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[THE DIFFUSION OF RENEWABLE ENERGY TECHNOLOGY - INTERACTIONS BETWEEN UTILITY STRATEGIES AND THE INSTITUTIONAL ENVIRONMENT]

By

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DECLARATION OF OWN WORK

I declare that this thesis

['THE DIFFUSION OF RENEWABLE ENERGY TECHNOLOGY - INTERACTIONS BETWEEN UTILITY STRATEGIES AND THE INSTITUTIONAL ENVIRONMENT']

is entirely my own work and that where any material could be construed as the work of others, it is fully cited and referenced and/or with appropriate acknowledgement given.

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ABSTRACT

This research is concerned with the role of incumbent electric utility companies in the diffusion of renewable energy technologies (RETs). The process of technology diffusion is studied from a co-evolutionary perspective, analysing not only the development of technological artefacts as such, but their interactions with supporting institutions and organizations. The specific focus of this research is on the different strategies of incumbent utilities to cope with the introduction of RETs and associated institutional and policy changes.

This thesis aims to make both a theoretical and an empirical contribution to the literature. Firstly, on a theoretical level, it extends the existing 'systems of innovation' framework by explicitly including the notion of corporate strategy. This addresses recent contributions in the innovation systems literature that criticized these approaches for neglecting individual agency, overly relying on structuralist and functionalist explanations of individual behaviour, providing a quasi-deterministic narrative for systems dynamics.

Secondly, on the empirical side, it applies this extended analytical framework to generate new insights into the behaviour of incumbent utility companies in the context of the introduction of RETs. Using a case study approach based on desk-based research and a series of semi-structured interviews, it compares the systemic environment in the electricity industry in three countries - the UK, Germany and Spain. It analyses the strategies of the incumbent firms and their dynamic interactions over time with the institutional and policy environment in shaping the particular diffusion path of RETs, both on a firm- and an industry-level.

While Spain combines high levels of wind power diffusion at the country level with high levels of involvement of the incumbent utilities, Germany exhibits high-levels of wind power diffusion with only marginal involvement of the incumbent utilities. Finally, the UK shows low levels of wind power diffusion, with a high level of involvement of the utilities. This is explained by the differential interaction of company strategy and institutional change in each of these countries, which affected the co-evolutionary pathway of wind power.

In conclusion, the thesis provides some recommendations for policy-making from the case studies and argues for the integration of individual agency into systemic innovation approaches.

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Glossary

CCGT	Combined-Cycle Gas Turbine
CO2	Carbon Dioxide
CPA	Corporate Political Activity
CTC	Competition-Transition Cost (Spain)
DTI	Department of Trade and Industry (now the Department for Business, Enterprise and Regulatory Reform)
EBIT	Earnings before Interest and Taxes; 'operational income'
FFL	Fossil-Fuel Levy (UK)
EC	European Commission
EU	European Union
FIL	Feed-in Law
GW	Giga Watt (1 GW = 1,000 →MW)
HHI	Herfindahl-Hirschman Index
IEA	International Energy Agency)
kW	kilo-Watt (1 kW = 0.001 →MW)
kWh	kilo-Watt hour
LUC	Levelized Unit Cost
MMC	Monopolies and Mergers Commission
MW	Mega-Watt (1 MW = 1,000 →kW)
NETA	New Electricity Trading Arrangement
NFFO	Non-fossil Fuel Obligation
NGC	National Grid Company
NIMBY	'not-in-my-backyard'
NWP	National Windpower
Offer	Office of the Electricity Regulator
Ofgem	Office of the Gas and Electricity Regulator
PPA	Power-Purchasing Agreement
R&D	Research and Development
RECs	Regional Electricity Companies
REE	Red Electrica de España (Spain)
RETs	Renewable Energy Technologies
RO	Renewables Obligation

ROC	Renewables Obligation Certificate
TIS	Technological Innovation System
TPA	Third-Party Access
TWh	Terra Watt hour (1TWh =1,000 Giga Watt hours (GWh))
UK	United Kingdom

1. Introduction

In early 1998, the head of policy for one of Germany's largest electric utility companies commented on the country's emerging wind power sector "we will do everything possible to stop it" (Windpower Monthly 1998). At the same time, National Wind Power, the wind development company owned by the UK's largest utility company, National Power, consolidated its position as the country's largest wind energy company, managing one third of the UK's installed capacity. Meanwhile, Iberdrola, Spain's second largest electric utility company, announced its largest ever investment programme for wind power totalling almost €1bn over three years.

As these brief examples suggest, utility companies in different parts of Europe have historically taken very different approaches when developing their wind power strategy. While some companies saw this technology as a threat to their existing business, others have actively embraced it, albeit for differing reasons. It is the aim of this study to shed more light on these different developments and to explore the reasons behind them. There is both an empirical and a theoretical motivation for this topic. Empirically, as introduced above, this thesis is concerned with the role of incumbent electric utility companies in the diffusion of renewable energy technologies, with a particular focus on wind power. Theoretically, the aim is to fill a gap in existing systemic innovation approaches by considering specifically the scope for differential individual agency within wider systemic changes. Both motivations will be explained in sections 1.1 and 1.2 of this introduction. Subsequently, the aims and objectives for this thesis will be outlined in section 1.3. Section 1.4 gives an overview of the methodology and intended outcomes of the research before section 1.5 provides a chapter outline. Finally, section 1.6 concludes the chapter.

1.1. Empirical Motivation

Contributions both in the academic literature and in policy documents have argued for an energy system transformation to ensure its long-run sustainability. This concerns at least two issues: Climate change and security of energy supply.

Regarding the former, the United Kingdom (UK) Treasury Stern Review of the economics of climate change (Stern 2006) has argued that the benefits of acting early to reduce greenhouse gas emissions, for example through new technologies and efficiency measures, outweigh the likely future costs of inaction. Similarly, the International Energy Agency's (IEA) World Energy Outlook (IEA 2007) predicts an unsustainable increase of carbon dioxide (CO_2) emissions in its business-as-usual scenario, which continues to be dominated by coal, natural gas and oil. Resource assessments have suggested that technically and economically available renewable energy resources are plentiful enough to serve the entire energy needs of the global human population (Scheer 2002;WBGU 2004).

With regard to energy supply security, a Green Paper of the European Union (EU) Commission points out that more than 70% of all energy needs might have to be imported into the EU by 2030 (European Commission 2002). By 1999, over two thirds of the EU's natural gas imports came from just two countries – Russia and Algeria (European Commission 2002). In this context, renewable energies are considered as a domestic supply source that could mitigate fuel import dependency (DTI 2007:143ff).

Governments have responded to this situation with a variety of policy initiatives. The EU issued a 2001 directive on renewable energy, with targets for an increased electricity production from renewable sources in each member country (European Commission 2001). This policy was recently updated with a new proposed directive that re-emphasised the need for an increasing contribution of renewable energy sources to total energy demand and included specific objectives for biofuels and renewable energy for heat generation (European

Commission 2008). The UK government's own 2007 Energy White Paper (DTI 2007) proposes an increase in the electricity supply from renewable energy sources to 20% in 2020. Similar initiatives have been initiated in other European countries, such as the German Renewable Energy Act (as updated in 2004) or the Spanish Plan on Renewable Energy (2004) (Reiche 2005).

Renewable energy technologies (RETs) are characterized as being structurally 'disruptive' and radical (Tsoutsos & Stamboulis 2005;Foxon et al. 2005) to conventional generation technologies, which makes the task of RET deployment a matter that goes beyond simple 'technology substitution'. Rather, they pose challenges to the established electricity system as a whole at various levels, from organizational structures, market institutions to grid operations (Markard & Truffer 2006).

In this context, the role of incumbent utility companies, which own large parts of the electricity supply structure in many European countries (European Commission 2005a), is of critical importance. In recent policy discussions, the market power of incumbents in European electricity markets is seen as a roadblock to further competition[1]. Specifically, new market entry can only be fostered by technology competition between different new electricity generation options. This is seen as inhibited by "structural barriers in the market" (European Commission 2005a).

Although RETs have been the fastest growing electricity generation technologies in recent years (Justus 2006), their development and diffusion has often been seen as hindered by incumbent operators in European electricity markets (Johnson & Jacobsson 2001;Jacobsson & Lauber 2006). This follows a precedent from more established technologies such as nuclear power and combined-cycle gas turbines (CCGT), which faced strong initial resistance from incumbent electric utility companies (Markard & Truffer 2006).

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[1] For example, the EC's 2005 investigation into the current failings of European electricity markets stated that "...a high level of concentration persists [...], which creates scope for market power for incumbent operators", and further that 'vertical foreclosure' in many markets between generation and retail reduces liquidity (European Commission 2005a).

The dominant market position of incumbent electric utilities, coupled with the appreciation of RETs as fundamentally 'disruptive', underlines the tension between these companies' objectives and new technological developments. Consequently, the question of the strategic approach of incumbent utilities to the adoption of RETs acquires a central role. Given their vertical integration along the whole electricity supply chain, these companies manifest a potentially formidable force that could block the diffusion of RETs into the wider market, yet, given their resources and reach, they could equally be one of the central driving forces for RET penetration.

Empirical observations on the behaviour of incumbent utility companies in Europe provide a mixed picture. In some countries, they have actively attempted to block the introduction of new RETs, while in other countries they are among the leading investors in this area. Utilities in Germany have had little involvement in wind farm installations, while their Spanish counterparts are involved in the operation of more than half of all domestic wind farms.

In summary, the diffusion of renewable energy plays a key role in current discussions on climate change and future energy supply security and sustainability. Given this empirical interest in the diffusion of RETs and especially in the role of incumbents in that context, a first task in this thesis was to identify an analytical framework through which this field could be analysed.

1.2. Theoretical Motivation

Large, vertically integrated utility companies have been inextricably linked with the historical evolution of the electricity system (Hughes 1987). Their organizational structures and technologies employed mirrored developments at the electricity systems level. Yet, incumbent firms have adapted to new technologies and societal requirements and it seems impossible to distinguish *a priori*, in the words of the *Economist*, between those that aim "to block the new technology in the hope that it will simply go away, and those who are moving to embrace it even though it undermines their existing businesses" (Economist 2005).

The analysis of such responses has been the subject of at least two separate streams of the academic literature. From a company perspective, the strategic management literature has attempted to provide a bottom-up picture of individual companies' behaviour with regard to technological change. Companies aim to develop unique capabilities that provide them with sustainable competitive advantages (Teece, Pisano, & Shuen 1997). These capabilities are the result of firm-specific combinations of resources, including both tangible assets, such as machines and raw materials, and intangible assets, such as knowledge and brand images (Burgelman, Christensen, & Wheelwright 2004;Grant 2005). New technologies tend to be embraced where they enhance or complement existing competencies, while competence destroying technologies tend to be resisted (Tushman & Anderson 1986). However, it has recently been pointed out that even when incumbent firms master a new technology, what is most difficult for them is to formulate an appropriate strategy and find the best markets to utilize this new technology (Christensen & Rosenbloom 1995;Rosenbloom & Christensen 1998).

One option for companies that aim to block the introduction of a new technology is to influence the institutional environment by lobbying for preferable types of regulation and market designs (Hillman, Keim, & Schuler 2004). This is especially important in highly regulated markets that are subject to strong regulatory and government influence, such as the electricity industry. For example, Frankenberger showed how the German utility company 'E.ON' actively tried to shape the emerging EU emissions trading scheme to suit its own capabilities (Frankenberger 2006).

Yet, this literature has not gone beyond narrowly defined domains, examining individual actors and assuming static decision environments (Madhok 2002). Moreover, if strategy is understood as the process that guides decision-making over the allocation of a fixed amount of resources in a given time period, this literature is primarily concerned with the short-term positioning of companies in an industry (Porter 1980), putting less emphasis on long-term transitions at the systems level.

Conversely, there is a growing literature that analyses technological change as a system-wide process, transcending changes in technological artefacts alone. Recent examples have been the work on 'carbon lock-in', 'socio-technical regimes', 'technological transitions' and 'technological innovation systems'. While details differ between these approaches, they broadly consider technological change not just in terms of developments of physical technologies but as a process interacting with changes in wider socio-economic structures such as the market environment and consumer preferences. Hence, this class of approaches to innovation studies can be called 'systemic studies of innovation' (Edquist 1997a).

Thus, for example, Unruh has aimed to explain the widespread reliance on fossil-fuels in western economies as the outcome of a complex interaction of company activity, government regulation, cultural interpretation of technology by consumers and research agendas by scientists (Unruh 2000;Unruh 2002). In a similar vein, Geels interprets the changeover from the sailing ship to the steamboat in the 18th and 19th century in terms of emergence of new markets, which themselves have been created by consumer preferences and government regulation, and the entrepreneurial activity and technological developments of individual actors (Geels 2002).

Hence, the systemic innovation literature has attempted to capture a multitude of relationships and variables, while at the same time keeping a long-term view on technological innovations and their socio-economic context. However, the aim for comprehensiveness has been increasingly traded-off against a lack of explanatory power to understand individual responses of companies vis-à-vis systemic changes. Often, the actions of these actors have been explained in terms of the structural and functional position, for example of a company, within the wider system. Hence, Smith et al. (2005:1492) highlight the "...tendency to treat regime transformation as a monolithic process dominated by rational action and neglecting important differences in context".

As previously outlined, incumbents have typically been characterised as being 'locked-in' to existing systems, attempting to block radical institutional

changes and the introduction of innovative technologies, since these are seen as threatening their established position within the system (Hughes 1987;Jacobsson & Bergek 2004). Yet, empirical observations from the electricity industry across Europe show that incumbents exhibit a variety of responses between countries and even within one country. This thesis argues that this cannot be explained by systemic changes alone but needs to be complemented by a deeper understanding of decision-making at the firm-level. Consequently, this thesis will develop and apply an analytical framework that combines relevant elements from both the strategic management and systemic innovation literature.

Hence, the juxtaposition of both literatures seeks to highlight the potential complementarity of these two approaches. The strategic management literature provides a conceptual model of individual agency at the firm-level that can buttress the systemic analysis of structural changes over longer time-scales. The research presented in this thesis seeks to combine the strengths of both approaches to garner a theoretically and empirically richer understanding of company behaviour vis-à-vis systemic changes, using the European electricity industry as a case study. A better understanding of incumbents' strategies in this context could help improve policy-making and contribute to the discussions on the incumbents' role in the ongoing transformation in the industry.

1.3. Research Questions, Aims and Objectives

The above sections set out the empirical and theoretical motivation for the research pursued. Both from a theoretical and empirical point of view, the research seeks to analyse the role of incumbent utility companies in the diffusion of renewable energy technologies. Technology is conceptualised here following the systemic innovation literature as the outcome of an interactive social process, while the individual company responses are considered in the context of insights from the strategic-management literature.

Consequently, the overarching **research questions** of this thesis are:

What are the main factors influencing incumbent companies' strategy when changes occur at the systemic level in the electricity industry?

To what extent do corporate strategy and the electricity system interact and influence each others' evolution?

This section sets out the specific **aims and objectives** for the research to answer these questions.

The first aim of this thesis is to develop an analytical framework that explicitly examines individual agency within the systemic analysis of innovation in the context of the electricity industry. The specific objectives for this aim include:

- A critical, comparative review of the strategic management and systemic innovation literature to identify key gaps for research.
- The identification of key components for an extended analytical framework that incorporates the notion of corporate strategy within systemic innovation analysis.
- The development of an analytical framework that captures innovation dynamics both at the systems and the individual level as well as dynamics between both levels.

The second aim is primarily empirical. Having established an analytical framework, *the second aim is to apply and test this framework by assessing empirically the individual strategies to integrate wind power among selected incumbent utility companies in three European countries – the UK, Germany and Spain.* The objectives for this aim include:

- To develop a research setting in which the dimensions of the analytical framework can be applied.
- To test empirically the interaction between systemic changes and corporate strategy of incumbent firms.

The final two aims in this thesis are to enhance the empirical understanding of wind power diffusion in the three countries presented and to embed the findings from the case studies in the initial theoretical framework.

Thus, *the third aim is to discuss what contributed to the incumbents' strategies to adopt or resist the introduction of wind power.* The objectives here include:

- To identify common patterns among the leading and lagging countries.
- To analyse the main factors that led to the adoption of pro-active strategies among incumbents.
- To specifically examine the role of government policy and its success in contributing to pro-active incumbents' behaviour.

Lastly, on a general theoretical level, the aim is to assess the extent to which the analytical framework deployed in this research complements and extends existing approaches in the 'systemic innovation' literature. The objectives here include:

- An examination of the role of functions in systemic innovation research
- A discussion of the relationship of the research presented in this thesis with wider systemic innovation frameworks

1.4. Methodology, Novelty and Outcomes

The research presented in this thesis is based on two main methodological approaches. Firstly, a comprehensive critical literature review was conducted to cover the main theoretical and empirical aspects of this research. This included academic journals and books, news reports and industry literature. This is reflected in chapters 2 and 3, which present the results of the academic literature review and develop the analytical framework, and in chapter 4, where the respective country policy environments and markets are presented.

Secondly, a case study approach was used, based on semi-structured interviews among the key companies in three countries, to complement and develop the insights from the literature review. The interviews were conducted with large electric utility companies in the UK, Germany and Spain. The aim of the case studies was to examine in-depth the factors underlying the strategy exhibited by the companies and their evolution over time.

The resulting research aims to make three novel contributions to the literature. Firstly, it presents a novel analytical framework to analyse the interaction between firm-level activity and system-level developments by focusing on the co-evolution of corporate strategy and institutional variables such as market design and government policy. Previous research has primarily focused on one *or* the other dimension, but few analyses have sought to combine these dimensions in a single interdisciplinary approach (Murmann 2003).

Secondly, the thesis will provide novel accounts of the development of renewable energy in three countries. These accounts provide an empirically deeper analysis than previously found in the literature. New empirical and theoretical insights are obtained by providing detailed and contextualised accounts of the evolution of both the electricity and renewable energy markets in each of the three countries *and* the concomitant strategic approach of the affected utility companies. Previous work, such as that of Jacobsson and Lauber (2006) provided a systemic perspective on the introduction of renewable energy in Germany, but focused on the development of policy without considering the specific strategic context for the German utility companies. Conversely, Mitchell examined the progress of renewable energy technology in the UK under two different policy regimes, but did not consider the specific motivations of incumbent utilities for or against investment in these technologies (Mitchell 2000;Mitchell & Connor 2004). This research aims to fill this gap.

Thirdly, the analysis allows for novel recommendations both for policy-makers and researchers in this area. Insights from the case studies highlight how policy-makers can engage incumbent utility companies in new technologies when

policy provides a perspective for strategic investments into new capabilities for the affected firms. However, it is suggested that this is a necessary but not a sufficient condition for companies' action - companies still have to engage with the policy environment and develop specific approaches to acquire new capabilities. The research will show that where policies opened the opportunity for strategic investments and companies consequently engaged in innovative activity, virtuous circles of new capability development and technological innovation and integration into existing markets could be witnessed. This is also important for researchers using systemic innovation approaches. It is argued that previous work focusing on the 'functions' of innovation systems needs to take into account the context-specific reasons for certain functions to perform well or not.

1.5. Chapter Outline

This final section details the chapter structure and highlights where the above aims and objectives will be pursued.

Chapter 2 – Critical Literature Review

This chapter pursues the first aim of this thesis in investigating the key literatures in order to help develop an analytical framework for this research. It will relate the above research questions to different streams in the innovation literature, especially in the strategic management and systemic-studies-of-innovation field. Building on these literatures, it will propose avenues to extend the current systemic innovation studies framework to address the research questions with a novel approach.

Chapter 3 – Analytical Framework and Methodology

This chapter will bring together the discussion from the previous literature review and consequently develops an analytical framework to analyse the research questions. The focus of the analytical framework is to integrate a firm's

development of corporate strategy with the systemic evolution of institutions and technology. In this way, it addresses the first aim of this thesis and provides the basis for the subsequent case studies.

The final section of this chapter outlines the methodology used in the data collection process and the selection process for the three case study countries and respective companies. It thus spells out in detail the research setting in which the analytical framework was applied and sets the scene for the individual case studies in chapter 4.

Chapter 4 – The Interaction of utilities' strategies and systemic change in three countries

This is a core chapter of this thesis. It will present the results from the case studies, presenting the data collected from the industry research and the interviews. Building on the analytical framework developed in the previous chapter, it will firstly provide data on the evolution of the electricity market and renewable energy policy environment in each country. Given this context, it will consequently discuss the strategy development of the incumbent utility companies in each country from the first introduction of specific wind power support policies up until 2005. The focus will be on corporate strategy with regard to investing into new technology and concomitant corporate political activities, and the interaction of these strategies with developments at the systems-level. In applying the analytical framework, this chapter addresses aim two of this thesis in generating novel insights into the role of incumbent utilities in the process of renewable energy diffusion.

Chapter 5 – Discussion of the Analytical Framework and Policy Implications of the Research

The purpose of this chapter is to bring together the analysis from the three case-studies presented in the previous chapter. It will firstly analyse the patterns of strategy formulation at the firm-level and subsequent co-evolutionary processes between the companies and their systemic environment. Building on this

discussion, it will identify the key mechanisms that lead to such co-evolutionary developments between organizations, institutions and technologies.

Consequently, the chapter will outline novel policy implications arising from these insights. This focuses both on the process of policy formulation and the key components that were successful in co-opting incumbent utilities into the policy process and engaging them into pro-active development cycles. Subsequently, implications for EU policy-making are discussed. This addresses the third aim of this thesis in discussing the main factors influencing incumbent utilities' strategy towards renewables and the role of policy within this.

Chapter 6 - The Applicability of the Analytical Framework within the wider 'Systemic Innovation' Literature

This chapter aims to broaden out the analysis to consider the novel contribution that the integration of corporate strategy can bring to systemic innovation research approaches. Here, the focus is especially on the role of 'functions' of innovations systems, and the way in which integrating corporate strategy into such analysis extends the understanding of why some functions in a specific setting might perform badly or otherwise. Furthermore, the applicability of the analytical framework in other research settings and its relationship to the existing literature is discussed.

Chapter 7 – Conclusions

This chapter draws together the results from the research presented in this thesis. It reviews the methodological approach and the applicability of the theoretical framework, as well as the main policy implications and theoretical contributions. It examines the strengths and limitations of the research and offers suggestions for further research.

1.6. Conclusion

Sections 1.2 and 1.3 have laid out the empirical and theoretical motivation for this research. Empirically, it is concerned with the role of incumbent electric utility companies in the diffusion of wind energy in three countries – the UK, Germany and Spain. Theoretically, the aim is to extend existing systemic innovation approaches by considering specifically the scope for differential individual agency within wider systemic changes.

With this background, chapter 2 will now put the research into the context of the existing literature. It provides a critical review of three literatures pertaining to the present research topic: Firstly, the technology diffusion literature, secondly the strategic management literature and lastly the systemic innovation literature. Throughout the literature review, important gaps in each individual literature will be highlighted, which render each individual literature insufficient on its own for the planned research in this thesis. This provides the basis for developing a novel analytical framework in chapter 3.

2. Critical Literature Review: Innovation, systems, and strategic management

As outlined in the introduction, this research focuses on the role of incumbent electric utility companies in the commercial adoption and diffusion of new RETs. This chapter puts the research into the context of the current literature pertaining to this topic. This critical literature review will focus on three selected key areas of the literature: Technology diffusion models, the strategic management literature and finally systemic innovation frameworks.

The starting point for approaching this issue was to find an appropriate level of analysis that recognizes both technological development as well as differential organizational responses to these technologies within different national institutional contexts.

Basic definitions often use the words 'technological change' and 'innovation' interchangeably when referring to the first market introduction of a new technology or process. The main distinction here is with the term 'invention', which is primarily concerned with the discovery of new products or processes, without necessarily considering their market applications (Schumpeter 1934).

In the Schumpeterian sense, innovations do not even have to be built on new discoveries but can be reconfigurations of existing products or processes in a novel way. Thus, the process of innovation makes use both of the existing stock of knowledge as well as recent discoveries (Schumpeter 1947). The crucial aspect of innovation for this thesis is what Schumpeter (1947:153) coined "getting a new thing done", which emphasises the importance not only of developing a product or process but of successfully introducing it into the market.

Building on this basic notion of innovation, Kemp and Rip put forward a more holistic conceptualisation of 'technology' (Kemp & Rip 1998:329ff). In

their view, merely focusing on technological artefacts is "black boxing" what is going on inside the process of technological change. While technologies can be seen as "tangible items", they are also embedded in specific skills, infrastructure and societal demands. Hence, technology can be seen as a "configuration that works", a specific combination of elements from different domains interacting to serve a specific purpose. Kemp and Rip (1998:335) give the example of the introduction of the motorcar in Norway: "The motorcar is not an isolated artefact, but the label for part of our socio-technical landscape, made up of steel and plastic, concrete (the roads), law (traffic rules), and culture (the value and meaning of personal mobility)." Hence, the market introduction of the motorcar in Norway not only encompassed the physical artefact itself, but concomitant innovations in the area of law, infrastructure and cultural adaptation.

What this classification of technology suggests is that innovation is far from a linear process of invention of new technologies and their subsequent application in the market but a circular and iterative development, depending on social and political as well as technological factors. Hence, in order to understand the innovation process, technological and societal change has to be considered in conjunction, as "technology is the outcome of institutional and societal processes and should not be regarded autonomous – that is, determined by a separate and distinct set of factors and rules" (Berkhout & Gouldson 2003:232).

The focus in this research is concerned with the role of incumbent utility companies in the diffusion of new renewable energy technologies. Hence, the research setting is in a field that has been characterised as 'complex', 'interconnected' and 'slow-moving' with regard to technological change (Hughes 1987). Following Rip and Kemp's (1998) definition of 'technology', it is insufficient to solely focus on technological artefacts in this area, because technologies are embedded in economic and political institutions. They are continuously modulated and shaped by societal interactions at different levels (Berkhout & Gouldson 2003). It is precisely those interactions that determine the pathways of new technologies, in terms of who adopts them and in which markets they enter first. Hence, narrowing the unit of analysis to only one variable. 'technology' for example, would foreclose much of the crucial processes in other

domains that influence the outcome of the technological diffusion process and would thus leave an empirically and theoretically unsatisfactory picture. Rather, the appropriate unit of analysis is the systemic interaction of these variables itself.

Consequently, it was identified at an early stage in the literature review that the research had to go beyond narrow technological diffusion models. Given the interplay of institutional, organizational and technological factors, a richer theoretical framework was necessary that takes into account these interdependencies while recognizing the heterogeneous responses by individual companies. Consequently, two additional literatures were identified as critical to this research approach: Firstly, the literature concerned with companies' approaches to strategically managing technological change and secondly the systemic innovation literature investigating the co-evolution and interaction of different domains in the process of technological change.

Consequently, this chapter will proceed as follows: Section 2.1 focuses on technology diffusion models, including path-dependency and technological-paradigm approaches. The strategic management literature and systemic innovation frameworks will be critically reviewed in sections 2.2 and 2.3 while section 2.4 summarises the discussion. In each of these sections, those aspects that contribute to answering the research question will be highlighted, but also the gaps in each individual approach will be pointed out. It will be argued that each literature on its own is insufficient to answer the research questions posed in this thesis. Consequently, building on the contributions that each literature makes, chapter 3 will develop an analytical framework that allows the specific analysis of the research questions of this thesis.

The first section of this chapter will now consider the traditional analysis of technology diffusion patterns and the treatment associated phenomena of lock-in of certain 'technological paradigms' in the literature (Dosi 1982).

2.1. *Technological Diffusion, Increasing Returns to Scale and Technological Paradigms*

One of the most widely used concepts in studies of technological diffusion is that of the 'S-curve' trajectory of product or process development (Foster 1986). This captures the various stages of technological development that can be distinguished. Coupled to these development stages, various phases of associated diffusion patters can similarly be identified.

The S-curve measures the improvements in product or process performance against the time or engineering effort invested into a particular technology (Foster 1986). According to Christensen (1992:334), it is "... an inductively derived theory of the potential for technological improvement, which suggests that the magnitude of improvement in the performance of a product or process occurring in a given period of time or resulting from a given amount of engineering effort differs as technology becomes more mature."

In the initial stage of development, characterised by uncertainty, progress is slow and individual new technologies are filtered against other alternatives. However, as they become better understood and produced at larger scale, the rate of technological improvement increases. This in turn leads to a period of rapid up-scaling in product performance and design. In the final stage of development, diminishing returns to time and engineering efforts appear, as the technology matures, and ever greater endeavours are needed to add to a product's performance. This leads to a stabilisation of a product or process' performance characteristics at a high level. This pattern is depicted in Figure 1 (Christensen 1992).

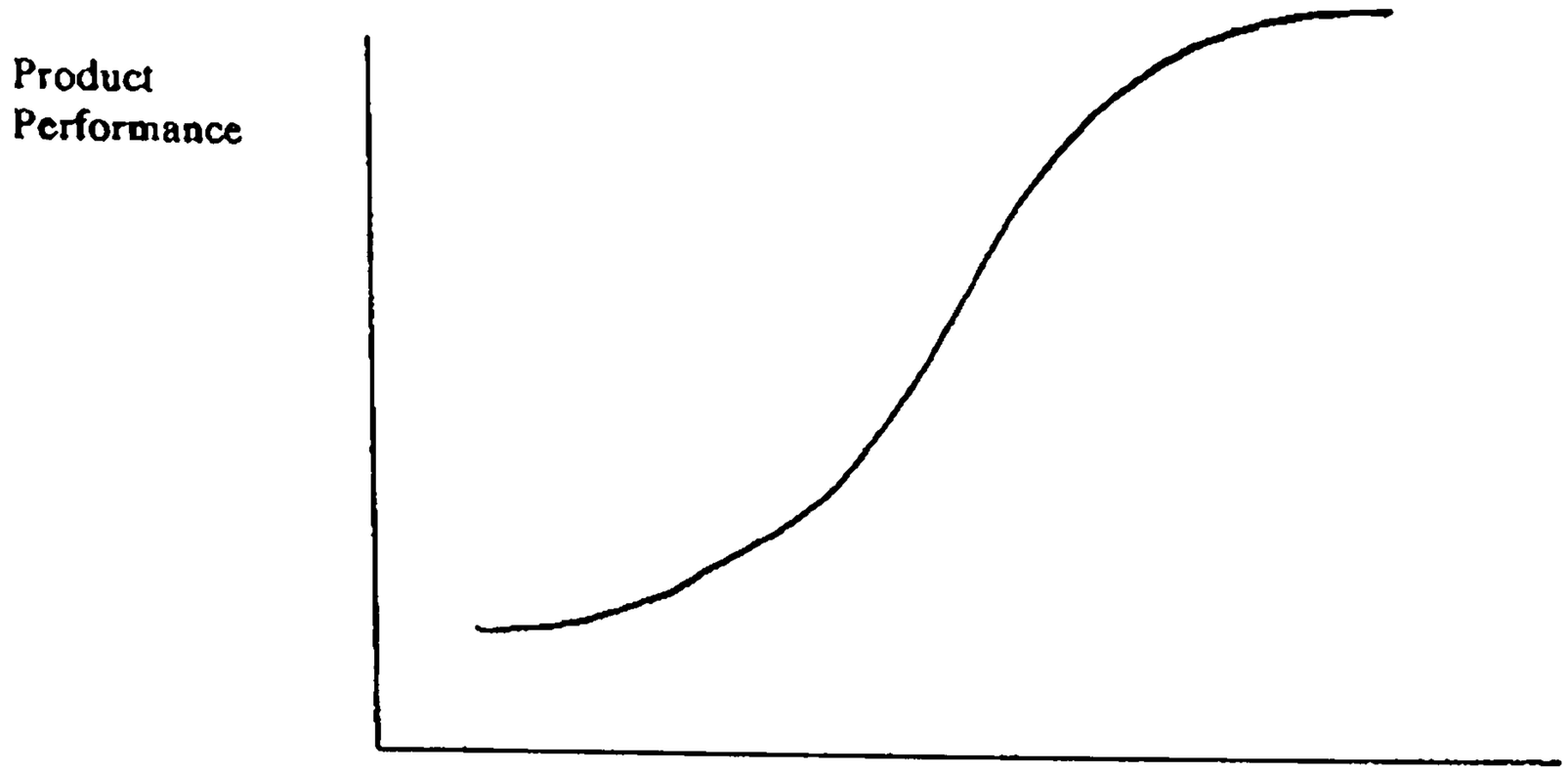


Figure 1: The Technology S-Curve (Source: Christensen 1992)

A similar way of illustrating the process of technological improvement is the use of experience curves, which plot the unit costs of a technology against its cumulative sales/installation (Grubb, Köhler, & Anderson 2002). Figure 2 below shows an example of experience curves for different energy technologies. While the S-curve and the experience curve of a technology are theoretically related, they actually stem from different research traditions (see (IEA 2000) and (Christensen 1997)).

In both literatures, when technologies are introduced into the market, they often have several properties that make them less competitive against their established rivals. This explains the low initial take up of new technologies in the S-curve. However, once introduced into the market, new technologies benefit from refinements and extensions through learning-by-using and learning-by-doing opportunities (Dosi 1988), which enhance their position, for example with regards to unit costs, over time.

This in turn improves the competitive position of innovations and spurs further sales, which in turn reinforces the scope for further cost reductions. This positive feedback cycle provides the rationale for the steeply climbing part of the S-curve where increasing adoption and cost reductions increasingly cement a technology's competitive position in the market. Similarly, experience curves typically show high rates of cost reductions per cumulative doubling of installed capacity when the total installed capacity is still low. Subsequently, as total

installed capacity increases, the cost reductions per each doubling of capacity become smaller as technologies enter diminishing returns and scale economies are spread over an ever larger number of units. Eventually, the scope for further cost reductions declines.

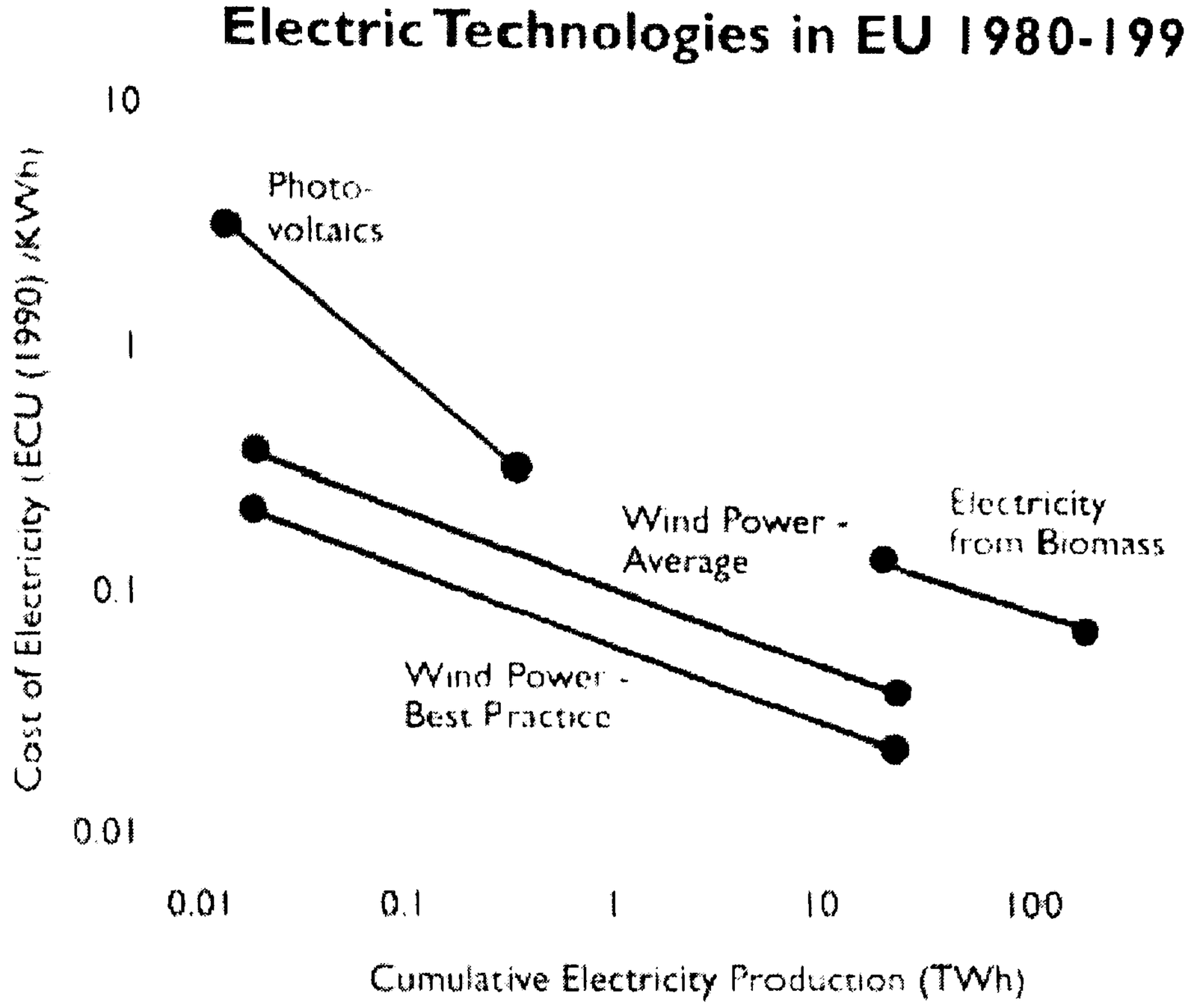


Figure 2: Development of Experience curves; Source: Grubb et al., 2002

These stylized models of technological development have led to the characterisation of 'technology life cycles' of "childhood, adolescence and maturity" (Grubler 1998:51). Quite literally, technologies are assumed to have a lifespan in which they are used and adopted before eventually being superseded by new technologies (see Figure 3 below for a schematic representation). In this respect, replacing "product performance" with "market share" on the y-axis in figure 1 above would yield an S-curve outlining the market penetration of a single technology over time.

The terminology of life-cycles is also appropriate when considering the time scales involved in the diffusion of new technologies into the market place (Tushman & Anderson 1986;Grubler 1998). Grubler (1998:58ff) provides

examples from a range of industries where innovations typically required several decades before replacing existing technologies.

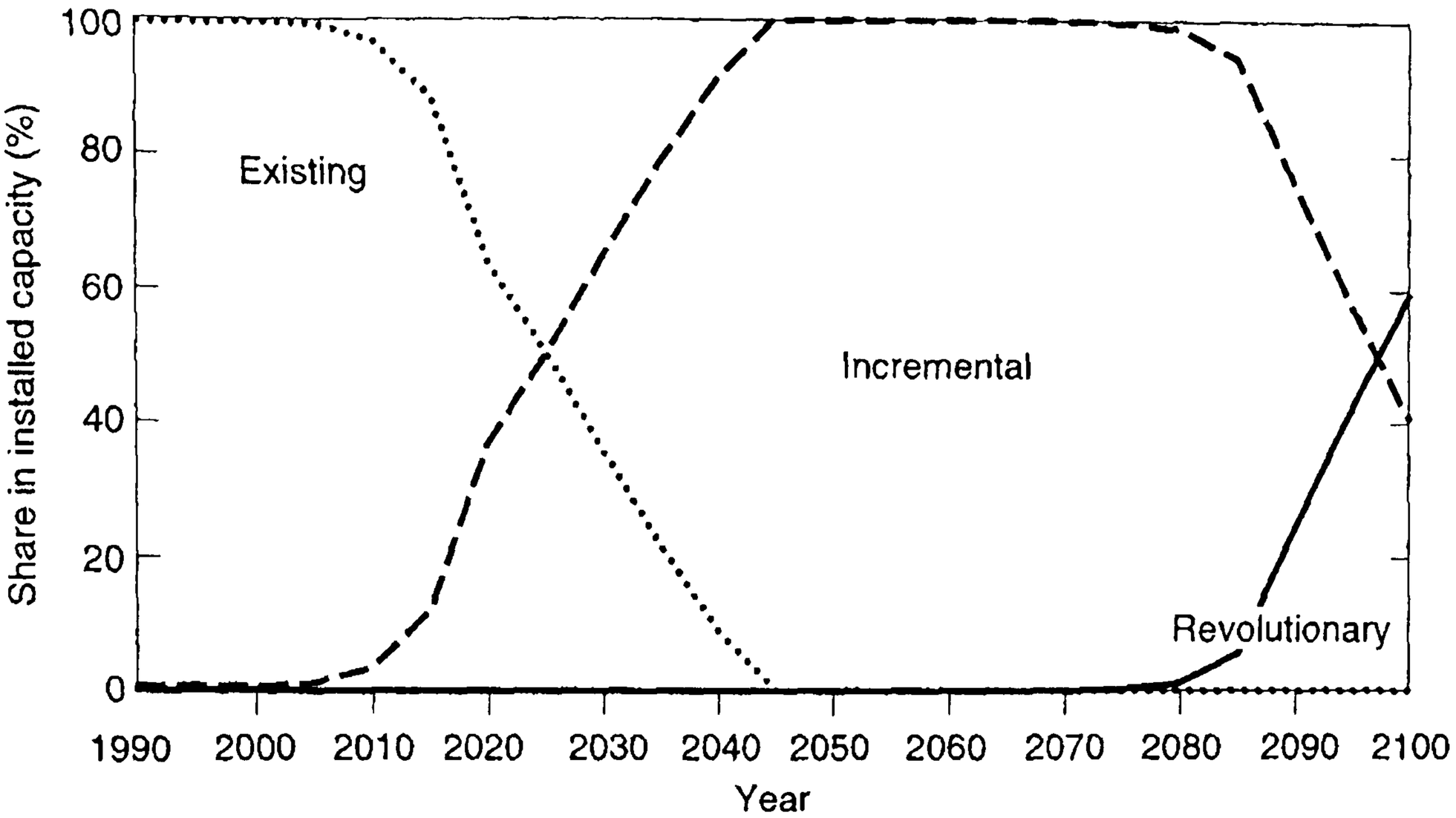


Figure 3: Technological life-cycles over time of subsequent technology 'generations'; Source: Grubler 1998

There are two important points in this respect that have a bearing on the research presented here.

Firstly, it is noted that the concepts of 'S-curves' and 'experience curves' are inductively derived and as such do not have a comprehensive theoretical underpinning (Christensen 1992). While they are frequently used in technological forecasting both among companies and policy-makers[2], they are based on historically derived observations without necessarily providing a detailed explanation for the causal mechanism that links the two variables. For example, Christensen (1992) shows how S-curve projections for the same technology can vary by as much as one order of magnitude between different firms in the same industry. In this sense they are useful research 'heuristics' without necessarily providing a theoretically firm foundation for the research pursued in this thesis.

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[2] For example, a recent report by Greenpeace International argued that wind energy could supply 12% of global electricity demand by 2020. This claim was based on calculations in which past 'experience curves' for wind energy were extrapolated into the future and adjusted at the authors' discretion (Greenpeace & EWEA 2005).

Secondly, however, a distinction is made in the literature between two types of innovation along the S-curve. In the early stages of a technology's development, performance criteria are typically still poorly understood and evolve as a product is adopted by different user classes. In this period, *product innovations* normally dominate, focusing on positioning a product in the market. Subsequently, as a technology matures, the focus of improvements shifts to incremental process innovations and cost reductions as the product becomes standardized and the market well defined (Abernathy & Utterback 1978).

Since incumbents tend to be associated with established, mature technologies, this implies that they are much better at nurturing their established products and processes, achieving incremental performance improvements from their current portfolio, rather than creatively exploiting new market niches. This point will be returned to in section 2.2.2 when discussing the strategic options for a company.

Yet, in some instances, incumbents' concern with existing technologies led to such dominance in the market that they were never replaced by a competitor. This phenomenon has been highlighted in the increasing-returns and lock-in literature, which shows how random variations in initial starting conditions can lead to situations in which alternative technologies are prevented from entering the market. This will be discussed in the next section.

2.1.1. Path Dependency and Technological Lock-In

'Path dependency' has been considered in the context of increasing returns properties of individual technologies (David 1985, Arthur 1989). It describes the diffusion path of a technology and argues that the future success of a technology is a function not only of its own historic adoption path but also of that of competing technologies.

The basic idea behind this notion is that the selection of one technology creates positive feedback loops to its users which furthermore encourage the

usage and adoption of that particular technology. As the relative benefits of one technology compared with another increase over time, the costs of exploring alternative technological avenues rise and hence their attractiveness falls. "Companies may feel the need to pick the right horse" (Pierson 2000:254) as "the costs of exit – of switching to some previously plausible alternative – rise." (Pierson 2000:252)

Arthur (1989) argues that small and essentially random variations in initial conditions can consequently lead to a situation where one technology becomes dominant and supplants all its competitors, without it necessarily being the most efficient long-run option. In a simulation model, he identified 'tipping-points' after which one technology dominates all its competitors, due to the particular diffusion path adopted. He identified four sources for feedback loops through increasing returns:

- Scale economies
- learning effects
- network economies and
- adaptive expectations.

Scale economies result from the spreading of fixed costs over more units and the generally better utilisation of production capacity. Learning effects stem from the increased familiarity, adaptation, usage and interaction with a technology, which allow specialist skills and know-how to be developed. This again leads to lower production costs. Network externalities result from technologies that exhibit certain properties such that they become more valuable the more users they have. The telephone is an example, as its value increases the more users are connected to the same communication system. Lastly, increased familiarity with and improved quality of a technology reduces uncertainty and leads to adaptive expectations such that it will be increasingly be accepted and selected over other (initial) competitors.

In sum, these factors can "...drive the adoption process into developing a technology that has inferior long-run potential" (Arthur 1989:117). This situation, commonly described as 'lock-in' (Kline 2001;Unruh 2000), applies where a technology has gained such a dominant position that it systematically locks-out potential alternatives, even where the initial conditions under which the technology was originally developed no longer apply. The prevalence of the 'QWERTY-keyboard' or light-water nuclear reactor technology have been cited in the literature as examples of such states[3] (David 1985;Walker 2000).

An important extension to path dependency has been its application to institutions (North 1990, Pierson 2000). Although the sources of institutional path dependency are primarily rooted in political economic arguments rather than economic-organizational behaviour, analogies can be drawn on all four counts mentioned above (Pierson 2000). Again, the fundamental argument turns on the incremental nature of change due to the high initial 'set-up' costs of radical alternatives, and the cumulative learning that is embodied in existing institutions.

The emergence of such dominant technologies has been characterised as 'technological paradigms' in the literature. This approaches the phenomenon from a technological-economic perspective, examining the selective 'problem solving activities' in science and industry, as well as their economic applications. Hence, a technological paradigm is defined as a "'model' and a "pattern" of solution of *selected* technological problems, based on *selected* principles derived from natural sciences and on *selected* material technologies." (Dosi 1982:152) This employs an evolutionary perspective of technological development in assuming that it is impossible for researchers and industrial companies to constantly scan all conceivable opportunities and options for scientific and industrial endeavour. Rather, "...economic agents tend to react to (or anticipate) changes in relative prices and demand conditions by searching for new techniques and new products

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[3] Liebowitz and Margolis have criticised such arguments from a classical economic perspective, contending that lock-in phenomena could ultimately be explained with rational behaviour (Liebowitz & Margolis 1995). However, they did not address the socio-technical dimension of lock-in arguments, which will be further pursued in this thesis.

within the *boundaries* defined by the nature of each technological paradigm" (Dosi & Orsenigo 1988:16-17).

The 'technological paradigm' concept gives a first-order explanation of why technologies might come to dominate in an industry despite the large variety of technology designs available in principle and underpins the path dependency argument. Initially random differences in knowledge acquisition and design improvements in new technologies can have lasting ramifications along a technology's development path. Once scientific and engineering efforts converge on a select few applications rather than a wide field, alternative technological options are at an increasing disadvantage to the dominant search and research consensus.

2.1.2. Discussion

How does the above discussion relate to the research pursued in this thesis? Three issues will be highlighted. Firstly, technology diffusion models are useful research 'heuristics' that allow a high degree of abstraction to focus on the dynamics of technology diffusion. Yet, as such they do not have a comprehensive theoretical underpinning, thus limiting their applicability in more complex research settings.

Yet, secondly, they provide two particular insights about the role of incumbents in technology diffusion. Firstly, incumbents are associated with what was successful in the past. Furthermore, incumbents have typically benefited from significant cumulative learning opportunities that provided them with the basis for their dominant position today. Yet, given the emergence of 'technological paradigms', their associated paths of investigation are selective and exclusive, discriminating against new and untried solutions that fall outside the dominant paradigm (Dosi 1982).

Lastly, incumbents are seldom the source of radical new products or processes, which is reflected in their low involvement in product innovations as

compared to incremental process innovations (Abernathy & Utterback 1978;Tushman & Anderson 1986). Engineering knowledge relevant to current 'technological paradigms' is often heavily concentrated among incumbents and their network of supply companies, while more unproven and new technology designs are more widely distributed in an economy (Dosi 1988).

In summary, while providing a rationale for particular patterns of technology diffusion, technology diffusion models are limited in explaining the causal mechanisms that underline such patterns. Hence, in order to better understand the sources of 'stickiness' of established technologies among incumbents from a company perspective, the next section will explore in more detail the strategic management literature's contribution to organizational behaviour. There are three sub-sections: Firstly, on the organizational structure of corporations, secondly, on the strategic management of innovation, and lastly, on corporate political activity.

2.2. Innovation in the Strategic Management Literature

The previous section provided a top-down picture of different technology diffusion models and the role of incumbents within them. This section will now provide a bottom-up picture, building on the strategic management literature, of why incumbents tend to be associated with established technologies and associated dominant paradigms. The first section will focus on the decision-making process in the organizational context and particularly the phenomena of bounded rationality an organizational routines. Consequently, it will consider how companies can strategically develop their capabilities to respond to new technological threats, allowing incumbents to adapt to changing technological environments. Finally, the option to politically influence their market environment is discussed.

2.2.1. Organizational Structure

One of the fundamental notions in conceptualising organisational contexts is the observation of 'bounded rationality' (Simon 1955) in the work place. This implies that "rational actors are significantly constrained by limitations of information and calculation" (Cyert & March 1992:214) and consequently underscores the problem of coping to work in an environment of resource constraints and uncertainties. Nelson and Winter build their concept of 'organizational routines' as dominant forms of organizational behaviour on this initial observation by Simon (1955). Routines are "...any technical, procedural, organisational or strategic process or technique used by a firm as part of its normal business activities (Foxon 2003:6)."

These concepts are particular relevant to the analysis of incumbents for at least two reasons: Firstly, they provide a coherent and comprehensive alternative behavioural framework to the standard neoclassical narrative of organizations that identify, choose, and implement optimal alternatives. The behavioural assumptions underlying the concepts of 'bounded rationality' and 'organizational routines' stress solutions that simplify decision-making problems. Thus, the focus is on alternatives that satisfy certain minimum criteria, rather than trying to find the best imaginable solution. The importance of pragmatism and standard operating procedures is stressed for the everyday workings of a company (Cyert & March 1992:214-215).

Secondly, this implies that incumbents, with their historically grown routines, are particularly prone to suffer from organizational inertia in the face of radical technological change. Routines are embedded at the same time in a company's historic development and the present network it operates in. New technologies often arise outside an incumbent's traditional domain and would furthermore erode the value of sunk investment in its present assets, whether tangible such as machines and products, or intangible assets such as the employee's knowledge base, organizational structures and established relationships with suppliers (Cyert & March 1992).

Both the notion of bounded rationality and of organisational routines is now explored in more detail.

Bounded Rationality, Routines and Search Heuristics

Simon (1955) explores the limits to the computational and predictive ability of the 'economic man' and thus, the limits to 'his' ability to behave in a 'rational' manner. An economic agent typically faces several choices and constraints: A set of given alternatives, the properties of these alternatives and finally the preference-order of these options. If perfect rationality and well-behaved preferences were assumed, knowledge of all three aspects would be complete, and the economic agent would be able to make an optimal choice within these boundaries. Simon (1955) argues, however, that in reality an economic agent is constrained by at least three factors: His or her computational power to process information, time constraints to take decisions and finally imperfect foresight about different future states of the world. Consequently, an economic actor will have to take decisions only using a subset of information on the different attributes of the available options.

Consequently, there will be some variables which are assumed as fixed or given. These can reside outside his or her control as is for example assumed in most short-run optimization problems of a firm. Simon argues, however, that "...some of the constraints that must be taken as givens in an optimization problem may be physiological and psychological limitations of the organism (biologically defined) itself." (Simon 1955:101) Hence, the key insight from Simon's work is that constrained optimization problems have to take into account the constraints inherent in the economic agent. There are limits to the 'rationality' – at least in an absolute sense - with which an individual can be expected to operate. Given these inherent constraints, it can be expected that he or she will resort to some mode of operation which will only approximate 'optimal' behaviour. Simon proposes the mode 'satisficing' as a dominant strategy, whereby individuals merely aim to satisfy certain minimum criteria (threshold levels of

profitability, acceptability of action in a hierarchy) but will not necessarily look for an overall optimum. This behaviour has been described as searching for a local but not necessarily for a global maximum (Metcalfe & Boden 1992).

In principle, there are two options to overcome this: Firstly, an avenue that Simon pursued in his subsequent work, is the idea to increase the capacities of what individuals and organizations can manage within given resource boundaries in order to maximise the amount of information on which decisions can be based (Simon 1978;Simon 1979).

Nevertheless, even if it were possible to overcome significant computational constraints, individuals would still be working under time and resource constraints and with imperfect foresight of future states of the world. This is the starting point for what Lindblom labelled "disjointed incrementalism" in policy making (Lindblom 1979). Recognizing the inherent short-comings of any attempt to use synoptic analysis, Lindblom argues that policy-makers should not aspire to be unrealistically comprehensive but make it explicit that they only have limited resources which they will aim to use as thoughtfully as possible. As Lindblom put it (1979:518): "An aspiration to synopsis does not help an analyst to choose manageable tasks, while an aspiration to develop improved strategies does."

While Lindblom focused on policy-making, Nelson and Winter (1982) developed a framework to apply the ideas of bounded rationality in the context of the private corporation. This led to the development of the concept of 'routines' as a way of understanding organizational processes.

Nelson and Winter's model starts with the recognition that the search for profitable new products and processes is routed in the local knowledge and operations of the firm[4]. Rather than constantly scanning all conceivable options

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[4] This has led some commentators to argue that it is 'tacit knowledge' rather than 'bounded rationality' which provides the theoretical foundation for organizational routines (Foss 2003). Yet, this discussion has no bearing on the subsequent research presented in this thesis and will thus not be explored further.

available to the company, a narrow set of options is evaluated, based on the existing stock of knowledge and incremental improvements that could be added. Thus, the search for, selection and retention of new options is guided by the accumulated knowledge and resources located within the boundaries of the firm and its employees. Consequently, routines are set up so that employees can perform otherwise complex tasks and processes in a consistent manner over time and across different functional units of a firm (Christensen & Overdorf 2000).

Two aspects of routines stand out: Firstly, routines are successful and widely used precisely because they have benefited from a lot of 'learning-by-doing' in the past that has refined and improved their application. Because they are time-tested and have benefited companies previously, deviating from them creates risks and uncertainty. Secondly, individual routines are typically part of a wider set of complementary routines which focuses and guides their development. Thus individual routines benefit from the availability of complementary resources and processes which are well-known and tested in themselves. This again increases the risk of applying untried or "idiosyncratic routines" (Nelson 2002:268) because not only are new routines risky on their own, but also a whole new system of support networks and complementary skills might need to be built up.

The term 'search heuristics' has been used interchangeably with routines and encapsulates the essence of this approach: Search as the means by which companies progress and heuristics (stemming from the Greek 'Eureka!') as the methodology – discovery and invention through incremental approaches such as trial-and-error. In an analogy to Simon's 'satisficing', routines are not guaranteed to be optimal in the sense of a global maximum but rather they deliver local maxima. Routines 'satisfice' in the sense that they are good enough to enable a company to operate and make profit but they are not an exhaustive search that will in every instance seek an absolute optimal outcome, such as maximum profits.

The impact of routines on the firm's mode of operation will now be illustrated. Christensen (Christensen 1997;Christensen & Overdorf 2000) gives an insight from a management perspective into why they might persist. In his

analysis, he uses the term 'company values' to characterise the standards, rules or guiding principles by which employees classify whether an order, a customer or an idea for a new product is attractive or unattractive. Given the scarcity of resources, it is a tool to help prioritise in an environment of bounded rationality.

Christensen and Overdorf (2000) give two examples to illustrate the impact of such routines on firm decisions: Firstly, companies frequently use targets for profit margins which companies require to invest in particular ventures. These are related to the overhead costs of a company. Typically, when selecting between different projects, managers are trained to reject any project which does not deliver the required return, i.e. which does not fit with the company's cost structure although under a different cost structure it might have been profitable. A second value relates to the size of a new venture relative to the original company. As share prices are the present discounted value of future earnings, managers are keen to maintain growth and more specifically, to maintain a constant rate of growth. Thus, while the threshold for small companies to grow at a constant rate is relatively low, a multi-billion dollar business needs to find new markets that match the company's size each year to maintain a constant growth rate. This tends to discourage large companies from entering small, emerging markets. This is not because large companies do not have the resources but because their routines discourage small projects. Thus, Christensen gives a micro-level view of how and why some of the processes are at work that evolutionary economists have been observing.

Awerbuch (2000) similarly highlights the entrenched nature of routines at a macro-level of the electricity industry. He demonstrates how the most commonly used yardstick to compare different electricity generating technologies – the levelized unit costs (LUC) of a technology (measured for example in €/MWh) - is biased towards "expense-intensive" (i.e. gas turbines) technologies and against those that are "capital-intensive" (i.e. wind turbines). Specifically, engineering-based models such as LUC ignore the value that flexibility and strategic and managerial options can offer in liberalized electricity markets. Furthermore, fuel price risks are ignored. Awerbuch argues that when LUC were first conceptualized, this approach was acceptable because technological choice

was broadly homogeneous (between oil- and coal-fired power stations) and markets stable, thus making the need for flexibility and options relatively unimportant. Yet, with market liberalization, different fuel prices and other risks today, utilities require more sophisticated tools to evaluate their options. Awerbuch argued that renewable energy technologies, though superficially more expensive, could often reduce overall risk-adjusted portfolio costs of utilities (Awerbuch 2000). Nevertheless, many publications and company and official reports still use LUC as a yardstick for comparison (See e.g. (IEA 2005d).

Discussion

The above examples highlight how certain 'search heuristics' or 'routines' tend to guide the search for new technological opportunities both at a company and an industry level. Neo-classical economists tend to stress that in real market situations learning opportunities and competition will ensure at least a close approximation to rational behaviour[5]. Yet, when analysing innovation and the inherent uncertainty involved in such situations, these assumptions do not necessarily hold, especially with regard to the type of market environment and organizational interactions. In a complex environment, changing at the level of technologies, customer preferences and the nature of competition, firms are unlikely to have the information or possibly the computational power to discover or maintain optimal profit maximising solutions at all times.

In this respect, the above discussion provides a company-internal argument for an incumbent's adherence to established 'technological paradigms'. Dosi (1988) argues that the conditions in which technological change takes place are rather different from the idealised states of the world in neoclassical economics. He identifies five stylized facts borne out of the empirical literature:

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[5] Friedman's (1953) 'as if' condition argues that as long as firms behave as if they were rational profit-maximisers, competition will ensure over time that only the most efficient techniques and technologies will prevail. However, this condition would break down where technological change constantly shifts the basis of competition over time.

- "uncertainty" … "the outcomes of innovative efforts can hardly be known *ex ante*."
- "increasing reliance [...] on advances in scientific knowledge" (which in itself is uncertain and complex)
- "increasing complexity of research and innovative activity…changing the nature of *search activities*"
- "a significant amount of innovations and improvements are originated through 'learning-by-doing' and 'learning-by-using'"
- "technological change is a cumulative activity [...] depending on technological levels already achieved"

For economic activity under these conditions, arguments about 'bounded rationality' and 'organizational routines' appear an adequate representation of firm behaviour. New technologies arise outside established (re-)search activities and uncertainty about their performance characteristics and market opportunities tends to tilt the playing-field towards established technologies. Where uncertainty prevails and knowledge is fragmented, evolutionary theory suggests inductive reasoning through knowledge interactions and trial-by-error as dominant organizational responses (Simon 1955; Arthur 1994). In the context of the incumbent firm, established search heuristics for new technologies might guide organizations towards technological change of established technologies[6]. To such an organization, radically new technologies might appear not only inferior *per se* but also inadequate to fit into the existing structures and hierarchies established in the company[7].

While this section was concerned with decision-making processes within organisational structures, the next section will look at the substance of such decisions, namely the strategies of firms and their technology policies. Building on the discussion so far, it will particularly be asked under which circumstances

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[6] In the electricity industry, for example, the interest of incumbent utilities in incremental improvements in established coal power plants through 'gasification' and 'carbon capture and storage' technology is notable.

[7] Compare Christensen's (1997:87ff) discussion of how incumbent integrated steel makers ignored the opportunities provided by new 'mini-mill' steel-making technology, eventually losing almost half their market share between 1965 and 1995.

incumbents can avoid the problem of failing to identify new profitable opportunities and to escape established routines.

2.2.2. Strategic Management and the Innovation Literature

The fundamental question in the strategic management literature is how companies can secure a sustainable competitive advantage over their rivals in the market place (Porter 1980). In relation to the research presented here, the impact of new technologies on the competitive position of an incumbent company gains particular currency. In the following, the question of 'what constitutes strategy' will firstly be explored, before this section turns to the question of what options companies have in strategically managing their existing, as well as new technologies. This will build on the resource based view of the firm (Penrose 1959;Barney, Wright, & Ketchen 2001), utilizing the concept of 'dynamic capabilities' as a key source of differentiating between companies.

The Notion of Strategy in the Literature

Strategy has been defined as "the determination of the basic long-term goals and objectives of an enterprise, and the adoption of courses of action and the allocation of resources necessary for carrying out these goals." (Chandler 1962:13) Yet, this traditional definition of strategy has been criticised as too narrow and inconsistent with empirical observations, since it implies that every commercial activity has been defined in advance (Mintzberg 1978;Mintzberg 1987).

Rather, it has been put forward that strategy can emerge as a pattern of activities without necessarily following a pre-defined plan. Thus, Mintzberg (1987) distinguishes between 'deliberate' and 'emergent' strategies. While an intended and realized strategy can be labelled 'deliberate', in an 'emergent' strategy, "patterns develop in the absence of intentions, or despite them..."

(Mintzberg 1987:13). Hence, a realized strategy can emerge out of unintended and undirected actions that have coalesced over time to become the dominant pathway for a firm.

In markets with fast-changing regulatory or technological conditions, companies can be expected not to tie their fortunes too closely to any one specific option in advance (Mintzberg 1987). In this context, strategy can be developed in hindsight based simply on what worked well and achieved success. Hence, an investment could have been made by chance, and a company only realises over time the value that it offers. In this respect, Mintzberg (1987: 13) offers the following quote from a business executive on such a fortuitous investment: "Gradually, the successful approaches merge into a pattern of action that becomes our strategy. We certainly did not have an overall strategy for this."

Yet, the essence of such developments, whether emergent or deliberate, is the 'positioning' of the company with regard to the key determinants of industry competition. Porter uses a model of 'five forces' within an industry to describe the major variables to be considered by the firm (Porter 1980). These are:

- The bargaining power of customers
- The bargaining power of suppliers
- The threat of new entrants
- The threat of substitute products
- The level of competition in an industry

According to Porter, the goal of company strategy should be to find positions that are defensible against competition, i.e. that are less vulnerable to one of the five forces, "drawing on an understanding of their determinants" (Porter 1983:3). In this context, technology becomes a strategic variable, which can bestow a competitive advantage upon a firm.

An alternative strategy could be to change the rules of the market in such a way that it makes a current company position more defensible. Technology could

be one lever for such a strategy, but more common is company activity to lobby and influence government and regulatory authorities to set market rules in a particular way. Both approaches will be discussed in the subsequent sections. The next section will draw on the dynamic capabilities approach for framing the discussion of the strategic management of technology, before section 2.2.2.4 discusses political activities of the firm.

Capabilities as a key differentiator of the Firm

One of the key aspects to finding a position of sustainable competitive advantage in an industry is the role of 'dynamic capabilities'. In the resource-based view of the firm (Penrose 1959), these are defined as unique combinations of resources and competences, which are not easily transferable or imitable. Teece et al. define dynamic capabilities "as the firm's ability to integrate, build and reconfigure internal and external competences to address rapidly changing environments" (Teece, Pisano, & Shuen 1997:516).

Consequently, in this view, dynamic capabilities are considered the key strategic differentiator between companies. Given differences in the availability of tangible and intangible resources among companies, different capabilities and corresponding strategies are built to gain competitive advantage (Teece, Pisano, & Shuen 1997;Grant 2005). Hence, capabilities are based on unique, company-specific combinations of resources and competences which distinguish a firm relative to its competitors. Figure 4 summarizes the relationship between resources, capabilities and strategy.

What Figure 4 underlines is that it is not the resources alone that make a firm productive or grant it a competitive advantage, but the specific combination of resources to create unique organizational skills (Grant 1995:118). Going one step further, Porter argues that in the long-run competitive advantages can only be defended where companies can create a 'fit' between several unique capabilities and a specific strategy that they underpin, in order to make a niche more sustainable (Porter 1996).

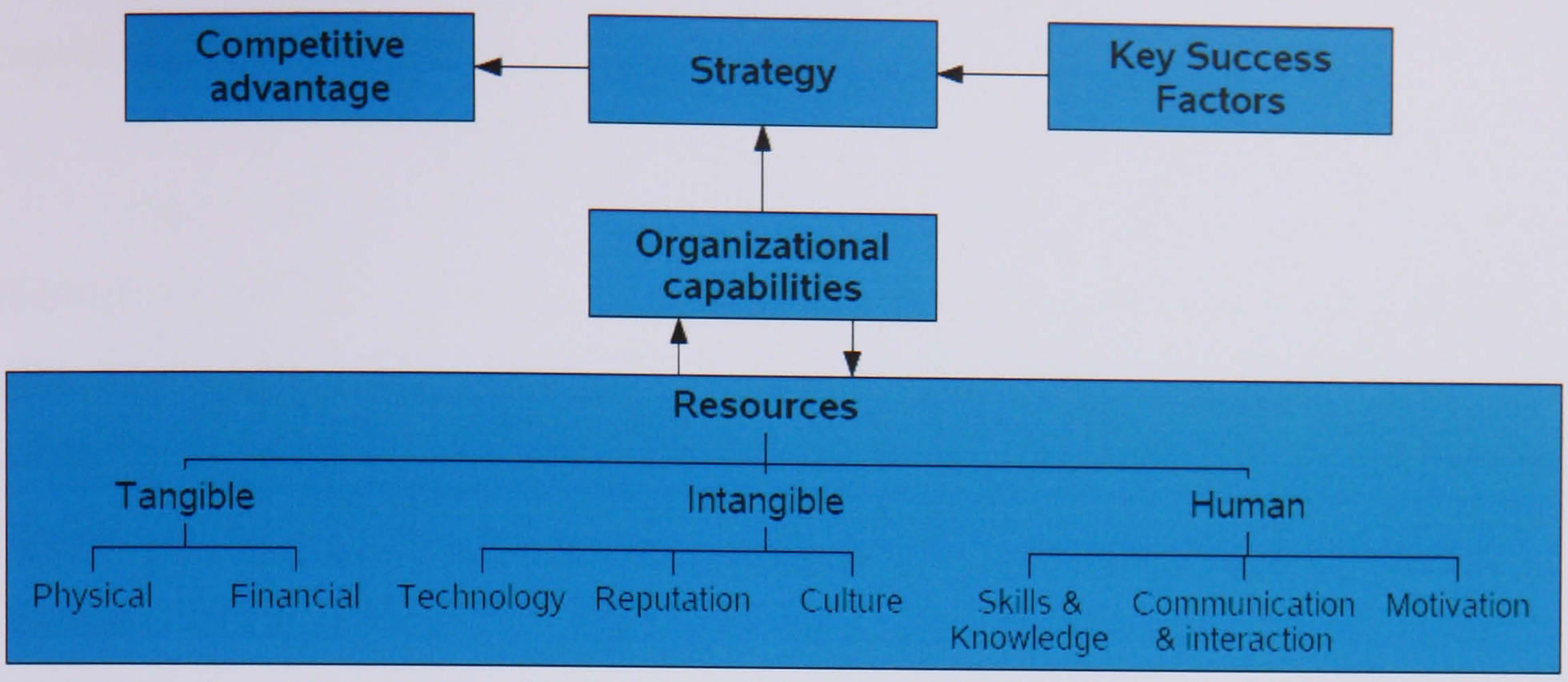


Figure 4: The links among resources, capabilities and strategy (From Grant 2005:139)

In both cases, the key feature of capabilities is their uniqueness with respect to individual companies. As Teece et al. (1997:514) put it: "From the resource-based perspective, firms are heterogeneous with respect to their resources/capabilities/endowments. Further, resource endowments are 'sticky': at least in the short run, firms are to some degree stuck with what they have and may have to live with what they lack." Capabilities cannot easily be replicated in the market place, at least in the short run, because of their underlying complex organizational processes and the often tacit knowledge involved. Furthermore, where this relates to intangible assets such as brand names and reputation, they cannot be easily transferred from one firm to another. Even where it is possible to transfer such capabilities through market transaction, it is difficult for a company to extract any extra rent from them that has not already been priced into the assets (Teece, Pisano, & Shuen 1997).

Like routines, capabilities evolve over time in a path-dependent manner, thus leaving companies in different starting positions, for example when faced with new technological challenges. Yet, both concepts describe two distinct aspects of the same process of organizational development. Indeed, it can be argued that routines and capabilities have a symbiotic relationship. Routines are the process by which companies search for opportunities and evaluate their options according to their capabilities. At the same time, since search is local,

bounded by the tacit knowledge embodied in the company and its employees. capabilities form the platform from which search activities are initiated.

This consequently links into the distinction made by Mintzberg (Mintzberg 1987) on the origins of strategy-making. Strategy can be a deliberate plan building on the existing set of capabilities and routines in a company. In an evolutionary perspective of strategy-making, this is carried out through the incremental learning experience with the actual execution of a strategic plan and the gradual adaptation of company capabilities and routines. Conversely, where strategies are emergent, capabilities are combined from resources hitherto seen as incompatible or unproductive. Yet, again, in an evolutionary perspective, the learning experience in the competitive environment provides companies with the opportunity to recognise new capabilities and to start formulating more deliberate strategies around them. This recognizes the incremental nature of change and information acquisition at the level of the firm, discussed in section 2.2.1.

Teece et al. consider that "indeed, if control over scarce resource is the source of economic profits, then it follows that such issues as skill acquisition, the management of knowledge and know-how, and learning become fundamental strategic issues." (Teece et al. 1997:514).

It is this learning experience that links capabilities and strategy over time. Strategy in this context is the link between the internal processes and capabilities of a firm and their application in the external environment. Feedback or 'experience' with actually performing a strategy is informing routine processes and guides the decision to adapt capabilities. Thus, strategy provides "a perspective that cuts across the boundary of the organization, matching capability (an aspect of the organizational context) with opportunity (an aspect of the environmental context)." (Rosenbloom 1978:228) Hence, strategy can be considered the result of an organizational learning process, but also its key input over time. As Burgelman and Rosenbloom put it, "Capabilities give strategy its force; strategy enacted creates experience that modifies capabilities" (Burgelman & Rosenbloom 1989:19). Figure 5 summarizes this relationship.

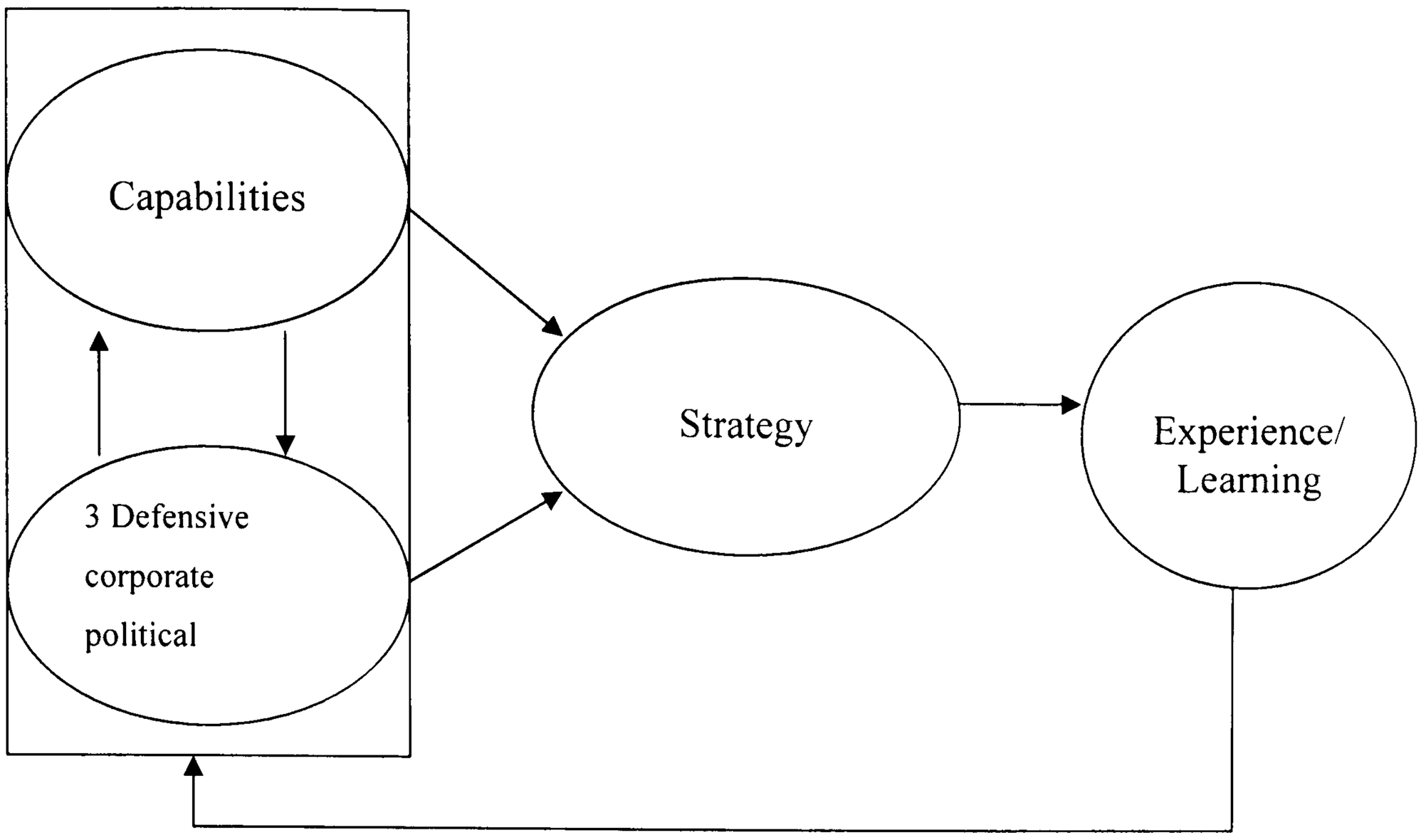


Figure 5: An Organizational learning framework of strategy-making (adapted from Burgelman and Rosenbloom 1989:5)

With this framework in mind, companies have in principle two routes through which to pursue their strategy. Firstly, they can explore opportunities to build capabilities and find niches in the market where they can capture a unique position. Alternatively, they can explore to what extent the market rules can be changed so that an existing set of capabilities becomes more profitable. Both options will be discussed in turn in the subsequent sections.

The Strategic Management of Technology

Having reviewed some of the basic concepts that seek to explain the internal context of the firm, it is now possible to examine in detail how a company can manage its technological capabilities in a strategic way.

The idea on which the technology strategy literature builds suggests that the technology strategy of a firm has to fit into its broader strategic goals (Porter 1983; Freeman and Soete 1997). Porter (1983:9) captures this succinctly: "Competitive Strategy is an integrated set of policies in each functional activity of the firm that aims to create a sustainable competitive advantage. Technology

strategy is but one element of an overall competitive strategy and thus must be consistent with and reinforced by the actions of other functional departments."

What this view on technology strategy suggests is that the specific organizational context of the firm is as important to the firm's strategic decision as are the wider developments around a firm's boundaries. So, the decision whether to engage in the addition of specific technological capabilities or not has to be considered not just in the context of the market (i.e. specific government programmes and subsidies) but also in terms of a firm's existing capabilities and routines. Firms have developed a set of capabilities in the past and operate unique routines for refining and adding to this capability set. Thus, the decision for the direction of new capability additions and/or refinements is set in the context of the historic development of the firm so far, and resource constraints limit the scope of involvement in any one activity and mandate the setting of priorities in each time period considered. Recent research has stressed the idiosyncratic nature of the discovery of new strategic opportunities (Denrel, Fang, & Winter 2003) as well as the localised co-evolution of learning and dynamic capabilities (Zollo & Winter 2002).

As noted, when evaluating new technological options, a company's search will initially be guided by its existing set of capabilities and routines. This influences the perception of expected market sizes, future technological development and impact on the competitive environment of the firm (Christensen 1997). Consequently, when evaluating technologies that require radically different capabilities, established companies are often observed not to capture the full scope of commercial opportunities, at least initially (Rosenbloom & Christensen 1998).

A second argument for the failure of incumbents to align their strategies to new technologies lies in the nature of a particular innovation and whether it appears to sustain or disrupt established markets of the firm (Christensen 1997). In this distinction, the difference between the types of innovation is not found in the character of the technology itself, nor in its impact on the company`s existing capabilities. Rather, the focal point may be the contribution an innovation can make to serve the needs of an incumbent's established customer base (its `value

network' – Christensen 1997). Thus, 'sustaining' innovations would add value to the business proposition presented to an incumbent's customers, while 'disruptive' innovations would be outside the demands of this particular value network. In an empirical study of the disk drive industry, Christensen and Rosenbloom found that incumbents were leading innovators "as long as the technology addressed customers' needs within the value network in which the incumbents competed." Conversely, "[new] entrants led in developing and adopting technologies which addressed user needs in different, emerging value networks. It is in these innovations, which disrupted established trajectories of technological progress in established markets, that attackers proved to have an advantage." (Christensen & Rosenbloom 1995:233)

So, in general, the strategic management and innovation literature points to the tension between radical new technologies and the ability of incumbent companies to adopt them. Incumbents tend to be good at doing innovative activity that builds on their existing technology portfolio, either where new technologies build on the same capabilities assembled in a company, or where the resulting innovations serve the needs of an incumbent's established customers. Organizational capabilities are difficult to create and costly to adjust, a fact that tends to favour incremental or sustaining innovations over radical or disrupting ones (Nelson & Winter 1982;Tushman & Anderson 1986;Christensen 1997).

Yet, companies that are aware of these limitations frequently decide to invest small amounts of resources to explore new technologies and develop associated capabilities outside their main business lines. This is consistent with the real options view of investments as developed by Dixit and Pindyck (Dixit & Pindyck 1995). This view builds on the basic idea that investment decisions have to be made under uncertainty or in conditions of bounded rationality and argues that by splitting investments into a series of small increments, a company can gain knowledge over time and thus make a more informed decision later on. On the one hand, this limits losses, should it become clear that an investment will not be profitable. But more importantly, it also allows a company to explore a wider range of potential opportunities that might not look profitable at the outset but require more information to make an informed decision. In this way, a company

can become involved in potentially 'disruptive' innovations, which might not have appeared profitable at the outset. Consequently, research and development (R&D) investments based on such strategies have been labelled "admissions tickets into a knowledge community", allowing a company to gain knowledge and stay abreast of technological developments should they become more profitable in the future. Such 'options' investments can be one source of an emergent company strategy.

The crucial question for incumbents, however, is whether they can turn technological know-how into a marketable competitive product. Section 2.2.1 discussed organizational mismatch as one source of failure to exploit new opportunities. The argument put forward now is that specific innovative activity is only carried out where technological development fits into the overall company strategy. Thus, Rosenbloom and Christensen (1998) qualify the observation about incumbents' ability to exploit new innovations in that the challenge lies less in understanding and developing new technologies *per se* but in changing and adapting strategy towards them. Consequently, the challenge is less to anticipate new technologies *per se* but to integrate them within the overall strategic aims of the firm (Porter 1983). Thus, newly acquired capabilities will be worthless where companies fail to build a strategy around them.

This is underpinned in a recent report to the Pew Centre on Global Climate Change on the investment cycles of large industrial companies into new technologies (Lempert et al. 2002). Lempert et al. found that there was no specific recurrent cycle in the investment patterns of the firms surveyed in the study. Rather, decisions about upgrading company processes and investing into more efficient technologies were driven by the strategic context of the firm and the ability to leverage such investments in the context of its wider market approach.

In another example of the interaction between technology and strategy. Porter provides a generic overview of the types of strategies that are available in a given market environment (Porter 1983). He proposes a distinction between a focus on cost-leadership or differentiation, either in the mass-market or in a focused segment of the market. Technology can play a role in positioning a firm

in each of these strategies, as outlined in Table 1. In each case, technology is used to underpin a specific strategic stance in the market. A mismatch between technology strategy and overall strategy can dilute the success of such management approaches.

What this example suggests is that technology can play a central role in defining a company's strategic stance. The type of product or process development will be decided according to the strategic differentiation a company aims for. Where a company decides to focus on overall cost leadership, it will aim to develop products and processes that allow mass production and scale economies, while companies focusing on overall differentiation might be more interested in the specific attributes of its products and services in terms of quality and design (Porter 1983).

Table 1: Technological Policies and Generic Competitive Strategies (from Porter 1983:11)

Generic Strategy				
	Overall Cost Leadership	***Overall Differentiation***	***Focus-Segment Cost Leadership***	***Focus-Segment Differentiation***
Technological Policies				
Product Technological Change	Product development to reduce product cost by lowering materials content, facilitating ease of manufacture, simplifying logistical requirements etc.	Product development to enhance product quality, features, deliverability or switching costs	Product development to design in only enough performance for the segments needs	Product design to exactly meet the needs of the particular business segment application
Process Technological Change	Learning Curve process improvement Process development to enhance economies of scale	Process development to support high tolerances, greater quality control, more reliable scheduling, faster response time to orders and other dimensions that improve the ability to perform	Process development to tune production and delivery system to segment needs in order to lower costs	Process development to tune the production and delivery system to segment need in order to improve performance

What follows from this is that technological choice will have to be evaluated not only in terms of the technological features of an innovation but in terms of the company-internal context and the market it will have to compete in. This in turn is the defining principle for strategic management decisions. While entry into a new technology can be based on the options approach (Dixit & Pindyck 1995), any larger scale commitment needs to be set in the context of the wider strategic goals and resources of the company.

Where new technological opportunities appear unattractive to a company, an alternative strategic route is direct intervention in market rules and institutions thus limiting the scope for a new technology to be exploited. This course of action has been explored in the 'corporate political activity' and institutional literature and will be critically reviewed below

Corporate Political Activity

Porter (1983) recognized that one potential path to gain competitive advantage in an industry is to change the rules of competition. Technology can be a carrier for such changes, but often it requires institutional changes to accommodate the specific requirements of new technologies. This can be seen especially in industries under strong regulation, such as the electricity industry, which will be considered in the case studies below (see also Frankenberger 2006).

There are two levels to the argument here. Firstly, as outlined, there is a fundamental premise that organizations do engage in the rule-making process that shapes the institutions in which they operate. Secondly, it can be asked what influences the precise nature of the strategic response to certain institutional environments?

"Institutions [...] are the humanly devised constraints that shape human interaction" (North 1990:3) and as such frame the basic rules of competition in a market place. They are not set in stone: Different actors negotiate and change them through channels of political and economic engagement. Institutions set the

boundaries to the value that can be extracted from individual technologies. In this respect, Eggertsson refers to the 'property rights' that institutions confer on individual investments, in the sense that they limit the value that can ultimately be reaped from them (Eggertsson 1996:8-9). Consequently, a company's strategic considerations include the degree to which it can actively intervene in the institutional rule-making process in order to increase (or decrease) the pay-off from new technologies

Given the case for institutional engagement by individual companies, consequently it can be asked what strategies they might pursue in the institutional field. Oliver (1991) distinguishes responses that range from acquiescence to manipulation, given the particular institutional context in which these decisions are taken. It is assumed that firms fundamentally prefer stability and legitimacy in their business environment over uncertainty and risks. Thus, the lower the degree of legitimacy attainable and the lower the economic gain from conforming to institutional requirements, the higher the likelihood of organizational resistance to institutional changes (Oliver 1991).

Yet, besides this external dimension to institutional strategies, companies also need to consider their own capabilities when determining the potential benefit from institutional changes. There is as yet little analysis in the literature of the strategic interaction between technology choice and the direction of institutional engagement by individual firms. The 'corporate political activity' (CPA) literature has been focusing extensively on the reasons for firms to engage in political activities and has identified numerous tactics, such as lobbying, advocacy advertising, constituency building, financial contributions, and coalition formation, which firms undertake to manage their political environment (Oliver & Holzinger 2008).

Nevertheless, a recent review of work in the CPA literature in fact highlighted the need to integrate 'political activities' with general 'business activities' (Hillman, Keim, & Schuler 2004). Furthermore, CPA has mostly been classified as a cost and a burden for corporations. Yet, institutional engagement, if used strategically, can be considered a key capability of a firm itself that can

potentially contribute to the value created by its activities (Oliver & Holzinger 2008). There has been little analysis of the strategic development of institutional-engagement capabilities in their own right and their value to the firm, albeit Holzinger and Oliver have recently provided a dynamic capabilities framework (Oliver and Holzinger 2008). They conclude that "in contrast to the conventional economic wisdom that firms outcompete rivals by offering higher quality or lower-priced products, [...] firms may also out-compete rivals by employing strategies that shift the supply curve of rivals upwards. Proactive lobbying efforts that result in public policies that prevent rivals from using substitute resources to those valued resources possessed by the lobbying firm (e.g. a new pollution control production technology) constitute a shift in the industry's supply curve that can raise rivals' costs or erode their competitive advantage. (Oliver & Holzinger 2008:36)"

Hence, the CPA literature fundamentally confirms the value of positioning a firm with regard to its competitors in an industry. Yet, rather than adapting their capabilities to the industry they are competing in, recent contributions have focused on the scope for firms to use political influence in order to adapt market environments to their particular capability set. This becomes particular important where industry regulation and public policy has a significant influence on industry competition, a feature directly applicable to the electricity industry. Here, markets for certain technologies can be effectively 'shut' or 'opened' by specific policy measures.

2.2.3. Discussion and Summary

The previous sections have outlined the contributions that organizational theory and the strategic management literature can bring to the understanding of the role of incumbent electric utility companies in the commercial adoption and diffusion of new RETs.

Three arguments have been put forward why incumbents might not realise the full potential of radical new technologies, such as RETs. Firstly, a mismatch

might exist between the organizational structure of a company and the requirements of a new technology. This can be found at different levels. Firstly, the size and overhead of a company might mandate certain minimum return criteria on investment, which in turn narrows the menu of suitable technology investments. More fundamentally, established company routines in a boundedly rational environment can prevent companies from identifying innovations in the first place.

In principle, companies have several options to cope with emergent innovations. Christensen and Overdorf (2000) suggest that in order to free an innovation from the structural inhibitions inherent in an established company, it should be developed in a separate spin-out venture. Furthermore, the options approach developed by Dixit and Pindyck (1995) outlines how investments into new technologies can be done in relatively small increments to learn more about their potential over time and thus put a company in a more informed position once it is ready to make a more substantial investment.

Yet, even where new technologies are properly understood, it is secondly argued that incumbents often find it difficult to formulate adequate strategies towards them (Rosenbloom & Christensen 1998). If innovations do not 'fit' into the strategic priorities of an incumbent, they might be disregarded despite their potential. Empirical observation show that 'discontinuous' or 'competence-destroying' innovations arise mostly outside the bounds of incumbent firms (Tushman & Anderson 1986). As will be further argued in section 2.3.2, in the case of the electricity industry, new small-scale technologies could erode the value of sunk investment in generation and transmission assets of established companies. Given the ownership of most conventional generation plant by large utilities, it is not in their interest to be competitively or otherwise forced to invest in radically new technologies while existing investments are still being depreciated (Neuhoff 2005).

Thirdly, given the scope for corporate political activity to influence the markets in which new technologies will be introduced, companies actually have the option to slow down or speed up their diffusion by means of political

intervention rather than direct market competition. Aldrich and Whetten (Aldrich & Whetten 1981) have long argued that dominant organizations in a network industry resist technological change unless it works to their advantage. As has been outlined in the section on lock-in, the dominant market position of utilities is partly based on the given 'technological paradigm' of the present electricity system. This potentially presents large barriers to new entrants. New technologies, such as small-scale renewables provide a technological threat to this set-up and could thus provide an entry door for new competitors, changing the rules of the game and challenging conventional corporate structures (Jacobsson & Lauber 2006).

Yet, there is a gap to bridge between company level incremental investments and industry-wide diffusion of new technologies. Throughout the previous sections, various potential obstacles have been highlighted that render the process of adopting emergent innovations by incumbent companies increasingly difficult. These processes are related to the short-run issue of positioning a firm in its industry and the strategic adaptation of company objectives. However, as highlighted by Rip and Kemp (1998), technological artefacts are embedded in economic and political institutions and continuously modulated and shaped by societal interactions, a fact particular salient in the electricity industry. Thus, technology diffusion is a long-run process that typically requires several decades and involves reconfigurations not only at the company level but at wider systemic levels such as market institutions.

Hence, while the various contributions in the literature outlined above examine particular aspects of the short-run impediments to technology adoption in incumbent companies, what is missing is an integrated long-run perspective that specifically examines the interactions of these wider reconfigurations.

Consequently, for the purpose of this research, it was decided not to restrict the unit of analysis to a partial view of the industry, but to use the systemic interactions between technologies, organizations and their institutional embedding as the focal point for the research. Furthermore, as noted, the timescales involved in technology diffusion are often different from the short-run investment horizon

that fits into the strategic management analysis, warranting a framework that allows for these systemic interactions over time.

As a final part of this chapter, the next section will consequently review the co-evolutionary and specifically the 'systemic innovation' literature, which provides a reference point for building a systemic framework for the research considered in this thesis.

2.3. *Co-Evolution and the Systemic Innovation Literature*

This section is divided into three parts. It will firstly give an overview of the variety of co-evolutionary and systemic approaches to innovation, outlining the breadth of possible applications depending on the specific research question investigated. Secondly, it will explain further the reasons for choosing the specific technological innovation systems approach as the focal point for my own study, and outline this approach in more detail. Lastly, it will discuss the limitations of this approach, which consequently links into the final discussion of the literature reviewed in this chapter and the elements employed in the analytical framework which will be developed in Chapter 3.

2.3.1. Co-Evolutionary and Systemic Studies of Innovation - Overview

In the general management and organizational science literature, research has aimed to explain such diverse phenomena as competitive advantage of firms and industries (Van de Ven et al. 1999;Murmann 2003), as well as vertical integration of industry structure (Jacobides & Winter 2005) through co-evolutionary arguments. These studies' aim is to combine multi-disciplinary approaches to establish a more contextualised and historically grounded explanation of their study subjects and thus provide novel answers to established problems.

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Van de Ven et al.'s study (1999) is the result of a large-scale research programme of longitudinal studies tracking fourteen diverse innovations in different settings over time. They find that innovations occur neither sequentially nor orderly. Rather they are best characterized as a nonlinear dynamic system. The research specifically investigates the development of corporate cultures for innovation within a company and its interaction with institutional rules to trace cycles of innovative activity. In this approach, the research question focused especially on the organizational context for innovation and the way in which policy-makers (through the interaction of companies and institutions) can foster such innovation-conducive environments. Thus, co-evolutionary processes were investigated in the context of policy-making and the resultant impact on management activity.

Conversely, Murmann (2003) uses an economic-historic approach to compare the development of an entire industry, the synthetic dye industry, in the UK, Germany and the United States. He considers the co-evolution of national institutions (such as educational system and patent laws), firm population and technological advances to establish why British synthetic dye manufacturers, despite being the first to develop this technology, ultimately lost their competitive advantage to German companies. Murmann argues that different co-evolutionary feedback loops between the institutional, organizational and technological sphere in Germany and the UK were responsible for the industrial leapfrogging that occurred.

Importantly, Murmann (2003) argues that a focus on any one the three dimensions alone – institutions, organizations and technology – would have been insufficient to fully understand the differential development that occurred. Superficially, the UK was endowed with better natural resources and the United States had a stronger entrepreneurial culture. Yet, in analysing the *co-evolution* of the three dimensions, Murmann was able to demonstrate the differential development between the three countries and hence explain the differential fortune of the three national industries.

In another co-evolutionary approach, Jacobides and Winter (2005) combine recent contributions from the economic transaction-cost literature with the recourse-based view of the firm (as also developed in section 2.2.2) to provide novel answers to the question of when industries vertically integrate and dis-integrate. Again, the importance of a systemic and co-evolutionary approach is highlighted in order to obtain both a *complete* picture of an industry and of its development *over time*. Using evolutionary language (as outlined in section 2.2.1), Jacobides and Winter argue that search activity and selection of capabilities is dependent on the evolution of transaction costs in an industry, which consequently amplifies trends towards specialisation or vertical integration over time. This in turn impacts on the 'roster of participants' in an industry and hence the pressure to widen or shorten search criteria for novel capabilities.

In summary, the essence of co-evolutionary arguments in this literature is two-fold. Firstly, they specifically embrace multi-causal explanations for technological change, with such change seen as a process transcending changes in technological artefacts alone. Technological change is explored using several dimensions, such as technological artefacts, organizational adaptation, market designs, and wider institutional rules. Secondly, this literature specifically emphasise the inter-dependent evolution of these dimensions. Changes in one dimension create tensions with the others, thus triggering further changes and creating continuous feedback loops between the different dimensions. Indeed, March (1994) argues that "...one of the more important post-Aristotelian developments in evolutionary theory is the emphasis on endogenous environments, on the ways in which the convergence between an evolving unit and its environment is complicated by the fact that the environment is not only changing but changing partly as part of a process of co-evolution. There is *mutual adaptation* between the unit of co-evolution and the environment." (March 1994:43)

In this tradition, a particular approach for the study of innovation at different levels has been the 'systems approach' to innovation. Delineating specific 'systems' allows researchers to set 'boundaries' for their research field and consequently to study interactions within these limits. Recent examples have

been work on 'carbon lock-in' (Unruh 2000;Unruh 2002), 'socio-technical regimes' (Kemp & Rip 1998), 'technological transitions' (Geels 2002;Geels 2004) and 'innovation systems' (Edquist 1997b;Carlsson et al. 2002;Nelson 2002;Jacobsson & Bergek 2004). While details differ between these approaches, they broadly consider technological change not just in terms of developments of physical technologies but as a process interacting with changes in wider socio-economic structures. Hence, this class of approaches to innovation studies will subsequently be called 'systemic studies of innovation'.

Systemic approaches to innovation have been built on 'co-evolutionary' perspectives of technological change (Edquist 1997a;Nelson 1998) and are characterised by slow-moving, incremental change due to the interlinked nature of various variables from the economic, social, institutional and technological sphere. This perspective is especially useful in the analysis of complex systems such as the electricity industry, which has been conceptualized not just in terms of the electricity generating technology, but in terms of the market set-up, organizational structure, policy environment and academic discourse in the field (Hughes 1987;Jacobsson & Bergek 2004;Tsoutsos & Stamboulis 2005). Kemp and Rip consequently refer to stable technological systems as "configurations that work" (Kemp & Rip 1998:338), while innovation is seen as a 'reconfiguration' of a set of variables, a process involving 'modulating' and 'shaping' existing regimes (Berkhout & Gouldson 2003).

Depending on the specific perspective taken in the various contributions to the systemic innovation literature, boundaries are set in different ways around the system. Typically, key parameters in these studies include:

- Number and type of dimensions in a system
- Level of analysis– macro-level to niche
- Timeframe – ongoing, months, years, decades
- Geography – region to nation to global (Carlsson, Jacobsson, Holmen, & Rickne 2002)

Geels, in his study of technological transitions in the shipping industry from the sailing ship to the steam-engine propelled boat, used a multi-level framework, including niche developments but also examining the macro-level landscape. Within this, he identified seven dimensions that influenced the socio-technical dynamics: "technology, user practices and application domains (markets), symbolic meaning of technology, infrastructure, industry structure, policy and techno-scientific knowledge" (Geels 2002:1262). The timeframe included in his study encompassed 120 years between 1780 and 1900 and involved the global shipping industry and its changing usage of different types of boats from the early sailing ships to the modern steamships.

Conversely, Jacobsson et al. in their study of German solar cell technology developments focused on just one country and technology and a limited time-period of 25 years (Jacobsson, Andersson, & Bangens 2004). Three elements of the 'technological innovation system' around the solar cell industry were examined: Actors and their competences, market and non-market networks among them, and the institutions in which they are embedded. The main concern in their study is the development of 'functions' that the technological system fulfilled in order to become self-sustainable. In this way they trace one technology along its development from niche to larger markets and the way in which actors, their networks and the wider institutions can adapt to accommodate further development or, indeed, can also slow it down.

Finally, Malerba proposes a focus on sectoral innovation systems to examine "a set of new and established products for specific uses and the set of agents carrying out market and non-market interactions for the creation, production and sale of those products" (Malerba 2002:250). Hence, this concept transcends both specific technological and national boundaries, with sectors being located sometimes in small regional clusters, yet sometimes also spanning global networks, as, for example, within multinational corporations.

The approaches outlined above echo the 'technological paradigm' perspective and the evolutionary-economic view on technological development, which similarly assume the formation of networks around emerging technologies

that consequently can define research agendas and influence companies' search processes (Nelson & Winter 1982;Dosi 1982). Hence, systemic approaches to innovation actually build on the same literature as outlined in the sections 2.1. and 2.2., which is reflected in the recent remark by Nelson that "the development of the conception of an innovation system [...] has largely been the work of economists and other scholars of technology advance who adhere to an evolutionary theory of economic growth" (Nelson 2002:265).

Still, the examples given above are but a small sample of studies that serve to outline the breadth of applications possible within the systemic innovation literature. In selecting the boundaries for the research in this thesis, the focus was on a framework that examines "...the competition between emerging technologies and incumbent technologies (and between the associated technological systems)" (Jacobsson, Andersson & Bangens 2004:5). This closely matched the technological innovation systems (TIS) approach as developed by Jacobsson et al. (Carlsson, Jacobsson, Holmen, & Rickne 2002;Jacobsson, Andersson, & Bangens 2004;Jacobsson & Bergek 2004). Its technology specific features and evolutionary-systemic character fit closest with the research questions pursued in this thesis.

2.3.2. Technological Innovation Systems

As outlined in Carlsson et al. (2002), TISs can be studied at different levels of analysis. Hence, the approach can be applied "...to technology in the sense of a knowledge field, to a product or an artefact, or finally to a set of related products and artefacts aimed at satisfying a particular function... a competence block" (Carlsson, Jacobsson, Holmen, & Rickne 2002:237). An example for the first level of analysis would be to open up the black box of wind energy technology and analyse the reasons for specific technological developments, for example direct-drive vs. gear box equipment or pitch vs. stall blades. However, this will not be the subject of this research. Instead, the interest is on the second and third levels of analysis, where the focus is on the specific relationship between a product and the market in which it is introduced. As Carlsson et al.

(2002:239) argue, "...a knowledge-based approach would tend to be concerned with technological problem-solving activities...whereas a product focus would tend to be chosen when the primary interest is in diffusion and use of new technology..." - which indeed is the focus of this study.

Jacobsson and Johnson (2000) outline a specific analytical framework for the investigation of the diffusion of RETs. This is based on the original notion of a technological system, introduced by Carlsson and Stankiewicz, who define it as "...network(s) of agents interacting in a specific technology area under a particular institutional infrastructure to generate, diffuse, and utilize technology. Technological systems are defined in terms of knowledge or competence flows rather than flows of ordinary goods and services. They consist of dynamic knowledge and competence networks." (Carlsson & Stankiewicz 1991:111) As in Jacobsson et al. (2004), three components are considered: Actors (and their competences), their associated networks, and finally the institutions in which they are embedded.

Here, and in subsequent work by Jacobsson et al. (Jacobsson & Johnson 2000;Johnson & Jacobsson 2001;Johnson & Jacobsson 2003;Jacobsson, Andersson, & Bangens 2004;Jacobsson & Bergek 2004), the main focus is on the process of creating a self-sustaining innovation system, which is able to carry a new technology from niche applications to the mainstream market. In this, it is stressed that "...the innovation and diffusion process is both an individual and collective act. The determinants of this process are not only found within individual firms; firms are embedded in innovation systems that aid and constrain the individual actors within them" (Jacobsson, Andersson, & Bangens 2004:4-5).

Building on the technology 'life-cycle' literature, technological development is conceptualised in terms of functions that need to be fulfilled by a system in order for a technology to be successfully improved and shaped to compete in the market. Hekkert et al. (2006) define functions as "the activities that contribute to the goal of innovation systems."

Jacobsson and Bergek (2004:818) identify five such functions:

- The creation and diffusion of new knowledge,
- The guidance of the direction of search among users and suppliers,
- The supply of resources such as capital and competencies,
- The creation of positive external economies,
- The formation of markets.

By focusing on the interactions between the constituent parts of an innovation system, both in terms of resource and information flows, it is possible to identify which functions are working well, and which functions are insufficiently developed. Where functions are well-developed, a system develops self-sustaining feedback loops, which aid the development and diffusion of new technologies into broader markets. Where functions are not developed, specific policies and measures can be targeted to overcoming potential obstacles (Jacobsson and Bergek 2004).

A key theme in the technological innovation systems literature is the competition between established and newly emerging systems. Hence, functions of new innovation systems are analysed in terms of 'inducement' and 'blocking mechanisms' for their further development. While 'new firm entry' is seen as unambiguously inducing the development of key functions such as the 'creation of new knowledge', the 'supply of resources' and the 'formation of markets', "ambiguous" behaviour by established firms is seen as having the reverse effect of blocking the development of such functions (Jacobsson and Bergek 2004:825ff).

Analogous to the 'technological paradigm' language, established systems are a closed network of agents and their competencies, embedded in a particular socio-economic rule-set, with a well-developed set of supporting functions. Where the economic basis of such a system is threatened by an emerging innovation system, it is expected that resistance towards the functional development of an emergent innovation system will be exerted by the established actors. With regards to the energy system, Jacobsson and Bergek (2004:826-827)

state that "the ambiguous and/or opposing behaviour of some established energy suppliers and capital goods suppliers has reduced the legitimacy of renewable energy technology and has, thus, blocked the supply of resources and guided the direction of search away from these technologies [...] it has also added to customer uncertainty and vulnerability, which has blocked market formation and delayed important steps in the knowledge-creation process."

Given this potential for obstruction, government policy is seen as a key cornerstone to aid the formation of the five functions mentioned above. Especially in the early stages of a technology's life-cycle, support for knowledge creation, the supply of resources and (niche) market formation are seen as critical for the creation of a self-sustainable innovation system. However, where policy fails to deliver such objectives, it can turn into a 'blocking' mechanism itself (Jacobsson and Bergek 2004).

While the TIS approach provides a comprehensive macro-level perspective on technology competition between different technologies and their supporting structures, it has not yet developed a comprehensive micro-level rationale for the behaviour of individual agents in the systemic context. For example, while the explanations for incumbents' behaviour with regard to an emerging TIS are intuitively appealing, in reality many different modes of behaviour can be observed, not all of which are consistent with the explanations provided by the TIS literature. Consequently, the next section will review some recent criticisms.

2.3.3. Critique of the TIS Approach

Critics have centred on three features of the analytical framework employed by the TIS approach. Firstly, it is argued that although governments are assigned an important role in the systemic dynamics through the role of policy, their constraints and the general dynamics of policy-making are under-represented. For example, incumbent companies can exert significant pressure on policy formulation and are often in an advantageous informational position

relative to regulatory authorities (Kern & Smith 2008). Hence, issues of power-relations and agenda setting need to be taken into account more explicitly (Smith, Stirling, & Berkhout 2005).

Secondly, Smith et al. (2005) argue that explanations of technological change in the systems perspective rely strongly on structuralist arguments and leave little room for individual agency. Furthermore, the role of individual actors is interpreted in functionalist terms with regard to their contribution to the overall system, neglecting the specific context in which agents are embedded. Hence, incumbents are often considered to block the introduction of novel technologies because of their structural position within the system. Similarly, Hekkert et al. lament that "the innovation system framework suffers from institutional determinism" and hasn't sufficiently developed an explanation for the "actions of the entrepreneur" (Hekkert et al. 2006).

A related critique of co-evolutionary research in general concerns the depth in which co-evolutionary processes can be demonstrated to occur. An important consideration for co-evolutionary studies is to establish a precise causal mechanism by which two study subjects co-evolve. As Murmann (2003:22-23) argues that "co-evolution may be mimicked by such things as sequential adaptation from different causes or simultaneous adaptation to the same environment." Hence, it is central for co-evolutionary research to establish "the bidirectional causality linking the two parties in the relationship… The key challenge for such arguments is to establish that causal processes indeed do connect the two partners in a co-evolutionary relationship." In focusing on structural arguments and functional arguments, an empirical problem arises to demonstrate the precise mechanisms that connect individual agents in a systemic framework and the causal link of their co-evolutionary relationship. Without a deeper notion of individual agency within systemic structure, the reasons for individual actions that deviate from what can be expected based on a structural and functional analysis are hard to identify.

A last criticism centres on the role and properties of the system's functions. It is worth remembering that systems as such do not have a leader or an

explicit direction on which everyone agrees. Rather, they are the sum of the individual actions and expectations of each system's constituent parts. What Smith et al. (2005:1492) label the "...tendency to treat regime transformation as a monolithic process dominated by rational action and neglecting important differences in context" seems to stem from a cognitive approach that implies a knowledge of the ultimate goal on behalf of each individual actor and a resultant rational behaviour to attain that goal. Yet, where uncertainty prevails and knowledge is fragmented, evolutionary theory suggests various modes of learning, knowledge interactions and trial-by-error as dominant responses (Simon 1955; Arthur 1994). Hence, as will be argued later in chapter 5, functions in this context can be conceptualised as 'emergent properties' of the system that arise as the accumulation of many individual interactions, each with their own purpose and context.

In summary, critics have called for more attention to the way actors can respond differentially to changes in common systemic variables and to the implications this has for the analysis of systemic change. Authors have attempted to address this criticism by focusing on the expectations of individual actors. This has allowed a link between future states of the world and present actions. Furthermore, by explaining the formation of expectations in terms of the socio-economic context and power structures within systems, it has allowed for a view of technological change that retains the notion of social embeddedness (Geels 2004; Smith et al. 2005).

Yet, in this literature, shifts in expectations have often been linked directly to shifts in behaviour. For example, Geels states that "[i]mportant cognitive rules are shared belief systems and expectations, which orient perceptions of the future and hence steer actions in the present" (Geels 2004:910). However, as has been argued in section 2.2.2, expectations in a company context have to be embedded into a wider strategic rationale in order to lead to concrete actions. Hence. the challenge is less to anticipate and develop new technologies *per se* but to integrate them within the overall strategic aims of the firm (Porter 1983). Hence, it can be argued that shifts in companies' expectations do not necessarily lead directly to shifts in behaviour but are filtered through the corporate strategy lens.

In summary, the TIS approach provides a comprehensive framework to capture key dimensions that impact on the diffusion of new technologies such as RETs. It builds on an evolutionary view of technology development that emphasizes incremental change and the importance of knowledge networks and the social dimension of the technological diffusion process in organizations and institutions. Yet, while the research has been able to penetrate deeper into the structural and socio-economic context of innovations, models of the motivations and behaviour of individual firm to complement the systems approach have failed to keep pace. Consequently, integrating elements from the organizational theory and strategic management literature, as outlined in section 2.2, could fruitfully extend the current analytical framework.

2.4. Summary and Discussion

The starting point for this chapter was the recognition that technological diffusion does not depend solely on the properties of the technological artefact but also on the properties of the wider market environment in which it is introduced. In order to analyse the role of incumbent companies in the diffusion of renewable energy technologies and following Rip and Kemp's (1998) definition of technology, an appropriate framework was sought that captured developments at the level of individual firms and market institutions as well as technologies themselves. Consequently, this chapter has critically reviewed three different literatures that can contribute to the research questions pursued in this thesis.

Each literature opened the black box of technological development to offer a partial insight into the underlying processes. However, none was deemed appropriate on its own to offer a comprehensive picture of the complex interactions at work. Table 2 summarizes the key messages of each literature with regard to three key dimensions of technological development – technological artefacts, organizations and institutions.

Table 2: The treatment of technologies, organizations and institutions in the three literatures

	Technology-Diffusion/ Increasing-Return Models	**Organizational Theory and Strategic Management**	**Technological Innovation System**
Technology	Cumulative Learning, Increasing returns	Strategic positioning device; dynamic capability	Competing systems, modulated and shaped by system interactions
Organization	Lock-in	Routines and bounded rationality; strategic adaptation	Inducing or blocking system functions
Institutions	Increasing returns	Corporate political strategy	Co-evolution with technological artefacts

Having commenced the review with simple technology diffusion models, their lack of a firm theoretical grounding and high level of abstraction from specific contexts was noted. Besides these abstract models, those focusing on increasing-returns diffusion paths offer some degrees of sophistication and complexity. The path dependency literature considers technological development in terms of the increasing returns properties that can be observed in some industries. Here, positive feedback loops reinforce initially small differences among competing technologies to an extent that one eventually dominates the other. This is reflected at an organizational level in the learning captured by the companies undertaking the technological development. Companies will eventually focus on the dominant 'technological paradigm' in order to benefit from complementary investment and higher market certainty. These arguments can be extended to the level of institutions as they, too, face high set-up costs, benefit from learning experiences and complementarities and ultimately reduce uncertainty.

The path dependency argument provides, however, only a partial picture of technological development in abstracting from concrete commercial and technological contexts. The narrative behind path dependency arguments relies on initially random variations, which in their extreme form denies the possibility of

purposeful technological development. Secondly, the path dependency literature only provides a linear story of how technologies can become dominant but not how such path dependencies are consequently overcome. This, lastly, ignores the dimension of strategic decision making within companies, which includes the option of exploring new avenues of technological development and strategic differentiation to overcome states of 'lock-in'.

At this point, the organizational theory and strategic management literature opens the black box of the firm and introduces two important dimensions of organizational decision-making. Firstly, this literature assumes boundedly rational firm environments, in which firms operate organizational routines to search, select and retain new technological options. Secondly, technology adoption by the firm is interpreted as a complex and interactive learning process that is characterized by uncertainty about its future outcome. This provides a firm-level explanation for the emergence of path dependencies and 'technological paradigms', which are interpreted as channelling and stabilising technological development within the firm.

In this context, the strategic management of organizational capabilities becomes the key dynamic decision-making variable to explain organizational development over time. Strategic positioning through the development of unique capabilities in an industry allows a company to gain sustainable competitive advantage. Hence, while the view on organizational structure provides an explanation of which technologies will be selected through organizational routines, the strategic management literature complements this with a company-internal 'demand pull' perspective, whereby technological development becomes a key lever for strategic positioning of the firm. The interaction of both dimensions of organizational behaviour consequently determines the degree and direction of technological development in a firm.

This view is complemented by the analysis of corporate political activity by firms to secure favourable regulatory environments and market designs. However, in this literature, the interaction of corporate political and corporate

business strategy has only received limited attention so far (Oliver & Holzinger 2008;Hillman, Keim, & Schuler 2004).

Hence, while the organizational behaviour literature in general complements the technological diffusion literature discussed earlier, there remain at least two weaknesses. Firstly, the strategic management of technology adoption in the firm is mainly concerned with the short-run positioning of a company, while industry-wide technology diffusion can be a matter of decades (Grubler 1998). Hence, while the strategic management literature provides an understanding of short-run, marginal trade-offs for company investments, it is less helpful in tracing the long-run evolution of a technological life-cycle, which often involves multiple firms at the different stages of maturity (Tushman & Anderson 1986).

Secondly, the organizational theory literature does not capture the reciprocity between firm behaviour and the evolution of social and technical systems alongside these organizations, as evidenced, for example, in the case of the corporate political activity literature. Hence, while specific interactions between companies AND technologies or companies AND institutions have been studied, the wider interactions between these three dimensions to technological development have not been the subject of study themselves.

Hence, the last section of this chapter reviewed the technological innovation systems framework as an example for such a systemic approach. While it builds on the concepts of technological paradigms and bounded rationality and hence provides a good fit with the other two literatures, it has a major drawback in not considering company behaviour in its specific context but rather in terms of the functional and structural embedding within the wider system. Hence, while it provides a framework that studies the interactions between all three dimensions, it so far has not developed fully a rationale for explaining specific individual behaviour within this structural context.

Yet, a key consideration for research in this tradition is the demonstration of a causal mechanism that links the evolution of different dimensions of a

system. As Murmann (2003:22) argues: "Co-evolution may be mimicked by such things as sequential adaptation from different causes or simultaneous adaptation to the same environment." Hence, what is often lacking in systemic innovation research is a detailed mechanism that explains how the inter-connection in a co-evolutionary relationship is causally linked. Consequently, this research seeks to extend existing systemic innovation approaches and address this critique by establishing an extended micro-level explanation for differential individual agency in response to changes at the systems level.

This literature review has provided the basis for such an analytical framework. This will be developed in chapter 3 and situated in the specific context of the electricity industry. It will take key elements from the literature review above to conceptualise the three key dimensions - technologies, companies and institutions - to provide a testable approach to the analysis of incumbent electric utility companies' role in the diffusion of renewable energy technologies.

3. Analytical Framework and Methodology

The guiding question of this research is to analyse the role of incumbent electric utility companies in the diffusion of RETs. In the previous chapter, it was argued that diffusion is a process not just involving technological artefacts alone, but also requiring adaptation of supporting institutions and organizations. Hence, it is necessary to generate insights into the interaction of companies and their wider systemic environment.

In reviewing the relevant literature in the previous chapter, it was argued that each of the frameworks presented had drawbacks which would restrict the analysis of the study subject. Hence, it was proposed that several elements of the existing literature could usefully be combined to an analytical framework that provided a systemic approach to the analysis of the diffusion of RETs that retained a behavioural model for explaining divergent responses by individual companies. The dimensions of such a framework will be outlined in the following sections.

This chapter is structured in three parts. Firstly, section 3.1 will introduce the analytical framework employed in this research. This includes the *technological*, *organizational* and *institutional* dimension to innovation and the interactions among them in the electricity industry. Secondly, in section 3.2, corporate strategy is introduced as a link between company internal activity and system-wide developments. Two specific aspects of corporate strategy will be considered: Technology strategy, which focuses on the link between company capabilities and system-wide technology diffusion and corporate political activity, which examines the effect of corporate lobbying activity on system-wide institutional developments. Lastly, in section 3.3, the research methodology and the case study approach are introduced.

3.1. *Co-evolutionary dimensions for the study of electric utilities and the diffusion of RETs*

As has been argued in the previous chapter, the diffusion of new technologies is both an individual and a collective act (Saxenian 1994). Companies develop capabilities and associated strategies to gain competitive advantage on the back of new technological developments. At the same time, innovation is conditioned by 'technological paradigms' (Dosi 1982) and institutional and organizational inertia.

These considerations warrant a research approach that takes into account the systemic interactions among these dimensions, while retaining a behavioural model of context-specific actions by individual agents. The literature review in the previous chapter highlighted that, while individual approaches can provide partial insights into these dynamics, none is sufficient on its own to investigate the problem of this research study. Hence, an analytical framework is now proposed to close this gap and at the same time provide a novel contribution to the literature in extending the systemic approach to innovation with a strategic dimension.

In the co-evolutionary perspective developed in this section, three dimensions will be considered: *Organizations, Technologies* and *Institutions*. This builds on the literature review in the previous chapter, hence each element will only briefly be introduced again below. Subsequently, Section 3.2 extends this framework by specifically considering strategic approaches to co-evolutionary change on the side of incumbent firms, thus making the framework dynamic. This opens up the black box 'organizations' and examines two strategic decision-making variables: The strategic development of technological capabilities and the strategic institutional engagement.

3.1.1. Organizations

Companies are conceptualised here in the evolutionary and resource-based perspective that has been developed in section 2.2.2. The most important aspect from these literatures for this analytical framework is the development of firm *routines* and *capabilities*, both as determinants of organizational performance and influences on strategic direction.

Routines are used in both the management and systems-of-innovation literature to conceptualise organizational processes. Based on the model originally developed by Nelson and Winter (1982), routines guide the search, selection and retention of options for the allocation of scarce resource within organizations. Routines are set up so that employees can perform tasks in a consistent manner over time and across different functional units of a firm (Christensen & Overdorf 2000). This makes them unique to the company in which they operate and creates path-dependencies according to the specific company's culture and history. However, there is a close relationship between routines and the concept of 'core competences' or 'capabilities' used in the resource based view of the firm (Burgelman, Christensen, & Wheelwright 2004).

Organizational *capabilities* are considered here as the key strategic differentiator between companies. Given differences in the availability of tangible and intangible resources among companies, unique capabilities and corresponding strategies are built to gain competitive advantage (Teece, Pisano, & Shuen 1997;Grant 2005). Hence, 'capabilities' encompass the specific combinations of resources and competences which distinguish a firm relative to its competitors.

Like routines, capabilities evolve over time in a path-dependent manner, thus leaving companies in different starting positions, for example when faced with new technological challenges. Yet, both concepts describe two distinct aspects of the same organizational development. Indeed, it can be argued that routines and capabilities have a symbiotic relationship. Routines are the processes by which companies search for opportunities and evaluate their options according

to their capabilities. At the same time, since search is local, bounded by the tacit knowledge embodied in the company and its employees (Foss 2003), capabilities form the platform from which search activities are initiated.

The development of routines and capabilities provides the company's internal dimension to the systemic interactions arising within this framework. Connecting this view with a systemic perspective on developments in the firm's external environment, such as institutional changes in the market and the availability of new technologies, allows a dynamic picture of co-evolutionary change. A company's development of capabilities is both framed by as well as framing institutions and technologies.

In this context, *strategy* provides "a perspective that cuts across the boundary of the organization, matching capability (an aspect of the organizational context) with opportunity (an aspect of the environmental context)" (Rosenbloom 1978:228). Hence, this research will specifically consider the interaction between organizational capabilities and routines with their external systemic environment. Before outlining the features of this specific approach, the other two systemic dimensions, technologies and institutions, will briefly be outlined.

3.1.2. Technologies

Despite arguing in the previous sections that technological change should be considered as a multidimensional process, for analytical purposes it is here separated out. Hence, '*Technology*' is used in a narrow sense as the current mix of technological artefacts deployed and under development. They require specific *capabilities (see section 2.2.2)* in order to be utilised to serve specific market demands, which can be forecast using 'experience curves' or 'learning curves' (IEA 2000).

Confining technologies to this narrow definition represents the perspective that firms take in a technology-user industry (Neuhoff & Sellers 2006), which is not directly involved in proprietary technology developments. Electric utility

companies focus on the production, transmission and supply of electricity by utilising a set of available technologies. These technologies are developed outside the realm of individual utilities but in specialised technology supplier companies (Hartmann & Boensch 2005;Markard & Truffer 2006). This was confirmed in the course of the interviews for this study, where it was stressed repeatedly that utilities were "*not in the business of technology development*".

Technologies are conditioned by the institutional environment in which they operate. While their technology-inherent features define the overall limit of possible value that can be extracted from them, institutions narrow this range by setting socio-economic limits on the possible applications of a technology. This will now be discussed in the next section.

3.1.3. Institutions

The term 'institutions' is used here in the sense developed by institutional economists, meaning the 'rules of the game' or more formally, the "the humanly devised constraints that shape human interaction" (North 1990:3). Although North distinguishes between formal and informal institutions, the focus here is especially on the development of *formal institutions* such as new markets for technologies. Markets are not considered to arise spontaneously but are conceptualised as the outcome of economic and political conflict (North 1990;Acemoglu 2004). Since market rules influence the allocation of scarce resources, actors will aim to influence rule development according to their own interests.

The notion of *institutional change* in this perspective implies an active involvement of actors with a stake in the institution's outcome. Hence, from a co-evolutionary perspective, the impact of institutions on the potential development of technologies, for example through market introduction programmes, as well as the direct impact on the profit opportunities in a market, are viewed as lying within the scope of a company's policy of corporate political activity (Eggertsson 1996).

As companies develop strategies for their capability developments, corporate political activity becomes an avenue to increase the value in the market of a specific capability and the size of the resultant market share that can be obtained (as discussed in section 2.2.2). Hence, a company's political activity builds on the specific capabilities that have been developed over time. In this sense, corporate political activity is assumed to be aligned with the specific capabilities built within a company. Given the differences of capability developments among firms and the stickiness of them in the short-run (Dosi 1982;Teece, Pisano, & Shuen 1997), specific political activities can diverge among companies with different capabilities.

3.1.4. Interactions between organizations, technologies and institutions

In practice, the above dimensions of the co-evolutionary perspective interact with and reinforce each other over time. Tensions at one level set off realignment processes and co-evolutionary changes at other levels. Using the simple set-up outlined above, specific configurations for the interactions of these dimensions can be identified (Kemp & Rip 1998).

Before using this framework to analyse the strategic decision-making process in companies, an illustration can demonstrate the connections between the different levels. As an example, the historic set-up of the electric utility industry in many developed countries is described below. These patterns were also visible in the three countries that will be introduced as the case study countries in section 3.3.2 below. Historically, this industry has been remarkably stable, which has been widely described in the innovation literature as a state of systemic 'lock-in' due to its historic path of development (Kemp & Rip 1998;Unruh 2000;Neuhoff 2005). There were three aspects to the established institutional configuration in the electricity industry before market liberalisation commenced in the 1990s:

Institutions

On the level of formal institutions, regulated monopolies with guaranteed markets were frequently the norm. State-ownership of electricity companies was witnessed in many countries. Geographically defined monopolies had a duty to supply electricity in return for being sheltered from competition. The aim of universal electrification of the populace and setting up of new infrastructure provided the overriding rationale for this institutional set-up at the outset of the industry[8].

Technology

The concomitant technological configuration consisted of large-scale, mostly fossil-fuel and nuclear power stations, coupled with long-distance high-voltage transmission lines to the load centres. The number of power plants relative to the number of load centres was small and consequently, the size of individual plants was large. These large capital expenditures were justified firstly with the economies of scale to be gained through larger unit sizes. Secondly, however, the captured customer base in a monopoly market meant that the capital-intensive investments could command a low interest rate due to the low-risk of recouping the initial capital outlays as long as technology risks were understood.

Organizations

Finally, the organizational structure was centred on the model of a vertically integrated electricity company that owned assets in generation, transmission and distribution, and retailing. In some countries, integration even stretched back into fuel supply, mainly in domestic coal mines. In this context, system planning was integrated in one organization and technological choice and the direction for new innovations mirrored the organizational and institutional

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[8] Hannah (1982) outlines how the electrification of remote areas in the UK was secured through cross-subsidies from urban areas within the nationalised electricity industry. The prevalent socio-technical configuration at the time served this purpose very well in the context of the post-war expansion of electric services.

structure, one reinforcing the other (Hannah 1982;Unruh 2000;IEA 2001;Helm 2003).

The triangle institution-organization-technology in Figure 6 below summarizes the relationship between these three dimensions. This basic structure proved to be stable over several decades in many European countries, and specifically in the three countries that formed the basis for the case studies presented in this thesis. In the absence of outside shocks, the interdependence between the technological and socio-economic dimensions provided the path along which re-configurations were gradually channelled.

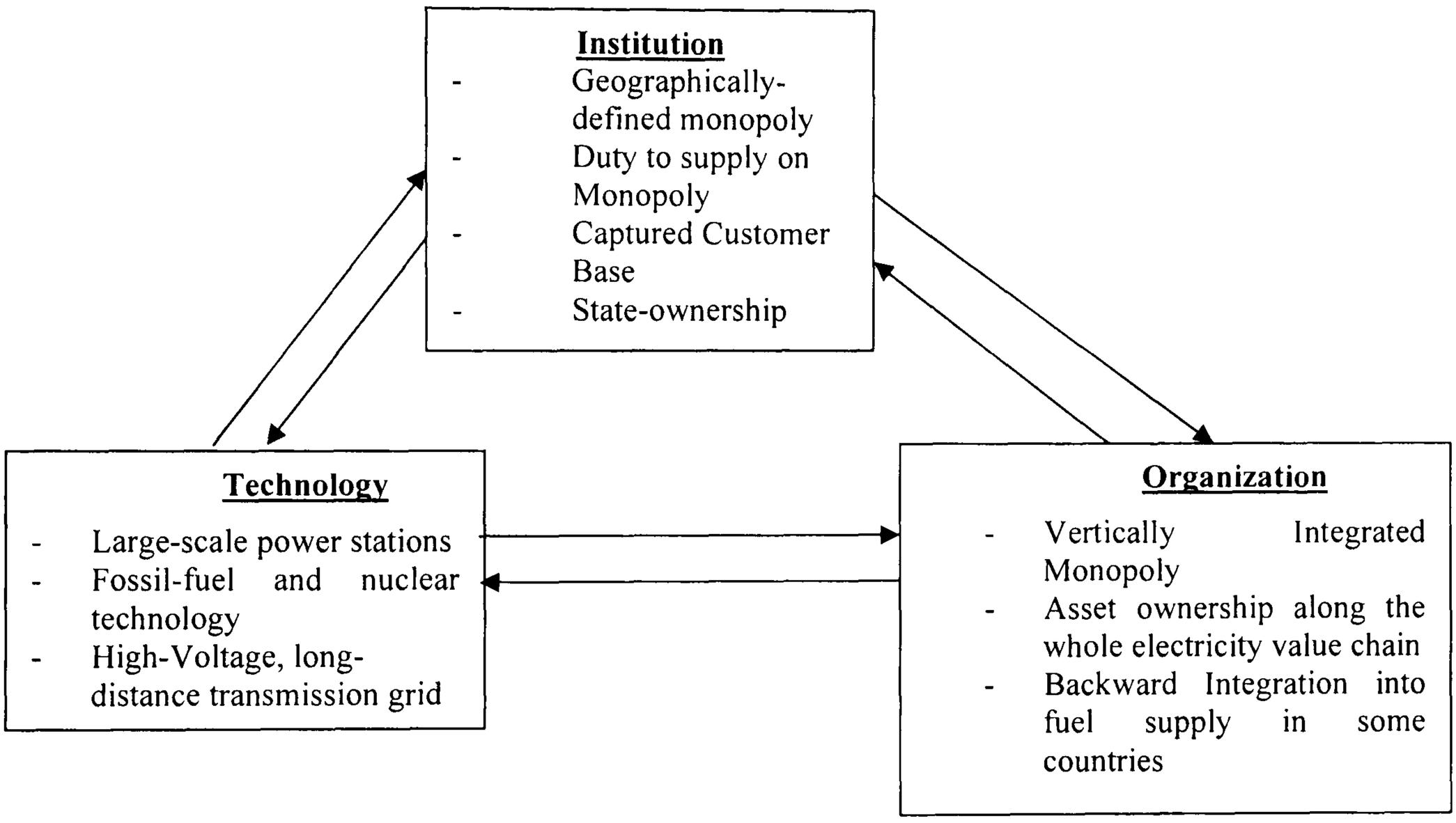


Figure 6: Relationship between institutions, organizations and technology in electricity markets

After about 1990, institutional changes at the European and national level altered the sheltered nature of the electricity market in most European markets. Measures to open the market to more competition created opportunities for new organizations but also led to a growing series of mergers and acquisitions among formerly geographically separated monopolies, which created new large-scale utility companies (Glachant & Leveque 2005; Bergman 2005). The EU recently put pressure on the implementation of its Electricity Market Directive

2003/54/EC[9], especially with a focus to 'unbundle' the different aspects of the electricity business. Thus, electricity transmission and distribution – which is considered a natural monopoly – now has to be legally and organizationally separate from the generation and retailing business[10].

Furthermore, new technological opportunities emerged, mainly in the form of CCGTs and new RETs. CCGTs can be built in relatively small, modular units[11] (Rukes & Taud 2004) while RETs are often one order of magnitude smaller than conventional generation technologies and thus do not necessarily fit into the established technological configuration (Rukes & Taud 2004). RETs are also amenable to decentralised applications and in many cases independent of an external fuel supply, which can be considered a further source of mismatch between the traditional organizational and technological structures (Awerbuch 2000; Tsoutsos & Stamboulis 2005).

In sum, these changes to the environment in which electric utility companies operated created significant tensions to their business model (Sine & David 2003). While the systems literature predicts significant inertia among established companies because of various sunk costs and the danger of "deskilling" their key capabilities (Hughes 1987), new opportunities emerged for utilities to expand into new business areas and differentiate themselves from key competitors (Markard & Truffer 2006).

The approach outlined above has some similarities with Murmann's work on the synthetic dye industry in the 19th century (Murmann 2003). In his analytical framework, he analysed the co-evolutionary development of three dimensions - institutions, organizations and technologies – to understand why the UK's synthetic dye industry could not hold on to its initial technological lead over its German competitors.

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[9] The Electricity directive 2003/54/EC updated the original electricity market directive 96/92/EC
[10] On 15 November 2005, the European Commission highlighted problems in the EU electricity markets, which were seen foremost in four areas: "Market concentration, Vertical Foreclosure and lack of Market integration and Transparency" (European Commission 2005a).
[11] Units start at 250MW compared to typical coal and nuclear power units of 1000MW

The research pursued in this thesis is based in a different industry and historical period but draws on similar dimensions as found in Murmann's work. However, there are two important differences. Firstly, the three dimensions, as used in this thesis, have been developed specifically to capture the key features of the electricity industry. For example, while in Murmann's study, the institutional dimension consisted primarily of the patent law and the university system at the time (important factors for his study), the institutional dimension in this study is concerned with formal electricity market and renewable energy policy rules.

Secondly, while Murmann's research question was concerned with the development of whole national industries over time, the research focus in this thesis is specifically on individual agency among companies in an industry. Hence, the aim of this thesis was to develop a co-evolutionary framework which allows for individual agency and thus differential responses to systemic changes. As argued in section 2.3.1 and 2.3.3, adopting a co-evolutionary perspective means going beyond merely describing interactions between technologies, institutions and organisations to analysing the specific causal links between these dimensions as they each change over time. Consequently, the next section will add a strategic dimension to the co-evolutionary framework established above, to provide a detailed causal mechanism for co-evolutionary interactions. This builds on the same theoretical insights that have already contributed to the systemic innovation view.

The next section outlines this approach in more detail, before section 3.3 will outline the methodology and research approach used in this study.

3.2. Strategic Dimension to co-evolutionary Change

The previous section outlined the interdependence between three dimensions of the electricity system – organizations, institutions and technologies. However, interdependence as such gives little guidance on the nature and direction of change over time among them. Hence, this section aims to provide a

dynamic perspective on co-evolutionary change by integrating a strategic perspective on organizational behaviour with regard to the other two dimensions.

It is noted at the outset, that the scope for differences in strategy within the same innovation system has long been highlighted. In their classic paper on technological innovation systems, Carlsson and Stankiewicz have already argued that "firms differ [...] in the extent to which they use the knowledge they have, and in *how* they use it. They differ in the resources they devote to advancing their knowledge base and the effectiveness with which they conduct research... Firms differ in their ability to perceive opportunities and in their willingness to take risks" (Carlsson & Stankiewicz 1991:100). Geels (2004) talks of 'strategic games' that will be played within structural boundaries.

In the context of competition emerging from market liberalization, the development of technological capabilities as well as the engagement with institutional rule-making become strategic decision variables for the affected companies. *Strategy* in this context is the link between the internal processes and capabilities of a firm and their application in the external systemic environment.

Two strategic decision variables will be introduced in the framework: *Acquiring new capabilities* and *engaging in the process of institutional rule making*. As introduced in section 2.2.2, these are the two corner stones for companies to build sustainable competitive advantages for their businesses. Capabilities define the technological opportunity frontier to extract value from new and reconfigured technologies. Institutional rules set the boundaries for the application of technologies in the market and hence set the societal limits to the extraction of value from a technology. Together, they define the opportunity set for a company to operate in (Eggertsson 1996;Teece, Pisano, & Shuen 1997).

The focus on these two decision variables is the last step to arrive at the first aim of this thesis. The aim was to create an analytical framework that specifically considered the interactions between changes at the systems level and the evolution of corporate strategy at the firm-level. In this context, the two strategic levers introduced above are used as the basis to analyse these interactions

and trace their co-evolution over time. Decisions about developing technological capabilities and corporate political activities will be taken simultaneously and interdependently. Technology development will be influenced by what is institutionally feasible and vice-versa. However, for analytical purposes, both will be discussed separately in the subsequent sections.

3.2.1. Building technological Capabilities

The idea on which the technology strategy literature builds suggests that a firm's technology strategy has to align with its broader strategic goals (Porter 1983; Freeman and Soete 1997). Porter (1983:9) captures this succinctly: "Competitive Strategy is an integrated set of policies in each functional activity of the firm that aims to create a sustainable competitive advantage. Technology strategy is but one element of an overall competitive strategy and thus must be consistent with and reinforced by the actions of other functional departments."

This view suggests that the specific organizational context of the firm is as important to its strategic decision as wider systemic technological developments around its boundaries. So, the decision whether to add specific technological capabilities has to be considered not just in the market context (i.e. technological improvements and market growth rates) but also in terms of a firm's existing capabilities and routines. Firms have developed a set of capabilities in the past and operate unique routines to refine and add to this capability set. Thus, the decision about the direction of new capability additions and/or refinements is set in the context of the historic development of the firm. Resource constraints limit the scope of involvement in any one activity and mandate the setting of priorities in each time period considered. Recent research has stressed the idiosyncratic nature of discovering new strategic opportunities (Denrel, Fang, & Winter 2003) as well as the localised co-evolution of learning and dynamic capabilities (Zollo & Winter 2002).

As a starting point for the analysis, it is assumed that the closer existing capabilities are aligned to new technological opportunities, the more likely will a

company integrate them into its strategy (Porter 1983;Rosenbloom & Christensen 1998). Hence, when evaluating new technological options, a company's search will initially be guided by its existing set of capabilities and routines. This influences the perception of expected market sizes, future technological developments and their impact on the competitive environment of the firm (Christensen 1997).

For example, Christensen (1997:87ff) describes how incumbent integrated steel makers ignored the opportunities provided by new 'mini-mill' steel-making technology and eventually lost almost half their market share between 1965 and 1995. Yet, Rosenbloom and Christensen (1998) suggest that the challenge lies less in understanding and developing new technologies *per se* but in changing and adapting strategy towards them.

In this sense, the notion of strategy adds to the systemic perspective on innovation through considering individual companies not just in terms of their structural position within a system's network of actors, but also in terms of their individual capabilities and historically grown routines. For example, in Christensen' case study of the steel industry, incumbents were focused on a particular higher-end part of the market and consequently geared their strategy increasingly towards meeting the demands from customers in this segment. Their industry position as such did not stop them from implementing the newly developed mini-mill steel-making technology. However, the historically grown cost structure of the incumbent corporations, as well as the requirements from their customer base, led to a conscious decision to focus resources and capabilities increasingly on particular segments of the market that fitted this historic evolution of the firms.

Again, it is argued here that if the strategic dimension to capability development is ignored, systemic innovation analysis would risk paying insufficient attention to company specific motivations for or against engaging in activities with system-wide ramifications. For example, in the recent emphasis on 'functions of innovation systems' (Jacobsson & Bergek 2004;Hekkert, Suurs, Negro, Kuhlmann, & Smits 2006;Negro, Hekkert, & Smits 2007), functions such

as 'the creation and diffusion of new knowledge, the supply of resources, and the guidance of the direction of search' are studied at the systems level to evaluate whether a technological innovation system is performing well or not. Yet, using the notion of corporate strategy provides a perspective from within a company of why resources are allocated in a particular way and thus not just *whether* a particular systems function might be inadequately addressed, but also *why*. We return to this theme in the discussion of the case studies in chapter 5.

In summary, incorporating a perspective that recognizes the capability distribution in an industry and the strategies built on them could provide a richer background for systemic analyses of technological change. As technological development occurs, it impacts differently on the company population in an industry, depending on the specific context of each firm. Hence, even among a class of companies, such as incumbents, a narrow focus on their structural position within a system would be insufficient to capture their possible responses.

3.2.2. Engagement in institutional Rule-Making

The institutional environment in which firms operate is not exogenous to them (Oliver 1991). It is shaped by firms that try to mould it to their advantage (Oliver 1997; Jacobides and Winter 2005). Corporate political activities, or corporate attempts to shape government policy in ways favourable to the firm, are commonly employed by firms across countries (Hillman, Keim et al. 2004). However, how to coordinate political activities with other business activities has received little attention in the literature, despite the parallels with the literature on technology strategies.

While the development of technological capabilities is a necessary pre-requisite for success in a new technological field, the ability to shape the institutional rule-set in which such technologies are introduced becomes an additional condition for success, even more so in highly regulated industries such as the electricity sector. Institutions hence become a conditioning factor for the amount of value that can be extracted from a given technology.

Hence, as a starting point for analysing this decision variable, it can be argued that the institutional rule-set governing a new technological field shapes the extent and direction of strategic involvement by the firm (Eggertsson 1996;Oliver 1997). In setting their strategy for technological capability development, companies need to form a simultaneous point of view of system-wide institutional developments and the companies' potential leverage within them (Oliver 1991;Oliver 1997). Hence, they will determine the potential benefit from institutional changes based on their own resources and capabilities and consequently the potential to exploit opportunities created by a widened institutional space (Hillman, Keim, & Schuler 2004).

Oliver and Holzinger (2008) have put forward a taxonomy of four different institutional engagement strategies that are based on the specific capability context within the firm. Hence, they distinguish between *defensive*, *reactive*, *anticipatory* and *pro-active* strategies that will be adopted depending on the firm's specific capabilities and type of regulatory environment (see Figure 7 below). Increasingly pro-active strategies can create increasingly sustainable competitive advantages for the firm as they aim to tailor regulatory institutions specifically to the dynamic capabilities of the individual firm. However, Oliver and Holzinger's (2008) framework a static capability and technology set is assumed, while in this research the co-evolution of both dimensions is investigated over time. Hence, Oliver and Holzinger did not address the question of the *dynamic interaction* of business and political strategy over time, and their impact on technology diffusion.

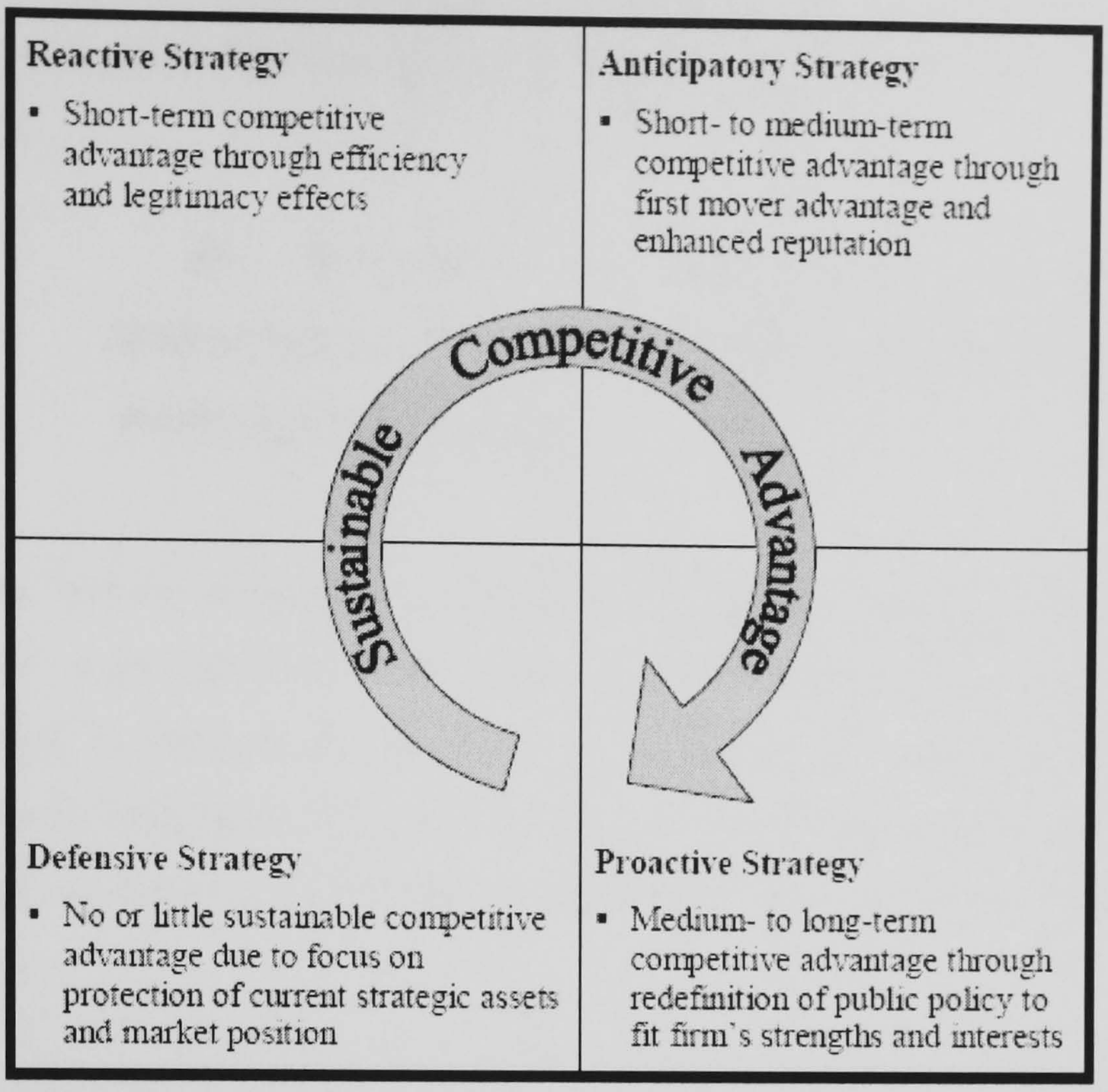


Figure 7: Taxonomy of corporate political strategies Source: Oliver & Holzinger 2008

Building on Oliver and Holzinger's (2008) framework, two different types of integrated strategies can be expected from the companies in this research: Companies that have actively developed new technological capabilities are expected to develop increasingly proactive CPA strategies. Conversely, companies that have not developed new technological capabilities will develop increasingly defensive CPA strategies.

Institutional change has played an important role in the systemic innovation literature (Carlsson & Stankiewicz 1991; Edquist 1997a; Geels 2004; Jacobsson & Bergek 2004). It is seen as a key stepping stone for the diffusion of new technologies and their wider social acceptance. Consequently, including the strategic decision-making process on institutional engagement into the proposed analytical framework enriches the systemic analysis of innovation. It underpins the analysis of systemic co-evolution by providing an analytical tool to examine the motivations of individual companies in institutional conflicts (Smith et al. 2005). Furthermore, it considers a previously unexplored dimension to the

development of systemic 'functions' by focusing on the strategic rationale of individual companies for blocking or inducing the formation of institutions.

3.2.3. An Analytical Framework for Studying the interactions between company strategy and co-evolutionary change

The first aim of this study was to enrich systemic studies of technological change with a perspective on individual agency. Consequently, the discussion above served to illustrate the idea of strategic choice for companies set within wider systemic structures. This section integrates this perspective to consider how the interactions between both levels could be used in a dynamic co-evolutionary framework.

The key aspect is that strategy serves as a feedback mechanism between individual companies and their external environment. Strategies are formulated on the basis of existing strength and capabilities of the firm (Rosenbloom 1978;Burgelman & Rosenbloom 1989). At the same time, strategies are influenced by opportunities in the external environment.

Figure 8 on the next page illustrates this idea graphically and brings together the co-evolutionary dimensions from section 3.1 with the company strategy aspects discussed above. Strategic choices at the firm level are influenced both by wider institutional and technological changes and by the firm's own resources and capabilities. Firms' existing capabilities and routines underpin the *starting position* for corporate strategy, providing the company-internal frame for decisions about developing new technological capabilities and associated political activities. However, these interact with wider systemic developments in institutions and technology over time. As a result, the execution of strategy provides *learning feedback* to the firm through the resulting interactions in both framing and being framed by the direction of change at the systemic level (Burgelman & Rosenbloom 1989). In an evolutionary perspective, corporate strategy consequently adapts to these wider systemic developments through

experience ('learning-by-doing') from strategy execution (arrows on the left and right). This in turn leads to adaptations of technological capabilities and political activities at the firm-level (flow arrows at the bottom). Furthermore, institutional and technological changes interact on a systems level (flow arrow at the top). It is with these interactions in mind, that the analytical framework is labelled *co-evolutionary* and *dynamic* over time.

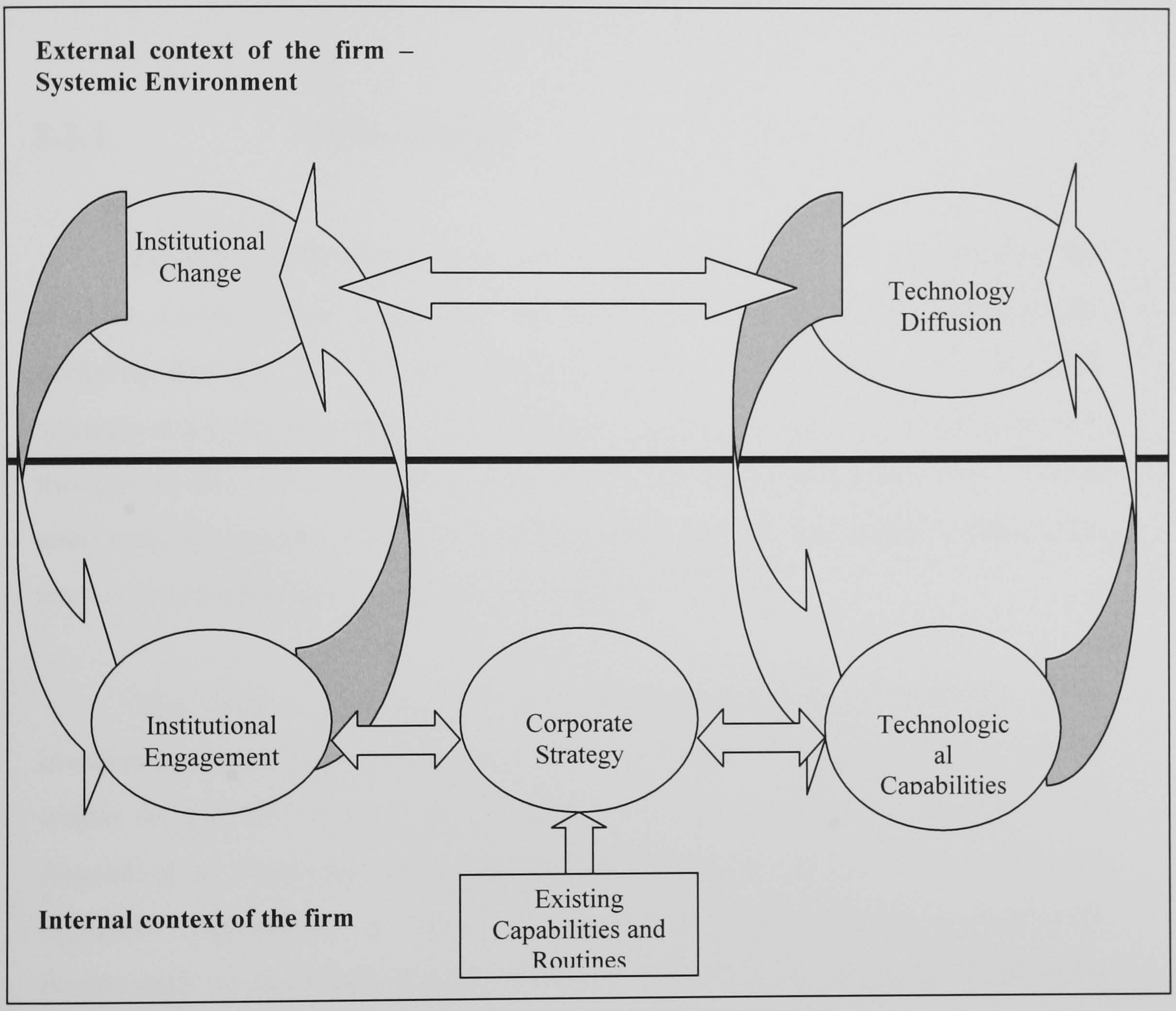


Figure 8: Co-evolution of firm strategy, technology and institutions

Smith el al. (2005) call for a closer examination of the specific contexts in which systemic transformations occur. This highlights the fact that even in long established systems incumbent firms are able to adapt to external pressures, rather than being overwhelmed by them. It is contended that strategy analysis, as positioned in this framework, can shed more light on the specific circumstances in which firms are able to manage such adjustments.

Having established the framework for the analysis, the next section will now outline its specific application in the context of the research for this thesis. Hence, it will explain the methodology used for this approach and the selection of the three case study countries.

3.3. Methodology and Boundaries of the Research

3.3.1. Methodology

Having outlined the analytical framework employed to analyse the research question, this section now discusses the choice of methodology and the sampling strategy. The research builds primarily on the systemic-innovation and strategic-management literature. However, given the lack of comprehensive theories in this field, this thesis integrated both approaches to develop a novel analytical framework, which was consequently applied and tested in three case studies to generate new empirical and theoretical insights.

Yin defines case studies as "...a strategy for doing research which involves an empirical investigation of a particular contemporary phenomenon within its real life context using multiple sources of evidence." (Yin 1994:48) According to Eisenhardt (Eisenhardt 1989;Eisenhardt 1991), case studies are especially appropriate in new topic areas where comprehensive theoretical frameworks or empirical support are lacking. One of the strengths of the case study method is the potential depth of analysis and the immediate connection of theory with empirical observations (Gassmann 1999).

As the aim of this study was both to test an extension to the existing theoretical frameworks and to generate new insights from this novel framework, the case study method was chosen as the most appropriate (Eisenhardt 1989;Robson 2002). A modelling approach to test the analytical framework would have been an alternative approach. However, the lack of theory to build causal links in a model, the opportunity for exploration of the phenomena with real

actors in the field and ultimately the limited time and resources at hand to carry out both in-depth case studies *and* a modelling approach led to a decision against model building. Modelling as a potential area of future research, building on the results from this study, is discussed in the conclusion in chapter 6.

Data Reliability, Validity and Generalizability

Two general problems with the case study method are firstly. the reliability and validity of data collection and secondly, the generalizability of the results obtained (Robson 2002;Flick 2002). With regard to the first issue, data was collected with the aim of triangulation in mind. This involves applying different methodologies, using multiple data sources and theoretical angles to increase the robustness of the results obtained (Flick 2002). Robson lists four main types of triangulation that mark out good research designs (Robson 2002:226):

1. Investigator triangulation – using different interviewers
2. Theory triangulation - "…approaching data with multiple perspectives and hypotheses in mind." (Denzin 1989:239-240)
3. Methodological triangulation – Combining quantitative and qualitative approaches
4. Data triangulation – use of different data sources

Point 1 – investigator triangulation – was not possible in the context of a PhD research project. However, the three other features of triangulation were followed in the research process. While it would have allowed for controlling investigator bias to his/her research subject, the number of interviews conducted and the relative homogeneity of interviewees (senior managers of incumbent electricity companies in three European countries) provided some compensation for this factor.

Theory triangulation was an implicit part of the research design, given the two distinct research traditions analysed in order to develop the novel analytical framework. Hence, data collection and evaluation was based on approaches that

emphasize different explanatory variables for the observed phenomena and thus allowed the juxtaposition and comparison of different theoretical arguments.

The method for data collection, -processing and analysis was primarily qualitative although quantitative data was used as part of the company analysis. However, the debate about the choice between either a quantitative or qualitative method has increasingly moved towards questions of research practice such as the appropriateness of each approach and should be based on the nature of the actual research problem at hand (Wilson 1982;Robson 2002). Bauer and Gaskell (Bauer & Gaskell 2000) stress that it is more the degree of formalization and standardization which distinguishes the two approaches than the juxtaposition of words and numbers. The aim for rigour in the research practise and concerns for reliability and validity of data is equally present in both research streams (Flick 2002) and was the main concern in the research design of the study presented here.

From the outset, it had to be recognised that the field of analysis in this research is an open system. It would have been impossible to capture all conceivable variables that influence decision-making on company strategy. Unlike the researcher in a laboratory, external influences cannot be shut out or controlled in the real world. Thus, a fixed and linear research design (what is considered the 'scientific approach'), consisting of hypothesis formulation, testing and evaluation is not strictly possible. As Robson (2002:168) observes, "...while the essential test of validity of a finding in the natural sciences is that it has been directly replicated by an independent investigator, this approach is not feasible when a [qualitative] design is used".

Hence, data triangulation was followed by seeking data from a variety of sources and using an iterative process in connecting the development of the analytical framework and the data collection process. Firstly, desk-based background research was carried out, which included the theoretical literature review outlined in chapter two but also provided detailed market and policy surveys in order to select appropriate case study countries. Furthermore, archive searches were conducted in industry journals and data providers such as

'Windpower Monthly' and 'Bloomberg'. Based on these surveys, companies were identified for inclusion into the case studies, and for each of them. a short profile was developed, giving an overview over a set of standardised data. This built on the discussion in the literature review in chapter 2 on company-related factors influencing technology strategy, with a specific focus on existing operational routines and capabilities.

Secondly, companies were contacted directly in order to gain a better understanding of the actions and interactions in each of the case study countries and to complement the information obtained from the secondary sources described above. Two alternative approaches were considered for this part: Survey questionnaires and interviews, which can be structured, semi-structured or unstructured (Saunders, Lewis, & Thornhill 2003). It was decided that semi-structured interviews offered the best approach for obtaining the necessary data while still remaining a realistic option within the time and resources available.

A semi-structured interview approach was deemed suitable for two main reasons. In an exploratory study, semi-structured interviews can be helpful to 'find out what is happening and to seek new insights' (Robson 2002:59). Given the multitude of potential influencing factors and the absence of a general explanatory theory to comprehensively predict the behaviour of the involved companies, obtaining individual viewpoints from involved actors was important in understanding individual market contexts and to inform the development of the analytical framework (Eisenhardt 1991). Understanding context specific-factors is important to delineate to what extent "data gained from a particular study provides theoretical insights which possess a sufficient degree of generality or universality to allow their projection to other contexts or situations" (Sim 1998:350). Perceptions of the opportunities and risks in the electricity market are likely to vary from company to company. Thus, in order to better understand the interactions between individual company strategy and system-wide developments. semi-structured interviews allowed the exploration of both the company perspective on past developments in the industry as well as their outlook on future developments.

Furthermore, semi-structured interviews are helpful to "understand the reasons for attitudes and opinions of the interviewees" (Saunders et al. 2003:250), which allows to gain insights into the motivations and incentives of individual actors. This would not be possible in a comprehensive manner with a standardised questionnaire. Freedom to discuss these areas of interest is instrumental in order to fully explore new ideas and issues (Saunders, Lewis, & Thornhill 2003). Hence, Robson (2002) argues that exploratory studies based on semi-structured interviews are particularly appropriate where the objective is to generate and test ideas and hypotheses (Robson 2002:59).

Still, conducting semi-structured interviews does not prevent the researcher from data collection in a rigorous manner. The main themes and questions asked were identical for each company, thus delivering comparable data. Similarly, in the background research on each company, a set of standard indicators was collected in order to compare the relative standing of each company in the market. In this way, a similar degree of standardisation was achieved compared to a questionnaire, while the interview format allowed an exploration and probing of the issues in more detail. The main themes of the interviews can be found in an appendix to this chapter, while the company indicators are listed for each country in the case study section of chapter 4.

Problems with bias in the data collection can arise where only small population samples are taken. (Saunders et al. 2003). In this respect, the depth of the background research prior to the interviews gains central importance. Before engaging in individual interviews, comprehensive background company profiles were created to be able to probe specific events in the company's history and question possible assertions made about past events. Hence, it was possible to evaluate and analyse the answers in the context of the companies' competitive standing and historical development. Furthermore, in each country selected, it was aimed to include companies with at least 50% of the total market share, to allow for a comprehensive view of the market. Glaser and Strauss (1967) argue that 'closure' in case study research is achieved when adding additional cases does not add or only minimally adds additional theoretical insights (Glaser & Strauss 1967). Besides this theoretical dimension, this phenomenon, known as 'theoretical

saturation', also involves a pragmatic considerations (costs of additional case study research versus additional insights) (Eisenhardt 1989). Given the homogeneity of the 'product' electricity and consequently the similarity of organisational approaches of utility companies and their market share concentration (Newbery 2005b), this seemed sufficient to capture country differences while maintaining a manageable workload.

Generalizations from case study results concern the "transferability of findings from one context to another" (Robson 2002:182). Multiple case studies do not allow for statistical generalizations but allow for *analytical* generalization; Findings and patterns of data from case studies which provide this kind of support, particularly if they simultaneously provide evidence which does not fit in with alternative theories, are the basis for generalization (Robson 2002:183).

A key concern for generalization is the robustness of the data that underlies any findings, which in turn can be improved by triangulation. In this context, "triangulation is less a strategy for validating results and procedures than an alternative to validation which increases scope, depth and consistency in methodological proceedings" (Robson 2002:227).

Using case studies for building or expanding new theories is now a frequent method in social science research (Eisenhardt 1989;Eisenhardt 1991;Flick 2002). If research is carried out in a rigorous fashion, "such theories are likely to be testable, novel, and empirically valid" (Eisenhardt 1989:547). However, they are still theories about specific phenomena. As Eisenhardt (1989:547) put it, ""Grand" theories require multiple studies - an accumulation of both theory-building and theory-testing empirical studies." Consequently, findings from this study will be able to contribute to the literature in extending existing theoretical frameworks and suggesting new avenues for research, both in applying the results in new settings and in aiming for higher-level generalizations.

3.3.2. Geographic and Technological Boundaries

This section describes in detail the process which led to the selection of the target countries and companies for this research. It also describes the process of carrying out the semi-structured interviews. Carlsson et al. (2002), in their discussion of key methodological issues with regard to innovation system analysis, stress the need for a clear delineation of the system boundaries. Hence, the first task in this section was to set boundaries for the proposed work and thus clearly define what is included and excluded in the research.

Given the resource and time constraints of this research, the focus had to be limited in terms of the technologies included and the number of different national markets covered. After surveying developments in a number of European countries (Stenzel, Foxon, Gross 2003), the decision about both types of boundaries was set simultaneously. Among the many new RETs[12], wind energy is the most widely used technology across Europe and thus has relatively good base data on which to build the analysis. As it is also the most widely used 'new' technology among large utility companies in Europe, it was consequently decided to focus on wind energy as a case study of renewables. For example, Table 3 summarizes data of European utilities from December 2002, which shows significantly larger interest in wind energy than biomass technology among the companies surveyed (Hamburgische Landesbank 2002).

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[12] Sellers (Sellers 2005) divides development of RETs into two phases – A first wave of 'traditional' RETs, consisting of geothermal, hydropower and traditional biomass technologies, and a second wave of 'new' RETs, such as wind energy, solar energy and advanced forms of biomass technologies.

Table 3: Current and planned investment in wind and biomass by European Utilities (Source: Hamburgische Landesbank 2002)

Utility Company	Wind in MW (December 02)	Biomass in MW (December 02)	Wind planned in MW (target year in brackets)	Biomass planned in MW (target year in brackets)
EdF	10	n/a	480 (2004)	n/a
EnBW	10	12	n/a	n/a
Endesa	825	16	1295 (n/a)	n/a
Energi E2	183	308	158 (2003)	n/a
E.ON	51	n/a	60 (2003)	100 (2005)
Iberdrola	1213	8	2256 (2006)	n/a
MVV Energie	n/a	n/a	400 (2005)	200 (2005)
RWE	229	50	771 (2010)	n/a
Scottish Power	185	n/a	2785 (2010)	n/a
Sydkraft	11	150	30 (2003)	100 (2005)
Vattenfall	28	448	n/a	n/a

Secondly, the number of countries to be analysed had to be limited, as time constraints would prevent an exhaustive analysis of utilities across the whole of Europe. Yet, Jacobsson and Johnson (2000) highlight that different networks and their constituent firms are likely to follow different courses of action in the face of new technological developments. "When new technologies become available, providing expanded and different technological opportunities, the bounded (and different) visions of managers imply that firms and their networks may differ greatly in their perception and ability to seize these opportunities. Rationality… could well be argued to be not only limited but quite different among both firms and networks." (Jacobsson and Johnson 2000:632)

Eisenhardt (1989:546) considers the potential for the "juxtaposition of contradictory or paradoxical evidence… across several cases" a key advantage of case study research for making new theoretical advances as it forces the researcher to "…reconcile these contradictions to reframe perceptions into a new

gestalt". Hence, it was an aim in the selection of the case study countries and companies to achieve a breadth and diversity of experiences.

In order to achieve a juxtaposition of different experiences both among countries and within countries among companies, three criteria were applied: Firstly, countries were screened by their overall success in installing wind energy. Secondly, these countries were analysed with regard to their renewable energy support schemes and electricity market design. Lastly, the utilities within the countries were screened according to overall market position and their involvement in the wind energy market.

As shown in Figure 9 below, only five countries shared over 80% of the installed wind capacity up to 2002. As has been proposed in the analytical framework, the institutional and technological dimensions of the wind energy system co-evolve over time. Hence, the institutional environment in those countries can be considered central to the wider development of the affected technology, wind turbines in this case.

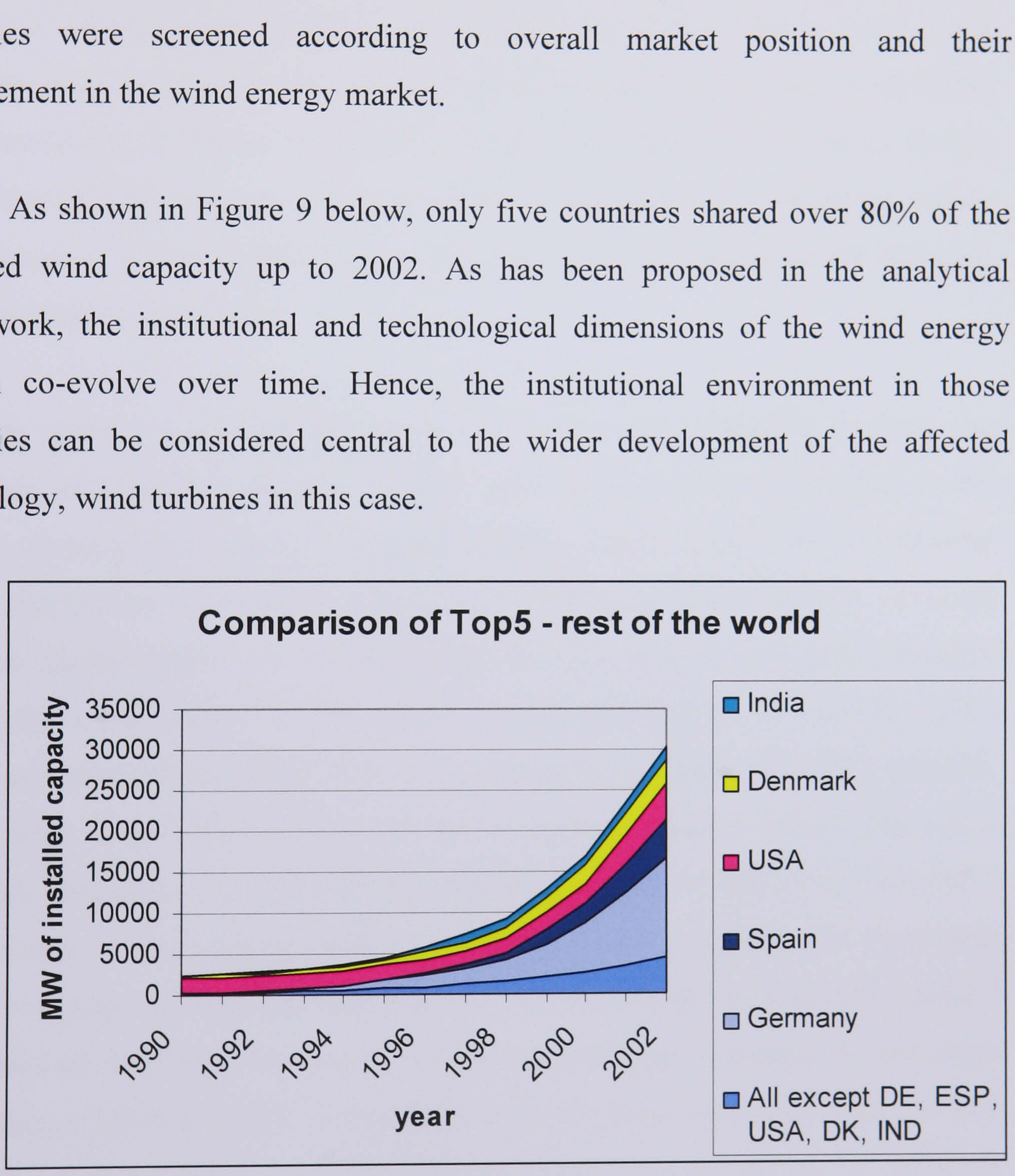


Figure 9: Worldwide development of wind power 1990-2002; comparison of installation in India, Denmark, USA, Spain, Germany and the rest of the world; Source: (Sellers 2005)

However, due to resource constraints, only European countries could be included in this study. Reiche (Reiche 2005) describes renewable energy policy developments in the 25 EU member countries. A key finding in this survey is that

sixteen of these countries have implemented a "feed-in" tariff renewable energy support scheme. The other nine countries use a variety of schemes, including auctions, tradable certificate schemes and tax credits to support renewable energy technologies.

The two countries with the most installed wind capacity globally, Germany and Spain, both operate feed-in tariff policies (Reiche 2005). However, both countries operate different electricity market designs, with Germany operating a wholesale spot market based on bilateral trading, while Spain has a mandatory pool market for all electricity generators in place[13] (Crampes & Fabra 2005;Brunekreeft & Twelemann 2005). Hence, including both countries in this thesis allowed the study of the two leading wind countries worldwide, while simultaneously analysing the effect of the feed-in policy system under different electricity market conditions.

In order to increase the variety of cases and especially include the experience of a relative laggard, a third case study country was added to the analysis. Among the countries without a feed-in tariff policy, the dominating support mechanisms are tradable certificate schemes in various guises. A recent report on harmonization of European support schemes for renewable energies listed such mechanisms as the main possible alternative to feed-in tariffs (European Commission 2005b). However, among the countries with such policies, there is little long-term experience in their operation (Reiche 2005). The UK's renewable obligation certificate (ROC) scheme has been in operation since 2002, which makes it the longest running certificate trading scheme for renewable energy in Europe. As the UK also has no prior experience with feed-in tariffs[14] and witnessed relatively low levels of wind installations compared to the other two countries (BWEA 2005), it was selected as the third case study country. The selection of these three countries allowed analysing the effect of different

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[13] The differences between both market designs will be explained more fully in the country sections in Chapter 4.

[14] Both Italy and Sweden have also been running certificate trading schemes since 2001 and 2003 respectively. However, both countries' previous policies included a feed-in tariff system (Reiche 2005).

institutional environments on the strategy of utilities, varying both the type of wholesale electricity market arrangement and renewable energy policy.

As can be seen from Table 4 below, there are broadly three combinations of wholesale market design and renewables policy across these countries: The UK relies mainly on voluntary electricity markets of bilateral and over-the-counter trade. In terms of the market, renewables are treated equally to other technologies but are additionally supported through a quota and obligation policy. Germany similarly relies mostly on voluntary trade through the EEX power exchange or bilateral contracts. Renewables, however, are promoted through a separate guaranteed feed-in tariff plus a duty on distribution companies to prioritise despatch of 'green' electricity. Finally, Spain operates a mandatory pool market for all electricity produced from generators over 50MW, while renewables are similarly supported through guaranteed feed-in tariffs which have priority despatch in the pool. Detailed policy and market background information are presented in the case study sections of the next chapter.

An empirical puzzle arose in the preliminary desk-based research, when examining the share of incumbent utility companies in the total installed wind capacity in each of these countries. It varied widely from around 1% to over 80%. Markard et al. (2004) had found in the field of green electricity retail products that utilities pursued different strategies, differentiating between strategy types with different degrees of engagement such *leading*, *learning* and *participating*. Given the variance in the renewable energy installations, it could be expected that similar strategy differences will be found in the present research as well. A short summary of the key institutional and policy features in the three countries is provided in Table 4 below:

Table 4: Properties of market regulation, renewables policy and incumbent investment into wind energy in the UK, Germany and Spain

	Main electricity market features	Renewables Policy	Share of incumbents in total wind capacity
UK	NETA/BETTA - voluntary bilateral trade, over the counter market	Renewable Obligation Certificates, obligation on suppliers to fulfil quotas	81.4%
Germany	EEX power exchange – voluntary bilateral trade, over the counter market	Guaranteed feed-in tariff, duty on distribution companies to dispatch all renewable electricity	1.2%
Spain	Quasi-mandatory Pool for generators over 50MW; priority dispatch for 'special regime' electricity	'Special Regime', guaranteed feed-in tariff or top-up premium on wholesale market price	57%

Having decided on the geographical and technological boundary, the third boundary had to be set with regard to the number of companies included in the study. The focus in each country was on the large incumbent utility companies that operate along the traditional value chain of the electricity market (i.e. electricity generation, grid operation and retail). As regulation of electricity grid ownership varied between the three countries, companies were required to operate at least in the electricity generation and retail field. As incumbents, they were furthermore required to operate at least one type of conventional power plants such as coal, nuclear, oil or gas turbines. In order to cover the majority of the market operations of these incumbents, the total market share of the companies included in the study was required to be at least 50% in the respective national markets. As argued in section 0 above, the 'product' electricity is highly homogeneous and similar organisational approaches and high concentration of market shares can be witnessed across the selected countries (Newbery 2005b). As the research progressed, the answers from the interviews were already processed in order to identify potential issues arising that required further enquiries. However, within the three countries, a level of 'theoretical saturation' was achieved within the initial set of target companies, meaning that no additional

questions arose that would have contributed to the present set of the research questions (Glaser & Strauss 1967;Eisenhardt 1989).

All the utility companies included in this study are vertically integrated concerns with significant market shares in their respective national markets. All of them have interest in electricity generation and retail. In Germany, where the national transmission network has not been unbundled from the rest of the electricity industry, these companies also own the transmission network. In Germany and Spain, four companies together make up at least 80% of the respective markets in electricity generation and supply. The lower level of company concentration in the UK and the unavailability of one company for interviews, as outlined below, meant that the five companies included in the UK section of the study cover just 51% market share in electricity generation, while still covering over 80% market share in electricity supply.

In building up a profile of potential companies, two main data sources were accessed: Firstly, the industry magazine 'Windpower Monthly' has an extensive archive reaching back 13 years, thus allowing the creation of a good background database about a particular company's moves in the wind power industry, especially with regard to innovation-related activity. Secondly, Bloomberg Data Services provides access to historic financial market news dating back over hundred years, thus far exceeding the lifetime of the wind power industry. From this source, the plant ownership structure and key financial information about investment behaviour of individual companies, as well as news such as mergers, acquisitions and joint-ventures were extracted. Furthermore, two UK government consultations on the 2001 'Energy Review' of the Prime Minister's strategy unit and the 2003 'Energy White Paper' were used to identify UK companies active in the institutional field. These information sources were used to identify the key companies in each market. The companies originally included in the case studies for each country are shown in Table 5 below.

Table 5: Companies initially included in the case studies from the UK, Germany and Spain

Country	Utility Companies
UK	- Centrica/British Gas - EDF Energy - E.ON UK (PowerGen) - RWE npower (Innogy) - Scottish Power - Scottish & Southern Energy
Germany	- E.ON - RWE - Vattenfall - EnBW
Spain	- Endesa - Iberdrola - Union Fenosa - Hidrocantábrico

All the above companies were contacted to participate in an interview in a six-month period between April and September 2006. The only company that did not agree to hold any interviews or provide any further information was "Scottish & Southern Energy" in the UK[15]. All the other companies were willing to engage in at least one interview. A total of 21 interviews were carried out. The primary focus for interviewees were departments with direct responsibility for wind energy developments. However, in order to get responses from different sections of the companies, interviews were also sought in the general corporate strategy and technical management departments in order to be able to contrast responses from within the same company. Besides the desk-based research carried out prior to the interviews, this provided a further source of triangulation of company-specific responses, as perceptions of company actions can vary between departments (Eisenhardt 1989;Denrell, Fang, & Winter 2003). A standardised interview guideline was used to generate comparable data from all companies.

Table 6 sets out the main themes that were explored in the interviews. They focus on the company-internal and external influences on the formulation of corporate strategy with regard to renewables in general and wind power in particular. The interviews were not conducted in a linear fashion as the different themes arose out of different responses in the general flow of the discussion.

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[15] The main reason given was fear of disclosure of sensitive information.

Nevertheless, themes that were not covered were specifically probed by the end of the interview. The interview guidelines with detailed questions can be found in Appendix 1.

Table 6: Themes and areas of interest for the interviews

Themes
Company's position in the market – strengths and weaknesses, development potential
Perception of the status of various renewables and wind energy in particular – awareness of technologies
Perception of the prospects of various renewables and wind energy in particular – strategic potential
Company's organizational set-up for renewables/wind and the amount and timing of investments
Outlook on regulatory framework for renewables – institutional perspective
Membership in industry and lobby associations – level and scale of regulatory engagement

Interview length was at least one hour, with the longest interview lasting three hours. Interviews were recorded on a tape recorder, transcribed and sent to the interviewees for confirmation of accuracy of content. All interviewees were guaranteed anonymity in order for them to be able to speak freely. Hence, Table 7 below does not give explicit names of the interviewees but only indicates the job title and the country of origin.

Table 7: Overview of the interviews conducted in the UK, Spain and Germany

Date of Interview	Country	Job description
21. April 2006	UK	Head of Renewables Strategy
4. May 2006	UK	Manager, Corporate Strategy
12. May 2006	UK	Business Development Manager
13. June 2006	UK	General Manager, Renewables
13. Jun 2006	UK	Head of Strategy and Special Projects
20. June 2006	UK	Head of Renewable Energy
26. June 2006	UK	Head of Renewables Policy
29. August 2006	UK	Commercial Manager, Renewables
5. September 2006	Spain	Technical Director, Renewables
7. September 2006	Spain	Head of Investment Projects
8. September 2006	Spain	Head of Regulatory Policy
11. September 2006	Spain	Head of Technical Operations
12. September 2006	Spain	Director of R&D Projects
11. July 2006	Germany	Vice President Corporate Development
11. July 2006	Germany	Senior Analyst, Corporate Development
12. July 2006	Germany	Senior Manager, Renewable Power
12. July 2006	Germany	Manager, Corporate Development
21. August 2006	Germany	Head of Windpower Development
22. August 2006	Germany	Head of Renewables
23. August 2006	Germany	Head of R&D
23. August 2006	Germany	Head of Renewables

3.3.3. Data Analysis

The presentation of the data collected will be undertaken in the subsequent chapter 4. In keeping with the analytical framework, the different dimensions will be presented independently in order to separate analytically each dimension`s evolution. This will be done for each of the three countries investigated. Subsequently, chapter 5 provides a synthesis of the data and a higher level comparison of the findings from each country.

The technological dimension can be outlined generically for all three countries, since the technology was equally available in all three countries throughout the time period considered. This will be done in the first section of chapter 4. It will provide the context for the subsequent analysis of the capability development decisions of the individual companies.

The institutional dimension of each country will be represented by two aspects: The design of the wholesale electricity market in which the incumbent utilities operated, and the specific renewable energy support policies enacted in each country. Again, this will provide the context for the subsequent analysis of the corporate political activity of the incumbent utility companies.

Finally, the organizational dimension will be examined through an in-depth analysis of the incumbent utility companies' response to these systemic changes. Here, the focus will be on the development of strategies around wind energy, the most important factors driving such developments, and finally the specific pattern of capability development and institutional engagement.

Bringing these factors together in one analytical framework provides an empirically rich and novel contribution to the literature and allows for the analysis of the research questions inquiring about the evolution of corporate strategy in response to a changing systemic environment. Hence, chapter 4 addresses aim 2 set out in the introduction, and provides the basis for the theoretical discussions envisaged in aim 3 and 4.

4. The Interaction of Utilities' Strategies and Systemic Change in three Countries: UK, Germany and Spain

The previous chapter set out the analytical framework and the methodology for the data collection and analysis for this research. This chapter will now provide the results of the case studies. Following the analytical framework developed in the previous chapter, the data will be presented to analyse the interaction between three dimensions: The evolution of the market institutions in the electricity industry, the evolution of the wind turbine technology and finally, the evolution of corporate strategy of the incumbent utility companies in three countries. Consequently, the structure of this chapter is as follows:

Firstly, section 4.1 describes the development of wind turbine technology. Wind turbine technology has been equally available in all three countries, providing the same technological opportunity set to all the companies considered (Neuhoff & Sellers 2006). This is important as it allows focusing on institutional and organizational cross-country differences, while technology was equally accessible to all.

Subsequently, section 4.2 introduces the case studies and briefly outlines two general features relevant for the framing of the country-specific case studies, respectively the value chain of the electricity industry and the capabilities required for the development of wind farms. Consequently, each country is presented in turn, section 4.3 covering the UK, section 4.4 Germany and section 4.5 Spain. For each country, firstly the evolution of electricity market regulation is outlined, followed by a section describing the prevailing renewable energy policy regime. Hence, these sections provide the institutional context of the analytical framework and serve as the country-specific institutional context of the corporate strategies of the respective utility companies. These strategies are outlined in the final parts of

each country section, presenting the results from the semi-structured interviews and the background research. The strategy discussion follows the analytical framework outlined in section 3.2.3, focusing on the strategy-formulation process at the firm level and the resulting interaction with the systems level.

Before turning to the case studies, the next section will now give a brief overview of the key milestones in the development of wind turbine technology.

4.1. *Wind Turbine Technology Development*

Following the first oil-crisis of 1973/1974, many industrialised countries rapidly scaled up their research budgets for alternative energy technologies, including wind power (IEA 2004b). This led to the emergence of several technology design options competing alongside each other. Firstly, designs competed on the principle of vertically vs. horizontally rotating blades. Secondly, among the horizontally rotating turbines, the number of blades varied, with designs exhibiting, one, two, three and even four blades. This design competition lasted from about 1970 to about 1990, with the three-bladed, horizontally rotating turbine ultimately emerging as the preferred design in terms of longevity, power output and amenability to the requirements of site developers (Heymann 1995;EWEA 2004).

Figure 10 exhibits the development of these turbines for the period 1980-2003, where they experienced a phase of rapid growth and refinement. Size increased tenfold and rated capacity hundredfold over these years. Furthermore, technology inside these turbines developed to incorporate various elements of power electronics, thus meeting increasingly demanding grid codes, for example with respect to resilience to outages and the provision of ancillary services (EWEA 2004). Technology development was initially dominated by US and Danish firms, which together held about 90% of the world wind turbine market between 1980 and 1990 (Garud & Karnoe 2003). Subsequently, technology providers diversified rapidly, with new entrants from Germany, Spain and India following the emergence of new markets.

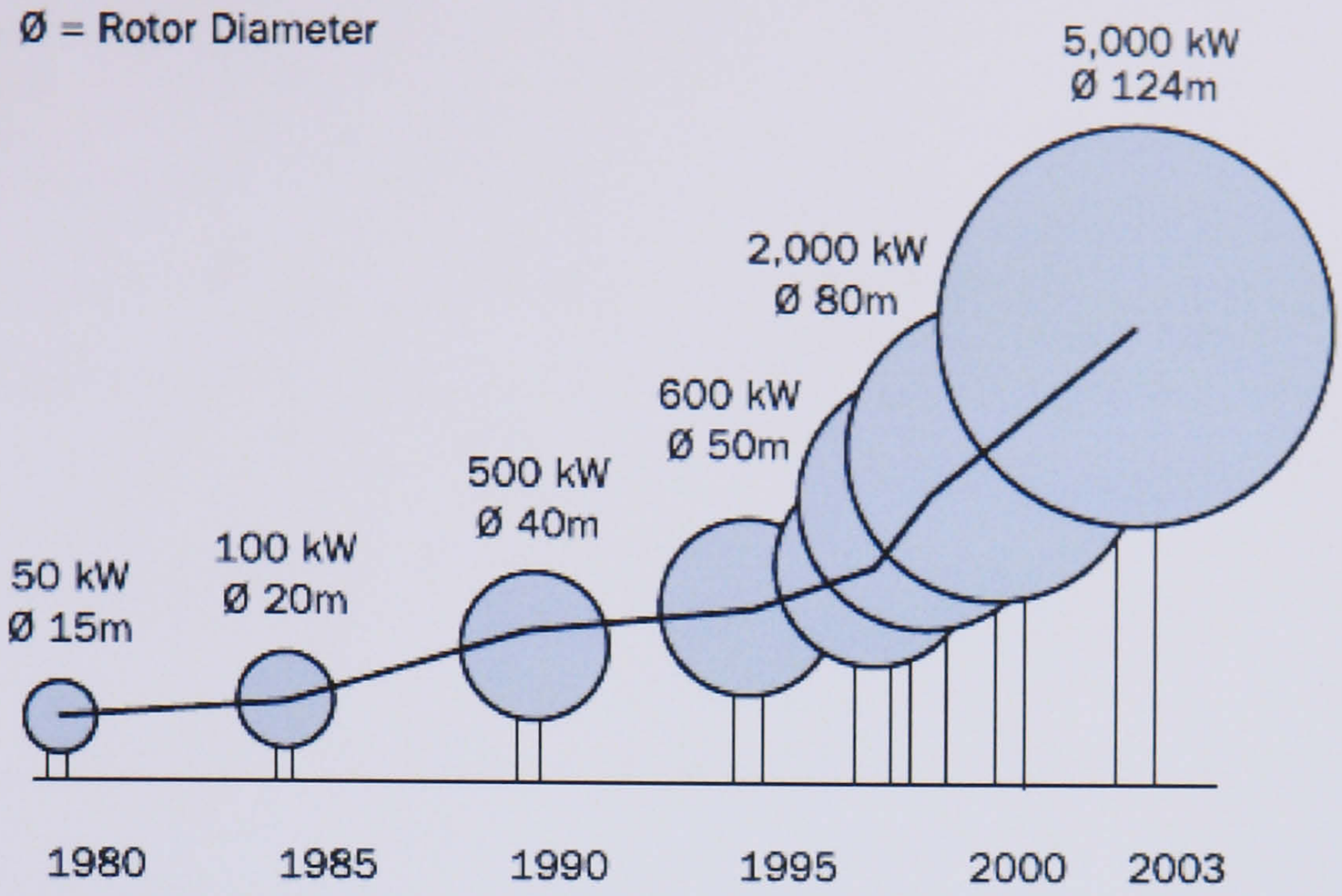


Figure 10: Evolution of wind turbines, 1980-2003 (Source: EWEA 2004)

The major driver behind the developments of wind turbines were the increasing support policies and public R&D budgets in IEA member countries, especially following the oil crises of 1973/1974 and 1980. Yet, wind power received only 1% of total public energy R&D budgets between 1974 and 2002, or $2.9bn out of a total of 291bn spent in that time period (IEA 2004b). Yet, as technology matured, more countries introduced additional policies, targeting the demonstration and market introduction of wind power. Figure 11 shows the evolution of policy instruments in IEA member countries from R&D support to demonstration grants and market introduction measures over time.

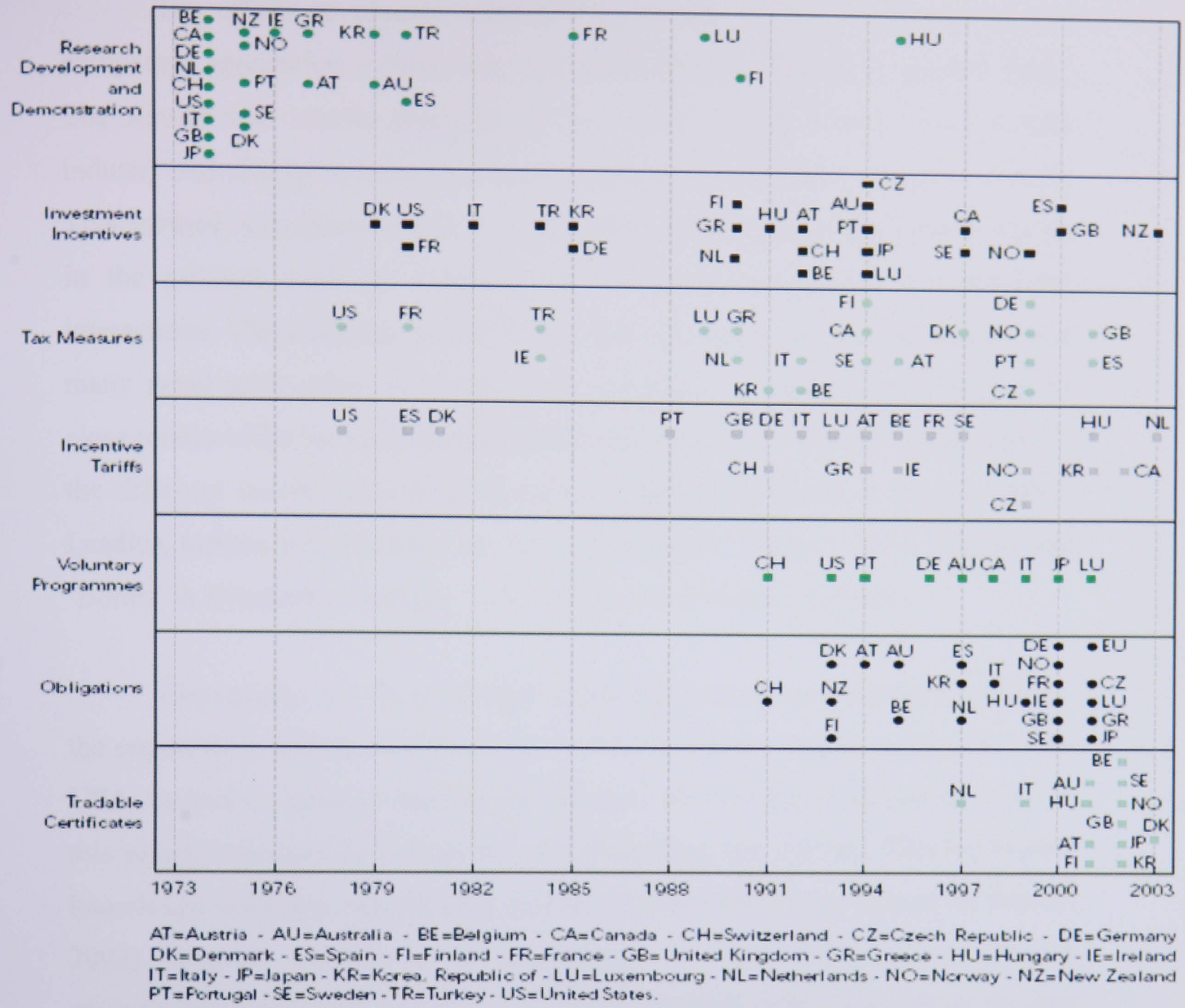


Figure 11: The introduction of renewable energy policies in IEA member countries (Source: IEA 2004:92)

As shown in Figure 10, wind technology was initially characterized by small unit sizes and low power ratings. This reflects the fact that individuals and companies involved in the initial design efforts and installations of wind turbines were similarly operating at a small and often localised scale. For example, the first single turbine set up in Denmark in 1975 was connected to the grid by an entrepreneur next to his house, without the knowledge or permission of the local grid company (Van der Steen et al. 2007). Yet, as wind turbine technology matured and new markets were opened up through government support schemes, the focus increasingly turned to larger and consequently more powerful turbines (Garud & Karnoe 2003).

The efforts to upscale wind turbine ratings were characterised by two competing approaches – 'bricolage and breakthrough' (Garud & Karnoe 2003). The former was mostly practiced in the context of the Danish wind turbine industry and also by several small-scale German manufacturers (Heymann 1995). This method was characterised by incremental developments and improvements in the turbines, with an emphasis on learning-by-doing and user-developer interactions. The character of the Danish and German wind turbine market with many small-scale users was particularly amenable to this approach due to the close relationships between manufacturers and users as well as the connectivity of the different stakeholders in close industry networks (Garud & Karnoe 2003). Leading turbine manufacturers in this mould were 'Vestas', 'NEG Micon' and 'Bonus' in Denmark, 'Enercon' in Germany, and 'Gamesa' in Spain.

Conversely, the 'breakthrough' approach focused on a concerted effort of the engineering and aerodynamics know-how of leading scientists, mainly in the USA, to quickly produce large-scale turbines. Most of the development work in this setting was done in laboratories and proprietary test stations. This led to poor knowledge diffusion and limited user-developer interactions (Garud & Karnoe 2003). Another example of this approach was the attempt by a German engineering consortium to develop a 3,000 kiloWatt (kW) machine in the late 1980s (Heymann 1995)[16]. Yet, these early attempts at rapidly scaling up the technology did not succeed at the time, and the development path took the incremental path depicted in Figure 10 above. Ultimately, one-megawatt (MW) and multi-megawatt machines emerged out of the incremental ('bricolage') design efforts, especially with the increasing interest in offshore wind farms.

Furthermore, with the emergence of the three-bladed, horizontally rotating 'dominant design', the technology spread internationally. Spanish company 'Gamesa' initially manufactured a Danish design under licence, while the UK market was almost exclusively supplied by foreign turbines from Denmark and Germany in the early NFFO[17] auction rounds (Mitchell (1995) cites that 345 of 415 turbines in the first two rounds were of foreign origin). Germany saw the

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[16] This case will be further discussed in section 4.4.3
[17] See section 4.3.2 for full details on the NFFO auctions.

emergence of several domestic windturbine manufacturers while also seeing activity by Danish and American companies. For example, 'Vestas' installed its 1,000th windturbine in Germany by the year 1998 (Vestas 2007).

Beginning in the mid-1990s, the wind turbine industry consolidated increasingly around a small number of leading manufacturers who were able to satisfy the rapidly growing demand for turbines worldwide. 'Vestas' took over 'NEG Micon', 'Gamesa' bought its smaller Spanish competitor 'Made' and 'Bonus' was taken over by German engineering conglomerate 'Siemens'. The evolution of the global wind turbine market is shown in Figure 12, while the global market shares of the leading turbine manufacturers is given in Figure 13.

As turbines approached sizes of more than 1 MW, increasing interest arose in developing windfarms on the sea. This 'offshore' environment provided higher and more constant wind speeds than would be attainable on land. Furthermore, the larger size of such windfarms offered the prospect of significant economies of scale in their development. These factors were seen as more than outweighing the higher installations cost that were necessary for such wind farms, while also avoiding some of the permitting obstacles witnessed at land (Gross 2004). Consequently, the first commercial scale offshore wind farms were built, starting in 2001 in Denmark with the 160 MW Horns Rev wind farm and in 2003 the 60 MW North Hoyle wind farm in the UK (IEA 2005c).

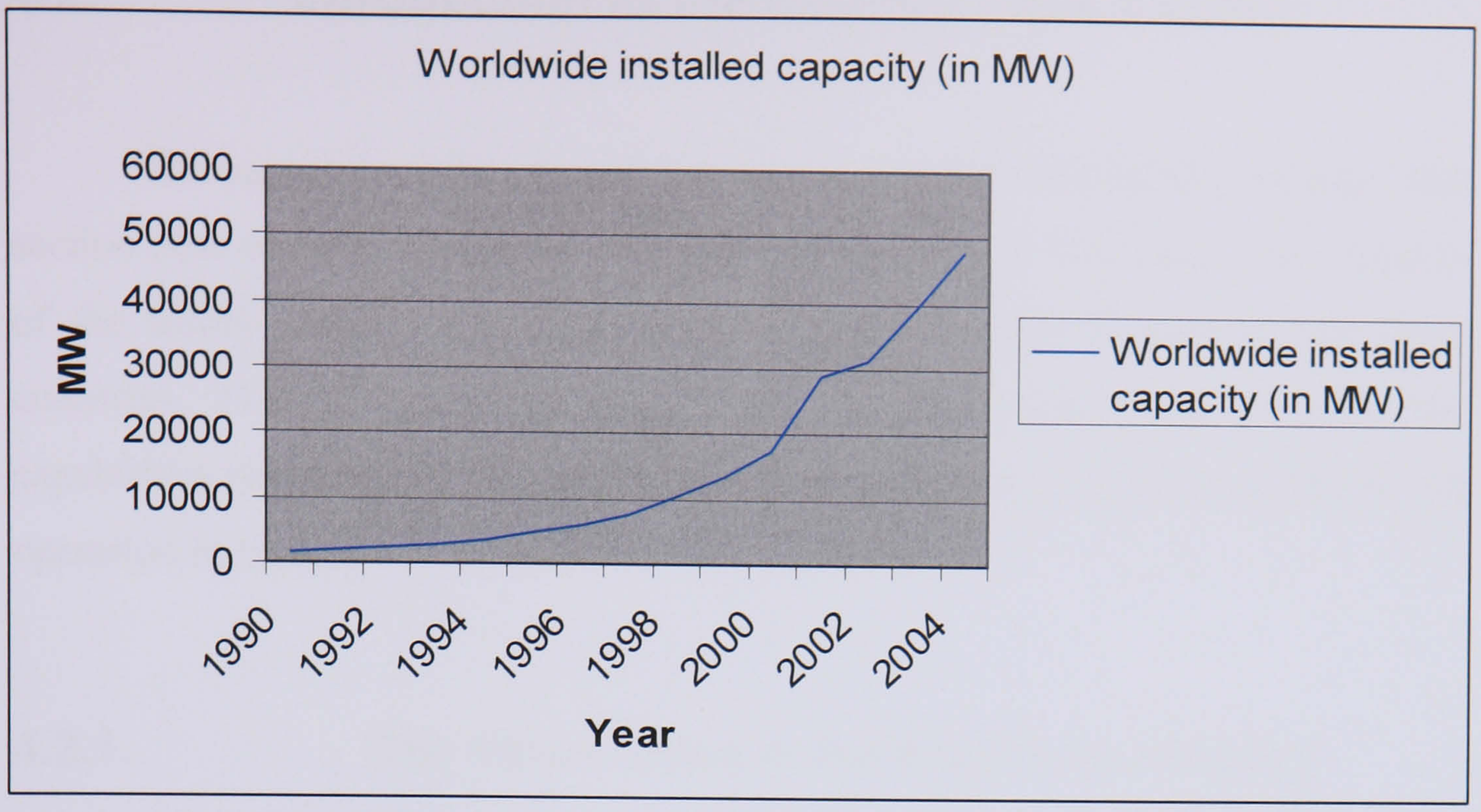


Figure 12: Worldwide installed wind energy capacity 1990-2004. Source: EWEA 2004, BTM Consult 2005

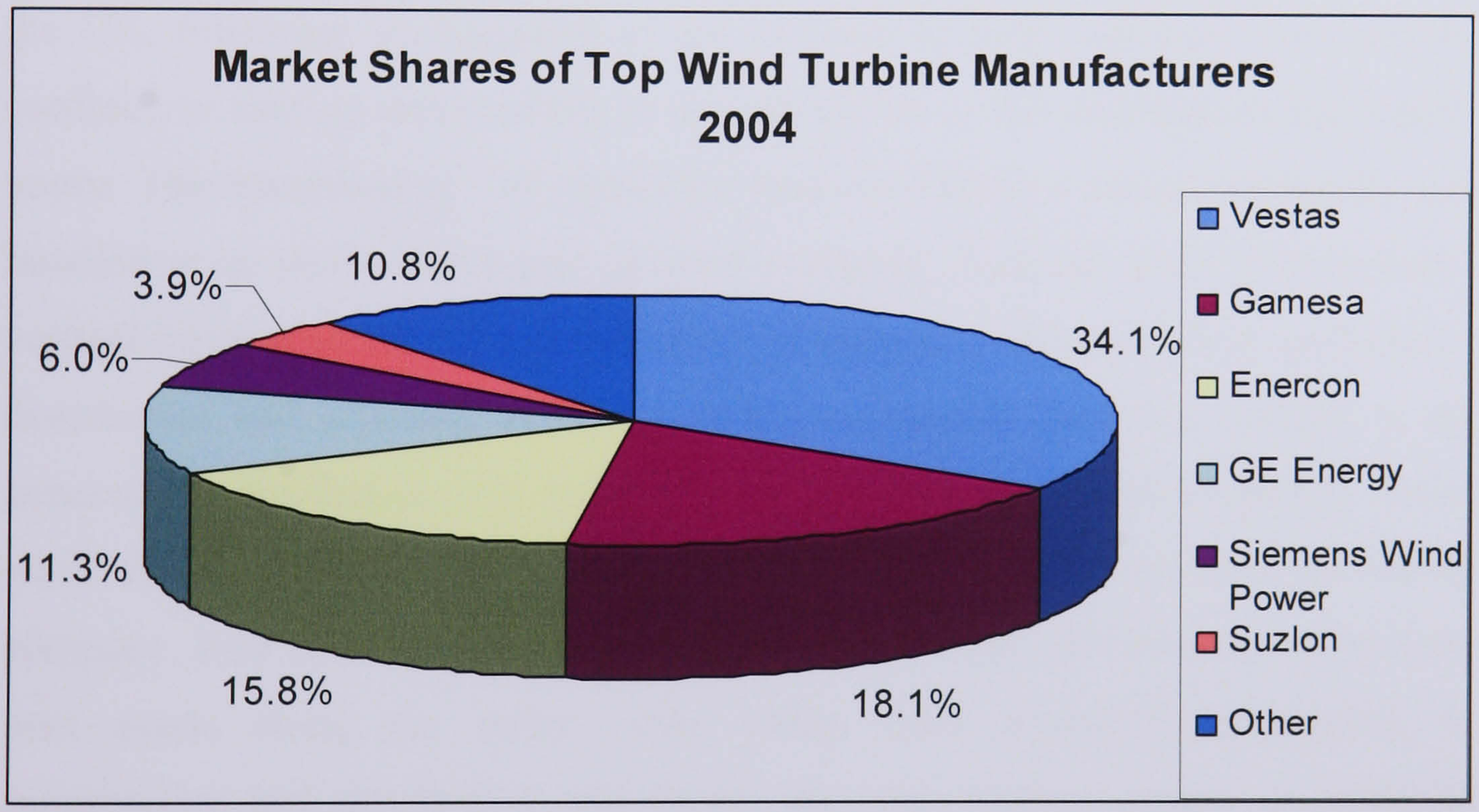


Figure 13: Worldwide Market Shares of Wind Turbine Manufacturers in 2004 Source: (BTM Consult 2005)

In summary, the wind industry saw a period of rapid growth in the turbine size and technological maturity over the past two decades. With the emergence of a 'dominant design' in the form of the three-bladed turbine, technology diffusion became increasingly global. Manufacturers took advantage of a growing market, which allowed the top companies to consolidate, to the extent that the top four companies supplied over 75% of the market in 2004, as Figure 13 above indicates.

4.2. *Introduction to the Country Case Studies*

Having outlined the general development of the wind turbine industry, this section now turns to the country-specific case studies. In this section two aspects of the utility industry are discussed that apply equally in each of the three countries. This is firstly the value chain of the industry and secondly the capabilities necessary for the successful development of a wind development and operation business.

4.2.1. The Value Chain in the Electricity Industry

To put the utility industry into context, the typical value chain of the electricity industry is outlined in Figure 14 below (Markard & Truffer 2006). In the UK, following privatization of the industry in 1990, utilities were initially confined to owning assets either in the generation or the distribution and supply sector. The transmission[18] of electricity was considered a natural monopoly and bundled in an independent grid operator company, National Grid. Subsequently, vertical integration led to the emergence of utilities owning assets in generation, distribution and retailing. In Spain, utility companies similarly operate in the generation, distribution and retail sectors, also on a regional-monopoly basis, while the transmission grid was consolidated in a separate, regulated monopoly company, Red Electrica Espana (REE), in 1985. Finally, in Germany, companies own assets along the entire value chain, from electricity generation, to transmission and distribution and finally the end-customer supply in particular regions, therefore being local monopolies.



Figure 14: Typical Value Chain for electric utilities

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[18] Transmission commonly refers to the long-distance, high-voltage (up to and over 375,000 volts) transport of electricity, while distribution refers to the lower-voltage (between 10,000 and 100,000 volts) supply of electricity on a regional basis.

4.2.2. Capabilities for the Development of Wind Farms

There are three capabilities in the area of the development and operation of wind turbines relevant to this research. These are knowledge about wind turbine technology and its suppliers, development of adequate sites from surveying to permitting and contracting, and lastly the integration of wind farms into the existing electricity system, both technically and economically. When discussing the company-specific strategy evolution, these three distinct areas of capability development will be distinguished (Hartmann & Boensch, 2005; Markard et al., 2006). Aspects of these capabilities include:

- *Wind turbine technology*; this includes knowledge about the state-of-the-art technology, development trends, supplier relationships and contract development.
- *Wind farm development*; this includes site selection, local negotiations, finance, local planning application and permitting procedures and (sub)contracting.
- *Network integration*; this includes the maintenance of grid stability, balancing of output and integration into financial electricity wholesale markets.

The analytical framework outlined in section 3.2.3 focused on the interplay of existing capabilities, corporate strategy and corporate engagement with the systemic environment. Specifically, a starting point in the literature was the assumption that distance between existing capabilities and the requirements for new technological capability developments will influence the degree to which corporate strategy will embrace a new technological opportunity. Similarly, it was assumed that the corporate political activity of a firm to influence the institutional environment for new technologies would determine the pay-off that a company could achieve from developing new technological capabilities. Hence, the relation between the existing capabilities and the needs of wind power development described above will be of specific interest to this study.

4.2.3. Three Case Studies on the Interaction of Incumbent Strategies and changing systemic Environments

We can now turn to the country-specific case studies. Each case study is structured in four parts. The first two parts outline the evolution of each country's respective electricity market design and renewables policy, while the third part discusses the companies' individual corporate strategy with regard to wind power. The final part summarises the co-evolutionary development of institutions and company strategy in each country.

In the first two sections, the timeframe is set to begin with the liberalization of electricity markets and the introduction of the first renewable energy policy, respectively. In outlining the evolution of these two areas, the institutional dimension to the analytical framework is represented. The sections on the electricity markets provide the wider context in which the utility companies operate, while the sections on the renewables policies introduce the context for the development of new technological capabilities.

In the sections on the incumbent strategies, results will be presented both from the literature review, the industry data analysis and the semi-structured interviews. The focus here is on the internal dynamics in formulating company strategy with regard to developing technological capabilities and corporate political activity.

Finally, the summary for each country brings these two levels together and examines the interaction between company strategy and systemic level developments. In this way the country-specific co-evolutionary paths can be examined separately, before chapter 5 will summarise the findings at a higher level for cross-country comparisons to investigate communalities among the paths in the three countries and their wider implications for theory and policy.

4.3. *The UK*

4.3.1. UK Electricity Market Overview

This section outlines the evolution of the UK electricity market in order to provide an institutional context for the development of individual firm strategies. It introduces the most important institutional changes in the market environment beginning with market liberalization in 1990 and outlines the organizational restructuring that had been taken place as a response. In section 4.3.2, the UK renewable energy policy environment is similarly outlined.

The UK's electricity market has undergone numerous changes since the start of liberalization and privatization in 1990. Originally, Britain's industry was entirely state-owned, overseen by the Central Electricity Generation Board and 12 Regional Area Boards (Hannah 1982). Privatization led to a separation of assets into three parts. Generation was split between three newly created companies. Two conventional generators took over the coal-, gas- and oil-fired power plants – 'National Power' (40 power stations with about 30 Gigawatt (GW) capacity) and 'PowerGen' (23 power stations with about 20 GW capacity) (IEA 2005b). The nuclear power assets remained in state hands after the initial attempt to privatize them as well did not receive a positive response. However, in 1996 a fleet of advanced-gas-cooled reactors and one pressurised-water reactor was eventually transferred to the private sector with the creation of 'British Energy' (12 nuclear power stations with about 10 GW capacity). The distribution system and end-customer retailing was split into 12 regional areas, each held by one of the newly created Regional Electricity Companies (RECs), broadly following the historic distribution regions. The government initially retained golden shares in each of them to prevent mergers and takeovers, but these lapsed in 1995. The transmission system was separated and transferred to the newly formed 'National Grid Company' (NGC) whose shares were equally held by the 12 RECs. However, in 1995, the government asked the 12 RECs to divest their shares, and NGC shares were floated on the stock market. Regulation was conducted by a new regulatory

authority, the Office of Electricity Regulation, 'Offer', which later merged with the regulator for the gas market, to become the Office of Gas and Electricity Markets, 'Ofgem'. In order to balance electricity supply and demand, the UK government instituted a power pool to act as a clearinghouse between suppliers of electricity (generators) and wholesale consumers of electricity (primarily the RECs) (IEA 2005b).

The Pool guaranteed a high-level of transparency, yet the initial market set-up with a *de facto* duopoly between 'PowerGen' and 'National Power' meant that these two fossil-generators set the price in the market for more than 90% of the time (Newbery 1995;Newbery 2005c). This was assisted by a system of capacity payments which was calculated according to the reserve margin in the market and thus the value of capacity in stand-by. Consequently, generators had an incentive to withhold plants only to release them close to real-time after capacity payments had increased (Helm 2003).

However, since RECs were initially forbidden to own generation assets directly, and generators were not allowed to own retailing assets either, new entrants into the market were stimulated. CCGT power plants were the preferred technology choice and new projects were constructed by independent power producers, covered through long-term back-to-back contracts that secured gas supply from the North Sea and electricity sale to the RECs simultaneously. Furthermore, by threatening PowerGen and National Power with referrals to the Monopolies and Mergers Commission (MMC), the government induced both generators to incrementally divest some 14,000 MW of plant capacity between 1990 and 2000 (Hunt 2002;Newbery & McDaniel 2003). Thus, over time, the duopoly nature of the market was slowly eroded and it has been argued that through the reduction of concentration in the industry, a high level of competition was slowly established in the UK market (Evans & Green 2005). In 1990, the three largest generators controlled over 90% of the market (effectively PowerGen and National Power), in 2000, their market share was down to 49% and still falling (Hunt 2002).

Still, Helm (2003:134) points to the pivotal role that the pool played in securing competition: "A crucial feature of the Pool was that participation by generators was *compulsory*. All plants over 100 MW had to be despatched through this mechanism, and any supplier could buy at the Pool price... Compulsion made the Pool transparent and liquid, and it made discrimination by generators between suppliers much more difficult."

The Pool's strengths resided in its separation of the generation and supply side, and, by offering a system marginal price reference, a high level of transparency. Due to low switching numbers, the customer base of the RECs came to be considered a good balance to the increasingly competitive generation side of the industry. Hence, any increase in competitive pressure could potentially be offset by the relatively stable supply business. Consequently, a tendency towards vertical integration became immanent in the market. Once one company started in this direction, a vicious circle of increasingly illiquid and less transparent markets was likely to lead other companies down the same path. The clear ownership separation between generation and distribution/retail could only be maintained with strong regulatory oversight. As Helm (2003:241) observes, "at any point at which the regulatory guard was relaxed, consolidation was inevitable."

Two events, happening almost alongside one another, led to a sharp reversal of the UK electricity market structure: Firstly, a series of takeovers and mergers between 1995 and 2002 consolidated the industry, in the wake of which every single REC changed ownership at least once, and in many cases twice. Secondly, following a review of the market structure in 1998, the mandatory Pool was replaced by a voluntary over-the-counter market, the New Electricity Trading Arrangement (NETA), in 2001.

The takeover 'mania' (Helm 2003) which started in the UK in 1995 was fuelled by three driving forces. Firstly, the expiry of the golden shares instituted by the government at the beginning of the privatization programme, secondly the drive to form 'multi-utilities' and lastly, the attempt by American companies to enter the European market.

When the golden shares lapsed in 1995, the UK Trade and Industry secretary Ian Lang declared, that he was neither opposed to takeovers nor to vertical integration of electricity companies *per se*. On the contrary, he argued that it was always expected that the RECs would eventually face 'normal' market pressures and that "exposing the RECs to such pressures is crucial to keeping management up to scratch and enhancing the efficiency of the industry as a whole" (Lang 1995). This was taken by many people in the industry as an invitation to pursue takeover attempts, and consequently led to sustained takeover activity in which a total of £16.2bn was spent between 1995 and 1997 (Helm 2003:221ff).

There were two main groups that were interested in the UK RECs. Firstly, water companies, which were privatized in the UK in 1989, aimed to expand their business following the 'multi-utility' model, which stipulated that utility companies should combine several related network activities such as electricity, water, gas, and telecommunication in order to gain economies of scale from synergies in their operations. Secondly, several American utilities were expanding abroad at the time and the recently liberalized UK electricity market presented a seemingly profitable opportunity to do so.

These takeover bids did not contribute to vertical integration in the industry *per se*, since none of the approaching companies had an interest in the UK electricity industry at the time. However, at the same time, the first bids by UK generators were also initiated.

The first approach was made by 'Scottish Power', which proposed to acquire the 'Manweb' REC in the greater Manchester region. Scottish Power was already a vertically integrated company in Scotland but had not expanded into the England and Wales market yet. Manweb did not own any generation assets and had not engaged in the 'dash for gas' which had led several other RECs to sign long-term contracts for electricity from new CCGT power stations. Thus, in this case, the only regulatory issue was the loss of a 'comparator' in the supply business for Offer. In the event, these concerns did not outweigh the perceived benefits and the takeover was approved without conditions.

However, when National Power and PowerGen followed suit with their own takeover bids in 1996, both were eventually blocked by the regulators. Only after more CCGT power stations came online, and National Power and PowerGen agreed to further plant divestures, did the regulator perceive competition to be sufficiently strong to allow vertical integration of both companies. PowerGen bought the 'East Midlands' REC in July 1998, and National Power took over the supply business of 'Midlands Electricity' in November 1998. This set the stage for a series of further restructuring in the UK electricity industry in which virtually every company aspired to the model of the vertically integrated utility. As Newbery observes, "Concentration was ended by trading horizontal for vertical integration..." (Newbery 2005a). However, many of the new American entrants could not stem the investments in a period of falling prices and consequently sold off their assets to the newly arriving continental European utilities.

Table 8: Generation capacity and customer numbers of the main utilities in the UK electricity market (Source: Company interviews, corporate reports and websites)

Company	*Generation Capacity*	*Percentage of total generation capacity*	*Electricity Customers*	*Percentage of total electricity customers*
British Energy	12,000 MW	17%	n/a	n/a
Centrica/British Gas	4,200 MW	6%	5.9m	22.1%
EDF Energy	4,980 MW	7%	3.5m	13.1%
EON UK	10,100 MW	14.3%	5.3m	19.8%
RWE npower	10,300 MW	14.6%	4m	15%
Scottish Power	6,200 MW	8.8%	3.5m	13.1%
Scottish & Southern	10,000 MW	14.2%	4.3m	16%
Total Utilities	**57,780 MW**	**81.9%**	**26.5m**	**99.1%**
Other	12,770	18.1%	0.2m	0.9%
Total UK	**70,550 MW**	**100%**	**26.7**	**100%**

Consequently, by 2003, three European utilities had entered the UK electricity market, each to create a vertically integrated energy company in the UK. 'E.ON' of Germany purchased PowerGen and its associated distribution and

supply businesses. Through these assets, E.ON UK today supplies around 6m customers and owns 9,900 MW of generation capacity. 'RWE' of Germany purchased Innogy and npower, which were the new names of National Power's separate energy and supply businesses. Through its retail arm, RWE npower now has around 6m customers and generation capacity of about 8,600 MW. Finally, 'EDF' of France purchased three distribution and supply regions in the south East of England, including London, and built up a portfolio of power plants, both under the name 'EDF Energy'. It today has about 5,000 MW of generation capacity and supplies about 5m customers. Furthermore, through its French mother company, EDF Energy has an indirect interest in the UK-France interconnector cable with a capacity of 2,000 MW, which typically imports electricity from France to the UK.

Besides these acquisitions from abroad, the two Scottish companies that had already been set-up as vertically integrated utilities in Scotland, purchased assets in England and Wales. As described above, Scottish Power purchased the 'Manweb' REC. Through these combined assets, Scottish Power has about 6,200 MW of generation capacity and serves about 5m customers today. The second Scottish company, Scottish and Southern Energy, was formed after the purchase of the 'Southern' REC in the South of England. Also supplying electricity in Wales through its 'SWALEC' brand, it has a total of 6m customers today and owns about 10,000 MW of generation capacity.

The two other main actors in the UK electricity market today are British Gas/Centrica and British Energy. Since complete market opening to all household customers in 1998, Centrica has built up an electricity supply business on the back of its position as former gas monopolist. Also acquiring a series of power stations across the UK, it has 3,770 MW of generation capacity and almost 5 million electricity customers today. British Energy remained a generation-only company, unable to acquire a regional supply business. However, by virtue of its fleet of nuclear power plants and the addition of one coal-fired power plant to its portfolio it is the largest UK electricity generator today with about 12,000 MW of capacity. A summary of these figures is presented in Table 8. The fuel mix of total UK electricity generation capacity is given in Figure 15.

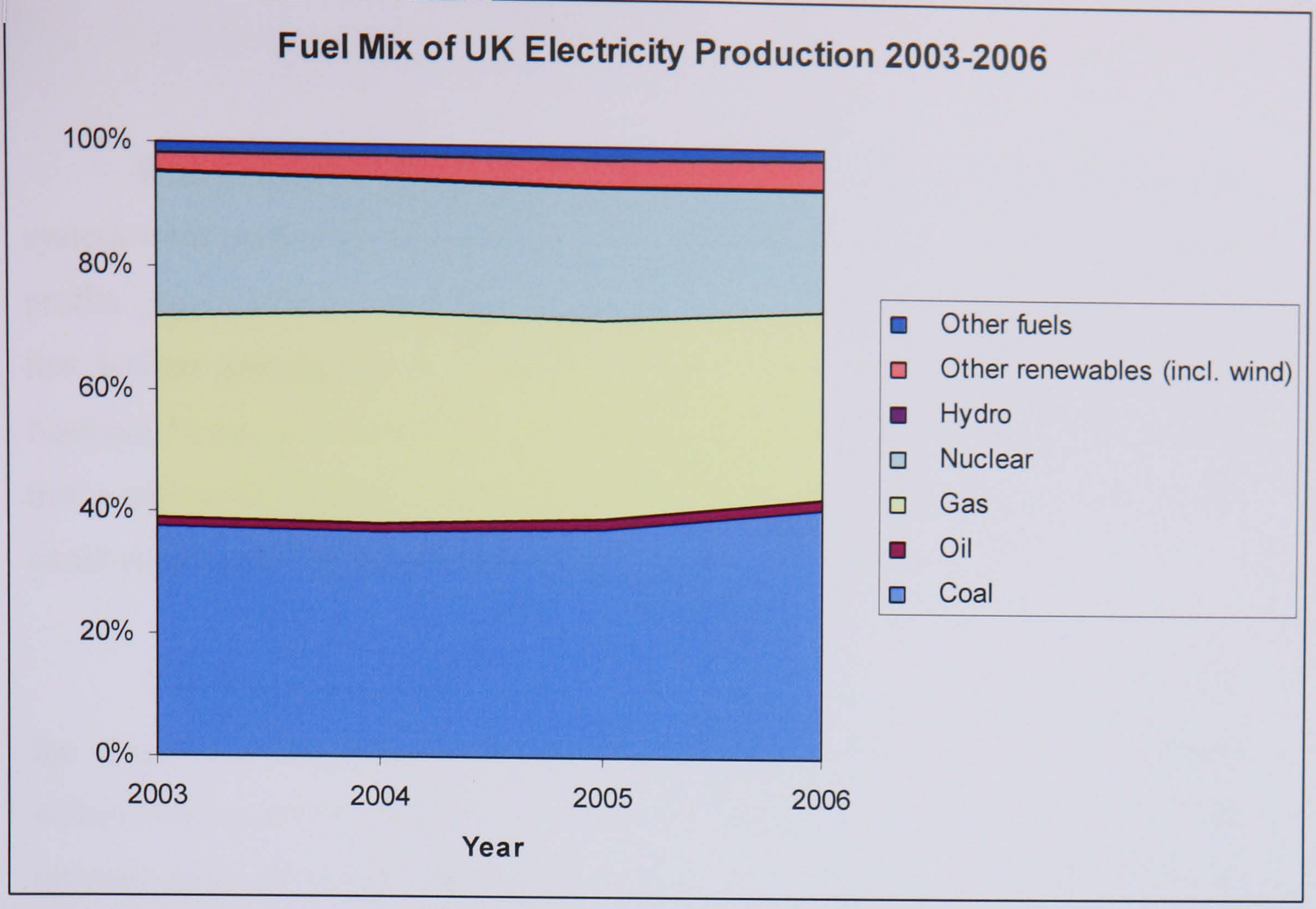


Figure 15: Fuel mix of UK electricity production between 2003-2006, source: (DTI 2005a)

Besides these large actors, several independent players remained in the generation business, two of which have significant generation assets. The giant Drax coal power plant of almost 4,000 MW of capacity was sold off by National Power in 1999 and, after being held by American company AES, has recently been floated as an independent company 'Drax Power Ltd.'. 'International Power Ltd.' is a global independent power producer, which has built up a generation portfolio in the UK of 2,750 MW of capacity. Total installed capacity in the UK stood at 70.55 GW at the end of 2002, while peak load reached 61.72 GW in that year (IEA 2004a).

The mandatory Pool was criticised from a number of angles. By 1997, the DTI had set up a review of the pool which ultimately culminated in the Utilities Act 2000, which instated the NETA, a voluntary market relying on bi-lateral contracts between electricity generators and retailers. There were two commonly cited criticisms of the Pool (Helm 1993:308ff.):

- The payment of one system marginal price instead of a pay-as-bid mechanism
- The liberal market principle of free voluntary trade instead of a mandatory market place

With respect to the first point, it was alleged that the operation with one system-wide market clearing price invited gaming from large operators to increase profits. Against this, it has been argued that it was not the market design *per se* that invited gaming but the market structure which conveyed market power to National Power and PowerGen, operating a *de facto* duopoly. While it was true, that a pay-as-bid system reduced the scope for gaming, a more competitive pool could equally reduce the scope for such market distorting behaviour.

The second argument is a matter of principle, and was mainly contested on the ideal that a liberalized electricity market should ultimately be able to operate without any coercive element. The Pool was seen as an evolutionary step to the ultimate goal of a free market. However, critics argued, that electricity as a 'commodity' would always need some form of intervention, since it could not be stored and demand and supply had to be balanced constantly. Furthermore, as noted above, the Pool also guaranteed a high degree of transparency and liquidity which maintained a form of competitive pressure (Newbery 1995).

As Helm notes (2003:308): "That there might be *different kinds* of competition, or that electricity generation might have a natural tendency to oligopoly appear not to have been seriously entertained…The lack of attention to the meaning of competition and competitive markets was to be a blind spot for both Offer (and Ofgem) and the Department of Trade and Industry (DTI) in the commitment to NETA."

In this context, Newbery and McDaniel argue that "By the time NETA was introduced […] the wholesale market was arguably one of the least [horizontally] concentrated in the world… The [Herfindahl-Hirschman Index (HHI)[19]] concentration of fossil plant (i.e. excluding nuclear) fell below 1800 in July 1999 and below 1300 in April 2000 – *before* NETA" (Newbery & McDaniel 2003:203). Yet, switching to NETA at a time when the industry progressed

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[19] The HHI is a commonly accepted measure of market concentration. It is calculated by squaring the market share of each firm competing in the market and then summing the resulting numbers. Markets in which the HHI is between 1000 and 1800 points are considered to be moderately concentrated, and those in which the HHI is in excess of 1800 points are considered to be concentrated

increasingly towards vertical integration, allowed the bigger players to exploit the links between their generation and distribution and retail assets while leaving market participants without such links increasingly vulnerable to the exertion of market power. Already in 1998, Newbery predicted that the increased risks of trading under NETA with penal imbalance charges would encourage vertical integration between generation and supply or retailing. This in turn meant that a vertically integrated industry with risky imbalance penalties would if anything be harder for new entrants to enter (Newbery 1998).

Helm summarizes this argument in two questions: "Would not the liberalization of contract forms suit the vertical players, so that different contracts could be set between own-generation and own-supply, from those offered to rival suppliers? Would not the big players also benefit from the lack of liquidity in the market place, which would result from a lack of transparency? [...] Though Offer and Ofgem thought that the Pool created the scope for gaming, to the main players the problem with the Pool was that its very transparency kept them in the regulator's spotlight and limited their scope to exploit vertical integration – hence, the numerous Pool price inquiries, plant divestments, threats of a MMC reference and the price cap." (Helm 2003:311-312)

In summary, within a few years of NETA being in operation, the electricity industry had consolidated into the above listed vertically integrated companies, and several generation-only companies, of which British Energy stands out. While British Energy is the UK's largest electricity generator, when it eventually went bankrupt it was bailed out by the government.[20] Helm (2003:240)

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[20] It appears that the government is determined to keep British Energy afloat, no matter what the economic circumstances. This fact was highlighted in the parliamentary discussions around the government bail-out. In a statement to parliament on 28/11/02, Patricia Hewitt, the then Secretary of State for Trade and Industry, argued: "I offered that loan because it was the best way of securing the safety of the nuclear power stations [...]" and further: "Let me stress, Mr Speaker, that if British Energy were to go into administration all its nuclear liabilities would fall to Government. We cannot just walk away from them; no responsible government would. This is the reason why the situation with British Energy is different from any other generator." This is echoed by a subsequent argument in the House of Commons by the Energy Minister Brian Wilson on 06/02/03. In response to a question, which asked why the government would not "rush to the House to ask for authority to buy [...] shares [...] when other companies go into administration", he stated: "Because nuclear is different... Other companies, even other power companies, can go to the wall. Though it is sad when jobs are lost, one can turn the key and walk away if nobody

summarises this situation succinctly: "The vision of a disaggregated market with many generators and many suppliers competing in a standardized transparent pool, with a supporting futures market absorbing the risk of long-term contracts, had gone. Politicians and regulators simply let it happen."

4.3.2. UK Renewable Energy Policy Overview

The first specific policy instrument to support renewable energy in the UK was the non-fossil fuel obligation (NFFO) introduced in 1990. The introduction of the NFFO occurred on the back of the UK support-system for nuclear power. In the context of the privatization programme of the industry, it was already noted that the government was unable to sell off its nuclear power assets initially. Consequently, a 'fossil-fuel levy' (FFL) was instituted which supported the continuous operation of the UK's nuclear power stations. In 1990, a share of the proceeds from the FFL was earmarked for contracts to support renewable energy projects. Consequently, the NFFO "developed out of the need to find a means of supporting nuclear power, once it was realized that the nuclear portion of the electricity supply industry could not be privatized in 1989 (Mitchell 1995)".

The NFFO provided an auction mechanism, in which projects could win long-term contracts if they were the lowest-cost bidder. There were a total of five auctions between 1990 and 1998 with increasing volumes, see Table 9 (Mitchell 2000;DTI 2005b).

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buys them, and that is the end of the story. In nuclear power generation that is the one thing that cannot be done. There must be an owner."

Table 9: Wind energy under the NFFO in the UK. Source: DTI 2005b, Mitchell 2000

	Year	Number of projects	Awarded MW	Actually completed projects	Actually Completed MW
NFFO1	1990	9	12.21	5	8.13
NFFO2	1991	49	84.43	23	52.45
NFFO3	1994	55	165.61	26	59.75
NFFO4	1997	65	340.67	11	33.55
NFFO5	1998	69	368.83	9	7.45
Total	**n/a**	**247**	**971.75**	**74**	**161.33**

Many projects that were successful in the bidding stage never progressed to construction and were never completed, as can be seen in Table 9. There is a significant discrepancy between the amount of MW awarded in contracts and the amount of MW actually built, with only 17% of the projects awarded actually completed. The structure of the NFFO meant that bid applications had to be comprehensive with regard to site measurements, technology selection and financial structure, while at the same time final planning applications were only submitted to local councils after the successful outcome of each round. Thus, a substantial risk element had to be included. Yet, competition drove prices down to levels where projects became sensitive to small changes in the underlying calculations hence turning out uneconomic at a later development stage. Furthermore, it has been suggested that some companies entered the competition with over-optimistic bids in order to lower the price range of the awarded contracts and thus squeeze out smaller competitors (Mitchell 1995, Mitchell 2000). Table 10 below shows the substantial downward trend of the average price of the awarded wind contracts.

Table 10: Average price for wind energy contracts under the NFFO auctions 1990-1998 (Source: Mitchell and Connor 2004)

NFFO-1	10p/kWh
NFFO-2	11p/kWh
NFFO-3	4.43-5.29p/kWh
NFFO-4	3.56-4.57p/kWh
NFFO-5	2.88-4.18p/kWh

In the absence of regular NFFO rounds, small wind developers were unable to plan their business in a continuous way. Only companies with sufficient equity were able to sustain long planning cycles and cope with the uncertainty over future business opportunities. Furthermore, in many instances smaller scale companies were unable to obtain project finance from third-party sources, due to the inherent risk in the NFFO mechanisms. Hence, even where projects were originally proposed by independent developers, they were subsequently bought up by the utility companies due to lack of resources or inability to secure financial backing from third parties (Mitchell 1995). Consequently, a clear trend towards large companies that were able to finance projects with their own equity was visible among the successful bids. This in turn set in motion a consolidation of the industry, reinforcing the trend towards large development companies (Mitchell 2000).

The reliance on large companies that were 'remote' from the local developments, contributed to the high failure rate of UK wind energy projects (Toke 2002). Toke argues, that despite widespread support for wind power in the UK in general, local objections to wind power developments often hinder their progress, as a classical 'not-in-my-backyard' (NIMBY) problem.

The last round of NFFO auctions was held in 1998, after which the incoming Labour-government announced a policy review for renewable energy technologies. Hence in April 2002, a new scheme, the Renewables Obligation (RO) was introduced. The policy put an obligation on electricity supply companies to supply a certain percentage of electricity from renewable energy sources, with the percentage rising annually to ensure continuous development (Mitchell & Connor 2004). Renewable Obligation Certificates (ROCs) had to be obtained through own-production or procurement on the market in order to cover each year's obligation.

While ROCs are 'technology-blind' in principle, i.e. there are no bands for specific technologies, in practice only those technologies that fall within the price-range offered by the ROCs are deployed. These are those nearest to the market in

terms of R&D, which has meant that most of the deployment taken place so far have been wind farms (Mitchell & Connor 2004).

Certificates were awarded for every kiloWatt-hour (kWh) of electricity from eligible sources to the operator of that plant. While selling electricity on the normal electricity market, a supplementary income was consequently earned by selling the according number of certificates on a separate certificates market. Supply companies that were unable to meet their obligation had to pay a 'buy-out' price for the shortfall, which was initially set at 3p per kWh, but linked to the Retail Price Index, tracking inflation. The amount collected in a 'buy-out fund' was recycled to those companies that had covered their obligation with certificates. Thus, while 3p/kWh represented the nominal price cap for an individual certificate, the actual value was higher due to the additional money flow from the buy-out fund. An additional source of income were exemption certificates for the Climate Change levy. Mitchell and Connor (2004) estimated that the total value of these separate income streams amounted to 6-7p/kWh in 2003, rising to 8.48p/kWh in 2006 at the latest auction for wind energy of the non-fossil fuel purchasing authority (NFPA 2006).

The initial long-term obligation target was set at 10.4% of annual electricity production in 2010, rising in small increments from about 3% in 2003. As long as renewables development lagged behind the annual target, prices for ROCs were at their maximum price plus the expected value of the buy-out fund. If supply of ROCs exceeds demand, i.e. if the obligation target is exceeded, the value of the buy-out fund becomes zero and ROC prices are subject to downward competitive pressure. Hence, as developments reach the mandated target, there is a tendency to undershoot as the value of the ROCs decrease with the expectations of target fulfilment. Reacting to industry demand, the government consequently raised the ROCs goal to 15.4% in 2015 with an 'aspiration' for 20% in 2020.

The ROC measure continued to favour large development companies that were able to finance projects off their own balance sheets. Since ROC revenues were subject to fluctuations and there was uncertainty over government policy beyond 2010, banks were unwilling to offer project finance for new developments

(Mitchell et al., 2004). This prevented companies without significant financial backing from entering the market and left most of the development with established large-scale companies. Furthermore, separating trades in physical electricity and ROCs present significant transaction costs to new market entrants. In the absence of 'consolidators' for such services, the ROC mechanism consequently favoured vertically integrated companies that were able to trade these commodities 'in-house' among their subsidiaries (Mitchell et al., 2004; Toke, 2002).

Today, the majority of wind power development in the UK is being undertaken by the large vertically integrated utility companies, and several smaller independent developers that are able to obtain power purchasing agreements (Toke 2002). Current total installed wind capacity in the UK is 1353 MW. The evolution of wind power development in the UK is given in Figure 16, while the ownership distribution is given in Table 11 below (BWEA 2006).

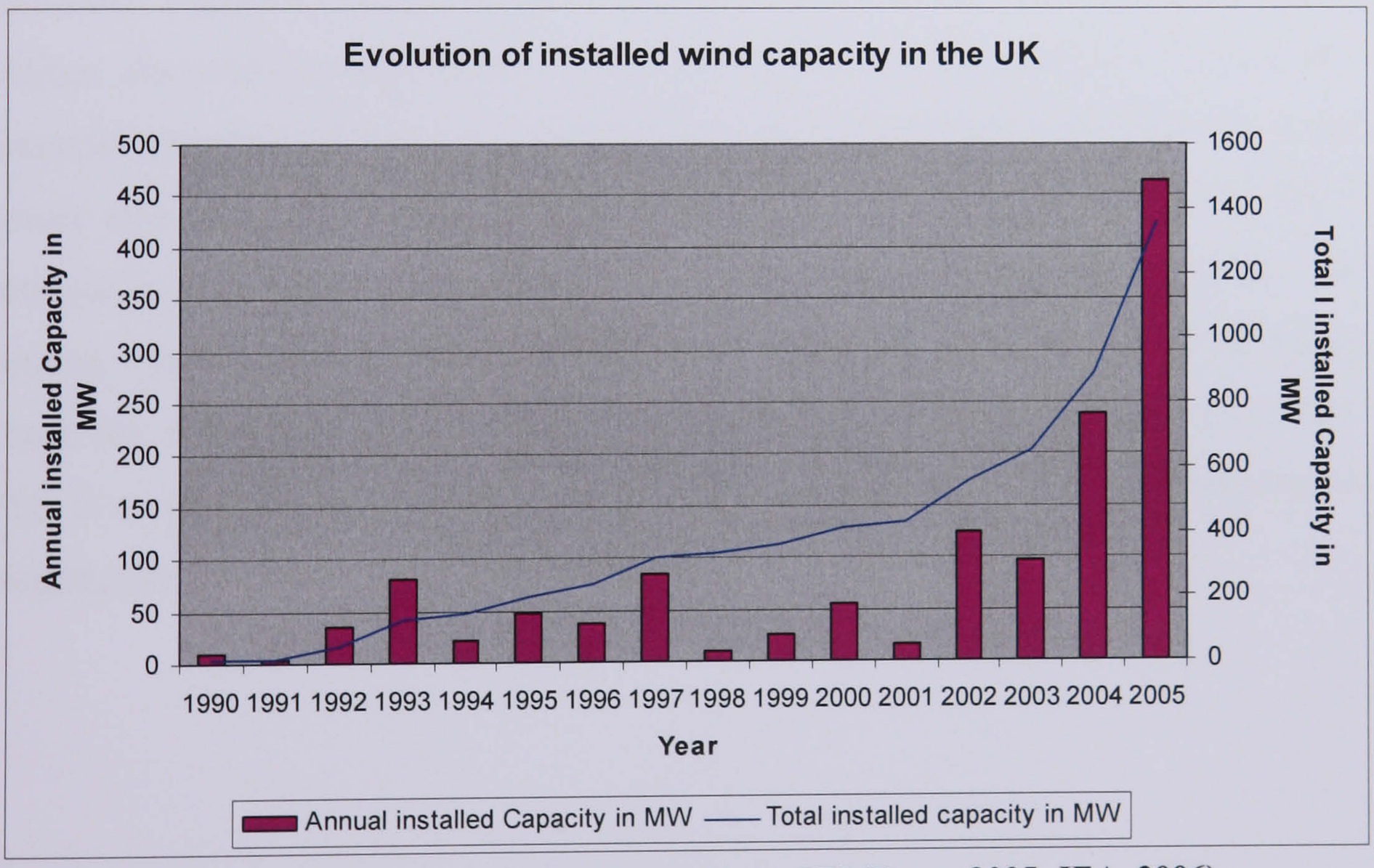


Figure 16: Evolution of wind power in the UK (Bwea, 2005; IEA, 2006)

Table 11: Installed capacity of wind farms owned by major UK utilities in 2005 (Sources: Company Annual Reports and Corporate Websites; BWEA 2006)

Company	Installed capacity	Percentage of total installed capacity
Centrica/British Gas	62 MW	4.5%
EDF Energy	4 MW	0.3%
E.ON UK	195 MW	14.4%
RWE npower	391 MW	28.9%
Scottish Power	288 MW	21.3%
SSE	162 MW	12%
Total utilities:	**1102MW**	**81.4%**
Other:	251 MW	18.6%
Total UK:	**1353 MW**	**100%**

4.3.3. UK Utilities' Strategies

Given this background, the incumbent utility company strategies are now presented. Figure 17 below provides an overview of the current fuel mix of the utilities discussed in this chapter, while Table 12 gives an overview of some key financial statistics of these companies. As can be seen from these figures, wind power still plays a marginal role in the fuel mix of the utilities studied. Most companies have announced specific renewable energy investment plans for the coming years. These plans with funds for three to five year periods often equal about the amount of total capital expenditure of the firms in the previous year. This is on the back of good financial health among all firms with operating results ranging from £345m to £1,44bn in 2006.

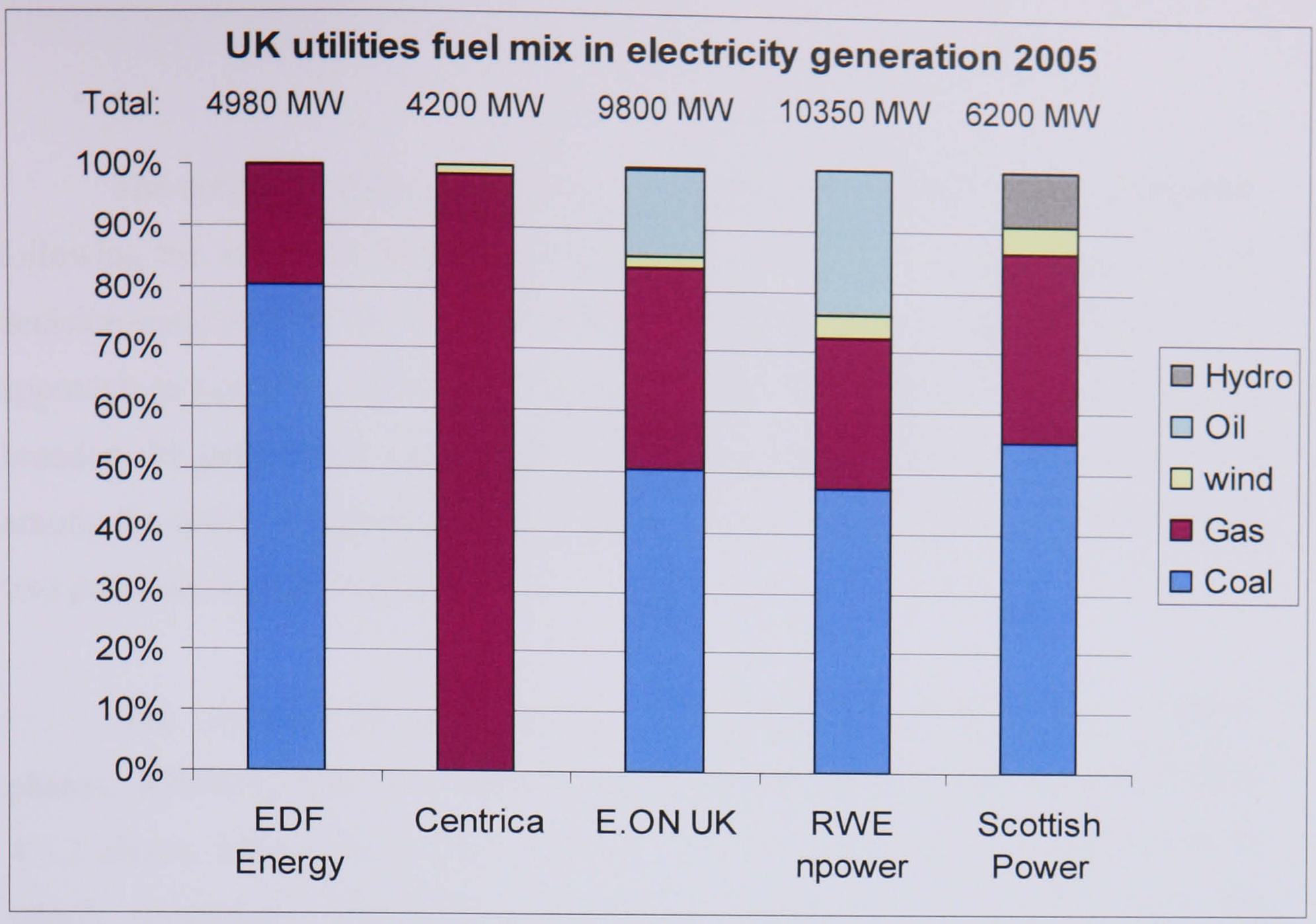


Figure 17: Fuel mix of UK utilities' electricity generation capacity in 2005. Source: company reports and websites

Table 12: Overview of key financial statistics of UK electric utility companies; Source: company reports and websites

	Market Capitalisation (year-end 2006)[21]	Ebit[22] (full year 2006)	Capital Expenditure (full year 2006)	Investment Programme for Renewables (latest available)
Centrica	£12.98bn	£1,44bn	£537m	1000MW of ROC-qualifying capacity until 2010; £750m investment
EDF Energy	£6.89bn (€10.23bn)	£654m (€941m)	£674m (€972m)	n/a
E.ON UK	£7.25bn (€10.76bn)	£828m (€1,229m)	£581m (€863m)	£406m (€600m) in ROC-qualifying capacity for the period 2007-2009
RWE npower	£4.84bn (€7.2bn)	£345m (€512m)	£274m (€407m)	€700m (£460m) across Europe 2007-2011
Scottish Power	£10.58bn	£805m	£940m	1000 MW of ROC-qualifying capacity by 2010

[21] In the case of EDF Energy, E.ON UK and RWE npower these are estimates based on the 'Enterprise Value" of the firm, which attempts to value each element of the firm on a discounted cash-flow basis ("sum-of-the parts analysis"); based on 'Credit Suisse' research reports, year-end 2006

[22] Ebit = Earnings before interest, interest payments and taxes; also termed 'operating result'

The corporate strategies with regard to wind power will now be presented following the analytical framework outlined in section 3.2.3. This focuses on the decision-making process for developing new technological capabilities, and the approach to corporate political activity. The summary section will consequently broaden the perspective and examine the interaction between corporate strategy among the utility companies and the wider systemic developments outlined in the two previous sections above.

The corporate strategies of UK utilities can be divided into two distinct phases, following the two renewables policy instruments described in section 4.3.2 above. Firstly, from 1990 to 1998, the NFFO provided the framework in which investment decisions were taken. Consequently, starting with the announcement in 2000 of a policy change by the government, the Renewables Obligation (RO) was the main point of reference for corporate strategy in this area and, as will be outlined, the companies adjusted their approach accordingly.

The NFFO Years

During the period of NFFO tenders, three UK utilities were bidders in every round – 'Powergen Renewables' (today part of E.ON UK), 'National Wind Power' (NWP today part of RWE npower) and 'Scottish Power'. The other utilities either did not exist in their present form or, in the case of Centrica, had not entered the electricity market yet.

Among those utilities that were involved in the NFFO rounds, significant company-internal obstacles had to be overcome. Here, especially the difficulty to align existing capabilities, new capability developments and company strategy were visible. In reference to these early projects, managers at the involved companies declared:

"There was serious opposition. We should not be doing this, we should put our money into 'real' power stations [...] The dash for gas was getting under way, so there was a real view of

"why waste your money on a plant that has dubious merits, when we can build these magnificent stations that deliver firm power with cheap gas" and so on [...] There was a great battle in the boardroom as to whether we should build any [NFFO projects]"

"There was almost a moral attitude, that we got a subsidised prize through the NFFO and therefore we should not be doing this, this was immoral! And there were arguments, I understand, at board level about that."

. *"It was very much project-by-project at the early stages, convincing the board of each project [...]."*

With regard to the NFFO market, the two main rationales for investment among the involved firms were stated as learning about this new technology and understanding the new markets. This came about mainly through searches among the companies to extend their existing capabilities following the liberalization of the electricity market.

In the case of Scottish Power, the case for wind power in its domestic Scottish market was pushed from early on by the regional government. Together with the emerging NFFO regime, Scottish Power aimed to position itself to take advantage of this institutionally created opportunity.

"In the early nineties, there was a study by the Scottish Office that charted at least 1500 MW of wind capacity – and turbines were significantly smaller at the time. So we saw an opportunity to develop some niche generation that could extend our existing renewables portfolio away from pure hydro. If it would happen in Scotland anyway we wanted to be part of it."

Furthermore, the NFFO gave Scottish Power the opportunity to step outside its Scottish home market and build generation capacity in the newly liberalized English and Welsh markets. It bid in every NFFO round (and in separate rounds for Scotland specific contracts in so-called Scottish Renewables Orders), acquiring development capabilities and also becoming acquainted with a variety of turbine manufacturers. In addition to own development, Scottish Power held a number of joint-ventures with local developers, providing expertise at the development stage and subsequently purchasing successful projects.

Powergen Renewables origins stemmed from the strategic aim of differentiation in the market. Privatization and liberalization of the electricity market provided the initial spur to initiate search activities for new opportunities beyond the traditional domain of the utility`s business. Hence. Powergen founded a small unit called 'electricity enterprises' which evaluated a variety of new energy technologies as potential new investment targets. This eventually led to the foundation of 'Powergen Renewables'. In this case, the jolt in the market environment (Sine & David 2003;Markard & Truffer 2006) provided the initial spur to assess strategic opportunities outside the established capabilities of the firm.

However, the wind energy business did not grow beyond a niche business within Powergen. This was blamed on the policy design of the NFFO which was considered unreliable:

"One of the great problems with the NFFO was that you never knew, if there would be another round of the NFFO... and if there was another round, if our projects would be selected [...] there came the point when we were actually spending quite a lot of money now, and consequently the question - is it worth doing it?"

In 1995, in the context of the policy uncertainty and Powergen's aim to acquire a stake in a major US utility, it decided to sell-off Powergen Renewables as it was considered a non-core asset which had to be disposed of to raise money. Hence, Powergen Renewables was sold into a joint-venture with an engineering group that had an interest in offshore wind developments. Yet, the new joint-venture actually allowed the company to focus its strategy solely on renewable energy projects and also provided the necessary resources for these projects.

"[...] that actually was the point, where the renewables efforts at Powergen took off... Because we were a separate company that had a remit, which was to build renewable plants, and it only had to satisfy its own board, that was where it took off. The efforts to build windfarms went from strength to strength [...]."

Finally, NWP was founded as a joint-venture wind development company between National Power (now RWE npower), which held a 50% stake, and the

'Wind Energy Group' (WEG), itself a joint-venture between British construction company 'Taylor Woodrow' and the airplane and turbine manufacturer 'British Aerospace', which owned the other 50%. The WEG brought capabilities in the upstream end of wind turbine supply through its stakes in a blade and a turbine manufacturer, while British Aerospace contributed their expertise in aeronautics. However, after a strategic review, British Aerospace pulled out of the consortium in 1993, and Taylor Woodrow followed one year later, "in order to concentrate on its core businesses of construction, housebuilding and commercial property and merchanting." In both cases, a focus on core capabilities within the companies led to the abandonment of this niche business for the firms.

Yet, by that time NWP had established itself as a small but profitable company, which was the UK market leader in wind power at the time. It continued to operate as a 100% subsidiary of National Power, having developed skills along the wind energy development value chain. NWP was active in the NFFO, bidding and winning projects in every round. In NFFO round three, awarded in 1994, it was owner or partner in half of all awarded wind energy contracts and the number of contracts was capped for NWP so as to allow other bidders a share of the round (Windpower Monthly 1995a;Windpower Monthly 1995c). By 1998, with 132 MW of operational wind farms, it owned and operated over one third of all wind energy capacity in the UK. In the words of one manager today,

"NWP has a relatively unique history in developing close-to market renewable technology projects, clearly leading the UK wind market [...] it was something 'useful to sustain' for National Power."

In summary, among all three companies mentioned above the primary motivation was learning about the new technology and market environment. None of the three companies had integrated wind energy into the core of its business. This was most visible at Powergen, which sold Powergen Renewables into a joint-venture so that it could focus on its "core business". However, also at Scottish Power and npower renewables, managers characterized their early wind power

investments as "learning investments" and about "understanding the market". Hence, typical statements included:

"All I can say is that I am glad I was not around then. I understand the processes, the hoops that we had to jump through to get the first project approved were much bigger than you might anticipate [...] it even comes down to how do you construct a contract when nobody has done it before? You have to dream up between you and the first developer the ground rules for how you deal with this kind of stuff."

"It was to learn about the technology and to find projects to make decent investments with decent returns."

The limited strategic integration of wind energy is also visible in the political lobbying of the three companies, or rather in the absence thereof. The NFFO itself was introduced on the back of a policy supporting the nuclear industry, which the government was unable to sell off at the time of the industry's privatization. The inclusion of renewable energy in this policy owed at least as much to the government's aim to comply with European Union rules over state aid as to the explicit desire to foster an emerging niche market (Mitchell 1995;Suck 2002). As outlined above, a major drawback of the NFFO for the companies was the erratic nature of the announced auction rounds. For example, while NFFO-1 and NFFO-2 followed each other in 1990 and 1991, NFFO-3 was only awarded in December 1994. Furthermore, serious delays in the handling of the auctions were reported due to the relevant departments being overwhelmed by 'waves' of bids after each announced NFFO round (Mitchell 1995). Yet, neither issue was the subject of any corporate political activity by the above-mentioned utility companies with a view to alleviating the situation.

In response to the government's consultation paper on a follow-up policy to the NFFO "no clear consensus" emerged among the utility companies for a preference of certain policy instruments. (Windpower Monthly 1999b). Consequently, the Renewables Obligation (RO) owed its emergence almost entirely to the regulatory change in the UK wholesale electricity market with the changeover from the pool market to NETA (see section 4.3.1 above for details). In this context, the Utilities Act 2000 abandoned the obligation on RECs to source

electricity from non-fossil sources (nuclear and renewables). which made a change in policy necessary. Consequently, the RO was considered a logical extension to the emergence of a bilateral market for electricity and no alternative was seriously put forward among the utility companies (Helm 2003;Mitchell & Connor 2004).

The Introduction of the Renewables Obligation

Corporate strategy among all UK utilities was significantly overhauled with the introduction of the RO. Its announcement arrived at a time when the UK electricity industry consolidated by vertical integration, as discussed in section 4.3.1. With the obligation of the RO falling on the electricity supply business, all vertically integrated companies were affected. Consequently, all utilities stated in the interviews that the RO was a main driver for their renewables investments. Typical responses included:

"The driver [for investment into renewables] is clearly the obligation, that there is a need to do something about it. With the economics, if the RO wasn't there, then I doubt very much that we would be doing it [...] So yes, the RO is the only driver."

"The RO gave a 'kick-start' to the renewables business and made it clear that governments had a long-term interest in these technologies."

"The stimulus at the time certainly was the expectation that the Renewables Obligation would come in. Renewables in the UK was seen as a core business. And that was because our supply business had the obligation to supply the ROCs."

"Fairly soon after the renewable obligation came in, there was a recognition that we needed to make a step-change in terms of our level of activity, so a few years ago, this gradually changed and a recognition of that is the fact that we are now an integrated business within [the company] ... effectively, renewables are part of that core business."

"Around the start of the decade was really when the strategic focus sharpened on renewables and wind in particular, because of the RO. [...] It was really the driver behind stepping up the gear with renewables development. We knew in the year 2000 that something

major was coming, although we did not know exactly what. But we then took the decision to take a good look at the strategy, have a good look at the available resource and get things under way to position ourselves."

Consequently, besides the three companies mentioned above, EDF Energy and British Gas/Centrica started investing in wind power capabilities. However, two distinct approaches emerged between the established companies and the newcomers.

EDF Energy bought the wind power portfolio of an independent wind company and commenced with the development one offshore wind farm. However, it considered not to have the technological capabilities in order to contribute to the industry. Instead, it was stated that

"EDF Energy wants to retain some specialist knowledge to be able to steer projects from the top. However, the detailed carrying out of work will be left to specialist consultants."

Hence, the mismatch of existing capabilities at EDF Energy and the requirements for wind power developments meant that no new capabilities were developed in this field. EDF did not see itself as having the local development capability for creating a continuous pipeline of onshore wind projects. Instead, it focused on becoming involved at an operational stage, through power-purchasing agreements and equity shares in completed companies. Consequently, its two onshore windfarms were bought from AMEC, the specialist construction company, while its offshore projects are developed in joint-ventures with specialist developers.

British Gas/Centrica initially decided to focus on buying ROCs on the open market.

"We don't go around the countryside looking for new opportunities ourselves, [...] we did not have the right skills in doing that, so we much prefer other people to do that sort of thing, do all the hard work and do all the development stuff, and when the project looks like it becomes serious and it will happen, then they will come to the market, and we can get involved [...]"

Yet, with the emergence of offshore wind farms as a viable commercial option, it consequently decided to enter this field with a total of six offshore wind projects now under development, the largest such portfolio among UK utilities. The main driver here was the perceived complementarity with its capabilities:

"When the 'Round II' bidding came around, it was an opportunity to say, hang on, here is an opportunity for us, something that we can contribute to, we do have offshore skills, we are offshore elsewhere in our business, so we know what we are doing, we have got engineering skills, we have got people that can do this kind of stuff – this is an area where we can make a contribution. [...] So, that seemed like a sensible place to become involved."

Consequently, Centrica's approach to wind power capability developments focused exclusively on the offshore wind sector.

Among the three established companies – RWE npower, Scottish Power and E.ON Renewables – capability development within the companies concentrated on the inner organizational context, and the integration of wind power in higher levels of the hierarchy.

"Wind had moved from a level where it was 'useful to sustain' but not material to our business, to a level where it became core business.".

"The focus on renewables grew exponentially [with the introduction of the RO] ... with an increasingly higher level involvement of people within the company."

Furthermore, the nature of the RO required other company departments to get involved in the development of the renewables business. This covered especially the trading of electricity and maintenance of the assets. In this way, renewables became more integrated into the mainstream company activities. This is reflected in statements discussing the areas of capability developments following the introduction of the RO:

"[...] your board becomes more familiar with these sort of projects, your trading people become more familiar with the way the electricity is produced, the legal people become more comfortable in dealing with the contracts, you can think it right across the business."

"So there is a separate renewables business, but my perception is that there is far greater integration between the renewables business and the generation guys who run the stations, or the energy management team that tries to capture the markets prices or forecast the output."

While the RO provided the major spur for increased activity in the wind power business, it also guided the utilities' long-term expectations with regard to the limits of the policy.

"Within our organization we are striving to achieve our target but there is no incentive to go beyond that [...] In fact, there is a big disincentive."

"We created the Renewables Obligation 'compliance' function which optimizes our assets accordingly [...] Managing renewables is all about managing our obligation, these are the terms of reference that we have."

Consequently, the UK incumbent utilities saw the technology potential limited by the government's policy limits. The forecasted growth in offshore wind farm developments is considered to fill a significant share of the total obligation, hence leaving only limited space for further onshore developments. Consequently, while organizationally integrated into the incumbents' businesses, wind power did not acquire a strategic role for the growth of the companies involved.

4.3.4. Summary of co-evolutionary developments in the UK

In summary, the incumbent utilities analysed in this section saw the development of new capabilities in the area of technology know-how and wind farm development to the extent that they operated more than 80% of UK wind farms by the year 2005. Yet in the context of the much higher total installation rates seen in Spain and Germany, it has to be asked why the UK lagged behind these two countries despite the involvement of the utility companies?

In the context of the analytical framework developed for this thesis, it is attempted to answer this question by examining the interaction between company

strategies and systemic developments. On the institutional level, the renewable policy design of the initial NFFO auctions provided several hurdles for new, independent companies to enter the market, as outlined in section 4.3.2. Simultaneously, the wind power subsidiaries of the incumbent utility companies bid aggressively for the contracts available, thus driving down the price and capturing a significant share of the market. In NFFO-3, NWP's projects were capped at half of all available contracts to leave some room for other developers.

The erratic nature of the NFFO rounds, coupled with the difficulty of independent developers to obtain project finance favoured larger companies that were able to sustain longer periods of uncertainty and finance projects off their own balance sheets. A lack of strategic outlook in the policy also meant that potential newcomers would have had to build a wind development business on the hope that the then-Department of Energy would provide continuous and possibly increased rounds of auctions for the indefinite future. This factor again favoured established, well-capitalised companies who could sustain a niche business in the wind sector without having to rely on it for its main funding. This is exemplified by NWP, which was sustained as a "useful" niche business without aiming to improve the policy environment in which it operated. Due to the low level of diversity in the UK wind industry, the incumbent utilities only faced a very limited competitive threat from the emergent technology to their established businesses. Furthermore, the small number of independent actors in the wind industry only provided a limited basis for alternative institutional engagement strategies.

With the wind power development being non-core and non-strategic within the larger organizational structure of the incumbent utilities, the policy changeover from the NFFO to the RO was met largely by indifference. Issues such as vertical integration and the changes in market design from a pool-market to a bilateral-trading model dominated the agenda at the time. Consequently, the introduction of the RO was announced as a sub-section of the Utilities Act 2000 that regulated the future of the industry.

Consequently, the RO cemented the *status quo* as it again presented substantial barriers to entry into the market for independent companies. Firstly, it introduced substantial market risks and policy uncertainty, which required adequate premiums that pushed up the cost of capital for independent developers (Mitchell & Connor 2004;European Commission 2005b). Furthermore, the RO introduced additional transaction costs for independent producers who had to set up trades for the physical electricity and the various associated certificates, while the just emerging integrated utility companies were able to do these 'in-house' with their established capabilities. Lastly, it again limited the possible growth in wind power through the small annual increments at which the target was increased and the long-term limit in the target beyond what was aspired to by the government. This limited the scope of any strategic business plan that was solely footed in the wind energy business.

However, as the renewables obligation fell on the suppliers' business at a time when the utility companies were vertically integrating, all utilities were now affected by it and had to respond to the policy. Consequently, companies assessed the opportunities for complying with the regulatory requirements and developed different approaches. In fact, 'compliance' was the explicit word used by two utilities when asked about their approach to the RO, since it did not provide a strategic window to develop beyond what was required by the policy framework.

Since ROC trading matched well with the existing electricity trading functions developed among incumbent utilities, all incumbent utility companies used this opportunity to extend their trades into the renewable energy area. For those utilities that had not entered the wind industry before, this provided the primary approach at first. Consequently, the emerging offshore wind market provided companies with the opportunity to expand into a new market with no established leader. This approach was especially sought by Centrica, whose existing offshore knowledge from its natural gas business provided synergies with the requirements in the offshore wind area. Those utilities that had already developed wind power capabilities also sought to expand their business into the offshore area, while it was furthermore integrated closer into their organizational hierarchy.

In summary, the incumbent utilities' position in this niche market, coupled with the limited scope offered by the institutional environment to independent wind farm operators led to a small overall industry population and low level of overall technology diffusion in the UK compared to the other two countries. The absence of a significant industry base in the institutional engagement process around the introduction of the RO led to the introduction of renewables policy as an afterthought in the wider electricity market regulation debate. The co-evolution between organisations and institutions was one of 'compliance' and 'accommodation' in a policy framework that limited competition in the emerging industry and set small, incremental development targets.

4.4. Germany

4.4.1. German Electricity Market Overview

Germany enjoyed a long tradition of regional monopolies in electricity generation, with nine large generation and transmission companies at the time of German reunification in 1990. Furthermore, the regional distribution and supply businesses were owned and operated by hundreds of small communally and regionally owned companies, so-called 'Stadtwerke'. Hence, overall, the German industry structure was highly fragmented and with significant state control at that time.

Germany opened its electricity market to competition with the Energy Act of 1998, transposing the 1996 EC electricity directive into national law. However, immediately after Germany's reunification in 1990, the market started to consolidate around the model of the vertical integrated utility. Four large utilities emerged, which are E.ON, RWE, Vattenfall Europe and EnBW. They were created through a series of mergers and takeovers, among the large generation and transmission companies, while many of the small distributors and retailers were acquired along the way. Hence, these four companies owned assets in generation,

transmission, distribution, and retail, although their different businesses had to be *legally* separated from 2005 onwards. In the process of this consolidation, state-ownership mostly vanished although several board members were still recruited from regional governments.

Their evolving market shares in electricity generation and the associated Herfindahl-Hirschman Index (HHI)[23], showing the level of market concentration, is given in Table 13. By the time consolidation had concluded in the year 2000, they operated together almost 90% of Germany's electricity generation capacity. Furthermore, on the supply side, only 'Yello', which is owned by EnBW, managed to establish itself with a presence across all parts of Germany and a significant customer base of around one million (Brunekreeft & Twelemann 2005). The main electricity trading platform in Germany is the 'EEX' spot and futures market in Leipzig, formed in 2002 as the result of a merger of two regional electricity markets. Liquidity on the EEX remains modest, with less than 10% of average daily electricity consumption traded in the various markets, yet the EEX prices remain the reference for the German electricity market (Green et al. 2005).

Table 13: Market Shares and HHI concentration in electricity generation in Germany (source: Brunekreeft and Twelemann 2005)

		Percentages of Output		
		1994A	1994B	2000
VEBA	**E.ON**	16.9	14	28.7
VIAG		11.2	8.3	
RWE	**RWE**	31.4	28.4	37.3
VEW		7.2	6.7	
EVS	**EnBW**	4.9	4.3	8.6
Badenwerk		4.9	4.3	
HEW	**Vattenfall**	3.6	3	15
BEWAG		2.9	2.3	
VEAG		-	11.8	
Other		17	17	10.4
HHI		1807	1595	2622

[23] The HHI is a commonly accepted measure of market concentration. It is calculated by squaring the market share of each firm competing in the market and then summing the resulting numbers. Markets in which the HHI is between 1000 and 1800 points are considered to be moderately concentrated, and those in which the HHI is in excess of 1800 points are considered to be concentrated (Newbery 1995).

New entry into the generation market has also been scattered. This is in part due to significant excess capacity at the start of market liberalization. One explanation for the lack of new entrants is that electricity prices remained very low in the period 1998-2001 and have only increased in recent years. This lowered the potential profit margin for independent power producers and made entry into the market more difficult. Bower et al. in an agent-based simulation argue that the price-fall can also be explained with strategic behaviour on the side of the incumbent utilities (Bower, Bunn, & Wattendrup 2001).

However, another problem cited by Brunekreeft and Twelemann (2005) was the merger between E.ON and Ruhrgas, a vertically integrated gas company which controls about 75% of Germany's gas imports and 60% of the gas supply network (Brunekreeft & Twelemann 2005). This merger was blocked by the cartel office in 2002 on the grounds that access to gas was increasingly seen as critical to competition in electricity generation. However, this vote was subsequently overturned by the Federal Economic Ministry and the merger went ahead.

Since new CCGT plants were the most popular candidates for new entrants into the generation market, it was difficult to bypass E.ON-Ruhrgas in order to secure gas supply contracts. This was seen as a barrier to entry, as independent power plant operators would have to negotiate with the subsidiary of a direct competitor and potentially reveal sensitive information. Consequently, of the four known CCGT developments in Germany, two projects pursued by independent companies failed outright, one is 25% owned by E.ON and 50% by EnBW, and only one 800 MW CCGT plant is currently being developed by a consortium of large energy customers and regional retailers (Brunekreeft & Twelemann 2005). The strongest growth in independent new power generation has been in renewables, which will be discussed in the next section.

Until summer 2005, there was also no regulator for the industry and third-party access (TPA) to the German grid was negotiated through a series of informal association agreements (*Verbändevereinbarung*) of all the main stakeholders in the industry. The German cartel office assumed a passive background role threatening *ex post* intervention if the outcome of the

negotiations was unacceptable in its eyes. This set-up led to a ratchet effect, whereby "every new Association Agreement had to be more competitive than the former one" (Glachant, Dubois, & Perez 2003:10) in order to demonstrate progress towards the goals of electricity market liberalization and to satisfy the cartel office. However, negotiations eventually broke down and the German government installed a dedicated regulatory authority for the electricity grid. While grid ownership remained with the four (legally unbundled) companies named above, grid tariffs now had to be cleared by the regulatory authorities *ex ante*. In its first review of tariffs in 2006, it cut the applied-for tariffs by €2.5bn or an average of 13% (Bünder 2007), thus establishing itself as a significant force in the German electricity industry.

Over the coming decade, the German electricity industry is facing a significant programme of new power plant constructions. Some 20GW of nuclear assets will be phased out as part of a government-industry agreement until 2023, and a further 20 GW will be shut due to the age of the assets. Consequently, up to 40 GW of new capacity will have to be replaced until the year 2020 (RWE 2006).

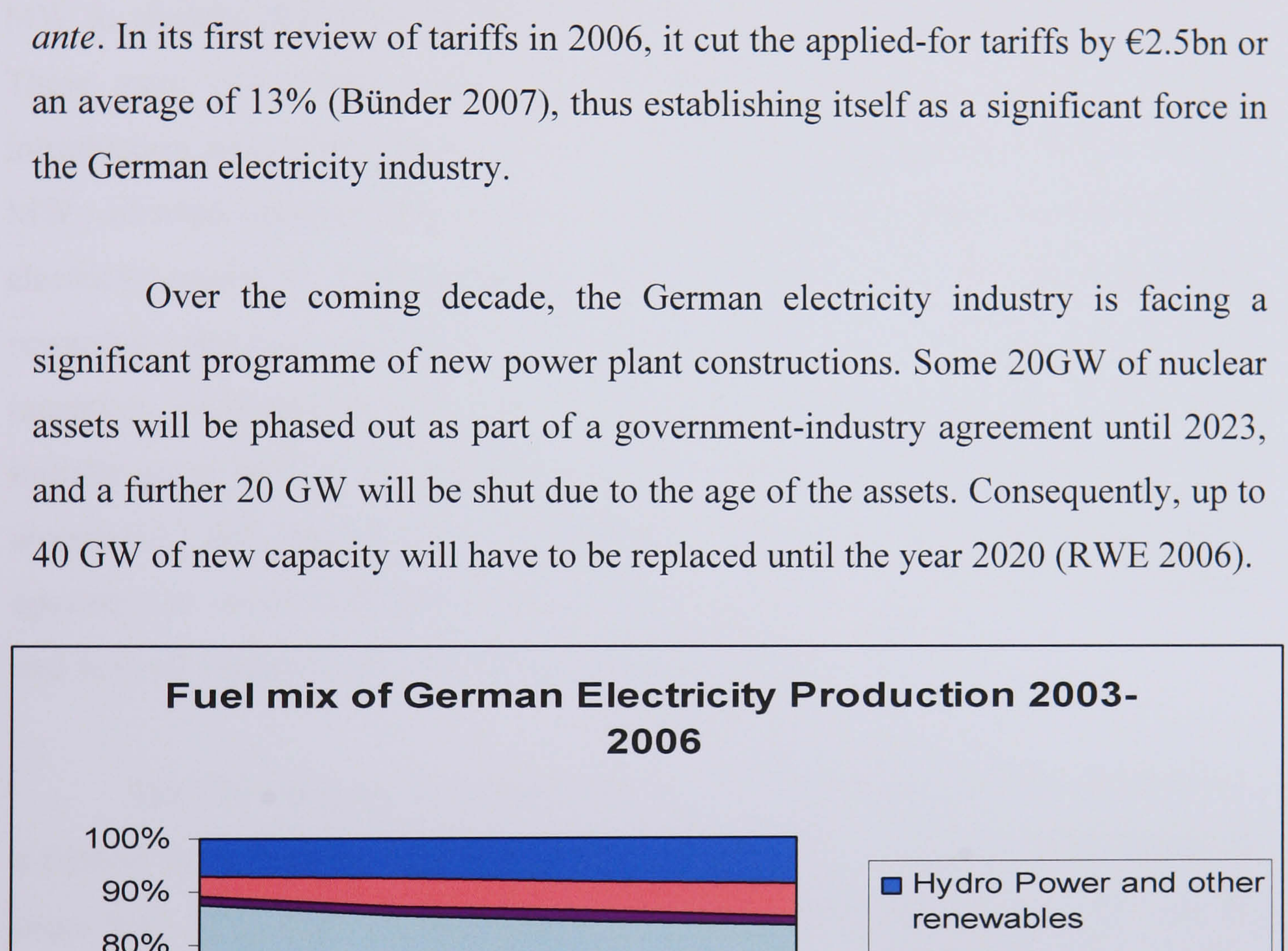


Figure 18: Fuel Mix of German Electricity Production 2003 – 2006; Source: BMWi 2007

Yet, the German fuel mix has been very stable between 2003 and 2006 with hard coal, lignite and nuclear power the dominating fuel choices, as shown in Figure 18 above (BMWi 2007).

4.4.2. German Renewable Energy Policy Overview

Between 1990 and 2000, total installed wind capacity increased from 56 MW to slightly above 6,100 MW (Stenzel, Foxon, & Gross 2003;BMU 2007). There were two pillars underlying this market expansion: Firstly, a market introduction programme aimed to install 100 MW - subsequently raised to 250 MW - of wind capacity through a mix of grants and a guaranteed payment for the electricity produced. Furthermore, in December 1990, a new law was passed that rewarded wind farm operators with a fixed price for every kWh produced. This incentive, enshrined in the new 'Feed-In Law' (FIL) (Bundestag 1990), was initially set at 90% of the average household electricity tariff, which represented around 0.17 DM (around €0.09) at the time. It furthermore put a mandate on grid operators to connect all renewable energy installations to the nearest grid point and feed all electricity production into the grid (Reiche, 2005).

The FIL excluded installations in which the Federal Republic of Germany, a federal state, a public electricity utility or one of its subsidiaries held shares of more than 25%. This affected many of the incumbent utilities that were still in state ownership. Yet, electric utility companies were allowed to benefit from the FIL if they invested in renewable energy installations outside their monopoly region (i.e. in competition to a neighbouring utility). Nevertheless, an annex to the law reiterated the point that public utilities were still allowed to recoup investments into renewables in their own regions through the regulated tariff base (Bundestag 1990).

Investments into wind energy have been undertaken by many private individuals. A common scheme in Germany were closed mutual funds which offered small equity shares in specific wind farm projects. These funds also benefited from a special tax break offered for investments into renewable energy.

Another popular type of schemes has been cooperatives, often involving farmers that planned to install wind farms on their local fields. These raised money predominantly in the local community and with the aid of local savings banks. In general, the simple formula of the FIL allowed these new types of energy investors to enter the market for the first time without facing significant administrative barriers. Grid access was guaranteed and paid-for by electricity customers through general transmission charges, while the FIL effectively acted like a 20-year power purchasing agreement, offering a high certainty of income over the guaranteed period. Consequently, a multitude of new wind energy development companies entered the market. Consequently, the ownership structure of wind farms in Germany is widely diversified today and a large number of independent companies are operating in this sector.

The FIL remained intact for ten years, even though it was repeatedly attacked by the German utility companies (as will be discussed in the next section 4.4.3). With the change in government after the federal elections in 1998, the new Social Democratic-Green government proposed several additions to the FIL to include new types of renewable energy technologies and stabilise the policy framework. Specifically, it aimed to decouple the price paid to wind farm operators from the average household electricity tariff and instead provide a more stable and predictable income stream.

Consequently, in 2000, the new government enhanced the FIL by providing fixed-price contracts over a 20-year period to new wind farms. Furthermore, to encourage innovation and cost-reductions, prices varied by technology and were decreasing annually by a fixed percentage to take account of technological improvements. Finally, it removed the geographical restrictions on utilities, thus allowing all energy companies to benefit from the tariffs in the same way, no matter where they invested. A 2004 extension to the FIL also updated the long-term target for renewables from previously 12.5% of electricity production by 2010 to 20% by 2020. It furthermore introduced a separate and higher feed-in tariff for offshore wind. The evolution of the fixed prices for wind energy is given in Table 14 below.

Table 14: Evolution of feed-in tariffs for wind in Germany 2000-2004 (Reiche 2005)

	2000	2001	2002	2003	2004
Onshore Wind (first five years)	9.1	9.1	8.96	8.82	8.7
Onshore Wind (after five years)	6.19	6.19	6.1	6	5.5
Offshore Wind (first twelve years)	As above (first five years)	As above (first five years)	As above (first five years)	As above (first five years)	9.1
Offshore Wind (after twelve years)	As above (after five years)	As above (after five years)	As above (after five years)	As above (after five years)	6.19

In the course of the FIL, Germany developed a substantial home grown wind industry. In 2005, there were 64,000 people employed along the value chain and annual turnover of companies in the sector reached €7bn, 51% of which was generated abroad (BWE 2006). In fact, Lauber and Jacobsson (2006) argue that the successful economic development of the sector was a key factor in building up a political lobby base, which was able to defend the FIL law against potential modifications. Again, the discussions around the FIL will be outlined in the next section 4.4.3. Overall, wind energy development in Germany since 1990 can be divided into three phases. A growth phase between 1990 and 1995 was followed by a period of stagnation and uncertainty between 1995 and 1998, while the post 1998 phase has been again marked by strong growth. The annual and cumulative installed capacity of wind energy is shown in Figure 19 on the next page. German utilities only have a small share in this development. As can be seen from Table 15 below, their combined ownership came to just 248MW in 2005, which represents a share of little more than 1% of total installations.

Table 15: Installed capacity and investment plans for wind energy by Germany's largest utility companies in 2005 (Sources: From interviews with senior managers of the companies)

Company	Installed capacity	Target
E.ON	224 MW	950 MW offshore projects
RWE	22 MW	n/a
Vattenfall	2 MW	n/a
EnBW	n/a	n/a

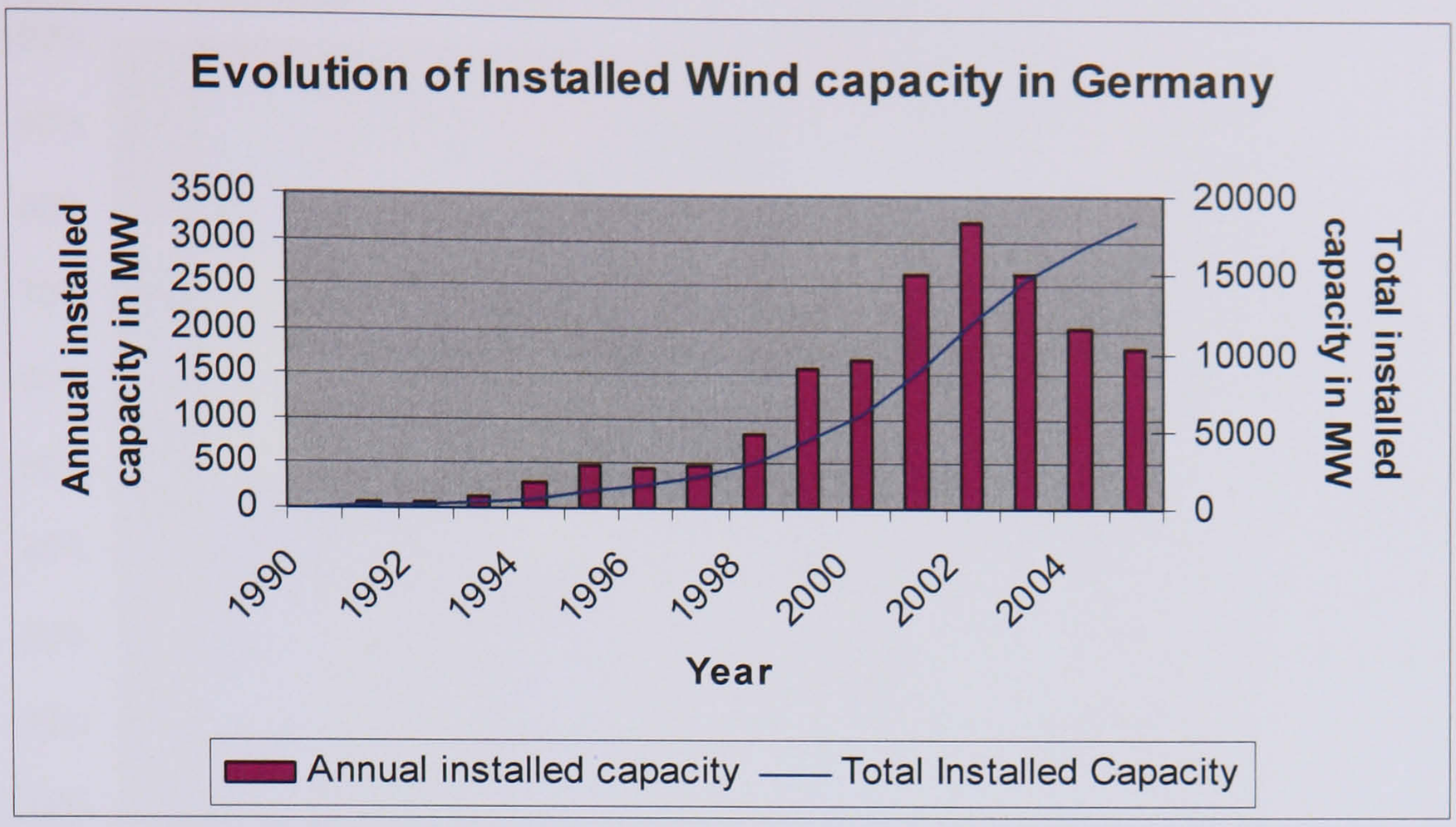


Figure 19: Evolution of Installed Wind Capacity in Germany (IEA 2006;BMU 2007)

4.4.3. German Utilities' Strategies

In the following section, the German incumbent utilities' strategies are now presented. Figure 20 below provides an overview of the current fuel mix of the utilities discussed in this chapter, while Table 16 gives an overview of some of their key financial statistics. As can be seen from these figures, wind power hardly appears in the fuel mix of the utilities studied, while nuclear, lignite and hard coal dominate the incumbents' portfolio. However, there are specific renewable energy investment plans for the coming years especially focusing on offshore wind. The total likely expenditure for these projects is currently hard to assess but are likely to fit within existing capital expenditure budgets on conventional generation. All firms reported positive operating results ranging from €1.1bn to €3.7bn in 2005.

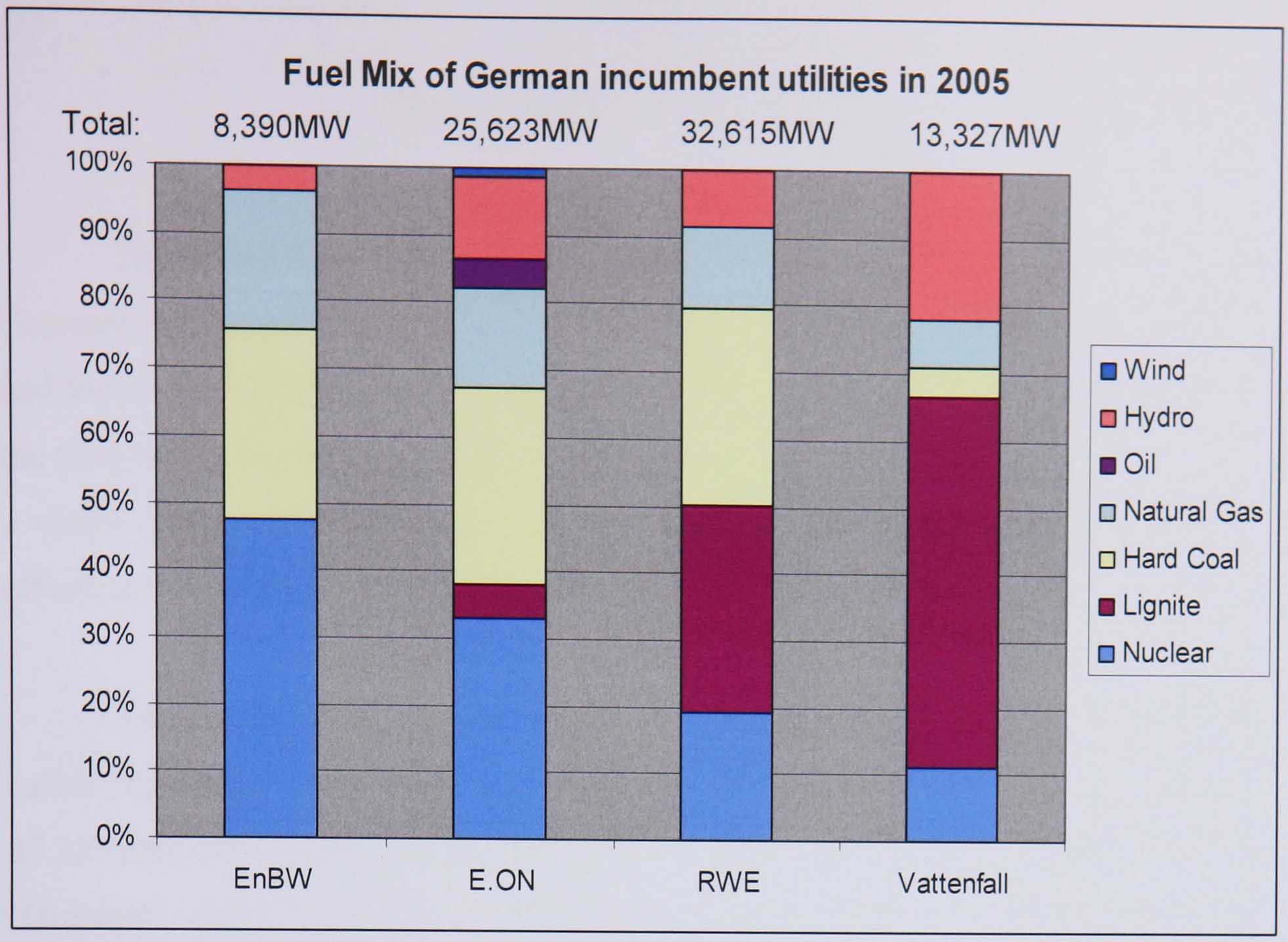


Figure 20: Fuel mix of German utilities' electricity generation capacity in 2005. Source: company reports and websites

Table 16: Overview of key financial statistics of German electric utility companies; Source: company reports and websites

	Market Capitalisation (year-end 2005)[24]	EBIT (full year 2005)	Capital Expenditure (full year 2005)	Investment Programme for Renewables (latest available)
EnBW	€11.5bn	€1.2bn	€547m	Extension of hydro plant for €277m (2007 – 2011)
E.ON	€35.8bn	€3.7bn	€1.3bn	1,350MW of German offshore wind projects 2011-2014
RWE	€42.5bn	€3.7bn	€2bn	€700m (£460m) across Europe 2007-2011
Vattenfall	€8.7bn	€1.1bn	€515m	1,500MW of German offshore wind projects until 2015

[24] In the case of E.ON and RWE, these are estimates based on the 'Enterprise Value" of the firm, which attempts to value each element of the firm on a discounted cash-flow basis ("sum-of-the parts analysis"); based on 'Credit Suisse' research reports, year-end 2005

The early Days 1990-1994

The initial approach to wind power among the incumbent utilities in Germany was marked by scepticism with regard to the viability of the technology and the fit with existing capabilities. Especially, the small scale of the turbines at the time relative to conventional plants meant that the German utilities did not see a viable business model at first. Hence, early considerations focused on R&D efforts to scale up the technology.

The largest and most well-known of these was the development of the so-called 'Growian' turbine between 1980 and 1987, which posted total costs of 87.2m DM (about €44.6m) for a single prototype turbine (Heymann 1995). The 'Growian' was a 3,000 kW demonstration prototype with a two-blade horizontal axis design and was co-sponsored by German utilities RWE, HEW (today part of Vattenfall) and Schleswag (today part of E.ON). However, the project was an abject failure, running over the original budget by 33%, operating for only 420 hours over a three-year period and breaking down several times along the way (Heymann 1995).

Preussenelektra (today part of E.ON) established a wind subsidiary, 'Preussenelektra Windkraft' (PW), in 1989. PW similarly became active in wind technology research, backing projects that aimed to develop large-scale wind turbines. This included two government-backed projects to develop two 1.2MW and 3MW rated wind turbines, the WKA 60 and Aeolus II respectively. However, both projects never moved beyond prototype status and ultimately failed due to inadequate design and costs (Windpower Monthly 1994b).

This focus on large-scale turbine development was a dominant topic in the German utility industry, even though typical turbines were rated at between 100 kW and 250 kW at the time (EWEA 2004). This was explained with the generally large size of the utilities' portfolio and the size of the traditional generation technology, with large power plants typically surpassing 1,000 MW in many instances.

In the interviews, managers stressed the limited outlook for wind power at the time and their own reservations with regard to the technology.

"If you think back 10 years with the monopoly structures in Germany, and the public ownership structures, it was politically motivated to be seen as investing a bit into renewables. This wasn't really a commercial project."

"We only had an observer role in the development of wind energy...it was more a topic that was en vogue, which you had to deal with...when the turbines still had this small size and the total installed capacity in MW was small, this was something that did not really appear on our radar screen."

"We could have invested, but we did not believe in this technology. The costs at that time were too high [...]. This led us to believe that with the availabilities of the wind parks that were known up to then, this technology will never become viable."

"[...] these were mostly small turbines that were not really of interest for us. I think this only changed with the recognition that you can generate electricity with this technology on a larger scale, it still has to fit into the business model somewhere. We are not a company that can install small power plants dispersed over several thousand sites, this does not fit our business model, we are not set up for that kind of task."

Furthermore, RWE board member Günther Klätte was cited declaring "we need 'Growian' to demonstrate that this technology does not work" (Heymann 1995:371; *own translation*), while the head of development for Preussenelektra Windkraft was quoted in 1994 as "...not seeing broad market penetration of wind within the foreseeable future" (Windpower Monthly 1994:41).

This early experience of failed research attempts to upscale the technology, together with the perceived mismatch between their existing capabilities and the requirements of the new technology, led German utilities to not engage with the wind energy industry when it first emerged. None of the utilities at the time invested in wind development capabilities or in building relationships with turbine suppliers. Two further reasons were mentioned that contributed to this decision.

Firstly, in the wake of the reunification, the entire industry was in the process of reorganisation, which involved integrating former East-German companies, merging among each other to form larger electricity generation groups and acquiring distribution and supply businesses to integrate vertically. This process absorbed most management capacity meaning that in the absence of obvious technology breakthroughs there was no reason to build new technological capabilities from the utilities point of view (Richter 1998;Liedtke 2006).

Secondly, the design of the FIL meant that utilities were only able to directly profit from it when they investing in wind farms outside their own monopoly area. As Germany had a long history of non-compete agreements among utilities (Liedtke 2006), this clause prevented utilities from entering this new technology field, as it would have wider competitive ramifications.

In summary, when faced with the first wind energy market introduction programme in 1989/1990 and the FIL, German utility companies did not take advantage of the opportunities provided. Importantly, this meant that they did not invest in new capabilities to plan, build and operate new wind farms, leaving this field largely to new specialised entrants into the field.

However, in these early years, there was also little recorded opposition to this new institutional market niche opened by the government. In fact, both laws were passed with an all-party consensus in parliament (Jacobsson & Lauber 2006). In this context, Johnson and Jacobsson argue that "at the time of the feed-in law, neither the opponents nor the proponents of wind power could have imagined the scale of the diffusion that ensued" (Johnson & Jacobsson 2003). Furthermore, Jacobsson and Lauber (2006:264) comment dryly that "a few hundred MW … was hardly a serious matter, and in addition the big utilities were at that time absorbed in taking over the electricity sector of East Germany in the process of reunification." Hence, wind energy was generally perceived as a small distraction from the bigger issues that faced the electricity industry at the time.

Uncertainty and rising Conflict between 1994 and 1999

However, beyond anyone's 'imagination' (Johnson & Jacobsson 2003), wind energy quickly emerged as a rapidly growing source of electricity generation. Total installed capacity in Germany soared from 56 MW in 1990 to over 600 MW in 1994 and was rising at a rate of at least 500 MW per year from there onwards (BMU 2007). This started to affect the German utilities' businesses. As grid operators, they were mandated by the FIL to give wind energy priority access to their system and buy all green electricity produced by independent wind farm operators. This would lead to situations in some regions where the utilities had to regulate their own power plants downward in order to accommodate wind energy produced, which directly affected their income. This created a negative perception of wind power among the utilities, as stated by the interviewed managers.

"In Northern Germany you have the situation by now, that nuclear power plants are sometimes used as peaking plants, because the feed-in law gives priority to wind energy. So in certain situations we have to regulate down our nuclear plants! This is unbelievable!"

"A large share of wind energy in total production will have an impact on the operation of the conventional power station fleet. This includes that we, as a power producer, can offer more balancing services, which is the energy that is needed to smoothen the fluctuating contribution from wind energy sources...but as a power plant operator, also I will not be happy if I have to regulate my output up and down just at the moment when my plant is operating smoothly on full power.

Furthermore, Germany's electricity consumption grew by just 6.5% between 1990 and 2002, or about 0.5% annually (IEA 2004a). Together, these two facts meant that the rapidly growing wind sector started to displace conventional generation in the German electricity mix. As the FIL set no upper limit on the development of renewables in terms of time or scope, independent wind farm developers were able to grow and gain market share as long as they were able to find sites that allowed production at below the price set by the law.

Yet, the earlier decision not to invest into wind power development capabilities meant that the incumbent utility companies were unable to profit from the boom at the time. Consequently, beginning in 1994, the main utility industry association (VDEW) started to argue vigorously for the abolishment of the FIL. Moreover, several forms of corporate political activity were initiated by the VDEW and its member companies to limit the institutional space given to renewable energy by the law. Consequently, the period 1994-1999 marked the second phase of wind development in Germany, which was characterized by various institutional skirmishes and uncertainty over future growth prospects. Total installed capacity grew fourfold between 1995 and 1999, after having expanded tenfold in the period 1990-1994 (BMU 2007).

A legal opinion commissioned by the VDEW in 1994 argued that the FIL was unconstitutional and could thus be challenged in the German Constitutional Court. Consequently, the VDEW advised its member companies that all payments under the FIL should be regarded as merely provisional (Windpower Monthly 1994a;Windpower Monthly 1995d). This had two immediate effects: Firstly, some utilities stopped payment of the FIL fixed price altogether, thus threatening the economic basis of existing wind farms. Secondly, banks became more hesitant in providing new finance for wind farms as future earning could no longer be calculated with certainty. However, ultimately a complaint was never submitted to the Constitutional Court and all financial disputes were resolved either through political and regulatory pressure or judicial decisions.

Concomitantly to this legal avenue, Schleswag, a regional utility in the windy North of Germany, started to refuse connection for new wind farms due to alleged technical grid constraints. However, in response a successful court case was brought against Schleswag and established the principle that wind farms should be connected as long as they had installed the technical equipment to be switched off in case of system emergencies (Windpower Monthly 1995e;Windpower Monthly 1997).

Besides this activity in the legal and technical area, utilities also lobbied political parties directly to abolish some of the key features of the FIL. The

conservative-liberal government of the time was not unsympathetic to the views of the utilities' industry, and a bill before parliament in 1997 proposed a drastic reduction in the guaranteed prices under the FIL. However, the German renewable energy lobby had garnered significant cross-party political support by that time so that the main pillars of the FIL were kept intact. Thus, the proposed reduction in tariffs was voted out at the parliamentary committee stage and subsequently the FIL was institutionally even further embedded in the 1998 energy market regulation that transposed the EU electricity market directive 96/92/EC into national law (Johnson & Jacobsson 2003;Jacobsson & Lauber 2006). This prompted another court case, led by the Preussenelektra utility (today part of E.ON), the parent company of Schleswag, which ultimately ended up before the European Court of Justice in order to clarify the legality of the FIL under EU law. This was decided in favour of the FIL in 2001 (Jacobsson & Lauber 2006).

In summary, this period was dominated by corporate political activity by several German utilities and their industry lobby association. The head of policy for Preussenelektra (today part of E.ON), Wolf Hatje, commented at an industry trade fair on the feed-in law, saying that "we will do everything possible to stop it" (Windpower Monthly 1998). In this environment, the development of capabilities to build wind farms was not a strategic option for the utility companies. Hence, one manger commented on this period:

> *"[...] the early feed-in law was no disadvantage to the big utilities, but the main problem was that they argued so vigorously against it and then sued against it, so it would have looked odd if they themselves profited from it."*

In consequence, wind power developed in an increasingly antagonistic climate, with small wind farm developers who profited from the FIL on one side and the large incumbent utilities, who were mandated to feed all electricity produced under the FIL into their grids, on the other side.

Yet, this mandate to manage their grids with increasing contributions from wind power led the incumbent utilities to develop capabilities in the field of network integration of wind farms. In 1997, together with the German research

institute 'ISET', a wind forecasting and integration tool was developed that was subsequently applied by the system operators to enable the larger scale network integration of wind farms in Germany (ISET 2007). Moreover, given the lack of a network regulator at the time, it appeared that the grid operators were able to exploit their monopolistic position in this field by charging higher grid fees for grid balancing services than strictly required. The fact that Germany had four different 'balancing zones' – one operated by each of the four incumbent companies – each of which required their own stand-by capacity was long criticised by the German cartel office. In one report, it suspected that tariffs could be up to 80% higher than required than if Germany would operate only one unified balancing zone with according stand-by capacity requirements (IEA 2005e). Finally, as the FIL operated separate from the electricity wholesale market, the integration of the trade of electricity from wind power remained outside the scope of these tools.

Consolidation and Accommodation of Wind Power 1999 - today

In this last time-period, corporate strategy of the German incumbent utility companies saw a significant change. Both on the level of developing new capabilities, as well as in the approach to institutional engagement, strategy began to increasingly accommodate wind power.

By 1999, two factors had changed that gradually influenced this adaptation of the utilities' strategy. Firstly, wind technology had grown significantly, with the first 1-1.5 MW turbines appearing on the horizon. Offshore wind farms began to emerge as a serious possibility in the near future. This meant that 'utility-scale' wind farms of comparable size to conventional power plants became conceivable.

Secondly, the election victory of the social-democratic/green coalition transformed the institutional outlook for renewable energy. Having staked their credibility partly on this issue, these parties agreed that support for renewables would – if anything – be broadened and stabilised. This became manifest in a new renewable energy law, the Renewable Energy Act 2000, which stabilised and

extended the original FIL. It also removed the geographical restrictions on utilities, allowing all energy companies to benefit from the tariffs in the same way, no matter where they invested. This created a new boom in the wind energy market, raising the total installed capacity from just under 3,000 MW in 1998 to almost 15,000 MW in 2003

With this backdrop, German incumbent utility companies re-evaluated the option to invest in capabilities in the field of wind farm developments. Especially, the option of offshore wind developments finally led to the creation of new subsidiaries and the addition of relevant capabilities. This is reflected in the responses from the interviews:

"There was a strategic decision within the company that we will only do offshore, which is easier to absorb into the grid anyway, because the wind blows more constant etc. So there is no onshore activity from our side and we would also not extend our portfolio in this direction."

"Our focus is on wind technologies because this is closest to economic viability, and within this focus, the main theme is offshore wind as this is what we can call "power stations" – which is what a utility company is mainly interested in."

Yet, in order to get involved in large-scale offshore wind projects, companies admitted to initially having to learn about the technology from scratch. This involved collaboration on a testfield in the North Sea to subject several new large-scale turbines to the offshore conditions and learn about developing such fields. Still, the utilities also started building and operating small-scale wind farms in the mean-time. Furthermore, one of the German incumbent utilities recruited its new head of wind power developments from an established independent wind farm developer.

"We had to learn, these were learning projects to see how they work, how these plants are operated. And we believe that we have a good know-how in these areas by now to be ready to go offshore when the moment is right. To go offshore directly would be a big challenge, so this was at least partly a learning run."

"The development of contracts was a big issue. For example, our first contract with Vestas contained 6 pages, it was a standard contract. And they did not even have a solicitor with

whom we could have discussed, but we did add 20 pages of annexes. Today, we have 200-pages contracts, and this you have to go through with a manufacturer."

"Onshore, we have a few projects, but mostly against the background of getting to know the wind turbine manufacturers and to learn the rules of engagement. Also, there are few projects that satisfy all the requirements of a utility company. As there were few economically viable projects, there was only limited involvement and the strategic focus on onshore in Germany is really limited, the main emphasis is on offshore. "

"Our portfolio at the moment is looking primarily at offshore wind, and we are waiting for the outcomes from the testfield near Borkum at the moment."

The creation of wind farm development capabilities took several routes among the German utilities. Hence, E.ON, soon after being established in the year 2000, started its 'E.ON Energy Projects' subsidiary with a view to enter the emerging offshore wind market. In 2001/2002, E.ON Energy Projects quickly bought shares in three proposed offshore wind farm projects totalling 950 MW when completed, and proceeded with several small-scale onshore wind developments totalling 70 MW in 2005. Furthermore, one of E.ON's East German regional supply companies, E.ON E.DIS, started developing regional onshore wind projects in 2001, building up a portfolio of 154 MW by 2005.

At RWE, its subsidiary 'Harpen', which originally was a small company focused on the building and decentralised energy services sectors, entered the renewable energy fielding 1998, although mainly in other European countries. Its portfolio in Germany totalled just 22 MW in 2005. Yet, RWE consequently embarked on a strategic realignment that ultimately led to the integration of Harpen's renewables energy business into the main RWE Power division in 2006. It furthermore benefited from personnel exchanges with the RWE's UK division npower renewables in getting acquainted with wind farm development capabilities.

Vattenfall created its 'Vattenfall Europe Renewables' subsidiary in 2005 with a strategic view to enter the emerging offshore wind market, having acquired one offshore site and also participating in the joint testfield in the North Sea.

EnBW is the only utility company covered in this study that decided not to enter the wind energy market in the timeframe considered. Two main reasons were cited for this decision. Firstly, in its core area in the South-West of Germany, the prevailing wind conditions are much weaker than in the windy North, thus giving much less scope for wind developments in its local market. Secondly, given the development of wind energy in Germany that had already taken place, EnBW felt that there were insufficient high-quality sites available and limited strategic scope to build a significant presence in the market. However, several other renewable energy options were investigated and implemented by EnBW at the time.

Concomitantly, to this capability re-alignment, the corporate political activity strategy shifted away from outright opposition to the renewable energy support schemes. Given the institutionally stable outlook for renewables, arguments were no longer put forward against the support of wind power *per se*. Instead, the political lobbying was increasingly shifted towards the *type* of instrument used. In this respect, support grew among the incumbent utilities for the introduction of a European-wide quota system complemented by a green electricity certificate trading scheme instead of the feed-in tariff mechanism. Given that market liberalization required the introduction of electricity trading functions, tradable certificates could thus be integrated easily into established trading divisions, as could similarly be witnessed in the case of the CO_2 emission markets, which started in 2005.

"The FIL contains many elements that are inefficient. Why do small biogas plants get a higher tariff than large biogas plants? This leads to inefficiencies as it increases the average per kWh tariff and it should be removed from our perspective. So maybe, we can start with capping some of these over-promotions. In a subsequent step, market mechanisms could be introduced and two years on from that a European certificate market could be envisaged."

"I presume that at some point in the future there will be a European-wide harmonization of renewables schemes as well. And I could imagine it will not be a feed-in law."

In conclusion, the German incumbent utilities belatedly started to develop wind power development capabilities, with the exception of EnBW. This came after the systemic environment for wind power matured both institutionally and technologically, providing new opportunities especially in the emerging offshore wind sector. Yet, in developing these capabilities, the companies had to go through several learning steps, in order to understand the technology and the market, before larger-scale investments were envisaged. Concomitantly to this capability development, institutional opposition to wind power, which had been fierce throughout most of the 1990s, weakened and shifted in focus to a critique of the FIL and the promotion of alternative policy tools such as a green energy certificate trading market.

4.4.4. Summary of co-evolutionary developments in Germany

The German incumbent utility companies underwent two distinct phases in their strategic approach to wind energy. Firstly, the decision not to develop technological capabilities to enter this new field was coupled with an increasingly vigorous effort to influence the institutional environment in order to limit the space given to this new technology. Only when this approach failed and various options for corporate political activity were exhausted, did the incumbent utility companies eventually enter the field, especially with a view towards the emerging offshore wind sector.

The institutional environment for wind power was initially opened up with the introduction of the FIL in 1990. This provided a relatively stable investment environment with a long-term commitment horizon. It was furthermore backed-up by a special market introduction programme providing additional grants for new wind farms. The design of the FIL, which provided for a standard power purchasing contract between the grid operator and the wind farm operator, also created low entry barriers into the market, thus resulting in a host of new independent companies that started developing wind farms. A diverse and often

localised investor base furthermore meant that there was little opposition to the siting of new wind farms (Toke 2002;Jacobsson & Lauber 2006).

However, German incumbent utility companies did not initially engage in the development of capabilities in this new area. There were two main reasons for this. Firstly, having conducted several R&D projects that failed to upscale wind turbines to larger outputs, they had concluded that this technology would not fit into their existing set of capabilities. Secondly, in order to profit from the FIL, incumbents were required o invest outside their core monopoly areas, at a time when the electricity market was not yet opened up to competition. This meant that the incumbent utilities could not profit from the expertise of their local and regional subsidiaries and would have to compete with other utilities in order to take advantage of the law. Consequently, giving up non-compete agreements to invest into an unproven niche technology did not appear on the utilities' agenda, and thus, the incumbents did not participate in the early boom in wind power in Germany.

However, as operators of the German grid, the incumbent utilities were increasingly affected by the rising wind power installation rates. As the FIL mandated them to prioritise all electricity produced from new wind farms at the premium price, this affected the operation of the existing base of conventional power plants.

Consequently, the German incumbent utilities increasingly aimed to undermine the institutional basis of the wind power boom by engaging in various forms of corporate political activity. Thus, through legal, technical and political avenues, it was attempted to halt the development of wind power in Germany. This sustained campaign between about 1994 and 1999 managed to slow the development of wind power in Germany and led to a levelling off of new installation rates.

However, all of these institutional activities ultimately proved to be unsuccessful with various defeats in the courts, in parliament and through regulatory decisions. Furthermore, in 1998, a change in the federal government

meant that the institutional environment stabilised, as the new Social-Democratic/Green government had staked its credibility in part on an expansion of the use of renewable energy (Reiche 2005;Jacobsson & Lauber 2006).

Yet, in this context, the potential to adapt the FIL to the German wholesale market in a similar fashion to the Spanish model (see section 4.5.2 below) was small, as neither utility- nor independent investors had an interest in such a solution. While utilities argued against *any* wind energy support scheme in principle, small-scale developers had not developed any market trading capabilities due to the sheltered nature of the FIL as a pure transfer payment. Hence, the arguments from either side became increasingly antagonistic and the opportunity for a middle ground to emerge vanished.

At the same time, the unabated growth in wind power led to increasing maturity of the technology and increasingly larger levels of output per turbine. The first 1 MW machines were introduced to the market around 1999, while the first commercial offshore wind projects were developed in the North Sea (IEA 2005c).

Consequently, German incumbent utility companies re-evaluated their strategy towards wind power. Through the creation of renewable energy and wind power subsidiaries, three of the four utilities began to develop capabilities in the assessment and development of new wind farms. Although not an immediate investment opportunity, they declared specific interest in the emerging offshore wind field, as it provided the prospect of large-scale wind farms, with higher and more stable output patterns than could be expected on land.

Nevertheless, even though the entry into the wind industry occurred at a late stage of the industry's development, initial steps of organizational and individual learning about this new technology were observed. None of the companies surveyed entered the offshore wind market directly, and in all the companies it was reported that early small-scale investments were made to learn about the process of building wind farms and to get to know equipment suppliers and understand the development of contracts and operational structures.

Concomitant to these capability developments, the institutional focus shifted from outright opposition to the FIL *per se*, to a stance that argued for a shift in policy towards a system of tradable green energy certificates, akin to the policy environment in the UK. Such a policy was seen not only as providing the best incentives to build renewable energy projects where the best resources could be found, but also as being best fitted to the existing trading capabilities and pan-European reach of the German incumbent utilities.

Hence, in summary, the Germany wind industry today consists of a wide diversity of developers, owners and operators of wind farms, with the German incumbent utilities exhibiting a marginal presence of just above 1% of all operational wind farms in 2005. This situation is mirrored in co-evolutionary process between incumbent utilities' strategies and institutional development. Wind power policy provides for a sheltered niche market, separate from the wholesale electricity market in which the utilities operate. While wind farm operators are confined to the task of wind farm development and construction, utilities are tasked with feeding the produced electricity into the grid, with no market integration into the wholesale electricity market visible yet. The antagonistic development of wind energy and incumbents' strategy does not provide incentives for either the utilities or the wind developers to integrate wind power beyond the current arrangement.

4.5. *Spain*

4.5.1. Spanish Electricity Market Overview

Spain's electric industry privatization and market liberalization process happened over two distinct time periods, which saw the emergence of four privatized vertically integrated electric utility companies before the market was subsequently opened to competition in 1997.

Up until the 1980s, the Spanish electricity system was run by a series of regional monopoly companies, most of which were state-owned, that owned assets in the electricity generation, transmission, distribution and retail sector. However, in the beginning of the 1980s, the government initiated a series of reorganisations of the industry in order to improve efficiency in the electricity sector and implement a form of cost-of-service regulation that provided a degree of competition between the companies, albeit this did not constitute a market opening yet (Arocena & Waddams Price 2002).

The largest group to be formed was "Grupo Endesa", which was created by a series of mergers among state-owned utilities in 1983, and partially floated on the stock market as 'Endesa' in 1988, with the state selling its final shares in 1998. Endesa was the largest Spanish industrial conglomerate at the time of privatization, owning power plants, transmission lines, distribution and retail services and industrial and technical support services (Vitzthum 1992).

Subsequently, 'Iberdrola' was created through the merger of the two largest privately-owned utilities Hidroeléctrica Española and Iberduero in 1992. The new company became Spain's second largest utility, exhibiting a similarly vertically-integrated structure with assets along the entire electricity value chain. Together, Endesa and Iberdrola controlled 80% of the Spanish electricity market in 1993 (Vitzthum 1993).

Besides these two large companies, two smaller actors emerged in the Spanish electric utility sector. Union Fenosa emerged as Spain's second largest privately-owned utility through the merger of 'Union Electrica' and 'Fuerzas Electricas del Noroeste' in 1982, built around their regional bases in Madrid in Galicia. Similarly, Hidrocantabrico was founded by the merger of several northern regional utilities based in the 'Asturias' and 'Cantabria' region. Union Fenosa had a market share of about 10% in 1993, while Hidrocantabrico held another 5%. Hence, 95% of the market was divided between four companies prior to market liberalization.

The Spanish electricity market was liberalised on 1 January 1998 through the Spanish Electric Power Act (54/1997), which transposed the EU directive on internal electricity markets into Spanish legislation. This and subsequent legislation set out a schedule for subjecting increasing parts of the market to competition, starting with large energy consumers and opening up all areas for competition in 2003. The 1997 electric power act also instituted a new market operating company, 'OMEL', to operate a pool market for all generators with plants above 50 MW rated capacity. The transmission system had already been unbundled from the rest of the industry in 1985 and was run by Red Electrica Espana (REE), a fully private company except for a remaining government share of 28.5%, which is expected to be floated soon (IEA 2005a).

A specific feature of the Spanish electricity market is its continuous strong demand growth. Spanish electricity consumption per head is below the EU average and to some extent still catching up with the rest of the continent. The yearly growth rate averaged 5.3% over the past decade and total annual electricity consumption reached 239 TerraWatt-hours (TWh) in 2003, compared to 195 TWh in 2000 and 130 TWh in 1990 (IEA 2004a;IEA 2005a). Correspondingly, total installed capacity by utilities rose from 42.10 GW in 1990 to almost 65 GW in 2003, and a further 5.3 GW of CCGT plants were expected to be added in 2005 (IEA 2004a;IEA 2005a).

The most important technologies to cover the rising Spanish electricity demand in recent years were natural gas and wind energy. Figure 21 below outlines the evolution of the fuel mix in Spanish electricity production between 2003 and 2006 (REE 2007).

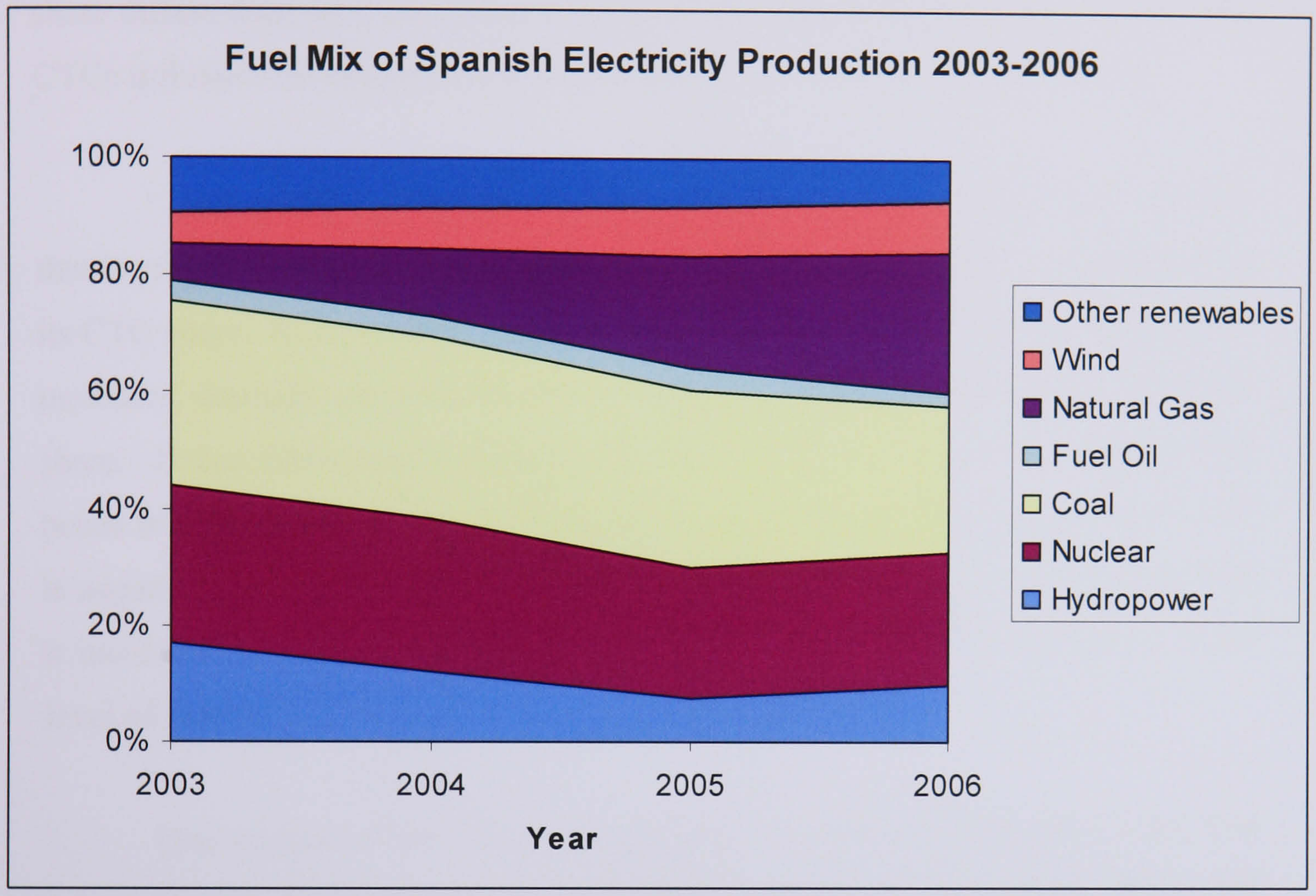


Figure 21: Fuel mix of Spanish electricity production 2003-2006 (Source: REE 2007)

A second particular aspect of the Spanish Market are the so-called Competition Transition Costs (CTCs), which are paid to the incumbent generators for a transition period. The argument behind CTCs was that the incumbents had invested in generation capacity before market liberalization commenced, and were thus saddled with 'stranded costs' that they would be unable to recover once competition brought prices down.

CTC payments are scheduled to be paid until 2010 and over that time period are worth up to €10.4bn. They are triggered when wholesale prices - or pool prices - fall below €36.1/MWh, an amount exogenously set by the regulatory authority as the expected entry level costs for new competitors. However, due to the incentive structure set by the CTC mechanism, prices have in fact converged

around that level. Each incumbent receives a fixed proportion of the total CTC payments, set according to market shares at the beginning of liberalization: Endesa's CTC share equals 51.2%, Iberdrola's 27.1%, Unión Fenosa's is set at 12.9% and Hidrocantábrico's at 5.7%. However, the incentive structure of the CTC payments has led to some peculiar actions when an incumbent's market share differs from its CTC share. Crampes et al (2005:134) describe the way that CTCs influence the bidding behaviour of the incumbents in the pool market:

"…an increase in the pool price has a positive effect on the firm's profits that is proportional to its market share and a negative effect that is proportional to its CTC share. Thus, whether a firm is better off or worse off when the pool price increases depends on the difference between its market share and its CTC share…If this difference is positive, the firm stands at a net selling position and hence it is better off the higher pool prices are. On the contrary, if this difference is negative, an increase in pool prices reduces the firm's CTC revenues more than it increases its market revenues. Hence, firms face a conflict of interest as to the level of prices."

One impact of the CTCs was to suppress market prices when fossil fuel prices increased. Incumbents did not have to raise prices as much due to the additional income from CTC payments, which raised the barrier for new entrants into the market. In 2004, Endesa and Iberdrola still controlled about 80% of the generation and distribution assets, which is only slightly less than at the beginning of market liberalization. Abuse of market power remains a recurring issue in the Spanish electricity market. In July 2004, the Spanish Competition Court imposed the maximum possible fines on Endesa, Iberdrola and Unión Fenosa for anti-competitive practices and abuse of dominant position. Furthermore, new investments have been announced strategically by the incumbents without them actually being carried out (Crampes et al. 2005).

Also, interconnection with neighbouring countries is generally considered weak, with a 700 MW link to Portugal and several smaller links to France adding up to 1100 MW. Together these links represent just 4.2% of total installed capacity. Spain also exports electricity to Morocco through a unidirectional 355

MW sub-sea cable. The Portuguese and Spanish government undertook to create a single Iberian electricity market, Mibel, which started operation in 2006. Under this agreement, a single market operator would be created (The Spanish 'Omel' and Portuguese 'Omip' would merge into 'Omi'), but the transmission system would still be managed by the two separate national companies. Still, there are plans for coordinating planning, expansion of network and the resolution of congestion between both companies (Crampes et al. 2005).

The evolution of market shares in the Spanish generation and retail market are outlined in Figure 22 and Figure 23 below. Despite the introduction of competition in 1998, the market shares of the four largest firms fell only slightly in the intervening period, despite growing electricity demand. The European Commission in its 'energy sector inquiry' investigated the HHI over the period 2003-2005 in Spain, and found the average value at 2,790 with the maximum at 3,259 and even the minimum at 2,318, thus pointing to a strongly concentrated market environment (European Commission 2007).

The CTC payments are due to run out in 2010, thus removing one important barrier to new participants in the market. Furthermore, the recent acquisition of 'Endesa' by Italian utility 'Enel' and Spanish construction company 'Acciona' led to a reorganisation of Endesa's assets and could well precipitate further mergers and takeovers. It has already allowed German utility 'E.ON' to enter the Spanish market through the acquisition of some of Endesa's assets, while Portuguese utility 'EDP' had already taken over 'Hidrocantabrico' in 2005.

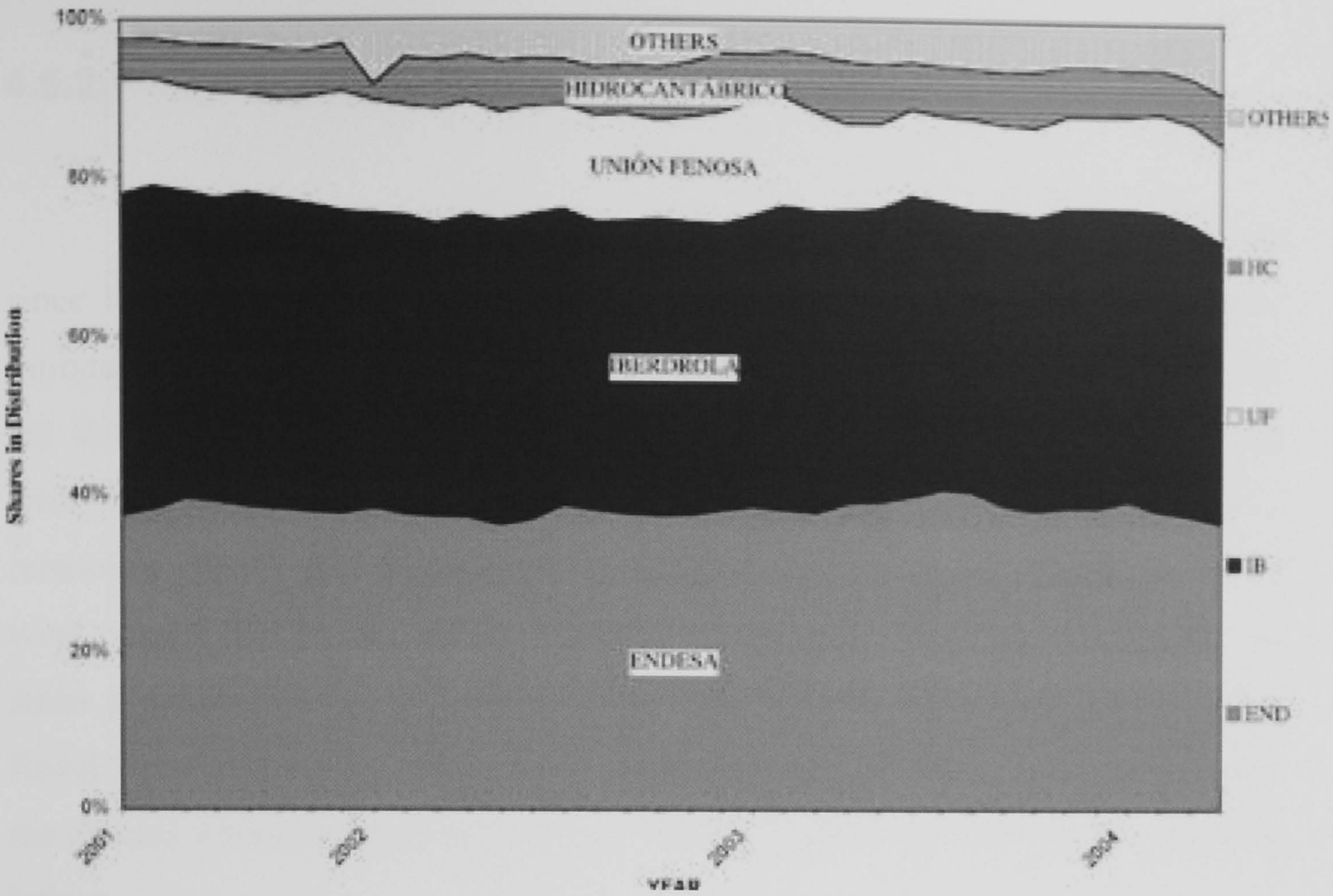


Figure 22: Shares of Spanish utility companies in electricity distribution and retail 2001-2004 (Source: Crampes & Fabra 2005)

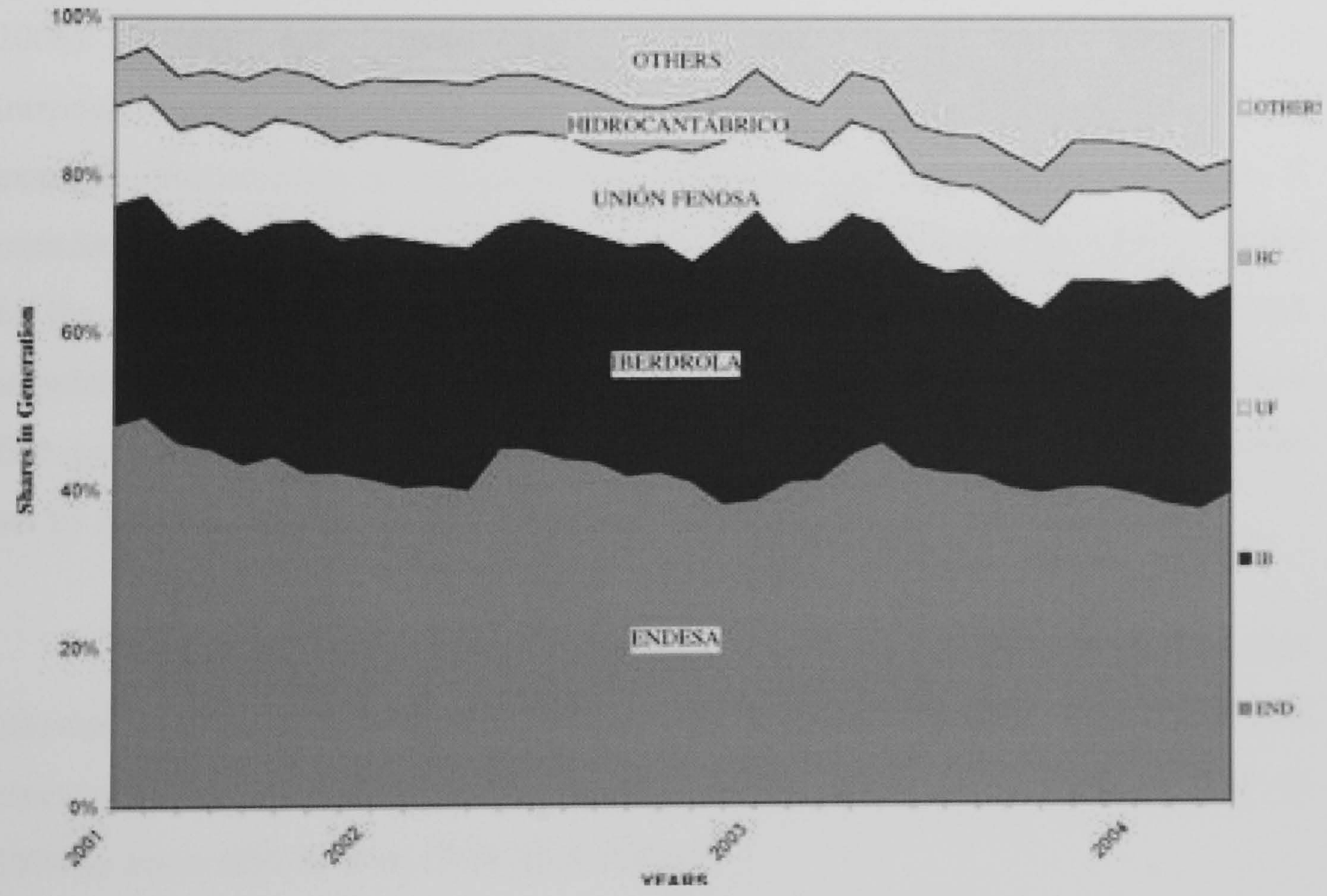


Figure 23: Shares of Spanish utility companies in electricity generation 2001-2004 (Source: Crampes & Fabra 2005)

4.5.2. Spanish Renewable Energy Policy Overview

This section outlines the evolution of renewable energy policy in Spain since 1994. There are three phases to be distinguished: Firstly, a phase of slow introduction of renewable energy technologies following the first special policy in the 40/1994 electricity law. Subsequently, this law was reviewed and extended with the Royal Decree 2818/1998 and complemented in 1999 by a specific renewable energy development plan ('PFER'). This led to a sustained boom in wind energy installations, which was only limited by a lack of grid capacity in some regions. Finally, the law was reviewed and extended again through the Royal Decree 436/2004, which promoted a closer integration of wind energy into the general wholesale electricity market. Each of these milestones will be outlined below.

Wind energy was supported with government grants and grid connection guarantees since the passing of the 82/1980 Energy Conservation Law (Dinica 2006). However, wind power started to grow seriously in Spain in 1994 with the introduction of a feed-in law in Royal Decree 2366/1994, following the German example (Bechberger & Dinica 2005). This law had two essential features: It mandated REE, the Spanish grid operator, to connect all renewable energy plants to the electricity grid unless they threatened system security. It furthermore stipulated that utilities had to buy all electricity from renewable energy sources in five-year contracts with an implicit renewal guarantee at a fixed price, which was set by a Royal Decree.

With these cornerstones, a protected institutional niche was created that allowed wind development to take place without being subjected to the liberalized electricity market. Consequently, installed wind capacity rose from 40 MW in 1994 to about 850 MW in 1998 (IEA 2005a).

However, Spain's subsequent boom in wind installations needs to be seen in the context of the 54/1997 Electricity Law and the 2818/1998 Royal Decree on Renewable Energy. Spain took the opportunity to combine a newly created 'pool

market' framework with its support system for renewable energy technologies (The Royal Decree explicitly speaks of 'developing' the 54/1997 law).

In this regime, renewable energy producers were offered three different options to sell their electricity. Besides allowing to negotiate power-purchase agreements directly with suppliers, the government offered two types of feed-in tariffs: (i) Electricity could be sold directly to the nearest grid company for a fixed tariff paid for each kWh produced (as in the German system); or (ii) the electricity could be sold to the wholesale market with the producer receiving the market price plus a premium. Under both options all green electricity output was guaranteed to be taken up. The support levels for wind under the Royal Decree are given in Table 17 below:

Table 17: Tariffs for wind energy under the Spanish Royal Decree 2818/1998 (Source: Dinica and Bechberger 2005)

	1999	2000	2001	2002	2003
Wind (fixed feed-in tariff in €c/kWh)	6.62	6.26	6.26	6.28	6.21
Wind (top-up premium in €c/kWh)	3.16	2.87	2.87	2.89	2.66

Uptake of the option to sell directly into the pool market was very slow initially with most market participants choosing to use the fixed-price system. Yet, this regulation together with the government's target of 13,000 MW wind energy installations in 2010 created a real boom in installations. By the year 2002, Spain had just under 5,000 MW of wind capacity installed and consequently experienced some serious grid constraints which led to a subsequent slow down in installations. Refusal of connections by REE created a backlog of several thousand MW of projects awaiting a place in the electricity grid (Windpower Monthly 2003f).

However, with Royal Decree 436/2004, REE dropped some of its objections to further connections of wind power after adapting the grid code to integrate wind energy with more sophisticated control technology. Consequently, the target for wind power was revised upwards to 20,000 MW by 2010. Concomitantly, the government revised the incentive structure of the feed-in tariffs to further integrate renewable energy into the Pool system. Hence, additional incentives were provided for companies that opted for the top-up premium and provided wind forecasts and certain ancillary services to the network operator (Bechberger & Dinica 2005). Consequently, the percentage of companies that sold electricity from wind power on the wholesale market rose from 20% in January 2005 to 90% by December 2005 (AEE 2006).

In this way, wind was increasingly treated like conventional generation in the pool market system. It is planned that the fixed feed-in tariff is slowly phased out in favour of the market top-up premium. Also, for the first time, renewable energy operators are rewarded for providing certain grid support functions such as reactive power services or continuity of supply in case of voltage dips.

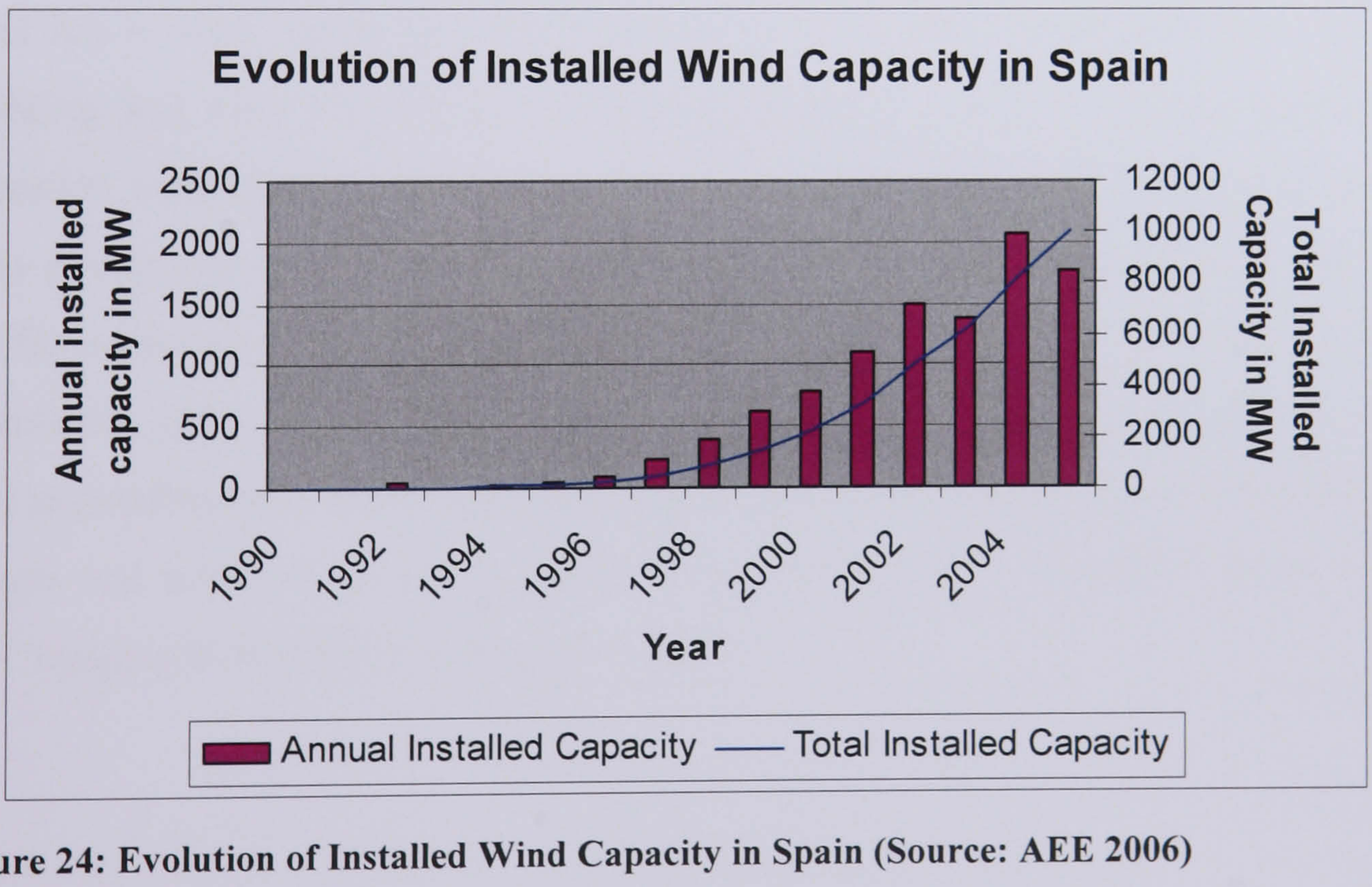


Figure 24: Evolution of Installed Wind Capacity in Spain (Source: AEE 2006)

Total installed wind energy capacity in Spain is shown in Figure 24 above, while the distribution among the main utilities is given in Table 18 below. While total installed capacity reached 10,000 MW in 2005, the incumbent utilities held a 57% market share in this total.

Table 18: Market shares of Spanish utilities in the domestic wind energy market (Source: Company Reports and websites; AEE 2006)

Company	Installed Capacity in MW (end 2005)	Installed Capacity in percent of total
Iberdrola	3494MW	34.8%
Endesa	1131MW	11.3%
EDP/Hidrocantabrico	738MW	7.4%
ENEL/Union Fenosa	354.9MW	3.5%
Total Utilities:	**5717MW**	**57%**
Other developers	4310MW	43%
Total	**10027MW**	**100%**

4.5.3. Spanish Utilities' Strategies

Given this background, the Spanish incumbent utilities' strategies are now presented. Figure 25 below provides an overview of the current fuel mix of the utilities discussed in this chapter, while

Table 19 gives an overview of some of their key financial statistics. Wind power has a share larger than 10% at Iberdrola and EDP/Hidrocantabrico, while providing less than 5% at Endesa and Union Fenosa. Among the conventional generation technologies, the mix is fairly broad including coal, natural gas and hydro power and nuclear power among all four companies. However, given the specific renewable energy investment plans for the coming years among the incumbents, the share of wind power is forecasted to rise at all four companies. Total expenditure for these projects is above levels of current capital expenditure budgets and comes in an environment of high profitability among all firms, with EBIT ranging from €923m to €4.2bn in 2005.

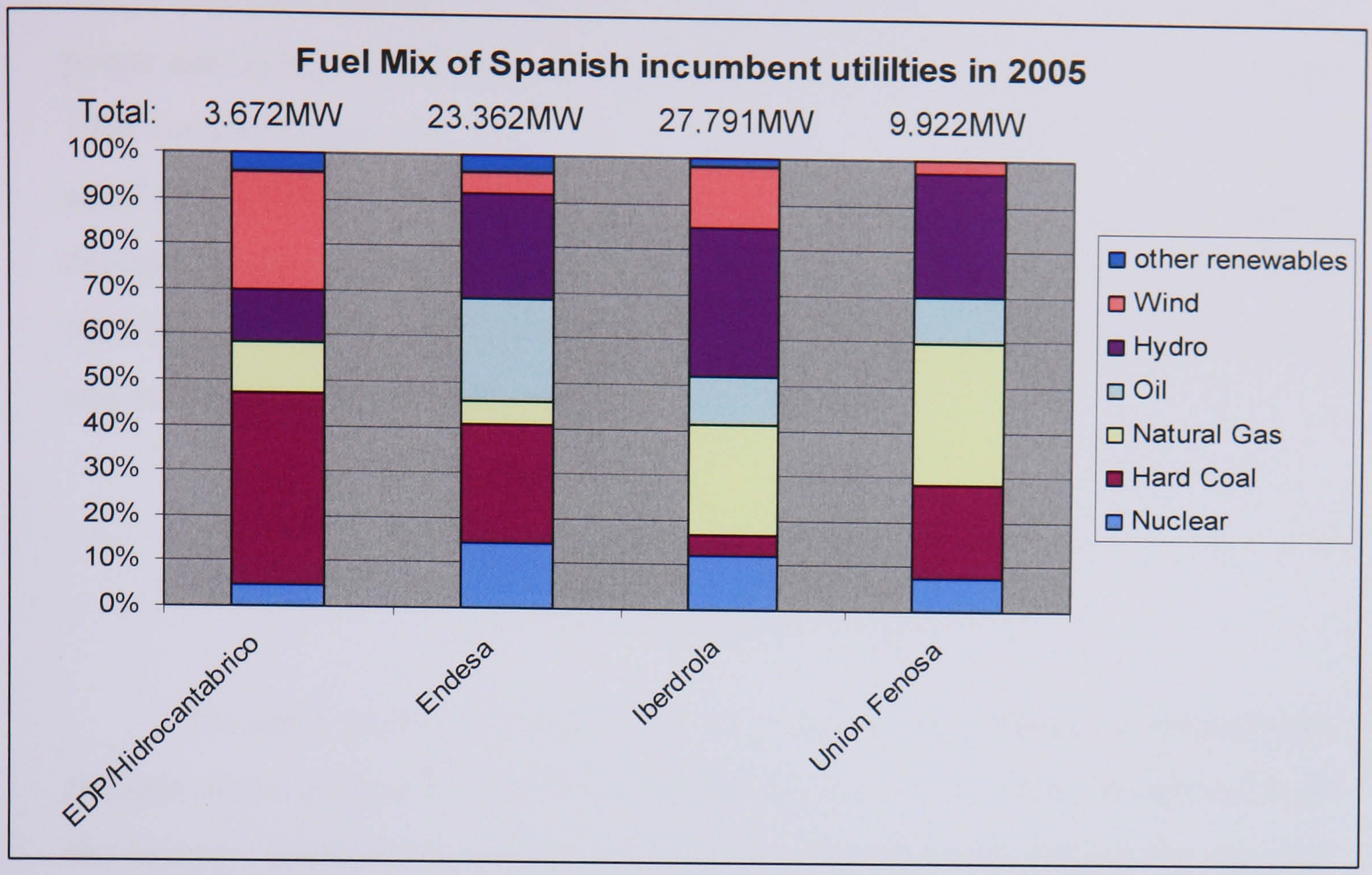


Figure 25: Fuel mix of Spanish incumbent utilities in 2005 (Source: Company reports and websites)

Table 19: Overview of key financial statistics of Spanish electric utility companies (Source: company reports and websites)

`	Market Capitalisation (year-end 2005)	EBIT (year-end 2005)	Capital expenditure in 2005	Renewables Investment Programme (latest available)
EDP/Hidrocantabrico	€9.5bn	€1.1bn	€932m	€2.1bn for years 2006-2008
Endesa	€23.5bn	€4.2bn	€2.4bn	€1.9bn for years 2005-2009
Iberdrola	€20.8bn	€2.3bn	€2bn	€3.25bn for years 2007-2009
Union Fenosa	€9.6bn	€923m	€1.1bn	€1.5-€2.1bn for years 2007-2011

The involvement of Spanish utility companies in the diffusion of wind power can be broadly divided into three phases. An early phase between 1990 and 1997 involved dispersed and uncoordinated activity to install wind power on a small scale. Subsequently, between 1998 and 2002, interest in wind power surged dramatically and investments were scaled up and brought into the core activity of the firms. Finally, following the 436/2004 Royal Decree the industry consolidated and stabilised at a high level of activity.

The early Days 1990 - 1997

The early period of wind power investments was marked by attempts on the side of the utilities to learn about the technology and to satisfy the demands of the Spanish autonomous regions. The focus of development was on the regional level, working with the utilities' local distribution and retail branches and through their diversification division.

Endesa, in its industrial diversification branch, owned a small pylon construction business, 'Made SA', which started to move into the wind energy business in 1987 with several small-scale 150kW wind turbines. By 1995, it had developed a 500 kW prototype turbine. Supported with grants from the Spanish Institute for Energy Diversification and Saving (IDAE), it built several small wind farms in areas where Endesa owned the distribution grid, among others in Zaragoza in the Aragon region and on the Canary Islands (Windpower Monthly 1990;Windpower Monthly 1995b). By the end of 1994, Endesa thus owned 35MW of wind power, slightly less than half of the total installed capacity of 77MW in Spain at that time (Windpower Monthly 1995b;Dinica 2006)

Iberdrola's entry into the wind energy market started in 1994, when its subsidiary Energia Hidroelectrica de Navarra (EHN) – 37%-owned by Iberdrola at the time – announced a plan to install six wind farms in the North-Eastern Navarra region of Spain. The background to this proposal was the desire of the regional government, the other major backer of EHN, to reduce its dependence on

imported electricity from other regions. What made it significant for Iberdrola was not just the scale – the total capacity of the proposed wind parks would be 100 MW, more than doubling Spain's total capacity at the time – but also the involvement of another Iberdrola subsidiary, Gamesa, which was originally focused on aeronautical and automobile components. However, it entered the Navarra deal through a licensing agreement with the Danish wind-turbine manufacturer Vestas, which granted it the exclusive right to construct its 500 kW turbine, one of the largest turbine available at the time, in a factory in Navarra. A final branch of Iberdrola that became part of the project was Iberinco, Iberdrola's engineering and services branch, which carried out installation and grid connection work for the EHN wind farms.

Hidrocantabrico entered the market through its diversification arm 'Sinae', which was originally an environmental services provider. Yet, in 1997 it established itself as a wind energy and cogeneration developer in the North-Western region of Spain, where Hidrocantabrico was originally based (Windpower Monthly 2000). Finally, Union Fenosa established its 'Union Fenosa Energias Especiales SA' in its home region of Galicia in 1995. The spur here was the plan of the regional government to install 384MW of wind power in the region (Windpower Monthly 2001a).

Spanish utility managers stressed the importance of local involvement in these early wind energy projects and also the role of the autonomous regions:

"Each company had their own renewables activity at a local level... You need to be very close to the local authorities, you need to speak the same language, you need to eat the same bread."

"...you can control the turbines centrally afterwards, but you contract your local people for all the project planning, for building the machines, you contract local people for maintenance."

"After the 1994 Royal Decree, many autonomous regions wanted their own wind energy plans. So we listened very carefully and made sure we would get a part of the pie."

The role of the 17 Spanish autonomous regions becomes very visible when considering the regional differences of installed wind capacity. Five regions – Galicia, Navarra, Castilla y Leon, Castilla la Mancha and Aragon – were far advanced over the other parts of Spain and by the year 2003 held just under 85% of total Spanish wind power installations (AEE 2006). These regions had been the first to put out specific plans for wind power installations in their areas and consequently held tenders and allowed for fast permitting procedures on this basis. And each of these regions provided a home base for the Spanish utilities, with Endesa established in Aragon, Iberdrola in Navarra and Castilla la Mancha, Union Fenosa in Galicia and Hidrocantabrico in Castilla y Leon.

The second factor for increased activity in wind power was the 2366/1994 Royal Decree, which specified a feed-in tariff with a minimum contract guarantee and priority grid connection for all wind energy installations. The passing of the law spurred the emergence of a host of new wind development companies as well as the entry of several foreign firms in the Spanish market, which in turn increased dramatically the number of planned wind farms. Development activity surged to such an extent that within a year of the law being passed, an unprecedented 10,000MW of wind farms had applied for licensing (Windpower Monthly 1996).

In this context, the incumbent utility companies initiated the development of key capabilities based on their regional expertise. Incumbents initiated wind development in those regions where they also owned the regional distribution network and had already established relationships with regional governments. Endesa and Iberdrola furthermore built on their wind turbine subsidiaries 'Made SA' and 'Gamesa' respectively to provide turbine supplies for their projects and additional technical and engineering knowledge. Consequently, a capability base was established along the entire wind supply chain from turbine manufacturing to wind farm operation, which provided the companies with an understanding of the requirements to develop wind farms in Spain, especially with regard to the importance of good relations with regional authorities and local knowledge about site selection and measurements for new wind farms.

Concomitantly to this capability development, institutional activity was confined to the lobbying of regional governments for favourable wind energy plans. While the 2366/1994 Royal Decree was heavily lobbied by the main renewable energy association 'APPA', which represented all forms of renewable energy technologies, utility companies focused more on the regional governments.

"If I do not invest in renewables in Spain, it is still a good business, so someone else will do the investment and take that part of the pie of the energy that should be mine. So where do I start most effectively? We know these people [in the regional governments], we meet with them regularly, we have had many, many discussions about all sorts of problems."

"There is nothing similar to the promotion of a wind farm. And it is not the same in Catalonia, Andalucia, Galicia, Portugal... So we started in [name of region] and grew our interest in line with the wishes of [name of region]."

"...what is really done in the local areas, is the contact, is the relationship building between the company and the local authorities."

"We are very active on the local level, we listen, we analyse and try to influence to get the best regulation for what we invest in."

Wind Energy grew rapidly from 77MW in 1994 to over 440MW at the end of 1997. All four incumbent utility companies had established their own wind development subsidiaries. Yet, simultaneously, a variety of independent companies emerged that aimed to exploit the favourable legislation and regional development plans. Together, this led to a diverse and very active industry, which is also illustrated by the entry of several foreign firms. For example, in Galicia, after the first wind energy plan was published in 1994, there were applications for a total of 880MW of wind farms, among them three foreign companies and four independent Spanish wind developers (Windpower Monthly 1995f).

The Take-Off of Iberdrola 1998 - 2002

Albeit a growing business, wind development activities were still dispersed among the utility companies' hierarchy. At the four incumbent utility

companies, they were grouped either in general 'Diversification' units, which operated non-core businesses for the companies, or in regional sub-groups that operated regional services. Hence, the stakes in the various wind farms were not yet centrally controlled, nor were the different operations consolidated at a higher level in the company.

This started to change with the Royal Decree 2818/1998 and the subsequent announcement of the government target for 13GW of wind power by 2010 in the 1999 renewable energy plan. Managers stressed the stability this brought to their business plans and the change in outlook on the market:

"In 1998, the company was ready to take the challenge and the president was ready to foresee the increase in value that was possible through investment in clean technologies and was ready to lobby the regulators that this happened."

"There was a plan by the government – PFER - so the original objective for renewables was 13,000MW of wind. With the associated feed-in tariff, with that regulatory framework, the wind sector started to grow a lot. It was very important to have a framework as such, even with some starting problems. The commitment of the government was very ambitious at the time. So people simply trusted in the government... And the technology was really available."

"At that point financial institutions started to believe in wind. This meant that investors started to gain capacity to finance their investments, because the financial institutions started to feel that this renewables business wasn't that risky anymore. So the technology started to become more reliable and cheaper."

"...before, we had to pray for the board to say yes, and now, but from then on, when we sent a project to them, it was simply ticked off. So it was much more predictable."

Consequently in 1998, Endesa created its group 'Endesa Cogeneracion y Renovables' (ECyR), which centralised its renewables and cogeneration activities in the Endesa headquarters in Madrid. Similarly, Hidrocantabrico transformed its environmental services business Sinae into a pure renewable energy developer and furthermore bought a smaller renewable energy developer, 'Becosa', in the Andalucia region in Southern Spain in 2001. Union Fenosa continued to focus on its home region in Galicia while increasing its investment budgets. Nevertheless,

the starkest change in the strategy towards wind power can be found with Iberdrola. This will be explored in more detail in the subsequent paragraphs.

Through its entry into the Navarra region, Iberdrola had been able to acquire capabilities along the full value chain of wind power development, including its subsidiaries 'Gamesa' and 'Iberinco'. Total installed capacity by Iberdrola and its subsidiaries stood at 364 MW in 1998 (Iberdrola 1999). Consequently, Iberdrola welcomed the Royal Decree 2818/1998 and subsequent government wind energy target of 13 GW and started to build a more focused strategy around it (Iberdrola 1999;Iberdrola 2000).

Like the other utility companies, Iberdrola started to consolidate its renewable energy interests in one dedicated unit. By 2001, renewables had moved away from the diversification unit into a 'renewable energy' business unit, IbeRenova, which was set up at the corporate centre and subsequently consolidated the various renewable energy interests.

However, more importantly, Iberdrola was able to replicate the original business model from the Navarra region across the rest of Spain. In doing this, it focused on building local development partnerships, establishing manufacturing and other engineering capabilities in the regions and involving its specialised Gamesa and Iberinco subsidiaries.

Hence, in the province of Castilla la Mancha, it co-founded Energias Eolicas Europeas (EEE) together with EHN while Gamesa set up a blade factory there. In the Castile and Leon region it co-founded Biovent Energia together with the local industrial group Grupo Gasindur. In the Basque region, it owned 50% of Eolica de Euskadi, while in the Rioja region it held shares in three developers, 36.25% in the DerRioja group, 25% in the Molinos de Cidacos company and 68.75% in Eolicas de la Rioja. Furthermore, Gamesa, which went public in 1995, set up its own wind development company with activities in several Spanish regions and EHN expanded independently from Iberdrola with several joint-ventures. This activity was underpinned by a significant expansion of Iberdrola's

investment budget to €900m for the period 1999-2001, which was now centrally managed by IbeRenova (Windpower Monthly 1999a).

Consequently, in January 2000, EHN announced the biggest ever order for wind turbines worldwide, placed with Gamesa, for 1400MW of capacity to be delivered over the coming three years. By the end of 2001, Iberdrola had already passed the mark of 1000 MW of wind installations. Following a strategic review at the corporate level, coinciding with the arrival of the new CEO Ignacio Sánchez Galán, a new strategic investment plan for the years 2002-2006 was passed with an even bigger focus on wind power. Its headline figures included the announcement of a €2.5bn investment budget for renewables, including about 3,800 MW for new wind generation (Windpower Monthly 2001b).

Yet, Iberdrola's rapid expansion led to rifts with its key partners. Underlying this was Iberdrola's desire to integrate the renewable energy business in the corporate centre and to oversee the investment planning and setting of regional priorities for development. Firstly, in December 2001, EHN and Iberdrola failed in an agreement to pool their renewables activities under Iberdrola's roof, allegedly due to the reluctance of Navarra's regional government, EHN's other main shareholder, to give up control of what had become its most important regional company. This ultimately led to the withdrawal of Iberdrola from EHN at the end of 2002. The separation settlement divided the assets between both companies along geographic lines, with Iberdrola inheriting wind farms in Castilla La Mancha, Murcia, Brazil and Nicaragua (Windpower Monthly 2002a).

Secondly, a rift occurred in July 2002 after Gamesa announced it would auction off almost 1000 MW worth of windfarms in operation and under development, despite Iberdrola's preference to keep them within the company. Still being its largest share-holder, Iberdrola consequently managed to strike a deal with Gamesa in purchasing all the windfarms on offer and agreeing to purchase a further 1,100 MW of wind turbines over the coming years at a discounted price. Both events together meant that by the end of 2002, Iberdrola owned 1,650 MW of wind generation (Windpower Monthly 2002b).

In the years 1999-2002, Iberdrola surged to become the utility with the largest wind portfolio in Spain. This was based on the capabilities already developed in the company and the emergence of an ever more favourable institutional environment for wind energy. Yet, the foundation of the dramatic increase in wind energy developments was the emergence of a targeted strategy around wind power which replicated its regional business model, first developed in Navarra, across Spain. Hence, Iberdrola simultaneously concentrated its wind energy strategy at the corporate centre, while simultaneously entering new markets through new regional joint-ventures, utilising Iberdrola's capabilities in the EHN, Gamesa, Iberinco and other regional subsidiaries. Consequently, the 2002-2006 strategic plan was the most ambitious such plan announced by any utility in Europe at the time.

Total installed capacity in Spain increased from 834 MW in 1998 to 4,891 MW in 2002 (APPA 2007). The share of incumbent utility companies in this total installed capacity stood at just over 45%, while independent developers held the remaining 55% (Stenzel & Frenzel 2007).

Consolidation, U-Turns and the increasing involvement of Spanish Utility Companies in the Wind Energy Sector 2003 - today

By 2002, with the wind energy industry experiencing a major boom phase, the limited capacities of the Spanish electricity grid emerged as a key bottleneck. The Spanish grid operator, REE, had effectively capped potential wind energy installations at 13,000 MW for fear of serious risks to the stability of the electricity system. This lead to a backlog in the applications for grid connections, as several regions reached their capacity limits, and annual installations in 2003 fell behind the 2002 level (Windpower Monthly 2003e;Windpower Monthly 2004).

At the same time, adjustments to Spain's feed-in law were considered in parliament, which eventually led to Royal Decree 436/2204, described in section 4.5.2 above. Discussions focused on three main changes to the existing regime: Firstly, there were proposed revisions of the feed-in tariff, both in terms of the level of support and the mechanism through which it was delivered, either as a top-up premium to the wholesale market electricity price or as an instrument entirely separate to the market. Secondly, with increasing amounts of wind energy on the system, REE pressed for a mandate on operators, to provide forecasts of wind farm output. In this way it was hoped that wind energy could be better integrated in to the electricity market as better forecasts would all a more efficient operation of the electricity grid. Thirdly, there were discussions about technical standards that wind farms had to fulfil in order to gain grid connection. It was proposed by REE that enhanced technological equipment of wind farms to master grid faults and contribute to grid stability would allow it to lift the 13,000MW cap on total wind energy installations .

In the run-up to these policy changes and the tightening market conditions, the Spanish incumbent utilities founded a new wind energy business lobby group 'Plataforma' – later renamed – 'Asociacion Eolica Empresarial' (AEE) in 2003 (Windpower Monthly 2003c). While the traditional renewable energy lobby group, APPA, mostly lobbied for wind energy on an environmental platform, encompassing all renewable energy technologies, AEE set out to work 'pragmatically' and in partnership with government and REE to overcome the most pressing obstacles to a further expansion of wind power (Windpower Monthly 2003a).

AEE's mode of operation was to set up working groups on the most important issues in the upcoming policy revisions. Consequently, in collaboration with REE, it initiated test trials for wind forecasting systems that would allow operators to better predict their output. At the time, penalties on imprecise or wrong forecasts were the main obstacle that prevented wind farm operators to participate in the wholesale market and receiving the top-up premium, instead preferring the fixed feed-in tariff. After success in the initial trials, the government set out to reward financially better wind forecasts and to further support systems

that would integrate REE's own forecasts with those of individual wind farm operators. Consequently, Royal Decree 436/2004 made wind production forecasts mandatory but penalties only applied for deviations of more than 20% from the original schedule. Furthermore, an additional premium was paid to operators that supplied certain information to REE. This allowed operators to enter the wholesale market and fine-tune their forecasting systems without risking significant penalties.

A second working group, again involving AEE and REE, investigated the technical standard of wind turbines and their potential contribution to grid stability. The government had so far implemented a de-facto upper limit on wind power of 13,000 MW, based on technical advice by REE. However, AEE argued that this was seen as conservative and based on outdated wind turbine standards. Consequently, the working group developed technical norms and grid codes that would allow more wind power to be connected to the grid, which in turn would allow the government to lift its wind energy target. Consequently, under Royal Decree 436/2004, wind operators that traded in the pool market were now able to receive not only the top-up premium, but also a special market trading and security-of-supply incentive, related to the technical standard of a wind turbine. Furthermore, a new renewable energy target was set at 20,000 MW of wind power by 2010.

Underlying these technical details was a fundamental debate about the mechanism of the feed-in tariff. Through its working groups and in its general lobbying approach, AEE strongly advocated a transition towards integrating wind energy into the wholesale market with a technology-related top-up premium and eventually abandoning the separate feed-in tariff (Windpower Monthly 2003b). In this respect, the outcome in the Royal Decree 436/2004 fully reflected AEE's objectives. Managers at incumbent utilities stressed the importance of these successes for their own business model:

"I think the 2004 regulation the actual bend on the way. From that moment, things completely changed. Renewables were a trend beforehand, but a fact from that moment and it made every actor change their mind."

"It was a change for REE because they realised that this was something they had to deal with. Wind is a good idea but it only works when it is windy. You need a system that has back-ups so you don't stop supplying electricity. Those things were all happening back in 2004 in a way that there was no way back."

"There were two approaches to controlling wind: It's a passive thing, you get a surplus when you produce, put in your pocket and you are done. Or you think that integrating wind is a main driver for the future, and you have to prepare all other things around, not just the cashing in, and you have to think that renewables and wind in particular is going to be one of the large technologies providing electricity for the future."

"And a very important reason to change our strategy and become more aggressive was that in 2004, the Spanish government issued a new Royal Decree and that was an inflection point in the development in renewable energy. It was a feed-in tariff with two possibilities: Going to the market with a premium or a stable fixed-tariff. But there was now this huge upside potential when going into the market and we made these investments to make it happen. We decided to be in renewables, we believed more in its long-term future, so we changed."

"Before the integration of wind, you needed to demonstrate that the investment in every project is a very, very good business, you needed to make a very good business plan and the returns had to be very, very high. Now, it is different. We are part of a very important utility in Spain, and it was clear that we needed to produce more wind, and 2004 showed that this was technically feasible..."

While the 1998 Royal Decree created the environment in which wind power was able to grow initially, the 2004 Royal Decree started to integrate wind power into the wholesale market and shaped its technological path towards more advanced control technology. However, among the incumbent utility companies, different strategies emerged how to take advantage of this situation. While Iberdrola and EDP mirrored the institutional integration of wind power with developments inside their organizations, Endesa and Union Fenosa considered selling their renewable energy units, when debt reduction targets required the companies to sell non-core assets (Windpower Monthly 2003d). Both strategies will now be considered in turn.

By 2004, Iberdrola was two years into its 2002-2006 investment plan, with installed capacities already exceeding its targets. Consequently, the 2004 Royal Decree allowed it to scale-up its investment plans and deepen its capabilities in the renewable energy sector.

The most visible example of this was the installation of a centralised renewable energies operations centre (CORE) in 2003/2004. CORE fulfilled two functions: Firstly, it provided weather forecasts and real-time output information for Iberdrola windfarms, thus aiding the market integration of renewable energy. Secondly, it allowed remote, real-time monitoring of every single wind turbine thus increasing the efficiency of operations and minimising maintenance costs.

In the interviews, it was highlighted that CORE was central to Iberdrola's strategy of wind power expansion. Nevertheless, the impetus for CORE came with the shaping of the 2004 Royal Decree.

"With the 2004 regulation taking shape, we spend a lot of money on two things: Prediction – if you don't know what is going to happen tomorrow you cannot deal in a liberalized market. So we did spend some money, some time and a lot of energy reducing forecasting deviations from 80 to 20%. Secondly, we said, when you have 3, or 10 or 100 machines, you can go to each one of them and see what happens to them. But when you have 4500 machines, you need to do something because you cannot have 4500 people sitting around to see what's going on. So we did spend a lot of money on a telecommunication system that is integrated in every machine, which allows us to tele-control every machine from a distance. [...] we now get about 350 variables from each turbine – rotation speed, wind speeds, revolutions, pitch status, the gearbox, and we get all those from every machine to our centralised control system. "

"...it is the only way that you can have large amounts of wind energy on the system."

"...we do it for the optimal exploitation of our assets. [...] If we know today that we will have strong winds in the southwest of Spain tomorrow, where we have about 1,500 MW of wind installed, and we know that we have to do some repair work on a CCGT, we can programm those things to coincide. You don't want to stop your CCGT on a day when the wind is flat, you stop it when you can use the wind."

With the introduction of CORE, Iberdrola was able to significantly scale-up its wind power investment programme, including an expansion into foreign

markets in Europe and South America. In 2004, it announced a new strategic plan for wind power, with a target of 5500MW by 2008, which was revised again to 2007 with a new aim of 7,000MW in 2009 and €3.25bn of total investments.

Hidrocantabrico, as the smallest of the four incumbent utilities in Spain, similarly held a small and regional position in the wind power market. However, with the 2004 Royal Decree taking shape, Hidrocantabrico significantly increased its presence in the wind power sector. Together with its Sinae and Becosa wind energy subsidiaries, it bought a stake in another independent wind developer from 'Caja Madrid', the regional savings bank, in 2004, and grouped them in its corporate centre in the new renewable energy wind 'Genesa'. After being taken over by EDP, the Portuguese utility, it bought 'DESA', another wind developer, for €700m and, together with EDP's own wind energy business, 'Enernova', founded a new group 'Neo Energia' that controlled all wind energy investments of the firm. In January 2007, it bought three further Spanish wind developers, Tarcan, Ceasa, and Agrupación Eólica for €346 million. This was summarised by one manager:

First, we decided to join together the companies, because it doesn't make sense in one company to have different groups with different strategies. So we integrated Enernova and Genesa, which became a big company in renewables in Iberia, and gave it the name Neo Energia. But then, the EDP board decision was to bet on renewables.

The build up in development capacity was eventually reflected in Neo Energia's wind portfolio. While grid constraints in several of its active regions led to a backlog of connections between 2002 and 2004, it started to grow significantly from 359MW in 2004 to 1,181MW in 2006 (EDP 2007). EDP's latest strategic investment programme in 2006 committed 47% of total group capital expenditure towards renewables and especially wind energy, with 2,800 MW targeted for 2008 and €2.1bn committed. In 2005, EDP overtook Union Fenosa, and in 2006 Endesa, to become Spain's second largest utility investor in wind energy.

Both Iberdrola and EDP/Hidrocantabrico are now also expanding outside Spain, leveraging their capabilities in wind farm development. Indicative of this were recent deals between Iberdrola and Scottish Power, which involved acquiring the US wind developer PPM Energy, and the acquisition of US wind developer Horizon Energy by EDP.

Endesa and Union Fenosa on the other hand, did not immediately integrate wind power into their strategy following the 2004 Royal Decree. On the contrary, in the period leading up to the new legislation, both companies put their renewable energy subsidiaries on sale.

When Endesa announced ambitious debt reduction targets in 2003, a 50% stake in ECyR and also the wind turbine maker 'Made' were put up for sale. At that time, it was seen as an opportunity to profit from the booming market environment for wind power to achieve a high price for this asset. Yet, by the end of 2003, and concomitantly to the negotiations over the revised Royal Decree 436/2004, Endesa called off the sale of ECyR and declared it part of its 'core' business. 'Made's' wind turbine manufacturing business was still sold to 'Gamesa', but its wind farm development unit was integrated into ECyR. Consequently, this was underlined with a new investment programme that aimed to increase its installed wind capacity to 3400MW in 2008, with €1.9bn earmarked. Furthermore, it opened its own remote monitoring and control centre for its wind farms in 2005 to aggregate its output across Spain and create and interface with its market trading unit.

In hindsight, an ECyR manager commented:

"Sometimes, what happens is that you have your structure, your experience in taking some decisions, but you still see what happens outside. And Endesa said, am I doing it right or not? So there has been a reflection of the direction. [...] Someone realised – I am losing business, I am losing opportunities. Then, the 2004 legislation and the increase in the targets was a confirmation that we were right to put ECyR at the core of the company."

Similarly, Union Fenosa, citing financial imperatives, put up for sale an 80% stake in its 'Union Fenosa Energia Especiales' subsidiary at the beginning of 2003, which was consequently purchased by Italian utility ENEL. Yet, in a similar turn of events to Endesa's handling of ECyR, Union Fenosa exercised an option to repurchase 30% in the renamed ENEL Union Fenosa Energias Renovables (EUFER) in 2004. Consequently, EUFER was run as a joint-venture between ENEL and Union Fenosa and developed a business plan to build 2750MW of wind energy in Spain and internationally by 2011, with at least €1.5bn of investments committed.

Today, all four Spanish incumbent utility companies are significant actors in the wind energy industry. Figure 26 below summarises the evolution of their market shares in the wind energy market between 2000 and 2005. It shows the significant increase in activity at Iberdrola, starting in 2002 and EDP's later rise in 2004. In 2005, utilities had a 57% market share in total installed wind energy capacity.

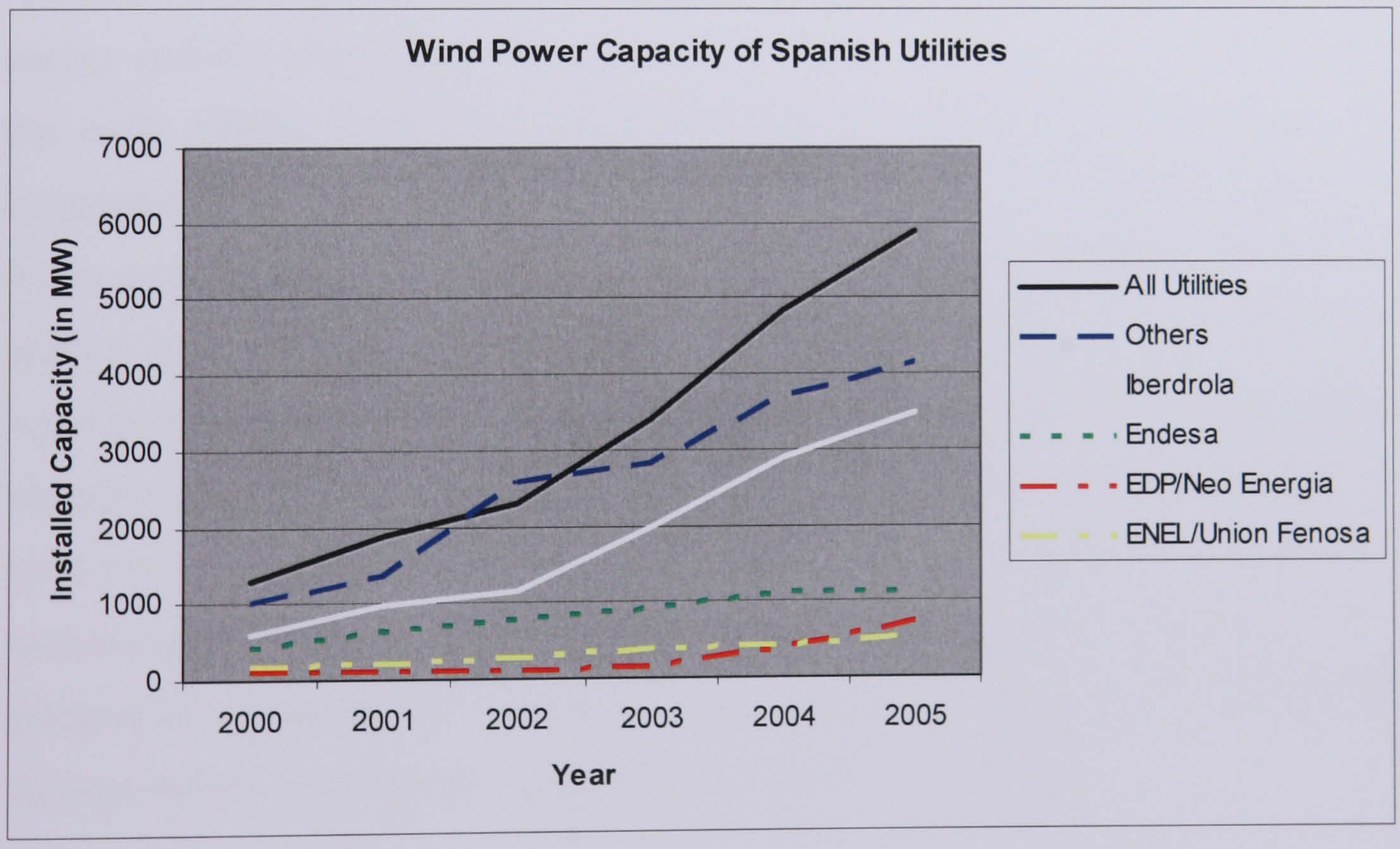


Figure 26: Installed Wind Capacity of Spanish Utilities (Sources: Own research based on company annual reports, investor presentations, press releases and AEE (2006))

All interviewed managers stated that wind energy had become a core activity of their company. The strategic investment plans, given in Table 20 below, indicate the continuous interest of the utility companies in developing this

technology further. Based on these plans and the increasing consolidation of the sector, it can be expected that incumbent utilities will increase their market share further in the coming years.

Table 20: Investment plans of large utilities for wind energy in Spain (Based on company reports and presentations)

	Investment period	Target value for wind energy	Total sum invested
Iberdrola	2007-2009	7,000MW in 2009	€3.25bn
EDP	2006-2008	2,800MW in 2008	€2.1bn
Endesa	2005-2009	4,100MW in 2009	€1.9bn
ENEL / Union Fenosa	2007-2011	2,750MW in 2011[25]	€1.5-€2.1bn

4.5.4. Summary of co-evolutionary developments in Spain

With Spanish utility companies having consolidated the fragmented operation of the electricity system throughout the 1980s, they entered the wind energy industry through small-scale diversification and regional investments in the early 1990s. From this starting position, they adapted their strategy and integrated wind energy at the core of their businesses as the market started to boom and the technology matured. Simultaneously, their institutional lobbying shifted from the regional to the national level, arguing for better integration of wind power into the wholesale electricity market. With the resulting institutional changes, this set in motion further capability developments among the utilities to treat wind power technically and economically similar to conventional generation technologies. This ultimately allowed them to become leading companies in the integration of wind power worldwide, using wind power as an avenue to enter into foreign markets and engage in merger and acquisition activity.

At the outset, there were two main institutional drivers for investments into wind power. Firstly, Royal Decree 2366/1994 specified a special feed-in tariff for wind energy production above wholesale market prices. Secondly, the

[25] Of which 850MW is planned for the Iberian Peninsula and 1,900MW internationally

Spanish autonomous regions set out their own wind energy plans, thus streamlining planning permissions and application procedures.

Consequently, the Spanish incumbent utility companies entered the wind power market through their regional and diversification units, building on their local knowledge and political connections to construct wind farms in their own distribution and retail areas. This led to the creation of specific capabilities in wind development. Furthermore, Endesa and Iberdrola involved additional subsidiaries in the wind turbine manufacturing and engineering field in their wind farm developments, thus establishing capabilities along the entire value chain of wind power development. Still, the design of the feed-in law meant that besides the incumbent utilities, a diverse wind developer industry emerged with several independent actors building wind farms, including companies from abroad.

The resultant growth in installed wind capacity turned into a significant boom with the passing of Royal Decree 2818/1998 and the government's 1999 renewable energy plan. As total installed capacity passed the mark of 1,000MW and the institutional environment became more favourable, the Spanish incumbent utilities began to centralise their wind energy activities at the corporate centre, consolidating formerly dispersed investments. Yet, wind energy investments in Spain were determined by the degree of local and regional knowledge and connections, as the incumbent utilities had learned over the past years. Hence, the strategic approach emerging in this period was the replication of the regions-based business model across Spain, partnering with local wind developers and supporting the local economies with investments into factories and other strategic assets.

The most aggressive approach was exhibited by Iberdrola, which soon emerged as the biggest utility investor in wind energy in Spain. Its strategy centralised the oversight of wind energy investments while rapidly engaging in several joint-ventures and strategic investments at the local level to create a reach across all of Spain. Having already developed a strong starting position, it consolidated its regional activities and bought out several of its former partners, among them its own wind turbine business, Gamesa, and EHN. Based on these

capabilities, a significantly increased investment budget and the favourable institutional environment, Iberdrola increased its installed capacity from 364 MW in 1998 to 1,650 MW in 2002, while all incumbent utilities operated close to 45% of total installed wind capacity at that time.

With the high level of investments among Spanish utilities, the approach to institutional activity shifted increasingly from the regional to the national level. This culminated in the formation of a new industry lobby group, AEE, in 2003, which would engage in detailed discussions with the government and the grid operator over upcoming changes to the basic renewable energy framework and the integration of wind power into the electricity grid. Building on their existing capabilities and the scale of the investments, AEE argued for a closer integration of wind power into the conventional electricity markets and increasing technological standards so that wind farms could be treated in the same way as conventional power plants.

Having been successful in their lobbying approach, the resulting Royal Decree 436/2004 provided numerous new incentives for wind farm operators, rewarding the installations of more advanced turbines and the sharing of wind forecasting data. This in turn allowed utilities an expansion of their capabilities in creating wind farm monitoring and control centres, that aggregate data from actual wind farm operations with forecasts for future output and market trading data, thus establishing sophisticated interfaces for the integration of wind power into conventional electricity markets. Hence, the new market framework made the development of new technical capabilities for the development and operation of wind farms economical and allowed Spanish utilities to establish themselves as leading wind power integrators worldwide.

In summary, the co-evolutionary process between institutions and incumbent utilities led to positive reinforcing feedback loops of capability developments and institutional accommodation of increasing amounts of wind power. Both utilities and independent developers drove regulation to allow increasing amounts of wind power on the grid to be connected and integrated with increasingly sophisticated methods.

5. Discussion of the co-evolutionary dynamics in the three countries and policy Implications of the research

The previous chapter outlined the co-evolutionary dynamics between the corporate strategies of incumbent utility companies and their institutional and technological environment in three countries. In this chapter, building on the analytical framework developed in chapter 3, the discussion moves beyond individual country borders and aims to draw out common patterns among the three case studies and to assemble the resulting implications for policy-making.

Thus, this chapter addresses the third aim of this thesis:

T*o discuss which factors contributed to the incumbents' strategies to adopt or resist the introduction of wind power.*

The premise for the research presented in the previous chapter was that incumbent utility companies hold a potentially powerful position in the electricity system with regard to the diffusion of new renewable energy technologies. Given their control over and historically grown links with the established electricity network, they could be a formidable force either in helping the introduction of these new technologies or in obstructing their wider application. In this respect, the case studies in the previous chapter highlighted the manifold interactions between incumbent utilities and their institutional and technological environment when faced with the introduction of wind energy technology.

This chapter is structured as follows: Firstly, in section 5.1, it will focus on the application of the analytical framework in the three case studies. It will provide a firm-level perspective on the formulation of corporate strategy with regard to developing new capabilities and corporate political activity in response to a changing systemic environment. Having examined the organizational level and the link between firms with their systemic environment, section 5.2 will broaden the discussion from company strategy to examine the wider co-

evolutionary feedback loops between the three dimensions 'organisations', 'technologies' and 'institutions'. On the basis of this analysis, section 5.3 will discuss policy implications derived from the case studies both at a general level and in the specific context of EU policy making.

5.1. Corporate Strategy vis-à-vis institutional and technological systems

Throughout this thesis it has been argued that co-evolutionary research needs to take note of the individual actions that underpin systemic changes, and the motivations behind them. The analytical framework developed in chapter 3 attempted to capture this premise by linking developments at the level of corporate strategy with developments at the systems level. Figure 27 outlines again the key interactions between both levels.

This section will now examine the key similarities and differences in the co-evolution of corporate strategy and systemic development in each of the three case study countries. It will firstly focus on the company-strategy level, summarising the key milestones in each country and classifying them according to the degree of institutional engagement and technological capability development and will illustrate these milestones in the context of the analytical framework. Subsequently, section 5.2 will broaden out the analysis and compare the wider co-evolutionary development between corporate strategy and systemic change in each country.

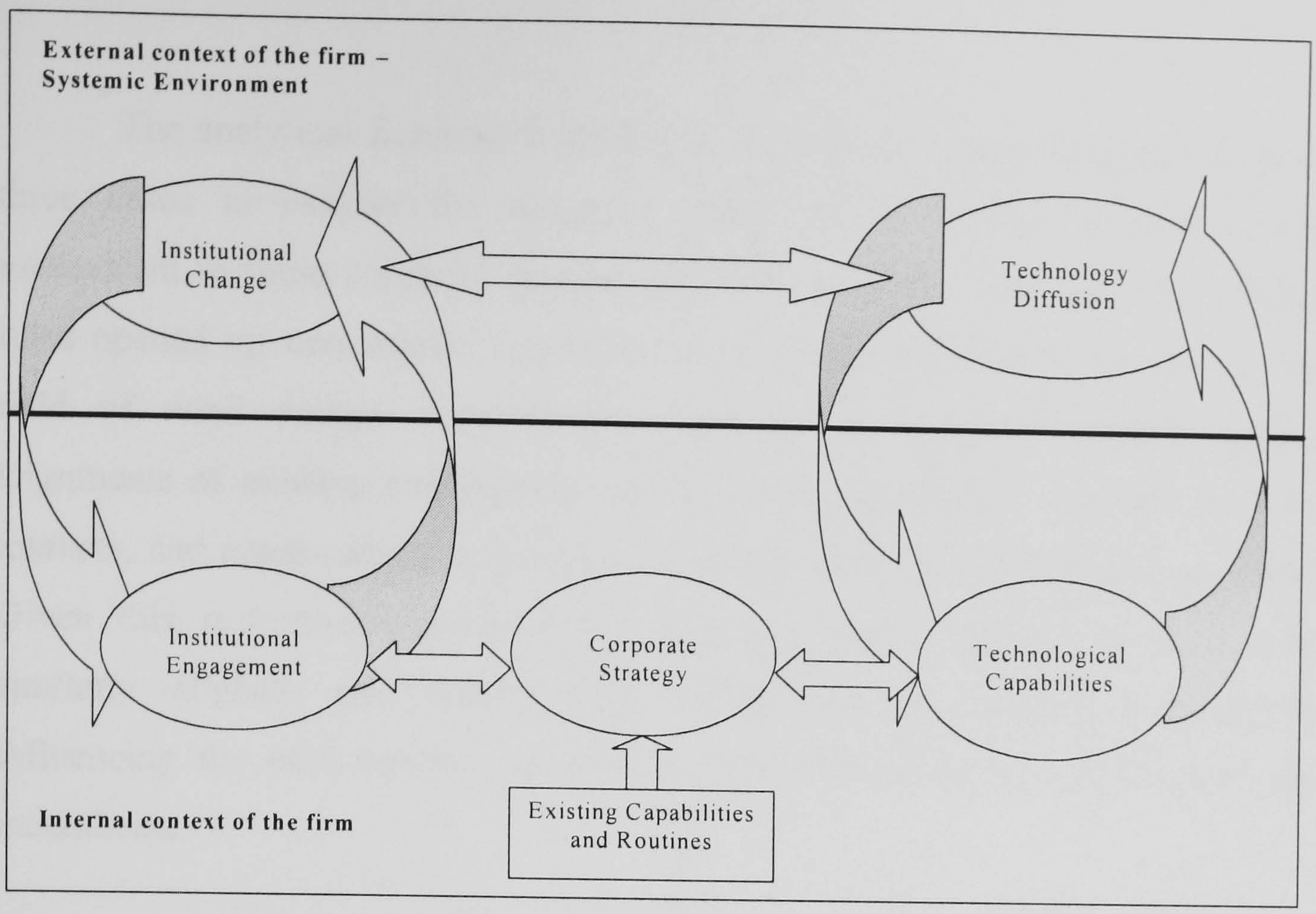


Figure 27: Co-evolution of firm strategy, technology and institutions

5.1.1. Development of corporate strategies in the three countries

The case studies showed similarities as well as differences between the firm behaviours and between the diffusion patterns in the three countries. While utility firms in both the UK and Spain were significant adopters of wind power generation, the German firms did not build a substantial base in this new technology. Yet, the national diffusion pattern of wind power is more similar in Germany and Spain, while the UK pattern is strikingly different. Table 21 below summarises the key figures from the three countries:

Table 21: Diffusion levels of wind power generation in the United Kingdom, Germany and Spain in 2005. Source: Reiche 2005, own research

	United Kingdom	Germany	Spain
Total installed wind capacity	1,337MW	18,428MW	10,028MW
Share of wind power in total electricity generation	0.45%	4.3%	7.78%
Total installed watts per capita	15	209	202
Largest capacity of big utility	RWE npower 395MW	E.ON 224MW	Iberdrola 3494MW
Share of all utilities in wind energy installation	81.4%	1.16%	57%

The analytical framework developed in chapter 3 is now applied to these three cases to explain the observed differences. The key co-evolutionary mechanism in these countries can be described as follows: Firstly, new market rules opened up new market opportunities for technologies and services in the field of wind energy development. This set in motion company-internal alignments of existing capabilities, potential new capabilities to serve the new markets, and consequently corporate strategy towards this new market segment. Given this re-formulated corporate strategy, corporate political activity was similarly aligned, and consequently institutional engagement focused on influencing the policy-making process towards the business objectives of the incumbents.

In this respect, the three countries offered three different illustrations of these interactions, each of which will be outlined in the paragraphs below.

UK

The focus of the UK case study was to understand the relatively low level of wind energy diffusion relative to Spain and Germany. With respect to the analytical framework, the main focus point was the institutional framework for wind energy (or lack thereof) and its impact on company strategy.

The UK's NFFO auctions were introduced at a time when two large incumbents were dominating the England and Wales electricity market, and 'Scottish Hydro' and 'Scottish Power' were largely unopposed in Scotland. Yet, witnessing the 'dash for gas' at the time, 'National Power', 'PowerGen' and 'Scottish Power' reacted to the incentives provided by the NFFO to engage in new technological capability development in wind power. Initially, each company used partnerships and joint-ventures to limit the technology risk of their involvement and to broaden their learning experience in developing the necessary capabilities. The NFFO allowed for slow, incremental developments of capabilities while restricting the overall growth of the technology through limited and erratically announced auction rounds. Thus, the UK failed to create a strategic market opportunity for wind power that would have allowed more new companies to

enter the emerging wind energy industry. The small market niche that was created did not provide for the stability and growth prospect that new entrants in Germany or Spain were able to take advantage of.

Given the policy design, incumbents were quickly able to dominate the UK wind power market as a whole, squeezing out small independent developers. Yet, among the incumbents, wind power continued to be a niche activity. Hence, the development of technological capabilities did not acquire central strategic importance, but rather, in the words of one manager, remained something "*useful to sustain*". In the interviews, it was highlighted that while limited technological capabilities were developed among the incumbents, the uncertain institutional environment acted as a key barrier to further development by preventing wind energy to be integrated as a core business of the incumbents in the UK.

Furthermore, the incumbents' institutional-engagement focus remained in the area of the recently liberalized electricity market. Consequently, the incumbent utilities did not respond with pro-active corporate political activities to overcome the most pertinent barriers to growth under the NFFO legislation. In the absence of significant alternative lobbying networks, the wind power policy framework was subsumed in the larger electricity market liberalization process. This process continued with the introduction of the RO as a subsection of the reformed Utilities Act 2000.

With the RO having a direct bearing on the performance of the utilities' core supply business, however, organizational adaptation acquired more strategic importance among the incumbent utilities. However, as outlined in section 4.3.2, the RO continued to disadvantage independent developers as it favoured companies with large balance sheets that stem the financial risks and transaction costs associated with the trade in ROCs. All utilities acquired new capabilities, especially with a view to entering the newly emerging offshore wind business. Investment budgets for wind energy increased substantially relative to the pre-RO period while institutional engagement by the incumbent utilities focused much more strongly on the support regime for offshore wind farms and an improvement of the RO rates in this area.

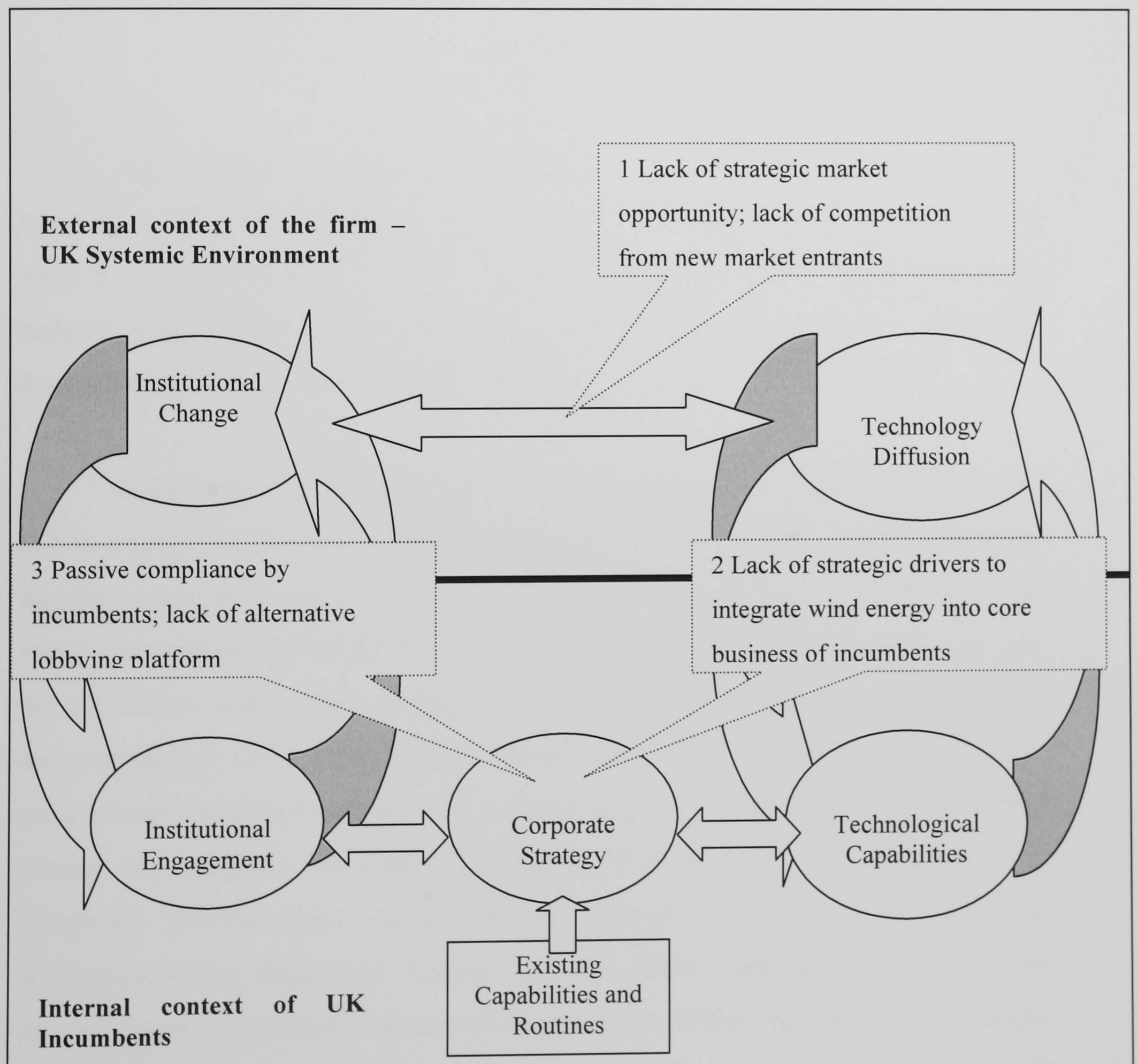


Figure 28: Key features of the analytical framework in the UK

Hence, in summary, incumbents had a dual role of "passively-compliant" but "industry leading" champions of the wind industry. Figure 2 illustrates the main causal relationships drawn from this case study. Starting with institutional changes (1), the introduction of the NFFO lead to low levels of technology diffusion and hence provided insufficient competition and a lack of market opportunity for the incumbent utilities. This in turn meant there were insufficient drivers to integrate the wind energy business into the strategic core of the UK utilities (2). Hence, corporate strategy was directed towards passive compliance with regard to both development of own technological capabilities and their institutional engagement strategy (3).

Germany

The German case study focused on the reasons behind the low-level of wind-energy adoption among incumbents, while the market was developing at the same time into the largest globally. It was a unique fact that the early wind energy support programme from 1990 did not spark any technological capability development among the incumbent utilities.

Three factors can be highlighted with regard to the incumbents' decision not to engage in this early phase of development. Firstly, the utility companies had been previously unsuccessful in achieving a technological breakthrough with rapidly up-scaling the relatively small wind turbines available at the time. As they did not believe wind power could contribute significantly to future energy demand and considered small wind turbines unsuitable to their business model of large-scale power generation, the utilities' outlook on the likely profitability of the wind market was negative. Secondly, German reunification and the prospect of an integrated pan-European energy market sparked a series of mergers and acquisition in the fragmented German industry. This remained the primary focus of the German incumbent utilities throughout the 1990s, as discussed in section 4.4.1, leaving fewer resources at the time for developing new business areas such as wind power. Finally, the design of the feed-in law prevented incumbent utilities from profiting from it when investing in their own monopoly areas. This meant

that they were not able to utilise their local development and relational networks for the development of wind power.

Yet, the continuous expansion of wind power started to impact on the core business of the incumbents, as they had to accept all electricity produced from wind power into their grids, while demand remained relatively stable. The decision not to develop capabilities in wind power development was complemented by an institutional engagement strategy that opposed this emerging market. Various channels of influence were used by the utilities to limit the expansion of new wind farms, with judicial court challenges, technical hold-ups in grid connection and direct political lobbying all documented as strategies to overturn the institutional basis for the German wind power boom in the 1990s.

Figure 3 illustrates the key mechanisms from the German case study in the context of the analytical framework. Here, the existing capabilities and routines together with the negative experience in wind power development (1) lead companies not to develop technological capabilities at the time of the introduction of the first feed-in tariffs (2). This is coupled with a defensive political strategy to limit the institutional niche for renewable energy (3), which is re-enforced by the rise of independent wind developers and their increasing impact on grid operations by the incumbent utilities. Continuous absence from the market closes the window of opportunity to profit from wind energy, which furthermore re-enforces the defensive political lobbying approach.

By 1998, two factors had changed that led to an overhaul of the incumbents' strategy. Firstly, after having exhausted various channels of corporate political activity, the supportive environment for wind power still remained largely intact in Germany. While the utilities achieved a slow down in the annual installation rate of wind power between 1995 and 1998, ultimately no measure was successful in reversing the upward trajectory of installations and the growing network of independent wind development companies. Secondly, the newly elected 'red-green' government had staked part of their election programme on the expansion of renewable energy technologies. This meant that the institutional environment for wind power was likely to stabilise even further.

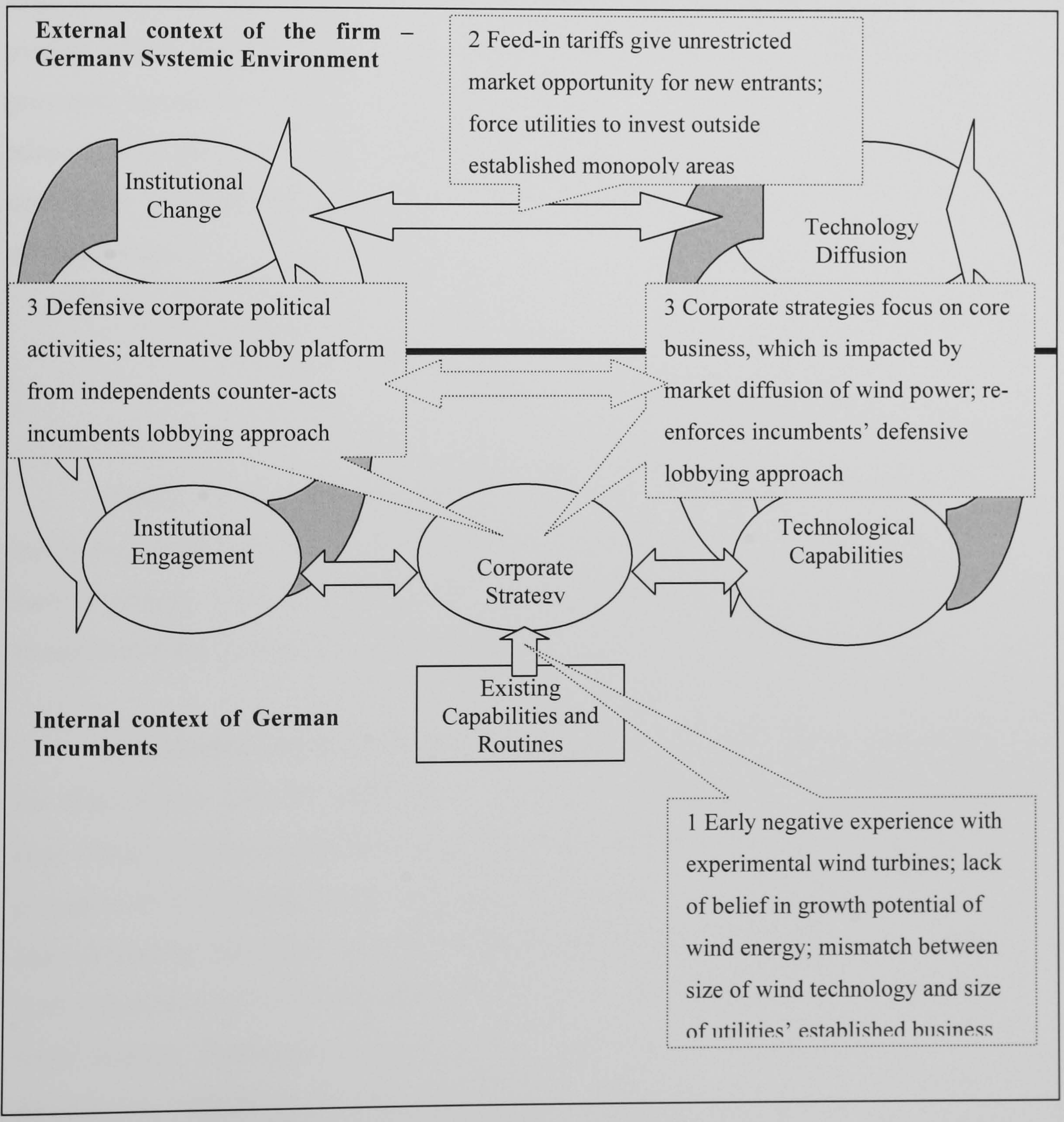


Figure 29: Key features of the analytical framework in Germany

Taken together, these two factors created the conditions in which incumbent utilities gradually adapted their strategy. As the institutional foundations of the wind industry's success were not changeable, their core business would be exposed to increasing amounts of institutionally-prioritised wind energy. Furthermore, the lack of any own capabilities in this area meant that incumbents still lacked the experience to enter the onshore wind-market in a meaningful way.

In this context, the emerging offshore wind market opened the prospect of large-scale production of wind power, thus offering the opportunity to enter a new market which matched the incumbents' scale and investment appetite and provided significant growth prospects. This strategic shift interacted with an adaptation of the institutional engagement strategy, which shifted from outright opposition to a targeted approach of policy change and increasing support for offshore wind.

Spain

Finally, the Spanish case study stood out as being both successful in integrating significant amounts of wind energy at the national level, becoming the second largest market globally, while also inducing sizeable investment by incumbent utility companies (>50% of total wind investments).

The incumbent utility companies responded to the first institutional niches for wind power with the development of new technological capabilities in this area. These companies were rooted in regional monopolies which allowed them to extend their local relationships in the area of wind power. Furthermore, as in the case of Endesa and Made and Iberdrola and Gamesa, they were able to leverage their diversification in related industries to build a competitive market position in wind energy. Furthermore, their political activities involved lobbying local autonomous regions to develop regional wind power plans that simplified the planning regime. With this understanding of the requirements for the wind

business, incumbent utilities were able to expand nationally with the stabilisation of the subsidy regime under the Royal Decree 2818/1998 and the subsequent wind power target of 13,000MW by 2010.

Profiting from the subsequent boom in wind power, the incumbent utilities' lobbying approach subsequently shifted to the national stage where a new lobbying group - 'Asociacion Eolica Empresarial' (AEE) – was created to engage with government, the market regulator and the grid operator to overcome the most significant barriers to further expansion of wind power. By 2002, Spain experienced significant grid constraints that threatened the continuity of the market expansion and thus the opportunities for the Spanish incumbents. Consequently, AEE's lobbying focused primarily on the area of market integration, better wind forecasting systems, establishing new grid codes and increasing the government target for wind power. These issues were all addressed in the subsequent Royal Decree 436/2004, which led to a renewed boom in wind developments, with a newly increased government target of 20,000MW of wind power by 2010.

At the company-level, the new institutional framework led to the development of further technological capabilities to better integrate wind farms with the conventional generation portfolio of the utilities, thus establishing remote monitoring and control centres to centralise data collection and exchange between companies and the market. This was also underpinned by new incentives for wind farms providing grid support functions, with existing wind farms being upgraded technically.

Finally, Spanish utilities increasingly used their knowledge in these areas to base their foreign expansion plans on wind power, with EDP purchasing US wind developer 'Horizon Wind' for €1.6bn in March 2007 and Iberdrola acquiring US wind developer 'CPV Wind' for €1.5bn in April 2007.

Figure 30 illustrates the key aspects of the analytical framework in Spain. Here locally-rooted, diversified utilities (1) were able to take full advantage of the opportunities that the feed-in tariffs provided (2). Especially, these allowed the

use of their local relationships to lobby regional government for planning support (3), while building up technological capabilities, partly leveraging their own industrial base (3). Building on the success of this strategy, institutional engagement was increasingly shifting to the national level, to ensure continuous government support for wind energy and better integration into electricity markets (4). The expansion of government policy in this respect allowed companies to further develop their technological capabilities and become the leading integrators of wind energy in Europe.

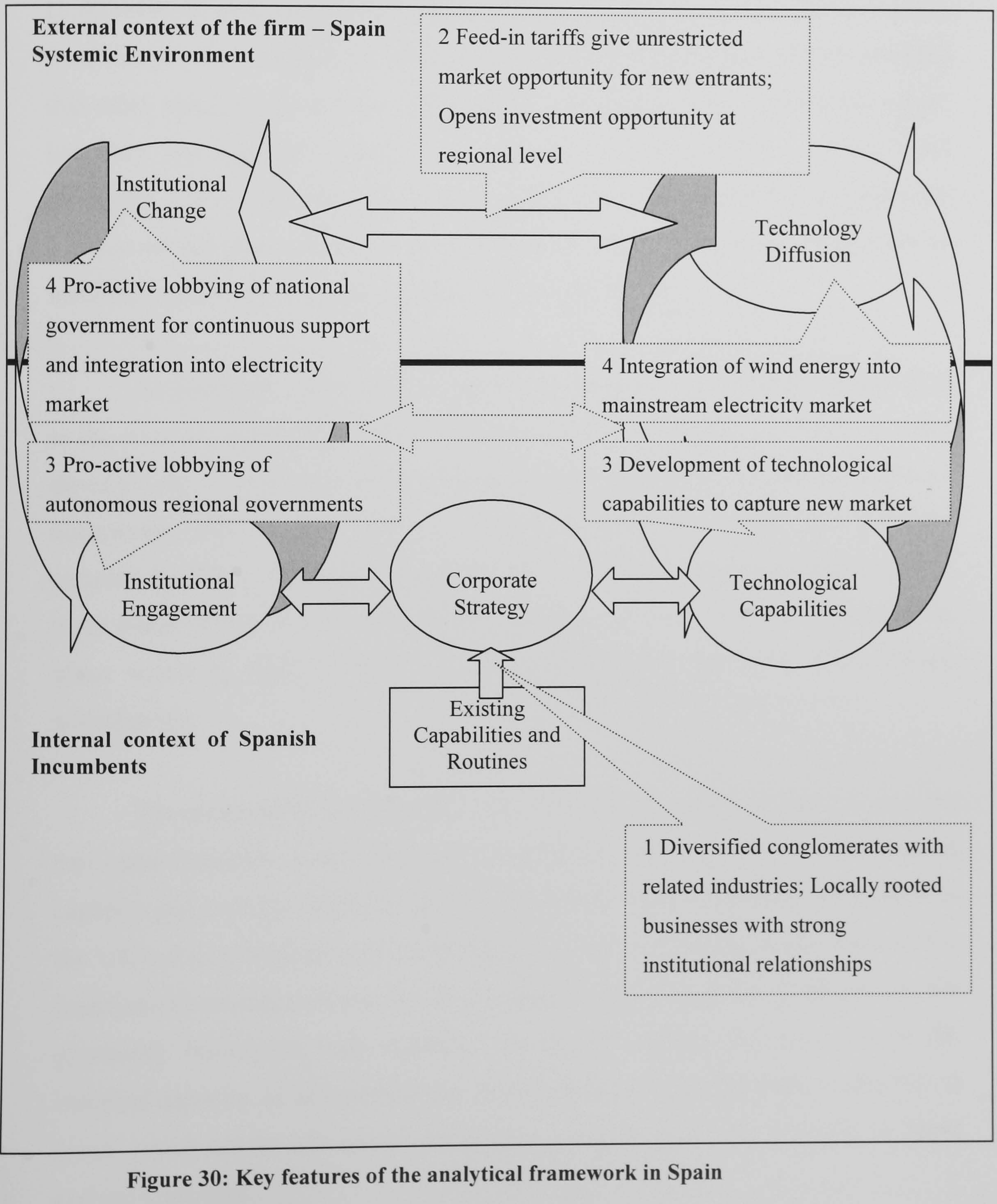


Figure 30: Key features of the analytical framework in Spain

5.1.2. Similarities and Differences between the three Countries

The diffusion pattern in Germany and Spain is similar in terms of the wind capacity installed per capita, although the share of wind power in total electricity generation is still smaller in Germany than in Spain. Yet, with 18,000MW and 10,000MW of total installed capacity in 2005, the two countries are the leading wind developers in the world. Diffusion is driven by government subsidy schemes that offer similar institutional opportunities. Importantly, the institutional set-up has very low barriers to entry, guaranteeing grid connection to every wind developer and a fixed payment for every kWh of electricity produced during the lifetime of the plant. Furthermore, the feed-in tariffs provide no upper limit to installed capacity as long as profitable sites can be found.

An important difference emerges between Spain and Germany with regard to the strategic approaches of the incumbent utility companies. In Germany, wind development was driven almost entirely by new independent wind development companies, with German utilities barely operating 1% of the total installed capacity by 2005. Conversely, Spanish utility companies were involved in nearly three fifths (57%) of the total installed capacity in 2005 and posted investment plans worth at least €8.75bn for the coming years for their wind energy subsidiaries.

The main difference between the wind energy market in the UK and the two other countries is the low level of diffusion, both in terms of total installed capacity and on a per capita basis of wind power. The institutional environment in the UK led to a market outcome where more than four fifths of the wind power installations are today owned by the six large utility companies. Furthermore, the regulatory framework only mandates an annual increase of about 1% in the installed capacity of all renewables, thus limiting the development in the UK to levels which can be considered marginal in comparison to the situation in Spain and the Germany.

When comparing UK and Spain, it is apparent that incumbents have been active in both markets. However, the motivations for engaging in the market were markedly different in both instances. Given the market set-up in the UK, the technology never provided a fundamental threat to the core businesses of the incumbent utility companies. Throughout the NFFO-period, the regulatory framework conceived the renewable energy market as a niche activity, which is substantially different to the situation created by the feed-in laws in Germany and Spain. Furthermore, the framework favoured the existing development capabilities of large utilities in terms of absorbing financial and development risks. This led to a squeeze out of smaller independent development firms. In this context, the RO solidified a market structure dominated by the big utilities, engaging in activity compliant with the regulatory mandated growth rate for renewables. Government regulation did not reward companies for going beyond mere compliance and in the context of industry consolidation and the absence of a competitive threat from alternative wind developers, utilities did not actively engage in shaping a more favourable policy environment.

In contrast to the UK situation, Spanish utilities did not merely comply with but actively drove the development of the regulatory framework. Wind power development occurred in an environment of intense competition with several regional based independent developers. In lifting the initial government target for wind power and lobbying for the better integration of wind into the wholesale market, Spanish utilities worked proactively to overcome the most pertinent barriers to its diffusion. This process of co-evolution of firm capabilities and the institutional environment led to high-levels of diffusion in Spain, coupled with high levels of adoption at the utility company level.

Conversely, in the UK's case, diffusion remained subdued at the national level, albeit with high levels of activity among utilities in the remaining market. With lack of competition and regulatory pressure, no incentives existed to initiate such virtuous co-evolutionary cycles, as in the Spanish case. An indication of this different standing in the wind industry was the recent take-over of Scottish Power by Iberdrola, which was at least partly based on Iberdrola's strategic focus on

wind power in its expansion plans and hence its ability to integrate and expand the wind power arm of Scottish Power (Mulligan & Burnett 2006).

Lastly, in Germany, high levels of diffusion at the global level are coupled with marginal levels of adoption at the incumbent utility level. While the overall level of technology diffusion is high, this was almost exclusively driven by new entrants into the wind energy development field. However, the antagonistic relationship between independent wind power developers and the incumbent utility firms did not give either one of these groups the incentive to further integrate wind power into the wholesale market, thus stifling the development of advanced technical capabilities compared to the Spanish case.

In order to classify the developments in the three countries, a matrix is developed in Table 22, below, that shows the adaptation of companies with regard to their lobbying effort and their capability development to a change in policy. This builds on the analytical framework of Oliver and Holzinger (2008) to integrate the dynamic capabilities framework with the literature on corporate political activities. The goal of Oliver and Holzinger's (2008) paper was to explore how and why firms drive institutional change. They categorize the multitude of different corporate political activities along the dichotomy of "compliance vs. influence". Political *compliance* strategies are defined as firm-level actions undertaken in conformity with political requirements and expectations. Political *influence* strategies are firm-level actions undertaken for purposes of mobilizing support for the firm's interests.

Oliver and Holzinger's framework only provides a static viewpoint of trade-offs, however, and does not consider the evolution of strategy over time. Complementing this typology of corporate political strategies, another dimension is thus added in Table 22 that distinguishes between firms that adapt their internal resource base to develop new technological capabilities or not. Hence, building on the original typology and the added dimension of capability development, four types of firm responses can be identified: They can be defensive (external influence towards regulatory regime, but no internal development of capabilities), reactive (external compliance, no development of capabilities) anticipatory

(external compliance, internal development of capabilities), or proactive (external influence and internal development of capabilities).

Table 22: A categorization of firm responses with regard to internal development of capabilities and corporate political activities

		Corporate Political Activities	
		Influence	Compliance
Internal development of capabilities	Yes	Proactive	Anticipatory
	No	Defensive	Reactive

Based on this matrix, we can observe the co-evolutionary patterns of incumbent utilities' strategy and their systemic environment in the three case study countries. In the UK, utilities developed new technological capabilities in the wind power field. However, comparing the UK situation with Spanish and German developments, the absence of a competitive threat led the incumbent utilities to passively *comply* with government regulation, while not seeking to go beyond it or change it radically. As the UK institutional environment subdued independent developers, no alternative lobbying platform emerged that could have altered the policy landscape. Hence, capability development only followed a path from *reaction* to *anticipation* of policy.

Conversely, German utilities did not develop new technological capabilities in wind energy but focused their strategic resources on a sustained *defensive* campaign of corporate political activity to undermine the institutional basis of wind. Wind power development was almost entirely carried out by new entrants into the industry. These companies, furthermore supported by a domestic manufacturing base, formed the antithesis to the incumbents' institutional lobbying approach, organising their own activities to counter the incumbents' activities. As the institutional basis for the wind power boom solidified, utilities reverted back to the original position and belatedly started to develop their own

technological capabilities, especially in the emerging offshore wind sector, and attempted to work within the existing institutional framework.

Finally, in the Spanish case, we can observe early *pro-active* development of technical capabilities and institutional engagement among the incumbents, driving both technology diffusion and the regulatory framework for wind power integration. This created self-reinforcing feedback loops leading to *'virtuous cycles'* of high levels of wind power diffusion on the industry level and high adoption rates among utilities at the firm level. Table 23 below summarizes these developments.

Table 23: Incumbent utility responses to renewable energy in Spain, Germany and the UK.

		Corporate Political Activities	
		Influence	Compliance
Internal development of capabilities	Yes	Proactive ***Spain***	Anticipatory ***UK***
	No	Defensive ***Germany***	Reactive

5.2. Discussion – Co-evolution of Institutions, Technology and Organizations

In the three case-study countries considered, the corporate strategies of the incumbent utility companies co-evolved with the institutional environment and technological development. In this respect, the previous sections outlined the mechanism, through the alignment of corporate strategy with regard to technological capabilities and institutional engagement, in which organizations interact with their systemic environment. This section will now consider the broader implications for an analytical framework in which the three dimensions, 'organizations', 'institutions' and 'technology' are considered to co-evolve.

As argued in section 2.3.4 and 3.1.4, it is important for co-evolutionary research to establish mechanisms that link causally the different dimensions of the analytical framework. The previous sections have described in detail the co-evolutionary interaction between institutions and corporate strategy. Most noticeable was the fact that the introduction of an institutional niche to allow the market entry of renewable energy under protected conditions provided the catalyst for incumbents' engagement with wind power in all three countries – whether pro-actively or defensively. Hence, rather than the technological opportunity as such, the institutional space created provided the initial spark by *altering the selection criteria* of the electricity market to accommodate a new technology. To some extent, this is expected from the literature, which considers incumbents to be less able strategically to integrate new technologies, at least initially, in their existing portfolio (Tushman & Anderson 1986;Christensen 1997). Rather, in such complex and highly regulated industries as the electricity sector, the threats to existing businesses of incumbents will come from institutional pressures through government policy (Hughes 1987). Consequently, incumbent utilities are prone to respond faster to new institutional requirements on their businesses rather than to slow moving technological developments (Frankenberger 2006).

Beyond the initial role of policy as a catalyst, however, institutions and organizations exhibited divergent co-evolutionary pathways in the three countries considered. The altered selection criteria led companies to develop different capabilities and to engage with divergent corporate political strategies and objectives in the institutional process.

So far, the analysis has pointed to a co-evolutionary relationship of institutions and technologies, moderated by organizational engagement and adaptation. At this point, the co-evolutionary analysis can be extended to include technological development. As outlined in section 4.2.2, three aspects of wind technology development entered the present analysis: Supplier-demander relationships, wind development capabilities and the technical and commercial integration of wind power in existing power grids. The development of supplier-demander relationships with turbine suppliers exhibited few features to

distinguish the companies in the three countries. All companies engaged in a learning process to understand the requirements of turbine manufacturers and the most important aspects for the development of standard contracts in the industry.

In the area of wind farm development, the most important aspect proved to be an understanding and intimate knowledge of the regional and local context in which wind farms were planned. Here differences emerged between the countries, with Spanish and German developers being able to leverage their local involvement to enhance their subsequent strategic positioning. UK wind farms were long hampered by local and regional planning laws. Yet, the institutional framework also subdued the emergence of a local wind development industry, providing an additional explanation for the low diffusion rates in the UK.

In the area of technical and market integration of wind power, the juxtaposition of the Spanish and German case is especially instructive. Spanish utilities continuously lobbied for further integration of wind power into the mainstream electricity market. As the Spanish feed-in law provided a top-up premium on wholesale market prices, even non-utility wind investors were able to profit from a development path that integrated wind power into the wholesale market while guaranteeing a premium of the plant's lifetime. Furthermore, the Spanish government widened the institutional opportunity space to make investments in wind forecasting, monitoring and integration centres attractive by shaping the institutional environment to give specific incentives for companies to invest in market integration tools,. This not only allowed firms to run their wind farms more efficiently, but created an interface with the Spanish Pool Market that allowed for a more advanced technical and commercial integration with the conventional power system.

In contrast, the antagonistic development in Germany between the incumbent utilities, who owned and operated the grid, and the independent wind developers who were given priority grid access for their wind farms, led to a different pathway. While the German utility companies did invest in wind forecasting systems to integrate wind power, this was driven primarily by their remit as grid operators to provide high levels of network stability and minimise

outages. Hence, in the absence of any wind power developments by the incumbents, the rationale for developing wind forecasts was based solely on technical considerations. Simultaneously, independent wind developers were disconnected from the wholesale market through the feed-in law, which guaranteed a simple, stable income stream. Given the dominance of the incumbent utilities in the wholesale market, they had no incentive to move beyond this institutional niche as this would imply competing with the incumbents without the stability of the FIL. Hence, no positive feedback loop emerged in the German market for a more efficient technological and commercial integration of wind power, as neither side had an incentive to move beyond their entrenched position.

5.3. Policy implications of the analytical framework

Based on the evidence from the case studies and the co-evolutionary analysis, this section derives implications for renewable energy policy and policy-making. Differences in the diffusion patterns of wind power were explained by different patterns of co-evolutionary adaptation of incumbent utilities to different forms of systemic change. Specifically, this divergence is explained by differences in firms' strategies of coordinating their development of their technological capabilities and corporate political activities to shape the regulatory environment. Such dissimilar strategies were shown to lead to different dynamics in the interactions between firms and their systemic environment, which in turn resulted in different technology diffusion and adoption pathways

It was shown that it is possible for firms to drive regulatory change to fit their capability base. Yet, firms only started to invest in wind power when they were in a strategic position to reap the benefits from a changing regulatory and technological environment. It is these case where firms pro-actively shaped, rather than passively complied with, regulation that highlight the importance of coordinated internally and externally focused strategies of firms. Specifically, in the Spanish case, *virtuous cycles* of capability development and regulatory change

allowed utility firms to gain sustainable competitive advantages in the global wind power industry. Neither in the UK nor the German case, did firms encounter the supportive environment and develop the respective strategies to initiate such a virtuous cycle.

The existence of such virtuous cycles as in the Spanish case complements existing analytical approaches to the role of incumbent utilities in the transformation of energy systems. As argued in chapters 2 and 3, contributions in the systemic innovation literature (Johnson & Jacobsson 2003;Jacobsson & Bergek 2004;Tsoutsos & Stamboulis 2005;Jacobsson & Lauber 2006) see the role of incumbent utilities primarily in defending their established structural and functional position in the conventional electricity system, while hindering the introduction of renewable energy technologies. Certainly, the cases of Germany and the UK point to evidence of such behaviour. However, the Spanish case study highlights that incumbents can be drivers of transformations of the energy system both in terms of technological development and institutional adaptation. This underlines the need for an analytical framework that takes specific note of strategic firm action within changing systemic environments. Thus, complementing the systemic innovation approach, the analytical framework introduced in this thesis focuses specifically on the configuration of firms' strategies to develop technological capabilities and associated corporate political activities. Focusing on these components was central in explaining the differential outcome in the three case studies and especially the proactive role of the Spanish utilities in the development of the technical and regulatory environment for wind power.

Some implications for policy-making have already been reflected in the analysis so far. Importantly, policy change was the initial spark for wind power developments in all three case study countries, thus confirming the key role that policy plays in technology diffusion. Yet, policy as such was a necessary, but not a sufficient condition to ensure widespread wind power deployment and diffusion. Important differences emerged in policy design, and consequently in policy impact on the electricity system. The precise capability development of incumbent utilities was dependent on situational context and specific policy incentives.

Hence, this section aims to summarise the policy implications from the analysis above in two main points, discussed in the next two sub-sections.

5.3.1. Interaction of business and political strategies – Scope for co-opting incumbent companies

The case studies illustrated the influence that incumbent utilities can have on the diffusion pathways of new technologies. It is proposed that the first lesson to be drawn from the case studies is that when developing policies for new technologies, policy-makers need to take the capability base of firms into account. Policies are not created in a political vacuum and incumbents will react where their core business is affected, as they align their business and political strategies. However, whether they will engage pro-actively or re-actively depends on the degree to which they expect to benefit from future polices. Importantly, firms only started to invest when they were able to build dedicated strategies around investments into wind power, thus reaping the benefits from a changing regulatory and technological environment. Policy that provides for an environment in which companies can strategically position themselves and actively shape the future development path attracts a diverse set of actors, a process which fosters competition and innovation.

This point is furthermore underpinned by the path-dependent nature of co-evolutionary interactions. Initial differences in policy affected initial alignments of political and business strategies among the incumbents and thus impacted on the subsequent technology adoption and diffusion paths. Once firms had decided on their strategies, path-dependent developments led to positive as well as negative feedback loops. In the German case, incumbent utilities were entrenched in institutional skirmishes over the feed-in law long after its inception, while their Spanish counterparts were actively engaged in enhancing their domestic feed-in law further - a decade after its first introduction. Thus, the initial policy design had consequences beyond the immediate market creation as it shaped the strategic approach by the incumbent utilities. Better understanding the motivations for firms' involvement in the policy-making process could thus allow policy-makers

to avoid setting off re-active feedback loops that slow down new technology diffusion. This is furthermore supported by analysis in the political-science literature on the increasing-returns properties of institutions and the resultant implications for path-dependency (Pierson 2000).

In the UK, policy provided no strategic rationale for new market entry and long-term investment, thus subduing innovative activity. In the German case, incumbent utilities did not develop a wind energy capability base and thus developed no strategic rationale for investment. Yet, in the Spanish case, initial policy provided a strategic rationale for investment that led to virtuous cycles of capability development and regulatory evolution which allowed high levels of technology diffusion and market integration.

5.3.2. Conditions for creating virtuous cycles through Policy

Despite the limited scope of this study, it is still possible to flesh out some of the pillars for an innovation policy that co-opts incumbent utilities. Most importantly, despite the concerns above for understanding firms' strategic position, this is not to argue that policy-makers should simply adhere to the wish-list of incumbent utilities. Building on the comparison of the three case study countries, two important features are highlighted which appear necessary (though probably not sufficient) ingredients for creating virtuous cycles as in the Spanish case.

At the outset, policy-makers need to remember that renewable energy markets are government induced and investors want to avoid being trapped with investments in markets that change with the political weather, a case of 'moral hazard' and 'time inconsistency' of policy making (Helm, Hepburn, & Mash 2003;Neuhoff 2005;Neuhoff & Sellers 2006). Hence, policy needs to create a market framework that provides both a long-term, stable investment horizon and low entry barriers for new market entrants, as well as an exit strategy that prevents

over-compensation for mature or unsuccessful technologies (Stenzel, Foxon, & Gross 2003).

Low entry barriers allow for a diverse industry population to induce competition and innovation in the emergent industry while keeping potential inertia by incumbents in check. Yet, because new entrants will only come forward if companies can build a clear strategy around their investments, policy needs to provide a sufficiently long-term and stable investment horizon. This is all the more important in the electricity industry where structural barriers to entry lie beyond the immediate business of developing wind farms (European Commission 2007).

In the UK, the erratic and limited policy design of the NFFO did not provide the institutional foundations on which new entrants could have built a sustainable long-term business strategy. Consequently, incumbents quickly dominated the industry and were able to squeeze out their independent competitors, even though wind power in itself remained a small fraction of their overall business. Even under the RO, barriers to entry remained as small-scale developers face disproportional transaction costs to benefit from the policy and incumbent utilities present the only counterparty for the sale of ROCs.

In Germany, independent wind developers were able to enter the emergent wind energy market on a wide scale due to the low entry barriers and stable institutional framework. Consequently, they developed the institutional clout to preserve the policy foundations of the high wind diffusion rates in the face of pressure from the incumbent utilities. In Spain, incumbent utilities competed directly with new entrants into the market for the best sites, thus creating a sustained boom in wind installations while simultaneously fostering pro-active institutional engagement to enhance the institutional pillars of the boom.

5.3.3. Implications for renewable energy policy making

Having outlined the policy implications above, this section will now examine what lessons can be drawn for EU energy policy. As highlighted in section 5.2., policy was the major institutional driver for investments into renewables in the three countries studied. Yet, detailed policy formulation remained within the domain and context of national energy policy. However, during the recent German (July 2007 – December 2007), Slovenian (January 2008 – June 2008) and French (July 2008 – present) presidencies of the EU council, a concern for a common EU energy and climate policy remained on the top of each presidencies' work agenda (See "Europe – succeeding together" - German Presidency Programme; "Si.nergy for Europe" – Slovenian Presidency Programme; "Europe taking action to meet today's challenges" – French Presidency Programme).

This section will discuss three issues which follow from the case studies presented in this thesis: EU competition policy, a common EU renewable energy policy and a common EU electricity market. Each of these three issues follows from the analysis of the co-evolutionary development in the three case studies and is considered to be inextricably linked to the other two.

With regard to competition policy, both the UK and German case study showed elements of how developments in the area of competition policy can also have an effect on renewable energy technology diffusion. In the UK, the introduction of the NFFO followed pressure from the EU Competition directorate as the initial policy proposal was conceived to benefit exclusively the nuclear power industry.

In the case of the German feed-in law, a clearly defined institutional niche with guaranteed grid connection and remuneration rules shielded new technology diffusion from defensive political activity by the incumbents. The German feed-in tariff was challenged by incumbent utilities on the grounds of alleged breaches of

EU competition policy. However, the EU Courts of Justice ruled in favour of the feed-in law arguing that no discrimination was applied between different competitors and that priority access to the grid for renewable energy was justified on competitive as well as environmental grounds under EU rules (Jacobsson & Lauber 2006). Here, from an EU perspective, it can be argued that pro-active competition policy is an important complement to specific technology-support policies.

A further element from the German case epitomizes the inter-linked nature of EU competition policy and the drive towards a common EU electricity market and renewable energy policy. This is the question of ownership and operation of the member states' electricity grids. In Germany, the utilities own and operate the transmission system, while in the Spanish and British case this is the remit of an independent national operator. Hence, the German utilities directly controlled access to the grid vis-à-vis third parties in the absence of a regulatory authority, which was only introduced in 2005 (Glachant, Dubois, & Perez 2003).

This question applies on two different levels. Firstly, it is a question of direct grid access for third-party electricity providers, and secondly, it is a question of arrangements for balancing electricity supply from intermittent sources and the incentives embedded within such institutional arrangements.

Section 4.4.1 already noted that few new entrants were successful in the German wholesale electricity market (as opposed to the emerging wind market), both in the electricity generation and supply segment. This has been attributed by several authors to the market dominance of the utility companies (Bower, Bunn, & Wattendrup 2001;Glachant, Dubois, & Perez 2003;Brunekreeft & Twelemann 2005). Where utilities operated their own electricity generating stations as well as the electricity grids, incentives exist to charge competitors arbitrarily high transmission charges and/or "game" the short- and long-term power markets to disadvantage competitors (Newbery & McDaniel 2003). In this context, it could be argued that specific measures to guarantee grid access for renewable energy, at least for a certain period of time, is acceptable in order to circumvent the market power of incumbents and signal the introduction of competition in this field.

A further aspect to this argument is the question of the optimal balancing of electricity grids with increasing amounts of intermittent generation sources such as wind. In previous work, it was highlighted that adding large amounts of wind power to the electricity grid entails additional costs and risks for the operation of the transmission system (IEA 2005e;Stenzel & Gul 2006). However, balancing of grids can be optimized the more and deeper grids are interconnected. The larger the balancing area, the more technologies are dispersed and the more flexible operators can react to specific balancing problems.

While this thesis did not investigate explicitly any direct link between the ownership structure of the transmission system and the strategic approach to wind energy, it can be speculated whether the defensive strategies of the German utilities (as opposed to the Spanish and UK utilities) were motivated in part by their ownership of and control over the transmission infrastructure. In IEA (2005), it is noted that the German balancing system quoted the highest costs for integrating wind power relative to its international peers and that it was estimated that costs could be cut by up to 80% if the four current balancing zones (each operated by one of the four incumbent utilities) were combined into one and the rules made more transparent.

In this context, two lines of arguments could be taken. Firstly, it is noted that German utilities were required by law to accept all electricity from renewable sources and provide the necessary balancing services. The costs of these balancing services were allowed to be passed on to the consumer through the transmission tariff. However, the rules for the operation of the balancing market did not come under regulatory scrutiny before the establishment of the German grid agency in 2005. Hence, in the period 1990 – 2000 the utilities were able to quote high costs of balancing intermittent wind power as an argument in their corporate political activities (and as a reason to refuse new connections – see Windpower Monthly 1997), while simultaneously profiting from the charges they could pass on to consumers. In this way, they were able to profit from the wind power boom in Germany, without actually having to build any capacities on their own.

However, while this argument mirrors developments in the early period of wind power development in Germany, it only takes into account a short-term view of policy development. Once the installed wind power base achieved a critical mass, it would increasingly displace the utilities' own conventional generation base. Furthermore, with the hardening of the institutional environment, such a strategy would run into diminishing returns, as the balancing regimes come under closer scrutiny and the losses from curtailing own generation outweigh the gains from transmission charges. This would consequently be reflective of the second phase of German wind power development following the period from about 1999 to today.

In summary, if incumbents' strategies were indeed motivated in part by their ability to strategically lever their existing asset base, the ownership structure of the transmission system would become a key determinant of the incumbents' reaction to the introduction of renewable energy. This would imply that the inertia of an existing energy system is in part governed by its ownership structure and the institutional rules over grid access and balancing costs, i.e. the distribution of risks and costs and benefits with respect to the diffusion of new technologies. The European Commission has recently concluded that the unbundling of generation and transmission assets is an important step toward a common European energy market (EU COM(2007) 1). In the EU Commissions proposal, two options are considered. Either, this could be achieved through an independent system operator, leaving incumbents as the owner of the assets but not responsible for their operation maintenance or development. This could incrementally include common trans-boundary operation of transmission systems in the EU. The alternative option would be a full ownership unbundling, as has already been achieved in the UK and Spain among other EU member countries.

Previous arguments over the efficiency and efficacy of different policy instruments (e.g. feed-in tariffs vs quota-based instruments) have often centred on abstract questions of market design and efficiency under rational behaviour (Meyer 2003). However, they have not yet addressed the question of their impact on incumbent utilities in imperfectly regulated markets. Given the incumbent

utilities' still powerful position in many markets, this question becomes an important factor in the deployment of renewable technologies.

As this thesis outlined, feed-in tariffs can, under certain conditions, create a strategic market opportunity large-enough to be of interest for incumbent utility companies and new entrants alike. Feed-in tariff rules with regard to remuneration and grid access can circumvent issues of market power and restriction of competition when simultaneously providing utility companies the same investment rights and benefits as new entrants. In this way, feed-in tariffs can be considered a transitory policy instrument that creates competition both between new and established technologies and companies alike.

Currently, there are 16 EU countries with some form of domestic feed-in tariff, varying in their details by level of remuneration, lengths of contracts and technologies covered (Reiche 2005). A first step could be to harmonise those feed-in tariffs, possibly adjusting by renewable resource availability and historic levels of penetration. In its latest draft for a new Directive on Renewable Energy (2008/0016 (COD)), the EU focuses on individual country targets and guarantees of origins but remains flexible with regard to specific policies that individual countries implement to meet their targets. Nevertheless, the clear policy signal given by the EU's 20% renewable energy target by 2020 could lead to changes in incumbents' strategies towards investments in renewables, provided that these are integrated into national energy policies in a clear and credible way.

An initiative by the 16 countries with feed-in tariffs could set a precedent for others to follow. Already, Germany, Spain and Slovenia have created a "feed-in co-operation" to lobby for the expansion of feed-in tariffs at the European level and have proposed a model for cost-sharing among all EU member states (Ragwitz, Resch, & Klessmann 2008). This could consequently put pressure on the other EU countries to join this group of countries, especially on those countries that are currently lagging behind on their targets, such as the UK.

Utilising the framework presented in this thesis underpins arguments for the introduction of a carefully designed European-wide feed-in tariff system, both

as a measure to promote the diffusion of renewables and to spur the drive towards a common EU energy market. Furthermore, it could become an important complement to competition policy, which is mainly concerned with specific cases of market abuse and structural market power *per se*.

5.4. Summary

This chapter has evaluated the research presented in chapter 4 in the light of research aim 3 of this thesis. It sought to answer two main objectives:

- To identify common patterns among the leading and lagging countries and to analyse the main factors that led to the adoption of pro-active strategies among incumbent utilities.
- To specifically examine the role of government policy and its success in contributing to pro-active incumbents' behaviour.

With regard to the first objective, it was noted that the co-evolutionary development in each country followed a unique pathway. Hence, although both Germany and Spain have the highest wind energy diffusion rates worldwide, the development of their wind industry took very different routes. Furthermore, even when considering the relatively high participation rates of incumbent utilities in Spain and the UK, they were the result of different motivations and rationales in the two countries. Thus, no overall commonality among the diffusion patterns emerged.

Yet, it is possible to draw some general conclusions about some of the key factors that led to the adoption of pro-active strategies among the incumbent utilities. Section 5.1 outlined the co-evolutionary mechanism that led to the differential outcome in technology adoption and diffusion in the three countries studied. Companies responded to initial renewable energy policy frameworks with strategic re-alignments of their internal capabilities and approach to institutional engagement. Consequently, different corporate strategies emerged among the

companies to engage with the new wind energy market, which subsequently led to the different development paths in each country.

With respect to the second objective, it was noted that in all three countries, policy provided the initial spark for companies to consider renewable energy technologies. Consequently, policy-makers should take the interaction between companies and their systemic environment into account when designing policy. Companies will react if their core business areas are affected. Whether they engage pro-actively or defensively, however, depends on the precise institutional environment and the degree to which they can strategically position themselves in a new technology niche. Policy design with low entry barriers for potential new entrants into the industry as well as a long-term policy horizon to provide a strategic horizon both for incumbents and new entrants was successful in fostering both competition from new entrants as well as pro-active policy engagement by the incumbents. Hence, it is argued that carefully designed feed-in tariffs would provide a positive input into the current debate on the harmonization of EU energy policy in fostering renewable energy deployment as well as supporting the move towards a common EU electricity market.

6. Reflections on understanding co-evolutionary dynamics using the analytical framework

This chapter aims to broaden the analysis from the previous chapter and, in addressing the final aim of this thesis, *discuss the extent to which the analytical framework deployed in this research complements and extends existing approaches in the 'systemic innovation' literature.*

It is argued in this chapter, that the main strength of the analytical framework was the ability to account for context specific factors that influenced decision-making both on the company as well as the policy level. Section 6.1 will discuss the different *foci* of the analytical framework in each country and show how the analysis was able to extend existing understanding of the co-evolutionary pathways. Subsequently, section 6.2 extends this analysis to consider the contribution of the analytical framework to the systemic innovation literature. Here, it is argued that the analytical framework connects well with existing theoretical approaches to innovation in the literature and addresses methodological concern about demonstrating the causal linkage between two interacting variables in co-evolutionary research. Hence, for example, it widens the understanding of 'functions' in technological innovation systems by considering not just whether a function is working at the systemic level but also why (or why not) it is functioning well.

6.1. Explaining co-evolutionary dynamics in the three case study countries

The central tenet of the analytical framework was the interrelationship between developments at the company level with developments at the systems' level. At the company-level, it was proposed that corporate strategy could usefully

be conceptualised to analyse the companies' interaction with its systemic environment. Here, the framework proposed two different avenues to analyse this interrelationship: Firstly, through the interaction of corporate political activity (CPA) with the wider institutional environment, and secondly, through the companies' development of technological capabilities and their wider impact on technology diffusion in the market place.

The three countries exhibited examples of these relationships at different levels and different degrees of complexity. Hence, the focus of the analytical framework was adapted to the particular technology transition trajectory and company-specific context in each country. Indeed, it is argued that one of the main benefits of applying the analytical framework used in this thesis is the ability to consider specific institutional and organizational contexts and consequently to emphasize the different impact of these variables in individual countries.

One of the key findings that came out of the UK case study was the lack of strategic market opportunity when incumbent utilities had to consider whether to invest further in their emerging wind energy niche businesses in the mid-1990s. While this fact on its own would not have been pivotal for the wider diffusion of wind power, if a wider market opportunity for new entrants were in place, it proved to be an important bottleneck for the wider development of wind power in the UK. Lack of strategic market opportunity for new entrants, coupled with incoherent and erratic renewables policy and a lack of alternative lobbying networks led to a subdued UK wind industry that was growing at a speed far below its theoretical economic potential. Using the analytical framework to focus on the interaction of company strategy formulation and the wider systemic environment provided a more detailed picture of the causal relationships that stifled the diffusion of wind power in the UK.

Conversely, in the German case, the main focus was on the repeated attempts by the German incumbent utilities' to use corporate political activity to limit the institutional niche for wind power. In this case, using the analytical framework allowed exploring the reasons behind this reactive stance in the first

place, and subsequently why it was ultimately not successful to limit the diffusion of wind power at the national level.

Finally, the Spanish case study offered an insight into how incumbent utilities can be co-opted into the process of developing renewable energy. Importantly, in this case, the incumbent utilities actively lobbied for improvements to the renewables policy, once wind power became a strategic business activity for the companies. Hence, using the analytical framework, it was possible in this case to trace the sources of the positive feedback loops that drove continuous innovation and through policy adaptation and company investments to make Spain the second largest wind power market in the world with equal shares of installations among incumbents and new entrants.

6.2. Contribution of the analytical framework to research on innovation and transitions and its applicability in further research

The theoretical basis for the analytical framework is rooted in an evolutionary economic theory and its application in the domains of technology and corporate strategy. These approaches allow for an understanding of strategy and technology development that is based on bounded rationality, reflexive learning and experimentation. Yet, these notions are all rooted in practices that occur as much at the level of the firm or even the individual, rather than just at the level of the system.

Hence, this thesis extended existing systemic innovation frameworks by integrating a firm-level analysis of strategic alignment of internal capabilities and political strategies with wider systemic developments. In this way, it has been embracing a wider family of co-evolutionary approaches to the analysis of technological change (Nelson 1998;Geels 2002;Murmann 2003).

The focus on individual agency in co-evolutionary contexts has recently received more attention. As discussed in chapter 2.3.3, systemic innovation approaches were criticised for suffering from "institutional determinism" and a lack of explanation for the "actions of the entrepreneur" (Hekkert et al. 2006), while Smith et al. (2005:1492) objected to the "...tendency to treat regime transformation as a monolithic process dominated by rational action and neglecting important differences in context".

Murmann (2003:23) argued that it is central for co-evolutionary research to establish "the bidirectional causality linking the two parties in the relationship... The key challenge for such arguments is to establish that causal processes indeed do connect the two partners in a co-evolutionary relationship."

In linking corporate strategy to wider co-evolutionary developments, this thesis provides a novel theoretical contribution that complements existing analyses in the literature. For example, Jacobsson and Lauber (2006) use a systemic innovation framework to trace the renewable energy diffusion path in Germany. Yet, they do not provide a firm-level explanation for the incumbents' obstructive behaviour, instead using structural explanations such as their dominant position in the electricity system. As argued throughout this thesis, generalising on the basis of a company's structural position in an innovation system neglects important differences in context, as evidenced by the differential technology adoption paths in Germany and Spain. Hence, Jacobsson and Lauber's (2006) analysis does not extend to the field of differential corporate strategy. Thus, for example, it would fail to address the recent strategic change among German incumbent utilities towards renewable energy, in the way that this thesis has tried to do. As argued in section 5.1 and 5.3, where new technologies acquire strategic importance for an incumbent company, these companies can adapt their strategies towards a more pro-active and supportive approach.

A second contribution of this thesis in relation to the work by Jacobsson et al. are policy recommendations that can be made on the basis of systemic innovation research (Jacobsson & Bergek 2004). In the innovation systems approach, recent research has focused on functions that technological innovation

systems (TIS) need to fulfil in order for new technologies to be self-sustaining in the market place.

As outlined in chapter 2.3.2, functions are used as a benchmark to assess the performance of TIS. Where functions are well-developed, firms have sufficient resources to invest in new technologies and are well-connected, which aids the development and diffusion of innovations into broader markets. Where functions are not developed, specific policies and measures can be targeted to overcoming potential obstacles (Jacobsson and Bergek 2004).

Yet, Jacobsson and Bergek (2004:819) acknowledge that "...there is no reason to expect a particular system structure to be related to the performance of a technological system in a clear and unambiguous way." However, in their analysis, incumbent utility companies are unambiguously seen as blocking the formation of functions in a renewable energy innovation system. Here, as argued in chapter 2.3, insufficient attention is paid to the heterogeneity of approaches within the same structural class of actors, in this case incumbent utility companies.

The analytical framework used in this thesis aimed to consider the specific context in which firms set their strategy, linking the firms' external environment to firm-level decision-making processes and the resultant feedback to the wider environment. Hence, the cases from Germany and Spain show how wind energy developed with widely different approaches to technological and institutional engagement by the incumbent utility companies. Although in both countries new market entrants played an important role in wind power diffusion, electric utilities were much more closely engaged in Spain than in Germany.

Consequently, the integration of a strategic dimension into co-evolutionary analysis provides an important qualification of the functional view. While recent contributions in the literature have focused on finding proxy variables for the measurement of functions (Negro, Hekkert, & Smits 2007), it is contended here that note should also be taken of the *motivations* for actors to perform certain functions. As an illustration, two functions are considered in the context of the

German and Spanish case studies: (1) Supply of resources and (2) creation of markets (Jacobsson and Bergek 2004).

In the German case, incumbent utilities did not start to invest significant resources in the wind energy field until about the year 2000. Furthermore, their lobbying approach used various routes to obstruct the market creation for this new technology. Thus, in the absence of investment activity by incumbent utilities, small-scale investors were able to develop the emerging market based on the resources provided through government-subsidised mutual funds, grants and the feed-in law. In consequence, knowledge and market creation was distributed among many small-scale development and engineering companies. However, the antagonistic discussion over the feed-in law in Germany and the increasing market dominance of the incumbent utility companies in the conventional electricity market meant that knowledge creation never extended into the market integration of wind energy and the associated capabilities this would require.

In Spain, both functions were addressed by the incumbent utility companies at various levels, complementing the activity of the new entrants in the wind industry. While activity was still distributed over a variety of actors, incumbent utilities were one of the main drivers for the provision of resources for investments as well as knowledge creation in the industry. Moreover, Iberdrola was a central driving force for the market integration of wind energy and helped to open up the institutional and technological space in this direction.

Consequently, it is argued here that integrating a strategy-perspective on the development of a system's functions could provide a complementary and deeper analysis of their (mal-)performance. Complementing existing approaches to functional analysis, it would allow policy-makers to obtain a more precise picture of the present state of a system's evolution and the potential requirements for policy intervention. Functions of innovation systems arise out of the specific strategies chosen by individual actors. These, in turn, arise out of the specific context in which individual actors have to operate in. Hence, it could be argued that they are higher-level aggregations of individual actions and thus emergent properties of an innovation system. Cataloguing proxy variables for individual

functions to assess their performance (as for example in Hekkert et al. (2006)) is a useful tool to identify weaknesses in a technology's development. However, it is contended here that a strategic analysis as developed in this thesis would allow the development of a better understanding of *why* weaknesses occur and what might be the motivations of individual actors to refrain from contributing to a particular function.

As outlined in section 2.3.3, it was argued that methodologically, co-evolutionary research needed to demonstrate the precise causal mechanisms that link two *co*-evolving populations. Integrating strategy analysis into systemic research provided a micro-level explanation for the organizational adaptation of the utilities in the three countries studied. Methodologically, this is important as it allows the researcher to identify the underlying rationale for differential individual agency among companies. This consequently allows the separation of what is labelled by Murmann (2003) as 'sequential adaptation' and 'causally linked co-evolutionary processes'. Taking both aspects together, the analytical framework developed in this research could thus be employed to develop deeper arguments about the nature of co-evolutionary processes by identifying differential causal mechanisms underpinning the observed development pathways.

An important methodological consideration for such research has been a deep understanding of the field of study on the part of the researchers involved and especially a close analysis of the individual actors and the particular contexts in which they operate. For the research presented in this thesis, three countries, thirteen companies and almost twenty years of development have been analysed. Yet, co-evolutionary arguments, by their very nature, are based on the established routines and networks in the respective institutional frameworks of each country. Consequently, historical analyses, identifying established approaches among individual companies and networks in the institutional and technological sphere, are necessary pre-conditions to build arguments relating individual company strategies to systemic developments.

As already highlighted in section 5.3, extending systemic innovation research with a detailed analysis of corporate strategy also aids the development

of policy-relevant arguments. By specifically considering the range of strategies available to companies in response to policy proposals, such a research approach acknowledges explicitly the interaction between companies and their policy environment. This addresses existing criticisms, as outlined in section 2.3.3, that systemic innovation research often assumes policy-making to occur in a 'vacuum' without company intervention (Smith et al. 2005). Secondly, it allows a better understanding of the impact of policies on individual companies as well as on the shape of an entire industry. This could offer policy-makers a better understanding of the competitive implications of new policies and their effect on the co-evolutionary pathways of new technologies.

Beyond the application in the energy industry, it is contended that the analytical framework could be used in other industry contexts as well. Corporate strategy, as conceptualised in this thesis, is especially fruitful in complementing co-evolutionary analysis in highly regulated industries. The importance of formal market rules for the electricity industry's business model made their inclusion particularly relevant to this study. Yet, in industries with less stringent regulatory requirements, it might be appropriate to widen the definition of 'institutions' to include less formal institutions such as patent laws, university and education systems or the nature of contractual relationships when analysing specific strategies (Alston, Eggertsson, & North 1996) and to consider corporate strategy with regard to these dimensions.

6.3. Summary

This chapter argued that the main advantage of the analytical framework was its integrated analysis of changes at the company level and the institutional and technological level. This allowed a context-specific analysis of the factors leading to the technology paths in each country. Consequently, it was argued that the analytical framework could more generally be used to enhance the understanding of individual agency vis-à-vis systemic changes. This argument has two dimensions: Firstly, it addresses existing criticisms of systems approaches that have focused primarily on structural and functional arguments to explain

actions of individual companies. Rather, strategy analysis as presented in this thesis allows a better understanding of the rationale behind differential individual agency. For example, it extends the understanding of 'functions' in the technological innovation system literature by providing a firm-level explanation of why individual functions might be supported or obstructed by incumbent companies. This secondly echoes methodological concerns about the arguments that are advanced to describe co-evolutionary developments. By providing a detailed link between activities at the company level and at the systemic level, this thesis has advanced a methodology to open up the black box of co-evolutionary change and to analyse in more detail its key contributing factors.

7. Conclusion

This thesis has sought to analyse the role of incumbent electric utility companies in the diffusion of renewable energy technologies. It had two overarching research questions: *What are the main factors influencing incumbent companies' strategy when changes occur at the systemic level in the electricity industry? To what extent do corporate strategy and the electricity system interact and influence each others' evolution?*

This chapter will draw together the main results from the research and reflect on how they contributed to addressing these two questions. Consequently, it will discuss both the strengths of and the limits to the present research and will suggest areas where further research is needed.

It has been argued throughout this thesis that existing approaches to the study of technological change are insufficient on their own to obtain a comprehensive understanding of the role of incumbent utility companies in the diffusion of new RETs. In the literature review in chapter 2, two separate approaches to the role of incumbents in the diffusion of RETs were critically examined. In this respect, it is important to notice that not only do the strategic-management and the systemic-innovation literature provide different frameworks, they also ask different questions.

The strategic-management literature is primarily concerned with the short-run positioning of companies, inquiring about the sources of competitive advantage and the nature of organizational strategic change. In contrast, systemic innovation studies take a longer-term view and inquire about the interrelationship of several dimensions of a socio-economic system whose evolution can be sketched over time to trace the co-evolutionary pathways of technological change. As has been argued in section 2.3.3, in this bigger picture there is often less explanatory power for the individual agency of firms that develop varying strategies in the face of a changing systemic landscape (Geels 2002).

Yet, sections 2.2.1, 2.2.2 and 2.3.1 outlined how the theoretical foundations of parts of the strategic-management literature and systemic innovation frameworks are interrelated. Arguments about the boundedly-rational firm environment, the context-specific transmission of tacit knowledge and the establishments of firm routines recur in both literatures and hence provided a starting-point for establishing a novel analytical framework, the first aim of this thesis, that combines both an explicit analysis of individual agency, as well as the linkage of individual companies' actions into system-wide changes. This in turn provided the basis for answering the set of questions for the specific research angle adopted in this thesis, in inquiring about a company-level explanation for the different adoption strategies of one group of organizations, incumbent utility companies, in the face of system-wide change in the electricity industry through the introduction of RETs.

Positioned within the literature on co-evolutionary research, the aim of this thesis was to develop an analytical framework that was both dynamic and interactive, thus allowing the researcher to trace technology diffusion pathways over time and in the context of differential evolutionary adaptations among companies. In developing the analytical framework, this sought to address two important critiques of co-evolutionary and systemic research approaches that were also highlighted in section 2.3.3. Firstly, by integrating corporate strategy into a systemic framework, it provided an explicit model of individual agency vis-à-vis systemic change, going beyond structural and functional explanations of company behaviour that is found in some of the existing literature (Smith, Stirling, & Berkhout 2005). Secondly, by tracing the adaptation of corporate strategy to changes at the systems level, it outlined in detail a causal mechanism that links co-evolutionary feedback between the different dimensions of organizations, institutions and technology. This addresses methodological criticisms of the level of analytical detail co-evolutionary studies provide in their arguments about precise co-evolutionary links (Murmann 2003).

Having established a novel analytical framework in chapter 3, the second aim of this thesis was to utilize this framework in a concrete research setting and

to generate novel empirical and theoretical insights. Chapter 4 discusses in detail the three case studies in the UK, Germany and Spain and consequently highlights the different RET adoption strategies among the utilities in the three countries. As outlined in the introduction in chapter 1, this thesis was motivated both by the desire to develop a theoretically richer framework for analysing renewable energy diffusion, as well as contributing to the ongoing policy debate in this area. Consequently, aims 3 and 4 sought to explore the novel findings that this thesis contributes to the theoretical and empirical debate around renewable energy technology diffusion.

Main findings

Chapter 5 outlines in detail the co-evolutionary argument derived from the application of the analytical framework in the three case studies. Using the matrix established in table 22 in section 5.1, different adoption strategies among the utilities in the three countries were identified. Spanish utilities were shown to have *proactively* driven the development of their regulatory framework to overcome the most pertinent barriers to wind power diffusion. Hence, the co-evolution of firm capabilities, technology and the institutional environment led to high-levels of diffusion in Spain, coupled with high levels of adoption at the utility company level. This continuous co-evolution of firm capabilities and the institutional environment was labelled as a "virtuous cycle". Conversely, in the case of the UK, diffusion of wind power remained subdued at the national level, albeit with high levels of activity among utilities in the residual market. Lack of competition and regulatory pressure led utilities merely to *comply* with regulation without initiating virtuous cycles as in the Spanish case. Lastly, in Germany, high levels of diffusion at the global level are coupled with marginal levels of adoption among the utilities. Initially, German utilities did not develop technological capabilities and used *defensive* CPAs, such as legal, political and regulatory instruments to limit the diffusion of wind power. However, none of them proved ultimately successful and the German utilities eventually changed their stance once the institutional environment solidified and technological developments opened new niches in the field of offshore wind.

The differences in the diffusion patterns of wind power generation in the three markets are explained by different co-evolutionary patterns of regulation, technology and respective strategic company responses. Specifically, this divergence is explained by differences in firms' strategies to coordinate development of technological capabilities and corporate political activities to shape their regulatory environment. Such dissimilar strategies were shown to lead to different dynamics in the interactions between firms and their institutional and technological environment that consequently result in different co-evolutionary development pathways and thus in different patterns of adoption and implementation of wind power.

An important finding was that in all three countries regulatory change provided the initial stimulus for investments into wind power. However, the subsequent reaction of the utilities and their strategic adaptation to the regulatory environment exhibited divergent patterns, with the pro-active activity of the Spanish utilities contrasting with actions by the German utilities to defend their *status quo*. This highlights the importance of coordinated strategies of firms in terms of their corporate political activities (CPA) and associated development of technological capabilities, as witnessed in the Spanish wind power market. Virtuous cycles of the development of firm capabilities and regulatory change led the Spanish utilities to become mayor players in the global wind power industry. Neither in the UK nor the German case, did firms encounter the supportive environment and develop the respective strategy to initiate and reinforce such a virtuous cycle.

It is argued, that the existence of such virtuous cycles as in the Spanish case support the argument for utilizing analytical approaches that focus on individual agency when exploring the role of incumbent utilities in the transformation of energy systems. Contributions in the innovation systems literature (Jacobsson and Bergek, 2004; Jacobsson and Lauber, 2006;Johnson and Jacobsson, 2003; Tsoutsos and Stamboulis, 2005) see the role of incumbent utilities primarily in defending the established electricity industry structure and hindering the introduction of renewable energy technologies. While, the cases of

Germany and the UK do give examples of such behaviour, the Spanish case study highlights that incumbents can drive transformations of the energy system both in terms of technological development and regulatory adaptation. This underlines the need for analytical frameworks that take specific note of strategic firm action within changing regulatory and technological environments.

Complementing the innovation systems approach, this thesis introduced an analytical framework that focuses specifically on the configuration of firms' resource bases and the resultant corporate political activities. Focusing on these components was central in explaining the differential outcome in the three case studies and especially the proactive role of the Spanish utilities in the development of the technical and regulatory environment for wind power. This underlines the complementarity of utilizing a research framework that combines the analysis of both the company strategy level with the evolution of the systems level. Each on its own would not have been sufficient to explain the observed changes, while together they allow the researcher to trace in detail the co-evolutionary pathway of development.

Implications for policy-making

Having highlighted the merits of introducing the focus on firm activities for the transformation of energy systems, three lessons for policy-making were drawn from the case studies and presented in chapter 5.3. Firstly, when developing policies for new technologies, the capability base of firms needs to be taken into account. Policies are not created in a political vacuum and incumbents will react where their core business is affected, as they align their business and political strategies. Whether they will engage re-actively or pro-actively, however, depends on the degree to which they can benefit from future polices. As evidenced in the Spanish case, co-opting incumbents into the policy process can lead to virtuous circles of technology diffusion and capability development. However, further research is needed to understand the conditions in which such virtuous circles can emerge.

Secondly, there is a need to understand policy-making as a process that will have firm involvement whether desired or not. As the case studies showed, co-evolutionary processes will occur between firms, their technological strategies and their regulatory environment. Once firms have decided their strategy, path-dependent developments can lead to positive as well as negative feedback loops. Thus, the initial policy design has consequences beyond the immediate market impact which shape the market approach by the incumbent utilities and their reaction. Thus, understanding the motivations that drive firms' involvement in the policy-making process potentially allows policy-makers to avoid setting off defensive political activities by firms that can slow down new technology diffusion. This is not to say, however, that policy-makers should simply adhere to the wish-list of incumbent utilities.

Finally, policies need to provide both a long-term, stable investment horizon and low barriers for new market entrants to induce competition in an emergent industry. Policy-makers need to appreciate that because renewable energy markets are to a considerable extent government induced, investors worry about being stranded with investments in markets that change with the political weather, a case of 'moral hazard' and 'time inconsistency' of policy making (Helm, Hepburn, & Mash 2003;Neuhoff 2005;Neuhoff & Sellers 2006). Hence, providing low entry barriers and a durable investment framework encourages a diverse industry population that keeps potential inertia by incumbents in check whilst inducing the long-term investments required for developing the novel market.

Section 5.3.3 argued that a well-designed feed-in tariff scheme could be used across the EU to address the above-mentioned policy implications. It address both competition as well as environmental objectives of EU policy making and would provide a strategic market incentive large enough to attract new entrants as well as incumbents into the renewable energy sector.

Outlook and future research

Having outlined a novel analytical framework for the analysis of incumbents' responses to technological change, a major challenge now would be to transpose its application into the specific contexts of other industries and research settings.

Furthermore, given the simultaneous longitudinal and cross-sectional research approach across countries and time in this study, it has not been possible to investigate in sufficient detail the precise conditions and mechanisms inside individual companies that lead to virtuous cycles of technology diffusion. As argued above, strategy analysis on its own might be insufficient to garner a detailed understanding of co-evolutionary developments in the energy system. However, in the context of the co-evolutionary framework proposed here, strategy analysis could fruitfully be applied as a complementary analysis. This could focus on specific company case studies to analyse in depth at an organizational level how strategic alignment processes are transmitted inside organizational hierarchies, how search heuristics (Geels 2002) are adapted and what individual actors are involved. Similarly important research questions relate to how different policy designs impact on a company's strategy-making processes and what might be necessary the conditions for pro-active organizational engagement.

In an extension to this point, existing research has argued that established routines within companies have led to inabilities to adopt technologies that lie outside established 'search heuristics' of the affected employees (Dosi 1982, Geels 2002). The results from the research find contradictory evidence in this respect. On the one hand, Spanish utilities were well-established in conventional electricity generation technologies, operating coal, nuclear, hydro and natural gas power stations. Nevertheless, they were able to identify the opportunities of renewable energy technologies and build dedicated strategies around them. On the other hand, German utility companies appeared unable to build strategies around the small wind turbines available in the early 1990s, declaring in one case that "*...this [did] not fit our business model, we [were] not set up for that kind of*

task." Hence, more detailed research at this level could uncover the mechanisms that led some companies to adapt positive expectations and strategies around renewable energy technologies, while leaving other companies within existing 'search heuristics'.

Taking this analysis forward, it is furthermore observed that adding large amounts of wind power to the electricity grid can entail additional costs and risks for the operation of the transmission system (IEA, 2005; Stenzel and Gül, 2005). In Germany, the utilities own and operate the transmission system, while in the Spanish and British case this is the remit of an independent national operator. Hence, the German utilities were directly exposed to the operational risks and costs associated with the diffusion of wind power. While this thesis did not investigate explicitly the direct linkage between the ownership structure of the transmission system and the strategic approach to wind energy, it is speculated whether the defensive strategies of the German utilities were motivated in part by concerns over their existing transmission assets. If this were the case, the ownership structure of the transmission system would become a key determinant of the incumbents' reaction to the introduction of renewable energy. In summary, this would imply that the inertia of an existing energy system is in part governed by its ownership structure and consequently the institutionally-determined distribution of risks and costs with respect to the diffusion of new technologies.

Approaching the subject from the policy perspective, the literature on 'national policy styles' (Jänicke 2005) highlights the different regulatory cultures among different countries, which influence a country's ability to support sustainable innovations. Thus, Blazecjzak et al. (2000) argue that "it is generally agreed that a culture of dialogue and consensus is an important condition for successful environmental policy. This seems especially important for the creation of a broad coalition for ecological modernization. An innovation oriented environmental policy needs networking and communication of all kinds" (Blazecjzak & Jänicke 2000:137). In this context, analysis of corporate strategies could focus on the extent to which they were conditioned by the regulatory culture in the respective domestic institutional environment and the degree to which for example the Spanish policy style supported the development of virtuous cycles in

the wind industry. More generally, the research has pointed to the positive impacts such a regulatory environment can have on industry population and technology diffusion, yet more research is needed to understand the precise design of policy that stimulates such pro-active firm reactions.

Reflecting on research design and methodology, a useful extension to the results presented in this thesis could have been to link the company-specific analysis not just to the diffusion of wind power but also to corporate performance measures such as return-on-capital-employed, revenue per employee and capital-expenditure-to-sales ratios. These variables are often used in company-internal performance measurements and as such an important decision variable in internal strategy discussions. These themes were discussed unprompted in several interviews, but they were not systematically collected across all companies and time periods considered in order to evaluate them in the context of the other research findings. Yet, they would have allowed a first approximation to the company-internal issues outlined in the paragraph above.

A second extension to the research design, if time and resources would have been available, could have been to include further countries and companies in the case studies in order to obtain a larger sample size for the comparative analysis. Specifically, a fourth country which uses a renewable energy certificate trading scheme like in the UK, but has a "pool market" electricity market framework such as in Spain could have rounded off the analysis on the key matrices of renewables policy and electricity market design. Italy would have been the closest candidate for this but in fact no country was identified that closely matched these requirements in Europe.

It is hoped that with the results from this research, further attempts are made to integrate company-specific perspectives into the systemic innovation research agenda. It became clear during the research that a co-evolutionary framework provides a more comprehensive approach to understanding the transformation of such a complex system as the electricity industry. The diffusion of renewable energy technologies is not merely achieved by the substitution of one technology by another, but by a complex institutional, organisational and

technological reconfiguration that has already been on-going for the best part of the last century and that will continue. Incumbent utilities are an important piece in that jigsaw and the more intelligently policy can be designed towards them, the more thorough the next energy transformation can become.

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Appendix 1 – Interview Guidelines for Semi-Structured Interviews

Central question:

What are the main drivers for the corporate strategy of incumbent companies when changes occur at the systems level? To what extent do corporate strategy and systems interact and drive each others' evolution?

Underlying lines of inquiry:

What strategic role did RETs play in the leading companies as compared to laggards? What factors influenced the strategic position of RETs in the utility companies?

Introduction:

Short introduction of ICEPT and previous work in this area (DTI renewables innovation review); Introduction of personal background and past experience.

Thesis: bridge to PhD project and the core of the thesis, focus on strategic integration of renewables among utilities

Method: Explanation of method and choice of interview partners; reiteration of anonymity of interviewee in data processing; offer of transcript to correct interview results.

Start into discussion by asking about personal background of interviewee and current job profile.

1st Topic – Company structure and environment

Objective/Content: Assessment of the company`s perception of its competitive environment; clarification of past evolution of company`s vision and objectives; Positioning renewables within the overall company: Allows to prioritise subsequent questions and provides context for the answers given:

- Description of current company structure, evolution of this structure over time (How did important events, such as ownership changes affect the structure?)
- What is the overall vision of the company, what are its strategic priorities?
- Where does the company see itself today in relation to its competitors?
- How would is the overall profile/structure of the company described?

2nd topic – Position of renewables within company; technology awareness

Objective/Content: Identifying the strategic role of RETs within the resource allocation process of the company; identifying company-specific processes that influence investment decisions on renewables

- How is the overall technology mix of the company decided and who makes this decision?
- What are the main criteria for investment projects?
- How are resources allocated among different investment projects?
- What was the rationale for the last five wind projects?
- How important is own-build vs investing into 3rd-party projects/ renewables certificates?
- How do you compare your own activity in the renewables market relative to your competitors?
- How is technology appraisal carried out in your company?
- Who is involved in technology appraisal, how important are direct interactions with suppliers? Is it an ad-hoc process or ongoing?

3rd Topic – Strategic Role of renewables within overall company strategy

Objective/Content: Position of renewables within overall company strategy; factors contributing to the assessment of renewables

- What role do renewables play in the overall company portfolio?
- In what direction do you see RETs (especially on- and offshore wind) evolving over the next 10/20 years? What are the biggest hurdles, what are the biggest opportunities?
- In your view, how does the current technology mix of your company match current and anticipated regulatory requirements?
- How do you expect the future evolution of
    - CO2 prices and trading mechanisms
    - Green certificates
    - Electricity prices
    - Demand for Green Power
    - General regulatory environment

- Which of the above do you see as the most important drivers of RETs?
- What role do investments into renewables play in the context of your overall investment plans?
- What technology mix do you expect for your company in the next 10/20 years?

  What technology mix do you expect for the industry in the next 10/20 years?

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