated view evidenced by Mainstream's activity in South Africa (Baker and Phillips, 2011; Baker, 2015) and Chile (Mainstream Renewable Power, 2016).

Element and Mainstream's most ambitious domestic projects were focussed on very large-scale electricity export schemes based in the Irish midlands. Element's Greenwire project and Mainstream's Energy Bridge both sought to generate electricity in Ireland for export via interconnection under the Irish Sea to Great Britain (see Figure 5.12). The scale of both proposals was thousands of megawatts, targets that would mean a substantial increase in Ireland's installed wind capacity. These projects were predicated on using Irish wind resources generated in a low-populated part of the country, where wind had not previously been exploited due to wind resources which were low in Irish terms, but still high in comparison to many other European regions. These commercially and technologically ambitious projects were underpinned by three narratives. The first narrative made the claim that Ireland's large endowment of wind resources could be commercially exploited at a national scale. The underlying imperative was the opportunity electricity export offered to assist with the large national debt burden placed on the post-recession economy[83] (Government of Ireland, 2011). The second narrative was a story about firms in the Irish wind sector having the technical capabilities and know-how to exploit this situation.The third narrative was one of job creation[84] which had been constructed and mobilised by actors in the industry over previous years. In 2009 Deloitte, funded by IWEA, released an

investment/#sthash.rpUMlO27.dpuf

[82]Most notably investing in offshore projects in the UK and onshore in Chile as well as a number of US ventures.

[83]The link between renewable electricity and economic recovery had been explicitly made in 2009 by DCENR minister Eamon Ryan when he envoked a "green investment" frame to justify increasing Ireland's 2020 renewable electricity targets from a 33% share of generation mix, to over 40% (Department Energy Communications and Natural Resources, 2009).

[84]Historically, short term job creation was a leading driver of industrial development strategy in Ireland, at times at the expense of sustainable long term industrial development (Breznitz, 2007).

industry report suggesting Ireland's wind industry could generate approximately 10,000 jobs[85] (Deloitte, 2009).

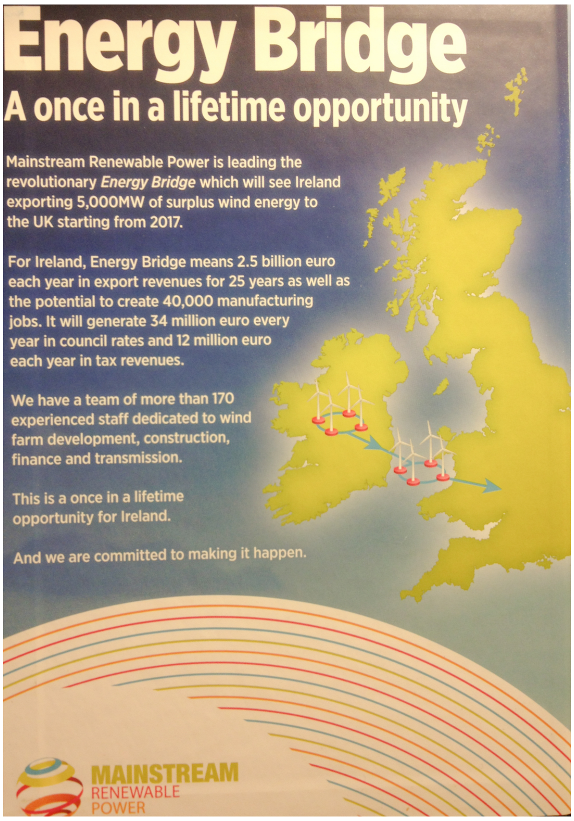

Figure 5.12. Mainstream Renewable Power advertisement, Energy Ireland Yearbook 2013.

These projects were implicitly legitimised in 2013 by DCENR Minister Pat Rabbitte who evoked these narratives when the Irish and UK governments signed a memorandum of understanding committing resources to feasibility studies of increased electricity trading between the two countries:

> "Ireland has the potential to generate far more wind energy than we could consume domestically. The opportunity to export this green power presents an opportunity for employment growth and export earnings which we must seize if we can."[86]

These visions focussed on wind as an export commodity and on opportunities to deliver

[85] It is possible to debate the veracity of these figures, however, the goal of this discussion to to examine the narrative role they played in the story of Irish wind development. The evidence suggests IWEA succeed in getting them into the sectoral discourse on Irish energy, evidenced in later years as job numbers were referenced in mainstream or business media as fact, rather than as scenario-based outcomes (for example, see "5bn set to be invested in onshore wind energy projects" in Irish Examiner, October 3, 2013).

[86] As reported in PA Newswire: Ireland, "Wind energy sale set to boost jobs" January 24, 2013

renewable electricity into a market where the generation of that electricity in England and Wales was a contentious political issue (Devine-Wright, 2011; Devine-Wright, 2005), where the Conservative-majority government in the United Kingdom would not, for political reasons, allow further onshore wind farms be built. Although both the Irish and British parties to the memorandum conceded in 2014 that the project would not proceed at governmental level due to commercial, technical and political reasons, the episode illustrates premisses and beliefs held by actors in the industry at the time. In the 1990s and 2000s actors in the wind sector had sought financial and regulatory support and offered in return solutions to initially environmental concerns followed by diversity in markets. Now, with confidence gained from having established an industry in Ireland, the wind sector was drawing on visions and proposing solutions to relevant to the recession, job creation and industrial export.

5.4.2 New challenges: innovation and opposition

During this period problems of curtailment came about as the installed capacity of wind generation on the grid increased which according to CER (2012a, p. 4) occurs:

> "when there is not sufficient demand in the SEM, when taking into account system operational restrictions for security of supply, i.e. a combination of low demand, excess wind production and technical minima of plants which can result in system security issues."

Problems of increased curtailment were causing both technological and investment risk for wind farm developers and owners in the RES. This had potentially different implications for older wind generators compared with new entrants, again explained by (CER, 2012a, p. 5):

> "Curtailment can be seen as being driven by the marginal wind generator in the dispatch stack, i.e. the last wind generator on the system causes the curtailment event. Under this viewpoint, a causer pays approach can be taken to solve the curtailment event, effectively a last-on, first off approach. This approach has been termed 'grandfathering', in that existing plant have different rights to new plant, under certain circumstances.
> An alternative view is that curtailment is a system wide problem; with each individual wind generator contributing partially to the overall problem and

> therefore each should make a contribution to solving the problem. This approach is termed 'pro-rata' as each generator contributes to solving the problem in proportion to their availability."

Over the course of 2012 and 2013 the Commission for Energy Regulation and the Single Electricity Market Committee worked with industry actors to ultimately agree to a pro-rata solution to the question of grandfathering, which likely favoured future development by allocating revenue risk amongst wind generators.

Independent of large scale, private energy export projects, interconnection of Ireland and Great Britain's grids had been proposed by advocates of the wind sector for technological and market based reasons. On the one hand it was argued that interconnection offered a technological solution to the increased levels of curtailment due to increases in intermittent generation capacity on the grid. Interconnection is not based on radical technological innovation but on Ireland's small-island network it was believed by proponents of the wind industry to bring about a technological step change required for further integration of intermittent generation, as this statement from a policy strategist illustrates:

> "It it's critical for our delivery of targets on wind energy because it reduces the level of curtailment of wind energy that would occur by at least 50% so, so it's significant in reducing the cost of wind energy integration.
> ...the levels of curtailment that would occur to meet our 2020 targets without the east west interconnector would be unacceptably high and it would be infeasible to finance wind farms with levels of curtailment that would be in excess of 10%."[87]

On the other hand, interconnection was an ensemble of material technologies with which to join Ireland and Great Britain's disparate electricity markets, a goal of Europe's single energy market agenda. In 2009 the ESB acquired approximately €500 million of funding from the European Investment Bank to construct the East-West interconnector, connecting Ireland's east coast to north Wales[88]. The 260 km, 500 MW, 200 kV high voltage DC transmission link was commissioned in 2012.

Yet the case being made for increased interconnection in the research emerging from Irish university departments was not straightforward. It was found that Great Britain would be better able to balance its wind resource by spatially distributing wind production

[87] Interview 130201

[88] This loan also included financing for wind farms to be constructed by the ESB, a source of funding accessible to large scale utilities. Source: European Investment Bank

within the country, rather than through interconnection (Foley, Leahy, et al., 2009). While increased interconnection would likely result in the reduction of average prices in the Irish electricity market, resultant displacement of greenhouse gas emissions from Ireland to the UK would lead to a close to zero net emissions reduction between the two systems[89] (Denny et al., 2010). Furthermore, there would be a resultant reduction in Ireland of excess wind generation. Diffney et al. (2009, p. 485) suggest that when modelled as a perfect arbitrageur, "allowing electricity to flow from the low price to the high price jurisdiction", increased wind generation and interconnection would lead to cost reductions in the wholesale price of electricity. But they warn that interconnection is not likely to operate optimally, and thus "a much larger infrastructure investment could be needed to obtain the same effect, possibly causing the high wind scenario to become too expensive" (ibid.). In a later study examining interconnection throughout the EU, (Lynch et al., 2012, p. 616) argued that

> "current interconnection capacities are therefore sufficient for the current generation mix and new interconnections are only warranted by EU mandates for renewable generation."

This episode is an example of the wind sector and wider electricity industry mobilising favourable wind narratives, to legitimise industrial activity on the one hand. On the other, we see in the resolution of the grandfathering issue, the ability of the regulator and market operator to mediate and regulate diverse and contentious issues within the RES.

> "All political parties have bought into [wind power]"[90]

This was the message from Minister for Communications, Energy and Natural Resources Eamon Ryan to the Irish Wind Energy Association annual meeting in Dublin in March 2009. Presciently he added that the biggest hurdle faced in achieving Ireland's its renewable targets was expanding and upgrading the nation's electric grid a significant constraint being the engineering and financial limits on putting new transmission underground. In a 2013 address to IWEA's annual conference, Andrew Garrad, president of the European Wind Energy Association, was reported as telling the audience that public

[89] The price lowering effect was due to pricing efficiencies gained from operating the interconnectors intra-day, whereby "the day-ahead prices are reduced slightly while the intra-day prices in Ireland are significantly decreased. This is due to being able to use the interconnectors instead of more expensive peaking units to make up for wind power forecast errors, or unit outages." (Denny et al., 2010, p. 6952)

[90] Media source S1-88

acceptability was now the main challenge to a 'jobs-rich export industry' being established in Ireland.[91] Mr. Garrad's views were informed by new opposition activity to wind farms, in particular the midlands schemes. This opposition was not only to the turbines, towers and access routes required for constructions and maintenance, but also to the new grid infrastructure under construction as part of EirGrid's multi-decade infrastructure scheme, Grid 25. The presence of these narratives in the evidence is illustrative of two aspects of recent activity in the sector. First, the increased scale and new location of proposed grid infrastructure and wind plant installation mattered. Second, the development strategies employed by EirGrid, Mainstream and Element Power initially underestimated the strength of antipathy their projects would encounter at a county level. These episodes highlight emergent tensions between stories of wind technology as a solution to economic difficulties at a national and international level, and sub-national and national level organised opposition to the construction of turbines and towers, roads and high-voltage transmission infrastructure.

In the ten years between take-off in construction of wind farms in 2003 and proposals for energy export projects, the scale of individual wind projects had remained remarkably stable (see Figure 5.13). Over time, turnkey generating plant increased in capacity coinciding with steady annual increases in the hub height, rotor diameter and full load hours recorded (Duffy and Cleary, 2015, p. 92). Yet average recorded wind speed at new locations decreased, suggesting wind farms were being constructed in areas with lower wind speed, as the best sites had been developed earlier. Duffy and Cleary (2015, p. 85) conclude

> "that although wind projects are increasingly using lower wind resource locations, average capacity factors for projects built in 2011 and 2012 remained high. This would suggest that the larger wind turbines with increased rotor diameters and hub heights are successful in achieving a viable energy yield from these locations."

We can draw two conclusions, First advances in turnkey technology achieved in research labs overseas have supported the commercial viability of project development in an increasing number of locations throughout Ireland. Second, although indigenous tacit knowledge of building wind farms in the industry has increased, and consolidation is occurring, the size of new wind farms being deployed has remained remarkably stable. Developers such as Mainstream and Element were getting better at rolling out wind farms, but they were

[91] Source: Irish Examiner, March 28, 2013

not, at the mean and median, constructing substantially bigger wind farms (illustrated by the linear trend of mean wind farm size in Figure 5.13).

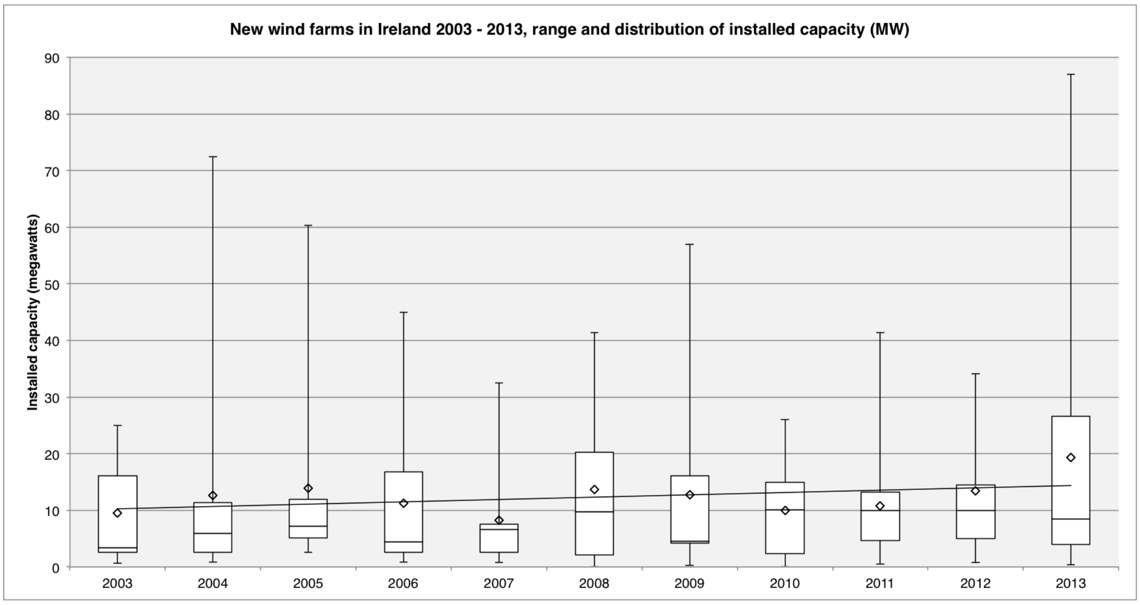

Figure 5.13. Scale-up of new wind farms in Ireland. A box and whiskers format is used to represent the distribution and range in sizes of newly completed wind farms for each year. Vertical lines represent the cumulative installed wind capacity per year. The boxes represent descriptive statistics on individual wind farms. Chart includes the 25th to 75th percentile (box), median (horizontal line within each box), mean (diamond), and minimum and maximum wind farm sizes (whiskers). The linear trend of mean wind farm size is indicated by the diagonal trend-line. Source: data compiled by author from various sources.

The average size of wind farms commissioned in 2013 was 15 MW, but this extended discussion on the narrative history of wind technologies in Ireland has illustrated that the scale of development of wind farms is not a given, but influenced by the outcome of technological, political and social choices made within and outside of the wind sector. An economist and policy expert made this point with regard to the influence of European policy on the wind sector in an interview:

> "relevant EU targets [matter] yes... but Ireland's solution to those EU targets is determined by the technological developments. They could be going for wood boilers in everybody's house, they didn't because they could meet the target cheaply and efficiently through electricity [generated] through this means. And then there is major uncertainty as to whether there will be a target after 2020 and the paper by Muireann Lynch."[92]

The interviewee's point is that in the electricity system, that policy has mattered, but not

[92] Lynch et al. (2012) show the influence, and how potentially costly uncertainty is in this regard.

exclusively. We have discussed at length how the technologies, actors' beliefs in technological opportunity, and their ability to influence policy has also played an important role in the pace and nature of developments.

Summing up

Garud and Karnøe (2003, p. 282) tell us that "modern wind turbines embody the steady accretion of inputs from many actors". The narrative history discussed in this chapter showed the accretion of inputs does not end with the manufacture of material technologies but extends along the value chain into new deployment contexts, by boat, by plane and by PDF.

The case narrative presented was the story of how and why these technologies arrived in Ireland, and what happened to them and the actors who brought them here once they arrived.

I found from the very first commercial projects in the 1990s, indigenous developers worked with overseas technology suppliers and consultancies, often through joint ventures. Regardless of developer, three dominant barriers to development were found; problems obtaining planning permission in sufficient time to enable commercial development, access to the national transmission grid, and the availability of power purchase agreements. Notable here are two potential impediments that were not widely found in the evidence – the availability of finance, and learning. While planning regulations were never well-aligned with the goals of wind RES actors, considerable progress was made on grid access and power purchase agreements and the reasons for these difficulties are largely explained as a local competence issue rather than being about organised resistance. I found that these were addressed through core institutions of the grid queue, the rules of the Single Electricity Market. These were further bolstered with a series of support payment schemes. These institutional shifts were influenced on the one hand by policy agendas at EU level, and on the other by lobbying activities by wind RES actors. The Irish energy department was relatively unencumbered by ideological drive, rather playing a role accommodating and corralling an initially reluctant ESB, whose growth strategies were initially focussed overseas.

Three episodes in the narrative illuminated particularly useful aspects of the system. The moratorium on grid connections illustrated the agency of actors in Ireland, the ESB and the asynchronous agency in the relationship they had with turnkey suppliers. The RESG illustrated ‘backstage’ processes by which knowledge, stories and agendas were shared amongst firms, the state and statue utilities. And the recession was a useful focussing event, allowing us to consider significant changes to the wind RES as the availability of Irish finance decreased after 2008, and ushered in a period of consolidation within the industry, new entry of overseas actors, and new industry rhetorics of societal benefits.

In Chapter 6 I focus on analysing the structure of the Irish wind RES. I analyse how and why European policy agendas have influenced the emergence and growth of the Irish wind RES. I examine what effect the three major system barrier had, we analyse the formation and effect of the three core wind RES institutions, and we discuss the alignment of these and other institutions with the goals of wind RES actors. Chapter 7 details the function analysis. Two emergent functional themes identified in this chapter are given special analytic attention, the role of legitimisation discourses and activities in Ireland and the influences on the direction of the search for new technologies from within Ireland and from overseas.

Chapter 6

Analysis of the Irish wind RES structure

This chapter contributes a structural analysis of the Irish wind electricity system. In doing so the chapter uses the structural aspects of the research framework outlined theoretically in Section 3.2, the operationalisation of which was presented in subsection 4.3.2. The analysis focusses on actors and networks in Ireland, technologies imported and created within Ireland, and actor networks constituted at least in part within Ireland. These concepts were introduced in Subsection 3.2.3 where I drew the theoretical focus to unevenly distributed agency within innovation systems and highlighted the role of prime movers. Furthermore we introduce a geographic perspective in which we might expect indigenous actors to be locationally advantaged or disadvantaged in certain situation. An ensemble of European regulatory institutions is constructed to which relevant Irish informal and regulatory institutions are added. The theoretical background was discussed in Subsection 3.1.1 where I introduced the concept of institutional alignment as a constituent process at the heart of large-scale transformation processes. In Section 6.3 I show when and under what circumstances elements of the ensemble are aligned to the goals of various wind RES actors. Furthermore, I account for how this alignment took place throughout each of the four analytic periods discussed in the previous chapter.

I address two of the thesis hypotheses relating to institutional change in subsection 6.3.2 and identify three 'core' wind RES institutions which played a significant alignment role.

With this structural perspective assembled, I consider a dynamic perspective on the emergence of the wind RES, and relevant structural drivers and barriers to attendant system alignments in section 6.4. Ultimately this allows me assess the consistency and inconsistency of institutions at different phases of the history, something I do not a priori assume to be constant over time and space. Finally, the extended discussion on contextual institutions necessitates the introduction of some further detailed evidence on European Union policy and policy processes, as well as details of national energy policy in Ireland which were mentioned in passing in Chapters 2 and 5 and is expanded where necessary below.

6.1 Components of the Irish wind RES

6.1.1 Actors, narratives and analytic stories

We begin the technological innovation system analysis by documenting and assessing the structural components of the system; the actors, networks and institutions.We build on the discussion of the system components introduced in the previous chapter, however, the task at hand is to focus on specific activities of the actors and networks and assess the influence of each on the emergent and evolving Irish wind RES. We assess these activities through narrative analysis, analysing appropriate stories mobilised by actors endogenous and exogenous to the system. The case narrative presented in the previous chapter was made up of actor narratives located initially in the evidence from interviews then extended and triangulated with periodical and media sources. These narratives mobilised by actors and coalitions of actors within and around the developing system and in short, accounted for who did what to whom, when it was done and where it happened. In this chapter, we discuss the context of the narratives and their underlying analytic storylines[1]. Thus the aim of this narrative analysis is threefold. First to account for the role of actors in the system and how they influenced or were influenced by institutions. Second, we assess which institutions were “in play” or contested (e.g. through lobbying), and which remained fixed, or exogenous to the influence of actors within the focal system. Third, and building on the first two tasks, we assess how well aligned (or not) the actors and institutions of system are.

We use the set of analytic stories – introduced in section 4.3.2 – to structure the dis-

[1]Of course, these stories in themselves are accounts often sympathetic to the interests of certain actors. However, these accounts are illustrative of real world events, processes and interests in the industry and assessed in aggregate, give us knowledge of the underlying generative structures, or analytic storylines. Recall from Chapter 4 that the analytic stories are the underlying generative structures or processes of reality of which narratives are one specific account, framed from a specific point of view.

cussion on components of the system and activities related to those components. To aid this, we summarise in Table 6.1 a mapping of the analytic stories relevant to each phase of development. Furthermore, by way of a simple classification system, the table indicates whether the narratives representing these analytic stories expressed broadly positive, negative or indeterminate sentiments with regard to wind energy technologies. These serve an heuristic purpose, helping guide us through the analysis of actors in the system in a manner which helps us locate formal and informal networks and coalitions. We thus systematically identify actor positions, coalitions, strategies and goals.

6.1.2 Wind developers

Wind farm developers typically acquired land through purchase or rental agreements, acquired planning permission, purchasing turnkey plant, managed project construction, acquired grid connection and power purchase agreements and managed or sub-contracted ongoing operations and maintenance. Each of these tasks required competencies and knowledge which was acquired through a combination of joint ventures with other firms, the hiring of consultants or skilled employees, learning from previous projects, learning through industry networks and workshops and professional training. Furthermore, many of these actors performed additional activities in order to further their own interests and often to promote the interests of the wider wind industry. These included lobbying for technology support instruments, competing against other electricity generation technologies for share of market or for limited investment capital from Irish and overseas financial firms.

The history of the Irish wind industry is told and re-told, often strategically, by developers themselves and is a central construct in the wider history of the industry (A–06). Actors cumulatively incorporated episodes such as the construction of Bellacorrick and other early wind farms to create confidence in the contemporary industry and to build positive expectations about the future industry. Developers interpreted and framed data on the country's wind resources as being 'Irish' and amongst 'the best in Europe' (A–01). These resources were in turn framed as commercially exploitable opportunities requiring government and European support. The wind resource being exploited was framed as 'Irish', which gave the industry a strong sense of national identity, despite the considerable monetary outflows to turnkey technology providers in Germany, Denmark and later Spain and engineering consultants in the United Kingdom. Commercial development opportunities were often framed as solutions to Irish societal, economic and environmental problems. The systemic 'story-of-self' encapsulated the wind industry not simply as a

Table 6.1 Analytic stories of the wind RES in Ireland

		Development period			
Ref.	**Analytic story**	**P1**	**P2**	**P3**	**P4**
A-01	The interpretation of Ireland's wind resource endowment	o	+	+	+
A-02	The influence of EU technology demonstration and support schemes	o			
A-03	The informal processes of access to the grid	o	-		
A-04	The role of turnkey technologies and the influence of manufacturers	o	-	o	o
A-05	Joint ventures with overseas firms	o	o	o	o
A-06	The construction of the story of what the Irish wind industry is	o	o	o	o
A-07	IWEA's role in the wind industry	o	o	o	o
A-08	Planning regulations (as barriers)	o	-	-	o
A-09	National technology support mechanisms	o	o	+	+
A-10	The EU market liberalisation agenda	o	o	o	o
A-11	The influence of macro economic growth	o	+		
A-12	The influence of the RESG		o		
A-13	The influence of the moratorium on the Irish wind sector		-	o	
A-14	The influence of the CER's regulation of industry		o	o	o
A-15	The influence of Irish research		o	+	o
A-16	European energy policy and processes		o	+	o
A-17	The grid allocation process			+	o
A-18	The role of the SEM			o	o
A-19	The impact of the recession			-	o
A-20	Industry consolidation			o	o
A-21	Wind as export commodity			+	+
A-22	The impact of increased interconnection			+	+

Key:

- primarily negative sentiments wrt wind RES.

+ Narratives expressed primarily positive sentiments.

o Inconclusive sentiment or contested narratives niche sector which required support and protection from market forces (e.g. from actors such as the monopoly utilities), but as a system that was able to address wider issues. First, the issue of climate change, then through the economic boom, 'keeping Ireland's lights on' (A–11), and finally through the recession, an indigenous industry capable of supplying jobs, electricity and revenue to the domestic economy (A–21). The narratives that represent these analytic stories matter, analytically, because as time goes by, we see them performed by a wider range of actors, including politicians and policy makers indicating increasing influence and agency in the system.

Despite this collective story-making, wind developers were neither homogenous nor harmonious. They were a heterogenous group of actors who maintained shared interests in the growth of the industry, but were also in competition with one another for limited resources such as finance and skilled labour, and access to markets. In the first two periods development was carried out mostly by small and medium sized private developers, then by increasing entry of utilities in the third phase, and a system reconfiguration in the fourth phase following the recession and merger and acquisition activity. The evidence of activity in the narrative correlates with actor-types identified in data identifying project activity obtained from the system operators. Using this data we have classified the developer firms into categories based on firm scale (utility and non-utility) and origin (domestic and overseas, or non-domestic).[2] From these categories, four sub-types have been identified. We trace the development and acquisition activity of these four actor groups through examining ownership of wind farms over time (see Figure 6.1). It is notable that this categorisation precludes a simplistic (fossil fuel) incumbent versus (renewable) challenger dichotomisation of the wider electricity sector at the national level. Furthermore, whilst an incumbent versus challenger division may have been an appropriate analytic lens in the first decade, from 2004 onwards composition of the sector becomes more complex, as illustrated.

These developers performed different roles and mobilised several different and sometimes contentious narrative frames in order to further their own interests. In the early years of the study period, Irish wind farm developers provided knowledge about local land,

[2]These two categories are based on two rationales. First, the evidence suggests the scale of the firm materially affected the ability of the firm to raise finance. Utility scale firms typically, though not exclusively, have direct relationships with electricity buyers and legacy fossil fuel generation revenue streams, allowing them to generate balance sheet finance. Second, national or transnational origin of the firm influenced its ability to draw on knowledge and other resources from overseas locations. Where evidence of joint ventures between different types of firms was found, category assignment was made based on best available evidence of how the scale and location of the joint venture influenced its activities in the wind system.

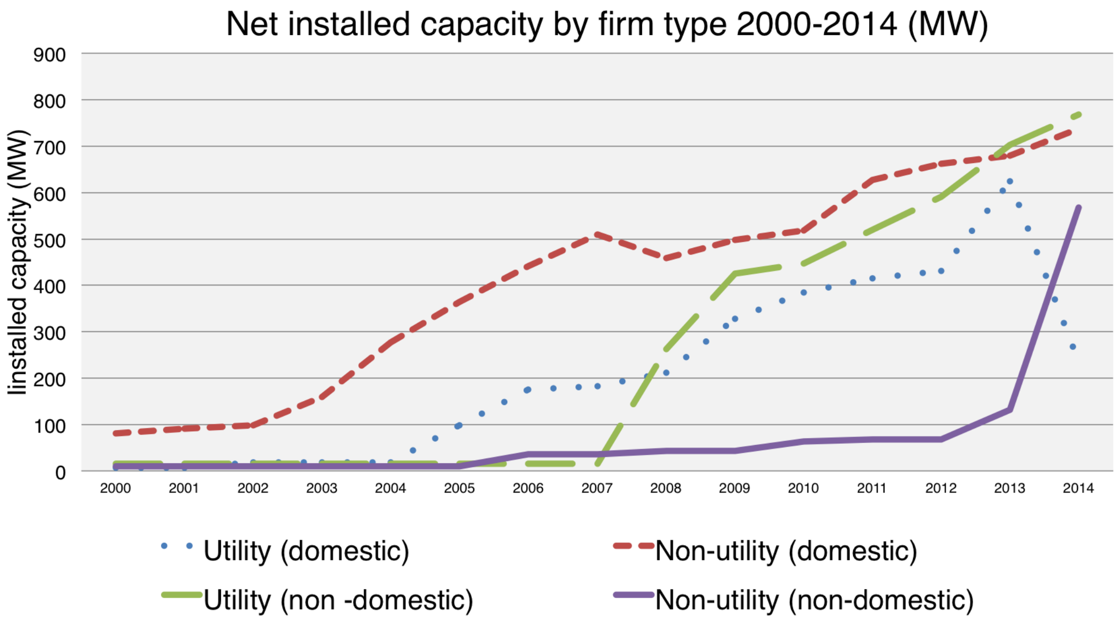

Figure 6.1. Growth and decline of cumulative installed capacity by four firm types, 2000-2014

political institutions and regulations to overseas joint venture partners (A–05). Through the volume of planning and grant applications they demonstrated commercial potentials of the system. As the system developed they pioneered new business models in gave often loud voice to post-recession frames of energy export and 'green' jobs (A–21). The ESB, Ireland's largest energy utility initially mobilised counter-narratives against the proponents of wind, the dominant of which suggested Ireland's grid would never be able to accept more than 7% wind generated electricity (A–01). However, by 2000 the ESB had begun exploring commercial opportunities independently and through joint ventures with overseas firms and local developers, at which point the utility's wind development actives began to resemble those of independent Irish developers. Overseas utility firms Scottish Power (as owner-developers), PowerGen (E-On) and RWE (as joint venture partners) invested in early development projects but ultimately did not pursue further opportunities in Ireland. However SSE's acquisition of Airtricity and Energia's entry into the market in the late 2000s changed the composition of the industry significantly (A–20). By 2010, utilities, both domestic and overseas, accounted for the majority of newly commissioned wind farms annually in Ireland (see Figure 6.2. While Figure 6.1 illustrates ownership in the industry and indicates mergers, acquisition and consolidation, Figure 6.2 illustrates which actor type was building new wind farms in each phase of development). Indeed, this evidence suggests that developers themselves perceived that commercial development was most clearly associated with large firms as this interview text - which was introduced in Chapter 5 - suggests:

> "If we were starting off now we would find it much more difficult I think that is fair to say. As time goes on, and it is inexorable since the early 90s, it has become more and more of a big boys game. It is a huge money game, why wouldn't it be."[3]

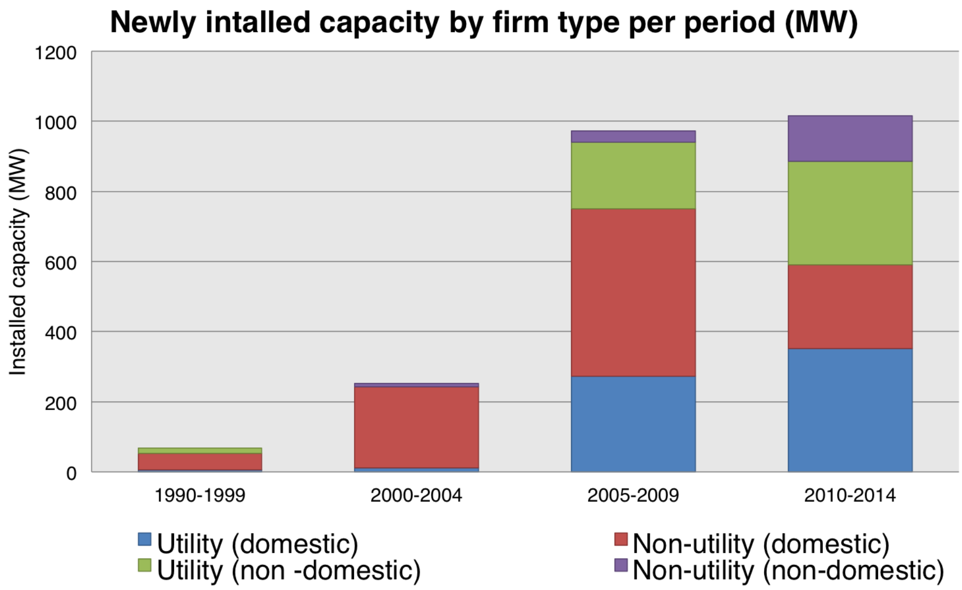

Figure 6.2. Development of new wind farms in Ireland by firm type (cumulative installed capacity, MW)

6.1.3 Other actors and networks

Utilities, system operators and engineers

Where developers did not have available and affordable competencies within the firm, external consultants and contractors were used. UK engineering firm Wind Prospect for example provided consultant engineering services on 46 developments in Ireland between 1998 and 2013, over 25% of all projects built in this period. Whilst some Irish firms developed competencies in this area over time, overseas consultancies retained significant market presence competing for tenders. Turbine manufacturers on the other hand played a less significant role in Ireland. More influential to the industry in Ireland were the system operators. The system operators for the first half of the study were vertically integrated as part of the ESB. Although unbundled as part of the 1999 Electricity Act, it was the mid–2000s, after the moratorium, when the analysis suggests EirGrid's approach

[3] Interview 130503

to the wind industry became more favourable, as new employees, attitudes to problems and research emerged. Through this period they retained high degrees of agency and power and played a 'gatekeeping' role with regard to grid access. The system operators worked closely with the regulator which was founded following the 1999 Electricity Act. The regulator according to a senior department official was reluctant to make policy as this text suggests:

> "The CER was saying 'Look, I'm not responsible for the law. I'm following the law here."[4]

However, in later phases the regulator facilitated processes for changes in market rules such as alteration of the grid allocation process or changes in the treatment of curtailment in tie-break situations (A–14) (CER, 2012b) and as such, may be thought of as providing an institutional space for industry debate and rule-setting.

Government actors and the civil service

The law was made by the civil servants in the Department of Communications, Energy and Natural Resources, based on government policy. The DCENR budget and headcount was modest, relative to other government departments, and energy was not a high priority policy domain. Their approach to policy making was guided on the one hand by Europe, and on the other by EirGrid and the CER, which according to an interviewer resulted in a situation where:

> "Three agencies overlapping who are independent of each other who don't always see eye to eye and question each other so the policy making process is not as simple as it looks. But I think that each knows that the other will question them on everything they do so it may slow positions but I think it has helped to rational decision making."[5]

The DCENR did play a co-ordination role by establishing the RESG and REDG processes. Furthermore, through the setting of national targets the department used the evidence of firm activity to frame and establish European energy targets and goals in Ireland (A–16).

Research and industry networks

From the early 2000s, we see the emergence of influential indigenous research actors (A–15). Evidence suggests they worked closely with industry, in particular the system operators. The analysis suggests that over time researchers in Ireland became more purposeful

[4]Interview 130703

[5]Interview 130703

and ‘political’[6] focussing on narrow, more locally specific problem areas. The research community played a role in the integrating of global turnkey technologies into an Irish context. Research actors also played a role as carriers of new wind-favourable narrative frames which represented underlying beliefs and attitudes, bringing them out of the universities and into modernising organisations such as EirGrid. In turn, utilities and system operators developed new attitudes to wind as well as acquiring new capabilities. However Irish wind actors did not make a significant contribution to turbine design, and similarly, Irish market issues did not significantly influence the development of plant in overseas research settings.

Specifically there is bibliographic co-authoring evidence of informal knowledge networks developing between the significant electricity research centres in University College Dublin and University College Cork and EirGrid and the intermediary SEAI. The most significant industry network was that of the industry associations IWEA, and to a lesser extent, Meithel na Gaoithe (A–07). Through the 1990s and 2000s IWEA’s membership consisted of a mix of corporate and hobbyist actors and even with changing industry composition, retained an argumentative and confrontational style of lobbying. Yet according to one former DCENR official, they had good engineers and technical skills in the association which according to one respondent:

> “helped because it means the main wind lobby group in that instance is sane and you can easily trust.”[7]

IWEA established and maintained transnational links to EWEA and in addition to lobbying, conducted knowledge building activities through workshops and conferences and commissioned research which in turn was mobilised within narratives to lobby for increased support from government. However, as overseas utilities entered the Irish wind industry in the later periods, Irish actors (in addition to the ESB) joined Brussels based industry associations and lobbying groups such as Eurelectric which gave Irish firms other than the state utilities access to policy processes at a European level.

In closing, the analysis of actors shows that wind farm developers played a crucial role (with regard to the wind innovation system in Ireland) in creating and recognising opportunities to construct wind farms. However, location, capabilities and access to overseas resources were also influential characteristics of actors. Overseas actors brought with them not only access to financial resources, but relationships with consultancies and other

[6] Interview 130202
[7] Interview 130706

expert groups.

6.2 The ensemble of institutions

6.2.1 Regulatory institutions in Ireland

We begin the analysis of Ireland's regulatory institutions[8] by examining the policy instruments, which were at least nominally designed and deployed to support wind industry growth (summarised in Table 6.2). The Alternative Energy Requirement (AER) schemes were created by the Department of Communications, Energy and Natural Resources in order to incentivise private firms to establish wind farms in a highly an electricity sector dominated by the monopoly utility, the ESB. The design logic of the AERs addressed a perceived misalignment (or simply non-availability) of investment capital to would-be wind farm developers with a capital grant. In addition to supplying capital, the AERs signposted to Irish and developers based overseas that commercial opportunities for wind generation were on their way. Furthermore, the AERs re-enforced and further legitimised domestic regulatory targets.

However, the narrative analysis shows there were both structural deficiencies and issues of actor contestation. The design of the AER schemes were on the one hand constrained by European state-aid rules which dictated how firms in industries could be financially supported and on the other hand influenced by the ESB, which retained and its vertically integrated system operator division and ultimately its gatekeeping position over the electricity sector through the 1990s and early 2000s. The design of the first AER effectively excluded domestic firms in favour of bids from overseas actors which were ultimately not commercially viable. Indigenous wind developers criticised the AER schemes as ineffective in aligning their needs with institutional structures such as planning permission, finance, grid access and power purchase agreements, the latter two issues influenced by the ESB's stated desire to limit the pace and scale of wind RES emergence and growth (Ó Gallachóir, Bazilian, et al., 2010). While some improvements were made in later AER rounds[9], the basic architecture of the 'bid and build' format meant that long-term market certainty in the industry was not enhanced. Developers and their investors simply had little cer-

[8] A chronological ordering of these polices is illustrated in section 5.2.1.

[9] AER V and VI adopted a number of lessons learned from the initial schemes. For example, projects with necessary statutory permits such as planning permission were prioritised. In AER VI there were accelerated upfront payments and AER V projects could resubmit to take advantage of even more favourable solutions, 15 year PPAs were introduced (Ó Gallachóir, Bazilian, et al., 2010).

Table 6.2 Irish energy policy instruments

Year	Instrument	Goal	Instrument type	Target year	Influence on wind system
1993	AER I	+ 30 MW installed wind capacity	Tender scheme	1997	Attracted overseas developers, half of the 10 awarded schemes were not constructed.
1997	AER III	+90 MW installed wind capacity	Tender scheme	1999	Attracted 279 expressions of interest, promoted industry activity. 42% of target capacity built.
1999	PSO	Revenue generation component of support instruments	Levy on all electrical bills	Ongoing	Levy on all electrical bills €48 per MWh
2001	AER V	+ 240MW installed wind capacity	Tender scheme	2005	18% of target capacity built.
2003	AER VI	+ 433MW installed wind capacity	Tender scheme	2006	64% of target capacity built
2006	REFIT 1	+ 450MW installed wind capacity	Feed-in tariff	2010	Payment due to supplier, only if wind farm has a 15 year PPA further systematising addressing of system barriers. Gave ongoing support to a greater number of actors than AER scheme. Was understood by international investors, legitimisng Irish wind system in global context
2012	REFIT 2	Support for up to 4,000 MW	Feed-in tariff	Ongoing	Extended duration of REFIT scheme in Ireland

tainty about when the next competition would be held, or what scale of development it would support. This uncertainty was one significant factor in Airtricity's decision in 2003 to withdraw at a late stage from the then current AER round and halt development in Ireland to focus on what they considered better opportunities overseas, a decision further exacerbated by the moratorium on grid connection[10].

The choice of technology support mechanism was a highly contested issue, with the Irish Wind Energy Association and other wind advocates strongly favouring, and lobbying for, the introduction of a feed-in tariff. This lobbying, combined with European institutional pressures described in the next section influenced Irish policy, and the first REFIT

[10] Interview 130722

was launched in 2006.

The REFITs addressed some of the deficiencies of the AER schemes by changing support payments from up-front capital grants to an ongoing supply related tariff. The scheme was designed to reduce risk involved in long term wind investment by guaranteeing a minimum revenue when the market price per unit of electricity falls below a given level. Under the REFIT, generators entered into 15 year power purchase agreements with a market supplier, who typically guaranteed fixed payments over the term (unlike other FIT markets, in Ireland, suppliers received the actual REFIT payment for onward settlement with their generator). The suppliers were compensated through the Public Service Obligation, a levy which appeared on consumers'[11] bills[12]. The REFITs, through the public service obligation (PSO), were the main source of revenue for generators from their launch in 2006 (Duffy and Cleary, 2015). As such, the REFIT was a powerful signal to developers such as Airtricity that there was now longer revenue certainty for developers and investors in wind electricity, and indeed Airtricity returned to development activities in 2006.

However, the design of the REFIT has drawn some criticism from advocates of increased wind generation. The architecture of the market, and the nature of the power purchase agreement meant that a relatively small number of suppliers, rather than generators or consumers, capture the revenue upside in the market when there is overproduction of renewable electricity (Doherty and O'Malley, 2011, p. 4919). The risk this presented, according to Doherty and O'Malley, was that market revenue intended to incentivise wind generation went unvalued and made no contribution to encouraging further generation or investment. Indeed, the long term suitability of the REFIT, as wind penetration levels rise, has been debated[13] (Foley, Ó Gallachóir, et al., 2013). However, given their overall market share and position, market suppliers – typically vertically integrated utilities – occupied a strong position from which to resist changes to the status quo once the market

[11]The average wholesale market price during 2013 was €107/MWh, as compared to the REFIT tariff of €69.235/MWh for wind farms larger than 5 MW and €71.664 /MWh for wind farms smaller than 5 MW, as calculated from the annual sum of 2013 half hourly single electricity market transactions, plus generation capacity payments, plus dispatch balancing costs, divided by the total generated electricity in 2013 (Duffy and Cleary, 2015)

[12]The projected cost to consumers of this levy for wind power in 2013–2014 was approximately €40 million. Public Service Obligation Levy 2013/2014 Decision Paper, July 2013, Commission for Energy Regulation. (Commission for Energy Regulation, 2013)

[13] Farrell and Lyons (2014, p. 2) note that "as more wind power enters the generation mix, a greater share of each consumer's electricity bill is made up of the PSO charge as opposed to the energy cost". While Irish consumers have traditionally not opposed these charges in significant number, this situation is not guaranteed into the future.

architecture around the REFITs had been established.

By the time the REFIT was launched in 2006 there was already considerable commercial activity in the industry. Merchant plant totalling 338MW (49% of total) had been built, that is, generators with power purchase agreements to the market which had not received AER funding (Ó Gallachóir, Bazilian, et al., 2010). The government no longer needed to incentivise new development firms to enter the industry, rather, the aim was to improve the "bankability" of prospective development projects, their ability to return regular and predictable revenues over a ten to fifteen year period. The REFITs addressed issues of revenue predictability which had a mitigating impact on risk assessment by lenders in the favour of developers; the guaranteed price was attractive to investors putting in high up front capital. The implementation of a feed-in tariff had been a policy demand of IWEA as it supported a greater number of firms than the AER awards. The REFIT thus sent a strong, long-term price signal to indigenous firms as well as overseas utilities, investors and manufacturers who had experience of feed-in tariffs in other markets.

The increasingly powerful position occupied by Airtricity and IWEA was institutionally embedded via legislation contained in the 1999 Electricity Regulation Act (Government of Ireland, 1999). The Act preceded the creation of the market and Commission for Energy Regulation and was instrumental in creating a number of institutional conditions by which private firms could supply electricity to the national grid. Amongst the functions of the CER listed in the Act were the following duties, lobbied for by actors in the wind RES:

> "(d) to encourage research and development into— (i) methods of generating electricity using renewable, sustainable and alternative forms of energy and combined heat and power, and (ii) methods of increasing efficiency in the use and production of electricity; and (e) to require that the system operator gives priority to generating stations using renewable, sustainable or alternative energy sources when selecting generating stations"[14]

Clause (e) was the basis for market entry rules successfully lobbied for by Airtricity and IWEA which allowed wind generators privileged access to newly liberalised market segments. Wind generators and suppliers who offered them PPAs were effectively given a head-start in acquiring business customers in the new market ahead of fossil fuel generators. The architecture of the Single Energy Market, launched in 2004 was also important in this regard. All generators in the market received capacity payments, however wind generators were also the beneficiaries of dispatch balancing payments, made to compensate

[14] ibid.: Pt. II, S.9, numbering and lettering as per source text

for constraint on the network. Several other regulatory institutions were also influenced the wind sector though to a lesser degree. The 1998 Finance Act which offered corporation tax relief on profits invested in renewable energy projects brought wind energy technologies into finance and investment conversations in banks and finance practices. The 2000 Planning Act took was somewhat influenced by the Renewable Energy Development Group, although ultimately did not address adequately, from the perspective of wind farm developers, systemic barriers related to acquiring planning permission in a timely manner.

Summarising the formal policy landscape in Ireland, we see a progression from no domestic support, through to a highly uncertain series of 'bid and build' capital grant schemes, ultimately to a feed-in tariff scheme. From the policy analysis alone it is unclear to what extent these schemes and their associated targets were drivers of the growing wind energy system, or came about because sectoral growth had legitimised the spending of public money supporting renewable energy technologies. The influence of these institutions are summarised in Table 6.3.

6.2.2 Informal institutions in Ireland

Analysis of the case narrative has shown evidence of informal institutions influencing the emergent Irish wind RES. First, we note the Energy Department's (DCENR) general style of policy making, in which they eschew a top-down unilateralist approach in-favour of engagement and consensus with industry actors. This approach of the DCENR to managing industrial relations with the energy sector fits with a 'competitive corporatist' modal[15] in which policy is made 'with' rather than 'for' certain stakeholders. But the strategy is also practical, given the relatively small size and limited resources of the department[16]. This policy approach from the DCENR was influenced the organisational architecture of the Renewable Energy Strategy Group, the Renewable Energy Development Group, and the structure of the regulator. In later periods, this industrial culture was evident in the construction of the group allocation process which sequenced access by developers to the grid(see Subsection 5.3.1), and in the resolution of the contentious curtailment episode

[15] See Adshead and Quinn (1996) and Hardiman (2002) for detailed discussions on the evolution of corporatist-style policy making in Ireland.

[16] This point is illustrated in this interview text: "... having the debate played out in public allows them to assess the evidence when they are weak on resources. They [the DCENR] have some really good people, impressive people, but they are under resourced and how do you deal with that by having an open and transparent debate which they can watch and then assess what the answer is. So it is one way of dealing with the situation where you don't have all the expertise in house and it's like the SEM transparency, if you can't be a player then having a transparent situation aids policy making." Interview 130501

Table 6.3 Institutions, location and influence on Irish wind energy system: Ireland regulatory and formal institutions

Institution	**Influence on Irish wind energy system (Signposting, stabilising, transmitting tacit knowledge)**	**Deviation between case findings and expectations**
Technology support instruments: AERs	Support to limited number of actors led to build up of system activity without providing systemic solutions to system barriers. Applications created virtuous cycle of legitimising government capacity targets which in turn signposted future expectations and belief in industry to DCENR	Flaws in instrument design observed in other national cases such as the UK NFFO scheme also found in Ireland. However despite flaws, some system benefits were derived as indicated
Technology support instruments: REFITs	Stabilised the rapidly developing industry. Signposted future stability of Irish industry to overseas investors and facilitated roll-out of proposed developments. Increased bankability of projects already under development.	The literature suggests that all things held equal, market support mechanisms such as FITs disproportionately benefited smaller players. However in Ireland, we have found that this is not straightforward.
Electricity market structure	Protected space between 2000 and 2005 was crucial given limited availability of capital grants. Grid codes supplied by manufacturers embedded industry knowledge into market	Unexpected, this course of events seems somewhat unique to Ireland
Grid allocation rules	Established an arena for transfer of knowledge between developers, regulators and system operators. Stabilised development processes which signposted to overseas manufacturers and investors future market size	Not considered in review of literature
National and sub-national planning regulations	Changes in planning regulations and culture was slow to diffuse to regional settings and remained a significant barrier to development throughout	Close match

around 'gradfathering' versus 'pro-rata' merit ordering (see Subsection 5.4.2). Second, the changing composition of the wind sector meant that the overall professional culture evolved through the phases of development and was "professionalised" at the end of the 1990s. Finally, attitudes to investment and entrepreneurialism within and exogenous to the sector influenced who got financing and ultimately, what kind of actor-groups were perceived as "typical" wind farm developers.

It is appropriate to extend our discussion of attitudes to investment and entrepreneurialism as approaches to industrial development in Ireland is not apparent from the analysis of the case narrative alone. The overarching objective of industrial growth policies in Ireland since the 1950s has been job creation[17] (Breznitz, 2007). This rationale explains the strategy of the Industrial Development Authority (IDA) and its successor agencies[18] of focussing on export-led foreign direct investment as a means of economic development[19]. The focus on achieving high levels of FDI related industrial activity came at the expense of domestic research and development activities, both private and public. Incoming multinational firms were historically reluctant to establish research facilities in Ireland while tertiary eduction was similarly focussed on fulfilling industry knowledge requirements. Furthermore, this structural and sectoral bias favoured product based start-ups over research and development intensive industries. These institutional arrangements exacerbated existing mistrust of Irish entrepreneurial activities, indeed, banks in the 1990s and even 2000s were reluctant to lend to businesses unless lending could be secured by property.[20] These development issues were addressed by the influential Culliton Report in 1992, which recommended the state address market failures created by existing conservative financial bodies reluctant to lend to new businesses (Culliton, 1992). As a result of this report, the IDA and other development bodies were undergoing a series of institutional restructure as the Irish wind industry, and wider economy, was beginning to take-off.

This context helps us account for a number of barriers and biases faced by the growing wind industry in Ireland. There was a structural bias against R&D which was not addressed until end of the 1990s[21]. This bias impacted attitudes to assessment of risk, lending and more generally the approach to entrepreneurial activity. It is one factor in why

[17] An understandable goal given high historic unemployment figures, typically greater than 10% until the early 1990s.

[18] Following the Culliton Report in 1992, the IDA was broken into a number of smaller agencies under the umbrella of Forbairt, including the Industrial Development Agency and Enterprise Ireland.

[19] This reached it's zenith in 2003 when Dell, then a global beamoth in the manufacture of personal computers, accounted for €8bn in exports, almost 5% of the annual gross domestic product (Breznitz, 2007).

[20] Interview 130503 and Breznitz (2007).

[21] The relatively recent increase in research actives and their reliance on European funding frameworks such as ESPRIT is significant. Breznitz (2007) in his history of the Irish software industry points out that as late as 1998, over one-third of the research budget of Trinity College came from these programmes, at a time when it was Ireland's leading research university by size of budget.

Irish entrepreneurs did not initially consider domestic research and development[22] a useful process by which to address systemic barriers. Moreover, the objectives of development agencies was on securing overseas FDI, or export-led, high employment start-ups. Small to medium sized domestic businesses which offered low employment opportunities were were typically excluded from funding programmes, and developing strategic national expertise in renewable technologies was considered. The influence of these informal institutions are summarised in Table 6.4.

Table 6.4 Institutions, location and influence on Irish wind energy system: Ireland informal institutions

Institution	**Influence on Irish wind energy system (Signposting, stabilising, transmitting tacit knowledge)**	**Deviation between case findings and expectations**
Professional culture	Multiple professional cultures observed as composition of wind system evolved over time	Inconclusive
Attitudes to investment	Low-jobs industries were not prioritised in industrial development strategies. However, the analysis suggests this did not significantly mitigate against wind system growth. Availability of finance was not a significant barrier to development in the first and second phases. Post recession, availability of finance from Irish investors influenced who could build new wind farms.	The case findings suggest a complex relationship between the availability and location of financial resources and the location of actors in the wind system
Corporatist modal of industrial relations	Influenced RESG which in turn was an arena for knowledge transfer	Findings illustrated how DCENR strategically managed relations with private and state-owned firms

6.2.3 The influence in Ireland of European institutions

Until the 1990s electricity policy in Europe was devolved to member states. Since then, as in other policy domains, harmonisation and integration of institutions, regulations and markets across European Union member states – an aspect of Europeanisation – has been a fundamental aspect of EU energy policy making (Jacquot and Woll, 2003). These policy

[22]Ireland's dearth of industrial engineering activity and heavy manufacturing history is also a considerable factor.

processes take two forms relevant to the story of Irish wind, the first is market liberalisation and the path towards single markets in goods, services, labour, capital and energy. Market liberalisation has been a major driver of European energy regulation process and design since the start of the 1990s (Pollitt, 2012; Lauber, 2007) as this extract from the 1991 green paper on the single energy market illustrates:

> "Energy is such an important component of all economic activity in the community that the completion of the internal market is inconceivable without an integrated internal energy market"[23]

The second major plank of European energy regulation has been environmental protection and the role of climate change (Helm, 2014; Mitchell, 2008; O'Brien and Penna, 1994). In this subsection I will account for how these sometimes oppositional forces have shaped European energy policy processes over the past quarter of a century, processes which have had specific impacts on Irish energy policy.

The EU's liberalisation agenda was strongly informed by neoliberal approaches to economic policy which have been influential at least since Leon Brittan's time in the DG Competition and Industry (Lauber, 2007; Stone Sweet et al., 2001). Liberalisation in the electricity sector has incorporated both privatisation of state owned firms and the creation of electricity markets. The European Union implemented a series of reform directives in 1996, 2003 and 2009 aimed at forming a cohesive single electricity market (European Commission, 1996; European Commission, 2003; European Commission, 2009). Two underlying strategic initiatives permeated these directives. First, the vertical and horizontal unbundling[24] of utility assets and services, and second, the establishment of independent industry regulators at a national level (Pollitt, 2012). While marketisation was been the dominant form of liberalisation in Ireland, the unbundling of system operators from the ESB, and privatisation of state assets and enterprises also featured, most notably with the sale of Bord Gáis Energy to Centrica. Furthermore, market liberalisation affects both the institutional structure of the energy sector, as well as the actor constitution. Market liberalisation is accompanied by a wide variety of institutional changes in associated sectors such as grid access, network pricing, power trading, consumer protection. Associated with these changes is the entry of new actors into the sector, including new power generators, traders and financiers.

[23] European Council (1991, p. 2)

[24] Vertical unbundling refers to the breaking up of integrated utilities to facilitate access to monopoly controlled grids and networks while horizontal unbundling is the establishment or strengthening of markets by the establishment of competitors (Pollitt, 2012)

The Brundtland Commission of 1987 had a profound effect on environmental policy in the European Union which was strengthened and accelerated by the UN Conference in Rio de Janeiro in 1992 and the subsequent Kyoto Protocol in 1995. Given an increasing awareness of the role energy production had in greenhouse gas emissions, energy policy in Europe was deeply implicated. By this time Danish and German renewables industries, predominantly wind, were already world leaders, and some actors within the DG Energy perceived a chance for Europe to gain competitive advantage by leading the 'rush to wind[25]'.

Policy battles between actors favouring a market liberalisation agenda and proponents of direct state-industry support have been a recurring feature of the policy process at a European level. There tensions were evident during the policy process leading to the Directive on Renewable Energy in 2001 (2001/77/EC). Proponents of further liberalisation favoured market based instruments such as tradable green certificates[26] (TGCs) whilst those prioritising the development of the renewables industry urged the Commission to promote feed in tariffs such as those in Denmark and Germany. The final directive was considerably less market orientated than the 1996 and 1997 Green and White Papers which marked a victory against the neoliberal orthodoxy (Lauber, 2007). Notably, the directive proposed the setting of national targets for each member state, including Ireland. During the policy process leading to the directive, market orientated instruments such as TGCs had been forcefully and publicly championed. So much so that in 1999, attempting to gauge the direction of travel in Europe, Denmark's new right-of-centre government scrapped their historically effective feed in tariff, in favour of a TGC approach. This evidence points to the influence not only of the final directive, but of the policy process itself observed in member states[27]. The contention over instrument support mechanisms recommenced in the lead up to the Renewable Energy Directive of 2009 (2009/28/EC) and Directive on internal market in energy (2009/EC/72). This time the Commission's support of TGCs was strengthened, however in the final draft of the directives they remained implicit (Helm, 2014; Jacobsson, Bergek, et al., 2009).

European energy and environmental policy can be interpreted as an historic process of contestation embedded in political and economic conflicts at multiple levels; inter-state

[25]Not withstanding the Californian "wind rush" of the late 1980s, much of which was powered by European technology (Est, 1999).

[26]The UK's choosen support mechanism.

[27]It may be that the Danish government used the EU process as justification for a switch to a market based instrument, but the point remains valid that it is the combination of setting of signposts in Brussels and the interpretation of them locally which counts.

level, inter-sectoral or inter-organisational level and state level (O'Brien and Penna, 1994). Instruments favoured by the Commission are not only ideologically or normatively driven but also favour specific actor groups. In short, ideological battles at European level matter at national and sectoral levels. Feed-in tariffs and state aid generally have benefitted non-utility actors such as entrepreneurs and co-operatives, while TGCs in operation have tended to benefit incumbent industries. Thus renewable associations such as European Wind Energy Association and environmental NGOs such Greenpeace and Friends of the Earth have lobbied for FITs, whilst the large industry associations such as Eurelectric and the Magritte Group of large utility firms (including France's GDF Suez, Germany's E.ON, Spain's Iberdrola and Italy's Enel) have formed a powerful coalition in which the support of TGCs is a central shared objective (Helm, 2014; Szarka, 2010; Jacobsson, 2009, Interview 140802). The evidence suggests Irish NGOs have good relationships with European counterparts and organisations such as Greenpeace have Brussels-based teams and specific policy experts who focus on climate and energy domains. These however are small compared with the size and scale of industry lobbying organisations such as Eurolectric who represent the interests of domestic utility firms, amongst the most powerful coalition groups in EU politics.[28] The ESB have been long-time members of Eurolectric though membership in recent years has opened up to a wider range of Irish utility suppliers such as Viridian and BGE[29]. Ultimately, Ireland's influence in each of these three domains, public, private and civil society, is modest. The influence of these European institutions are summarised in Table 6.5.

6.2.4 The ensemble of European and Irish institutions

The review of Ireland and Europe's regulatory regimes shows that while technology support instruments since the late 1990s have been constructed at national level, targets have been strongly influenced from Europe, with some scope for national interpretation. In the domain of energy policy, Irish actor have had relatively little influence on a European level. Ireland has traditionally targeted its relatively small influence on strategically important policy domains such as agriculture and competition. Energy has not been a priority.[30] However, while Dublin based policy actors did not exert significant influence in Brussels, they did influence how EU policy was interpreted in Ireland. Policy actors in Ireland be-

[28]Interview 140801

[29]Interview 130103

[30]Private correspondence 140801

Table 6.5 Institutions, location and influence on Irish wind energy system: European policy

Institution	Influence on Irish wind energy system (Signposting, stabilising, transmitting tacit knowledge)	Deviation between case findings and expectations established in review of the literature
Renewables directives, ETS directive, EU 2020 targets, Roadmap 2050 (inc. state aid rules)	Signposts future local policy goals and targets. Stabilises / de-stabilises local system under certain conditions	Close match
Market liberalisation agendas Energy market deregulation, single energy market directives	EU agendas destabilised local institutions before re-stabilising. Local actors drove change by influencing structure of new institutional arrangement	Close match, notably we find that actors with local institutional knowledge influence creation of new markets, which ultimately attracted overseas new entrants once established and stabilised
Technology demonstration instruments including ALTENER, VALOREN, THERMIE, JOULIE-THERMIE	These instruments provided strong signposting to Irish developers and policy actors engaged in energy as well as regional development domains	Not considered in review of literature

came expert at anticipating and transposing[31] directives (Carswell, 2010). The European energy agendas were embedded and institutionalised with strong national influence. Furthermore, the European Union was influential in how the DCENR understood their role in relation to the electricity market, shifting from an operational to strategic role during the 1990s, in the new market environment becoming a regulator, a shareholder and a policy maker (Hastings, 2003). However, failures to articulate this changing role led to nervousness at the utility, manifesting as defensive and reactive behaviour with regard to long term strategic action, of which the moratorium was one resulting event.

This influence can be seen in number of locations. First, in the adherence to state

[31] Ireland's institutional translation, engineering and opportunism was not limited to the policy domain of energy. More significantly, the period between 1994 and 2002 was exceptional for the fortunes of Irish industry more widely as firms and the government took advantage of European market changes with lowering corporation tax rate according to former EU competition advisor and GATT chief Peter Sutherland (Carswell, 2000).

aid rules. The timing of the introduction of the REFIT suggests it was influenced by the ruling of Preussen Elektra v. Schleswag in the European Court of Justice, before which DG Energy was strongly influencing member states to avoid a feed-in tariff that would be counter to state aid rules (CJEU, 2001). The introduction of the REFITs are an example of institutions stabilising and transmitting knowledge across jurisdictions. The policy design behind REFITs had been developed elsewhere, yet in implementing them in Ireland, knowledge was stabilised in another European country. We have seen that the REFIT also was an important 'institutional signpost' which gave investors and manufacturers in Europe long terms confidence in Ireland's wind market. Finally, the 2020 and 2030 targets indicated how European targets could act as a stabilising force in sectors, and conversely as a de-stabilising force, when actors within the electricity industry expected new rules which were not forthcoming.

The European Union, and in particular the Commission and DG Energy played a role in coordinating and maintaining common frames and goals such as the single market agenda, which in the national level energy policy domain manifested itself as marketisation with some privatisation. We have shown how new technological, institutional and organizational forms have emerged from individual member states, and become solutions to policy conflicts between interest groups thus shaping subsequent expectations, interactions, and institutional innovation across the continent. These ongoing interactions between EU organisations and interest groups are what make up the day-to-day politics at a European level, and in new institutional arenas they structure and produce rules which are then transposed in member states, influenced by local interests and institutions.

6.3 Institutional alignment and actor goals

6.3.1 Alignment of institutions and actors' goals

In the first period of development the Irish development firms were active in the emergent wind electricity system. The narratives they mobilised – of increasing commercial opportunity and industry formation – were indicative of both positive expectations in the emergent wind energy system and returns on investment available from winning grants and other speculative activity. However, sustained growth in commercial activity was blocked by a number of institutional barriers. The technology support instruments were misaligned with the project requirements needed to realise actors' commercial goals (e.g. obtaining planning permission, grid access and PPAs). Furthermore, these instruments were out of alignment with other regulative institutions in Ireland. For example, the actors who obtained planning permission were not in many cases the same actors who received grid allocation offers or PPAs. At this time Irish energy legislation was strongly influenced by the EU. The transposing to Irish law of energy liberalisation directives created the opportunity for wind firms in Ireland to influence the national institutional setting, ultimately creating protected market segments which gave generators renewable electricity direct access to the consumer electricity market. On the other hand, EU state-aid rules in conjunction with opposition from the ESB precluded the DCENR from increasing the size of AER grants, or implementing feed-in tariffs. Thus, while there was relatively little commercial deployment of wind technologies, some institutional re-alignment took place towards the end of the phase.

The establishment of the regulator, the CER, and electricity market was a significant institutional development for actors in the wind RES, the composition of which throughout the second phase remained predominantly Irish developer firms. The formal rules of the new electricity market were well-aligned with the goals of wind generation firms, and moreover, were constructed with some flexibility which allowed further institutional changes over the following years. These included the introduction of the REFIT, public service obligation and curtailment payments which were introduced with the launch of the SEM in the next phase. While the establishment of the CER brought independent regulation of the energy sector, the analysis suggests for the duration of the moratorium it was still strongly influenced by the ESB and the system operators, and was not well-aligned with the interests of actors in the wind RES. This was illustrated by the CER and ESB's shared narrative framings and strategies at this time, which in halting grid connection offers, reversed some of the progress which had been made through the Renewable Energy Strategy Group. Narratives that incorporated positive expectations of the possible contribution of wind energy to the wider economy and in particular to industrial energy demand, intensified at this time. These stories were reproduced and performed by wind actors, aligning the economic needs of the country with potential supply offered by wind development. Rather than the institutional aligning with the goals of the actors', in this case the actors attempted to reframe their goals as mutually aligned with industrial and economic policy. In these cases, the ESB and other utilities evoked similar narrative frames to IWEA and independent firms.

Legal cases in Europe which set precedents that were favourable for feed-in tariffs occurred in the second period of development. In Ireland, the influence of these cases were seen in new technology support policies in the third phase. With the REFIT, Ireland's primary technology support instrument was significantly better aligned with private developers‘, investors' and manufacturers' interests. Furthermore, the EC's 2020 targets influenced national policy in Ireland, further aligning it with the wind RES. During this period the composition of actors in the wind RES changed, influenced by the dynamic institutional ensemble. While the ability of Irish developers to access financial resources within Ireland decreased because of the recession, expectations of future growth ultimately increased, in part due to the institutionalisation of new grid allocation rules, and the introduction of the REFIT, which allowed a greater number of actors participate than within the AER schemes and which contributed rents to successful applicants. Although the wind sector was not a priority area in national government R&D spending and industrial development strategies, indigenous research that was carried out at this time was well-aligned to the needs of commercial actors and system operators, specifically those seeking technological advances in increasing the penetration of intermittent electricity on the small island grid. Informal research networks consisting of researchers, system operators and some firms further enhanced these processes. With the onset of the recession, we observe consensus amongst wind developers regarding the wind sector's ability to contribute to "green growth" through job-creation and energy export schemes. However overseas firms, such as ABO Wind Ireland, were able to keep developing new projects because they could access resources located outside of Ireland, whereas there is negative institutional alignment within Ireland as the Irish financial sector restricted lending.

By the fourth phase of development, core wind RES institutions – the Single Electricity Market, REFIT and grid allocation process – were well aligned with the needs of international institutional investors, asset management firms and yeildcos. Irish firms such as Mainstream and Element created revenue strategies around these rules establishing positions for themselves in the value chain between the needs of overseas investment-led firms and development opportunities in Ireland which had opened up due to the availability of initiated but uncompleted pipeline projects. As the recession continued, two significant frames were mobilised around the wind RES's story of self, which have bearing on the structure analysis. First, firm and policy actors re-framed the opportunities around large scale interconnection, aligning them with job creation and national energy export goals and opportunities. In the energy export story, interconnection was primarily about market access, allowing Ireland's wind energy firms access to UK markets. This contrasted with the story of interconnection as a technological fix which would, according to its promoters, enable system optimisation and more rapid progress towards national renewable energy targets. This framing asserted a belief that Ireland's wind developers as actors who could assist the economic recovery. Second, the framing of the wind industry exemplified by the 'wind is now a big boys game' narrative was reinforced by the misalignment of the Irish investment landscape with the needs of those smaller actors who did not have access to international capital. This framing illustrates the relative locational effect of the economic turbulence following the recession[32]. Finally, we note the misalignment of European targets with the goals of all actors in the wind RES. The perception by system actors in Ireland of delays in the announcement by the Commission of 2030 targets resulted in uncertainty in Ireland and is an indication of how the the process of target making has itself become institutionalised, resulting in negative alignment when expected rounds of targets are delayed. We summarise these alignment positions in Table 6.6.

Table 6.6 Alignment of institutions with system actors' goals

Level	**Institution**	**P1**	**P2**	**P3**	**P4**
European	Energy policy (inc. state aid rules)	-	-/+	+	+
	Market liberalisation agendas	+	+	+	+
	Climate policies and targets	o	+	+	+/o
Ireland (formal)	Technology support instruments	-	o	+	+
	Grid allocation	-	-	o	o/+
	Planning regulations	-	-	o	o
	Electricity market structure	-	-/+	+	+
Ireland (informal)	Professional culture	o	+	+	+
	Investment environment	-	+	+/-	-
	Corporatist modal of industrial relations	o	+	+	o
	Demand	o	+	+/-	-

Key: '-' negatively aligned with RES, 'o' neutral or indeterminate alignment, '+' positive alignment with RES. Two entries in a cell represents a significant change of alignment during that period.

[32]IWEA further highlighted this issue when lobbying for special support measures for smaller players in the REFIT and REFIT 2 who they claimed were especially disadvantaged

6.3.2 How alignment happened

We hypothesised in Subsection 3.4.3 that in situations where we observe rapid system growth, we would expect to find examples of pre-existing institutional alignment, in addition to relatively fast institutional change processes. In the early phases of the system's development, Ireland's formal institutions were not aligned to the needs of wind actors, although European regulatory institutions and economic growth were more favourable. However, we have observed fast and favourable institutional change in several parts of the ensemble. Most notably in the creation of the market structure and the SEM, which occurred in two stages (over the periods 1999 to 2004 and 2005 to 2007), both of which brought about greater alignment with the needs of system actors. We also noted rapid re-alignment following the recession as the negative effects of consumer electricity demand reduction was somewhat negated by the ability of wind actors to make the case for wind as an export commodity. On the other hand, the change in alignment between the following institutions and actors' interests was either slow, or negligible. The allocation of grid was a significant barrier until the third phase and problems with planning permission were never comprehensively, nationally or systemically resolved to the satisfaction of wind project developers. These findings suggest that a high level of development activity – if not completed projects – was possible without significant alignment between Irish formal institutions and actors in the system. Indeed, it may be that it was this activity which in part prompted and supported the gradual Irish regulatory changes which became more wind-favourable over time.

The analysis shows that EU-led market liberalisation was favourable to the development of the wind RES in Ireland. We have discussed how ideological battles within the EU took place not necessarily over technologies, but over the means by which technologies would be supported. In other words, over what firms would receive support finance, and what form this finance would take. Processes of liberalisation then did not directly benefit the wind industry, rather it created the opportunities for actors to engage and influence national regulatory change processes. Alignment of market rules and wind RES actors came about as the result of deliberate and strategic intervention from actors taking advantage of institutional changes signposted at EU and national level. In other words, it was not market liberalisation per se that has led to the commercial and technological opportunities for wind in Ireland, but rather the ability of actors, notably Airtricity[33] and

[33] We have noted that Airtricity had both motive and means, and were at the forefront of lobbying activity at the turn of the millennium. They and their majority shareholder, NTR plc, were staffed with

IWEA, to exploit the institutional changes occurring the in an Irish setting, in this case the electricity market. These actors recognised that the underlying goal of European policy to be both coherent, and consistent across members states, could be met in a manner that would satisfy both Brussels and their own commercial interests.

We suggested that some actors will be able to influence and alter institutions through lobbying and processes of institutional entrepreneurialism[34] (see the hypotheses in Subsection 3.4.3). The analysis confirms this hypothesis, and we see that crucially it was the combined influence of institutional change at European and national level which created the opportunity for actors to lobby for favourable market structures in Ireland. Thus while the SEM was subject to, and designed to overcome, a series of complex technological constraints, we also see how it was a socially constructed arena, embedding specific actors, interests, and rules of engagement. The alignment of the technology support mechanisms followed a similar path. Here we noted that it was the implementation of the REFIT that created significant alignment. Two institutional changes that proceeded the REFIT were also significant. First, the funding of the REFIT via the Public Service Obligation, which facilitated floor price payments, was possible only after a 2001 European Court of Justice ruling on state aid (Szarka, 2010). Second, the architecture of the REFIT was made possible by the implementation of the 1999 Electricity Act which led to the creation of the Commission for Energy Regulation and subsequently the electricity market. Again, we have discussed how Airtricity and IWEA were influential in lobbying for the necessary regulatory conditions.

The creation of the grid allocation processes was somewhat different. This institutional structure was designed to address the difficulty in obtaining power purchase agreements, a barrier endogenous to the wind energy system and applicable primarily to wind farm developers. In this case the alignment was strongly influenced by attitudes to planning, a corporatist approach to industry and firms in Ireland, and a national perspective on ‘fairness’ and agency in the decision making process though it is notable that concepts of fairness were prioritised for commercial developers, rather than end users, bill payers, or citizens who finance the capital expenditure. This was indicative of the group of actors who were involved in the decision process and from a policy perspective is an important

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former utility employees (Eddie O’Connor was former chief executive of Bord na Móna, and NTR had experience lobbying for, financing and building privatised national infrastructure assets since the 1970s.

[34] This fits well with institutional entrepreneurialism defined as action performed by “actors who have an interest in particular institutional arrangements and who leverage resources to create new institutions or to transform existing ones” (Maguire et al., 2004, p. 657).

indicator of how the direction of the technological pathway is being set and influenced during the roll-out phases. The grid allocation process also mitigated some of the negative effects of the recession. It reduced investment risk by giving overseas actors confidence in future roll-out targets (e.g. Gate 3 gave assurance that greater than 3,000MW would be installed on the domestic grid), which in turn lowered risk ratings and interest rates. In this way it stabilised uncertainty in the industry and backed-up the sign-posting of Irish and European emissions reduction targets.

A notable aspect of the first phase of development was the rapid rise in activity coupled with the low levels of alignment. The ESB's early narratives were incorporated research which suggested a maximum of seven percent of grid generated electricity could be sourced from wind due to intermittency issues. In the early 1990s, that meant an effective upper bound of 400MW on cumulative installed capacity. Certainly installing that amount of wind generating capacity was relatively unproblematic given the the high level of development-related activity in the system. Furthermore, we can understand the ESB's strategic response as the result of exogenously influenced discontinuity, not to fossil fuel generation, but rather the threat of a discontinuing of the closed-market, monopolistic sectoral structure on which it was based. Thus the ESB retained a powerful position in the market and the analysis shows that, for early emergence of the wind RES in Ireland, a high degree of institutional alignment was not required. With regard to informal institutions in Ireland, the investment environment influenced how actors with access to international resources were advantaged over actors with only Ireland-based network relations. We saw a substantial influence on the ability of actors to mobilise resources at different stages of the development. This in itself had an impact on the momentum of the system building processes and the embedding in external institutions. This concurs with observation by Wirth et al. (2013b) that informal institutions have a modulating effect on public support policies.

6.4 The structure of the Irish wind RES

6.4.1 The emergence and growth of the RES structure over time

We illustrate the emergence of significant actors, coalitions, policies and institutions in the Irish wind RES in Figure 6.3. We use this figure to illustrate our discussion of key structural drivers and barriers in the next subsection

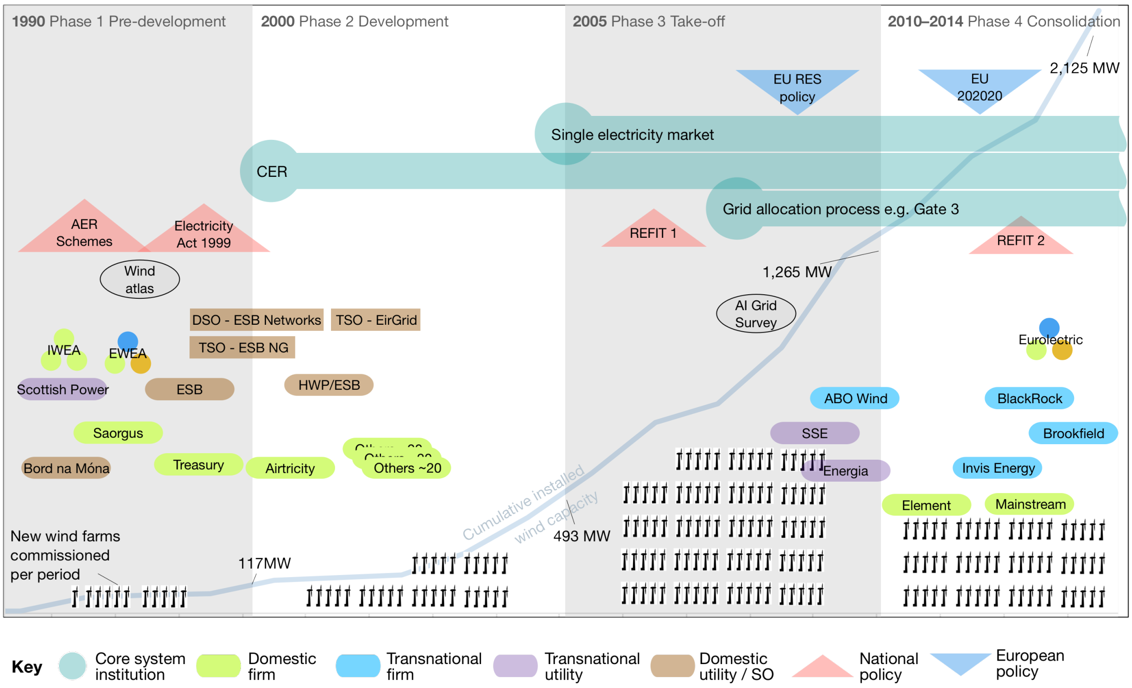

Figure 6.3. Periodisation of emerging significant actors, coalitions, policies, institutions and technologies in the Irish wind electricity system

6.4.2 Structural influences of the emergence of the RES

Ultimately, the alignment of these institutions with the goal of system actors, influences the opportunity structures for both groups of actors in the system, as well as for potential entrants. Barriers to system development identified by actors themselves, and corroborated through the analysis include county-level and national planning regulations, access to grid and power purchase agreements. Specifically it is the design and implementation of these regulatory institutions which are barriers to further development of the wind RES. Further barriers included availability of financial resources – primarily financial capital – and knowledge resources, both tacit and formal. The structural aspects of these barriers are less clearly defined. For example, the explanations for difficulties in raising investment capital in the early phases of development differ significantly from those in the late 2000s. Furthermore, not only do the causes of these barriers change over time, the distribution of the effects of these barriers also alters. It is sufficient at this point to note the complexity of these system barriers, to which we will return during the function analysis in Chapter 7. The moratorium on grid connections was another noted barrier to development, but again diagnosing the nature of the barrier is not straightforward. While the moratorium was upheld by regulation and the authority vested in the CER, the cause of the issues which led to its imposition included insufficient locally appropriate grid codes (formal knowledge) on the one hand, and power and a corporate threat perceived by the ESB on the other. Other structural barriers located in the analysis of the institutional ensemble included the misalignment of the needs of wind RES actors and Irish policies and policy instruments; misalignment between Irish and European legal precedents which resulted in delays to state-aid approval; and competing and conflicting industrial development strategies within Ireland.

Turning to structural drivers of system emergence and growth, the analysis has shown that the REFIT technology support instruments, when implemented, were a strong driver of system activity, subsidising the production of electricity on wind farms over historically cheaper fossil fuel based generation technologies. Other regulatory drivers included the formalisation of grid queue acquisition processes and the formal rules embedded within the Single Electricity Market. In addition, the formation of cross-industry advisory groups such as the Renewable Energy Development Group and the Renewable Energy Strategy Groups were drivers for some system emergence. These groups promoted strengthened actor networks and were the location for knowledge activities such as the diffusion of formal knowledge created in Ireland to mitigate against grid integration problems, which was crucial in facilitating an increasing amount of turnkey generation technology on the grid.

By the fourth period of development, the structure of the wind RES in Ireland included three core institutions fundamental to its onward development; the Single Electricity Market, the grid allocation process and the REFITs (illustrated in Figure 6.4). The SEM embedded generators and suppliers of wind electricity within the national electricity market. The SEM was highly dependent on material properties of the electricity grid such as level of interconnection and distribution of high voltage transmission lines to windy parts of the country. And, as we have discussed at length, the design of the SEM and its transaction rules were significantly shaped by actors with nationally specific knowledge or Irish institutions who influenced the growth of market segments. The grid allocation process was a set of formal rules specifying how and when actors would gain access to the physical grid and thus the market. The existence of these rules offered certainty of connection that mitigated against the risk of demand reduction following the recession, as it reduced uncertainty and reinforced the ‘sign-posting’ of Irish and European targets, which on their own did not explicitly state what mix of technologies and actors would build new renewable generation plant. The REFIT was an internationally understood support mechanism which led to increased ‘bankability’ of projects under development.

While not a novel instrument in an international context, the Irish REFITs incorporated national design elements (specifically the payment to market suppliers rather than generators) and played a significant role in stabilising existing developments and reducing risk levels of proposed projects. Thus we see these core institutions played a role in stabilising the RES in Ireland by further embedding it in the wider electricity institutions, signposting future opportunities and expectations to actors within Ireland and to overseas actors, and transmitting knowledge to actors and through actor networks. This institutional core was predominantly produced, or re-produced, in Ireland, and was highly influential in the onward development of the wind energy system. The influence of these core structural components on system processes are discussed in further detail in Section 7.3.

EU level emissions reduction targets as well as marketisation agendas which had significant impact on the Irish wind RES and thus drove system activity. EU policy (narrative) goals such as EU targets and industry diffusion rates were formalised and embedded in Irish institutions. National emissions and RET targets in Ireland although instigated by European policy processes often evolved closely with industry growth in a cycle of increased target ambition, system activity and updated narrative framing for IWEA and other wind actors in which the wind sector needed support in order to meet government targets. Given the relative low agency of the Energy Department, the DCENR, where there were only weak direct signals from the state regarding the state's ability to impose long-term infrastructure plans, developers attempted to build legitimacy for wind technologies in other ways such as though the creation of narratives extolling the societal benefit of wind. In this context, European policy processes provided an important backstop, from which national targets and regulations would not regress, whilst also providing the signposting for the future direction.

The results of this structural analysis challenges two explanations for the rapid roll-out of Ireland's wind electricity. The first explanation, located in a narrative common amongst developers, was that 'Europe drove everything'. The structural analysis shows that 'European' institutional influence is insufficient to explain 'everything'. We have seen how the EU, and the Commission specifically, have influenced the Irish wind RES through long term policy processes, agendas and directives. However this influence was mediated and systematised in Ireland, through processes of transposing, and through the cumulative and multi-level influence throughout the ensemble of institutions. An economist interviewed in the course of the research agreed that Europe was influential, but offered an additional explanation:

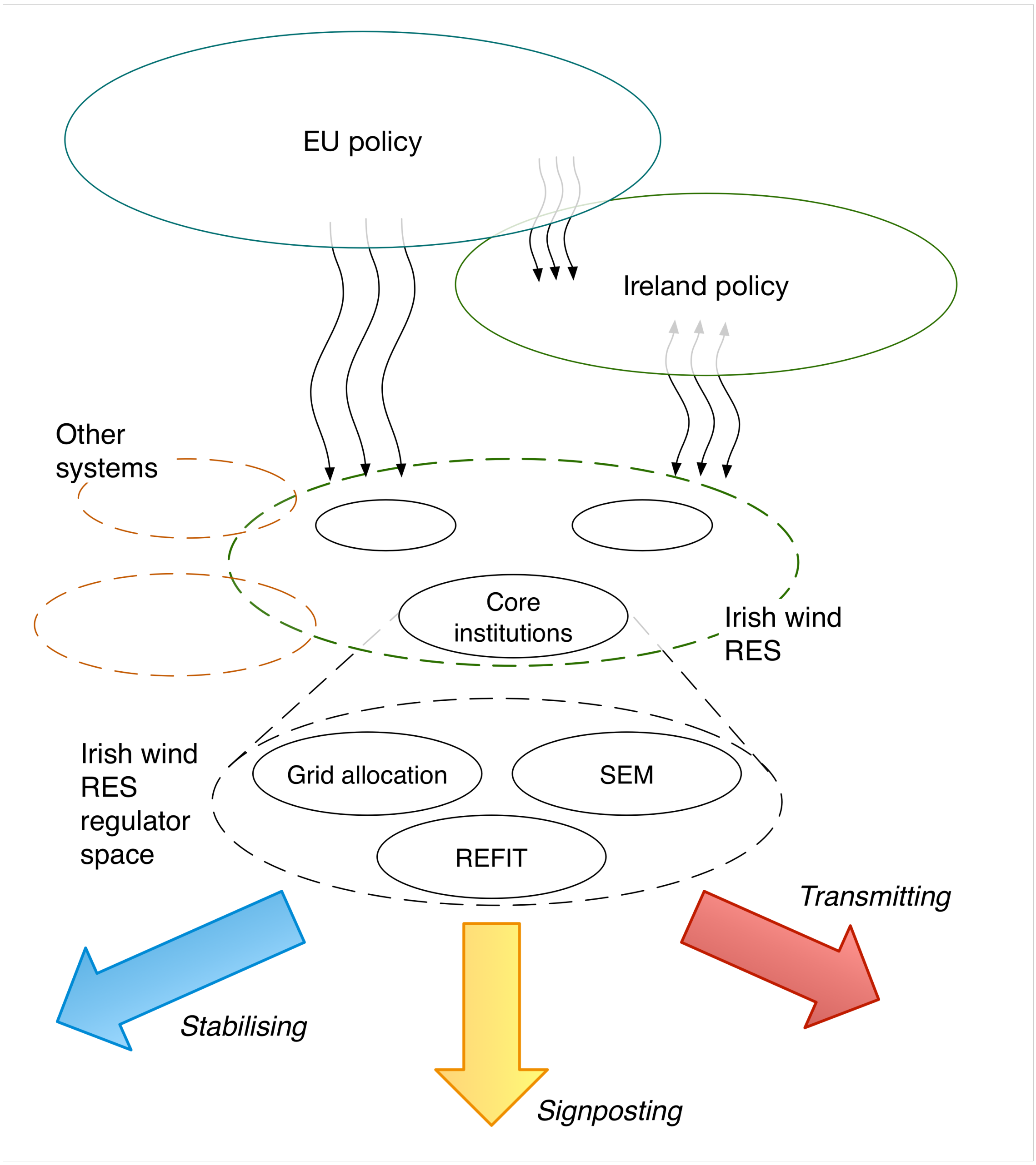

Figure 6.4. Illustration of the core Irish wind RES institutions

> "targets were met because they were achievable cheaply through wind means."[35]

This economic policy explanation suggests that the REFIT, and other technology support instruments explain the build up of wind through a) public subsidy and b) technology costs which eventually fell to a point where, combined with subsidy, wind became an 'obvious' or rational choice. Yet this second rationale does not explain why the public subsidy was offered prior to a certain efficiency threshold being reached, a matter we address further through our discussion of the function analysis in Chapter 7.

[35] Interview 130501

The analysis has added to the explanations of European policy and Irish subsidy, additional institutional explanations; the establishment of the regulated electricity market and the architecture of the SEM, which were significant, as was the design and implementation of the grid allocation process which was influenced by informal institutions in Ireland. In both of these processes, the discussion of institutions has precluded an in-depth analysis of the innovation processes. While the SEM in particular can be thought of a socially constructed market, embedding actors and interests, it was also subject to considerable technological constraints. We will address this in the next chapter. We have also identified that the sequencing of these developments played a role in the final outcome. We have discussed that the alignment of institutions, it is notable that significant alignment, and re-alignment of institutions occurred in the the first phase of development in Ireland, which we suggest is a rule-setting period, which took place from 1999 to 2004. The building and energising of wind farms took-off towards the end of this phase in what we will refer to as an implementation phase.

Summing up

In this chapter I have introduced and discussed the results of the structural analysis of the Irish wind electricity system. Through the analysis I identified structural drivers and barriers of system development. I achieved this by building up a view of national ensembles of mutually reinforcing sets of institutions and carried out the technological innovation system analysis by documenting the structural components, the actors, networks and institutions of the Irish wind RES. Drivers of system development in Ireland included the establishment of core institutions, contextual influences from the ensemble of institutions, and several hybrid arenas including the Renewable Energy Strategy Group, Renewable Energy Development Group and the Grid Allocation Process. Outside of Ireland, European policy processes were found to be influential in setting a direction of technological development, and provided a backstop against potential rollback of national policies. Structural barriers included partial access to system resources, the economic effects of the recession as well as certain alignments of the institutional ensemble. I detailed the influence of the core wind RES institutions identified in Chapter 5. These were found to influence the wind RES by stabilising the RES, signposting future opportunities and expectations to actors within Ireland and to overseas actors, and transmitting knowledge to actors and through actor networks. I showed that structural alignment did not come about from the implementation of technology support instruments alone but rather it came from market architecture and activities/composition of industry. This is significant as it indicates that the REFIT alone does not account for the rapid growth of wind, but rather it was a combination of the core institutions and system activities. Finally, the cumulative industry activity of actors in periods one and two was a significant influence in bringing about the institutional changes needed for the acceleration of roll-out of technologies in the third period, the speed of which was strengthened by the REFIT.

The results of the analysis challenge two explanations for the rapid roll-out of Ireland's wind electricity, that Europe was singularly responsible for the direction of Irelands energy technology pathways, and that the REFIT and other public subsidies were singularly responsible for the rapid roll-out of RETs. In both cases, the structural analysis has implicated explanations including institutional influence and the corporate political strategy of actors.

I use these findings to focus the function analysis in the next chapter. I identify the causal sequences of functions which led to the creation of the core wind energy system institutions and explain the imposition and influence of public subsidies on the development of the system.

Furthermore, I use the integration of spatial indicators to examine in greater detail the imposition of direction of the search for new technologies via both European Union political processes, and national level activities.

Chapter 7

Function analysis

This chapter contributes a function analysis of the Irish wind RES. It documents the salient findings of an in-depth analysis of the case narratives for evidence of each of the TIS functions. The system TIS functions, introduced in Section 3.3 are recapped in Table 7.1. In Section 7.1 the strength of each of the TIS functions is assessed. In parallel, I use the narrative analysis to assess how key narratives 'perform' in the wind RES, building up a picture of when and around which narratives actors come together to form coalitions. In Section 7.2 the fulfilment of each of these TIS functions are mapped first through time, indicating when the emergent RES in Ireland was well-fulfilled by each function. The functions are then mapped against the *build-up* and *touchdown* heuristic, indicating processes of system construction within Ireland and transnationally. Finally, in Section 7.3, I identify in the analysis two cycles of cumulative function build-up, these are discussed at length. It is these cycles of positively reinforcing functions that add explanatory heft to the chapter.

7.1 Analysis of system-building functions

7.1.1 The creation and diffusion of knowledge

Ongoing development of wind generating technology took place almost exclusively outside of Ireland and was diffused within Ireland as turnkey plant. Yet the processes of building and integrating these turnkey technologies required, and ultimately generated, tacit knowledge amongst actors. Actors in Ireland learned through working on joint ventures with overseas firms and from the 'doing' and building of the projects. The creation of

Table 7.1 Functions of the technological innovation system, adapted from Bergek, Hekkert, et al. (2014)

Function...	**...is the process of**
Knowledge creation	technological learning by actors in the system and the breadth and depth of the knowledge base
Knowledge diffusion	the distribution of the knowledge base and how that knowledge is utilised in the system
Influence on the direction of the search	the incentives and/or pressures for actors to enter the system. These may come in the form of visions, expectations of growth potential, regulation, articulation of demand from leading customers, crises in current business, etc.
Entrepreneurial activity	the performance by actors of commercial activities or experimental projects around a new technology or in a new location.
Market formation	the factors driving the formation of new markets or new market segments. Factors include the articulation of demand from customers, institutional change, changes in price/performance.
Legitimation	the acceptance and compliance with relevant institutions. Legitimacy is not given but is formed through conscious actions by organisations and individuals
Resource mobilisation	the extent to which actors within the system are able to mobilize human and financial capital as well as complementary assets such as network infrastructure.

indigenous formal knowledge through research and development activities gathered pace in Ireland from the mid–2000s. These activities were predominantly focussed on problems faced by Irish grid operators, utilities and investors. Resource assessments, grid integration of renewables, overcoming intermittency problems on high wind penetration grids and system operation are examples of active research topics in Irish universities through the mid- to late–2000s. In later years, further engineering and economic and policy based research was carried out on additional issues such as interconnection and economic growth and the provision of 'green' jobs. Thus the analysis shows that research in Ireland was predominantly focussed on Irish wind RES development. Supporting this perspective is evidence of system operator EirGrid's (formerly ESB National Grid) position as one of the top three sites of research activities, the other two being university research groups; the Electricity Research Centre at University College Dublin and the Sustainable Energy Research Group at University College Cork[1]. Moreover, EirGrid built strong links with these research groups, particularly the ERC, and were an active recruiter of graduates with advanced degrees.

The importing of plant was the primary transnational knowledge diffusion activity. By coming relatively late to the global wind industry, Irish developers were importing turbine technology that had been field tested extensively in Denmark, Germany and elsewhere[2]. These activities were supported in the initial development period by joint ventures between Irish and overseas development actors. So while the analysis confirms that to some extent codified knowledge was easily transferred as turnkey plant, that was in part because it was accessed by actors with existing relations to manufacturers and suppliers already established. Furthermore, it is notable that while joint ventures were a feature of development in all periods of system development, the nature of these partnerships changed over time. In the early periods, tacit knowledge related to project management and electrical engineering was acquired through these commercial arrangements, whereas financing knowledge and crucially relationships to overseas investors is notable following the recession.

Knowledge diffusion occurred through workshops and conferences organised by industry bodies such as IWEA who used national conferences as locations in which to bring overseas experts. Furthermore, the small size of the country and electricity sector positively enhanced national coordination efforts which were facilitated initially by a small number of actors working in voluntary capacities. Knowledge in Ireland resided within and was diffused through several institutional structures closely related to system events. For example, the Renewable Energy Strategy Group and moratorium on grid connections catalysed and coordinated aspects of knowledge development by creating shared problem sets of barriers common to the grid operator and developers. Such institutional spaces, or arenas, were also the location of diffusion of informal knowledge created through experience of planning and building projects by developers. From these locations, knowledge was diffused by participants through institutional organisations such as planning associations and the planning departments of county councils. Knowledge creation and diffusion activ-

[1]These research groups, both based in engineering schools, became the main centres for indigenous research during the mid–2000s growing over the next decade.

[2]Indeed, on occasion, Irish developers were importing technology that had been deployed elsewhere. One developer told, and perhaps embellished, a story of sourcing pre-deployed turbines from a Greek island though it is unclear whether a sale was ultimately agreed.

ities are summarised in tables 7.2 and 7.3. In summary, tacit knowledge created during these system activities resided in firms, within industry associations and crucially within institutions in the form of rules, grid codes, entry requirements.

Table 7.2 Knowledge creation

System activity in Ireland	Transnational activity influencing Irish system	Notable findings
ESB initially challenged wind actors through counter-narratives based on their own research. In later phases they contributed to positive framing of Ireland's wind resources through emergent wind resource research. RESG and REDG influenced some knowledge development through agenda setting and cross industry participatory fora. System integration became a focal area of engineering R&D activities within and between universities and system operators.	R&D activities related to generating plant are performed almost exclusively outside of Ireland.	Local tacit knowledge important despite turnkey nature of imported technology. Formal knowledge creation activities in Ireland (system integration) and overseas (generation plant) are largely independent. Irish wind surveys such as the All Island Grid Survey (Meibom et al., 2008)

Table 7.3 Knowledge development

System activity in Ireland	Transnational activity influencing Irish system	Notable findings
RESG led to knowledge diffusion across the electricity sector. IWEA and other industry associations became a repository for knowledge, and an active actor is diffusing knowledge.	Material buildup of technology in Ireland through plant imports. Tacit knowledge was transferred via joint ventures and consultancy contracts. In early periods joint ventures between Irish and overseas firms combined local institutional knowledge with tacit knowledge of material building of wind systems. In later periods, joint ventures exploit local and overseas capabilities and access to resources.	Core wind system institutions (SEM and grid queue) stabilised and embedded knowledge (rules, grid codes, entry requirements). This knowledge was influential in legitimising the Irish wind industry for overseas investors in later stages.

7.1.2 Influence on the direction of the search

The narrative that 'Europe drives Ireland's energy system' was common amongst utility and private firm actors[3]. The institutional analysis supported this narrative and showed how the European Union, and specifically the Commission, influenced the prospective Irish wind RES through cohesion and structural funding programmes and institutions incorporating varied domains including habitats, market deregulation, climate change and specific targets for renewable diffusion (see Figure 5.7, Subsection 5.2.2). In addition to policy outcomes, policy processes were influential as they facilitated actors in Ireland anticipating future regulation.[4] Furthermore, the manner in which EC directives were transposed to Irish law created opportunity for local interpretation, giving civil servants in the Department for Communications, Energy and National Resources some influence during the processes of transposing European law. The narrative evidence also shows that the influence of European policy on the direction of search in Ireland of the Irish wind RES was at times negative, as uncertainty over future targets in Brussels was reproduced in the Irish wind RES as uncertainty over the direction of development. Thus it is clear that Europe did indeed play a significant role in driving Ireland's energy policy in all four phases of development. European legislation set broad policy direction of development, both augmenting and influenced by developments and actors in a global wind innovation system. And while this influence did not directly determine the technology deployed, it had a profound influence on the institutions and actors in the Irish wind RES.

The analysis indicates three significant aspects to the strengthening of the *direction of the search* function in Ireland. First, reports, stories and expectations of the emergence and growth of wind electricity systems in Denmark, Germany, Spain and to a lesser degree the USA influenced actors in the Irish system with visions of new energy technologies carried to Ireland through academic conferences, and a small number of enthusiastic entrepreneurs located domestically but with access to international networks[5]. The characteristics and capabilities of the incoming actors in Ireland in turn shaped the configuration of the system, and the nature of the RES emergence. In short, these visions and expectations

[3]Interview 130104, 130503

[4]For example, the DCENR anticipated directives such as 2009 RES Directive in advance and waited until the completion of the European policy process only to adjust final target numbers (Interview 130501). This influence was almost entirely asynchronous, Ireland had little influence in DG Energy, as a small member state it choose to concentrate its lobbying influence on a small number of areas such as agriculture. As such, its voice at the policy table was relatively small.

[5]For example, the presence of in experts at industry workshops and conferences is a constant from the early 1990s.

influenced who was attracted into the developing wind RES, while the issue of (turn-key) technology selection was comparatively less significant. Second, national technology support mechanisms such as the REFIT were influential. Supporting policies were 'co-produced' with actors in the industry, and influenced on the one hand by contemporary wind RES activity and on the other by European directives, policy agendas and targets for the futures. Third, the new wind and energy fora, institutions and organisations such as the RESG, the grid allocation process and IWEA were an important location for the selection and coordination of visions and growing expectations within the system. Therefore the analysis indicates that the focus on European policy tells only part of the story of the direction of the emerging system.

This analysis indicates a virtuous sub-cycle of the strengthening of the *direction of the search* function through (1) the creation and promotion of new visions, expectations and regulations which framed commercial opportunities. This led to (2) the influx of new actors and increased levels of lobbying and commercial activity which in turn led to (3) the stabilising and embedding in the national context of internal RES institutions such as the REFIT and single electricity market (see Figure 7.1).

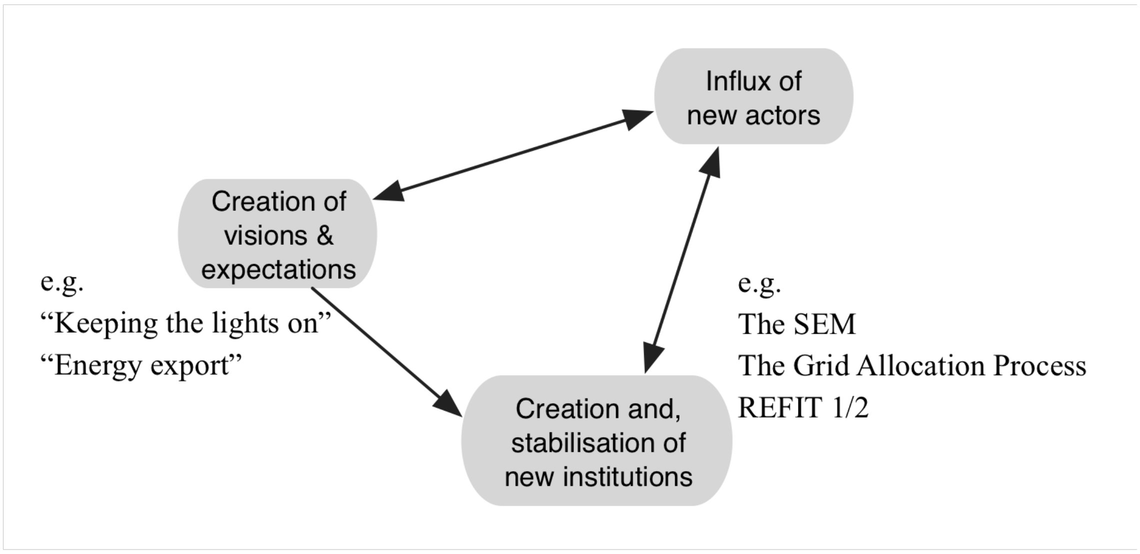

Figure 7.1. Influences on direction of the search function

Following the recession, this sub-cycle continued, though the narrative frames of the wind industry's analytic stories shifted from 'keeping the lights on' to 'energy export' narratives. Favourable and stable institutional architecture attracted large global players into Ireland while national economic conditions gave them competitive advantage and ultimately facilitated consolidation in the industry. Summarising, while the *direction of* *the search* function was influenced at European and Irish levels in each period studied, we see that its influence is mediated by resource availability (finance) and within Ireland strongly influences actor selection as summarised in Table 7.4).

Table 7.4 Influence on the direction of search

System activity in Ireland	Transnational activity influencing Irish system	Notable findings
Technology support mechanisms co-produced with actors in the wind system Ability to reframe national visions around wind around live issues, e.g. from 'Keeping the lights on' to 'energy export'. Visions and beliefs in Irish wind system gained in strength significantly over time, attracting large global players by the end of the period of study. Wind system institutional architecture and perceived stability of institutions provides direction for overseas investors.	EU market liberalisation and climate change targets provide long term influence on the direction of the search. This influence at times exerted negative influence on local wind system development. Political economy of wind in UK influenced opportunities and decisions within Irish system	Function constitutes influence from multiple levels. Resource availability rather than technological fit (as suggested in the literature review) drove consolidation of indigenous firms. Local visions influenced who was legitimately active in the wind system. Institutional culture within Ireland affected DCENR's ability to set long-term goals. Rather institutions endogenous to the system provided the stability after period three.

7.1.3 Entrepreneurial activity and experimentation

entrepreneurial activity within Ireland peaked in the second period with the arrival of new entrants – specifically developers – and again in the fourth period when the scale of ambition of a number of developers was raised following successful exits by Airtricity and SWS[6]. In the second phase of development the quantity of *entrepreneurial activity* though small in historic terms, was significant to the contemporary system. In addition to the new capabilities and resources now present, the activity reached a threshold at which the Department of Communications, Energy and Natural Resources could use evidence of 'promising activity' of the wind RES as a rationale to justify further government policy support. In addition to transposing European law committing to increased renewable energy production Irish policy makers had to create an industrial strategy to reach new targets. This strategy was focussed around new market niches and crucially new market entrants. And while joint ventures facilitated the entry of overseas firms into the Irish sys-

[6] As measured quantitively by number of unique development firms.

tem, local actors played a crucial role interpreting EU and national policy as opportunity for profit-making ventures. Several of these Irish firms played influential roles lobbying for the formation of a new market niche for wind and mobilising resources through grants and joint venture capital funding. In the fourth phase, the nature of entrepreneurial activity shifted, and was then based around identifying projects already in the grid queue, or in pre-development stage, and getting these to market. And with this shift in activity, came consolidation within the industry. Ultimately, while the analysis indicates the presence of entrepreneurial activity such as new firm creation and new project activity, we found limited evidence of experimentation – as defined by opportunities and tacit knowledge developed through testing of new generation technologies – as we might expect to find in wind energy system in lead jurisdictions.

Where the evidence suggests there was experimentation, it was focussed on institutional settings and business plans rather than on scaling up generation technology efficiencies. For example, we have discussed how Airtricity engaged in institutional entrepreneurialism, lobbying government as market liberalisation regulations were being created. They created and exploited opportunities in globally created institutional setting (liberalisation of markets) which was unpredictable, though their strategic actions were based on anticipated future outcomes. In this regard, the relational space in which Airtricity inhabited or had access to (e.g. the policy domain and industrial sector) was more significant than the geographic context, Ireland. In the previous subsection we discussed how Irish energy policy was co-produced through industry activity and departmental strategy. In a similar manner, the development of the market was influenced on the one hand by *entrepreneurial activity*, and on the other by regulation which facilitated by new market segments being opened and renewable generators being granted special protected position. Crucially, this (institutional) *entrepreneurial activity* was performed by predominantly indigenous firms and coalitions of electricity industry actors. By the time overseas firms began to consolidate through the purchase of Irish firms and utilities, the major institutional pieces were in place. Thus in period four, although there was a resurgence of *entrepreneurial activity*, it was focussed on building and buying, and new business plans, not on institutional re-alignment. Finally, evidence from the literature suggested processes of *entrepreneurial experimentation* were inherently social, and the networks and relations of entrepreneurs, or in the case of developers in Ireland, would be for the most part formed in Ireland. The analysis shows that where there was experimentation in Ireland, it took place in the middle of the supply chain (between generation and end-consumer delivery). This analysis runs counter to some findings in lead nations, where local *entrepreneurial experimentation* was crucial to the development of turbines and the wider industry (Garud and Karnøe, 2003), as summarised in Table 7.5.

Table 7.5 Entrepreneurial activity

System activity in Ireland	**Transnational activity influencing Irish system**	**Notable findings**
Industry 'stories of self' central to this function occurring locally. Knowledge of how to win grants important (Initial Thermie winners were overseas). Wind becomes a 'big boys game', certain types of entrepreneurs and activity were deemed acceptable in late stages. Policy was co-produced, but so was the market, which was heavily regulated. . . The entrepreneurs can't do this unless the govt open up the space.	Technological experimentation at play largely occurs at global level. Relatively strong transnational activity via overseas firms in phases one and four. Joint ventures important source of knowledge. Many of the 'big boys' were from overseas - brought with them knowledge.	Entrepreneurial activity, and role of location in phase two and phase four different. Joint ventures at the beginning and asset sales at the end are significant. The actors involved in production of function matters. At various times we see the ESB and overseas players get involved. Some of this is explained through institutional shifts. We did not plan to look at this in the framework, so it is an addition. Local re-production of function is integral part of co-production of policy. Domestic entrepreneurial activity takes place in the middle of the supply chain.

7.1.4 The formation of markets in Ireland

Evidence of significant market formation processes were evident in three analytic stories. These were 'the establishment of the Commission for Energy Regulation', 'the creation of the Single Electricity Market' and stories of 'the material expansion and growth of the wind RES in Ireland'. Antecedents of the formation of the CER were found in stories conveying the policy processes leading up to the 1999 Electricity Regulation Act which, as we have discussed, was influenced by European market liberalisation on the one hand, and lobbying from Airtricity and IWEA on the other. The creation of the independent regulator, a core institution of the wind RES, was an important step which enabled further market formation processes to take place in phase two as this quote from a 2001 interview with Eddie O'Connor of Airtricity suggests:

> "Many of the teething problems we have had with the provision of key information by state power company ESB are being resolved and the Commission for Electricity Regulation (CER) is now fully up and running, which is vitally important in an industry where a clear and fair regulatory framework is essential."[7]

It was the DCENR's responsibility rather than the CER's to create a 'fair regulatory framework'. However the analysis indicates that over time the regulator fulfilled a role addressing both technological and market based issues within the system. The CER was tasked with managing the group allocation process in the third phase, the coordination of the Renewable Energy Feed-in Tariff in periods three and four, and the cross-industry process to resolve the treatment of curtailment in tie-break situations in the final phase. As such the CER was a generative component of the institutional architecture under which market renewable segments could be created, although it did not facilitate the *entrepreneurial activity* which was also crucial for the establishment of the market.

While the CER provided regulatory framework within which the wind RES developed, it was the electricity market, the newly established SEM, which formed the most significant institutional context which influenced the emergent renewable market segments during phase two. The CER was legislatively mandated[8] to facilitate the necessary electricity market conditions whereby renewable generators and suppliers with requisite power purchase agreements were given priority access to the emergent electricity market. The establishment of the CER was the basis for market entry rules successfully lobbied for by Airtricity and IWEA which allowed wind generators this privileged access to newly liberalised market segments. The architecture of the all-island market incorporated wind into the market architecture from its inception, further strengthening the market position of wind generators and leading to further institutional embedding, and legitimisation of wind technologies. The final regulatory instrument that accelerated firm activity and market transactions was the REFIT. By 2006 wind power in Ireland was a 'serious contender' as this comment indicates:

> "[Wind power] became a serious contender, it deserved serious attention... the policy decisions had been made to... invest heavily in renewables, in re-

[7] Evidence S1-266

[8] See section 6.2.1 for a discussion on appropriate institutional aspects of the CER and 1999 Electricity Regulation Act relevant to this analysis.

newable"[9]

By the end of the third phase, the Irish wind sector was institutionally and technologically embedded in the wider electricity market. The establishment in Ireland of sales and support office by Siemens in 2008 was a further indicator of the strengthening market and expectations of further growth.

How then did these institutional components feature in the production of the *market formation* function? Economic growth and consumer demand was an influential factor in infrastructure and energy expenditure during the early 2000s, with new combined cyclic gas turbine (CCGT) projects also given regulatory and financial support from the DCENR. Consumer demand though was for generic electricity provision, not specifically for renewably produced power, and although consumer groups were available and accepting of new generation technology, little evidence has been found to suggest that end-consumers significantly influenced the technology choice of generators. Rather we suggest this technological choice was influenced by other opportunities created and discovered by wind RES actors. As the structure of the market was being designed in the early 2000s, the visibility and influence of wind generators was growing. Recall that with the ESB focussed on growth overseas, opportunities for third party developers were created. These opportunities encouraged *entrepreneurial activity* amongst new-entrant firms which further worked with *market formation* processes to legitimise the nascent industry, in turn attracting more entrepreneurs into the industry. Evidence of firm activity was crucial in the process which led from the creation of the CER to the launching of the SEM and ultimately the launch of the REFIT. We have discussed how these opportunities were sufficient to attract the actors with capabilities into the system. And although not all these actors had sufficient resources to complete projects, the often long, multi-year process of project building, meant failure, as well as success, took place after several years. Finally, the literature review suggested networks play an important part in the coordination of *market formation* activities. Certainly we see formal networks such as IWEA perform this role. Again, institutional components of the system were important; they provided arenas (the RESG, the market) and rules (the grid queue, market rules) which contributed to coordination within and around the market.

The formation of the Irish wind market segment was not possible without overseas turnkey technology. Ireland's early wind developers were end-users in a market of wind generation technology developed and built almost entirely in Denmark and Germany.

[9] Interview 130501

Taking the perspective of the plant manufacturers we can view the growth of Ireland's wind RES as an emergent, locationally specific, market segment in a global marketplace. In this perspective, we would see a system of approximately 80 wind farm development firms as customers in a global marketplace for wind generation technology. In a global context these are relatively small numbers, and as suggested in the previous chapter, the influence of Irish firms on the market, or on research and development of the generation technology was modest. Once we account for the inward flow of turnkey technology and the European Union policy landscape, there is little other overseas functional influence on *market formation* in the first three periods. In other words, *market formation* in Ireland shows a high degree of Irish functional influence and overseas structural influence. However, in the fourth period the analysis shows that we might consider Ireland's wind farms as part of a global market in bankable renewable assets.

One developer commented that by this time the Irish market was "in much better than Spain or Italy'[10]' which taken with the evidence presented so far indicates two findings. First that Irish developers were competing for finance with other European wind or solar investors, and winning, at least some of the time. And second, the regulatory setting in Ireland had become more favourable for developers with the introduction of the REFIT, a market support mechanism, the mechanics of which were easily understood by investors at European finance institutions. Irish wind RES components were now aligned with a transnational system. However, from a systems perspective, we question whether this is really *market formation*, or rather market reformation. The overseas firms have been attracted after all by the existing institutional structure.

market formation was a dominant nationally constitutive TIS function, sub-processes of which were produced and re-produced throughout all four phases of development. This discussion on processes of *market formation* in Ireland has touched on three structural factors. The formation of the CER, the formation of renewable market niches within the SEM and the formation of the wider wind and renewables market. These structural factors were augmented by actors with appropriate capabilities and access to resources. When access to resources for these actors changed, we see systemic changes to actor compositions. Contrary to findings in the literature discussed in Subsection 3.3.6, consumer groups did not play a significantly influential role in technological selection processes. Instead, selection occurred through the rules of the technological support mechanism, the REFIT, and protected market niche for wind generators. Furthermore, while there is

[10]Interview 130722

some transnational activity, in the main, the reproduction of market formation processes were generated within Ireland. The literature suggested that the formation of markets would occur in sequence by way of a nurturing, bridging and mass market phase through processes of the creation of market segments, and an increase in diversity of market transactions. The evidence indicates that in the case Ireland's wind RES, access and proximity to financial and knowledge resources was more important than physical proximity to end users. We suspect that this phenomena is more relevant in product orientated markets however it is not appropriate for the aims of this thesis to develop this line of inquiry. We summarise in Table 7.6.

Table 7.6 Market formation

System activity in Ireland	**Transnational activity influencing Irish system**	**Notable findings**
Establishment of regulator and the development of the all-island electricity market. The material growth of wind farms and industry activity 'visible' to policy makers. Advocacy coalitions, IWEA and ESB co-contribute to creation of *'stories of self'*.	Share of foreign firms in the domestic market. Global manufacturers opening offices in Ireland. Institutional stability attracts firms in fourth phase. Transnational flows of capital into the system in later stages. Interconnection and expressions of confidence and interest by overseas players further stabilises industry during recession.	Technology selection not through intentional adoption by end-users as suggested in literature review, but through imposition of market protection rules and REFIT instruments. The availability of actors with capabilities and resources was significant, with location influencing resource access. Networks supporting market formation activities was influential – relatively low costs of coordination in a small market, thus network size quickly sufficient aided by local institutions. Local market formation strengthens after institutional core established, closely associated with transnational direction of the search and resource mobilisation functions. Market formation processes were strengthened as transactions were embedded within institutional structures such as the SEM.

7.1.5 Legitimisation of and within the wind RES

The analysis of the *legitimation* processes in the system incorporates both an assessment of the legitimacy of the wind energy system for a given phase, and the processes of legitimising (and de-legitimising) engaged in by system actors. Four distinct types of activity were responsible for an increase (or decrease) of this legitimacy. First, legitimisation of wind technologies in Ireland increased as new actors entered the system from a number of locations or sectors, such as agricultural services firms, utilities, property and finance speculation and the civil services[11]. Actors typically brought with them existing relationships, networks and capabilities required to form cohesive national social networks and interest groups. Crucially, actors successful in other sectors also conferred legitimacy to raise capital and run firms. We observe these activities within the 'story-of-self', which is closely interrelated with narratives featuring the increase in material wind technologies in Ireland. Yet we note that legitimacy is not evenly distributed amongst all actors within the system. By the third phase of development, the narratives used in publications and repeated by actors in the industry conveyed the wind industry as a 'serious contender'. But by this time it is also a 'big boys game', a gendered, scalar and normative framing referring not only to those who can access resources, but also those who should, legitimately, be allowed to participate in the RES.

The second set of legitimising activities within the emergent system was the formation and development of coalitions and interest groups. Formal and informal coalitions were formed in the nascent industry initially by private individuals and small firms in order to exert greater influence over national and regional decision makers and incumbent electricity suppliers. Groups such as the Irish Wind Energy Association and Meithel na Gaoithe lobbied political actors and also worked with, lobbied and attempted to impart knowledge to regional level actors such as planners and county engineers by creating visions of successful future wind energy systems. Thus, in addition to being active agents within the system, some coalitions were generative networks for the development of further visions and expectations. From the perspective of the Department of Communications, Energy and Natural Resources and EirGrid, IWEA became a highly legitimate voice of the wind industry. Furthermore, the membership of IWEA, and influences within the organisation, evolved along with the composition of the wider system. Thus we see that while the development of IWEA in particular increased the legitimacy of the wind RES, the

[11] The entry of actors such as Paddy Teahon from the Taoiseach's Department and Eddie O'Connor from Bord na Móna are notable examples of powerful individuals entering the industry.

interests and goals of the association changed over time reflecting both the composition of the association, and changing system factors.

Lobbying and other corporate political strategies undertaken by actors in the system contributed to changes in legitimacy within the system. Lobbying typically took the form of direct approaches to ministers and senior civil servants in the department. However effective lobbying also took place within institutional group processes such as the RESG, Renewable Energy Development Group and the Grid Allocation Process as this comment indicates:

> "The lobbying is quite sophisticated. Lots of engineers involved and they bring a lot to the table when they do lobby. Mixed in with economists they provide a skilled team."[12]

This is a description of codified expert knowledge being used to shape expectations of technological opportunities and possibilities. Of course, lobbying activities were not necessarily straightforward battles between wind advocates and entrenched interests; and wind lobbyists did not always win. Indeed through the 1990s the ESB attempted to delegitimise the nascent wind industry, primarily though counter narratives based research showing limited commercial wind resources in Ireland. Furthermore, by 2000, a binary description of incumbent and challenger is no longer appropriate, as we see the ESB lobby with an IWEA coalition against regulatory proposals made by investor and developer Treasury Holdings.[13] The analysis leads us to make two points here. First, by the third phase of development, the ESB were not longer actively contesting core pro-wind technology visions and expectations[14]. Second, simplistic incumbent versus challenger or pro- and anti- wind technology perspectives are insufficient to explain influence of lobbying activities. Thus for further explanation we turn to the content of the narratives.

The fourth sub-process identified in the system is the production and reproduction of system narratives. We have discussed how actors in the early phases of the development of the Irish wind RES were influenced by energy security narratives which followed the oil shocks of the 1970s, stories which have been credited with kick-starting technology developments which ultimately led to the modern wind industry (Staudt, 2000; Est, 1999).

[12] Interview 130501

[13] Treasury Holdings lobbied unsuccessfully for combined heat and power generators to be given the same favourable market access condiitons as 'real renewable' generators were being given in the new electricity market. Source: S1–294

[14] Indeed, we see little contestation until the rise of organised grassroots opposition movements in the final phase.

Yet the overall numbers and influence of these actors was modest with low levels of legitimisation taking place in the first phase. There then occurred a discontinuity between dominant narratives as new actors entered the system in the late 1990s and early 2000s. Narrative framings promoting societal benefits continued to be reproduced. However in subsequent phases framings were more often based on national economic growth and contraction, rather than globally situated environmental and climate change frames. This system phenomena is evidenced in industry reports such as Deloitte and IWEA's 2009 report entitled 'Jobs and Investment in Irish Wind Energy: Powering Ireland's Economy' (Deloitte, 2009, p. 3):

> "We are now striving to re-invent our economic model to preserve and continue improving our standards of living but to do this in a way that is more stable and that can be sustained... Developing Ireland's wind energy potential falls very firmly into this space."[15]

These legitimising narratives were endogenously created within the RES, but significantly influenced by exogenous factors during the economic boom and bust. This economic framing is in accordance with evidence from literature review which suggested societal benefits may be important framing devices. However, the findings indicate what kind of content and framing of the narrative stories mattered. Societal benefits were of an economic and specifically national Irish kind. These are summarised in Table 7.7.

Finally, contesting these narrative framings of societal benefits were emerging narratives of contention. Quoted in a news media report of one public opposition meeting in 2013 is this comment, seeking to delegitimise the large scale midlands developments evoking 'English' as the colonial other (rather than 'British' or 'foreign').

> "This is an English wind farm you're looking at," Duncan told the meeting. "It will have [more wind energy] than in all of Britain to supply them over there."[16]

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[15] The authors of the report portray Ireland's wind energy resource as an opportunity for policy makers to contribute to economic growth, whilst when critically analysed, it publicly re-orientates the narrative framing of Irish wind behind Ireland's new economic reality. The 42 page report further legitimises this re-purposing of the wind industry with claims of job-creation.

[16] Source: S3-23. The same article goes on to discuss the energy export memorandum of understanding signed by the UK and Irish governments and comments: "Whether this is a good deal economically, environmentally, and socially for this country is a question that will dominate debate on the project over the coming year."

These types of narratives contributed to an analytic story of new opposition to wind, however, it is unclear at the time of writing the impact they have had on the ongoing development of the RES.

Table 7.7 Legitimisation activities

System activity in Ireland	Transnational activity influencing Irish system	Notable findings
Actors entering the system. The formation of coalitions and lobbying activities e.g. IWEA activity framed wind as solution to 'lights going out', specific lobbying. The creation of visions by coalitions and interest groups. Industry *'stories of self'* (by P3 wind as a *'serious contender'* was a powerful driver of legitimacy). Economic boom provided exogenous legitimacy through local energy demand narrative framings.	Global environmental and climate change narratives. Local institutional setting legitimised inward investment from overseas Interconnection and UK market / political economy drives demand. The local interpretation and reproduction of global stories through transposing of EU legislation.	Legitimacy was co-produced by the DCENR and the emergent wind industry over time. Local legitimation processes and European originating direction of the search worked in combination. Crash did not de-legitimise wind, wind actors successfully re-framed the societal benefits of wind.

7.1.6 How narratives matter

Following the function analysis, and specifically the analysis of the influence on the direction of search and legitimacy, we identify analytic stories around which we find evidence of coalitions formation via the collective performance of narratives. Recall from Subsection 4.3.4 the starting point here is that coalitions form around analytic storylines, producing and mobilising narratives. The utility with regard to the study is the identification of specific narratives mobilised by actors or coalitions which consider a TIS function to be weak. Working with the narrative evidence mobilised, eight analytic stories have been traced, around which coalition formation has taken place. These are listed in Table 7.8. Functions that are addressed by these coalitions in Ireland include *resource mobilisation*, *legitimation* and *influence of the direction of the search* (each in at least four of the eight analytic stories). Furthermore, these are at times contested indicating controversies and actor dynamics within the RES not apparent from the identification of historical events alone. These results inform later discussions on the role of *legitimation* and *direction of the search* in Chapter 8.

Table 7.8 Performance of narratives

Ref.	Analytic story	Coalition, narrative performance and functions
A-01	The interpretation of Ireland's wind resource endowment	P1 Contested meanings by ESB and early wind practioners (KD) P2, P4 Performed by Irish wind RES boosters, factor in 'eduaction of banks' and Irish lenders, and later European lenders (RM)
A-06	The construction of the story of what the Irish wind industry is	P1-P2 Wind pioneers and DCENR co-produce policy (DOS, EA) P1-P2 ESB contests viability of wind RES (DOS, LE) P3-P4 Utility scale and professional services firms shift framings from 'serious contender' to to 'big boys game' (LE) P4 Performance of 'bankablility' narratives by wind RES boosters influences overseas investment (RM)
A-07	IWEA's role in the wind industry	P2-3 New coalition of 'professionals', alter identity of IWEA (LE) P3-4 From utility and SO perspective, IWEA viewed as big tent, with activist members not afraid to 'bang fists on tables' (LE)
A-09	National technology support mechanisms	P1-3 IWEA highlighted deficiencies of AERs, sought institutional realignment via FITs, contested by ESB (P1-2) and CER (P3) (DOS,EA) P3-4 The REFIT as policy narrative performed by DCENR, wind farm owners and investors facilitates alignment with overseas actors (MF) P4 Bankability narratives performed by owners/investors influences overseas actors (RM)
A-13	The influence of the moratorium on the Irish wind sector	P2 Wind developers and CER/system operators/ESB contest viability of wind RES expansion (LE,MF) P2 Performance of technological knowledge deficit narratives by system operators influence creation of dynamic grid codes (KD)
A-16	European energy policy and processes	P2-P4 Powerful narrative that 'Europe drives everything' performed by actors across the wind RES in Ireland (LE) Actors reproduce and perform in Ireland policy narratives created at EU level (DOS)
A-21	Wind as export commodity	P3-4 Narratives used in Deloitte 'Green Jobs' report are a site of coalition forming (KD,DOS,LE) Much stronger opinion coming from elsewhere P4 Site of dissensus: opposition movements use 'export' narrative to oppose large scale turbine and infrastructure developments (LE)
A-22	The impact of increased interconnection	P3-4 Coalition of wind developers and policy experts forms around interconnection as a technological solution to curtailment (LE, RM) Researcher narratives on interconnection in general support pro-wind framing, but are less strident and conditional tones (KD,LE) Opposition movements use interconnection to evoke negative colonial framings of wind export (LE)

Key: KC knowledge creation; KD knowledge diffusion; DOS influence on the direction of search;
EA entrepreneurial activity; MF market formation; LE legitimisation; RM resource mobilisation

7.1.7 The mobilisation of resources

Emerging technologies are often linked to high-risk and long pay back periods which impede the raising of financial resources. This was the case in Ireland in the first two periods. Both private firm business models, and wind-generation technologies were commercially unproven in the Irish context. Pay-back terms for borrowed capital were typically fifteen years, however that period began only when wind farms started generating revenue, often between five and ten years after project activities were initiated, necessitating bridging finance in addition to capital finance. Limited funding was available through through EC THERMIE and VALOREN programmes, or was nationally distributed capital grants via the AER schemes, themselves recipients of European infrastructure funding. In fact, through 2000, all connected wind farms were recipients of grant from at least one of these public funding schemes. The narrative evidence indicates scale-up from public to private finance occurred as Irish banks became more familiar with wind technologies and commercial business plans. Processes of teaching and learning in the financial sector took place as private firms and IWEA ran investment roadshows and conferences from the mid–1990s. These were purposeful strategies designed to influence public, private and venture capital organisations. By the early 2000s IWEA's membership included banks, finance organisations and financial services firms. The introduction of the REFIT in 2006 was then a significant catalyst of financial scale-up by facilitating the underwriting of up-front private capital lending from indigenous banks via long-term guaranteed operational payments, raised from pubic levies.

While the REFIT accelerated *resource mobilisation*, and thus roll-out of generation plant in the system, it is now clear that the scale-up of financing required for large-scale commercialisation was significantly influenced by structural and functional aspects of the wind RES prior to and in addition to the catalysing impact of the REFIT. Regarding structure, the relationship between developer firms, lending organisations and intermediating networks such as IWEA were significant. The most significant functional relation was that between *resource mobilisation* and *entrepreneurial activity* either directly as firms raised finance or through the *direction of the search* and *legitimisation* functions as special interests lobbied for new regulations and legitimised the technologies which in turn facilitated the mobilisation of resources at lower interest rates and from a wider range of lending organisations. In the first three periods of development interviews with Irish developers indicated the mobilisation of capital was relatively less problematic than other system barriers, such as the allocation of grid connectivity, power purchase agreements or the acquisition of planning permission. Analysis indicates that many successful developers brought with them into the wind RES, or quickly developed, skills necessary to raise finance. For these developers in the early periods then, Ireland's wind RES was the location of investment opportunity. The narrative evidence and analysis supports this perspective and firms such as Treasury, SWS and Airtricity had strong in-house finance teams which were enhanced by the 'professionalisation' of IWEA by 2000 and it may be that the opportunities that attracted developers into the system, were particularly appealing to those with existing finance raising skills[17]. This contrasts with some studies of emergent systems that have found the sourcing of specialised capabilities and capital has been classified as a pervasive problem, e.g. (Binz, Truffer, Li, et al., 2012). We account for financial competencies in the Irish wind RES through the capabilities of actors in the system on the one hand, and the fact that in the fast-follower context of Ireland, from an early point in the system development, finance was being sought for commercial operations rather than knowledge creation activities such as research and development; the promised duration of return on investment was relatively short.

However, the competencies of Irish developers did not mitigate against the effects negative effects of the recession. After 2008, finance in Ireland was harder to obtain and we note a reversal of the *entrepreneurial activity* to *resource mobilisation* function relation. We note three significant impacts of the recession to the mobilisation of resources in Ireland.

First the tightening of lending conditions in Ireland negatively impacts Irish private developers as well as mid-supply chain firms such as engineering consultancies indicating a strong locational impact: non-utility firms highly were susceptible to economic landscape shocks whereas firms with access to overseas resources, utilities and overseas developers, were relatively advantaged. Second, visions of wind technology benefits were reframed, e.g. 'wind as an export commodity' was used by firms in Ireland to support arguments for continued regulatory support. Third, the scale-up in finances continued, but this time went overseas, with the EIB, German and Nordic banks playing a bigger role in lending. Ultimately the *resource mobilisation* function was weakened in Ireland, but due to reconfigurations in the system structure, and strong institutional core, which included the REFIT, continued to be strongly fulfilled (findings are summarised in Table 7.9). We have shown then that in the early stages of the system it was Irish developers who bore much of the risk early in the system, rather than the government, incumbent utilities or service

[17] This is one explanation for the remarkable strength of the merchant plant sub-sector in Ireland, the wind farms constructed and energised without aid of regulatory support instruments such as the REFIT.

operators. Investing in renewable developments is an inherently risky proposition (Newell and Paterson, 2010), adding the overseas risk, possibly including currency speculation makes that an even greater risk. But while developers bore the risk, they played a crucial role in connecting *direction of the search* functions to *market formation* and *resource mobilisation* functions.

Table 7.9 Resource mobilisation

System activity in Ireland	Transnational activity influencing Irish system	Notable findings
Local non-utility firms highly susceptible to economic landscape shocks. Airtricity back because of REFIT introduction (links with DOS). *'Wind as an export commodity'* pushed wind into a financing place. Irish plays part of international finance game, based in Dublin, or with Irish experience. This is where Irish players enter international value chain.	Bankable yields (because of institutional stability). Large flows post recessions. Big flows in (relatively) in the first, and then the final phase. EIB and private capital interested. Nordic banks replace Irish and Portuguese in debt markets (S1-13).	Differentiated access to funds important. Locationally privileged, but also sectoral issues. Institutional mix in Ireland married with narratives provides assurance. It remains mixes of venture capital all the way through, not production capital.

7.2 Mapping of wind RES system functions

7.2.1 Mapping of functions through time

We have presented an account of the production of individual TIS functions and emergence of RES components, noting when, where and how specific RES components have become embedded in wider innovation and production systems or institutions, and conversely which components have been drawn into the emergent wind RES. We now map the configuration of functions through phases of system development, thus assessing the 'functionality' of the Irish wind RES in terms of how it supports firm entry, variety and the formation of market segments in the early phases of development, and market expansion and the supply of resources to exploit that market in the later phases. We analyse the cumulative effect of the functions by assessing the functional pattern for each phase, and evaluating the pattern against analytically assessed system goals (Table 7.10). Recall, these system goals are analytic constructs, created during the analysis using the structural assessment in Section 6.4 along with stated actor system goals found in the narrative evidence. In other words, they convey structurally and functionally what the Irish wind RES required during a specific phase, for further development. Using these 'goals', we compare how close each functional pattern gets to a 'well functioning' ideal (i.e. how the functions, or key processes, are performed and improved, can be analysed with respect to the requirements of each phase.)

The structural analysis indicated the first phase was a crucial period of rule-setting, both in the electricity sector more broadly, and specifically the creation of protected renewable market segments. Despite the fulfilment of the *direction of the search* function – essentially the process of setting rules – the analysis shows that the functional pattern is relatively weak and system goals are not met. There was sporadic system activity in the first phase, specifically *legitimisation*, some *entrepreneurial activity* and discernible strengthening of the *direction of the search* function (illustrated in Figure 7.2). While these system functions influenced the creation of the regulator, it is clear that these processes were only one factor in the liberalisation and marketisation of the electricity sector which was subject to substantial exogenous pressures at both European level and in Ireland. In this case we have both European and Irish national policy influence over the direction of the search, closely intertwined with an accumulation of legitimacy of wind RES components which in turn is influenced by new actors.

The creation of the Commission for Energy Regulation and subsequently initial market

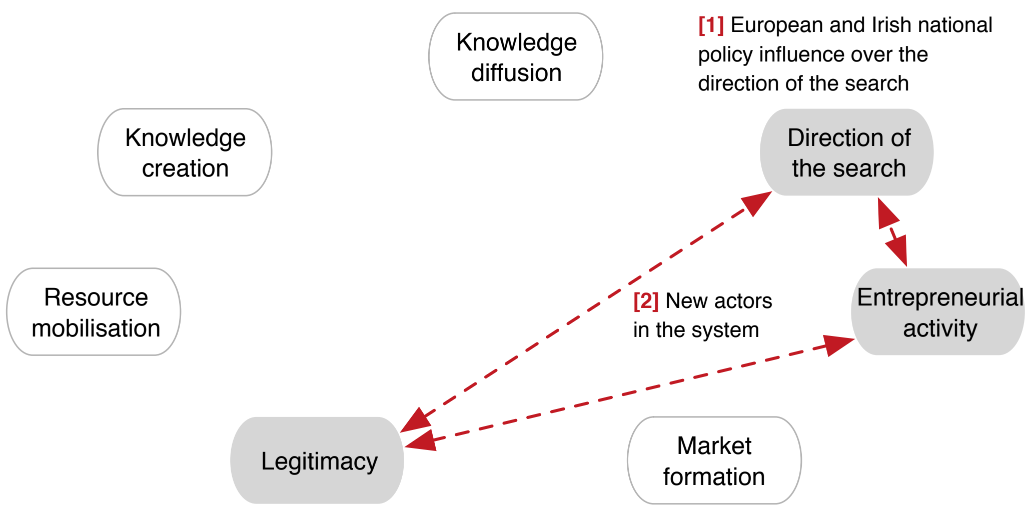

Figure 7.2. Mapping of significant system function patterns in period 1

rules enabled stronger fulfilment of *entrepreneurial activity* and *market formation* in the

Table 7.10 Requirements for continued system development

Period	Characterisation of wind system in Ireland (based on function mapping)	Idealised structural and functional requirements
1990-1999	Small number of commercial plants operational, regulatory support for limited number of firms, low levels of indigenous knowledge creation, build-up and diffusion. Slow build-up of network activity. Privatisation and marketisation of utilities sign-posted in policy European agendas.	Market formation required. Finance required. Strong knowledge creation and knowledge diffusion required. Institutional architecture required for market and market access. Reduction in risk required. Goals: find partners, acquire knowledge, exploit opportunities
2000-2004	Substantial development of new market and industry regulatory institutions and frameworks. Irish firms begin to make commercial break-throughs, carry much of the risk in the industry. Market niches for wind created in the developing electricity market in Ireland. Locally specific knowledge creation begins to develop. Change in nature of wind system network activity to include financial actors, research actors.	Resource mobilisation required Institutional support required: specific actor demands for feed-in tariffs and improved planning regulations and allocation of grid access. Knowledge functions require fulfilment. While improved market arrangements were being created, financial resources remained a barrier.
2005-2009	Well-fulfilled wind energy system. Creation of market and rapid increase in diffusion of generation technology. Creation of secondary institutional structures such as grid-queues further de-risk industry. Creation of feed-in tariffs reduced perceived system risk, open up support mechanisms to more actors. Further structuring of market via SEM and GAP	Shortages of skilled labour in engineering fields. Institutional support required: specific actor demands for more favourable feed-in tariffs and planning regulations. Post-recession, capital finance required by non utility firms
2010-2014	Consolidation of wind farm ownership. New international expectations and investment. Some de-legitimisation of large-scale project plans. Expectations scale-up, certain actors expectations are privileged Fall in electricity demand.	Finance required to bring to market planned projects within the gate queue. Institutional support required: specific actor demands for more favourable feed-in tariffs and planning regulations. Allocation of grid and further market rules such as 'tie-break scenarios' now an internal system issue for CER to resolve. Infrastructural, legislative and resource barriers to Irish firms accessing UK market

second phase (illustrated in Figure 7.3 [1]). Cumulative and reinforcing processes of *entrepreneurial activity*, *market formation* and *direction of the search* indicate for the first time a strong, virtuous cycle of system function fulfilment. This activity also influenced the mobilisation of financial resources as lending and financial services firms in Ireland gained experience with wind projects and joined industry associations, locations of *knowledge diffusion* [2]. As European and national policy frameworks supporting wind technologies strengthened, the creation of national policies further influenced the *direction of the search* which in turn positively influenced *knowledge creation* and *knowledge diffusion*, the accumulation of which was crucial for TIS function performance during the third phase [3]. The patterns of the TIS functions during period two explains the entry for firms (*entrepreneurial activity*) and accounts for the formation of niche markets and improved market arrangements which further accelerated RES emergence and development.

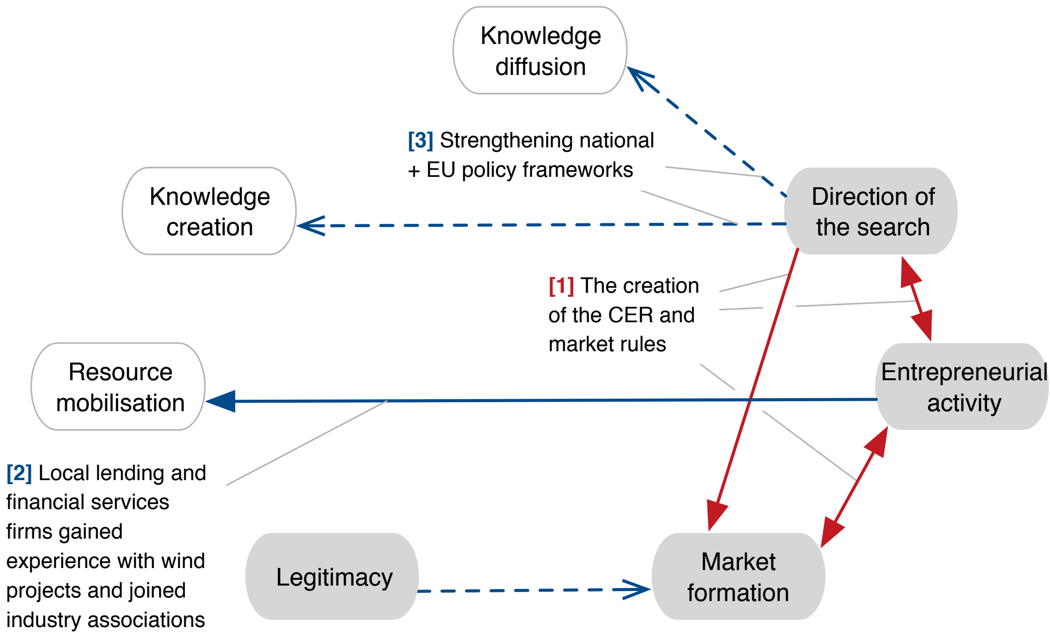

Figure 7.3. Mapping of significant system function patterns in period 2

While the mapping of individual functions shows all were well-fulfilled in the third phase, aspects of the system in Ireland was still structural and functional influences, both negative and positive. Increased fulfilment of the *resource mobilisation* function led to new or more favourable commercial opportunities (Figure 7.4 [1]) which increased the legitimacy of the system [2] and the strength of the policy support, culminating the the first REFIT (*direction of the search*) [3]. This virtuous cycle is illustrated by tracing [1–2–3]. This strengthening of the *resource mobilisation* function was integral to the roll-out of new generating technologies during this phase. While project planning in Ireland, lobbying and rule making activities happened, all contributing to system function fulfilment, and often in an accumulative fashion over time, without project capital finance available to developers in Ireland, wind farms simply could not be built. Narrative evidence indicated Ireland was by this time a 'serious player' in the global market for wind turbines indicating high levels of *legitimisation* [4]. More pertinently for this study however, increased access to financial and knowledge resources by firms (*resource mobilisation* and *entrepreneurial activity*) also enhanced *market formation*, driving a second strong virtuous cycle (as illustrated by solid arrows in Figure 7.4 [5]). This functional pattern in the third phase is crucial in explaining the expansion of the market within Ireland for wind energy.

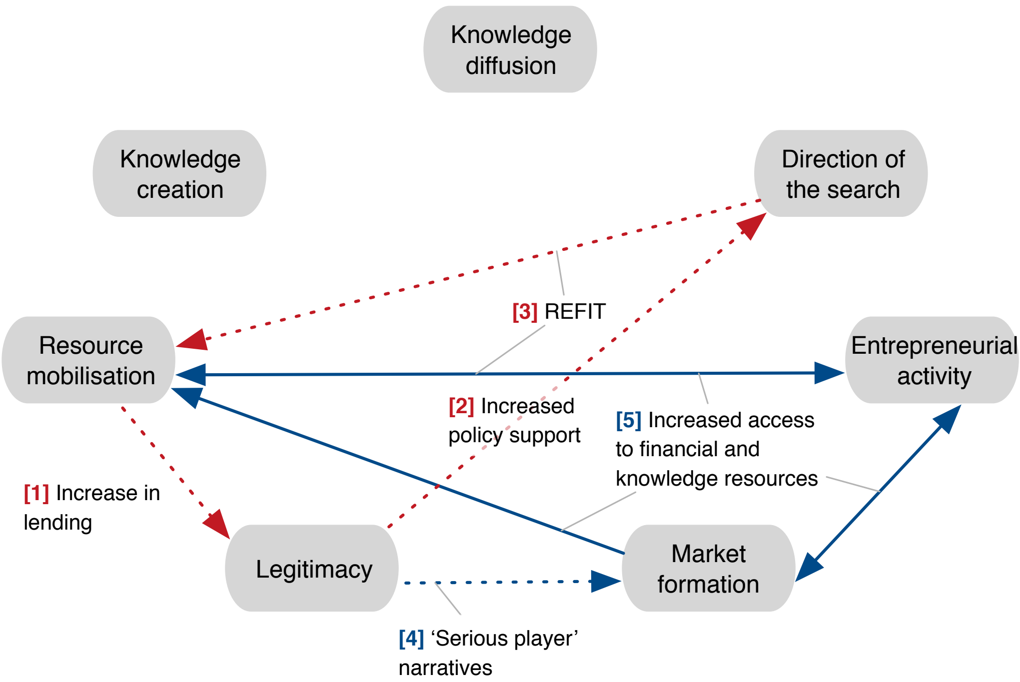

Figure 7.4. Mapping of significant system function patterns in period 3

Increasingly in the fourth period, continued market formation was largely the result of strengthening (or stabilising) policy instruments such as REFIT 2 and continued firm activity (as illustrated in Figure 7.5 [1] and [2]). This is in contrast to phases 2 and 3 where the legitimising work of coalitions played a stronger role in *market formation*. Notably, these coalitions do not go away, we continue to see wind industry actors mobilising around 'energy export' narratives for example, however we do see the rise of better organised anti-wind coalitions contesting the legitimacy of the wind RES. In a similar manner, resource mobilisation is no longer well-fulfilled in Ireland following the recession, the result of the ending of indigenously sourced finance, rather than a reduction of total finance coming into the wind RES. Yet, we have discussed in Chapter 5 how the attractiveness of the Irish wind RES from an international investment perspective is certainly undiminished, if not in fact enhanced [4]. For more nuanced analytic perspective on the functional performance of the system we bring in a locational perspective.

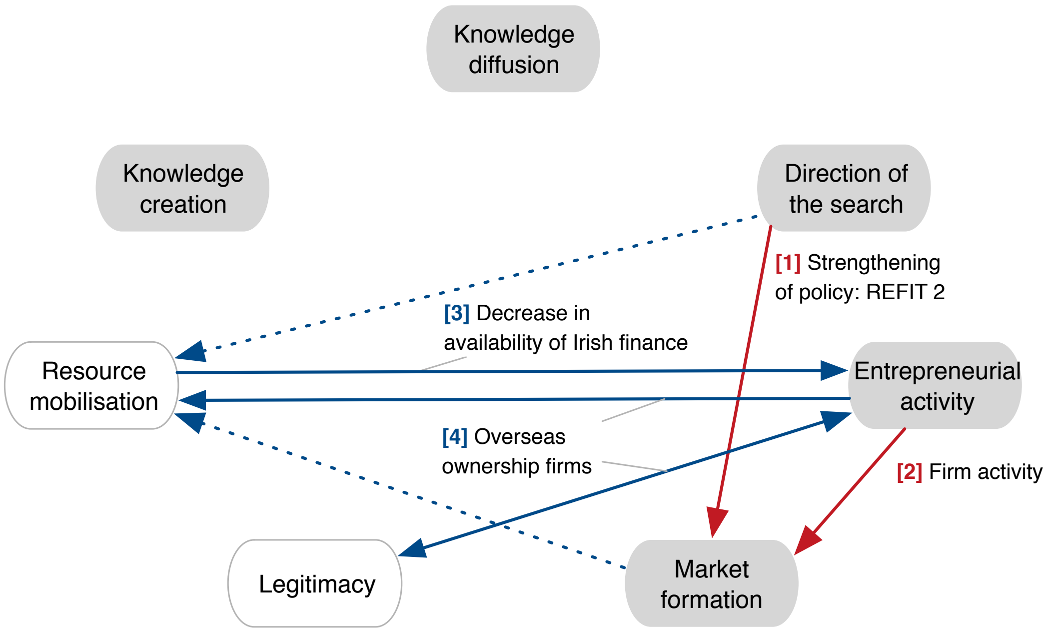

Figure 7.5. Mapping of significant system function patterns in period 4

7.2.2 Fulfilment of functions over space and time

As well as mapping influences between functions, we also map the reproduction in Ireland of functions over time. From the boxed findings in Section 7.1, we illustrate the locational production of functions in table 7.11.

To aid the discussion on the locational distribution of system functions, we bring together the mappings illustrated in figures 7.2 to 7.5 and disaggregate Irish and transnational influence functions (see Figure 7.6) using the geographic indicators utilised in the previous chapters. The mapping illustrates that not all functions are re-produced in Ireland. The importing of turnkey generating plant for example is a feature of the system throughout all four phases and thus a significant amount of technological development (*knowledge creation*) takes place overseas. Furthermore, in the first phase, *entrepreneurial activity* was influential, however disaggregating using the narrative evidence, we note the fulfilment of the function was significantly influenced by joint ventures between overseas and indigenous firms. Focussing the analysis on the functions that were produced and re-produced in Ireland we concentrate our enquiry on examining the location distribution of specific influential functions and their influence on the cycles of system change. In partic-

Table 7.11 Transnational and Irish function fulfilment, periodised

Function	**Position**	**1990-1999**	**2000-2004**	**2005-2009**	**2010-2014**
Knowledge creation	Transnational	+	+	+	+
	Irish system			+	
Knowledge diffusion	Transnational	+			
	Irish system	+		+	
Direction of the search	Transnational	+	+	+	+
	Irish system	+	+	+	+
Entrepreneurial activity	Transnational	+			+
	Irish system		+	+	+
Market formation	Transnational		+		
	Irish system		+	+	+
Legitimation	Transnational				
	Irish system	+	+	+	+
Resource mobilisation	Transnational	+			+
	Irish system			+	

Key: + indicates well fulfilled function

ular the *direction of the search* function and *legitimisation* followed by *market formation*, *entrepreneurial activity* and *resource mobilisation*.

7.3 System functionality analysis

7.3.1 A system rule-setting cycle

A central explanation for long term systemic change within the technological innovation system approach is that, through process of cumulative causation, functions strengthen one another and together lead to a positive, self-reinforcing dynamic allowing the technology-specific innovation system to develop – e.g. Suurs and Hekkert's 'motors of innovation' (2012). The structural analysis illustrated the emergence in the second and third periods of nationally specific, endogenous system institutions which were created or embedded with specific wind RES components. We interpret from the mapping of the functions a number of virtuous cycles, the first of which significantly influences the institutional components of the system. The initial cycle starts in the first period with the fulfilment of the *direction of the search* function influenced by European policy agendas and ultimately

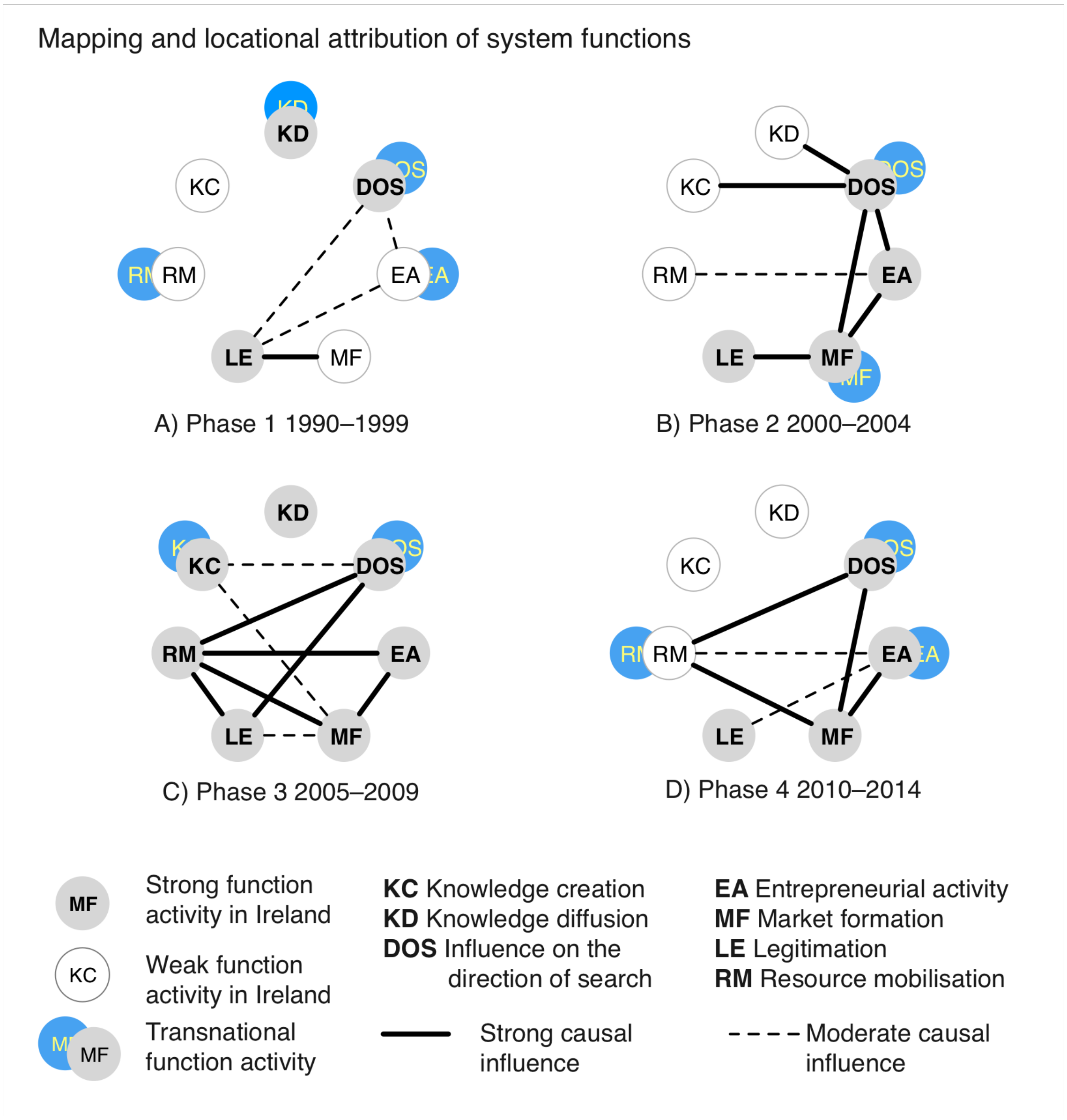

Figure 7.6. Mapping of system functions through four periods of development. Note that these maps are not static snapshots of the system, but rather represent cumulative functional activity in the system during a given period

Ireland's Electricity Act (1999) (Figure 7.7, [1]). This set the conditions for increased *entrepreneurial activity* [2], and the actor groups who drove these two functions were responsible for co-producing Irish policy, which ultimately led to further market rules and increased firm activity through the 2000s [3, 4]. This initial cycle is illustrated by the thick dashed lines in Figure 7.7. The cycle continues and gains strength in the third period as an increasing number of Irish institutions influence on the one hand the mobilisation of finance from banks and venture funds in Ireland, and on the other the legitimacy of the Irish wind RES, which in turn increases the availability of finance (the solid lines in Figure

7.7 [5]. Finally, *resource mobilisation* was further strengthened by increasing firm activity in the system and the embedding of wind interests in the market rules (indicated by the dotted lines in Figure 7.7 [6]. Given the focus on institutional alignment and configuration, we call this the *rule-setting cycle*.

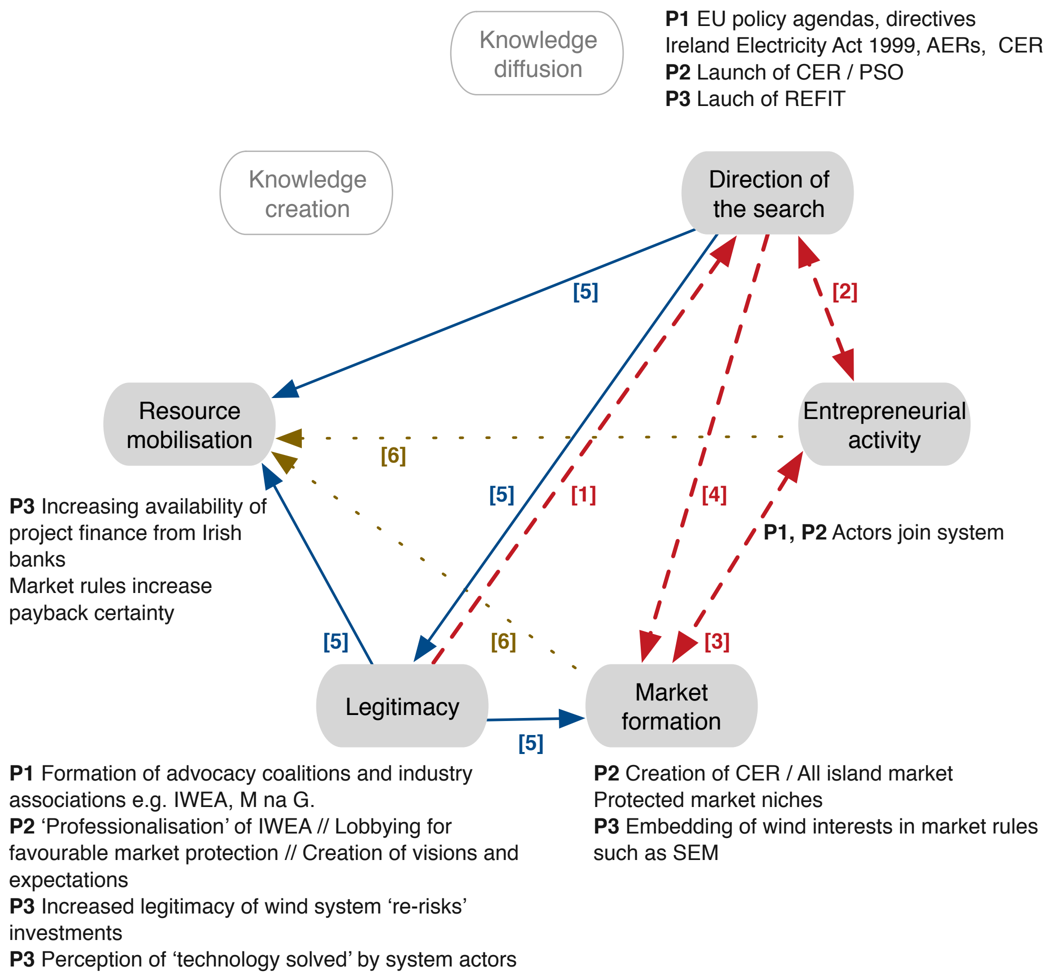

Figure 7.7. The rule-setting cycle

Two primary generative functions are present in the cycle – i.e. the functions that those that drove the activity – *legitimation* and *direction of the search*. Crucially both were well-fulfilled within Ireland (as per Section 7.1), however in addition, the *direction of the search* function is being fulfilled through system activity at multiple locational levels, within Ireland and at a European policy level. European processes drive the cycle via long running (multi-decade) policy agenda alongside emissions reduction goals which do not explicitly express preferences for 'winning' technologies. That the European policy processes around these agenda were somewhat impenetrable to influence from Irish wind and electricity actors at the time may be interpreted as advantageous for the development locally of the

RES, and both the Department of Communications, Energy and Natural Resources and wind sector coalitions. This had the effect of providing a backstop to potential policy changes locally; actors in Ireland often presumed that even if national policy agendas changed, the European policy process was ‘driving’. We illustrate the relevant European and Irish subprocesses in Figure 7.8. TIS functions at national level drove the cycle through an influx of actors, who articulated demand and shaped expectations through new visions and goals which in turn were embedded in nationally constructed policies and institutions. So while we see the broad *direction of the search* set at European level (e.g. the provision of low emissions technology in a liberalised electricity market), more complex choices of who influenced the roll-out were decided in Ireland.

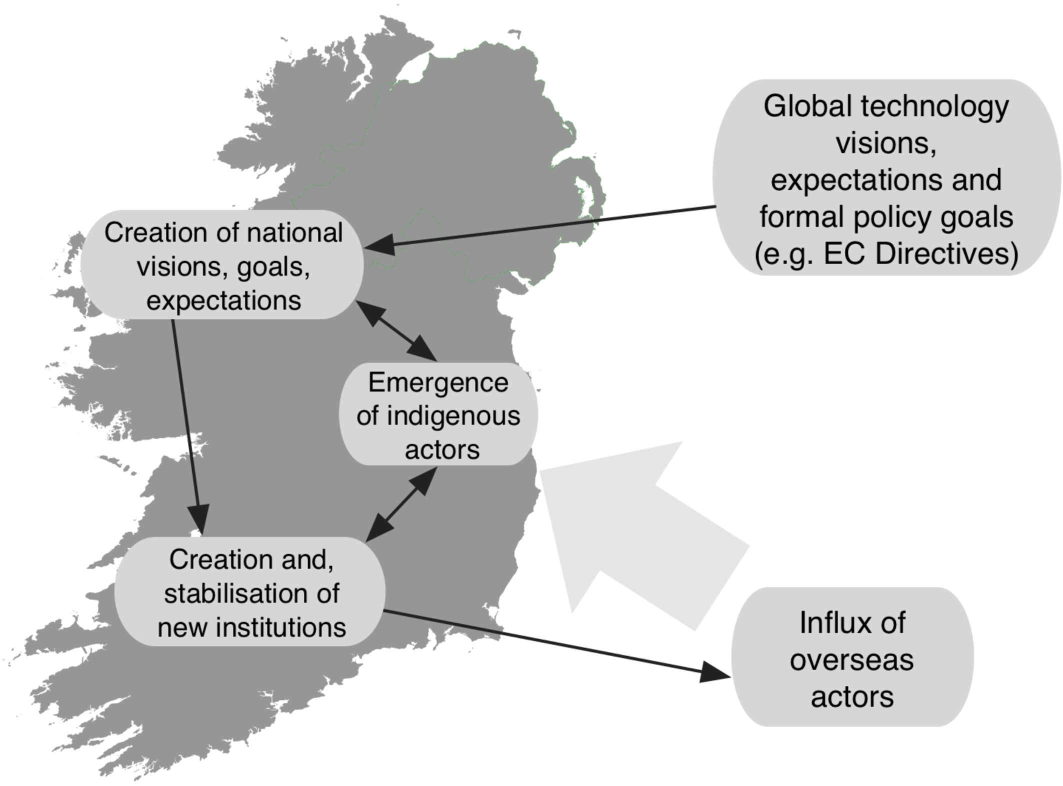

Figure 7.8. Location of influences on ’direction of the search’ function within Irish wind RES during rule-setting cycle

The *legitimation* function was also influential on the *rule-setting cycle*. System activity that led to increases in legitimacy took place predominantly in Ireland. Relevant national-subprocesses are illustrated in Figure 7.9. Where the *direction of the search* function incorporated interests and expectations through European and Irish processes, the *legitimation* function drove these interests and the direction embedded in constituent narratives through processes of lobbying and expectation setting. Legitimacy was generated from distributed system activities and was important to the emergence of wind RES components in Ireland because of the low levels of agency and legitimacy within the DCENR; the government or civil service could not mandate the roll-out of renewable technology unilaterally. Hence, the co-production of policies and goals based on firm activity was important given the powerful state owned interests endorsing the status quo – the increase in visible firm activity was a considerable factor in the increase in ambition of policy goal in period two. Notably, legitimation activities, through lobbying by firms and actor coalitions, influenced the creation of market segments in the second and third periods. The structural analysis showed how sectoral and geographic proximity facilitated the formation of networks, and the lobbying of national government. So while the setting of visions and expectations through stories influenced both *direction of the search* and *legitimation*, geographical proximity was influential in the creation of wind-supporting actors coalitions in Ireland which had a profound influence on shaping the internal institutions of the system.

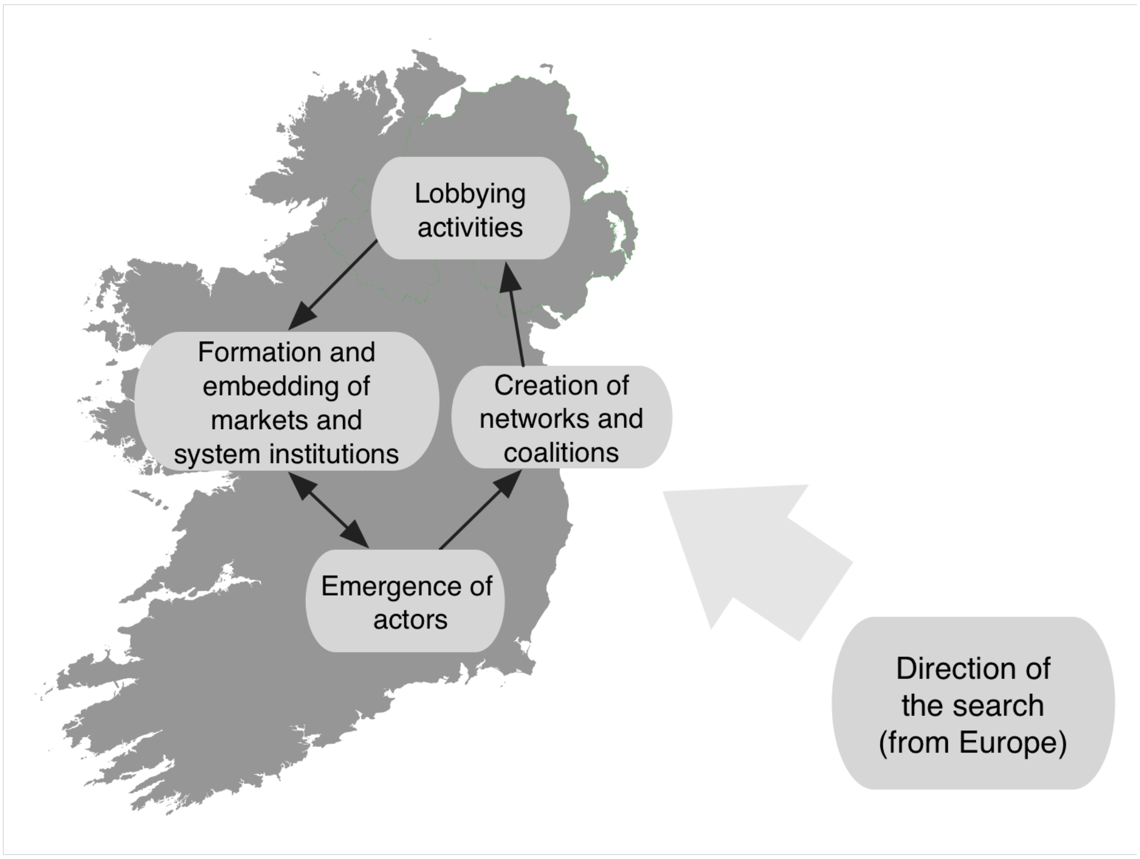

Figure 7.9. National sub-processes of *legitimisation*

The *rule-setting cycle* arose at the end of the 1990s when the structural conditions of the system were beginning to facilitate opportunities for actors already within the system, and also for actors outside the system to enter the Irish electricity sector. These conditions included first, the rapid rise in system activity at the end of the 1990s. This activity was coupled with the low levels of alignment between system actors and Ireland's regulative environment (see Table 6.6 on alignment). Following the pattern of the *rule-setting cycle*, the link between firm activity and *direction of the search* was a crucial system relation by which the growing numbers of actors influenced the alignment which ultimately led to *market formation* and increased *legitimation*. This is an example of cyclical, reinforcing system activity in which actors acted initially based on perceived (exogenous) market demand and opportunity. Second, the organisation by actors in Ireland themselves into networks and coalitions with the capabilities and legitimacy to lobby successfully. Third, the removal of previous structural barriers to electricity customers creating a de-facto 'institutional void', filled over time by new rules and regulations (processes coordinated by the Commission for Energy Regulation who managed the market rule creation process from the period after the 1999 Electricity Act to the formal launch of the all-island market in the mid 2000s). Fourth, the EU provided strong and consistent institutional signposts which prevented institutional 'backsliding' within Ireland. Fifth, it allowed the creation of rules into the system, such as the curtailment payments and rules on 'grandfathering' which served to manage contentious issues as the wind RES grew. Finally, the cycle ended as amongst the actors in the system a perception that the turnkey technology was 'solved' began to take hold, and the core institutions began to influence the system, fundamentally changing how the *market formation* function was being fulfilled.

The *rule-setting cycle* took place as the wind RES in Ireland was developing a significant market segment. However, despite the cycle, several weaknesses inherent to the system structure persisted as the market and core institutions were established (as indicated by the institutional alignment summarised in Table 6.6). The substantive issues around planning permission were mitigated through processual innovations, but never fully overcome through regulatory change and still existed at the end of the period covered by this study. Technology support instruments underperformed with regard to the goal of system actors, though were improving over time. Issues relating to the allocation of grid connections were addressed only at the end of the cycle. Furthermore, the narrative analysis indicated that despite improved national institutional alignment during period two[18], the CER remained strategically aligned to the goals of the ESB and not, initially, orientated towards the

[18]E.g. improving economic conditions during the recession and resultant access to resources

interests of early wind developers.

The cycle accounts for the formation of a set of core institutions of the wind RES in Ireland. Of these, the formation of the market rules is a significant feature (the spatial composition of these processes is illustrated in Figure 7.10). Similarly the creation and launch of the REFIT was also an important outcome of the cycle. The cycle accounts for the drawing-in of further actors to the system, who not only contributed to rule making and other system building activities such as influencing knowledge creation. These 'new' actors included the ESB, the primary 'incumbent' initially exogenous to the wind RES, and the system operators, whose attitudes and strategic approach to wind shifted and ultimately helped drive indigenous knowledge activities. Finally, the cycle accounts for the strengthening of networks (e.g. the 'professionalisation' of IWEA) as an increasing diversity of actors from other sectors joined the system. Ultimately this *rule-setting cycle* explains that European and Irish policy, created or co-produced at EU and national level, is adapted in Ireland and then evolves discreetly. This is because the *direction of the search* functions at multiple levels in the cycle which we have noted in the national stories, interests and institutions incorporated in the cycle through the function explanation.

7.3.2 An implementation and reconfiguration cycle

The second system cycle explains the acceleration of the roll-out of wind technologies starting in the mid- to late–2000s. It began in the third phase as the institutional support for the wind RES increases and finance is acquired by a greater number of developers. With core wind RES institutions influencing strong national *direction of the sesarch* processes, following the moratorium on grid connection, the cycle began with further *market formation* processes (illustrated by the thick dashed lines in Figure 7.11, arrow 1) which drove firm activity (2) by creating expectations of commercial demand, which resulted in the mobilisation of finance (3) and significant construction of wind farms and roll-out of infrastructure technologies. By the end of the third period, market formation processes were being driven by construction and operational activities through market relations and transactions, rather than through the legitimisation activity of advocacy coalitions as per the rule-setting cycle (4). In other words, the operation of the wind energy market, and its successful embedding within the wider market iteratively strengthened the market from 'within'. The first part of the cycle is illustrated by the thick dashed lines (2–3–4) in Figure 7.11.

Following the recession, and with the increased stability and legitimacy of the mar-

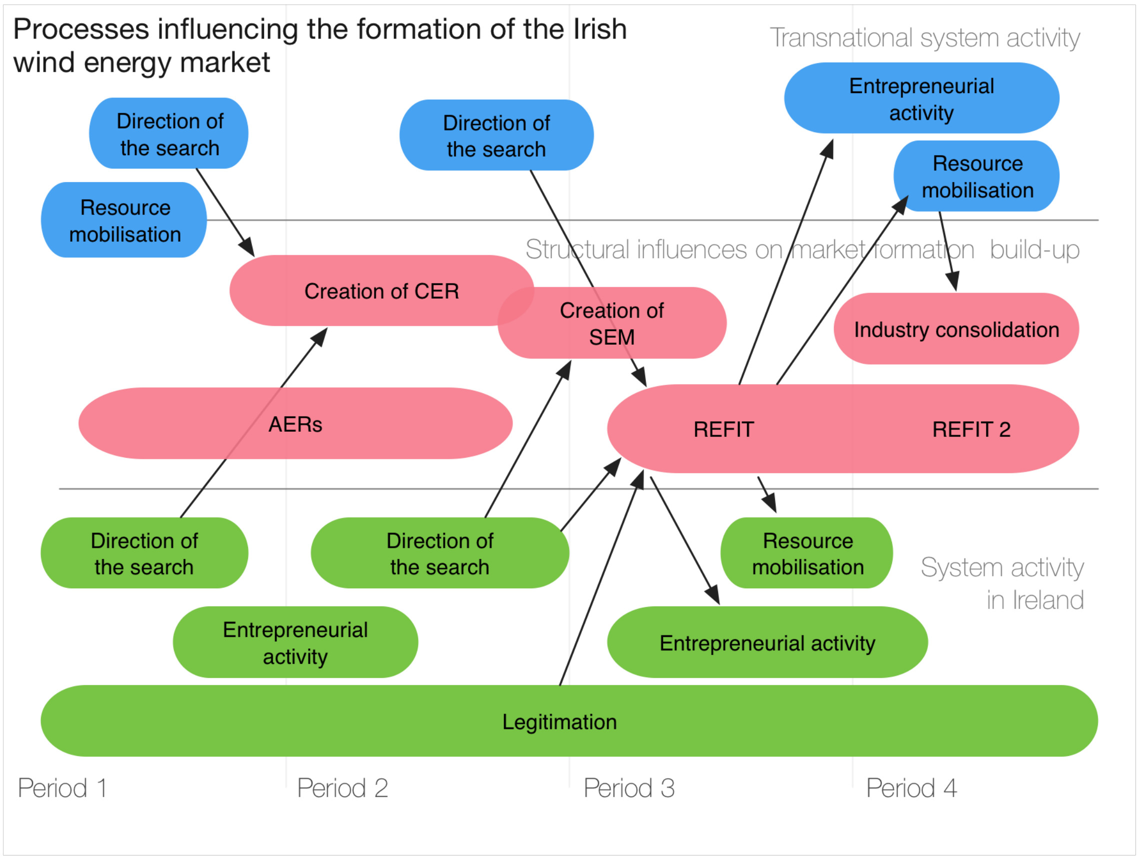

Figure 7.10. Linear illustration of the transnational and national influences on the formation of markets, including the influences behind the creation of the REFIT

ket, the orientation of the cycle shifts. Exogenously influenced lending conditions worsened domestically, firm activity was strongly influenced by lending conditions, advantaging utilities and firms with access to overseas finance (illustrated by the solid lines in Figure 7.11, line 5). While conversely, *entrepreneurial activity* continues to influence the mobilisation of resources (6), the firms accessing the resource changed due to merger and acquisition activity in the industry. Despite this, the continued market operations has by this time 'locked-in' wind RES interests, resulting in a influence on the *direction of the search* (7), a signal for investors with available funds that the Irish wind RES is open for business (8). As such, ultimately this is a phase of Irish wind RES structural emergence, TIS functional strengthening and some reconfiguration, thus an *implementation and reconfiguration cycle*. And because the central 2–3–4 cycle continues, we view this as a single cycle with overlapping processes, rather than two cycles running in serial.

The REFIT, launched in 2006, was the most significant, and powerful, structural driver during this cycle. As a technology support instrument, it was a mechanism by which government finances – raised directly from electricity consumers – were used to subsidise a

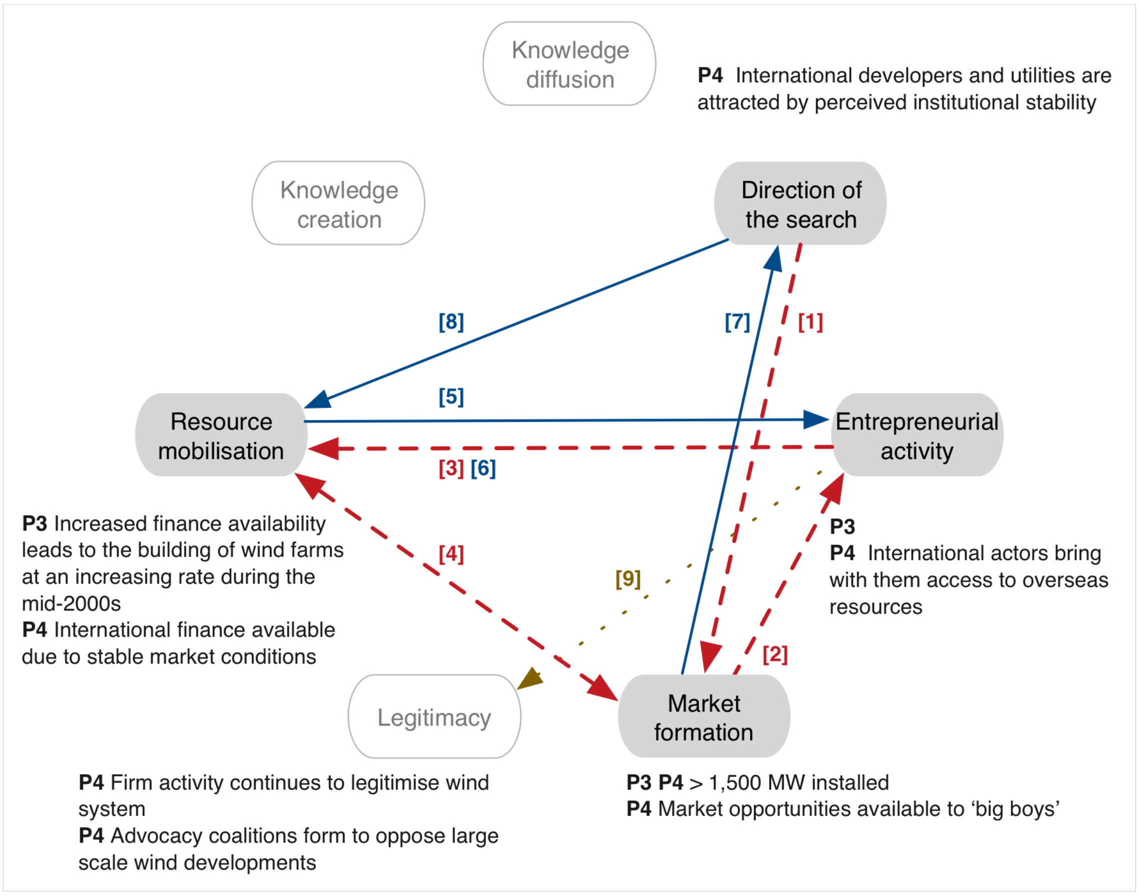

Figure 7.11. The Implementation and reconfiguration cycle

specific form of generation technology over another. Through guaranteed payments it de-risked firm investment in new technologies, and – in theory – endogenised the interests of society, or at least those who lobbied for its implementation. We can now explain the imposition and structural impact of the REFIT in terms of system functions. Irish advocacy coalitions had lobbied for a feed-in tariff for some time (*legitimisation*) but were initially blocked by opposition from incumbents (negative *legitimisation*) and European state aid rules (negative *direction of the search*). However, a number of processes led to a change in the policy support regime in Ireland: increasing evidence (*knowledge creation*) suggested the Alternative Energy Requirements had under-achieved, and critically, that REFIT's would be more cost effective (Elliott, 2005; Toke and Lauber, 2007). Furthermore, opposition to the REFIT diminished as a greater number of actors, including some utilities, joined the wind RES networks (*legitimisation*, the growing actor network behind wind is discussed in Section 6.1.2 and illustrated in Figure 6.2). The wider system conditions which facilitated the REFIT were created by the *rule-setting cycle* discussed above. So while ultimately the implementation of the REFIT was a political decision announced by the DCENR, structural and functional changes in the system account for the timing of its launch and scope of its implementation.

What about the structural impact of the REFIT and the *implementation and reconfiguration cycle?* The REFIT took the form of a power purchase agreement, a contract which guaranteed market access and ultimately market transactions, over a 15-year term. By underwriting potentially loss making transactions and thus investments, it drove powerful *market formation* processes. When compared with the preceding instruments, the AERs, the REFITs supported participation in the market by a greater number of firms[19] (*entrepreneurial activity*). And by guaranteeing revenue over a 15 year term, the REFIT was a catalyst for project financing from banks (*resource mobilisation*). Thus the REFIT was a significant force in accelerating the processes during the implementation cycle (line 2–3–4 in Figure 7.11).

A number of other structural drivers were present during the *implementation and reconfiguration cycle.* These included the other core institutional drivers established during the *rule-setting cycle*; the SEM and Grid Allocation Process which drove the creation of other rules and processes as well as social spaces in which system actors could create and diffuse knowledge (as discussed in Section 6.4.2). EU policy continued to provide strong institutional direction, providing a backstop to the domestic *direction of the search* function. Finally, the perception of the turnkey generation kit having reached a commercially suitable threshold , elaborated through the 'technology is solved' analytic storyline, was an important consideration for actors within utilities and firms and thus contributing to *entrepreneurial activity.* These functional and structural processes which led to the formation of the Irish wind energy market, and the REFIT within it, are illustrated in Figure 7.10. This shows the REFIT not as an instrument from which a well-functioning wind energy system has emerged, but as an accelerator of processes which had been building-up over the proceeding decade.

The *implementation and reconfiguration cycle* arose when the system was on the brink of developing a serious market and lasted through the economic tumult of the recession. Yet despite the REFIT and other structural drivers, barriers inherent to the structure of the system persisted or arose through the cycle. The institutional tumult that followed the economic crash of 2008, manifested in issues of national energy demand reduction and

[19] Totalling 450MW initially, was approx 30% of Ireland's 2010 target. The evidence shows that the REFIT attracted new firms into the sector, and also attracted Airtricity back from focussing on overseas opportunities in the mid–2000s.

the negative impacts on the Irish investment landscape.[20] The system impact of these of these exogenous barriers are explained through the function cycle in Figure 7.11 where *resource mobilisation* function negatively influenced actors in Ireland attempting to access project finance from Irish banks and are thus unable to continue the development projects (lines 5 and 6). However, these barriers did not significantly impede all system activity, as evidenced by the continued growth installed wind farms (see Figure 7.12). Recessionary barriers were mitigated in part by the increasing reputation of the Irish wind RES due to its core structures, including the REFIT (*direction of the search*, Figure 7.11 line 7), which by that time had created a signal for overseas investors that the Irish wind sector, in an open market economy within the Eurozone[21], could generate low-risk, guaranteed returns (8).

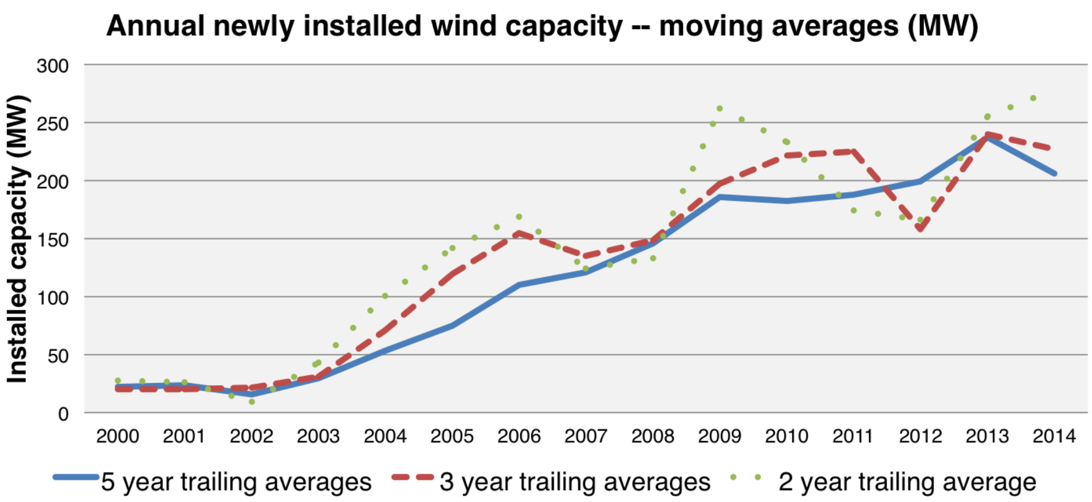

Figure 7.12. Annual newly installed wind capacity in Ireland, 2000 - 2014, moving averages used due to smooth outlier years

7.3.3 The accumulation of nationally-specific knowledge

The structural analysis indicated the importance of knowledge to the developing RES , however, knowledge functions did not form a significant part of either of the system innovation cycles of institutional emergence and acceleration. Thus far, we have accounted for the creation and diffusion of knowledge through function fulfilment of *knowledge creation* and *knowledge diffusion*. Formal knowledge creation activities in Ireland – focussed on power system integration – were largely independent from those overseas such

[20]See Subsection 6.3.1 for an extended discussion on these structural issues.

[21]Shorthand for the block of states using the European single currency

as generation technology R&D. The generation within Ireland of tacit knowledge was required despite turnkey nature of imported technologies. This was driven through Irish firm activity including joint ventures with overseas firms (see Figure 7.13, 1). Significant formal knowledge creation commenced in Ireland as the scale-up in roll-out started towards the end of the second period, driven by direction of the search and the formation of markets (2). Irish research activities led to three notable impacts on the system (3). First they contributed to the mitigation of grid integration issues. Second, research 'outputs' supported increased targets in regulation as they were embedded within positive framings of Irish wind resources and maximum resource yields possible. Third, these positive frames legitimised (and de-legitimised) wind technology vis-a-vis other electricity technologies. Ultimately knowledge creation in Ireland is instigated by a range of factors and it has not been possible to identify a strong cyclical cumulative causality amongst the functions. Rather, we see a progression of distributed activities.

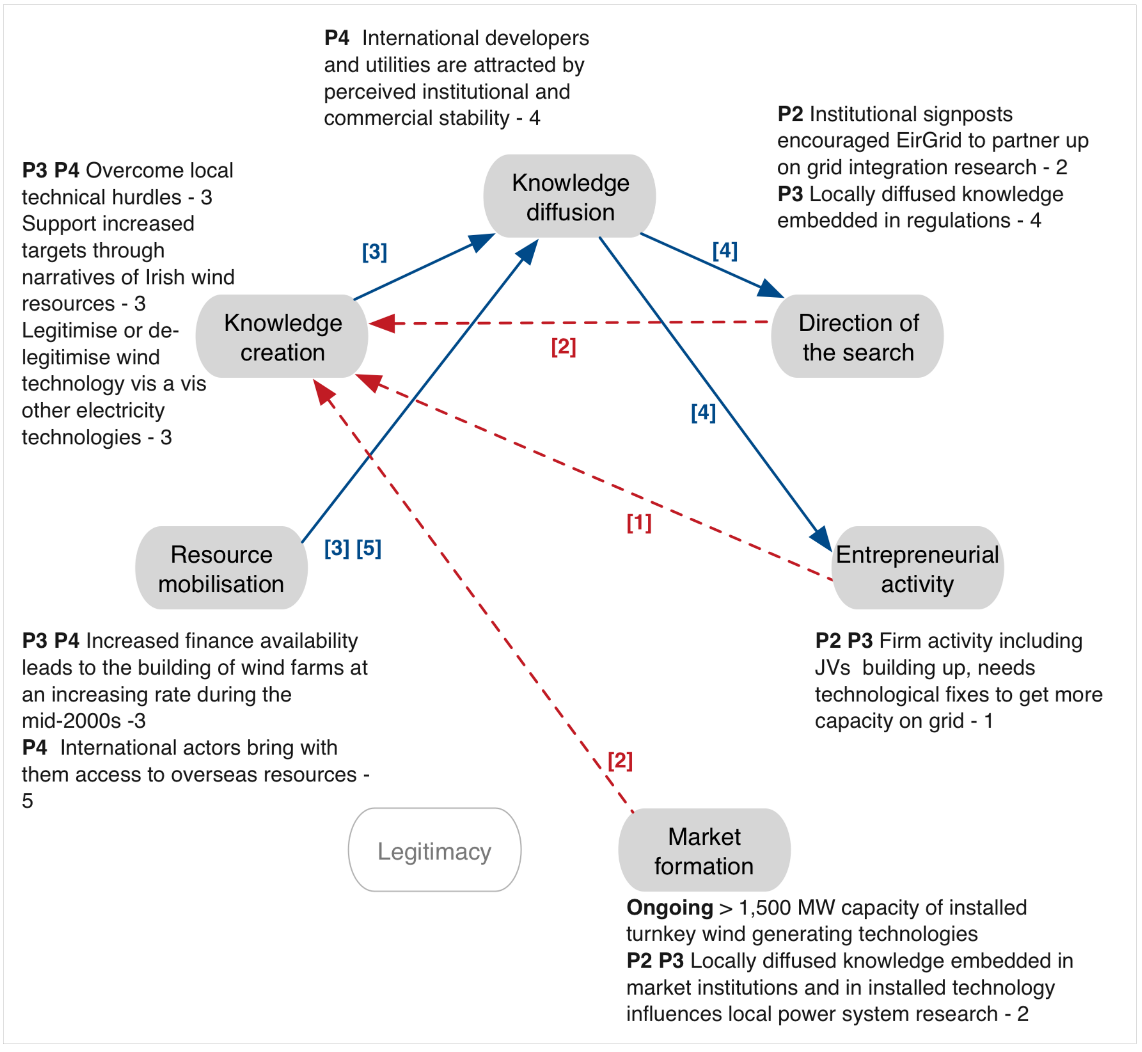

Figure 7.13. Accumulation of knowledge function relations in the Irish wind energy system

As with the *implementation cycle*, significant knowledge activities in Ireland arose when the wind RES was on the brink of developing a functioning market segment. Structural drivers included the nascent market and support instruments. The development of sites of knowledge activity such as the RESG and REDG, formal industry networks, and regular industry events such as conferences and networks facilitated these activities and are chronologically and locationally illustrated in Figure 7.14. The SEM and grid queue not only facilitated knowledge activities, but stabilised and embedded knowledge (rules, grid codes, entry requirements, Figure 7.13, 3) which in turn was influential in legitimising the Irish wind industry for overseas investors in later stages (4). However, further technological barriers remained, and indeed emerged as higher levels of intermittent energy generation was added to the wind. In other words, the inward acquisition of formal (turnkey) knowledge, created a need for further power system research in order that further intermittent generation sources could be added to the grid. We can deduce from this analysis that knowledge generation was pre-dominantly demand-led rather than following a science push model of innovation.

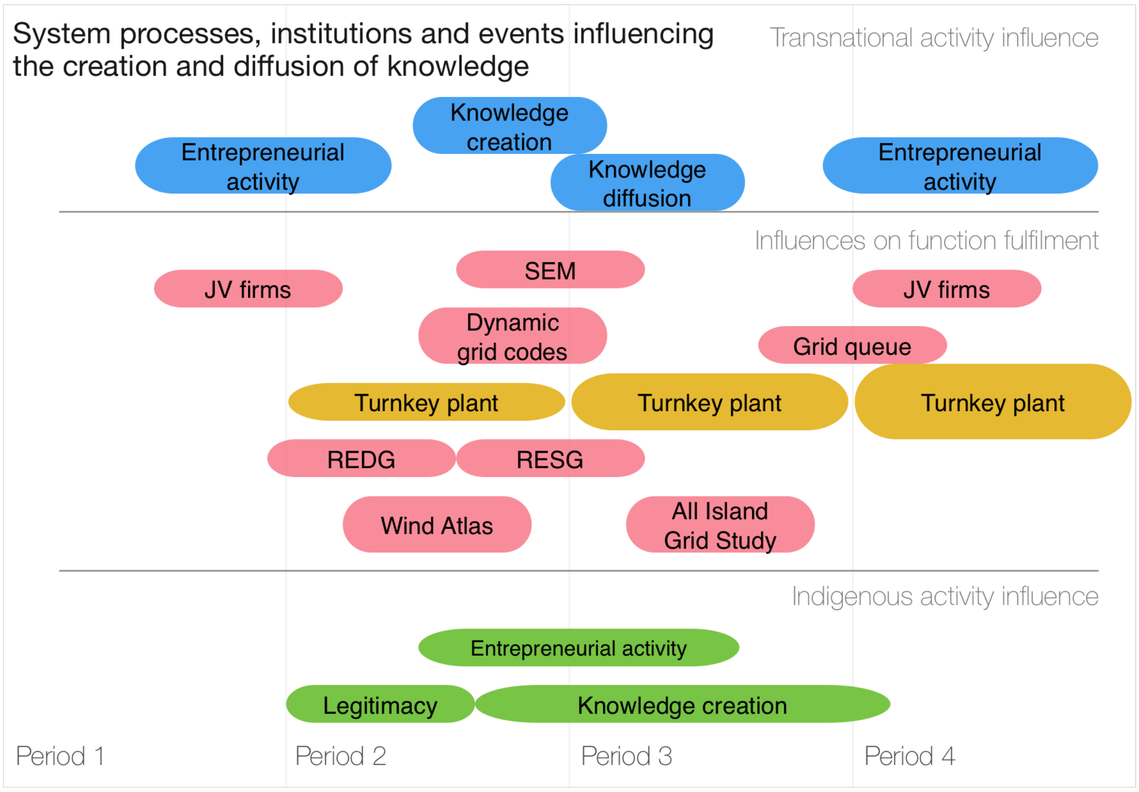

Figure 7.14. System processes, institutions and events influencing the creation and diffusion of knowledge

The development of a modest but globally influential power systems research community in Ireland is one significant spillover effect of the integration of wind in the country.

However, the implementation of the demand-led knowledge progression was not sufficient to kick-start a *science technology push* (STP) cycle, or motor of innovation, which the literature review told us is often found early in the development technology innovation system. This is likely because turnkey technology was readily available, little ambition found in the evidence to instigate an indigenous manufacturing industry, and no significant industrial manufacturing base to call upon. Furthermore, in Ireland there were policy frameworks designed to subsidise the turnkey technology, but not specific research and development needs, or tacit knowledge generation. The result of this is was discrete demand-led activities, not powerful enough to sustain a cycle. Rather the development of wind energy in Ireland consisted of a progression of knowledge activities in addition to two virtuous system function cycles.

Summing up

This chapter documented the salient findings of an in-depth analysis of each of the system functions of the Irish wind RES and, where appropriate, influential functions of a transnational nature. The chapter's major contribution was the detailed discussion of the two system cycles identified through the analysis, with which we explained system changes with reference to two cycles of system functions. Following strong national and European direction setting in the first period, the rule-setting system gained momentum in period two as an increasing number of institutions in Ireland influenced on the one hand the mobilisation of finance from banks and venture funds, and on the other the legitimacy of the Irish wind RES, which in turn increased the availability of finance for developers. System processes at national level drove the cycle through an influx of actors, who articulated demand and shaped expectations through new visions and goals which in turn were embedded in nationally constructed policies and institutions. While I showed the overarching direction of the search was set at European level, more complex political choices, such as which actors were subsidised to enter the market, were were decided in Ireland. The *rule-setting cycle* explains that European and Irish policy, created or co-produced at multiple levels, was adapted in Ireland and then evolved relatively autonomously.

The *implementation and reconfiguration cycle* explains the the acceleration of the rollout of wind technologies starting in the mid- to late–2000s as institutional support for wind led to more rapid market formation and increases in entrepreneurial activity. This shows the REFIT not as an instrument from which a well-functioning wind energy system has emerged, but as an accelerator of processes which had been building-up over the proceeding decade. Somewhat unexpectedly, I found that knowledge processes did not form a significant part of either of the system function cycles. I deduced from the analysis that knowledge generation was pre-dominantly demand-led, instigated by emergent system barriers, rather than following a science push model of innovation. However, the development of a modest but globally influential power systems research community in Ireland is one significant spillover effect of the integration of wind in the country. Finally, the analysis was clear in showing that during any given phase of development, not all functions are re-produced at national level.

The identification of the two function cycles are a significant empirical contribution to the understanding of why wind energy in Ireland was established. In Chapter 8, these cycles are reviewed against findings in similar cases in other countries. These cycles inform our final analytic contribution and inform the empirical part of the answer to why given aspects of the Irish wind energy system needed to be constructed within Ireland.
This question is addressed with reference to the *build-up* and *touchdown* heuristic, which takes as input findings from this chapter, and structural observations from Chapter 6.

Chapter 8

Discussion and conclusions

This thesis is about the innovation processes that were reproduced to support and develop the emergence of the wind electricity system in Ireland. This chapter discusses the implications of the findings from the structural and functional analytic chapters, and synthesises and interrogates them against the thesis hypothesis, and against findings from empirically or analytically similar studies found in the literature. First the function cycles identified in Chapter 7 are evaluated. This discussion leads to the first set of empirical findings addressing the question of what needed to be constructed in Ireland for the emergence of the Irish wind RES to happen. These findings are illustrated in timeline, employing the periodisation used in Chapter 5. Focus then turns to a discussion *build-up* and *touchdown* heuristic, core aspects of which illustrated and discussed using the empirical findings. The research questions and hypotheses are then directly addressed.

In conclusion I clarify the empirical, theoretical and methodological contributions of the thesis and make brief recommendations to policy markers and other interested actors based on these contributions and findings. 7

8.1 The emergence of the Irish wind RES

8.1.1 Comparison of function cycles

The function analysis discussed in Chapter 7 yielded two distinct overlapping function cycles, it indicated an extended phase of distributed knowledge activities, and no evidence was found of any significant vicious cycle. The functional mappings of activity in Ireland indicate the existence of a pattern of activity that resembles a *system building motor* in periods two and three, and a *market motor* in periods three and four. This compares with four distinct motors identified in the literature (Suurs and Hekkert, 2012). Of these motors, there is insufficient evidence to indicate the existence in Ireland of a *science and technology push* motor. The knowledge functions were insufficiently fulfilled within the Irish RES and the evidence is clear that Irish actors did not have significant influence on generation technology research and design processes at any time throughout the period of development. Ultimately neither the knowledge functions, nor those they interacted with were strong enough to sustain a full STP cycle though the demand-led research capabilities within Ireland were significant in themselves for reasons discussed in the previous chapters. For similar reasons, the functional pattern analysis shows that the relations between *entrepreneurial activities* and knowledge generation was insufficient to drive an *entrepreneurial motor* . Findings from the case are summarised in Table 8.1.

These findings share a number of similarities with studies which have addressed the emergence of renewable electricity systems in new locations have suggested, two dynamic cycles. In the case of Portuguese wind, a *knowledge development cycle* and an *implementation cycle* was identified (Bento and Fontes, 2014). Similar cycles were found in the Danish wind RES and Japanese solar PV system (Kamp, 2008b; Vasseur et al., 2013). Whilst some form of implementation cycle can be found in all of these cases, the Irish case is unique amongst them in failing to produce a knowledge cycle, instead featuring a *rule-setting cycle* , which shares some attributes with the Suurs and Hekkert's *system building motor* . Ireland's limited manufacturing base and low levels of heavy engineering industries mitigate against the development of indigenous turbine industry before and after Danish and German lead firms had established market presence. Given that we expected relatively open flows of capital goods, services and designs coupled with low domestic government spending on research and development, the absence of an *STP cycle* is not surprising. However, the strength of the *rule-setting cycle* was, with regard to findings in other cases, unexpected. The Portuguese case suggests that the development of an indigenous wind RES there was predicated on the assimilation of knowledge spillovers from abroad, made possible by improved absorptive capacity, which in turn was possible thanks to the STP motor. Instead of this knowledge based rationale for the development of the early stages of the wind RES in Ireland, we have a structural explanation. Or put another way, rather than explaining early system development through the ability to acquire knowledge, the Irish system was built, in part, through the construction of core

Table 8.1 Evidence of motors of innovation found in the analysis

Motor	**Description of motor (Suurs, 2009, pp. 242-243)**	**Case findings**
Science and Technology Push	The Science and Technology Push (STP) Motor is dominated by knowledge development, knowledge diffusion, guidance of the search and resource mobilisation. All the other system functions are either absent or relatively weak.	The analysis suggests that this motor was not present. A locally specific progression of distributed knowledge functions was identified, however these functions did not sustain a causal cycle. These functions were 'demand led' through other system activities and unlike the STP motor, did not take place early in the system development.
Entrepreneurial motor	The entrepreneurial motor is similar to the STP motor. What sets the entrepreneurial motor apart from the STP Motor is the particularly important role of support from advocacy coalitions (legitimacy) and entrepreneurial activities.	An entrepreneurial motor was not identified in the analysis. Although there was entrepreneurial activity, it did not cumulatively influence and interact with knowledge functions to form a strong motor. In other words, entrepreneurial actors in the Irish wind system did not drive development of generating technology.
System building motor	In the system building motor the set of dominant system functions is similar to those of the entrepreneurial motor but it includes a more important role of market formation. The main difference lies in the newly formed connection between market formation and direction of the search as more powerful and influential actors join the system than the advocacy coalitions which had been there previously.	The patterns of self-reinforcing functions in the second and third periods are similar to those we would expect of a system building motor. The analysis indicates this cycle locks-in interests and knowledge to the developing RES. The cycle accounts for the strengthening of networks as an increasing diversity of actors from other sectors joined the system e.g. the 'professionalisation' of advocacy coalitions and IWEA. This rule-setting cycle explains that European and Irish policy, created or co-produced at multiple levels, is adapted locally and then evolves discreetly.
The market motor	The Market Motor is characterised by a strong contribution to all of the functions, which are strongly fulfilled, expect for the legitimacy function. According to Suurs, the latter is not as important for the dynamics of this motor because market formation is no longer a political issue; a market environment has been created through formal institutions. Instead, continued Market Formation is influenced through business activities,e.g., marketing activities connected to Entrepreneurial Activities.	Cycle begins with strong institutional alignment and a strong institutional core is formed. By the end of the third period, market formation processes were being driven by construction and operational activities through market relations and transactions, rather than through the legitimisation activity of advocacy coalitions as per the rule-setting cycle The continued market operations has by this time 'locked-in' wind system interests, resulting in a influence on the direction of the search. The REFIT was significant: This analysis matches Bento and Fontes (2014, p. 172)'s findings in Portugal, where the authors attributed 'hard market formation' which drove investment to the implementation of a FIT in the early 2000s. Core institutions stabilise, transmit and signpost, to overseas investors following the recession. The analysis indicates that local market players can be replaced by overseas players, who may not initially have had the local legitimacy that the system needed.

institutions.

The Bento and Fontes (2014) paper posits that transnational activities play a fundamental role in capturing knowledge spillovers, whereas we suggest that in the Irish case, transnational activities had a structural and institution building influence which mitigated against the need for an extensive knowledge cycle such as an *STP motor* . The typical *STP motor* according to Suurs involves a sequence consisting of positive expectations and research outcomes (Suurs and Hekkert, 2012, p. 161). We found that in the Irish case the core institutions made up for the lack of nationally generated knowledge by embedding and transmitting formal knowledge; signposting future technological pathway directions and financial commitments from the government; and stabilising relations and knowledge within the developing wind RES. In achieving this, they mitigated against short term contextual institutional shocks. Indeed, despite being highly localised, the core institutions provided transnational 'signposting' that Ireland's wind RES was 'open for business'. As such, the Irish *rule-building cycle* combined aspects of the *STP motor* and *system building motor*. In this sense that the rule building incorporated aspects of a knowledge cycle, but with little concern for where that knowledge came from. The influence of EU policy processes in the 1990s (a strong *direction of the search* for new technology/knowledge) was crucial in instigating this cycle through its destabilisation of the pre-marketised electricity system. Yet the cycle continued, influenced by firm actors (strong *direction of the search* from Ireland) as they joined the system in the late 1990s and early 2000s. This finding matters as there is a strong generative attribute to the institutions. Where it is not practical to develop knowledge activities in Ireland, the case has shown how institutional development can overcome national and transnational TIS structural issues.

A final substantive difference in this case and the others discussed is the multi-level *direction of the search* function accounted for above. Several recent studies have shown that in their case, strong national level policy signposts *direction of the search* function tends to be the lead function instigating dynamic cycles in new locations, e.g. Bento and Fontes (2014); Tigabu et al. (2013). Some of this difference we put down to analytic focus using event analyis, and in the case of Bento and Fontes (2014) particular methodological emphasis was put on the processes that enabled (domestic) absorptive capacity. But in the Irish case, through close analytic attention to actor narratives in addition to events, we have found multi-level *direction of the search* , functioning in parallel throughout the development of the system. At national and sub-national governance level, system building was built up through a sub-cycle of activities (visions, regulations, incoming firms, embedded within institutions, regulations) before being accelerated by the REFIT. EU governance actors, such as the Commission, could set the direction of travel for future energy policy, yet had relatively little legitimacy or agency to mandate technological change on a country by country basis. Ultimately the *rule-setting cycle* explains how European and Irish policy is created or co-produced at European level, adapted in a national context and then evolved discreetly at each level. This is because the *direction of the search* functions at multiple levels in the cycle which we have noted in the national stories, interests and institutions incorporated in the cycle through the function explanation. We could imagine this set of coupled processes performing something of a *'localisation'* function. In summary, given the stated influence of a diversity of actors in creating and embedding stories and institutions, the creation of the wind RES was not the result of narrow policy prescription alone, at either European or national level, but rather consistent but differentiated direction setting at both levels.

8.1.2 What needs to be nationally constructed: system build-up and touchdown

The analysis of the function cycles brings us to a core concern in the thesis. In the development of the Irish wind RES, what was reproduced in Ireland and what were the processes that contributed to the formation of the RES as the technologies emerged from lead nations and reached new locations? The analyses discussed in chapters six and seven provide evidence that these phenomena have both domestic and transnational causes, which are variously connected within the emerging RES. We now return to the empirical case to offer an explanation of what needed to be nationally constructed through the four periods of development.

In order to clarify locational aspects of the Irish wind RES, its development processes and their drivers, barriers and directional influences, we return to the heuristic introduced in Chapter 2, distinguishing between the *touchdown* of overseas components, through transnational flows, or driven by transnational functions; and the *build-up* of activities and RES components in Ireland, utilising national resources or driven by enacted TIS functions in the Irish wind RES. Recall that *touchdown* is an umbrella term that encompasses the structures, functions and flows of resources and other RES components which came from overseas and through inter-organisational linkages and relations. *Build-up* activities are the set of RES structure components which have come from or been significantly influenced by Irish contexts, and TIS functions which are enacted or influenced by Irish actors and institutions. We use these terms to elaborate further the explanation for the development of the Irish wind RES, over the four periods of development, illustrated in Figure 8.1.

In the first period significant events and decisions included the marketisation of the electricity sector and the creation of market niches for Irish renewable generators, an event influenced by lobbying activities in Ireland. *Build-up* activities in Ireland were weak, but where they existed included coalition building and some diffusion of knowledge through a small number commercial wind projects. *Touchdown* activities were influenced by national capital grant schemes, which were the recipients of European fundings. These in turn attracted a small number of development joint ventures which enhanced the acquisition of tacit knowledge within the small wind production network forming. In the second period crucial events and decisions took place around the moratorium on grid connections. Processes in Ireland driving the emergence of the wind RES were enhanced by the distributed agency of firms entering the RES and lobbying the Department of Communications, Energy and Natural Resources and were facilitated in institutional spaces such as the Renewable Energy Strategy Group. *Touchdown* processes included the generation of dynamic grid codes by overseas manufacturers, increased import of turnkey technology and European policy targets. These contexts and functions led to a cycle of rule-setting which significantly influenced the establishment of core RES institutions beginning with the Single Electricity Market. This cycle continued through the third period as the Renewable Energy Feed-In Tariff and the Grid Allocation Process were launched.

Crucial events and decisions in the third period included the widespread economic recession and the launch of the REFIT which benefited operators and developers of wind farms, who by now included domestic and overseas utility firms. Furthermore the REFIT gave long term assurance to lenders, making more affordable the capital costs required to build plant infrastructure. The REFIT was significant to system build-up by accelerating development plans and interests which were already present within the system. These system conditions and functions powered a cycle of *implementation and reconfiguration* through the fourth period which facilitated the rapid construction of wind generation plant and associated infrastrcuture, and consolidation of firms in the sector. *Touchdown* processes were less pronounced during the third period of development as domestic actors and institutions were well-aligned. In the fourth period crucial events and decisions were the continued difficulty developers had in acquiring project finance in Ireland and the continued support by the DCENR of the REFIT scheme. Irish wind RES *build-up* was driven in part by visions of the societal benefits of wind as an export opportunity and

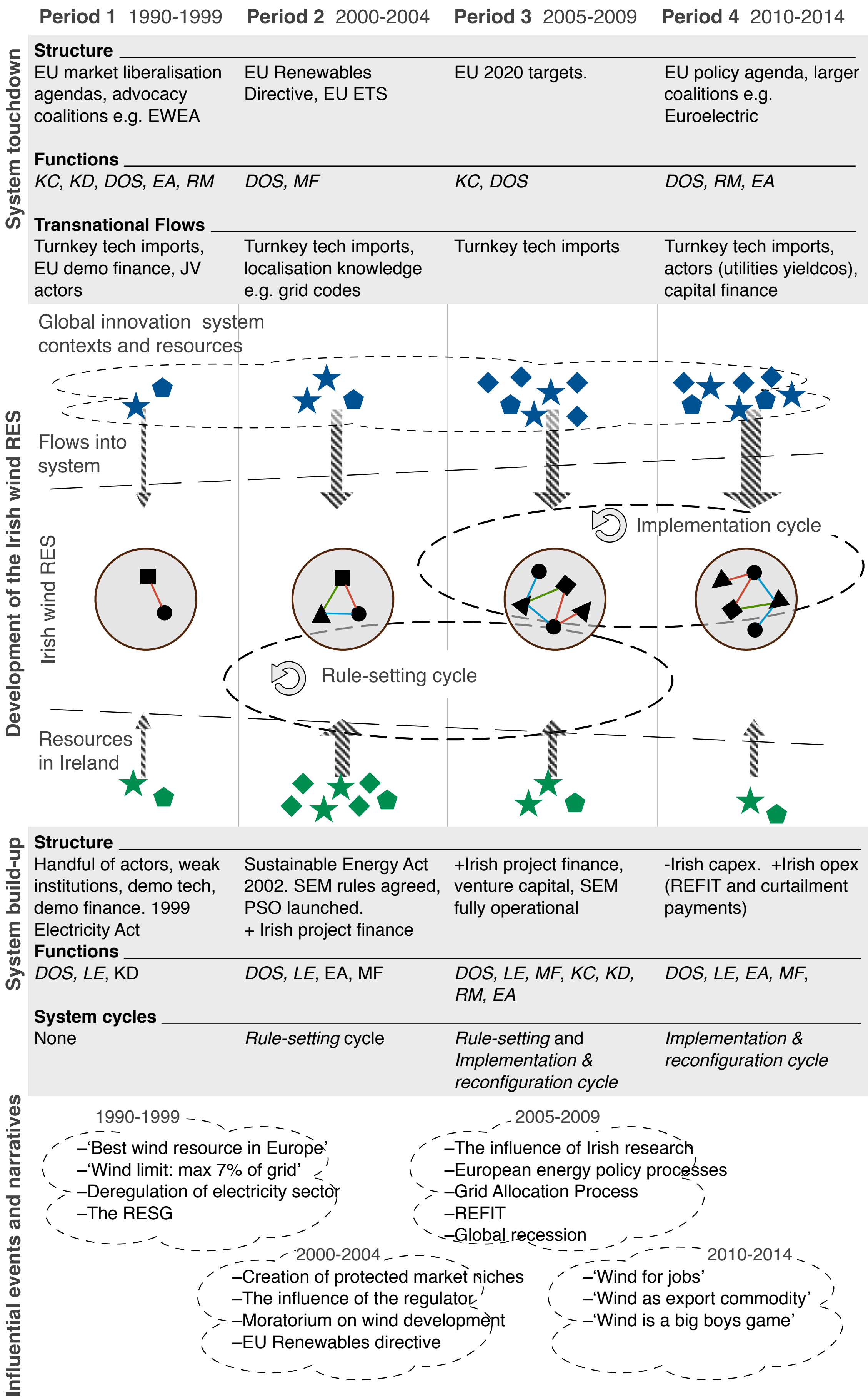

Figure 8.1. The development of the Irish wind energy system integrating structure, functions, cycles and flows. Key to functions: DOS direction of the search, LE legitimisation, MF market formation, KC knowledge creation, KD knowledge diffusion, RM resource mobilisation, EA entrepreneurial activities

industry that could provide significant jobs, reconstructed and recreated by firm actors and special interest groups. *Touchdown* again became significant, as resource access to overseas finance, and the entry into the Irish wind RES of overseas actors was a significant driver of successful development projects. The combination of strong internal institutions in the Irish wind RES and lack of finance in Ireland created the conditions for a new wave of joint ventures with overseas firms, and the entry into the Irish market of new utilities and yieldcos.

8.1.3 Integrating the transnational dimension in the emergence of the Irish wind RES

From this explanation of the development of the Irish wind RES, the thesis makes a number of conclusions about *build-up* and *touchdown* of the RES. Several kinds of transnational linkages and activities were important in facilitating *touchdown*, the dominant functions and cycles of which are illustrated in Figure 8.2. The flow of capital and ultimately access to overseas finance – unevenly distributed amongst actors in Ireland – strongly influenced the ability of domestic and foreign actors to respond to commercial opportunities in Ireland. National economic conditions were instrumental in creating the situation where Irish lenders shut down lending activities. Development firms with financial relations only to Irish lenders tended to be disproportionately negatively affected and these tended to be smaller Irish developers. Meanwhile, for the overseas firms considering entering the Irish market, capital was secured typically with overseas banks they had existing relationships with. Here then, locational factors included the framing of opportunities, and the ability of the overseas actors to enter the market through merger and acquisition activity. For this, pipeline projects (indicating a maturing RES) were needed and a strong institutional base, which de-risked investment was required. By 2010 these were in place. Access to turnkey technologies on the other hand was not problematic, however, access to specialised formal knowledge required from manufacturers for grid integration did at times create barriers to development for actors in Ireland. This issue was in part mitigated by the rise in indigenous specialised knowledge creation activities, discussed below. In the formative years of the system, sales of turnkey technologies were expedited by charismatic entrepreneurial agents based in Ireland and deeply implicated in the emergent (Irish) processional networks and associations and Ireland's membership of the Single Market was a minor contributory factor in the movement of labour, technology and capital.

There was a low level of formal knowledge spillovers in Ireland but there was not the

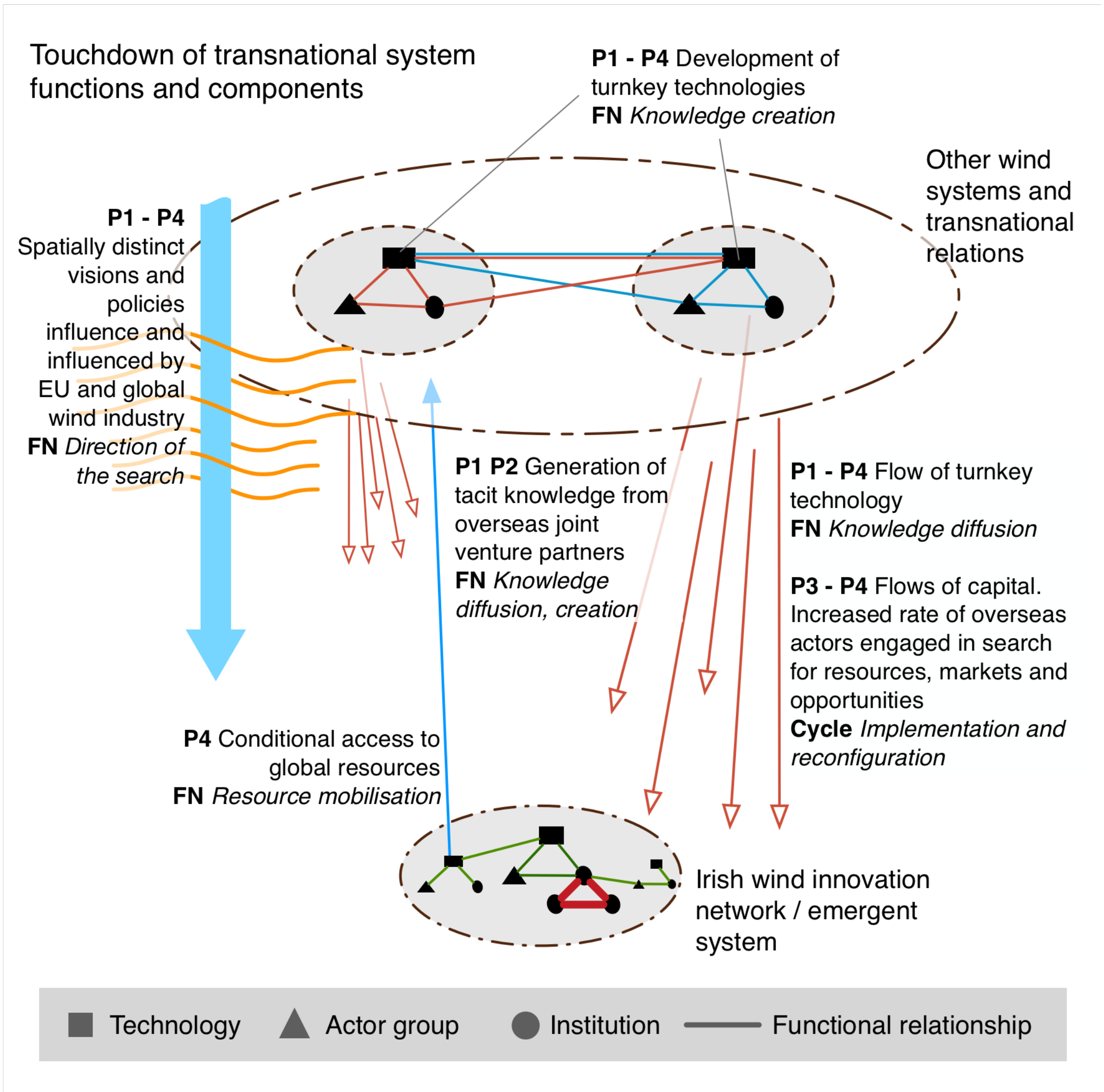

Figure 8.2. Touchdown of transnational system functions and components

transplanting of global technology pathways (e.g. anchoring activities à la Binz, Truffer, and Coenen (2014)), however local spillovers of tacit knowledge did occur as joint ventures took place in the early development periods (as evidenced in analytic story A–06 in Table 6.1). In these cases we found the sectoral proximity to larger markets (the UK and Germany) and the low coordination costs of running a relatively small Irish project were important in enabling engineering firms to develop Irish projects. The final major form of transnational linkage was the flow and influence of spatially distinct regulation across governance levels. While the flow of policy influence has been shown to be bidirectional, that is the nation influences the superstate and vice versa, the case has shown us that with regard to energy policy, this direction was highly unidirectional, from the EU to Ireland. However, policy agendas and directives were mediated, embedded and translated by actors at the national level (government and others) and were co-influenced by the institutional ensemble. Here then TIS structural conditions of the RES were important, and in Ireland that meant the opening up of institutional opportunities in the 1990s as the electricity sector was marketised. Furthermore, competencies relating to transposing European regulation, and taking advantage of European funding had built up during years of structural cohesion projects, which many of the early (commercial) demonstration wind projects bore resemblance to. And again, as with the flow of capital, the construction of strong internal institutions within the wind RES, particularly the REFIT, accelerated development across the system.

This Ireland-based TIS-structural explanation accounts for a final observation, *touchdown* increased in the final period through the greater utilisation and access to overseas resources (illustrated in Figure 8.1 via wider flow arrows). The analysis showed how further and greater draw-down of overseas resources and the implication of a greater number of overseas actors in the Irish wind RES. This indicates a strengthening of relations between Ireland's wind RES and transnational markets and innovation systems. Unlike the highly internationalised ICT and pharmaceutical sectors in Ireland, this is not an export-led relationship. Rather in the wind RES, Ireland-based actors were exporting low quantities of electricity though interconnection, and a relatively narrow portfolio of knowledge such as power systems research and through Mainstream and finance actors, some business models. The REFIT payments, and the increasing difficulty faced by those actors attempting to raise capital finance combined in Ireland to moderately accelerate RES activity and encourage entry and investment by overseas actors. Our findings inform us that the strength of *touchdown* activities were contingent on conditions and TIS functions both exogenous and endogenous to the RES. Here then we see that not only did the relative strength of *touchdown* and *build-up* matter, temporal qualities and sequencing mattered too.

Build-up is the local construction of the innovation system, driven by locally specific contextual and systemic components, functions and activities within Ireland. The substantive aspects of what was locally constructed have been discussed in the previous subsection (8.1.2). We summarise these *build-up* processes and cycles, illustrated in Figure 8.3. Where we see the strongest locational influences are

- In the strengthening of the discrete knowledge creation activities within and between Irish power systems research groups and the system operators. Here both relational and geographic proximity advantaged actors in Ireland.

- In the legitimation activities, specifically the construction and reconstruction of 'Irish' visions, stories and framings which we have discussed were closely related to the level at which policy formation took place (*direction of the search* in Ireland).

- The construction of the strong, nationally specific specific institutional core driven by the highly localised rule-setting cycle which took place after a significant sectoral and institutional shift towards marketisation in the electricity sector. Here we see that national institutional knowledge, often acquired tacitly in ancillary sectors in Ireland was influential.

- The access to project finance, achieved through the within and between Irish banks, the Irish financial services sector and wind developers in Ireland.

- The construction of markets and market niches in Ireland. These were geographically bounded by Ireland's island grid and relationally bounded by the jurisdictional limitations of the Single Electricity Market.

In each of these cases, location, played a significant role, and the analysis makes a strong case against location being treated as a passive background variable.

8.2 Discussing findings and hypotheses

8.2.1 Answering the research questions

This inquiry has yielded a set of complex explanations for the emergence of Ireland's wind RES. These are now summarised as we address individually the research questions posed at the beginning of the thesis.

RQ1: What explains the emergence and growth of the wind electricity system in Ireland and what does this tell us about why and how renewable electricity systems emerge in new locations?

The growth of the wind electricity system in Ireland can be explained by a series of overlapping and mutually constitutive processes. First, from the early 1990s there was a prolonged, and at times rapid rise in wind energy related commercial activity within Ireland, encompassing a growth in the number of wind farm developers, construction and engineering firms, financiers and indigenous researchers. Second, a relatively small population and low coordination costs aided the rapid formation of actor coalitions and industry networks initially by wind developers and then by a wider diversity of sectoral actors. During the course of the late 1990s, a small number of actors and coalitions successfully lobbied for favourable regulatory conditions within the newly liberalised energy sector and

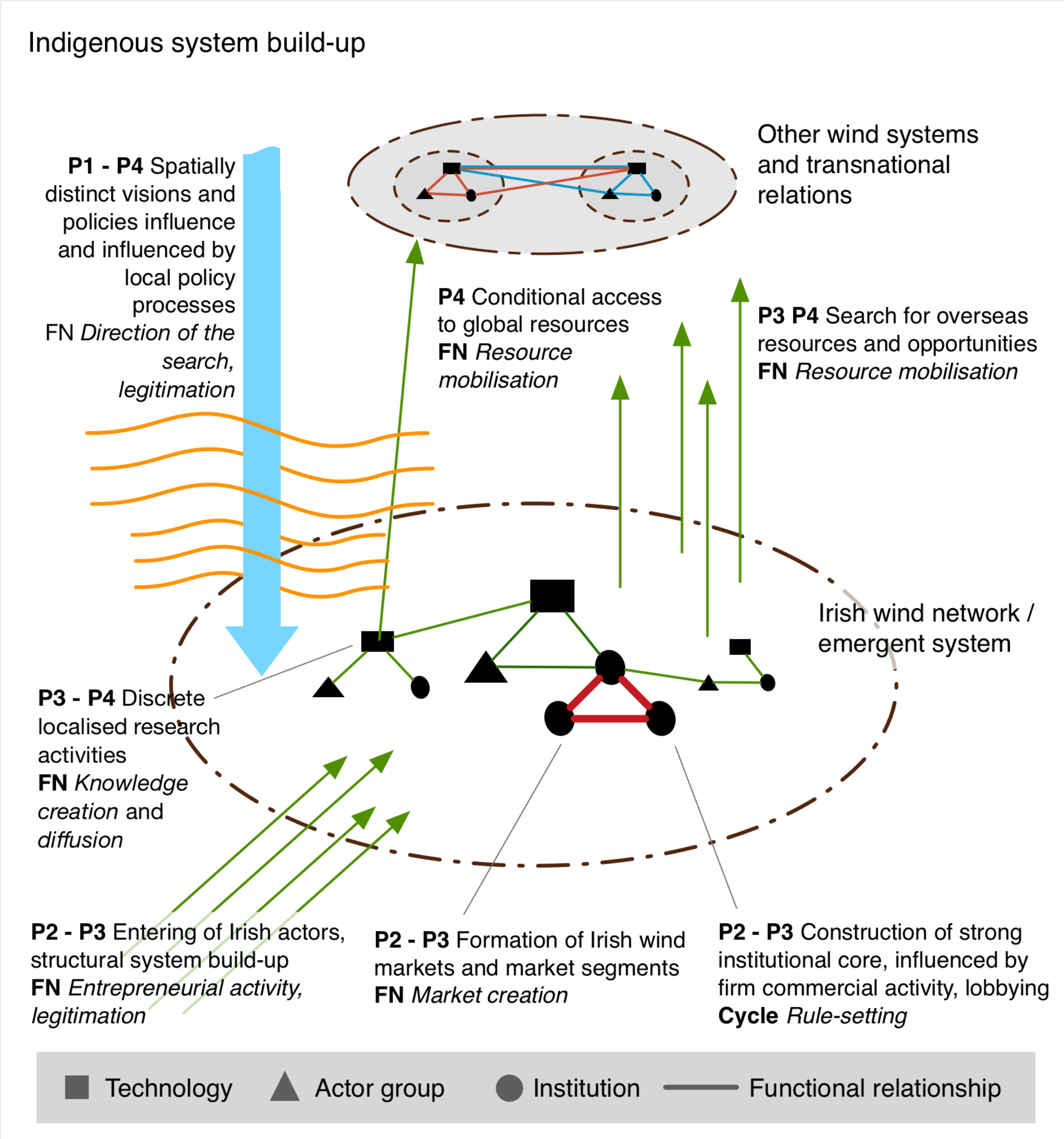

Figure 8.3. Indigenous system build-up

capital grant schemes – through much maligned by wind firms at the time – stoked increasing commercial interest in the sector. Third, factors in the success of this lobbying include strong signals from European policy debates that energy market liberalisation was happening, wind actors with experience and capabilities of working for Irish infrastructure projects and gaining European funding, and the ability of these actors to incorporate visions of societal benefits into their lobbying activities which addressed contemporary government concerns about electricity demand in a rapidly expanding domestic economy. Fourth, the construction – in Ireland – of an energy market with formal rules and payment structures for wind generators, a formal queuing system for gaining access to the market and grid, and a feed-in tariff, to subsidise wind generators were significant developments. These were crucial institutions which accelerated the roll-out of generating and infrastructural technologies, and formalised and strengthened relations between actors. This in turn accelerated learning processes and further legitimised the emergent sector from the prospective of both domestic actors and overseas players who played an influential role in supplying experience of delivering projects, and access to finance in later years. We reflect on these answers and assess what general points can be made in Subsection 8.2.2 .

RQ2: How can the emergence of a wind-based renewable electricity system in Ireland be explained by the formation and development of technological innovation system functions?

The thesis found that at no time did a discrete wind energy innovation system exist in Ireland, autonomous of connections to overseas institutions, actors or resources. Instead, the emergence over time of a dynamic and partial wind RES in Ireland can be explained with reference to a complex set of innovation processes and institutional contexts and influences within, outside of and between Ireland and other countries. The construction of the substantive aspects of the RES in Ireland was driven by two overlapping cycles of TIS functions, first a *rule-setting cycle* , and then an *implementation and reconfiguration cycle* . The *rule-setting cycle* accounts for the multiple processes by which core indigenous institutions were constructed. Dominant functions in this cycle included a strong *direction of the search* function constituting transnational and Ireland-based activities, *entrepreneurial activity* within Ireland and a shift from *legitimising activity* to ongoing *market formation* functions. The *implementation and reconfiguration cycle* explains further institutional stabilisation as well as significant roll-out of material generation and grid technologies. Dominant functions in this cycle included transnational *resource mobilisation* , indigenous *knowledge creation* and the cycle facilitated a shift from indigenous to transnational *entrepreneurial activity* , as opportunities for overseas actors to enter the Irish electricity market were created. Although these cycles foreground explanation based on innovation processes, the thesis found that aspects of TIS structure and informal institutions in context mattered too.

This explanation incorporates the alignment of institutions to the goals of system actors though often contested by incumbent firms and interested challengers. Furthermore, it explains how incumbent monopolistic firms, predominantly the *ESB*, entered the wind RES and aligned their own goals and interests with those of actors already present. In addressing this question the TIS framework has added explanatory value. It has enabled us to explain how imported turnkey technology, and European Union policy agendas were integrated and embedded into the RES at the national level respectively through increased but discrete advances in research capabilities in Ireland, and through a locationally differentiated *direction of the search* function.

RQ3: What aspects of the RES are re-produced in the new location and why?

The answers to research questions one and two have shown that three significant aspects of the wind RES were re-produced in Ireland. First, the *legitimacy* and *direction of the search* functions were strongly fulfilled in Ireland through the creation of indigenous visions and national regulations respectively[1]. In the case of the former, many of the narratives that were mobilised for legitimising the wind RES referenced or drew upon existing parochial visions and perspectives on Irish society, technology and resource endowments. The *direction of the search* function fulfilment in Ireland acted along side *direction of the search* in other countries and at other levels[2]. Second, the construction in Ireland of the core wind RES institutions was crucial. The *direction of the search* and *legitimacy* functions were instrumental in kick-starting the rule-setting cycle which drove the construction of the REFIT, the grid queue and Single Electricity Market. While on its own the REFIT was influential in accelerating *build-up* activities, the thesis has shown that it was the combination of these three locally constructed, institutions that ultimately led to the RES stabilising through the recession in 2008 by attracting overseas investment in later periods. Third, in the early periods of development, entrepreneurial activities within Ireland were significant drivers of *direction of the search* and *market creation* , specifically the creation of market niches. Importantly these activities were not limited to development and construction of wind farms, but included the building of actor coalitions, nascent industry-research links between Irish universities, firms and system operators, and lobbying activities focussed at Irish government and civil service actors.

RQ4: What is the balance of influence on the RES of indigenous versus overseas structure and TIS functions in the Irish context?

Using the *build-up and touchdown* heuristic, we discuss the relative balance between indigenous and overseas influences on the wind RES, drawing on the extended findings discussed in Subsection 8.1.2. At a fundamental level, there was a ‘preferential substitution’ relation. In several episodes in the emergence of the RES, *build-up* activities were initiated over *touchdown* due to reasons of sectoral, cultural or geographic proximity.

[1] Discussed at length in sections 7.1 and 7.2.

[2] In doing so, we note this contributes to the answer to RQ4.

A case in point is reconfiguration activities in the wind RES due to ownership changes after the 2008 recession, when some Irish wind farms were re-constituted as fixed financialised assets in a globalised market consisting of new actors such as pension funds and 'yield cos'. In that case we saw the substitution of lending activities in Ireland for those overseas, and the influence of an uneven distribution of 'global' resources and access to those resources. However, it should be clear by now that *build-up* and *touchdown* activities were not, in terms of location, mutually exclusive. Indeed some TIS functions were co-constitutive from national and European levels, in particular *direction of the search.* With regard to the influencing of the technological pathway direction of the RES, we found that European policy agendas set the direction, but within these parameters, the direction was strongly orientated by actors and institutions in Ireland. Further findings in Subsection 8.1.2 showed that the intensity and timing of *touchdown* activities were contingent on structural context and TIS functions both exogenous and endogenous to the Irish wind RES. In other words, not only was the relative strength and location of *touchdown* and *build-up* influential, temporal qualities and sequencing mattered too. In the most stark example, the construction of institutions in Ireland was required before overseas investors entered the RES following the 2008 recession. What is more, the co-constitutive and sequential properties were additive in the case of the direction of the Irish wind RES. Specifically we noted how the direction was set through national influences[3], whereas the acceleration of emergence and growth was accounted for through *touchdown.*

8.2.2 Addressing the hypotheses

Returning to the hypotheses posed at the beginning of this study, it is now possible to draw a number of conclusions. Hypothesis **1a** , **1b** and **1c** are concerned with the distribution of TIS functions over space and inter-organisational and transnational linkages.

H1a: Not all TIS functions needed to be re-produced in Ireland, some system functions originate in overseas renewable electricity systems, or are produced through transnational innovation activity.

The review of the literature in Chapter 3 showed a number of studies which shared a common theoretic perspective that emergent nationally specific innovation systems are often dependent on distributed system formation processes (Gosens et al., 2015; Fornahl et al., 2012; Lovio and Kivimaa, 2012). The analysis has clearly shown that not all system

[3]While an overarching direction was set at European level through – on the one hand – regulation, and – on the other – technical choices made in more developed markets, many complex choices of who influenced the emergence and growth of the RES were made in Ireland.

functions are required to be reproduced in the country in which the RES is emerging (see Figure 8.1 in Subsection 8.1.2) confirming – in general terms – the findings summarised in the literature review. A notable addition to the hypothesis was the observation of the dynamic and systemic nature of shifts in the geographic distribution of TIS functions through each period of emergence and development of the wind TIS. In Subsection 8.1.3 we discussed how the sequencing of *touchdown* activities mattered, for example with flows of finance from overseas influencing the emergent wind RES in different ways in the first and fourth development periods.

Furthermore, *knowledge creation* TIS functions (producing turnkey technologies) were transnational, and Ireland was not the site of a significant knowledge network created as found in other studies[4] e.g. Binz, Truffer, Li, et al. (2012); Binz, Truffer, and Coenen (2014). Indeed, access to and the influencing of overseas knowledge networks and finance networks was not evenly distributed amongst actors in the Irish wind RES. Finally, with regard to the formation of local markets, we note that Dewald and Truffer (2012) showed that proximity between knowledge producers and end users influenced the formation of markets. However in this case, we see that proximity was most important to the developers and operators who sought to form alliances and influence the alignment of institutions, through corporate political activity. Of course, the difference between markets in renewable technologies and markets for the generation and supply of electricity is a significant factor here. In conclusion, the thesis finds that distributed TIS functions are influential in the emergence of the RES, access to resources and strength and direction of the emergent RES are affected by the nature of the distribution.

H1b: TIS Function strength reflects structural components which are exogenous as well as endogenous to the wind RES at national and European levels.

The review of the literature indicated that contextual institutional conditions are an important influence on the emergent RES (Bergek, Hekkert, et al., 2014). The structure and function analyses bore this out, illustrating how alignment with an ensemble of institutions, within and outside of Ireland, influenced the performance of TIS functions relevant to the Irish wind RES. The thesis found *legitimation* and *the direction of the search* were strongly influenced by the exogenous context of the wind RES in Ireland, in accordance with Meelen and Farla (2013). The thesis supported these findings by showing how legitimisation was strengthened often by deliberate alignment, through the construction

[4]Not withstanding the creation of nationally focussed knowledge activities aimed at addressing power systems integration problems.

of specifically Irish narratives of societal benefit which evolved with changing economic and informal institutional contexts. Structural components that were endogenous to the wind TIS included policy instruments, the market arrangements and grid allocation. The thesis has shown that these internal institutions had a profound influence on the emergent RES (see Subsection 6.4.2). A notable finding in this instance was the that these indigenous internal RES institutions ultimately strengthened transnational *resource mobilisation* activities. TIS function strength was also influenced by European policy agendas and processes, which we come to next. In conclusion, the *influencing direction of the search* function was influential at national and European governance levels in several ways.

H1c: Changes in the contextual institutional environment due to market liberalisation and European policy push climate targets were sufficient for the formation of new electricity sub-sectors including the wind RES.

The analysis has shown how the influence of the *direction of the search* TIS function was a strong driver of the emergence of the Irish wind RES and the function was itself influenced though the alignment of actors and institutions at national and transnational level, and by actors in front-running innovation systems and RES. This is broadly in line with contributions which have asserted the influence of transnational institutions on technological innovation systems functions (Gosens et al., 2015). Activity and institutional alignment which constituted *influencing direction of the search* was prevalent throughout the four periods of system development both within Ireland, and in other jurisdictions and at the level of European Union governance. European Union political agendas and legislation provided forceful impetus and direction to market discontinuities and institutional turbulence and inconsistencies in Irish electricity supply sector. This was a contributing condition in the development of distributed, private sector supply of wind electricity. Europe also provided a policy 'backstop' against local political roll-back and allowed the creation of a strong 'European' narrative, effectively deployed by Irish actors. And we have discussed how important this was in the Irish context given the Department of Communications, Energy and Natural Resources had relatively little agency to drive through unilateral policies against the interests of incumbent utilities, and existed in a short term planning culture (see Subsection 6.1.3). However, these institutional contextual influences were not sufficient on their own to set the pathway direction of the RES development. Processes of liberalisation did not directly benefit actors in the wind RES, rather they created the opportunities and the contextual structure for local actors to engage and influence local regulatory change processes[5]. In addition to expected findings, we found that

[5] Furthermore the dominant model of wind generation business to develop in Ireland was a privatised,

local policy, co-produced by DCENR and interactions with sectoral actors, contributed increasingly favourable technology support instruments. In conclusion the thesis finds that institutional influence acts not only at national levels, but at European levels through global energy and environmental regulations.

H2a: Increases in legitimacy of the technology system, attained through the production of visions, policies and regulations at a national level, are powerful drivers of RES emergence

Hypothesis **2a** and **2b** are concerned with the territoriality of the influences on the emergences and development of the wind RES in new locations. The analysis has confirmed that increases in *legitimacy* of the RES at a national level are powerful drivers of virtuous cycles which strengthened the emergent wind RES (see subsections 7.3.1 and 8.1.2 and Figure 7.7). These occurred through through virtuous cycles of TIS functions driven by the mobilisation of resources and influence on the direction of the search. *Legitimation* activities such as lobbying, by firms and advocacy coalitions, demonstrably impacted the creation of market segments in the second and third periods. The co-production of policies and technology roll-out goals were in part informed by firm activity. This was important in during the early periods of RES emergence given the powerful state owned interests endorsing the status quo, post monopoly market structure. However, the legitimacy was less important during the later *stabilisation cycle* (see subsections 7.3.2 and Figure 7.11). By this stage of system development, legitimacy mattered less for market formation as the market was supported and stabilised by internal formal institutions, and continuous *resource mobilisation*. This is in line with findings in the literature, such as studies by Markard, Wirth, et al. (2016); Suurs and Hekkert (2012). The thesis concludes that the legitimacy of the Irish wind RES was formalised and embedded within national energy regulations and market structures, essentially institutionalised. Yet the while the characteristics of initial *legitimation* were highly national, this is contrast to the dual transnational/national influence on direction of the search which like legitimation activities was also significantly influenced through the production of visions supportive of the RES.

H2b: Rapid roll-out of a technology within a RES or an implementation cycle of TIS functions is preceded by a local cycle of knowledge development functions.

The review of the literature indicated that the emergence or initial take-off of a wind RES would occur in a functionally distinct period from that of acceleration (Bergek, 2002;

for-profit firm, rather than a community or co-operative model.

Suurs and Hekkert, 2012), and include significant knowledge creation or diffusion activities (Bento and Fontes, 2014). This is essentially an argument that absorptive capacity[6], that is the capabilities of firms to utilise new technologies (knowledge), must sufficiently increase before the roll-out of the new technologies might take place (see discussion, Subsection 3.1.5). This perspective on absorptive capacity is complemented by studies such as that by Kamp (2008b) who found with wind technologies it is especially important for actors to gain a lot of experience with the technology while it is in use (accumulation of tacit knowledge), due to the characteristics of the technology such as large number of material components which work under high-stress conditions However in the Irish case, we found that institutional alignment and the building of the RES institutional core through a rule-making cycle was more significant than inward flows and accumulation of knowledge vis-a-vis TIS functions (see subsections 7.3.1 and 8.1.2). Of course, this is not to say that the accumulation of knowledge did not matter. Knowledge flowed in and sometimes out of the country in early development periods through joint ventures and in overseas firms entering the RES. Yet the TIS analysis has foregrounded the role of institutions, signposting, stabilising and transmitting knowledge and de-risking investment in the wind RES (see Subsection 6.4.2). We reflect further on the role of knowledge and institutions in the thesis and theoretical framework in the next subsection.

H3: Despite the import of turnkey technologies, national innovation activities were an important factor in the rapid integration of wind technologies.

The thesis has explained how and why significant innovation took place in Ireland, in part necessitated by local context such as the small island grid, the pace of deployment and quality of capital and knowledge resources. Indeed, these innovation activities consisted of not only technological fixes, such as those addressing intermittency and constraints due to increased wind capacity, but also the institutional embedding of local visions of societal benefits of wind generation. Where there was knowledge generation in Ireland, we have shown it was pre-dominantly demand-led rather than following a linear science and technology push model initiated through the funding of original research in university labs. In other words, barriers to integration and grid optimisation drove the creation of knowledge in Irish research institutes and between these institutes and system operators.

[6] Cohen and Levinthal (1990, p. 128) defined absorptive capacity as "the ability to evaluate and utilize outside knowledge... ... largely a function of the level of prior related knowledge. ... Prior related knowledge confers an ability to recognize the value of new information, assimilate it, and apply it to commercial ends". It has been noted in the literature that the distribution of absorptive capacity is not even (Rosenberg and Steinmueller, 1988).

Several TIS functions re-produced in Ireland played an important role in contributing to these activities. These were *influencing direction of the search* , *market formation* , *resource mobilisation* , and *legitimisation* (TIS functions were mapped in Subsection 7.2.2) However, knowledge may likely play a role in direction setting and the ability to change direction. Recall in Subsection 7.1.2 we discussed how the *direction of the search* function was influenced by new actors, institutions and the mobilising of visions.

The finding that national level institutions as well as European policy institutions influence the direction of the technology has important implications for policy in two ways. First as a counter to narratives that would strip national government and government agencies of agency. This thesis demonstrates that the claim that 'Europe drives everything' is false. Second, if indeed within the Irish wind RES there does exist the (distributed) agency to set national direction, there is the ability to decide in what direction, as well as how fast. In conclusion, the thesis finds that *build-up* and *touchdown* activities of the Irish wind RES were not instigated only by uni-directional processes of learning *from* front-running nations, but through the cumulative effect of TIS functions at a national level.

8.3 Outlook

8.3.1 Contributions of the thesis

Using an innovation systems framework, this thesis has contributed an explanation for the emergence of a renewable electricity system in a new country – Ireland. It has made clear that – in the Irish case – no single actor group, institution or regulatory instrument can be apportioned sole responsibility for the emergence of the wind RES. The system functions of the TIS framework offered a firm analytical grasp when describing advances in innovative activity in Ireland. The framework supplemented explanations based on market failures and externalities and broadened the explanation for the strength, direction and pace of the emergence to include the alignment of institutions in context, the formation of actor groups and development and diffusion of knowledge. Much of the existing innovation studies literature on the emergence of innovation systems in new locations uses concepts such as 'increasing absorptive capacity' or 'better aligning institutions' for improving the likelihood of success[7] (Gosens et al., 2015). This contribution identified specific local core

[7] Indeed, 'success' itself is often implicitly taken as the development and roll-out of a specific RES, with little explicit regard for the direction of the technological pathway.

institutions, such as policy support instruments, and the cumulative and self-reinforcing cycles of innovation processes. The findings support evidence in the literature that the emergent system functions may be distributed across space, and found that not all TIS functions are required to be reproduced at a national level. And although the specific sequence and mix of functions is likely to change by country and technology system, the thesis argues that given the distribution of European Union energy policy at multiple levels, these results matter. The thesis has shown that when describing emergence in follower contexts, the TIS functions offer an alternative analytical lens when compared with factors of diffusion, technology transfer or internationalisation. As explanatory processes, the functions may be thought of as general dilemmas that occur in the emergence of renewable electricity systems everywhere. The contribution of this thesis is not to assert a specific general pattern and sequencing – although this was required to establish explanation of RES emergence in Ireland. Rather the general point to be made is that these TIS functions and cycles of TIS functions play out differently depending on context, institutions and cultures.

To this end, in Chapter 3 I discussed the growing body of literature on the distribution of innovation system functions over space and time. This thesis contributes directly to the ongoing discussion in the literature such as innovation system development in context, context fields, anchoring and nested systems (Lovio and Kivimaa, 2012; Binz, Truffer, and Coenen, 2016; Bergek, Hekkert, et al., 2014; Wieczorek et al., 2013). A major strength of this contribution is that it avoids a 'leader-follower' or 'core-periphery' story of technological diffusion or transfer. Instead, I embedded the explanatory power of the TIS framework within a custom heuristic, calibrated to assess the sometimes multi-directional flows and access to resources which are fundamental to the global proliferation of renewable electricity systems. Doing this provides analysis of sometimes strategic, opportunistic and contentious processes of institutional alignment of actors' goals and system and exogenous structure within and across jurisdictional lines. I also contribute this perspective on sequencing, a useful aspect of a process theory. The assumption in EU member state policy is that a direction is established (e.g. towards renewable energy futures) and then incentives are set through the distribution of public finances to those actors most likely to build the required infrastructure fast. However the heuristic has shown how the direction is set at multiple levels, and the support instruments, in this case the REFIT, accelerates[8]. The lesson here is that protective institutional arrangements have to be negotiated

[8]Indeed, this observation is one advantage of studying the roll-out of technologies via an innovation system lens rather than an analysis of the policy system, in that we incorporated both leading indicators

through complex political and social contexts and that the direction of emergent pathways cannot be simply downloaded from one level to another.

Two contributions arise from operationalising and testing the analytic framework. First, the *build-up* and *touchdown* heuristic was robustly tested in this thesis and is a novel, and in this case useful approach to organising the explanatory components of the TIS framework. This approach offers some promise for future research and is, I suggest, well suited to comparative case analysis where the national and transnational might be investigated in parallel. Second, in analysing the evidence, I employed a novel analytical approach, paying specific attention to the generative power of narratives and their underlying analytic stories. The narrative methods employed in the analysis was an important aspect of testing the hypotheses, particularly hypothesis H2a dealing with legitimacy and direction of the search functions. With these I showed the formation of coalitions to mobilise relevant narratives and sometimes counter-narratives, and as such, evidence of power and politics was found. For example, this has allowed me to explain that the Irish visions and policies were, in later stages, mobilised with narratives of economic performance and strategy, both prior to and after the recession[9] (e.g. through narratives such as 'keeping the lights on' and 'energy export'). This offers a fruitful direction for future research given our discussion of localised legitimacy and distributed agency within the system and may present one approach to addressing recent calls for an explicit engagement with politics, agency and structures in technological innovation systems analysis (Kern, 2015) which is elaborated upon in the next subsection.

Reflecting further on the role of knowledge in the TIS framework and building on hypothesis 2b, in a study of the roll-out of electric mini-grids in Laos, Blum et al. (2015, p. 230) suggest extending the definition of the TIS function *knowledge diffusion*, to *knowledge absorption*, defined as "all processes that influence information flows in networks, including the acquisition, assimilation (storage and distribution), transformation and exploitation of knowledge (also in terms of learning by doing, using and interacting)". There is merit to this suggestion, coming as it does from a relational geography perspective which focusses on connectivity and the impact of economic activities in specific locations. However, this thesis has contributed to this agenda by taking another approach, addressing the issue through also foregrounding of system activity and institutional context in the

(policy decisions) and lagging indicators (the construction of wind farms).

[9]This is consistent with findings in the literature which have illustrated strategies combining ecological goals – e.g. carbon dioxide reduction targets – with narratives of economic competitiveness (Hodson and Marvin, 2009; Späth and Rohracher, 2010; Hansen and Coenen, 2014).

given location, rather than by examining interconnected firm activity alone. In the case of the Irish wind RES, this was explained through the processes of a system building cycle. This is an important institutional contribution if we are to take seriously the role of the national institutional ensemble and the possibilities of political change. Furthermore, this institutional approach taken in the thesis affords us the ability to take into consideration the variations in institutional consistencies, over space and over time. Here I reflect on a point made by Bergek, Hekkert, et al. (2014) that nations may exhibit varying coherences among institutional structures, such as those proposed in the varieties of capitalism literature (Hall and Soskice, 2001). The degree of institutionalization of elements in these contexts does differ and may influence the focal RES to a stronger or lesser degree. This thesis has contributed examples of how coherences among institutional alignment varies over time as well as place[10].

8.3.2 Towards a wider agenda: politics and transitions

The story of the Irish wind sector, and the contributions offered by this thesis fit also into broader context to which I now open up. The thesis matters to scholars working on sustainability transitions and specifically technological innovation systems; the theoretical framework affords several fresh perspectives on the politics and agency of actors within innovation systems emerging in new locations. Politics is important because sustainability is a normative goal. State intervention is often considered essential, and governance reform may be prescribed as a means to achieve new social or market conditions (Meadowcroft, 2011). However, concepts of underlying power and politics have been somewhat under-theorised in TIS, despite recent contributions in the wider sustainability transitions literature[11] (Geels, 2014; Stirling, 2014). The problem with regard to innovation system policy approaches according to Flanagan et al. (2011, p. 711) is that a "normative structure assumes an underlying or achievable rationality and coherence to the 'system' as a target for policy action which is unrealistic". And yet given that in any given innovation system we are likely to encounter a diverse range of interests aligning and realigning, Landon

[10]Which as suggested in the review of the literature, and borne out by the analysis may relate to established technological directions and trajectories, commonly held beliefs, societal discourses and shared problem or policy agendas Fuenfschilling and Truffer (2013)

[11]In the construction of the TIS framework, it is likely that policy concepts were derived somewhat hastily, leading to at the very least some instances of policy-determinism, and at worst, techno-determinism. Normative aspects have not been elaborated enough, so that we as researchers sometimes fail to ask in our analysis what is sustainable in the transition, or question sustainability for whom and under what conditions.

Winner's article title from 1980 "Do artefacts have politics?" remains a relevant question. Following Winner, choice is central to processes of politics and choices of design, where implementation effects users and uses of technology (Hess, 2007). We have encountered technological choice on numerous occasions in the case and the analysis has indicated that choice, and politics, are fundamental aspects of how fast and in what direction energy systems emerge, or not.

In evolutionary ontologies such as technological innovation system framework, the processes and dynamics of politics (beyond simply policy 'making') can be conceptualised within the selection environment and are enacted through selection pressures (Negro, Alkemade, et al., 2011). But while typically institutions are viewed as the selection environment, relatively few studies have explicitly turned the analytic focus to selection processes in fast follower contexts[12]. Within the TIS framework, politics and political activities such as lobbying and public acceptance interventions are usually captured analytically under the legitimisation function[13]. Indeed, in this study I have implicitly operationalised the selection environment and selection pressures though the (contextual) institutions and functions the framework. In the case, legitimacy came about because of actors entering the RES, the formation of coalitions, lobbying and corporate political strategy activities and the reproduction of powerful system narratives. The utility of this approach was the identification of specific narratives mobilised by actors or coalitions which indicate they consider a particular TIS function to be weak. Specifically I traced analytic stories around which coalition formation took place, invariably processes of contention and coordination. In the main, these were processes of *legitimation* and *direction of the search*. This approach is generalisable, the methodology will allow analysts track closely how narratives are performed and by whom, revealing a politics of a RES. The approach may be especially useful for assessing the formation of new incumbencies, and for analysing how system actors adjust to new selection environments and pressures whether that be in new market spaces or in new institutional settings or within boundary organisations, two arenas which we have shown play a crucial role in the reproduction of system processes in new locations.

A strengthened perspective on politics – through an enhanced cognisance of the selection environment and associated selection pressures – is useful also in bringing into focus

[12]Often implicitly, TIS studies have tended to focus on processes of variation and retention and where selection has been a focus, it has been of technologies emergent from the lab or workshop. For example, in a fascinating recent paper, Kukk et al. (2016) show how single powerful actors within a TIS might significantly influence dominant institutions through processes of institutional entrepreneurship.

[13]See Bergek, Jacobsson, and Sandén (2008) for an extended discussion on processes of legitimacy and TIS.

aspects of agency, and how it relates to location and context. The thesis gave several perspectives on the role of agency, location and context regarding the politics of emerging innovation systems which are generalisable beyond the case. It showed the role location played in the co-production and institutionalisation of national policy. It showed how over-arching EU agenda have influenced the restructuring of national institutional ensembles via long-term processes of market liberalization[14] and shorter-term EC directives, ultimately reshaping the selection environment. And it showed that legitimisation processes changed significantly over time, influenced by context and endogenous system changes, but crucially, reproduced within a national context. Consider then the relationship between legitimacy and agency[15]. Agency with regard to the emergence and reproduction of RES processes in new locations is important as it is crucial to processes of legitimisation such as the creation of advocacy coalitions and the reproduction of narratives. Agency has been understood in the TIS as distributed, yet, as with perspectives on politics, it has been under-conceptualised in the literature and strategic activities towards coordination and the integration into the system of complementary actors tend to be overlooked (Musiolik, Markard, and Hekkert, 2012; Jacobsson and Jacobsson, 2014). The thesis has found the agency of system building actors to be locationally influenced, unevenly distributed throughout the system and dynamic over time.

An analytic and policy innovation resulting from early work on TIS functions was a shift from prescribing competition as a sole policy driver, to finding mutual interests around which collaborative development between actors within or between an innovation system may work together for mutually beneficial system development (Bergek, Jacobsson, and Sandén, 2008). This thesis contributes to that agenda through the consideration first of the space in which collaborative development takes place, and second, of the nature of that collaboration. The opening-up or construction of space which facilitates the formation of actor coalitions is vital. These spaces might include organisational boundary space[16] where disparate actors can come together over common issues, or markets or regulatory arenas. In this observation we go beyond considering the jurisdiction in questioning the location of

[14]Increased market liberalisation has altered innovation processes in the field of electricity supply (Markard and Truffer, 2006), primarily because the selection environment has changed in and around the regulator, influencing the *direction of the search* for new (renewable) energy technologies and ultimately the emergence of the new technological system.

[15]Where agency is the realisation of the capacity of actors to translate their potential for action into practice (Scott, 2006).

[16]See for example the work by scholors of Science and Technology Studies on boundary organisations (Cash, 2001; Guston, 2001).

the selection environment and selection pressures. This work then might provide a guide to asking where the selection of future energy pathways takes place, and how locational context might influence the reproduction of system processes and the ensuing direction of the technology. This has important implications for governments and other actors who may want to promote, accelerate or steer the direction of transitions towards sustainable energy systems. Crucially actors may cross national boundaries. Overseas actors can influence the institutional arrangement abroad, as well as in the host jurisdiction. Finally, this line of thought on legitimacy, politics, context and location might justify future work bringing to bear explicitly relational approaches of inquiry on issues of system agency[17]. This is also an important policy consideration I will address next.

8.3.3 Policy recommendations

The empirical findings in this study contribute a new explanation of how and why the Irish wind electricity system has emerged and developed in the manner it has. While these research findings are most directly relevant to innovation studies scholars, they also matter to those working on European and specifically Irish energy matters. The thesis has contributed a systemic, socio-technical history of a small island grid system, and its integration of a high percentage of intermittent electricity generation. The findings go someway to addressing two narratives found amongst actors in the system, that through policy push processes 'Europe drives everything', and that the development of wind can be explained through the distribution of subsidy, specifically the REFIT. Both of these rationales are partial, they tell only part of the story, a story which has been elaborated significantly in this thesis.

This thesis makes policy recommendations on a 'systemic failure' basis. In other words, I argue that government intervention in the energy sector is justified based on the analysis and diagnosis of system failures (and successes) observed in the study. To be clear, in Section 1.2 the thesis rejected market failure based interventions on the basis that neoclassical theory does not adequately consider the complex evolutionary character

[17] Whilst beyond the remit of this thesis, Garud and Gehman (2012) offer a promising exploration along this line of thought on which to end in order to discuss agency further. The authors explain selection environments by contrasting to relational perspectives and mobilise Actor Network Theory; "whereas the evolutionary perspective considers agency as determined by prior events, selection environments as given, and the criteria for success as unequivocal, the relational perspective draws attention to the many ways in which agency is distributed, selection environments are molded, and evaluation criteria are equivocal" (Garud and Gehman, 2012, p. 984).

of innovation, and therefore provides an insufficient basis on which to make innovation policy. The thesis then made the case that nationally mobilised innovation processes are vital for the emergence of a renewable electricity system. Furthermore, the thesis aligns with previous findings in the literature and suggests that the problems associated with market failure, such as societally unacceptable greenhouse gas emissions, cannot be fixed through the simplistic heuristic of 'getting the price (incentives) right'. Indeed, a general recommendation I make is the promotion of systemic failure frameworks in the ongoing and future analysis of renewable energy policy implementation and decision making.

More specifically, the findings presented have a number of practical implications for those who seek to make and influence the making of energy policy. I have found the building-up aspects of a renewable electricity system in a new location requires the promotion of other localised innovation-related activities. Perhaps most obviously from the perspective of policy makers in the host nation, this calls for specialisation in a global innovation system which should be chosen to best match indigenous capabilities or resource endowments. The contribution of Ireland's power systems researchers is notable in this regard. Furthermore, strategic focus should be placed not only on funding the generation technology needed to meet CO_2 reduction targets, but rather on systemic blockages and drivers, of the type indicated in this thesis. This process approach has serious implications for policy frameworks; it suggests that in addition to creating price incentives to buy and build turnkey plant, policy frameworks should focus on instigating and influencing innovation processes in a dynamic and reflexive manner. Dynamic and reflexive approaches are particularly important when rolling-out emerging technology, in uncertain conditions, where future societal needs and returns on investment are unknown. In the Irish case, the thesis has discussed how economic conditions and improvements in globally produced turnkey technology have altered the fundamental structure under which investment decisions are made. It makes sense then that the structuring of incentives and rents should be appropriately flexible.

The thesis found that development of a renewable electricity system in new locations is simultaneously strongly influenced by transnational aspects of system actors relations, regulatory regimes both national and transnational, and local context such as culture and other 'soft' institutions. In other words, the actors, institutions and resources which influence the direction of development at a national level are distributed across jurisdictional boundaries, across sectors and policy domains, and what is more, are likely to fluctuate over time. This presents both risk and opportunity to those with vested interests in the emergence of a local renewable electricity system. The case illustrated how local conditions opened up and closed down opportunities for overseas players in the Irish market, and furthermore, the thesis showed that these transnational linkages were not stable over time. Indeed, generally these opportunities may be influenced by intentional strategies of some actors. The opportunity then is for policy makers at national level to make interventions not only at national level, but to engage across borders and sectors. However, the thesis found that transnational linkages are not necessarily aligned to benefit the local emergent system or actors indicating that we should not expect benefits and gains to be evenly distributed. In an open market economy, shifts in the balance between national innovation processes to processes and firms from overseas may lead to crowding-out of local firms. This has serious implications for the distribution of benefits after the fact, all the more so given the position that typically 70% of capital expenditure on wind developments is exported, a situation that is likely to be prevalent in many follower situations given the concentration of turbine research, design and manufacturing in Germany, Denmark, China and the United States. Indeed, whilst certainly some Irish investors have benefited from access to international markets though returns on investments abroad, it is clear from the evidence that the trend over the final period of development analysed is that of increased overseas investment in Ireland relative to indigenous financing.

Two questions arise from these findings, generally relevant to policy aimed at promoting the emergence of renewable electricity systems in new locations. First, how should policy makers at national level, design, incentivise or steer the emergence of new renewable energy systems? Second, what is the role of the state in these processes? In addressing the first question I will use the concept of the *direction* of the technological pathway emerging in a given new location[18]. For example, the provision of renewable electricity is a clear deviation in direction from fossil-fuel based incumbent electricity systems. Often the roll-out of renewables are framed around narratives of speed, such as how fast can systems be decarbonised, backgrounding notions of direction. Direction matters because it shapes the distribution of benefits; certain actor-groups and places gain or lose through lock-in

[18]We can explain different courses or deviations from a global technological pathway in terms of direction. Discussions of the direction of technological change have been a feature of innovation debates for decades (Dosi, 1982). National Systems of Innovation scholars looked towards national institutions, their incentive structures and their competencies to determine the rate and direction of change generating activities in a country (Patel and Pavitt, 1994). Bell and Pavitt and later Bell (2009) highlighted the role of learning and capability building in technology transfer. More recently, there have been calls to integrate perspectives on direction into theories of socio-technical transitions and transformations (Stirling, 2009; del Río González, 2009).

to dominant pathways and because alternative pathways, which meet different needs, may be obscured (Ely and Bell, 2009). So influencing the direction of emergent technological system is a crucial role for government to play, all the more-so given the provision of public subsidy to support the players in emergent renewable electricity markets. In Ireland, in addition to the provision of subsidy, the government used evidence of distributed system activity to its advantage, it co-produced policies with industry actors, and crucially it established state-level boundary organisations and spaces such as new regulatory environments which influenced both the institutional structure and actor relations within the renewable electricity system. These were processes which facilitated activity of certain indigenous and overseas firms and created momentum within and expanding RES shaping markets and other structural features of the RES in specific directions.

Thus we see in the Irish case, strong evidence that the state not only influenced the emergence of a wind RES through subsidy, but also steered the development of the subsequent technological pathway.

What then might we generalise from the Irish experience of the steering of an emerging renewable electricity system? First, direction-setting by government is highly relevant in a liberalised energy market such as an EU member state, where state-aid rules and an overarching liberalisation agenda preclude against a government 'picking winners' and where regulatory and infrastructure decisions may be devolved from departmental responsibilities. The careful consideration of strategies of direction-setting can serve to address potential constrictions of agency at a national level. We have seen that policy actors play an important role in constructing the selection environment for new technological systems, and shaping selection pressures. Thus 'boundary work' is important, where rather than pushing the state's duties into the private sphere, spaces and processes are co-produced by the state and other actors to bring together diverse actors, interests and problem agendas. Following the establishment of such organisations and institutional settings, the state has a further responsibility in ensuring that they remain free from capture by powerful interests such as new incumbents. These considerations are generally and specifically relevant in liberal or non well-planned economies – for example in southern Europe or outside the EU – where central planning is not a feature of government or industrial culture.

Second, often direction is considered in relation to large shifts in technological pathways, for example from fossil fuel based technology systems to renewables[19]. However, in a fast-follower context we can expect to encounter a nuanced steering. The direction of

[19] Again, following from the work by Dosi (1982) on technological paradigms.

progress is not necessarily orientated between material technology alternatives (e.g. fossil fuel production vs renewables). Rather, the Irish case has provided an example of orientations which incorporate systemic and structural features. To be clear, direction then may be assessed against choices between alternative logics in the setting of market rules, regulatory environments, the distribution of costs, or the selection of which actor-groups are positioned to accrue benefits or realise opportunities. Thus we see that steering by government is not only accomplished by creating demand through the provision of incentives.

Third, the findings in this thesis may guide future policy interventions in the consideration of who gets to steer emerging electricity systems. Variously these choices might include civil society actors and publics, 'packs' of entrepreneurs, incumbent generators and system operators, and indeed the state itself. Crucially, we have seen that with regard to the reproduction of system processes in a new location, the role of transnational actors is vital, particularly in relation to knowledge creation and diffusion, learning and access to resources. Again, policy makers might consider how they can influence spaces in which these actors might interact – for example at industry events, within stakeholder associations, within institutional setting, within learning networks – and the conditions under which transnational relations might be formed or influenced. A strategy the state may usefully employ here is that of being attentive to the narratives which are reproduced as part of these processes. Early in the reproduction of a renewable electricity system in a new location, proponents might make an effort to shape expectations and normative legitimacy by mobilising narratives that deliberately 1) avoid technical specifications, which may be defeated by counter-narratives of technical impossibility; 2) incorporate sub-narratives which embed their stories in new locations; 3) evolve narratives to changing contextual selection criteria – often related to the macro economy. The state might seek at regular intervals to identify and test such narratives and furthermore, identify which actors are included and excluded from the making of such narratives. By doing so, the state might usefully attend to the danger that promises of societal benefits, strategically embedded in the narratives of national energy futures – narratives we have encountered in this thesis – are not, or will not be met. Indeed future research might usefully compare the expectations of technological emergence promised within such narratives, with progress attained, both in terms of speed, and crucially direction. Collectively, these perspectives indicate the state has an important role in steering the direction of technological emergence.

In summary then, the thesis has shown that as renewable energy technologies such as onshore wind emerge at utility scale in new locations, a wide range of actors have the opportunity to influence what kind or electricity system is appropriate, not merely how fast existing systems are decarbonised. The analytic approach offers a framework with which to address systemic electricity system issues on the one hand, and through narrative analysis, incorporate an understanding of actors, their collective actions and the innovation processes they reproduce. Policy makers, firms and actors in wider publics have contributed at times to a rapid and impressive emergence of a new wind RES in Ireland. Innovation was systemically driven towards meeting the needs of commercial actors – both indigenous and those from overseas – while there was a negligible role afforded to electricity consumers in addressing system needs. Indeed there continues to be an implicit assumption that centralised wholesaling and distribution of electricity is cheaper because of economics of scale[20]. The case presents a useful example for researchers and policy makers who seek to reproduce innovation processes at other sites and locations, be they in support of wind or other renewable energy technologies.

Furthermore, maintaining a reflexive position with regard to research and policy assessments is an important societal issue as we attempt to transition and transform our energy infrastructures, processes which involve large costs and disrupt and reproduce powerful incumbent interests. Success in this regard should rightly be celebrated.

Yet success must be judged with regard to diverse interests in many locations who have promoted and borne the costs of renewable electricity systems. Success therefore is unlikely to be attained through a linear race-like evaluation measured simply by units of energy production deployed. In this regard, the innovation system approach utilised in this thesis can contribute toward an assessment of progress.

[20] A point discussed in Subsection 2.4 and made by Foley, Ó Gallachóir, et al. (2013)

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Appendix A

Media sources for narrative data

Ref	Headline	Publication	Date
S4-118	Islanders are forced to defer the great switch on	The Irish Times	18/02/1987
S4-6	Mayo wind farm links up with the ESB	The Irish Times	24/11/1990
S1-420	Danes in Irish wind farm scheme	FT Energy Newsletters	03/05/1991
S1-419	EC-backed windmill project close to collapse	FT Energy Newsletters	04/07/1991
S1-418	Ireland favours greater integration of Community energy policies	FT Energy Newsletters	16/08/1991
S1-416	Regional programme to share Ecu400m for local energy draws to a close	FT Energy Newsletters	13/09/1991
S1-415	Irish wind farm to take off in 1992	FT Energy Newsletters	26/09/1991
S1-414	News: Power plant plans	FT Energy Newsletters	31/10/1991
S1-413	Publications Review: EC's energy aid & lending facilities:É	FT Energy Newsletters	17/01/1992
S1-409	Private wind farm planned	FT Energy Newsletters	10/04/1992
S4-61	Grants for energy savers	The Irish Times	29/07/1992
S1-406	Wind farm on Kilronan mountain	FT Energy Newsletters	14/08/1992
S4-178	Wind of change to a greener way of life	The Irish Times	20/08/1992
S1-405	Commission analysis suggests 1988 guidelines need developing	FT Energy Newsletters	11/09/1992
S1-404	Cape Clear wind project problems	FT Energy Newsletters	25/09/1992
S1-403	Ireland's first wind firm coming on line	FT Energy Newsletters	09/10/1992
S1-402	Wind power promise for Ireland as 6.5 MW farm comes on line	FT Energy Newsletters	16/10/1992
S1-400	Wind on Rathlin	FT Energy Newsletters	23/10/1992
S4-6	Mayo wind farm links up with the ESB	The Irish Times	24/11/1992
S1-399	First Irish wind farm under way	FT Energy Newsletters	27/11/1992
S1-397	Position changes on windpower	FT Energy Newsletters	12/02/1993
S1-395	Electricity generating venture capital	FT Energy Newsletters	07/05/1993
S1-393	Wind farm planned for county Kerry	FT Energy Newsletters	16/07/1993
S4-88	ELECTRICITY FOR DONEGAL	The Irish Times	20/07/1993
S1-389	High hopes for Thermies results	FT Energy Newsletters	04/08/1993
S1-388	Vestas takes stake in Irish wind farm	FT Energy Newsletters	13/08/1993
S1-385	Energy Market Report: Electricity	FT Energy Newsletters	01/09/1993

S1-384	New electricity legislation	FT Energy Newsletters	10/09/1993
S4-45	WINDMILLS, NOT SHEEP	The Irish Times	05/10/1993
S1-382	Proposal by Vestas to build windfarm on Mt Eagle	FT Energy Newsletters	22/10/1993
S1-381	Windfarm in county Kerry	FT Energy Newsletters	17/12/1993
S3-162	IRISH WIND ENERGY	The Irish Times	06/01/1994
S4-55	Danes smell money on the wind after government energy rethink	The Irish Times	07/02/1994
S1-378	Energy Market Report: Electricity	FT Energy Newsletters	01/04/1994
S3-161	Minister announces alternative energy scheme	The Irish Times	13/04/1994
S4-100	Minister announces alternative energy scheme	The Irish Times	13/04/1994
S1-376	Irish power interests eye BG's proposed sub-sea gas pipeline	FT Energy Newsletters	21/04/1994
S1-375	Ireland to encourage development of renewables	FT Energy Newsletters	22/04/1994
S1-374	Total electricity production by the EU	FT Energy Newsletters	06/05/1994
S4-33	Wind farm gets planning permission	The Irish Times	18/05/1994
S1-373	Renewables	FT Energy Newsletters	03/06/1994
S1-372	Grants for renewable generating proposals	FT Energy Newsletters	15/07/1994
S4-38	Permit for wind powered electricity farm may face constitutional test	The Irish Times	04/08/1994
S4-5	CO KERRY WIND FARM	The Irish Times	10/08/1994
S1-370	Wind farm joint venture	FT Energy Newsletters	12/08/1994
S1-369	Wind farm being built in county Kerry	FT Energy Newsletters	26/08/1994
S1-367	Interconnector between Republic and Northern Ireland could be restored	FT Energy Newsletters	09/09/1994
S4-13	Wind farms "benefit to rural areas"	The Irish Times	27/09/1994
S4-135	Ireland fails to promote a scientific culture	The Irish Times	04/11/1994
S1-365	Irish Wind Energy Association critical of the ESB	FT Energy Newsletters	18/11/1994
S4-22	34 alternative energy sources selected for ESB	The Irish Times	08/03/1995
S1-360	Results of Ireland's alternative energy requirement tender	FT Energy Newsletters	10/03/1995
S4-19	Tipperary wind farm contract	The Irish Times	22/03/1995
S1-359	News: Planned wind farm in county Donegal	FT Energy Newsletters	07/04/1995
S4-105	Number of wind-energy projects to doubleÉ	The Irish Times	27/04/1995
S1-357	Nordtank sells sare in Bellacorrick windfarm	FT Energy Newsletters	05/05/1995
S4-4	Institute issues guidelines for siting of wind farms	The Irish Times	31/05/1995
S1-353	Wind power making an impact in Spain	FT Energy Newsletters	02/06/1995
S1-352	News: Alternative energy development an embarrassment	FT Energy Newsletters	23/06/1995
S4-35	Priest's charity highlights changing times	The Irish Times	14/08/1995
S4-8	North's first wind farms opened	The Irish Times	15/08/1995
S1-350	MEPs investigate cuts in renewable R&D funds	FT Energy Newsletters	22/09/1995
S4-30	Tipperary groups to campaign against scheme É	The Irish Times	27/09/1995
S4-44	Countryside groups vow to foster mutual trust	The Irish Times	16/10/1995
S4-53	CONCRETE ACHIEVER From a small farm in Co Fermanagh É	The Irish Times	20/10/1995
S4-32	ENERGY FROM WIND HAS ITS SNAGS, TOO	The Irish Times	30/10/1995
S4-71	Donegal may get Pounds 13m 'windfarm'	The Irish Times	09/02/1996
S4-109	Blow for clean energy at Donegal wind conference	The Irish Times	20/04/1996
S1-345	EIRE'S EUROPEAT PROGRESSES	FT Energy Newsletters	30/04/1996

S1-344	Diversification by Danish electricity market	FT Energy Newsletters	31/05/1996
S1-343	Publications Review: European Union: Renewables report	FT Energy Newsletters	14/06/1996
S1-341	EIB lending boosts energy projects	FT Energy Newsletters	12/07/1996
S4-372	Howth group tells developers to "back off" East Mountain	The Irish Times	15/07/1996
S4-69	UK may get first offshore windfarm	The Irish Times	15/08/1996
S4-134	700 new jobs in prospect over five year period	The Irish Times	01/10/1996
S4-11	Winds of change blow powerfully	Belfast Telegraph	08/10/1996
S1-338	MEPs clear new TENs projects as Maghreb-Europe gas pipe opens	FT Energy Newsletters	15/11/1996
S1-337	TENS	FT Energy Newsletters	13/12/1996
S3-160	ENERGY FROM WIND	The Irish Times	06/01/1997
S4-25	ENERGY FROM WIND	The Irish Times	06/01/1997
S4-76	USING THE MUSIC OF THE WIND	The Irish Times	12/02/1997
S1-335	EU countries agree to cut emissions by an average 10% by 2010	FT Energy Newsletters	14/03/1997
S1-332	Ireland/Companies-Power Generation - Ex peat boss mulls gas power	FT Energy Newsletters	04/04/1997
S1-331	New Irish power company planned by former peat company head	FT Energy Newsletters	11/04/1997
S4-57	Stagg ticks off wind energy experts for ignoring scheme	The Irish Times	14/04/1997
S4-216	15 companies interested in new peat plant	The Irish Times	21/04/1997
S4-51	Larne firm scoops windfarm contracts	Belfast Telegraph	22/04/1997
S4-29	Donegal wind farm will give power to 100,000	The Irish Times	10/05/1997
S1-329	EUROPEAT INTEREST HOTS UP	FT Energy Newsletters	27/05/1997
S4-24	Donegal wind farm opened	The Irish Times	20/06/1997
S1-326	ENVIRONMENT: IRELAND	FT Energy Newsletters	18/07/1997
S1-325	ELECTRICITY SUPPLY BOARD	FT Energy Newsletters	23/07/1997
S4-23	Residents oppose wind farm plan	The Irish Times	20/08/1997
S3-159	State urged to double power from renewable energy sources É	The Irish Times	07/10/1997
S4-14	Wind turbines' environmental effect defended	The Irish Times	07/10/1997
S4-52	State urged to double power from renewable energy sources É	The Irish Times	07/10/1997
S4-158	McKenna calls for binding agreement to cut greenhouse gas emissions	The Irish Times	02/12/1997
S3-158	Welcome for tax reliefs on energy	The Irish Times	04/12/1997
S4-10	Firms compete for wind farm franchises	The Irish Times	30/12/1997
S1-321	LINKOHR'S RENEWABLES VISION É	FT Energy Newsletters	01/01/1998
S4-68	High winds will be welcome down at the farm	The Irish Times	05/01/1998
S1-320	NORD NA MONA GETS MORE CASH	FT Energy Newsletters	30/01/1998
S4-127	French greens warn on use of incineration Environmentalist points to lesson in closure of incinerators servicing Lille	The Irish Times	04/02/1998
S1-317	IRISH WINDPOWER PROJECTS INSPIRE INTEREST	FT Energy Newsletters	27/02/1998
S4-7	West Clare residents oppose wind farm	The Irish Times	09/03/1998

S4-15	Windmills as high as Liberty Hall opposed on south coast	The Irish Times	25/03/1998
S4-41	ESB faces new controversy over plan for wind farm at Carnsore site	The Irish Times	26/03/1998
S4-49	Renewable energy plan needs (pounds) 160m	The Irish Times	09/04/1998
S4-54	Restaurateur's wind-farm project could light up Tralee	The Irish Times	05/05/1998
S4-9	Minister opens wind farm	The Irish Times	16/05/1998
S4-1	Turn aside the winds of change Renewable energyÉ	The Irish Times	02/06/1998
S1-315	RENEWABLES: IRELAND	FT Energy Newsletters	05/06/1998
S4-48	Wind energy is passing the test Wind is a proven,É	The Irish Times	11/06/1998
S4-2	No Future For Wind Farms	The Irish Times	22/06/1998
S1-312	EUROPE LEADS THE WAY IN WIND GENERATION	FT Energy Newsletters	31/07/1998
S4-79	ESB boosts power	The Irish Times	10/08/1998
S1-311	ENERGY EFFICIENCY - EUROPEAN UNION	FT Energy Newsletters	31/08/1998
S1-309	COMMISSION TO PROPOSE 'CONVERGENCE' É	FT Energy Newsletters	01/10/1998
S4-16	Supporter of wind power site in Galway switches to opposition	The Irish Times	16/11/1998
S1-306	UNITED IRELAND INITIATIVE TO HARNESS OFFSHORE WIND	FT Energy Newsletters	27/11/1998
S1-304	WIND COULD SOLVE ELECTICITY SUPPLY CRISIS	FT Energy Newsletters	11/12/1998
S1-305	IRISH PROJECTS SUPPORTED BY THERMIE ROUND	FT Energy Newsletters	11/12/1998
S4-36	Animal Act does not meet EU standards, Commission warns	The Irish Times	21/12/1998
S4-28	Wind Power	The Irish Times	05/01/1999
S1-300	THE EU'S YOUNG POWER MARKET - A BIRD'S EYE VIEW	FT Energy Newsletters	01/02/1999
S4-20	Group plans wind powered project on the Kish bank	The Irish Times	09/03/1999
S4-34	Group may build wind farm on Kish bank	The Irish Times	09/03/1999
S1-298	250MW OFFSHORE WINDFARM PLANNED IN IRELAND:É	FT Energy Newsletters	12/03/1999
S1-297	SAORGUS PROPOSES OFFSHORE IRISH WIND PARK	FT Energy Newsletters	01/04/1999
S4-50	Galway's first wind farm opened and blessed on windswept Connemara bog	The Irish Times	07/04/1999
S4-42	Kerry wind farm investors first to avail of tax relief	The Irish Times	16/04/1999
S3-157	Call for wind energy	The Irish Times	17/04/1999
S1-295	EU BACKS UK-STYLE RENEWABLES SUPPORT	FT Energy Newsletters	26/04/1999
S4-37	Treasury plans (pounds) 50m electricity investment	The Irish Times	08/05/1999
S4-182	Competitors clash over Bill	The Irish Times	14/05/1999
S4-21	Wind farm groups accused of distortion	The Irish Times	14/05/1999
S1-294	TREASURY HOLDINGS TO BECOME MAJOR É	FT Energy Newsletters	21/05/1999
S1-293	CHP DEBATE HEATS UP	FT Energy Newsletters	01/06/1999
S4-131	Business On Television	The Irish Times	02/07/1999
S1-292	PARLIAMENT RULES CHP IS NON-RENEWABLE	FT Energy Newsletters	02/07/1999
S4-46	Project on wind energy with NI	The Irish Times	14/07/1999

S4-31	YARD SIGNS POUNDS 200M WIND POWER DEAL	Belfast News Letter	15/07/1999
S4-72	Woods sees bright future for energy from waves	The Irish Times	15/07/1999
S4-3	Proposal for Co Clare wind farm is rejected by An Bord Pleanala	The Irish Times	04/08/1999
S4-26	Wind Farms In The West	The Irish Times	10/08/1999
S4-143	Energy agency supports proposed Aran windfarm	The Irish Times	16/08/1999
S4-17	Debate On Wind-Farms	The Irish Times	16/08/1999
S4-59	Development plan for Co Donegal runs into trouble	The Irish Times	20/08/1999
S1-288	The dash for gas in Dublin	FT Energy Newsletters	13/09/1999
S4-58	ESB bill 'tariff' set to boost renewable energy É	The Irish Times	24/09/1999
S4-27	(pounds) 200m wind farm plan for Kish Bank	The Irish Times	20/12/1999
S1-284	IRISH PROJECTS MOVE FORWARD	FT Energy Newsletters	01/02/2000
S1-283	INDEPENDENT POWER EXCHANGE LAUNCHESÉ	FT Energy Newsletters	24/02/2000
S1-281	POINTS EUROPE	FT Energy Newsletters	01/04/2000
S1-277	IRISH PLANNING BOARD FAVOURS SMALL WIND FARMS	FT Energy Newsletters	07/04/2000
S1-278	EIRTRICITY SECURES EURO 1.27M IN POWER CONTRACTS	FT Energy Newsletters	07/04/2000
S1-279	ESB WILL IMPORT POWER FROM NORTHERN IRELAND É	FT Energy Newsletters	07/04/2000
S1-276	NEW WIND ENERGY BRAND LAUNCHED ON IRISH MARKET	FT Energy Newsletters	21/04/2000
S1-275	Germany Electricity - HEW clinches second emissions trading deal	FT Energy Newsletters	17/11/2000
S1-273	Ireland Renewables - New 'breed' of windfarms helps Republic meet Kyoto targets	FT Energy Newsletters	15/12/2000
S3-156	Objectors welcome council decision to refuse planning É	The Irish Times	29/12/2000
S1-270	Ireland: New wind farm helps Republic meet Kyoto targets	FT Energy Newsletters	05/01/2001
S1-271	Clare maintains stance against wind power	FT Energy Newsletters	05/01/2001
S1-268	Ireland: Eirtricity applies for first offshore wind farm	FT Energy Newsletters	12/01/2001
S1-266	eirtricity: orchestrating change	FT Energy Newsletters	26/01/2001
S1-263	Ireland: Projects awarded EU funding	FT Energy Newsletters	31/01/2001
S1-264	Ireland: Eirtricity applies for offshore	FT Energy Newsletters	31/01/2001
S1-265	Farm planned for Tipperary	FT Energy Newsletters	31/01/2001
S1-258	Vestas and NEG Micon gear up for explosive 2001	FT Energy Newsletters	02/04/2001
S1-260	Ireland - ESB plans farm at Moneypoint	FT Energy Newsletters	02/04/2001
S1-261	Clare farm given green light	FT Energy Newsletters	02/04/2001
S1-255	Ireland: Eirtricity advises customers to return to ESB	FT Energy Newsletters	01/05/2001
S1-256	Ireland: Kish Bank wind farm gets closer	FT Energy Newsletters	01/05/2001
S6-6	Government Gives Green Light to World's Biggest Wind Farm	IHS Global Insight	15/01/2002
S3-154	Stirring up a storm off shore É	The Irish Times	29/01/2002
S3-153	Donegal council prepares to decide on EUR63m project for three more wind farms	The Irish Times	08/02/2002
S3-152	Wind lobby warns on energy target	The Irish Times	04/10/2002

S3-151	Warning on wind energy shortfall	The Irish Times	11/10/2002
S3-150	Wind industry criticises Budget	The Irish Times	11/12/2002
S3-149	Green energy contracts to ESB understated The Irish Times	The Irish Times	12/07/2003
S3-147	Jobs & E2bn industry at risk - Government told by IWEA;É	Sunday Tribune	27/07/2003
S3-146	Mayo council gives go-ahead to wind farm The Irish Times	The Irish Times	31/07/2003
S3-145	IWEA Continuing to Promote Wind Energy;	Wind Energy Sunday Tribune	05/10/2003
S6-5	Eirgrid Temporarily Bans Wind Power Plant Connection to National Grid	IHS Global Insight	05/01/2004
S1-253	Show me the money: new pledges made to finance renewable É	Platts Renewable Energy Report	01/07/2004
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