Departamento de Ingeniería de la Organización,
Administración de Empresas y Estadísticas

UNIVERSIDAD POLITÉCNICA DE MADRID
Escuela Técnica Superior de Ingenieros Industriales

Who is in the driver seat?

Evolution of actors in the renewable electricity industry

PhD Thesis

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2015

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Realizado el acto de lectura y defensa de la Tesis el día ... de de 2015 en la Escuela Técnica Superior de Ingenieros Industriales.

El Presidente

El Secretario

Los Vocales

This research was conducted within the framework of the “European Doctorate in Industrial Management”
- EDIM - which is funded by The Education, Audiovisual and Culture Executive Agency (EACEA) of
European Commission under Erasmus Mundus Action 1 programme.

The author is grateful for the provided opportunity.

Abstract

There is consensus about a need to reduce the amount of green-house gas emission in the electricity industry to be able to deal with the probable consequences of climate change. This necessitates extensive investments in technologies used to generate electricity from renewable energy sources (RES-E). To stimulate such investments, governments have enacted several policy instruments. However, the outcomes of these instruments are mixed. This thesis delineates two reasons for the different effects of policies. First, the development of the renewable electricity industry hinges on a set of driving forces that differ across regions, through the years and for different actors. Given that, policy instruments are not only driving forces behind the renewable electricity industry and can thus by themselves not explain its development.

Second, RES-E investors comprise a heterogeneous group of actors whose perceptions of business opportunities vary substantially and are also based on a variety of driving forces. Hence, RES-E investors may react differently to changes within the electricity industry, as well as to government policies that aim to create a more sustainable electricity industry. Garnering a better understanding of these reactions is therefore important as they influence the pace of transition to a more sustainable electricity industry.

This is an interdisciplinary study that brings together several theories and research areas. First, using the technological innovation system perspective, it identifies systemic driving forces behind the development of the renewable energy industry that will also accelerate the electricity industry transitions to sustainability. To gain a better insight into the role of policy instruments as such as well as in relation to other driving forces, this thesis explores what factors are accounted for in attempts to assess the instruments' performance. Second, drawing on sustainability transition studies and dynamic capability theories, this thesis seeks to explore which firms are willing to contribute—and capable of contributing—to sustainability transitions in the electricity industry. The thesis argues that good forecast and policy plans need to be built on a solid understanding of the firms that change the structure of the electricity industry through their RES-E investments.

This thesis leverages a mix of qualitative and quantitative methods. Empirical data are collected through two extensive literature reviews on the driving forces of the renewable energy industry development in Europe, a longitudinal case study on a European multinational energy company, and statistical analyses of data on RES-E investors in Sweden. The thesis makes theoretical, methodological, and empirical contributions to this area of research. The findings explain what motivates the development of the renewable energy industry; who competes in the renewable electricity industry; and what the future renewable electricity industry may look like. The thesis outlines implications for policies, for managers as well as for renewable energy technologies.

Keywords: Electricity from renewable energy sources; sustainability transitions; actors; institutions; dynamic capabilities; energy policy; investors; technological innovation system.

Resumen

Existe consenso sobre la necesidad de reducir la cantidad de emisiones de gases de efecto invernadero en el sector eléctrico para enfrentar las posibles consecuencias del cambio climático. Esto necesita inversiones extensas en tecnologías para la generación de electricidad a partir de fuentes de energía renovable (RES-E, por sus siglas en inglés). Para estimular dichas inversiones, los gobiernos han promulgado varios instrumentos políticos a favor de las RES-E. Sin embargo, los resultados son diversos. Esta tesis delinea dos razones para esto. En primer lugar, el desarrollo de la industria eléctrica renovable depende de un grupo de agentes conductores que varía entre regiones, el tiempo y los diferentes actores. En consecuencia, los instrumentos políticos no son los únicos agentes conductores detrás de la industria eléctrica renovable y, por lo tanto, no pueden su desarrollo por sí mismos.

En segundo lugar, los inversores en RES-E componen un grupo heterogéneo de actores cuyas percepciones sobre oportunidades de negocio son substancialmente diferentes entre ellos, y estas se basan en diferentes agentes conductores. Por lo tanto, los inversores en RES-E pueden reaccionar de manera diferente ante los cambios que ocurren en los mercados eléctricos, así como ante las políticas gubernamentales que buscan una industria eléctrica más sostenible. El comprender estas reacciones es importante dado que estas influyen la velocidad de transición hacia una industria eléctrica sostenible.

Esta es una investigación interdisciplinaria que conjunta diversas teorías y líneas de investigación. Primero, siguiendo la perspectiva del sistema de innovación tecnológica, se identifican las fuerzas conductoras sistemáticas para el desarrollo de las tecnologías y los mercados de energías renovables. Posteriormente, para obtener una mejor visión del rol de los instrumentos políticos entre otros agentes conductores, esta tesis explora cuales son los factores tomados en cuenta por académicos para evaluar el desempeño de dichos instrumentos. Continuando con esta primera parte, a partir de estudios de transición hacia la sostenibilidad y las teorías de capacidad dinámica, la tesis busca explorar cuales inversores están dispuestos y son capaces de contribuir a las transiciones de sostenibilidad en la industria eléctrica. Esta tesis argumenta que las buenas predicciones y planes políticos necesitan estar contruidos sobre un entendimiento sólido de los actores que cambian la estructura de la industria eléctrica sostenible a través de sus inversiones en RES-E.

En esta tesis se utilizan una mezcla de métodos cualitativos y cuantitativos. Datos empíricos son recolectados de dos extensas revisiones de la literatura sobre los agentes conductoras de las energías renovables en Europa, además de análisis estadísticos detallados sobre inversiones en RES-E en Suecia. Esta tesis realiza contribuciones teóricas, metodológicas y empíricas a la literatura disponible. Los hallazgos explican que motiva el desarrollo de la industria eléctrica renovable, quien compite en la industria eléctrica renovable, y como se verá la futura industria eléctrica renovable. Los resultados de esta tesis remarcen diversas implicaciones políticas y directivas y su efecto en ciertas tecnologías de energía renovable.

Keywords: Electricidad por fuentes de energía renovable; transiciones hacia la sostenibilidad; actores; instituciones; capacidades dinámicas; política energética; inversores; sistema de innovación tecnológica.

Sammanfattning

Det råder enighet om att det finns ett behov att minska utsläppet av växthusgaser kopplat till elindustrin för att bättre kunna hantera de troliga konsekvenserna av klimatförändringar. Detta i sin tur kräver omfattande investeringar i teknologier som genererar el från förnybara energikällor (RES-E). För att stimulera dessa typer av investeringar har regeringar lanserat flertalet policy instrument som ska stöda framväxten av RES-E, men effekterna är inte entydiga. Denna avhandling pekar på två orsaker till detta. För det första, framväxten av förnybara energikällor påverkas av många faktorer som samtidigt skiljer sig åt mellan regioner, över tid och mellan aktörer. Givet att policy instrument inte är det enda som förklarar framväxten av förnybar energi så måste vi även förstå andra faktorer för att i sin tur kunna förstå utvecklingen av RES-E.

För det andra, investerare inom RES-E består av en heterogen grupp av aktörer vars uppfattningar av affärsmöjligheter varierar kraftigt och som dessutom är kopplade till förståelsen av olika drivkrafter. Sålunda kan dessa investerare reagera på olika sätt till följd av förändringar inom elindustrin såväl som till följd av policies som syftar till att skapa en mer uthållig elindustri.

Detta är en interdisciplinär studie som bygger samman flera teorier och forskningsområden. Genom att tillämpa teorier om teknologiska innovationssystem identifierar den, för det första, viktiga drivkrafter bakom utvecklingen av branschen för förnybar energi. För att även förstå betydelsen av policy instrument i relation till andra möjliga drivkrafter undersöker studien vilka faktorer som forskning tidigare pekat på kan förklara instruments prestation. Grundat i detta argumenterar studien att gedigna förutsägelser och scenarier samt policyplaner måste byggas på en grundlig förståelse av de aktörer som förändrar strukturerna i elbranschen genom sina investeringar i RES-E. Byggt på studier om förändring för hållbara system samt teorier om dynamiska förändringsförmågor försöker denna avhandling utforska vilka företag som är villiga respektive har förmågan att göra elbranschen hållbar.

Denna avhandling bygger på en blandning av kvalitativ och kvantitativ metodik. Data är insamlad genom två omfattande litteraturstudier av drivkrafter bakom förnybar energi i Europa, en longitudinell fallstudie om ett europeiskt, multinationellt energiföretag samt analys av kvantitativ data om investerare i RES-E i Sverige. Avhandlingen leder fram till teoretiska, metodmässiga och empiriska bidrag till forskningen. Resultaten förklarar vad som motiverar utvecklingen av en förnybar energibransch, vilka som konkurrerar inom utvecklingen av förnybar energi, samt hur den framtida branschen för förnybar energi skulle kunna se ut. Avhandlingens resultat pekar på flera implikationer för företag, för myndigheter samt för vissa specifika förnybara teknologier.

Nyckelord: El från förnybara energikällor; hållbara förändringar; aktörer; institutioner; dynamiska förmågor; energipolicies; investerare; teknologiska innovationssystem

Acknowledgement

During the past four years, I have changed as a person and learned to think differently. As Albert Einstein said in 1921, “*the value of an education is not the learning of many facts, but the training of the mind to think something that cannot be learned from textbooks*”. The training of my mind to think in new ways that cannot be found in textbooks, I owe to many people.

First of all, I would like to express my thanks to the professors from different universities who helped me to pave my research path. I am sincerely thankful to my supervisor in Spain, *Antonio Hidalgo* for guiding and supporting me throughout this process, and allowing me to develop into a calm, collected researcher. I am also grateful to my Swedish supervisor, *Niklas Arvidsson* for all the kind guidance and inspiring discussions that he provided me with from the beginning of my Ph.D. journey. I appreciate all your contributions of time and ideas to make my Ph.D. experience productive and stimulating.

Furthermore, I would like to express my special appreciation to my co-supervisor *Staffan Laestadius*, with whom I shared many inspiring talks both academically and socially. A special thanks also goes to *Annika Rickne*, who while not my supervisor, supported me; and who also taught me that while researchers can be independent, they do not need to feel alone. I also express my sincere gratitude to *Anna Bergek* for her thorough review of one of the final drafts of my thesis and helping to improve it in every possible way.

I also would like to thank the EDIM Scientific Committee, especially *Mats, Cali, Felipe* and *Paolo*. I know it took immense effort to create and run EDIM; being among the program pioneers, I learned a lot in EDIM. I acknowledge your devotion to our program, which I sincerely appreciate. I also appreciate all the help of our administrators, *Kristin, Isabel*, and *Martina*, who did their best to smooth out the complicated bureaucratic processes (when possible!). You were not only our administrators but also our friends and that meant a lot to me.

During my Ph.D. I found a great chance to spend a 3-month period visiting at the Copernicus Institute of Sustainable Development of *Utrecht University* in the Netherlands. I express my sincere gratitude to my supervisors, if I may call them that, at Utrecht University, *Eva Niesten* and *Marko Hekkert*. I thank you for allowing me to grow as a researcher in your department and training me to think like one. My experience indeed gave me a new perspective about academic life.

Moreover, my great colleagues and friends in Sweden have contributed immensely to my personal and professional life. My deepest thanks to *Monia* for all the heartfelt talks, for understanding me perfectly, and even for my nickname! Thank you for sharing your amusing daily experiences with me (over morning coffee) and listening to mine. Also, thank you *JoJo (Jonatan)* for your sincere friendship and for showing me a part of Swedish life that I would never have experienced without you; thank you *Matthew* for your ‘awesome’ kind supports, often expressed by “you will be fine”, and for proving together with me that Iranian and American

can be true friends against the (unrealistic) odds; thank you *Pranpreya* for being a real colleague and supporting all my endeavors; thank you *FB12 buddies*, especially *Jacques*, for taking my mind off work many nights with the korridorcrawls, wizards, movies, (tea) talks and laughs. I also would like to say a big Mersi my lovely friends in *Setad*, specially my caring flatmate *Maryam*, for always being a part of my life in Sweden and making it feel like home.

I am grateful to all *38 Edimers* for being my family in Europe! Year after year I was amazed how many wonderful people can gather together in one program. I learned a lot from each and every one of you. I would like especially to thank *Nidal* for starting this journey with me and supporting me not only as a colleague, but also as a friend through the entire process. Thank you *Andres* for your smile and a supportive brotherly manner, and for listening to me even when you didn't have enough time for yourself! *Emrah* you deserve special thanks for always being with me, even though we never found a chance to be in a same city physically (until now). Your support is one-of-a-kind. Thank you *Isaac* for showing me that a language barrier is a small problem if somebody has a true friend like you. *Hakan*, I am grateful for your presence in Madrid, I learned a lot from you and I am truly inspired by your spirit.

I am also grateful for the *Erasmus mobility* scheme, when I was going to Spain in 2013 I was not sure if it was going to be a challenge or opportunity; but now looking back, I could have not asked for a better life experience. Owing to the mobility, I saw great things, learned and experienced new cultures, and met people who changed my life for the better. Thank you *Roxana* for building a deep friendship with me in the shortest possible time. Thank you *Angela* for simply being the girl whom I wanted to hang out with everyday; all the dates we had together are among my most cherished memories in Europe. Thank you *Christian* for inspiring me with your kind, calm, and yet adventurous personality; and also for showing me a bit more of each city we explored together. I am also grateful to *Brenda*, *Mahdi*, *Nenad* and *Prad* with whom I shared many unforgettable memories.

Mobility also gave me the great lifetime chance to meet my best friend *Jörn*, who believed in me when I did not believe in myself. I am deeply grateful to you, Schatz, for improving my Ph.D. journey with all your professional support and also my life with your trust, friendship, and unconditional love.

Last but not least, I would like to thank my beloved family. *Maman* and *Baba*, thank you for raising me to be a better person, while respecting all my qualities. No words can express how grateful I am for having your support. *Pegah* and *Ardalan*, my beloved siblings, it is never easy to be far away from you, though no distance is that far when you know your loved ones always keep a place for you in their heart. I do appreciate that more then I can express.

Anna Darmani
Autumn 2015

Disclaimer

Some parts of this PhD Thesis have already been published as:

Paper I

Darmani, A., Arvidsson, N., Hidalgo, A., & Albors, J. (2014). What drives the development of renewable energy technologies? Toward a typology for the systemic drivers. *Renewable and Sustainable Energy Reviews*, 38, 834-847.

Paper II

Darmani, A., Arvidsson, N., & Hidalgo, A. (2016). Do the strategic decisions of multinational energy companies differ in divergent market contexts? An exploratory study. Accepted in *Energy Research and Social Science*, 11, 9-18.

Paper III

Darmani, A. (2015). Renewable energy investors in Sweden: a cross-subsector analysis of dynamic capabilities. Accepted in *Utilities Policy*, 37, 46-57.

Paper IV

Darmani, A., Niesten, E., & Hekkert, M. (2015). Which Investors Drive the Development of Wind Energy? INDEK Electronic Working Paper Series (Currently under review in *Energy Policy*).

** This thesis is conducted within the framework of the double degree program of "European Doctorate in Industrial Management", which is funded by The Education, Audiovisual and Culture Executive Agency (EACEA) of European Commission under Erasmus Mundus Action 1 programmes. Therefore, parts of the material presented in this thesis, both in terms of data and text, are also used in the thesis titled "Who is in the driver seat? Insights into the mixed outcomes of renewable policy instruments in the electricity industry" published in and defended at KTH Royal Institute of the Technology.*

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*“The Stone Age didn’t end for lack of stone, and the oil age will
end long before the world runs out of oil.”*

The Saudi Oil Minister (1970s)

1 Introduction

1.1 Setting the scene

Wally Broecker was the first to introduce, in 1975, the concept of “global warming” to the scientific literature. In his paper titled “Are we on the brink of a pronounced global warming?,” he predicted that “*the present cooling trend will, within a decade or so, give way to a pronounced warming induced by carbon dioxide*” (Broecker, 1975: P. 460). Global warming is one of the greatest challenges that society currently faces, and Broecker’s projection has become a reality. To find a solution to this challenge, various countries worldwide have been cooperating; this cooperation can be seen in the Kyoto Protocol, a proactive treaty in 1997, in which 37 countries committed to the reduction of greenhouse gas (GHG) emissions. Pursuant to this commitment, the European Commission set a target for 2020 to reduce GHG emissions in Europe by 20%, in comparison to 1990s levels¹ (European Commission, 2012a). This target has been followed by a roadmap to 2050, which aims to reduce GHG emissions by about 80–85% across the whole of the European energy industry (European Commission, 2012a). This level of reduction commitment necessitates a complete decarbonization of the European electricity industry (Jägemann et al., 2013).

Sustainability transitions are essential to said decarbonization of the European electricity industry (Gupta and Grubb, 2000). Sustainability transitions “*are long-term, multidimensional and fundamental transformation through which [established systems of users, institutions (e.g., regulatory and cultural), technologies and complementary infrastructure²] need to shift to more sustainable modes of production and consumption*” (Markard et al., 2012:P. 956). Transitions to sustainability in the European electricity industry require an “energy technology revolution” (IEA, 2008, 2009c) that on the electricity generation side as one possible alternative can be achieved through massive investment in renewable energy technologies (RETs), leading to a larger share of electricity generation from renewable energy sources (RES-E).

Renewable energy, as a clean and abundant source of energy, introduces to the environment the least amount of pollutants (Bull, 2001); as such, it serves as an assuring solution to climate-related challenges. However, the viability of renewable energy is questioned at least on account of two reasons. First, renewable energy depends on natural sources of energy that are intermittent and not equally widespread (Oswald et al., 2008). Second, although renewable energy sources do not have fuel cost, technologies harnessing renewable energy are still far more costly when compared with traditional fossil-based energy sources (see Figure1-1). At present, the popular sources of renewable energy are wind, solar, hydro, and biomass. While there exist types

¹ Directive of 2009/28/EC.

² This system has been referred to as a socio-technological system. See Markard et al. (2012).

of RET that do not produce electricity (for example technologies that only produce heat), this thesis primarily focuses on RETs that produce renewable electricity (i.e. RES-E) ³.

Figure 1–1. Average cost of electricity generation from renewable energy sources (Source: IPCC, 2011b: 14)

Notwithstanding of its shortcomings, renewable energy is still recognized as an effective solution to existing climate challenges (EREC, 2010; Schneider et al., 2010). Hence, since 1990, the development of RETs and investments in RES-E have been prioritized in the energy sectors of many countries. However, far larger investments in RES-E are needed if a sustainable electricity industry is to be achieved⁵ (see, IPCC, 2011b). Previously, a lack of such investment has been evident, as 77.9% of global electricity production at the end of 2013 had been derived from fossil fuels; the remaining sources (22.1%) were hydropower, a well-established and profitable RET, which accounted for 16.4%; wind power, 2.9%; biopower,⁶ 1.8%; solar photovoltaic (PV), 0.7%; and other sources, 0.4% (REN21, 2014). In Europe, renewable sources accounted for 25.4% of electricity production in 2013 (Eurostat, 2015).

To take action and increase the share of RES-E, governments have enacted policy instruments (e.g., regulations and taxes) that take into account their domains' unique features (Haas et al., 2011b). It is often assumed that any substantial sustainability transition requires solid governance and policy support (Markard et al., 2012; Smith et al., 2005), in the form of “government policies that affect the structure and functioning of markets and the competitive advantages of its participants” (Baron, 2001: P.47). In the electricity industry, save for the case of remote off-grid renewable energy (Kaldellis et al., 2012), policy instruments play a pivotal role in emerging renewable electricity markets (Norberg-Bohm, 2000). Nevertheless, they have resulted in mixed outcomes. In other words, similar policy instruments have stimulated a varied percentage of RES-E across countries

³ Nonetheless, in this thesis both literatures focusing on RES-E, as well as all RETs is incorporated, since it is assumed that findings on all RETs are transferrable to its largest subgroup (RES-E).

⁴ The word ‘power’ throughout this thesis refers to Electric power.

⁵ Note that sustainability transitions in the electricity industry need changes on all generation, distribution and consumption sides. But, throughout this thesis focuses on the generation side of this industry.

⁶ The word “biopower” refer to the production of electric power from biomass. See, Jacobsson (2008).

and regions, or have been supported or disputed by different segments of society and (or) industry. This thesis delineates two reasons for this.

1. Driving forces behind the renewable energy industry development

First, this thesis argues that the development of the renewable electricity industry, apart from policy instruments, hinges on a set of driving forces. However, note that as it is hard to distinguish if the respective driving force acts to exclusively increase share of renewable electricity or renewable energy in general, this thesis widens its perspective by examining the driving forces behind the development of renewable energy technologies and markets in general (i.e. renewable energy industry). It is therefore assumed that the development of the renewable energy industry will also lead to a larger share of RES-E and accelerate the electricity industry transitions to sustainability.

Driving forces behind sustainable technologies (e.g., RETs) in general are the factors or arrangements that are implemented to increase or accelerate technological development and deployment in a market (Nilsson et al., 2012). Such forces are necessary for a specific technology to be chosen among alternative competitive options and to incentivize firms to enter an emerging market (Bergek et al., 2008; Hekkert and Negro, 2009). Driving forces can originate in the industry, the market or the government (Hekkert et al., 2007). Thus, policy instruments can by themselves neither fully incentivize nor explain the development of the renewable energy industry.

In fact, driving forces behind the development of RETs vary across subsectors (i.e., wind, biomass, solar or hydro), in different regions, among different actors, and through the years (Björheden, 2006; Darmani et al., 2014a). As an example, while social acceptance was previously neither a driving force of nor a barrier to RETs, at the moment, social parameters play a decisive role in renewable energy markets (Wüstenhagen et al., 2007). To accelerate transitions to a sustainable electricity industry, it is important to identify all the driving forces behind the development of the renewable energy industry and understand that various energy markets can benefit from a number of different driving forces.

So far, a number of studies explored the driving forces behind sustainable technologies, specifically of RETs. However, the studies often focused on policy instruments, when generally the development of a technology can be pursued by a system of actors, networks and institutions. Hence, there is still a lack of scientific contribution combining various system elements to understand which role policy instruments may play among other driving forces. Therefore, the first area of interest of this thesis is:

Area of interest 1: Driving forces behind the development of the renewable energy industry combining all the system elements including actors, institutions and networks.

2. Heterogeneity of RES-E investors

Second, RES-E investors are heterogeneous (Haas et al., 2004; Markard and Truffer, 2006; Wüstenhagen and Menichetti, 2012), and due to that policy instruments alone cannot leverage all the driving forces behind their investment processes (Masini and Menichetti, 2013: P. 511). Besides, different RES-E investors are likely to benefit from different types of policy support schemes which the current designs of enacted policy instruments frequently do not consider (Couture and Gagnon, 2010; Wüstenhagen and Menichetti, 2012). In this thesis, RES-E investors⁷ are “*actors who invest in renewable electricity production (e.g. utilities and farmers) rather than as actors who finance such investments, e.g. banks, funds, investment advisors, private equity firms or venture capitalists [...]. The former initiate the idea for a new plant, mobilize resources to realize it and take ownership of the plant once it is in place. Electricity production then becomes a part of their business.*” (Bergek et al., 2013: P. 569). An understanding of the heterogeneity of RES-E investors is essential, as they are in position to influence the pace of transitions to a more sustainable electricity industry (see, Schmidt et al., 2012). Therefore, the second area of interest of this thesis is:

Area of interest 2: Heterogeneity of RES-E investors in the renewable electricity industry.

Heterogeneity among RES-E investors is acknowledged on a variety of levels. This thesis makes a specific distinction between the contributions of two groups in the renewable electricity industry: first, powerful utility-type electricity producers that were often part of an oligopoly of the old regulated market (hereinafter, incumbents) (see, Högselius and Kaijser, 2010), and second non-traditional electricity producers (hereinafter, new entrants), including local utilities, private investors, independent power producers, and cooperatives (Bergek et al., 2013b; Verbong and Geels, 2010).

Concerning the first group, the relevant literature argues that sustainability transitions in the electricity industry can conflict with the path dependence of incumbents (Smink et al., 2015). This is because the transitions require massive changes, given that they demand investments in technologies (i.e., RETs) that differ completely from established ones (Verbong and Geels, 2010). The literature on path dependence suggests that incumbents tend to follow their “past pattern of investments” and thus are less willing to adapt to changes (see, Markard et al., 2012; Pinkse and Kolik, 2010; Smink et al., 2015; Smith et al., 2005). Path-dependent incumbents often consider a new technology a challenge, because it forces them to question their already-established assets (Nelson and Winter, 1982; Teece, 2007). The challenge could even be such that the incumbents will block the advancement of such technologies (Smink et al., 2015). As a result, instead of massive changes, only incremental changes are adopted, and these are insufficient to curbing climate challenges (Markard et al., 2012). Therefore, a further area of interest of this thesis concerning RES-E investors’ heterogeneity is:

⁷ In this thesis, the firm is the unit of analysis. Therefore, the words “firm” and “investor” are used interchangeably throughout.

Area of interest 2.1.: Incumbents' reaction to the sustainability transition happening in the electricity industry.

On the other hand, new entrants invest in the emerging renewable electricity industry because doing so helps them secure a favorable market position (cf. , Negro et al., 2007) and thereby gradually overtake incumbent positions (Verbong and Geels, 2010). New entrants possess diversified characteristics, in terms of ability, motivations, existing recourses, experiences and investment portfolio (e.g., Bergek et al., 2013b; Darmani, 2016; Dinica, 2006). An understanding of RES-E investors' characteristics—representing both incumbents and new entrants—sheds light on what makes firms of different kinds to invest in RES-E. This understanding is also relevant for policymakers as it enables them to design policy instruments that can effectively target certain type of investors and technology. Therefore, a second area of interest of this thesis relating to RES-E investors' heterogeneity is:

Area of interest 2.2.: RES-E investors' characteristics to understand what makes firms of different kinds to invest in RES-E.

In summary, the point of departure of this thesis is the observation that the electricity industry is undergoing transitions with regard to sustainability, specifically on the electricity generation side. For that, several policy instruments have been introduced into the electricity industry to stimulate a larger share of RES-E. However, these policies have generated mixed outcomes. This thesis delineates two reasons for this. First, this thesis explains that policy instruments are not the sole driving forces behind the renewable energy industry development (that leads to a more sustainable electricity industry). Through a systemic perspective, the thesis sheds light on other driving forces of the renewable energy industry development, combining various system elements in term of actors, institutions and networks, to understand the role that policy instruments play among others (area of interest 1).

Second, the thesis explores heterogeneity of RES-E investors and discusses that consequently the same policy instrument can affect the investors' investment process in different ways (area of interest 2). To do so, the thesis takes an actor-oriented perspective, choosing firms as the unit analysis. Firms are important actors of the electricity industry, who are in the position to change the nature of this industry through their contributions and developing technological solutions. Their understanding hence is essential to the said sustainability transitions in the electricity industry.

This thesis aims at illustrating that the sustainability transition in the electricity industry needs to be directed by a group of actors akin to evolving and various actors, including policymakers, taking the **driver seat**, in order to steer us more efficiently towards sustainability. It further argues that the contextual factors, by which these actors are confined, can influence the direction towards which the electricity industry navigates.

1.2 Background research

The sustainability transitions taking place within the electricity industry constitute a highly relevant field of research that has developed impressively in recent years. Various research lines contribute to this field of knowledge. This thesis specifically builds on and (or) contributes to four distinct research lines:

To start, the thesis borrows literature from **technological innovation system (TIS) framework** that is defined as “*a dynamic network of agents interacting in a specific economic/industrial area under a particular institutional infrastructure and involved in the generation, diffusion, and utilisation of technology*” (Carlsson and Stankiewicz, 1991: P. 93). Given this definition, actors, institutions and networks are the main structural elements contributing to the development of a TIS. The TIS perspective has emerged in studies on the field of sustainability transitions and “*is concerned with the emergence of novel technologies and the institutional and organizational changes that have to go hand in hand with technology development*” (Markard et al., 2012: P. 959).

The TIS literature shows that it is through a “well-functioning” TIS that a new technology can diffuse successfully (Negro and Hekkert, 2008). Analyses of the TIS framework in sustainability transition studies enable policymakers to identify system barriers and propose a mean of resolving them (Jacobsson and Bergek, 2011). Thus far, several scholarly studies have explored the barriers to and driving forces of renewable energy technologies and markets (e.g., Foxon et al., 2004; Negro et al., 2008; van Alphen et al., 2008). In this research line, there is a comprehensive body of work on system barriers of an emerging technology combining all system elements of TIS (Woolthuis et al., 2005). However, there is a lack of research exploring the driving forces behind new technologies, specifically RETs, considering all various kind of actors, policies, social and customer segments and network. This lack of knowledge is captured in the *area of interest 1* of this thesis.

Furthermore, this thesis builds upon recent research within the **energy policy** literature. In this literature, several authors have underscored the necessity of further empirical and theoretical studies on heterogeneous RES-E investors (e.g., Darmani, 2016; Masini and Menichetti, 2012, 2013; Wüstenhagen and Menichetti, 2012). It is argued that a lack of knowledge on RES-E investors couples with the design of ineffective driving forces including policy instruments. As Bergek et al. (2013: p. 568) argue “*if investments of this magnitude [as planned for RES-E] are to be achieved, markets cannot be driven by government investments alone. [...] to support the deployment of renewable electricity technologies, it is necessary to identify the main drivers and obstacles for self-sustaining markets to develop. For that, knowledge about [...] the actors who invest in RES-E and their investment decision-making processes, is needed*”.

To explicate which types of RES-E firms contribute to, or block changes in, an emerging sustainable industry, this thesis primary draws on the literature on **sustainability transitions**. In the sustainability transitions studies, old market players with sizable market shares (incumbents) often are identified as powerful actors whose investment decisions for new technologies are delimited by their path dependence

(Smink et al., 2015; Wüstenhagen and Menichetti, 2012). However, simultaneously, the incumbents are recognized as players with a significant bundle of resources that enable them to outperform new entrants in times of change (see, Bergek et al., 2013a). Therefore, the results remain inconclusive, and there is a call for further longitudinal industry-specific studies to deepen knowledge of the incumbents in the sustainable electricity industry. The *area of interest 2.1.* of this thesis sheds light on this unexplored topic.

Also, to explore which characteristics of RES-E investors—representing both incumbents and new entrants—allow them to overcome their path-dependence and make decisions in favor of RES-E investments, this thesis incorporates theories from the **dynamic capabilities** literature. Building on the dynamic capabilities literature, this thesis assumes that firms with higher levels of dynamic capabilities are better able to contribute to changes that give rise to a more sustainable electricity industry. By virtue of incorporating theories from the dynamic capabilities literature into the sustainability transitions studies, the thesis proposes a new analytical framework that not only enables a better understanding of RES-E investors' heterogeneity but also contributes to the sustainability transitions studies. The *area of interest 2.2.* of this thesis is dedicated to this topic.

As Markard and Truffer (2012) discuss that a better understanding of historical and ongoing sustainable transitions necessitates the incorporation of new theoretical frameworks and methodological approaches into transition studies. *“We think that there is much to learn from established concepts and frameworks in other fields, which can be used in a complementary way and to support competing explanations [in sustainability transitions studies]. Examples include neo-institutional theory, actor-network theory, resource- and capability-based approaches, complex systems theory, institutional and relational economic geography, political and policy sciences and many more. Advances in the theoretical frameworks will have implications for the methodological styles that will be prevalent in transition research as well—i.e., how different kinds of quantitative and qualitative datasets could be related to each other, what types of explanation are accepted in different conceptual frameworks”* (Markard et al., 2012: P. 962). So far, scholars contributed in this research line such by proposing a framework marrying TIS and multilevel perspective of sustainability transitions (Hillman et al., 2011; Markard and Truffer, 2008), or incorporating spatial and regional studies (Coenen and Truffer, 2012; Smith et al., 2010). However, incorporation of dynamic capabilities theories into this field has seldom been taken (see also, Lieberherr and Truffer, 2015).

1.3 Research questions and objectives

The above discussion brings about two interrelated research questions (RQs) that are developed based on the thesis's two areas of interest: *What are the driving forces behind the development of the renewable energy industry leading to a more sustainable electricity industry?* And, *Which firms contribute to the transition to a more sustainable electricity industry?* Below, the RQs, their objectives (OBJs), and methods of the study are discussed:

RQ 1. What are the driving forces behind the development of the renewable energy industry leading to a more sustainable electricity industry?

Driving forces of the renewable energy industry development, contributing to a more sustainable electricity industry, vary from country to country, across renewable energy subsectors, for different actors and through the years. Therefore the first objective (**OBJ1**) of this thesis is to investigate the systemic driving forces behind the renewable energy industry development and present a typology for them. The thesis incorporates the TIS perspective to explore driving forces relating to all the system elements, including actors, institutions and networks. Hence, this thesis contributes to an understanding of the driving forces behind the development of the renewable energy industry leading to a larger share of RES-E.

Method: a literature review of 30 papers on the driving forces behind the wind, solar, biomass and ocean energy development in EU7 countries and Ireland.

Presenting a comprehensive picture of the systemic driving forces behind the renewable energy industry development, this thesis highlights the pivotal role that policy instruments play among other driving forces. Successively, to understand what makes a policy instrument succeed as a driving force, the second objective (**OBJ2**) of this thesis is to explore which analyses criteria have been used in order to assess the performance of policy instruments (in this thesis the focus is on tradable green certificate systems (TGC)). The analysis criteria determine which factors are accounted for or disregarded when policy-instrument outcomes are evaluated.

Method: a literature review of 63 papers assessing the performance of TGC systems in various countries.

RQ 2. Which firms contribute to the transition to a more sustainable electricity industry?

Heterogeneous RES-E investors respond differently to changes happening in the electricity industry as well as to the governmental policy supporting RES-E. Such reactions determine the pace of sustainability transitions in the electricity industry. Therefore, it is important to understand who are the RES-E investors and what makes firms of different kind to invest in RES-E. Making a specific distinction between incumbents and new entrants, this main research question will be answered through two sub-questions.

RQ 2.1. How do incumbents react to specificities in national policy frameworks and social commitments to sustainability transition?

Incumbents of the electricity industry are oligopolistic firms of the old regulated markets, in Europe often in the form of multinational energy companies (MNC:s). These incumbents still own sizable market shares in the European electricity industry. The third objective (**OBJ3**) of this thesis is to

investigate how incumbents perceive the sustainability transitions happening in the European electricity industry. More specifically, it addresses how incumbents have reacted to the renewable electricity industry, especially as policy frameworks and societal commitments have been influenced by sustainability considerations. For doing that, this thesis investigates if MNCs prioritize their own core global strategy or national institutions when operating in home or host countries to understand how they react to specificities in national policy frameworks and social commitments to sustainability transition.

Method: a longitudinal case study on Vattenfall, a known European multinational energy company.

RQ 2.2. Which characteristics of RES-E investors foster their decision to contribute to sustainability transitions within the electricity industry? How do those characteristics differ across RET subsectors?

Market deregulations and incumbents' limited interest in RES-E has created a unique opportunity for new entrants to enter the renewable electricity industry. Therefore, in the current renewable electricity industry, new entrants are competing side-to-side with market incumbents. In order to understand what makes firms of different kinds to invest in RES-E, this thesis examines certain characteristics of RES-E investors—representing both incumbents and new entrants.

Hence, the fourth and fifth objectives of this thesis is respectively to explore which characteristics of RES-E investors positively affect their capabilities in exploring new market opportunities during sustainability transitions in the electricity industry (**OBJ4**) and how those characteristics differ across RET subsectors (**OBJ5**). For that the thesis borrows theories from the dynamic capabilities literature. Exploring RES-E investors' heterogeneity within and across subsectors, this thesis explains how one policy instrument can result in various outcomes for those subsectors. This thesis makes one of the first attempts to incorporate theories of dynamic capabilities into sustainability transition research; it makes a theoretical contribution to the literature, by virtue of its proposal of a new analytical framework.

Method: Statistical analysis of RES-E investors in Sweden.

Table 1–1 illustrates an overview of the area of interests, research questions, and methodological approach.

Table 1–1. An overview of thesis areas of interest, research questions, and methods

<i>Area of Interests & objectives</i>	<i>Research questions</i>	<i>Level of analysis</i>	<i>Method of analysis</i>
1 (OBJ1,2)	1. What are the driving forces behind the development of the renewable energy industry leading to a more sustainable electricity industry?	System	Literature study
2	2. Which firms contribute to the transition to a more sustainable electricity industry?	Firms	
2.1 (OBJ3)	2.1. How do incumbents react to specificities in national policy frameworks and social commitments to sustainability transition?	Firms	Case study
2.2 (OBJ4,5)	2.2. Which characteristics of RES-E investors foster their decision to contribute to sustainability transitions within the electricity industry? How do those characteristics differ across RET subsectors?	Firms	Statistical analyses

1.4 Research context and delimitations

To achieve the objectives of this thesis, an interdisciplinary study is conducted with a special focus on the European electricity industry. Empirical data are obtained from the Swedish electricity industry, due to the reasons that are specified in the following. This thesis primarily focuses on the electricity industry; however, if during the analysis it was found impossible to determine whether driving forces, or firms' strategies had affected the energy industry in general or exclusively the electricity industry, the energy industry was made the focus (concerning OBJ1 and OBJ3).

1.4.1 The case of European electricity industry

Electricity availability is vital for keeping today's living standards. In Europe, a fifth of all the energy consumed is in the electricity sector (European Commission, 2012b). "*Electric power systems are generally regarded to be the largest and most complex industrial systems ever built.*" (Laloux and Rivier, 2013: P. 1). In order to have a fully functioning electricity industry and meet consumers demand, three general systems need to be integrated, namely generation, transmission and distribution systems (See Figure 1-2). This integrated system necessitates involvement of actors in the whole supply chain, among others electricity generators, trading companies, manufacturing companies, grid operators, and power marketers (Markard and Truffer, 2006).

Figure 1-2- An overview of the electricity system (Chappin, 2011: P. 80)

In the European electricity industry, market deregulation was a major step in the industry transition (Markard and Truffer, 2006), resulting in “a shift from a system dominated by engineers to a market-based system, ruled by managers” (Verbong and Geels, 2010: P. 1215). Before deregulation of the European electricity industry, in 1990s, a few monopolies, mainly state-owned companies, represented the main actors from generation through distribution to the final consumers (Domanico, 2007: P. 5064). However, in 1996 the European Union (EU) with the Directive 96/92/EC paved one of the first steps toward deregulation of electricity markets in member states. Market deregulation opened up the electricity industry boundaries and resulted in far-reaching changes to its structure. Market deregulation enabled non-traditional types of actors to enter the market from the generation to sale as well as new fields such as trading or demand aggregation (Markard and Truffer, 2006). The deregulation specifically concerned the generation side of the electricity industry (Battlé, 2013), because transmission and distribution systems are still heavily regulated.

In a deregulated market each investor finds a chance to make investment decisions based on its individual cost-benefit analysis (Laloux and Rivier, 2013) and processes (Masini and Menichetti, 2013). An understanding of such processes for RES-E investment is essential, as it affects the pace of sustainability transitions happening in the electricity industry.

The EU issued a renewable energy directive in 2001, to increase the share of RES-E in each European member state (European Commission, 2001). In Europe, production of RES-E has increased successfully, from 12.5% of the energy mix⁸ in 1990 (European environment agency, 2013) to 25.4% in 2014 (Eurostat, 2015). Nevertheless, Europe still needs to adjust its electricity generation portfolio considerably, if it is to

⁸ The energy mix refers to a range of energy sources.

fulfill its plan for 2050 (Jägemann et al., 2013). Hence, the European electricity industry not only provides a long and interesting development history to analyze, but also an extensive development plan for the future.

1.4.2 The case of Swedish electricity industry

In this thesis, while descriptive analyses are at the European level, empirical data are obtained from the Swedish electricity industry, particularly from the Swedish (onshore) wind power, biopower and hydropower industries. Sweden has been an EU member state since 1995; this means that Sweden must follow EU requirements with regard to renewable energy, electricity, and gas markets, energy taxation, and GHG emissions (IEA, 2013). Although Sweden is already on track to meet the EU target set for 2020, the country needs to adjust its generation portfolio if it is to meet its vision of “zero net GHG emission by 2050” (Profu, 2012). This necessitates the examination and monitoring of Sweden’s policy instruments and its larger investments in clean energy technologies (see, IEA, 2013).

Sweden is the fourth-largest country in Europe, with more than 9 million inhabitants (IEA, 2013). Sweden consists of scattered rivers and lakes throughout the country, and mountains along its northwest region (IAEA, 2014). Owing to Sweden’s considerable natural resources, the share of renewable energy in its final energy consumption is considerably high; this owes largely to the country’s extensive use of biomass and hydropower. Water resources alone generate more than one-third of the country’s consumed energy (Wang, 2006). Nevertheless, Sweden remains an importer of energy in the wintertime, because of its low water reservoirs and nuclear power availability (Ecologic Institute, 2013).

Sweden is a relevant case for this thesis, for several reasons. First, the Swedish electricity industry has been deregulated since 1996, meaning that all investor groups have the opportunity to connect to the national grid and sell their produced electricity, regardless of their size or position (CEER, 2010; Högselius and Kaijser, 2010).

Second, the Swedish economy is characterized by large vested interests in cheap electricity produced by nuclear and hydropower plants, and this has resulted in actor lock-ins (Wang, 2006), and path dependence. Consequently, sustainability transition in the Swedish electricity industry has been slow and tenuous (Söderholm et al., 2007) and therefore interesting to study. To illustrate, Sweden’s installed wind capacity was only 4 GW at the end of 2013, whereas that of Germany and Spain was 33 GW and 22 GW, respectively (EWEA, 2014).

Third, over the past 10 years, a significant but limited number of changes have occurred in Sweden’s policy framework, and these changes have helped induce further investments in RES-E. *Ergo*, the Swedish electricity industry has undergone interesting changes in line with the analyses undertaken in this thesis, while the limited numbers of changes restrict the influence of extraneous variables. More specifically, Sweden has since May 2003 enforced the TGC framework, to promote investments in RES-E. The TGC framework is technology-neutral and provides a concrete context for comparative study across RET subsectors (i.e., wind

power, biopower, and hydropower). For this reason, the TGC framework is the policy instrument highlighted in this thesis.

Finally, in Sweden the electricity industry is transparent. This transparency can be traced in a database published by the Swedish Energy Agency on all RES-E investors in Sweden, each of whom receives certificates for electricity production. The TGC database is a reliable source of data for analysis in this thesis, and it has been used in earlier research (see, Bergek et al., 2013b). In all, this thesis looks to study the contributions and characteristics of RES-E investors, and these factors point to the likeliness of finding them in Sweden.

1.5 Thesis outline

This thesis is organized in five chapters. After this introduction, chapter 2 presents the theoretical background of this thesis, comprising 3 sections. Section 2.1. draws on the sustainability transition literature to explain the general features of the sustainability transitions in the European electricity industry. Section 2.2. focuses on the TIS literature to present a systemic overview on the renewable energy industry development. Section 2.3. summarizes intriguing literature on the role of firms in the sustainability transitions, presents a review of the dynamic capability theories, and proposes the hypotheses and propositions of this thesis on RES-E investors' characteristics. Successively, chapter 3 explains methodological approach of this thesis. Chapter 4 of this thesis illustrates the findings and analysis within three sections. The section 4.1. presents the typology of the driving forces behind the renewable energy industry development and explains analysis criteria used for assessing policy-instrument outcomes. Next, Section 4.2. outlines the findings of this thesis on the reaction and contribution of RES-E investors in the renewable electricity industry. Finally in chapter 5 conclusion and implications of this thesis are presented.

2 Literature Review

This chapter provides a review of the central concepts addressed in this thesis, organized in three sections. First of all, section 2.1., presents studies from the sustainability transition literature, to explain the general features of sustainability transitions in the European electricity industry. Successively, section 2.2., provides a review on the TIS perspective that is incorporated to identify the systemic driving forces behind the renewable energy industry development. This section also provides an insight into the prevalent policy instruments supporting RES-E to reflect on their importance as driving forces. Next, section 2.3. focuses on RES-E investors' characteristics and presents a review on dynamic capabilities theories to explain certain energy firms' behaviors during sustainability transitions in the electricity industry. Each section is concluded with a summary explaining how the incorporated theoretical framework has contributed to obtaining the thesis's objectives.

2.1 Transition to the sustainable electricity industry

Sustainability transitions exhibit “*long-term, multidimensional and fundamental transformation through which [established systems of users, institutions (e.g., regulatory and cultural), technologies and complementary infrastructure⁹] need to shift to more sustainable modes of production and consumption*” (Markard et al., 2012:P. 956).

Sustainability transitions differ from general transitions by three specific features (Geels, 2011). First, sustainability transitions are ‘purposive’ (Smith et al., 2005), meaning that they are to satisfy environmental objectives, instead of emerging from an opportunity. Second, technologies deployed for sustainability transitions are often inferior when compared with established technologies regarding their price or performance. Third and last, sustainability transitions can collide with strong path dependence and lock-in (Åhman and Nilsson, 2008; Unruh, 2000; Verbong and Geels, 2010), both of which are caused by adherence to already-established user practices, technologies, business practices, organizational routines, and institutional and regulatory structures (Markard et al., 2012). Consequently, sustainability transitions tend to be pursued through incremental rather than radical change (Dosi, 1982; Markard and Truffer, 2006). This is insufficient in curbing ongoing sustainability challenges (Markard et al., 2012).

In the European electricity industry, similar features characterize the ongoing sustainability transitions. First, sustainability transitions are prioritized in this industry with the ‘purpose’ to avoid the severe side affect of electricity generation from fossil-fuels on the environment.

Second, as RETs enter national electricity markets worldwide, they find themselves in direct competition with already-established technologies, i.e. fossil-fuel power sources (see, Foxon et al., 2004). However, RETs

⁹ This system has been referred to as a socio-technological system. While a technological system is associated solely with technological changes, a socio-technological system is associated with changes in the institutions and user practices of a society. For further reading, please refer to Markard et al. (2012).

cannot compete economically with established technologies, and when compared to other available options, they are the least cost-efficient (Jacobsson and Lauber, 2006; Sandén and Azar, 2005). To enhance the economic competitiveness of RETs in the market place, the intervention of governmental policies is crucial (Björheden, 2006; Del Rio and Unruh, 2007; Foxon et al., 2004). Without policy instruments, immature RETs will penetrate only a few market niches; this is clearly insufficient when the goal is to induce technical changes that lead to RET development (Menanteau et al., 2003) and market establishment.

Third, sustainability transitions in the European electricity industry continue to be characterized by path dependence (Del Rio and Unruh, 2007), as we see in the existing fossil fuel system (e.g., Smink et al., 2015), the profitability of the nuclear power industry (Wang, 2006), centralized distribution (van der Vleuten and Raven, 2006), and/or established systems and technologies (e.g., power plants, cables, and transformer stations) (Verbong and Geels, 2010).

Notwithstanding these challenging features, sustainability transitions are prioritized in the European electricity industry to tackle climate change. For that purpose, policy instruments are introduced into the electricity markets across countries as an effective tool; to enhance cost-competitiveness of RETs; and contribute to lock-out of RES-E specifically by influencing investment decision of energy firms. Nevertheless, the enacted policy instruments so far have resulted mixed outcomes. To explain this, the thesis delineates two reasons, which are based on literature from two theoretical frameworks, namely the TIS framework and dynamic capabilities theories.

First by a mean of a study that combines various system elements using the TIS perspective, this thesis study the driving forces behind the development of the renewable energy industry. Driving forces of sustainable technologies (e.g., RETs) are factors or arrangement that can induce and stimulate activities for innovation and technological substitution ¹⁰ (Elzen et al., 2004; Nilsson et al., 2012).

The TIS perspective is adapted in studies on sustainability transition in the energy industry as it can explain what activities drive or hamper the development of a new technology and system. A systemic aspect of TIS emphasize that technological development and changes is not simply determined by competition between technologies, but rather “*by the competition between various existing innovation systems, both fully developed and emerging ones*” (Hekkert et al., 2007: P. 415). Building on the TIS literature, this thesis explores how an innovation system for a technology came about and how it can be driven and induced by various system elements. Drawing on this literature this thesis presents a comprehensive overview of the driving forces behind the renewable energy industry development to understand what role policy instruments play among other driving forces.

¹⁰ Driving forces are also defined as “*the processes that influence trends and our ability to meet agreed-upon targets*” Parris and Kates (2003: P. 8068). The proposed definition in this thesis however provides a more comprehensive definition for the driving forces.

Second, the thesis explores which firms are affected by path dependency and which firms contribute to the sustainability transition, using the dynamic capabilities literature. The differences among energy firms' responses to sustainability transitions in the electricity industry can explain partly why policy instruments produce mixed outcomes across countries. This thesis assumes that the RES-E firms *per se* can be the drivers of the sustainability transition in the electricity industry—for example, through lobbying (Sühlsen and Hisschemöller, 2014) and reducing path dependence through the investment decisions (see, Markard and Truffer, 2006).

Note that this thesis borrows literature from sustainability transitions studies only to explain specific features of the electricity industry and certain firms' behaviors during sustainability change processes happening in this industry. However, for achieving its objectives, the thesis incorporates two main theoretical frameworks, namely TIS perspective and dynamic capabilities. Accordingly, while the thesis provides a review of two theoretical frameworks, it does not go to the same level of detail in the sustainability transitions studies.

2.2 Development of the renewable energy industry

2.2.1 Technological innovation system perspective

In the mid-1980s, the concept of the innovation system was developed as a key to understanding the innovation process, with an emphasis on the flow of technology and information among people, enterprises, and institutions (Lundvall, 1985). The innovation system has been formed rather as a policy concept that features a number of system dimensions (Carlsson et al., 2002; Jacobsson and Bergek, 2011), including the national innovation system (Sharif, 2006), the sectorial innovation system (Malerba, 2004), the regional innovation system (Cooke, 1996), and the TIS (Carlsson and Stankiewicz, 1991).

Among the identified dimensions, TIS have been used widely to study the emergence of a new technology (Hekkert et al., 2007), especially in research pertaining to sustainability transitions (Markard et al., 2012). TIS is defined as “*a dynamic network of agents interacting in a specific economic/industrial area under a particular institutional infrastructure and involved in the generation, diffusion, and utilisation of technology*” (Carlsson and Stankiewicz, 1991: P. 93). Given this definition, TIS comprises four structural system elements—namely, actors, institutions, networks, and technology (Jacobsson and Bergek, 2011).

The systemic perspective of TIS suggests that for a system to generate a new technology, product or process integration and functionality among all the system elements are essential. In fact, a fully functioning system cannot be achieved unless we understand the importance of all system elements and ensure their functionality (Carlsson and Jacobsson, 1997; Edquist, 2001). This is because weaknesses¹¹ inherent in each

¹¹ System weaknesses are also labeled as “system imperfections,” “system failures,” and “system problems,” *inter alia*. For more examples, refer to Negro et al. (2012).

system element can affect the performance of the entire system (Clément et al., 2002; Foxon, 2003; Foxon et al., 2004; Jacobsson, 2008; Jacobsson and Bergek, 2011).

TIS structural elements are factors that can create system emergence, changes, advances, or breakdowns. It is therefore essential to define TIS structural elements in concrete terms and explore their requirements in various TIS evolutionary phases.

2.2.2 Structural elements of a technological innovation system

Actors

Actors within a TIS can constitute any group of public players (e.g., government, policymakers), private actors (e.g., private firms along the full supply chain), universities, and research institutes, as well as non-government organizations (NGOs) (e.g., consumer organizations) and/or influential associations (e.g., venture capitalists) (Jacobsson and Bergek, 2004; Meijer et al., 2006). “Actors” can refer to either individuals or organizations that are “prime movers” (who perform innovation activities directly (Jacobsson and Bergek, 2004)) or “secondary actors” (who affect the behavior or interactions of the primary actors) (Sanyal and Cohen, 2004). Remarkably, not all actors within a TIS share necessarily share the same goal, which means that conflicts among actors’ goals or activities can comprise parts of the innovation system dynamics (Bergek et al., 2008). Note that while this thesis investigates different actors in the renewable energy industry, it particularly examines firms that invest in RES-E.

Institutions

The term “institution” is defined and interpreted in various ways in different studies. In one leading definition, North (1990: P. 3) describes institutions as the “*rules of the game in society*”. This definition implies that institutions are delimiting firms by way of their established framework (Jacobsson and Bergek, 2004; Van de Ven and Garud, 1989) and hence play an essential role in the development of a technology (Freeman and Louca, 2002).

The prevailing role of institutions in the energy industry is acknowledged (Jacobsson and Bergek, 2004, 2011; Lewis and Wiser, 2007; Lund, 1999; Lund, 2008). Institutions can influence the energy industry through two distinct types of hard and soft institutions (see, Woolthuis et al., 2005). Hard institutions comprise any formal and written material proposed through regulations, policy instruments, labor and employment laws, related technical standards, risk management regulations, safety laws, intellectual property rights, and the general legal system (Smith, 2000; Woolthuis et al., 2005). On the other hand, soft institutions comprise norms and informal interfaces among individuals, firms, organizations, regions, and/or industries (Negro et al., 2012).

Networks

Networks, as the third group of TIS structural elements, are built on relationships among various firms, government, knowledge institutions, and third parties (Musiolik et al., 2012) to transfer both tacit and explicit knowledge (Jacobsson and Bergek, 2004). “*Networks influence the perception of what is desirable and possible, i.e. shape the actors’ images of the future, which then guide the specific decisions of firms and other organizations*” (Jacobsson and Bergek, 2004: P. 818). These network relationships are interpreted as being either orchestrated (e.g., standardization networks, public–private partnerships, supplier partnerships) or less orchestrated (e.g., firm–customer relationships, buyer–seller relationships, industry–university relationships, the social community, public associations, and research interest groups) (Bergek et al., 2008). It has been noted that while formal relationships are easy to explore, the identification of informal ones might require additional connections or sources (Bergek et al., 2008).

Technology

Technology is a direct result of actors’ knowledge assets and the innovation process (Jacobsson and Bergek, 2011). Technology *per se* is an influential element in TIS progression, because it can affect the cost, value, and advancement of an emerging system. However, whether or not technology is considered a structural element of TIS depends on a given study’s approach (Malerba, 2004; Suurs and Hekkert, 2009).

2.2.3 Structural processes of a technological innovation system

Defining each TIS structural element allows us to see how the attributes of the elements can evolve and change as a new industry forms and grows (Jacobsson, 2008). The formation of a new TIS occurs through three structural processes.

The first structural process is associated with the entry of firms and other organizations throughout the full supply chain (Jacobsson and Bergek, 2011). Furthermore, firm entry can contribute to TIS formation in three ways (Jacobsson and Bergek, 2004): 1) they augment the market’s knowledge base and resource bundle, 2) they meet “novel” demand or a “gap” in the market, and thereby increase market expertise, and 3) they improve external economies (e.g., financial assets and network knowledge) and returns for future system newcomers. Therefore, prosperous firm entry can assist and inspire additional firms in entering an emerging market (De Fontenay and Carmel, 2001).

The second process is associated with institution alignments. A technology can obtain legitimacy and actors can access essential resources if they receive institutional support (Jacobsson and Bergek, 2004). An institution can regulate actors (North, 1990) and affect their decisions effectively (Geels and Raven, 2006). Therefore, for the emergence of new technologies, indeed, institutional changes and alignments—especially in terms of policies—are at the heart of the change process (Freeman and Louca, 2002).

The third process relates to the formation of networks in terms of any social, political or learning networks. In this process, actors from different groups form a specific advocacy coalition¹² in support of a technology (Smith, 2000), to affect institutional set-up and alignment (Jacobsson and Bergek, 2004).

When the above structural processes are still forming, the evolution of a TIS is in its formative phase (Jacobsson, 2008). In line with the literature on an industry life-cycle (Bonaccorsi and Giuri, 2000; Utterback, 1994), the formative phase includes processes such as market formation, the entry of firms and actors, and the establishment of institutions and authorities in relation to a new technology (Jacobsson and Bergek, 2004). During the formative phase, a new technology is often relegated relative to already-established technologies (Breschi and Malerba, 2001). The development of a new technology can therefore be tenuous or fail, due to barriers (Carlsson and Jacobsson, 1997). In this phase, small markets form, competition takes shape, institutions develop, and new firms enter the emerging market by overcoming system uncertainties.

Subsequently, when all three processes are realized and in operation, a TIS can shift into a growth phase (Jacobsson, 2008). During the growth phase, the market matures and develops its own features. The growth phase comprises activities such as the implementation of large-scale technologies or the establishment of mass markets. The needs, features, and functionality of the growth phase differ from those of the formative phase; hence, it is a basic mistake to compare the outcomes of the growth phase—like diffusion, performance, and profitability—to those of the formative phase (Bergek et al., 2008).

Summary

The above review illustrates how the TIS perspective explains the emergence of a new technology in a large system of actors, institutions and networks in a specific sector. Identifying the structural elements of an innovation system and explaining the processes behind its development, the TIS perspective further enables a better understanding of factors affecting the emergence of a new technology, both in terms of barriers and driving forces that can influence how a new technology emerges in a market. The TIS framework also allows one to connect a technology's maturity level to various system driving forces and barriers (Foxon et al., 2004).

Thus far, several scholarly studies have aimed to identify driving forces and barriers behind the development and deployment of RETs (Beck and Martinot, 2004; Del Rio and Unruh, 2007; Foxon et al., 2004; Karakaya and Sriwannawit, 2015; McCormick and Kåberger, 2007; Painuly, 2001). The results of studies exploring the barriers comprehensively explain that when a technology is still developing, barriers can relate to any of the TIS structural elements (Foxon et al., 2004; Woolthuis et al., 2005). However, when it comes to the driving forces behind the development of RETs and markets for such technologies (what in this thesis is referred to as renewable energy industry), the roles of institutions—especially policy instruments—have often been

¹² A coalition comprises a group of actors who hold a similar set of beliefs.

highlighted (see, Haas et al., 2011a); and therefore, there is a need for further comprehensive research that combines all various system elements in terms of actor, institution, network and technology.

To contribute to the literature, the first step of this thesis is to develop and present a typology for the systemic driving forces behind the development of the renewable energy industry (OBJ1). Successively, this thesis examines the breadth of existing driving forces for each RET type in various European countries, to explore their importance as well as their actual effect on the development of each RET, across European countries. For doing that, this thesis makes use of the TIS literature (further discussed in chapter 4).

Developing and presenting a typology for the systemic driving forces, this thesis acknowledges that institutions—particularly policy instruments—are not the only driving forces behind the renewable energy industry development, although their role is still pivotal. To better understand this role particularly in the electricity industry, below this thesis takes a closer look at policy instruments that specifically are to increase share of RES-E.

2.2.4 Policy instruments for the renewable electricity industry

Policy instruments are introduced into national electricity markets in a variety of forms and with different objectives. Among other roles, they are meant to support the development of emerging RETs and thereby induce technical changes (Menanteau et al., 2003; Söderholm et al., 2007), or to increase the share of renewable energy sources in electricity production by reducing the cost of RES-E production (Delmas and Montes-Sancho, 2011; Haas et al., 2011b). Policies designed to enhance the cost competitiveness of RETs for electricity generation generally follow two policy routes: 1) they directly influence the price of electricity generated from a specific RET, and 2) they set a desirable level for RES-E production. These two policy routes (also referred to as policy mechanisms) are categorized and labeled, respectively, as price-based and quantity-based policies (Fagiani et al., 2014; Menanteau et al., 2003; Weitzman, 1974).

In price-based policies, a fixed price is determined for a technology; to reach that price, additional policies—such as tax deviation or subsidies—are introduced to the market. The feed-in tariffs (FIT) schemes introduced in countries such as Germany or Spain are known examples of price-based policies. With a FIT policy scheme, regional or national transmission system operators are obliged to feed-in the full RES-E-produced capacity at a fixed price determined by regulators (Menanteau et al., 2003). The price (i.e., tariff) differs according to RES-E type (i.e., wind, solar, bio, or hydro). The tariffs are either set higher than or in addition to the market prices (Ringel, 2006). Accordingly, investors in RES-E receive additional fixed revenue for their renewable electricity production for a defined period of time (e.g., 20 years for solar power in Germany (Karakaya et al., 2015)).

On the other hand, quantity-based policies oblige electricity producers to meet a set target (e.g., quantity). TGC systems, on which this thesis focuses, is a recognized example of quantity-based policies. TGC systems are cost-efficient and technology-neutral policy instruments (Menanteau et al., 2003), and electricity

producers within them receive a certificate for every megawatt hour (MWh) of RES-E production. Depending on the TGC system's design, certain parties with a quota obligation (i.e., obliged parties) shall purchase the certificates (Bergek and Jacobsson, 2010). The obliged parties can be suppliers, distributors, or consumers, and they need to show that a certain proportion of their electricity originates from renewable sources. To do that, they have two options: build eligible renewable power plants, or purchase a certificate from existing RES-E producers. With the second of these options, the RES-E producers receive extra revenue by selling electricity certificates in an artificial market where the price is determined by the supply–demand mechanism.

The technology-neutral designs of TGC systems ensure that different types of RETs are eligible for the same level of subsidies—meaning that electricity produced from any type of RET is sold at official electricity market prices, in spite of their varied production costs¹³ (Madlener and Stagl, 2005). The TGC system is applied in several European countries, such as Sweden, Belgium, and the United Kingdom (see Table 2–1 for an overview).

Table 2–1. Overview of TGC systems in European countries (Ringel, 2006: P. 10)

Country	Year	Demand stimulated by	Excepted sources	Maximum price limit	Sanctions	Validity
Austria	2002	Quota for consumers (non tradable)	-	-	-	-
Belgium	2001	Quota for producers	Waste incineration	Implicit limit given by fixed sanction fees	2004: 12 Ct./kWh fine to regulations authorities	2 years
Denmark	2004/2005	Quota for consumers (20%)	Large hydro >10 mwh, waste	Implicit limit given by fixed sanction fees	0,27 DKK/kWh (=3,63 Ct.) fine to fund for renewable energies	Unlimited
Italy	2001	Quota for producers	Pump water storage	-	Denial of access to transmission grid	2 years
Netherlands	2001	Voluntary	Hydro, waste	-	Loss of tax deduction possibility	-
Sweden	2003	Quota for producers and consumers	Large hydro	-	-	-
United Kingdom	2002	Quota for producers 5% (2003), 10% (2010)	Large hydro >10 mwh, waste	Implicit limit given by fixed sanction fees	0,03£/kWh (ca. 5 Ct./kWh)	Unlimited

¹³ Several countries such as the United Kingdom have reviewed their TGC framework. Based on the new framework, certain RET types (e.g., offshore wind power) is eligible to receive more certificate for every MWh electricity production than others (e.g., onshore wind power).

Table 2–2 presents an overview of price-based or quantity-based policies introduced to increase the shares of RES-E. Note that a combination of these two policy routes is also possible, but it increases the chance of complexity (Hepburn, 2006).

Table 2–2. Overview of the main policy instruments (source: (Haas et al., 2011b: P.2187), reported in (Resch et al., 2008)).

		Price-based	Quantity-based
Regulatory	Investment focused	<ul style="list-style-type: none"> • Investment subsidies • Tax credits • Low interest/Soft loans 	<ul style="list-style-type: none"> • Tendering system for investment grant
	Generation based	<ul style="list-style-type: none"> • (Fixed) Feed-in-tariffs • Fixed Premium system 	<ul style="list-style-type: none"> • Tendering system for long-term contracts • Tradable Green Certificate system
Voluntary	Investment focused	<ul style="list-style-type: none"> • Shareholder Programs • Contribution Programs 	
	Generation based	<ul style="list-style-type: none"> • Green tariffs 	

Given the importance of both policy routes, several studies have analyzed the performance of price-based and quantity-based schemes, to assess the performance of different policy schemes in promoting a larger share of RES-E and, subsequently, to provide recommendations for policymakers on how to improve the design of such schemes. Nevertheless, when putting the results of these studies into perspective policymakers should consider that researchers take various analysis criteria for assessing the performance of policy instruments. For example, thus far, several studies have concurrently analyzed the performance of price-based and quantity-based schemes, to explore which scheme derives better outcomes (e.g., Agnolucci, 2007; De Jonghe et al., 2009; Finon and Perez, 2007; Jaraitė and Kažukauskas, 2013; Johnstone et al., 2010; Ringel, 2006; Verbruggen and Lauber, 2012). The answer varies, but often connotes ‘it depends’ (IPCC, 2011a). The analysis criteria reflect what has been accounted for or disregarded when the outcomes are examined for evaluating the policy instruments’ success. Therefore, only if such analysis criteria are considered, a fair position could be taken on the outcomes of a policy instrument.

Summary

Policy instruments play a pivotal role in the development of industries for sustainable technologies. Similarly, in the electricity industry policy instrument are crucial by stimulating a larger share of RES-E. Currently in the electricity industry, two main routes of policy instruments are enacted to encourage a larger share of RES-E, namely: price-based and quantity-based policy.

This thesis focuses on the TGC framework as a prevalent type of quantity-based policy. TGC systems was enforced in electricity markets of several countries including Australia (MacGill, 2010), 29 states in the United States as of 2012 (Ford et al., 2007), several European countries, including Sweden (Ringel, 2006), which primarily founds the empirical context of this thesis.

The TGC systems of several countries are currently under reevaluation such in Sweden and Norway (Fouquet and Johansson, 2008; Swedish Government, 2014) and the United Kingdom. In this reevaluation

process, academic publications assessing TGC systems play an influential role by shedding light on some of the systems' actual outcomes. Nevertheless, the publications' findings are limited by the analysis criteria that researchers take for assessing the policy-instrument outcomes. Given the importance of these analysis criteria and their influence on the findings, taking a precise methodology, this thesis will shed light on the most common analysis criteria taken for assessing the TGC framework (OBJ2).

2.3 Firms' contribution to the renewable electricity industry

The long development history of the old regulated electricity market is associated with the establishment of oligopolistic firms (in this thesis referred to as incumbents) that tend to hold significant market share (see, European Commission, 2005). Incumbents often hold shares in fossil-based or nuclear power sources. Given their shares and positions in the electricity industry, incumbents therefore favor exiting systems of technology and therefore may resist changes.

Following a same logic, the literature on sustainability transitions discusses that incumbents may block the advancement of new RETs, because the emerging sustainable electricity industry draws into question their established technological assets (Kolk and Levy, 2003; Smink et al., 2015). Incumbents therefore can be a "roadblock" to the development of new technology (Markard and Truffer, 2006), such as that by RETs in the electricity industry (Jacobsson and Lauber, 2006; Stenzel and Frenzel, 2008). Indeed, in industries characterized by path dependence, exiting technologies could be prioritized over alternative options, while not necessary being superior (Cecere et al., 2014). As Grubb (1990, P. 716) states: "*technological advances, and in some cases breakthroughs, are certainly needed: but the revolution required is one of attitudes.*"

With slight variations, the sustainability transition literature tends to define incumbents as old and large firms that enjoy sizeable market shares (see, Hockerts and Wüstenhagen, 2010). In the European electricity industry, multinational energy companies (MNCs) are among the most powerful utility-type firms (see, Stern, 2006), with most being incumbents. The position of MNCs in the European electricity industry is made evident by their power generation market share, which in 2009 was about 90% in France (IEA, 2009a), 85% in Sweden (CEER, 2010), and 85% in Spain (IEA, 2009b).

European energy MNCs are challenged by the ongoing sustainability transition, which draws into question their existing assets—many of which are among fossil-based or nuclear power sources. Incumbents' assets and competencies for existing technologies reinforce their interests in old established systems. Consequently, incumbents are less willing to invest in technologies that are new to their business with uncertain outcomes (Nelson and Winter, 1982; Teece, 2007; Tushman and Anderson, 1986; Wesseling et al., 2013).

Kolk and Levy (2003) explain that institutions including policy instruments can particularly influence the position that incumbents take on the ongoing sustainability transitions (see also, Oliver, 1991). But, in the

case of MNC this institutional pressure is conflicting because of the differences between their home and host countries' institutions (Darmani et al., 2016; Kostova and Roth, 2002).

Indeed, sustainability transitions are dictated to MNCs, not only through the national institutions of their home countries, but also the diverse institutions of the host countries into which their businesses have expanded (Kolk and Levy, 2003). Therefore, in this transition process, MNCs have two options. First, they can follow their core global strategy (Prahalad and Doz, 1987), which is built on similarities across regions (Luo, 2001). This option is often prioritized because of its associated benefits, such as economies of scale, global sourcing advantages (Bartlett and Ghoshal, 1999), and greater control over the decision-making process (Zellmer-Bruhn and Gibson, 2006).

Second, MNCs can conform to diversified national institutions (Kolk and Levy, 2001, 2003) by adapting local strategies (Luo, 2001). This option leads to variations in timing or project types that are taken by MNCs in various countries (Kolk and Levy, 2001). Christmann (2004) shows that the option that MNCs choose can vary with industrial context —although as yet, knowledge of the option taken by MNCs in the European electricity industry, especially after rising concern on climate issues, is lacking. Addressing this knowledge lack is essential at least due to two reasons. First, MNCs are the prevalent players of the European electricity markets and any changes in these markets without their contributions tend to be incremental. Second, this knowledge results in drawing better policy recommendations and market plans by partly explaining the mixed outcomes of policy instruments. Accordingly, an understanding of MNCs responses is essential.

Nevertheless, incumbents are not anymore the only players in the electricity industry, not after the electricity market deregulation, which opened up market boundaries and gave a chance to new entrants to compete in this industry. This specifically can be seen in the renewable electricity industry, because market deregulation encouraged firms of any types to take decisions with environmental objectives (Delmas et al., 2007). Therefore, in the renewable electricity industry RES-E investors comprise not only incumbents, but also the new entrants (Masini and Menichetti, 2013). In fact, deregulation of electricity markets and incumbents' lack of interests in the renewable electricity industry has opened up a unique opportunity for new entrants (see, Negro et al., 2007; Tushman and Anderson, 1986). Such opportunity can be noticed in the momentous contributions of new entrants in the renewable electricity industry (e.g., Bergek et al., 2013b; Hain et al., 2005; Masini and Menichetti, 2013; Wüstenhagen and Menichetti, 2012), although contributions of incumbents and new entrants are varied from one country to another (Stenzel and Frenzel, 2008).

The above arguments suggest that RES-E investors—which encompass both incumbents and new entrants—are found to be heterogeneous. This heterogeneity can be seen among other in various characteristics of RES-E investors, including their types and motives (Bergek et al., 2013b), experiences (Bollinger and Gillingham, 2012; Drury et al., 2012; Wüstenhagen and Menichetti, 2012), investment behaviors (Aguilar and Cai, 2010; Bollinger and Gillingham, 2012; Drury et al., 2012), positions in value chain (Schmidt et al., 2012), belief in a technology or market efficiency (Dinica, 2006; Masini and Menichetti,

2012), risk aversion and propensity for change (Fagiani et al., 2013; Meijer et al., 2007; Worch et al., 2013), and technological capabilities (Delmas and Montes-Sancho, 2011). This heterogeneity is worthwhile because certain characteristics of firms can reinforce their decision for RES-E investments by overcoming their path dependency and thereby explain reactive or proactive responses to governmental policies and to some extent the pace of sustainability transitions in the electricity industry.

Summary

The above literature draws attention to the existing differences between the positions that energy firms may take after the introduction of sustainability transitions into the electricity industry. It specifically distinguished between responses of incumbents and new entrants.

As explained above in the European electricity industry, MNCs are the incumbents with market shares mainly in fossil-fuel and nuclear power sources. To motivate the decisions of MNCs for investment in RES-E, institutions in terms of national policy frameworks and social commitments and norms are assumed to be effective. Nevertheless, the effectiveness of institutions on MNCs' business strategies tends to be conflicting. This is because MNCs need to choose between their core global strategies designed partly in line with institutional frameworks of their home country, or adapt domestic business strategies corresponding to national institutional frameworks of their host countries. This thesis takes a closer look at this choice, in order to explore which position European energy MNCs take on electricity industry sustainability transitions, and what role policy instruments play in these sustainability transitions (OBJ3).

Successively, the thesis discuss that in the renewable electricity industry contributions of new entrants appear to be momentous. Thus far, a number of studies have been undertaken on RES-E investors, to explore what motivates firms of different kinds to contribute to the renewable electricity industry. However, still research on the factors that foster RES-E investors' decision for RES-E needs further contributions (e.g., Bergek et al., 2013b; Wüstenhagen and Menichetti, 2012). This thesis addresses this research need by focusing on firm characteristics that can aid RES-E investors to overcome their path dependence and empower their adaption of technological opportunities (e.g., RETs) in the electricity industry. This thesis contributes to the research literature by leveraging theories on dynamic capabilities—something that has seldom been implemented in the energy literature. Dynamic capabilities are the capabilities of firms that allow them to adapt to changes in a market.

Incorporating dynamic capabilities literature into the sustainability transitions studies enables a better understanding of how heterogeneous RES-E investors respond to the ongoing changes in the electricity industry. Also, said incorporation allows explaining the dynamic of a process through which firms invest in an industry that is experiencing sustainability transitions. As Markard and Truffer (2012: P. 962) state: *“we think that there is much to learn from established concepts and frameworks in other fields, which can be used in a complementary way and to support competing explanations [in sustainability transition studies]. Examples include neo-institutional theory,*

actor-network theory, resource- and capability-based approaches, complex systems theory, institutional and relational economic geography, political and policy sciences and many more.”

2.3.1 Dynamic capabilities perspective

Dynamic capabilities are the firms’ capabilities that allow them to overcome their path dependence and empower their adaption to technological opportunities and changing customers (Vergne and Durand, 2011). Hence, dynamic capabilities facilitate successful adaptation to market changes (Teece et al., 1997). This thesis explains how the landscape of the electricity industry is changing in the midst of ongoing sustainability transitions, all of which call for considerable technological changes in the electricity industry (Krewitt et al., 2007). Subsequently, in line with the dynamic capabilities literature, this thesis assumes that firms with higher levels of dynamic capabilities are better able to contribute to changes that give rise to a more sustainable electricity industry. In other words, firms with a higher level of dynamic capabilities invest more in RES-E and thereby hold a higher amount of technological assets in RETs that produce electricity.

Below, first a review on the concept behind the dynamic capabilities is presented. This thesis borrows theories from dynamic capabilities literature to investigate certain characteristics of RES-E investors that are embedded in their dynamic capabilities. Next, investigating the relationship between the RES-E investors’ characteristics and their amount of technological assets in RETs, the thesis explains which of the characteristics are likely to foster the investors’ decisions for RES-E investment.

The concept behind dynamic capabilities

The concept of “dynamic capabilities” was first introduced to the academic literature by Teece et al. (1990: P. 11), who said that *“our view of the firm is somewhat richer than the standard resource-based view. It is not only the bundle of resources that matter, but the mechanisms by which firms learn and accumulate new skills and capabilities, and the forces that limit the rate and direction of this process.”* In the original standard definition, dynamic capabilities are those capabilities that allow firms to integrate, build, and reconfigure resources in a changing market environment (Døving and Gooderham, 2008; Eisenhardt and Martin, 2000; Teece et al., 1997). Given this definition, the concept of dynamic capabilities is therefore built on a resource-based view.

The resource-based view explains that firms have heterogeneous resources, which are valuable, rare, hard to imitable and substitutable (Barney, 2001; Leiblein, 2011). The resources are sources of competitive advantages for firms (Barney, 1991). The resource-based view explains that how firms with specific resources are capable of gaining considerable profits in a market. It also elucidates that how particular attributes of a firm affect its potential to excel its competitors (Leiblein, 2011; Peteraf and Barney, 2003). Nevertheless, resource-based view falls short to explicate why and how resources are built or changed and this is when the dynamic capabilities perspective comes into use (Ambrosini and Bowman, 2009).

The dynamic capabilities literature focuses on how a firm has to create, change, or renew its resource mix (Teece et al., 1997). Teece (2007) explains that although firms are affected by their history, they are not essentially trapped by their history when they possess dynamic capabilities. In the same study, Teece (2007: P. 1319) disaggregates dynamic capabilities “*into the capacity (1) to sense and shape opportunities and threats, (2) to seize opportunities, and (3) to maintain competitiveness through enhancing, combining, protecting, and, when necessary, reconfiguring the business enterprise’s intangible and tangible assets*”.

Sensing

In the current global environment, opportunities introduced into markets are available to all potential firms, whether they are incumbents or new entrants. Whereas a group of opportunities is easy to spot, there are others that need to be scanned, created, and, in a word, sensed (Teece et al., 1997). Sensing is made viable by searching out and exploring opportunities across both “local” and “distant” markets (March and Simon, 1958; Nelson and Winter, 1982). Inevitably, in this process, competitors can alter the nature of those opportunities if they see and invest in them (Teece, 2007).

Seizing

When an opportunity is sensed, it needs to be exploited through investment in appropriate development and commercialization activities (Teece, 2007). These activities can relate to the implementation of a new/alterd product, process, service, or approach (Lieberherr and Truffer, 2015; Teece, 2007). To select appropriate activities, a firm should decide the strategic path it wants to take; the number of path choices diminishes as a market matures (Teece, 1986). Teece (2007: P. 1327) state “*the issue that the enterprise faces is not just when, where, and how much to invest. The enterprise must also select or create a particular business model that defines its commercialization strategy and investment priorities. Indeed, there is considerable evidence that business success depends as much on organizational innovation, e.g., design of business models, as it does on the selection of physical technology.*”

Reconfiguration

By sensing and seizing opportunities by undertaking appropriate activities, a firm can improve its resource bundle and assets (Teece, 2007). A firm needs to reconfigure its activities and assets if it is to retain its potential to adapt to future changes. This reconfiguration process is costly, because a firm has already-established routines by which to calibrate technological opportunities, and so any changes made to those routines will incur costs (Lieberherr and Truffer, 2015). Accordingly, a firm needs to choose the right time at which to make a change, and reconstruct its routines using its dynamic capabilities (King and Tucci, 2002; Zollo and Winter, 2002).

The definition of dynamic capabilities is not only conceptualized in the studies of its pioneers, Teece and Pisano, but also several other authors contributed to this literature. Eisenhardt and Martin (2000: P. 1107) describe dynamic capabilities as “*The firm’s processes that use resources – specifically the processes to integrate, reconfigure, gain and release resources – to match or even create market change. Dynamic capabilities thus are the organizational and*

strategic routines by which firms achieve new resources configurations as markets emerge, collide, split, evolve and die". Zollo and Winter (2002: P.340) offer "*a dynamic capability is a learned and stable pattern of collective activity through which the organization systematically generates and modifies its operating routines in pursuit of improved effectiveness*". Winter (2003) defines "dynamic capabilities" by elaborating on the concept of "zero-level capabilities." He states that firms with zero-level capabilities produce the same products and on an equal scale, and sell them to the same customers as other firms. In contrast, firms that practice a "new way of product development" (e.g., change their products, product scale, or customers) possess dynamic capabilities (Winter, 2003: P. 993). In a more recent definition, Helfat et al. (2007: P. 1) explain dynamic capabilities as "*the capacity of an organization to purposefully create, extend or modify its resource base*". Ambrosini (2009: P.33) discuss that "*dynamic capabilities are organizational processes in the most general sense and their role is to change the firm's resource base*".

To understand what exactly dynamic capabilities are, it is also beneficial to discuss what dynamic capabilities are not (Ambrosini and Bowman, 2009). First, Dynamic capabilities differ from ordinary capabilities. Winter (2000: P.983) defines a firm capability as "*an organizational capability is a high-level routine (or collection of routines) that, together with its implementing input flows, confers upon an organization's management a set of decision options for producing significant outputs of a particular type*." Given this definition and comparing it with the ones for dynamic capabilities, it becomes clear that dynamic capabilities differ from ordinary capabilities (e.g., operational), because they are combined with changes (Winter, 2003).

Second, Dynamic capabilities follow a pattern and are repetitive; this means that they do not represent a mere reaction to sudden environmental changes¹⁴ (Schreyögg and Kliesch - Eberl, 2007; Winter, 2003). Hence, dynamic capabilities are intentional and are not built on chance (Zahra et al., 2006). Third, dynamic capabilities often couple with strategic changes, although these terms are not synonymous (Ambrosini and Bowman, 2009).

The above review illustrates that the concepts behind dynamic capabilities has been studied remarkably and is concerned with why and how some firms are more competitive than others in a changing market environment. However, yet there are confusions in the dynamic capabilities literature which have partly caused the dynamic capabilities theories to be puzzling and reduced its applicability (e.g., Zahra et al., 2006). Below, the main reasons of confusion are discussed.

Confusions in the dynamic capabilities literature

There are at least three main sources of confusion in the dynamic capabilities literature. First, there are differences between the definitions of dynamic capabilities in different studies. Cepeda and Vera (2007: P. 426) explain that in the earlier research, for instance in the works of Teece and Pisano, dynamic capabilities

¹⁴ A firm's reaction to sudden changes is referred to as an *ad hoc* solving problem. Please refer to Winter (2003) for further reading.

are defined as firm's capabilities that allow them to create, renew and alter their capabilities. In these studies dynamic capabilities are proposed to be similar with competitive advantages. Nevertheless, in more recent studies, dynamic capabilities are not only defined as the sources of competitive advantages, but also as operational capabilities (i.e., how you earn your living) (see, Helfat and Peteraf, 2003; Winter, 2003).

Second, Zahra et al. (2007) argue that in the relevant literature researchers often examine outcomes of a firm to evaluate firms' dynamic capabilities. This inhibits differing between an effect and existence of dynamic capabilities, which in turn results in the characterization of dynamic capabilities to be invisible and hard to observe. Third, the dynamic capabilities literature often suffers from lack of empirical data and measurement methods (Ambrosini and Bowman, 2009; Pablo et al., 2007; Pavlou and El Sawy, 2011).

To avoid sources of confusion when using the theories of dynamic capability, this thesis first takes a specific definition for the dynamic capabilities and second measures dynamic capabilities using a clear and precise methodology. As for the definition, this thesis take the original definition proposed by Teece et al (1997: P. 516) into spotlight: *"Dynamic capabilities [are] the firm's ability to integrate, build and reconfigure internal and external competences to address rapidly changing environment"*. Also this thesis deliberately considers that *"dynamic capabilities are organizational processes in the most general sense and their role is to change the firm's resource base"* meaning that *"a dynamic capability is not a resource. A dynamic capability is a process that impacts upon resources"* (Ambrosini and Bowman, 2009: P. 33,34).

For examining RES-E investors' characteristics that are embedded in their dynamic capabilities, in what follows five hypotheses are built using the theories on dynamic capabilities. Next, a precise measurement method is proposed for each of the characteristics (variables) to clarify how the empirical data are treated. The measurement methods are discussed in chapter 3 presenting methodological approach.

Summary

The aforementioned theoretical arguments illustrate that in a changing market environment, firms with dynamic capabilities are more likely to maintain their competitive advantages, adapt to market changes, and their surrounding environment (Teece, 2000, 2007).

In what follows, this thesis demonstrates that across renewable electricity technology subsectors (e.g., wind power, biopower, and hydropower), RES-E investors follow various investment paths. This thesis only focuses on the investment paths in terms of accumulating experience and diversifying their industrial profile. This choice is motivated because of the significance and relevance of both parameters for the firms' dynamic capabilities.

Drawing on the dynamic capabilities literature, this thesis argues that through certain investment paths, investors can obtain resources. Hence, in this thesis, it is assumed that the investment paths are similar to organizational processes (i.e. dynamic capabilities) through which firms can change their resources (i.e.,

building up certain characteristics that are embedded in their dynamic capabilities). This line of argumentation is inspired by the one proposed by Ambrosini and Bowman (2009). Overall, this thesis expects to observe that:

In the renewable electricity industry, firms follow different investments paths through which they built up certain characteristics that are embedded in their dynamic capabilities. Such characteristics in turn foster the firms' decisions to adapt to changes that give rise to a more sustainable electricity industry, by investing in RES-E and thereby acquiring a higher amount of technological assets in RETs.

In interpreting and measuring those characteristics, this research, first of all, sheds light on the relationship between certain RES-E investor characteristics and their amount of technological assets (OBJ4); second, it assesses the differences in those characteristics across RET subsectors (i.e., wind, bio, and hydropower)(OBJ5). Note that, in this thesis, RES-E investors include incumbents and new entrants.

2.3.2 RES-E investor characteristics: hypotheses and propositions

Investment experience

Dynamic capabilities affect a firm's resources and "*transform [them] in such a way that a new resource bundle or resources configuration is created so that the firm can sustain its competitive advantages*" (Ambrosini and Bowman, 2009: P. 35). This transformation and reconfiguration process is exercised through experience: Teece (1997 : P. 521) asserts that dynamic capabilities are built through experiences, stating that "*The capacity to reconfigure and transform is itself a learned organizational skill. The more frequently practiced, the easier [it is] accomplished.*"

In practice, firms with more experience are identified as having higher-level capabilities to change or improve their current activities and respond to emerging market opportunities (Zollo and Winter, 2002). Experience acts as an instrument for a firm in assessing emerging market opportunities in various ways (Nelson and Winter, 1982). Through experience, firms learn from their incorrect assumptions, explore new markets, and reevaluate their market-engagement decisions (King and Tucci, 2002). For this reason, Baron (2006) identifies experienced firms as players with stronger capabilities to sense and seize emerging market opportunities (Baron, 2006).

Firms can acquire experience in a variety of ways. For example, experience can be obtained through the establishment of large-scale projects or repetition (Papineau, 2006). For the renewable electricity industry, the relationship between cumulative experience and a larger share of assets has been investigated (Neij et al., 2003; Söderholm and Sundqvist, 2007). Hence, this thesis expects to observe that:

Hypothesis 1. An investor's investment experience (herein linked to (a) investment size and (b) investment frequency) within a subsector of the renewable electricity industry positively affects its amount of technological assets in the same subsector of the renewable electricity industry.

In this context, it is important to draw a line between experience gained through “stable activities” that create dynamic capabilities and those that result in static capabilities (e.g., path dependence). Dynamic capabilities can be built on a “*learned and stable pattern of collective activity*”, when a firm can improve the effectiveness of its current and ongoing processes (see, Zollo and Winter, 2002: 530). Such a learning process allows a firm’s activities to be “*performed more effectively and efficiently as an outcome of experimentation, [thus] reflecting on failure and success*” (Ambrosini and Bowman, 2009: P. 35). The accumulation of experience through stable activity patterns is relevant in industries that face technological and regulatory changes (Zollo and Winter, 2002), such as the renewable electricity industry. However, in a stable market environment, accumulating experience on mature and already-diffused technology can lead to path dependence (e.g., Arthur, 1989; Dosi, 1982; Pinkse and Kolk, 2007) and hence create a static form of capabilities.

Management experience

Experience also can be accumulated through the knowledge inherent in human capital—especially that of managers, who direct the employees of a firm (Teece, 2007). The experience, motivation, and expertise of a firm’s managers are thought to play a pivotal role in a firm’s decision-making with regard to exploiting emerging opportunities (Penrose, 1958); they also help decide a firm’s level of dynamic capabilities (Zahra et al., 2006). Indeed, a top-level management team is in a position to influence performance and organizational evolution, and therefore the dynamic capabilities of a firm (Rindova and Kotha, 2001). To capture breath of management experience, this thesis explores the number of firms that a CEO is managing concurrently. This is based on the assumption that a manager can gain his experiences through successive ventures (cf., Parker, 2013). Therefore, this thesis expects to observe:

Hypothesis 2. A firm’s management experience in a subsector of the renewable electricity industry positively affects its amount of technological assets in the same subsector of the renewable electricity industry.

Remarkably, in various RET subsectors within the renewable electricity industry, firms follow various investment path, and this results in their varied levels of experience. Based on the above arguments, accumulated experience can positively influence an investor’s amount of technological assets. Given the various shares of renewable sources in electricity production of Europe in general (see Figure 2–1) and Sweden in particular (see Figure 2–2), this thesis expects to observe:

Proposition 1. In different subsectors of the renewable electricity industry, investors follow different paths to accumulating experience (herein related to (a) investment size, (b) investment frequency, and (3) management experience), which in turn affect capabilities for responding to changes in the renewable electricity industry.

Figure 2–1. Share of renewable sources in electric power production in Europe in 2013 (Source: Eurostat (2015)).

Figure 2–2. Share of renewable source in electric power production in Sweden in 2011 (Source: IEA, 2013)

Unrelated and related diversification capabilities

As members of various industries, firms can access various sets of resources (Musiolik et al., 2012). Given the restrictions imposed by those resources, firms can invest only in a select number of opportunities (Zahra et al., 2006). Firms can hedge the restrictions created by their industrial profile by diversifying their business (e.g., Palich et al., 2000; Teece, 1982). “Diversification is defined by the degree to which an organization expands its pool of resources to discover their varied uses in incomplete markets” (Ng, 2007: P.1484). Firms can diversify their resources into both unrelated and related fields, which necessitates strong and weak forms of dynamic capabilities, respectively (Ng, 2007).

Strong form of dynamic capabilities: unrelated diversification

The strong form of dynamic capabilities is linked to capabilities that allow a firm to make decisions independent of its current resource bundle (Ng, 2007). With the strong form of dynamic capabilities, a firm can explore opportunities that necessitate new resources and improvisational processes (Eisenhardt and Martin, 2000); in this way, it can acquire new “branch” resources in a changing market environment (see, Eisenhardt and Martin, 2000; Helfat and Peteraf, 2003; Helfat and Raubitschek, 2000; Rindova and Kotha, 2001). In other words, a firm possessing the strong form of dynamic capabilities can diversify its resources into unrelated fields (i.e., unrelated diversification) and seek opportunities outside its industrial network (Ng, 2007).

This thesis proposes that in the case of the renewable electricity industry, the strong form of dynamic capabilities (i.e., unrelated diversification) can be seen among RES-E investors who join the renewable electricity industry from industries other than electricity generation, such as agriculture or real estate. Indeed, while a group of firms can have a long operational history in the electricity industry (e.g., electric utility firms), others are new to the industry (Darmani et al., 2014b). In other words, there are firms whose business is dedicated to electricity generation, while others are joining the electricity industry from other industries (e.g., a real-estate company that invests in wind power subsector). This proposal is based on the assumption that investors from industries other than electricity generation (e.g., agriculture) need to acquire new resources, such as those pertaining to knowledge of electricity market legislation, structure, and competition.¹⁵ Therefore, this thesis hypothesizes that:

Hypothesis 3. An investor with capabilities for unrelated diversification (i.e., a diversified industrial background) in a subsector of the renewable electricity industry has a larger amount of technological assets in the same subsector of the renewable electricity industry.

Several scholarly studies have found that firms with diversified industrial backgrounds will enter various RET subsectors (e.g., Bergek et al., 2013b). This thesis examines whether the contributions of firms with a diversified industrial background vary significantly across subsectors. Hence:

Proposition 2. In different subsectors of the renewable electricity industry, investors pursue varying paths to industrial diversification, which in turn affect their capabilities for responding to changes in the renewable electricity industry.

¹⁵ Please note that different industries require different levels of diversification capabilities if they are to engage in the renewable electricity industry. For example, real-estate firms, farmers, or pulp and paper firms require different types of capabilities if they are to engage in the wind or biopower subsectors. However, this thesis distinguishes only between firms whose businesses are dedicated to electricity generation, and others.

Weak form of dynamic capabilities: related diversification

Unlike the strong form of dynamic capabilities, the weak form of dynamic capabilities is built when firms focus on new uses from their existing resource bundles, through related diversification (Ng, 2007). Using the weak form of dynamic capabilities, a firm can reduce redundancies (Penrose, 1958; Zahra and Nielsen, 2002; Zahra et al., 2006) and deploy all its resources (Døving and Gooderham, 2008). Montgomery and Wernerfelt (1988) illustrate that firms are more interested in exploiting their excess resources, rather than creating resources that they do not already possess. King and Tucci (2002) argue that when firms diversify their resources into related fields, they can adapt to market changes more effectively.

This thesis assumes that in the electricity industry, the weak form of dynamic capabilities (i.e., related diversification) can be the case for firms that invest in a diversified generation portfolio—for instance, when a firm with assets in the wind power subsector makes new investments in the solar power subsector. RES-E investors holding a diversified generation portfolio possess assets in more than one RET subsector of the renewable electricity industry. When a firm has assets in one of the subsectors, the firm can draw from its knowledge base on existing legislation, consumer preferences, and local electricity markets, and exploit available opportunities in other subsectors of the renewable electricity industry. Therefore, this thesis hypothesizes that:

Hypothesis 4. An investor with capabilities for related diversification (i.e., a diversified generation portfolio) in a subsector of the renewable electricity industry has a larger amount of technological assets in the same subsector of the renewable electricity industry.

Firms' investment choices of their generation portfolio diversification can vary significantly across RET subsectors. Hence, it is likely that RES-E investors in different renewable electricity technology subsectors will build up different levels of weak-form dynamic capabilities. Therefore, this thesis examines how:

Proposition 3. In different subsectors of the renewable electricity industry, investors follow different paths with respect to generation portfolio diversification, which affects their capabilities for responding to changes in the renewable electricity industry.

Firm age within the subsector, and RES-E investors

This thesis distinguishes market incumbents from new entrants in electricity markets, which is in alignment with the literature on dynamic capabilities. In this literature, incumbents are often identified as old market players with a lack of dynamic capabilities (King and Tucci, 2002; Teece et al., 1997). Paradoxically, new entrants—who tend to be younger in age—exploit emerging market opportunities to reach a favorable position (Meijer et al., 2007; Negro et al., 2007). Bearing the same rationale, this thesis expects to find younger firms to be more assertive in exploiting market opportunities through investments in RES-E; hence, it hypothesizes that:

Hypothesis 5. An investor's age within a subsector of the renewable electricity industry negatively affects its amount of technological assets in the same subsector of the renewable electricity industry.¹⁶

In the above hypotheses, theories on dynamic capabilities act like a model to summarize realities; they do so by mapping relevant variables and illustrating their interrelationships (Teece, 2007). Figure 2–3 illustrates the conceptual model of this thesis with regard to the RES-E investor characteristics that are under scrutiny. Figure 2–3 maps only the variables studied in this thesis; note that there are other variables that affect investors' technological assets, but which lie outside the scope of this thesis (discussed in chapter 5).

Figure 2–3. Conceptual model of this thesis on the relationships between RES-E investor characteristics and their dynamic capabilities¹⁷

¹⁶ As the development of various renewable electricity subsectors began at different points in time, no proposition is put forward based on differences in RES-E investors' ages within various subsectors.

¹⁷ This representation of the relationships among variables is inspired by Masini and Menichetti (2012).

3 Research Methodology

This section will summarize and discuss the three different research methodologies used in this thesis; it will also discuss why these methodologies were chosen and how they were been applied. Therefore, the main aim of this section is to provide a clear view of the research methods used, the data analyzed, and the quality of the results. Furthermore, it discusses the limitation of each methodology used.

3.1 Methodological approach: an overview

To achieve the objectives of this thesis, three different research methods were applied. This thesis's analyses were initiated by undertaking two extensive literature studies corresponding to OBJ1 and OBJ2.

The OBJ1 of this thesis is to explore the systemic driving forces behind the development of the renewable energy industry. Given the diversity of RETs' driving forces across the European electricity markets and the large amounts of data involved, it was not feasible to explore the driving forces by using first-hand data. Fortunately, the basic preliminary literature study pointed to the availability of a notable amount of information in the relevant scholarly papers; this motivated the selection of the literature study method. Therefore, this thesis provides comprehensive knowledge of the driving forces of the renewable energy industry development within the TIS framework through a literature study method.

The OBJ2 of this thesis is to examine the ways in which scholarly studies have assessed the outcomes of policy support schemes. This study explores the analyses criteria that scholarly studies take for assessing the performance of policy instruments (which, in the case of this thesis, are TGC systems) in stimulating a larger share of RES-E. The taken analysis criteria demonstrate which policy-instrument outcomes have been examined for evaluating instrument success. Given its objectives, the literature study is the research method most appropriate to achieving the OBJ2.

The thesis continues its research path, taking an actor-oriented perspective. The thesis OBJ3 of this thesis is to examine the ways in which incumbents of the European electricity industry (i.e., MNCs) have reacted to the sustainability transition happening in this industry. The case study method was selected to achieve the OBJ3 because of two reasons. First, the aims to understand a contemporary phenomenon (i.e., reactive responses of incumbents to sustainability changes in the European electricity industry) (Yin, 2009) and second there are the limited number of MNCs in the European electricity industry, which made it impossible to conduct statistical analyses. Both reasons motivated the choice of the case study.

Following from this study on market incumbents, the OBJ4 and OBJ5 of this thesis focus on RES-E investors—comprising incumbents and new entrants—to understand which of their characteristics foster their decision for investment in RES-E. For doing that, the thesis uses statistical tests to explore the

relationship between the characteristics of RES-E investors—which are embedded in their dynamic capabilities—and their technological assets in RETs. Also, the thesis statistically tests if the characteristics are significantly different across RET subsectors. The results of statistical analyses shed light on the validity of the hypotheses and propositions of this thesis.

Note that this thesis focuses primarily on the electricity industry. Nevertheless, in some analyses it was not possible to distinguish whether the driving forces or firms' strategy had affected the energy industry in general or the electricity industry exclusively. This was the case in the first literature study, which explores the driving forces behind the renewable energy industry development (OBJ1). Indeed, the reviewed papers did not discuss which industry consumes the energy derived from RETs. The second case occurred during the case study analysis. It was not feasible to explore whether energy derived from an MNC's technological assets (both renewable and nonrenewable) was consumed by the energy industry or exclusively by the electricity industry (OBJ3). In both cases, this thesis focuses exclusively on the energy industry (see, section 1.4).

3.2 Methodological approach: step-by-step

3.2.1 Literature study method

An literature study can provide a synthesis of all the dominant studies on a certain topic (Cook et al., 1995). A literature study needs to be systemic, meaning that it should be based on a replicable and detailed methodology (Cook et al., 1997). Below, each of the steps taken in the two conducted literature studies is explained in detail.

First literature study

This thesis's first literature study was conducted in two steps, to ensure that its findings would be comprehensive (Figure 3–1).

Figure 3–1. Methodological steps in the first literature study

Step 1. Literature selection method, and check for relevance

In the first step, relevant publications and the keywords pertaining to RETs' driving forces were identified. The unit of analysis for this literature study is a TIS for a RET. The list of literature keywords was as follows: technological innovation system, innovation system, drivers, motivators, technology push, renewable energy technology, RETs, development, progress, renewable energy, green energy, wind, solar, biomass, bioenergy, ocean, and wave. Subsequently, using these keywords, all the relevant scholarly papers were extracted from two primary research engines—namely, Web of Knowledge and Google Scholar. Next, all the papers' titles and abstracts were scanned, and stand-alone papers particularly pertinent to the driving forces of RETs were set aside. To deal with the extent of the amount of data available and create compatibility among the chosen markets, this thesis limited its analysis to:

- EU-7 countries (United Kingdom, Sweden, Italy, France, Germany, Netherlands, Spain) and Ireland,
- Wind, solar, biomass, and wave energy; this was done to analyze the three most mature types of RETs (wind, solar, and biomass) and also one immature but promising RET.

Furthermore, it was often found that the subject matter of some of the papers overlapped. In those cases, the paper with a broader contribution and more comprehensive analytical framework was selected for the review study. Overall, 30 papers that met all the research criteria and expectations were selected for analysis.

Step 2. Review method

The review process started with an in-depth review of all 30 papers. During this process, all their empirical data on the driving forces behind the development of the renewable energy industry were classified in terms of dimension, country of origin, and technology. Subsequently, using the conceptual analyses of those papers, a first draft of the typology of the systemic driving forces was designed. Next, using the classified empirical data, the typology was enriched, and the peculiarities of each RET were assessed (See section 4.1 for a discussion of the results thereof). Note that in this literature study the focus was on driving forces and therefore any information on systemic barriers was neglected. This means that, although driving forces and barriers in some cases are interrelated, the literature study only focused on the factors that are exclusively identified as a driving force for the renewable energy industry development.

Remarkably, the results of the literature study indicate that an uneven number of publications has been written on various countries. Those results showed that a large share of the publications are about the German energy industry; this can be explained by the renown of the German energy industry in driving renewable energy forward, which has gained considerable scholarly interest. In terms of ranking, Germany is followed by Sweden and the Netherlands. A limited numbers of studies have been written on other countries, such as France, Italy, and even Spain, in spite of those countries' high shares of renewable energy production.

When it comes to the number of publications written on various RET types, while a number of valuable studies examine wind energy development in various countries, knowledge of other RET types—such as solar energy—is lagging behind. For example, while biomass is a fairly well-deployed RET type in Spain, there has been no research to explore its driving forces. It is worthwhile to address this lack of interest (i.e., lack of scholarship, lack of data, and lack of interest in the region) in prospective studies.

Limitations

This literature study suffers from at least two limitations. First, there are some potential keywords that may lead to further findings. Second, this literature study was conducted on both Web of Knowledge and Google Scholar, which led to a large number of papers for the analysis purpose. However, a more precise selection method targeting a single database would have enhanced replicability of this review study. In all, although this literature study successfully captured the 30 most significant papers written on the topic under study, its findings could be extended in future research with a more systematic methodological approach.

Second literature study

The second literature study of this thesis can be summarized in two steps (see Figure 3–2).

Figure 3–2. Methodological steps in the second literature study

Step 1. Keyword search, and check for papers' relevance

In the first step, the main keywords used to conduct the literature study were identified. Given the objective of the second literature study (i.e., to explore the analysis criteria taken to assess TGC systems), a keyword list was derived by using the following search criteria: *(electricit* OR power) AND (certificate*)*. Here, the word “power” refers to the term “electric power,” a term often used in place of “electricity.” Additionally, although the term “TGC systems” has many different synonyms in different countries, in all cases, the word “certificate” is used. Accordingly, these keyword search criteria appeared to provide the full population of papers published on this topic.

The keyword search criteria combination was applied to terms within the titles, abstracts, author keywords, and additional keywords of the Social Sciences Citation Index of the Web of Science Core Collection. This database has been used in earlier research (e.g., Crossan and Apaydin, 2010; Karakaya and Sriwannawit, 2015; Sriwannawit and Sandström, 2015). The literature study was limited to the 2005–2013 period, for the following two reasons.

- TGC systems were enacted in several countries worldwide, between 2000 and 2005; therefore, analyses published prior to 2005 are based on short-term data (see Table 2–2).
- The citation records of papers published after 2013 are significantly limited, and so their inclusion in the analyses of this literature study would skew the final results.¹⁸

The search yielded 199 scholarly papers. Next, the abstracts of all the 199 papers were analyzed, to examine their relevance. In this process, only those papers that sought to analyze the performance of TGC systems were selected. This delimitation process yielded 82 full-text papers.

Step 2. Full-text analysis

In the second step, all the papers were reviewed to extract the two main parameters of each paper: the study's analyses criteria for assessing TGC framework performance, and its respective outcomes. In addition, using the Web of Science database, descriptive and statistical information were recorded for each publication, including citation record, the country of authors' institution, and journal publisher's title. For papers with multiple authors data for each of the authors are recorded. Through this process, an additional 19 papers were excluded from the literature study, given their lack of relevance.

The descriptive statistics of this review study illustrated that the interest in this topic has definitely increased over the years (see, Figure 3–3).

Figure 3–3. Number of publications per year and number of citations per year

The results showed that authors from institutions located in more than 21 different countries had contributed to the literature on TGC system performance. Sweden (14%), the United Kingdom (11%), the United States (11%), and Belgium (10%) were the top-listed countries in terms of their contribution rates.

¹⁸ As will be discussed, the citation records of papers published within each identified criterion were used to investigate the impact of each criterion on forthcoming studies.

Note that each of these countries has an enforced TGC system within its national electricity market (refer to Table 2–1), and each has expectedly attracted the interest of researchers from local institutions.

Besides, of the 63 papers analyzed, 53 focused on a specific country or region for their empirical studies. The top studied countries/regions were Europe (17%), Sweden (16%), the United Kingdom (12%), and the United States (12%). These rankings align with the ranking of countries of authors' institution.

Limitation

In the second literature study, a systematic literature study method is applied to limit any biases with the findings. However, this literature study only relied on the database of the Social Sciences Citation Index of the Web of Science Core Collection. This means that there might be published and valuable papers that are not covered by the second literature study of this thesis.

3.2.2 Case study method

To derive comprehensive actor-oriented insights into the reactions of incumbents to sustainability transitions in the European electricity industry, a longitudinal case study was adapted. As explained briefly at the beginning of this chapter, this methodology was chosen based on this thesis's aims of understanding contemporary phenomena (i.e., responses of incumbents to sustainability changes in the European electricity industry) and creating and validating the propositions (Eisenhardt and Graebner, 2007; Yin, 2009). In addition, as discussed in chapter 2 of this thesis, MNCs are the incumbents of the European electricity industry; the limited number of MNCs in this industry made it impossible to conduct statistical analyses, and these circumstances therefore further motivated the selection of the case study method.

Case selection and description of the enterprise

MNCs are the main producers and prevalent players of the electricity industry in Europe (see, Stern, 2006). Given their age and market shares, MNCs are the incumbents of the electricity markets in various European countries, including Sweden¹⁹ (CEER, 2010). Vattenfall, a leading European energy MNC, was chosen as the case study of this thesis. Vattenfall was founded in 1990 as a state-owned company in Sweden with the major aim of harnessing cheap and clean sources of energy, specifically hydropower. This company currently offers its services in more than seven countries, and its generation portfolio comprises nine different energy sources.

The case study focuses solely on Vattenfall's operations in Sweden, Germany, and the Netherlands throughout the 2000–2013 period. These criteria were selected for four main reasons: 1) 85–90% of Vattenfall's cash flow originates within these three countries, 2) Sweden, Germany, and the Netherlands have

¹⁹ In the report by Council of European Energy Regulators (CEER), five multinational companies with significant market shares—including Vattenfall—are identified as Sweden's "main" energy producers.

different local and institutional frameworks, and this allows for an ideal comparative study, 3) Vattenfall became a leading player in the European energy market after 2000, and 4) in the years between 2000 and 2013, Vattenfall's core strategic plan went through several critical changes, given industrial and institutional changes that took place at both the global and regional levels.

To conduct the case study, first of all, available information and data on Vattenfall's market development were gathered from all kinds of internal and public company documents, annual reports, and news items. Given the open culture of both this MNC and Sweden, a substantial amount of data were obtained during this step. Upon classifying these data in terms of year and country, the time periods and events lacking sufficient data could be identified.

This lack of information was compensated for, by undertaking a number of interviews certain with top-level Vattenfall managers. The interviewees worked in different units at Vattenfall, but all had valuable information on the company's reactions and decisions concerning sustainability transitions in the electricity industry. To triangulate the acquired data, first, additional interviews were conducted with the Swedish Energy Agency and other firms active in Sweden's renewable electricity industry. Second, supplementary data were collected from press releases, newspapers, reports, and others items, to enrich and validate the findings. Notably, given confidentiality restrictions, the precise attribution of quotes to interviewees was not possible.

In addition, to verify and extend the findings of this case study, second-hand data were obtained on several other powerful MNCs active in the European electricity industry (i.e., E.ON, Endesa, and Enel). These MNCs were chosen because they have ownership structures, market responsibilities, and histories different from those of Vattenfall, and accordingly, arguments pertaining to these MNCs could extend the case study's findings.

Limitation

This study is conducted based on a single case study. Although an in-depth case study can provide valuable information about contemporary phenomena, its findings are based on a single case, which draws to question its generalizability. Therefore, further case studies on a same topic are advisable to extend the findings.

3.2.3 Quantitative analysis method

Although there are few MNCs in the European electricity industry, RES-E investors—representing both incumbents and new entrants—are quite numerous and heterogeneous. Therefore, the case study method was not suitable for examining RES-E investors. To analyze the characteristics of RES-E investors and test the hypotheses of this thesis, two statistical analyses of the Swedish TGC database were performed.

Description of empirical context and data

Analyses were conducted on the Swedish renewable electricity industry, for the reasons explained in section 1.4.. The Swedish Energy Agency publishes a database of all investors who received certificates for producing electricity from renewable sources. In Sweden, all renewable electricity sources save for large hydropower plants (>1.5 MW) are eligible to receive electricity certificates. The plants to which certificates are issued belong to one of two groups (Bergek and Jacobsson, 2010: P. 1258):

- Plants constructed before 2003: these plants received certificates until 2012 or 2014, depending on whether they had already received governmental supports,
- Plants constructed between 2003 and 2016: these plants will receive certificates for 15 years.

Each version of the Swedish TGC database is a snapshot of all the plants that had been approved to receive certificates for their electricity production at that point of time. Accordingly, the database fails to provide explicit information on market exits and their corresponding dates. Note that in 2013, the Swedish Energy Agency published a database on 1,400 plants that had been phased out at the end of 2012; as the Swedish Energy Agency declared, this has been the only major phase-out in Sweden, and the number of phase-outs prior to that time was considered negligible.

For the purpose of this thesis, a combination of two databases was used: a database on all the active and approved plants to receive certificates until the end of 2013, and a database on the 1,400 plants phased out at the end of 2012. Hence, the analyses of this thesis do not investigate market exits. Additionally, note that an unknown number of renewable power plants were not registered in the certificate database, as they either did not apply to receive them, or were not eligible. This thesis examines only the data available in the certificate database, rather than assess the full population of plants functioning in Sweden. Table 3–1 summarizes the data available from the database analyzed in this thesis.

Table 3–1. Summary of data available from the Swedish electricity certificate database

	Number of plants (including private persons) ^a	Number of plants (excluding private persons)	Number of firms ^{b,c}	First year of investment
Wind power	2227	1897	663	1983
(onshore)	(2158)	(1829)	(661)	(1983)
Biopower	215	208	144	1948
Hydropower	1239	910	369	1890
Solar power	461	135	82	2001
Total	4140	3150	1211	1890

^a Plants' name are used to distinguish between the plants.

^b Organizational numbers of plants' owner are used to distinguish between firms (RES-E investors)

^cAs firm is the unit of analysis for this thesis, plants owned by private persons are excluded from the analyses.

The database yielded data on the plant name, plant owner (firm), organizational number of owner, plant capacity, the first date that a certificate was obtained for electricity production by the plant, and the plant's location (electrical region, state, municipality, and region). Organizational numbers are used to distinguish among firms investing in RES-E.²⁰

To proceed with statistical analysis in this thesis, further information on each firm was obtained from other sources. For each firm, data on 1) registration date as an official entity in the Swedish companies registration office (*Bolagsverket*),²¹ 2) partnership status, 3) current chief executive officer (CEO) (or management board), and 4) industrial classification code (SNI) were extracted from the official website of *Allabolag*.²² It needs to be noted that if no data were found for one or more variables, those variables were reported as missing values. Missing values are illustrated in Table 4–4.

To categorize the industrial backgrounds of RES-E investors in Sweden, the first (primary) SNI code for each firm was extracted. An industry was distinguished as a category only if it comprised a minimum of three investors. Industries with fewer than three investors were amalgamated under the category “others.” Notably, several firms were found to simultaneously offer services in several industries, such as electricity generation, consultancy, and agriculture; however, as this thesis considers only the first SNI code of each firm, the issue of multiple responsibilities could be neglected.

The analyses reported in this thesis were performed for the period from 1996—when Swedish electricity deregulation was initiated—to the end of 2013. This thesis calls for analyses on two levels: on a single-subsector level, and across several renewable technology subsectors (corresponding to research question 2.2). For analyses at the single-subsector level, the case of onshore wind power was selected and the case of offshore wind power is excluded from the analysis. This is because, first, onshore wind power is a fairly mature RES-E type with a high potential (GWEC, 2013), and its construction is not limited to a specific location or industry. These circumstances allow for the engagement of a more heterogeneous group of investors. Second, wind power has a worldwide development history in excess of 40 years (Jacobsson and Bergek, 2011), and in Sweden, at least 20 years of continuous investment (based on data obtained from the TGC database). This extensive history allows for solid longitudinal analyses. Note that the analyses of this thesis showed that only three firms invest exclusively in offshore wind power.

A comparative study was conducted of investors in onshore wind power, biopower, and hydropower, to explore firm characteristics embedded in their dynamic capabilities (Propositions 1–3) across subsectors. The case of solar power was excluded, because its contribution to electricity production in Sweden is minimal

²⁰ Note that this thesis delineates neither firms' partnership backgrounds nor their related competencies.

²¹ The Agency collects data from *Bolagsverket* (the Swedish companies registration office).

²² *Allabolag* belongs to a service agency that brings together Swedish companies' business information. The website gathers data from the Swedish companies registration office (*Bolagsverket*), the Swedish Tax Agency (*Skatteverket*), and Statistics Sweden. This website is acknowledged by the KIA index (the official measurement index for Swedish websites) as one of the most frequently used sources of information.

(see Figure 2–2) (IEA, 2013). Nevertheless, the case of solar power still is considered when measuring firms' capabilities for diversifying into related fields.

Operationalization of variables

Figure 2–3 illustrates this thesis's conceptual model that was built on the five hypotheses of this thesis on RES-E investors' characteristics. To statistically test Hypotheses 1–5 and examine Propositions 1–3, one dependent variable, six independent variables, and three control variables were measured. The results of the statistical analyses are presented in section 4.2.3. and 4.2.4. The variables were measured as follows.

Dependent variable. *Technological assets* were measured by recording the cumulative installed capacity of each of the investigated RET subsector (i.e., wind power, biopower, and hydropower), separately and for each investor as of the final year of analysis (i.e., 2013).

Independent variables. The *investment experience* of an investor was broken into two separate variables—namely, investment size and investment frequency.

Investment size of an investor was measured by the average size of investment made by each investor in wind power, biopower, and hydropower, separately. This amount was measured by dividing the amount of cumulative installed capacity in each subsector by the total number of registered plants in the same subsector for each investor.

Investment frequency was captured into the total number of years in which an investor made investments, within the time span under study.

Management experience was measured by extracting the name of a firm's CEO and recording the number of firms managed by the CEO as of the final year of analysis. Thus, the number of firms managed by the same CEO represents management experience. For firms managed by a board of managers, the number of firms managed by each board manager was extracted, and the maximum number was used to represent the firm's management experience.

Unrelated diversification (industrial background) was defined as a binary variable; it distinguishes between investors whose main industry is electricity generation (=1) and those whose main industry is not (=0: firms with unrelated industrial background and therefore unrelated diversification capabilities).

Related diversification (generation portfolio) relates to the number of RETs in which an investor has made an investment. When this variable's value is equal to 1, it indicates that a firm invested in only one subsector (e.g., investment solely in wind power = 1); however, when that value is 2, 3, or 4, it indicates that a firm invested in more than one type of RET (e.g., investment in wind power, biopower, and hydropower = 3) and thus has a diversified generation portfolio.

Firm's age within a subsector is measured by subtracting the first year that a firm made an investment in the same

subsector from the final year of analysis.

Control variables. In separate steps, different control variables were introduced into the model to provide possible alternative explanations.

Firm age is measured by subtracting the final year of analysis from the firm's registration date as listed in data from the Swedish companies' registration office (*Bolagsverket*).

Number of invested regions is measured by counting the total number of municipalities in which the firm has made an investment. In many countries, firms need to acquire permission to construct RET power plants (e.g., wind or hydro). This permission process often varies by municipality (see for example, Del Rio and Unruh, 2007). Figure 3–4 illustrates the municipalities of Sweden.

Figure 3–4. The municipalities of Sweden

Firm's partnership status is defined as a binary variable that distinguishes firms with a parent company (=1) from firms without one (=0).

Data analysis, and results quality

To analyze the empirical data, two different analyses were implemented.

Analysis 1: Linear regression modeling

Analysis 1 aimed to explain the relationships between certain characteristics of onshore wind power investors²³ and their amount of technological assets, thus testing Hypotheses 1–5. The analysis, using ordinary least squares (OLS), mapped the relationships as at the end of 2013.

To observe changes in the variables under study, two additional OLS estimates were applied while changing the final year of analysis from 2013 to 2008 and then to 2003. This was done only to observe trends in those

²³ For simplicity, these will be referred to as “wind power investors.” However, please note that in this thesis, only data pertaining to investment in onshore wind power are analyzed; all offshore investment is excluded from analysis.

variables, rather than to test or demonstrate any assumptions regarding those trends. Explaining trends in the variables necessitates gathering knowledge on several other market parameters and changes in those parameters, and doing so lies outside the scope of this thesis²⁴. The years 2008 and 2003 were chosen, because within the Swedish TGC framework—which is considered the most prevalent institutional driving force behind wind power development in Sweden—those years are considered momentous:

- 2003: initiation of the TGC system
- 2008: the year in which TGC recorded its highest market prices (see Figure 3–5)
- 2013: the final year of analysis

Figure 3–5. Trends in TGC prices in Sweden from 2003 to 2013 (in Swedish kronor) (Source: skm.se)

Durbin–Watson tests were implemented following these analyses, to check for the presence of any autocorrelation among model residuals. The test results ascertained the assumption of independent errors (Field, 2013). The tolerance score and variance inflation factor (VIF) were then used to check for the possible presence of multicollinearity between the independent and control variables. According to Bowerman and O’Connell (1990), any VIF substantially different from 1 indicates a problem with the variables; as the VIF here ranged from 1.087 to 3.352, the results indicate a lack of multicollinearity problems within the data.

²⁴ Please bear in mind that as *Allabolag* provides only information on the current CEO of each firm, the calculation of this number for the years 2008 and 2003 was done by assuming that the same CEO had been directing the firm through its lifetime. This may not be true; however, analyses of the years 2003 and 2008 were conducted only to provide insights into trends of the characteristics under study, and not to demonstrate any causality.

Note that, as explained in section 3.1.3, although the Swedish TGC system was enacted in 2003, the plants constructed before 2003 had also received certificates for electricity production. However, the numbers of entries before and after 2003 could vary significantly, and therefore affect the results of the regression analyses. This is because, first, there is the possibility of there being missing entries from before 2003; second, the Swedish TGC system encouraged far larger investments in RES-E after 2003. Therefore, to ascertain the results' reliability, the model was tested with two periods—namely, 1996–2013 and 2003–2013. The analyses yielded the same results.

Additionally, to ensure the results' reliability, the initial plan was to conduct the regression analysis on all the available subsectors and compare the results. However, given the limited number of firms investing in biopower and hydropower (see Table 3–1), the assumptions for regression modeling could not be satisfied.

Analysis 2: Differences among several independent groups: Kruskal–Wallis and Mann–Whitney tests

To explore the heterogeneity of the investors' characteristics in wind power, biopower, and hydropower in Sweden, Kruskal–Wallis tests were applied. The tests statistically measured differences among the three subsectors (Propositions 1–3). Note that the aim in taking this step was not to test the hypotheses, but rather to compare several groups and evaluate Propositions 1–3.

Generally speaking, the Kruskal–Wallis test is applied to data that are non-parametric in nature (Kruskal and Wallis, 1952). In this thesis, if the results of the Kruskal–Wallis tests were to indicate significant differences among the subsectors, then Mann–Whitney tests (a non-parametric *post-hoc* procedure) would be used to compare the variables' rankings. Nonetheless, one shortcoming of the Mann–Whitney test when applied to several groups is that it can increase the chance of a type I error, wherein even though the results are believed to be valid, they are not. To restrict the chance of raising a type I error in the Mann–Whitney test results, the Bonferroni correction method was applied (Field, 2013). With this method, the critical value (often estimated as 0.5) is divided by the total number of groups in a study, which in the case of this thesis is three (i.e., wind power, biopower, and hydropower). Accordingly, in this analysis the significance level of 0.0167 ($0.5 / 3 = 0.0167$) was used.

Both Kruskal–Wallis and Mann–Whitney tests leverage data rankings. This means that in both tests, rather than analyze the actual data, the rank of one piece of data is compared against that of another (i.e., the rankings of wind power, biopower, and hydropower against one another). In this way, the influence of a few extremely large or small outliers could be ignored (Field, 2013).

As in the last step of analysis 1, in that of analysis 2, both the Kruskal–Wallis and Mann–Whitney tests were applied to two different time periods—namely, between 1996 and 2013, and between 2003 and 2013. The analyses yielded the same results.

Limitations

This thesis proposed a new, yet precise methodology for measuring the characteristics of RES-E investors that are embedded in their dynamic capabilities. Note that in the dynamic capabilities literature, it is common to measure a firm's level of dynamic capabilities by undertaking a survey study. In this thesis, the initial plan was to measure investors' dynamic capabilities by using a survey and comparing the results thereof with those of this thesis's statistical analyses. However, on account of the low survey response rate (1%), this was not feasible. Nevertheless, it is still advisable to further validate the results of this thesis by using other methodological approaches comprising different measurement methods.

Besides, as with any estimation, the conceptualization of a regression is based on a number of assumptions such as the independence of the error terms. This thesis is aware of the existence of unobserved factors that are not captured in the analyzed data and yet might have an impact on the dependent variable (i.e., technological assets).

4 Findings and Empirical Analysis

This section summarizes the findings and outlines how they contribute to the overall objectives of this thesis.

4.1 What are the driving forces behind the development of the renewable energy industry?²⁵

4.1.1 Systemic driving forces behind the renewable energy industry development

Today, climate change is among the greatest concerns in society. Climate concerns will not be effectively addressed unless multilateral drivers, agreements, and solutions are brought forward in the energy industry (Björheden, 2006).

Thus far, several studies have explored the system driving forces and barriers behind the renewable energy industry (e.g., Clément et al., 2002; Del Rio and Unruh, 2007; Foxon, 2003; Haas et al., 2004; Haas et al., 2011a), even though knowledge of the barriers has become more developed (e.g., Negro et al., 2012; Owen, 2006; Painuly, 2001; Woolthuis et al., 2005). One may argue that the system's driving forces of renewable energy development are the flipside of the system's barriers; however, there are distinctions among driving forces and barriers, as they can originate in different phases of market evolution and expansion (in section 2.2. the different phases are explained). Therefore, knowledge of driving forces of the renewable energy industry development needs to be extended (OBJ1), if better insights are to be garnered into the factors that can not only accelerate the development of RETs (Darmani et al., 2014a) but also contribute to the success or failure of an emerging TIS (Truffer et al., 2009). Knowledge of the systemic driving forces can be used by policymakers as a tool by which to establish suitable strategies (Björheden, 2006; Växande energi, 2003) or effective policy designs (Foxon et al., 2004; Gan and Smith, 2011) and hence augment the development process of RETs.

Until 2011, few researchers explored the driving forces behind the renewable energy industry development with a systemic perspective. Among others, Jacobsson and Bergek (2004) suggest that the inducement mechanism of RETs may relate to government policy, firm activity, and feedback from market formation. Markard and Truffer (2006) propose that the deployment of innovation processes that are as radical as expected for the advancement of RETs may depend upon the actors' economy, supporting policies, the demand of customer segments, niche markets, reverse salient and technological development, and knowledge breakthroughs, or any interplay of these factors. Björheden (2006), by evaluating the Swedish

²⁵ The arguments provided in this section aim to further conceptualize and elucidate the discussion that takes place in the first published paper of this thesis's author.

forest energy industry, discusses the driving forces behind such technologies can be introduced by any of policies, economic pressure, public opinion, and research activities. Nevertheless, to the best of the author's knowledge, still the literature needs further comprehensive overviews of the driving forces behind the renewable energy industry development, combining various system elements in terms of actors, institutions, networks and technologies.

By undertaking a literature study of 30 relevant papers (see section 3.2.1), this thesis enters this vein of research and proposes a typology for the systemic driving forces of the renewable energy industry development. The typology yielded 12 different categories embedded in four structural elements of TIS, as well as a dimension of region (see Figure 4–1). The typology further suggests that energy-related policies are not the sole driving forces behind the emerging renewable energy industry (see, Del Rio and Unruh, 2007; Foxon et al., 2004). Below the details of each dimension, and factor are described precisely. The identified dimensions and categories are explained below.

Figure 4–1. Typology of the driving forces behind the renewable energy industry development (Source: Darmani et al. (2014, P. 839))

Typology of the systemic driving forces behind the renewable energy industry development

Incentives for actors

For a TIS to evolve, committed actors are essential at different system levels. This importance intensifies in the case of RETs, since even though transition might happen on a relatively small scale it affects a variety of

stakeholders in different domains of society (Meijer et al., 2006). Therefore, *“for all actors involved in the decision making process the question of acceptability is at stake”* (Wüstenhagen et al., 2007: P. 2628). The RETs’ driving forces that originate in the actors dimension can be categorized into four groups. Note that the literature study showed that energy firms (i.e., energy producers) are often been in focus as the main actors of the energy industry and due to that the identified driving forces of this dimension (i.e., actors) relate more to this actor group.

Economic

The energy market is exceptionally capital intensive (Markard and Truffer, 2006). Hence, financial reasoning is influential on actors’ (e.g., energy firms) decisions to engage in technological innovation. Holding a leading position in an energy market forces energy firms to plan their strategies with respect to market demands to maintain their profitability. Evidence of this is the reluctance of firms to engage in new technological projects with an absence of financial incentives (Bergek et al., 2008).

Innovation is one of the main pillars of economic growth. Therefore, provided that there is a positive outlook concerning the future of a new technology, financial incentives are attainable. This is clear with RETs, since some sources cite certain RETs’ relative cost efficiency as one of the main driving forces of energy firms’ decisions to invest in such projects (Del Rio and Unruh, 2007; Jacobsson and Bergek, 2011). Unexploited potential and the knowledge available in the market lead to the crystallization of opportunities in profit and competitive advantage (Foxon, 2003; Foxon et al., 2004) through innovation. Notably, while progress in a given technology brings innovation to a system, innovation is associated with novelty in adaptation, organizational structure and other areas that all benefit a system as a whole (Foxon et al., 2004).

Competences

Global competition implies that organizations must be able to operate successfully in diversified markets (O'Neill and Sohal, 1999). A firm always risks losing its position due to the emergence of a new technology (Negro et al., 2012) or competitors (Wüstenhagen and Bilharz, 2006). Gaining new competences through investment in new technologies to counteract these threats is therefore a strong driving force. Hence, competence incentives clearly affect the way that the market and its actors choose both old and emerging technologies (Negro et al., 2012). Wüstenhagen and Bilharz (2006) highlighted this phenomenon in the energy industry by introducing the ambition of differentiation as a strong motivation for establishing RETs in both start-ups and incumbent utilities.

Targets

Targets are becoming significant driving forces of innovative decisions in the energy industry (Dalton and Ó Gallachóir, 2010). Government targets or those of the firms themselves have bound actors’ decisions and have shaped investment plans. At the present time, specified targets at the continental, national and

firm levels have encouraged actors' ambitions to contribute to the renewable energy industry. A clear example of this case is the European Commission's 2020 target (European Commission, 2012a), the speed of response to which has varied between countries (Haas et al., 2004).

Structure

Change acceptance within a market is another inherent characteristic that encourages RETs development (Del Rio and Unruh, 2007). Level of change acceptance could be analyzed at both the (national energy) system and firm level. A flexible and cooperative system is more responsive to oncoming technical changes, while lack of flexibility in a system (Jacobsson and Bergek, 2011) or a firm (Woolthuis et al., 2005) has been pronounced as one reason that hinders the viability of RETs. The Swedish experience with incumbent technologies (i.e., nuclear power) (Jacobsson and Bergek, 2011) and the global lock-in fossil fuel system (Negro et al., 2012) offer good examples of this situation.

Institutional incentives

Firms competing in the energy industry are inevitably influenced by their surrounding institutional framework (Jacobsson and Bergek, 2004; Van de Ven and Garud, 1989). The critical role of institutions in the energy industry (Woolthuis et al., 2005) and ensuring that a new technology takes off (Freeman and Louca, 2002) is widely acknowledged.

As discussed in chapter 2, institutions in general have been defined in two main ways: hard and soft institutions. Hence, for the sake of clarity, the identified factors as the driving forces are split into hard and soft institutions.

Hard institutions

Energy policies, as the most known forms of hard institutions, have been one of the most scrutinized topics in recent decades (Jacobsson and Bergek, 2011; Lewis and Wiser, 2007; Lund, 1999; Lund, 2008). Political intervention is a key factor in technology transition in the energy sector (Jacobsson and Bergek, 2004, 2011). The effectiveness of these policies depends on the following three attributes.

1. Policy formality: Energy policies encouraging RETs development differ from country to country in terms of both type and level of support. Variations may arise in demand-side policies such as tax exemption, supply-side policies such as advanced cost-reducing schemes (i.e., feed-in-tariff, certificate system) (Wüstenhagen and Bilharz, 2006), and policies to facilitate the regulatory framework for authorization and permission procedures (Foxon et al., 2004; Haas et al., 2004; Jacobsson and Bergek, 2011). Thus, policies' supportiveness and effectiveness play an influential role on the progress of RETs.

2. Policy stability: The second attribute is associated with energy policy long-term stability concerning a specific technology. The extent to which an energy firm is convinced of constant and supportive energy policies undoubtedly affects its future planning. Clear examples of this are the highly successful

development of wind and solar power in Germany (Wüstenhagen and Bilharz, 2006) and Spain (Del Rio and Unruh, 2007).

3. Policy conformity: Regulatory frameworks in different regions and harmonization between them are also driving forces of the renewable energy industry development. This uniformity, which promises a smooth development process, could exist at both the continental (i.e., across Europe) and national (i.e., between a country's regions) levels. The European Commission has emphasized the advantages of harmonization across Europe (European Commission, 1998). Nevertheless, energy firms in Europe are still deploying divergent climate policies (Hamilton et al., 2003) and adopting different strategies and planning processes in different regions (Baron, 1997; Kolk and Pinkse, 2004).

At the regional level, ensuring uniformity of regional policy and the consequences of this action demonstrates the importance of harmonization. The Spanish experience in the wind and solar power sector exemplifies this. Scholars have indicated that unconformity of regional policies has hindered RETs development and increased the difficulty for these technologies to break through (Del Rio and Unruh, 2007).

Soft institutions

The literature review of this thesis showed that soft institutions affect the development of the renewable energy industry through market norms and societal norm.

Market norms: development of the renewable energy industry is a long and uncertain process. During this process market norms can act as both a stimulus and a limitation, which can be characterized by:

- innovative entrepreneurs (Meijer et al., 2007),
- entrepreneurial spirit (Negro et al., 2012),
- culture for shaping suitable public policy and regulation environments (Smith, 2000),
- trust and risk tolerance (Meijer et al., 2007; Woolthuis et al., 2005),
- willingness to share resources (i.e., other actors) (Woolthuis et al., 2005).

Based upon their inherent features, market norms inevitably determine the extent of innovativeness and consequently the development of the renewable energy industry.

Societal Norm: Although academics have neglected to perform in-depth research into social norms, their importance as both driving forces and barriers in the TIS formation for RETs is significant (Wüstenhagen et al., 2007). This importance is so great that society norms are proposed as the main explanation for varied development rate of RETs in different countries (Toke et al., 2008). Social factors are often strong driving forces of changes in energy markets. A clear example is the willingness of retail customers to pay more for electricity from renewable sources (Eurobarometer, 2003; Wüstenhagen and

Bilharz, 2006). This interest in the society is what that accelerated the development of the renewable energy industry.

At present, due to the society's positive opinion of RETs, policymakers believe that social acceptance is no longer a barrier to the development of the renewable energy industry. In reality, however, the experience has revealed a different scenario (Bell et al., 2005). Occasionally, opposition to the installation of new sites and facilities is an obstacle to developing RETs, such as is the case with the UK's experience of wind energy development (Foxon et al., 2004).

Network incentives

The third recognized structural component of TIS is associated with elements related to the system's network. The driving forces of network dimension for the renewable energy industry development can be subdivided to two main categories.

Strength of supply chain network

The first acknowledged stimulus group of this dimension is linked to the availability of essential actors and their interrelations in a network. As discussed, the energy system encompasses a variety of players. The actors range from suppliers and manufacturers to political authorities (Clément et al., 2002; Foxon et al., 2004). Although achieving cooperation between them may seem challenging, convenience of access and availability of all the required actors in a supply chain promises to be a successful system establishment. Effective and efficient interaction among system actors is found in a variety of processes such as network information (Clément et al., 2002), learning problem-solving techniques and competence sharing (Woolthuis et al., 2005). Overall, this category has formed one of the most dominant driving forces in the system.

Societal networks

As discussed, social norms and the green movement within a society influence the awareness and preferences of actors in a system. This, therefore, stimulates private initiatives by society through the formation of independent associations, NGOs and communities as well as increasing the number of private customers. Results of this driving force could be assessed using an eco-labeling scheme by NGOs (Truffer et al., 2001; Wüstenhagen and Bilharz, 2006), private customers' investment in small-scale projects in their territories (Negro et al., 2012), non-residential customers' (i.e., government authorities), superior investments in green energy (Wüstenhagen and Bilharz, 2006) and others metrics²⁶ that measure enhanced motivation at the system level.

²⁶ For more examples, refer to Wüstenhagen, R. and Bilharz, M. (2006).

Technological incentives

The importance of the technological dimension is clear from the title of TIS. Technology is an inseparable element of a technology-based industry. It is assumed that introduction of a new technology or improvement of an existing one may drastically change the functionality of an industry or a society (Del Rio and Unruh, 2007; Farzin et al., 1998; Foxon, 2003). Therefore, technological progress could be one of the main motives for firms to change their business logic or consider transformation (Farzin et al., 1998). When examining the motivators of the development of the renewable energy industry, the contribution of the technological dimension is based on the following three categories.

Technology specifications

Both practicality and profitability of a technology are dependent on its status and maturity. Nonetheless, adaptation of a new technology requires significant effort and suitable timing, since arriving too early or too late to the market may change the future of a technological transformation (Farzin et al., 1998). This driving forces can be noticed in the development history of the most mature type of RETs, namely wind power (Del Rio and Unruh, 2007).

Additionally, RETs have their own stand-alone specifications due to their dependence on natural sources. These specifications make energy firms' somewhat biased in their decisions regarding the development of each RET type (Del Rio and Unruh, 2007). While technological maturity of a RET is an important element due to its direct impact on the technology's cost, generation capacity and practicality, the energy source (e.g., wind, solar, tidal) by itself influences the assurance of supply and the maximum generation capacity. This can be illustrated by the differences between natural qualities of tidal and wind power. While tidal energy is based on a reliable and fairly constant source of renewable energy, the more inconsistent wind transmission technology is the main source for the production of wind power.

Technology infrastructure

It is often assumed that for firms to succeed, physical and solid knowledge infrastructures are essential (Negro et al., 2012; Woolthuis et al., 2005). These infrastructures effectively strengthen the foundation of an emerging system.

Physical infrastructure refers to technical structures that form the functional basis of a society including but not limited to: grid connection, infrastructure, accommodation and facilities (Negro et al., 2012; Woolthuis et al., 2005). Evidently, energy firms' decisions on investment in RETs are dependent on these infrastructural factors (Negro et al., 2012). Strengthening infrastructure would therefore add additional value and motivation to the system.

On the other hand, knowledge infrastructure encompasses elements such as knowledge, skills and training (Smith, 2000; Woolthuis et al., 2005). This category can contribute to enrich the existing

knowledge in a network, inspiring perceptions of what is probable and favorable in the system; and therefore influencing network perception and the possibility of new system emergence.

Regional incentives

In this thesis, regional incentives is the only stand-alone acknowledged dimension for driving forces of the renewable energy industry development that is not a structural element of TIS. Consideration of the regional dimension as one of the main dimensions of the driving forces is due to the pivotal role of regional attributes on RETs evolution.

Regional attributes

Regional attributes are features inherent in the geography of a region in which a technology is planned to function. Such attributes can be influential in two distinct ways. First, they determine the availability of a source of a RET in a region. Extensive coastlines to harness wave or tidal energy or large sunshine duration for solar power generation are clear examples of this factor.

Second, environmental vulnerability is another regional attribute, which can influence development of an industry for a RET. Scientifically speaking, harnessing different source of renewable energy has some unavoidable side effects on both the biodiversity and ecology of an environmental system. These impacts might be that they interfere with the ecological system of a region and consequently with other regional industries such as agriculture. Thus, the current environmental status of a region and the existing industry are influential factors in the development of the renewable energy industry.

As explained in the methodology section, this thesis explored the driving forces behind four types of RET (i.e., wind, solar, biomass, and wave energy) in EU-7 countries and Ireland. The identified driving forces of RETs in the countries studied are listed in Table 4–1. Those driving forces are categorized in terms of dimensions, RET subsector, and countries (refer to, Darmani et al., 2014a: P. 843).

Table 4–1. Overview of driving forces behind the development of renewable energy industry per country and technology (edited from , Darmuni et al., 2014a: P. 840-841)

Country	Energy Source	Drivers					Reference
		Actors	Hard	Institutions Soft	Network	Technology	
United Kingdom	Wind Energy	Considerable number of Project development (learning-by-doing)	Policy Support (granting site license; financial support; obligation certificates; quota scheme)			Technology advancement (on-shore)	(Elliott, 2000; Foxon et al., 2004; Szarka, 2006)
	Solar Energy	Considerable number of Project development (learning-by-doing); R&D effort; prospective market opportunity	Supporting policies (quota scheme; Specifically Funding)				(Foxon et al., 2004)
	Biomass	R&D effort; High level of business risk acceptance	Policy support		Availability of all actors; availability of strong overseas developers; Active niche markets		(Foxon et al., 2004; McCormick and Kåberger, 2007; Upreti, 2004)
	Wave Energy	R&D efforts	Policy support (Funding - until 1999-, SRO3*)				Potential resource (Clément et al., 2002; Foxon et al., 2004)
	Wind Energy		Policy Support (tender system' encouraging off-shore energy framework)	Established public support; awareness about dependency on depletable fossil fuel	Technology improvement	Potential resource	(Dalton and O Gallachóir, 2010; Held et al., 2006; Routke et al., 2009)
Ireland	Solar Energy		Policy pressure (Taxation)	Awareness about dependency on depletable fossil fuel	High potential of technology		(Jäger-Waldau, 2007; Routke et al., 2009)
	Biomass	Firms and Farmers interest (e.g. additional income)		Environmental awareness (awareness about dependency on depletable fossil fuel)			(Augustenborg et al., 2012; Routke et al., 2009)
	Wave Energy	Targets incentives	Policy Support (R&D funding, FIT*, encouraging off-shore energy framework; AER-3*)	Public awareness	Public support (Mainly funding); Organization cooperation (universities and research centre and research funding)	Potential resource availability	(Clément et al., 2002; Dalton and Ó Gallachóir, 2010; Routke et al., 2009)

Table 4-1. Overview of driving forces behind the development of renewable energy industry per country and technology (continued)

Country	Energy Source	Drivers					Reference	
	Atoms	Hard	Institutions	Soft	Network	Technology	Region	
Sweden	Wind Energy	Policy support (certificate system with low prices)	Positive public opinion			Technology improvement (Cost reduction)	(Bergek and Jacobsson, 2010; Gan et al., 2007; Held et al., 2006) (Jacobsson and Bergek, 2004)	
	Biomass	Political support (additional funding, grant for switching to bioenergy; certificate system)	Governmental awareness (Awareness and requirement of shift from nuclear power and imported oil); Public opinion (interest in green technologies)		Public opinion and activities (influential numbers of campaign)	Public activities and strong knowledge formation	(Björheden, 2006; Gan and Smith, 2011; Gan et al., 2007; Jacobsson, 2008; McCormick and Käbberger, 2007)	
	Wave Energy	Establishment of many research centres (e.g. Wave energy research, Interproject service AB; Technocean)			Cooperation between research centres(e.g. Wave energy research, Interproject service AB; Technocean)		Potential resource	(Clément et al., 2002; Dalton and Ó Gallachóir, 2010)
								(Del Rio and Urruh, 2007; Elliott, 2000; Gan et al., 2007; Held et al., 2006; Jacobsson and Bergek, 2004, 2011; Markard and Truffer, 2006; Szarka, 2006; Wüstenhagen and Bilharz, 2006)
Germany	Wind Energy	Organizational effort to differentiate themselves, R&D effort; Joint of farmers association; small companies lobbying	Policy support (FIT*, EEG*, Funding, supporting niche market); stable policy support	Public Interest (Green movement); Social acceptance	Increasing rate of employment; Strong manufacturing companies	Technology improvement (Cost reduction)		(Del Rio and Urruh, 2007; Elliott, 2000; Gan et al., 2007; Held et al., 2006; Jacobsson and Bergek, 2004, 2011; Markard and Truffer, 2006; Szarka, 2006; Wüstenhagen and Bilharz, 2006)
	Solar Energy	Interested organizations (pioneering and lobbying activities)	Policy Support (FIT*, EEG*)	Public Interest	Increasing rate of employment; Strong network formation around this market	Technology improvement (Cost reduction)		(Dewald and Truffer, 2011; Gan et al., 2007; Jacobsson et al., 2004; Jäger-Waldau, 2007; Wüstenhagen and Bilharz, 2006)
	Biomass	Join of farmers association	Policy Support (FIT*, EEG*)					(Negro and Heckert, 2008)
	Wave Energy	R&D efforts in private companies			Cooperation of research groups and companies with off-shore engineering			(Clément et al., 2002)

Table 4-1. Overview of driving forces behind the development of renewable energy industry per country and technology (continued)

Country	Energy Source	Actors	Drivers		Network	Technology	Region	Reference
			Hard	Soft				
Spain	Wind Energy	Organizational competence (manufacturing competences, Pioneering entrepreneurs); Learning effects (R&D efforts); Supporting Financial institution (low investment cost)	Policy support (Taxation; Premiums; FIT*); Policy stabilities		Social Support (environmental NGO); Network support (Supporting Niche Market, strong manufacturing companies)	Technological improvement (Cost reduction; learning and innovation)	Availability of energy sources	(Del Rio and Unruh, 2007; Held et al., 2006; Markard and Truffer, 2006)
	Solar Energy	Strong PV industry (quality, innovativeness, commercial dynamic and flexibility)	Global institutional target (Koyoto protocol); Supporting policies (obligatory installation of PV; FIT*)	Social awareness	Increasing rate of employment	Technology improvement (Cost reduction)	Availability of energy sources	(Del Rio and Mir-Artigues, 2012; Del Rio and Unruh, 2007)
	Wind Energy	Personal initiatives; Private financial supports	Policy support (TGC* system, subsidies and tax exemption)	Public opinion (Opposition to Nuclear power, society interest)		Technology improvement		(Haas et al., 2004; Held et al., 2006; Jacobsson and Bergek, 2004)
Netherlands	Solar Energy	Personal initiatives	Policy support (TGC* system, tax exemption)					(Haas et al., 2004; Van Rooijen and Van Wees, 2006)
	Biomass	Initiative and pioneer companies; (entrepreneurs, farmers association, public transportation)	Policy Support (Regulation on water quality, TGC* system and tax exemption)	Existing motivation in private sectors of the society				(Haas et al., 2004; Meijer et al., 2007; Suurs and Hekkert, 2009)
	Wave Energy	Establishment of research groups (Teamwork Technology BV); R&D efforts in private companies						(Clement et al., 2002)

Table 4-1. Overview of driving forces behind the development of renewable energy industry per country and technology (continued)

Country	Energy Source	Actors	Drivers		Network	Technology	Region	Reference
			Hard	Soft				
France	Wind Energy		Policy support (FIT)					(Held et al, 2006; Szarka, 2006)
	Solar Energy		Policy support (FIT)					(Haas et al, 2004)
	Biomass		Policy support (FIT, in progress)					(Haas et al, 2004)
	Wave Energy					Potential resource		(Clément et al, 2002)
Italy	Solar Energy		Partial policy support (FIT*)					(Jäger-Waldau, 2007)
	Biomass	Organizational incentives (Mainly forest owners both public and private and their intention of utilizing woods)	Policy support (certificate system); EU-policy forces		The project announcement by EU		Availability of Biomass resources and massive agricultural lands	(McCormick and Kåberger, 2007; Warnburg et al, 2004)
	Wave Energy	Research activity (Specifically University of Rome)			University and industry cooperation		Moderate potential resource	(Clément et al, 2002)

* SKO3 = third Scottish Renewables Order. | FIT: Feed-in-tariff | AER-3= Alternative Energy Requirement
EEG= Erneuerbare-Energien-Gesetz (German Renewable Energy Act) | TGC = Tradable Green Certificates

Cross-subsector and cross-country comparative analyses

The second objective of this thesis's first literature study was to compare the acknowledged driving forces across RET subsectors and countries. This was done to shed light on the unique features of the driving forces behind each case (i.e., a RET in a country) and to observe their breadth and effectiveness. To do so, this thesis drew upon the empirical data presented in 30 reviewed papers and conducted a cross-sector and cross-country comparative study. Comparative analyses are effective tools in deriving a full picture of the phenomenon, while simultaneously illustrating the unique and diverse features of several cases (see, Eisenhardt, 1991).

To conduct cross-subsector and cross-country comparative analyses, first the number of driving force types (which in an indicator of the existence of various driving forces) that are listed in Table 4-1 is counted for each RET in each country within each dimension (i.e., actors, institutions, networks, technology and region). Successively, the numbers are compared for the purpose of conducting cross-subsector and cross-country analyses. To estimate the effectiveness of each driving force's dimension on a RET development, the numbers of driving force types are analyzed in parallel with actual shares of renewable energy in gross inland energy consumption in the studied countries (See Figure 4-2). In other words, it is studied whether a country comprising a high number of driving force types has a higher actual shares of renewable energy in gross inland energy consumption.

Figure 4–2. Share of renewable energy in gross inland energy consumption per country in 2010 (%)

The results of a **cross-subsector** comparative study of RETs' driving forces found more advanced and successful development and deployment for the technologies that have received support from various TIS structural elements (Darmani et al., 2014a). One such technology was wind energy: the successful development of wind energy industry is evident in the current low generation price of onshore wind energy (USD86.60/MWh²⁷) in comparison to profitable nuclear energy (USD108.40/MWh) (U.S. EIA, 2013). The development of offshore wind energy, however, has lagged behind, as its price is significantly higher than onshore wind energy (USD221.50/MWh) (U.S. EIA, 2013). The low price of onshore wind energy has even allowed energy producers to benefit from policy supports extensively (see, Del Rio and Unruh, 2007; Wüstenhagen and Bilharz, 2006). Nonetheless, barriers such as tedious permission processes (Del Rio and Unruh, 2007), energy policy instability (Held et al., 2006), or local opposition (Foxon et al., 2004) have hampered the development of this technology.

The results of the first literature study showed that solar energy is second to wind energy in terms of receiving support from various and multilateral dimensions of driving forces (Darmani et al., 2014a); this can be explained by the technology's potential and popularity. One such dimensions contributing to development of solar energy is actors, as it is possible for diversified groups of actors to install solar energy (e.g., households, farmers, and energy companies), and this can lead to more significant development for this technology (Foxon et al., 2004). Nevertheless, the technology's relatively high price (i.e., USD144.3/MWh for solar PV and USD261.5/MWh for solar thermal) (U.S. EIA, 2013) suggests the immaturity of the technology and is a barrier to further development and deployment of this energy source²⁸.

Biomass energy found to be in the third position in receiving support from various driving forces. Interestingly, in this subsector, the role of actors as a driving force behind the biomass industry has been said to be at par with that of policy support schemes (see, Negro and Hekkert, 2008; Suurs and Hekkert, 2009). This is because the production of energy from biomass sources is considered an additional way of earning profits. Accordingly, policy support schemes have triggered actors' interest and decisions to engage in bio-based energy production as a "side project." However, parameters such as society's lack of trust in or awareness of this technology, or weak relationships among network members, constrain the potential of this technology (Upreti, 2004).

Driving forces behind the development of wave energy—a relatively immature RET type—are found to be less explored and less various than the other subsectors (possibly due to the technology immaturity) and hence reveal a different market history. Factors such as the availability of wave-source energy, the technology's potential, and actor interest are currently the most remarkable driving forces of wave energy

²⁷ All the data reported by the U.S. EIA (2013) are based on 2011 prices, in USD, and are for plants entering service in 2018.

²⁸ Note that the price of Solar PV has decreased significantly in recent years.

(Clément et al., 2002). However, the technology needs much more development before it can be commercialized.

The importance of various and multilateral driving forces was also revealed in **cross-country** comparative studies. The countries that had incorporated various and multilateral driving forces were found to be more prosperous in terms of advancing RETs. To illustrate, Germany and Spain are the known forerunners of the renewable energy industry, specifically in the cases of wind and solar energy (Del Río and Gual, 2007; Del Río and Unruh, 2007; Gan et al., 2007; Wüstenhagen and Bilharz, 2006). Both countries appear to nurture the driving forces of these technologies' development, especially in comparison to other countries (see, Table 4-1 for details).

In all, the findings of this literature study further suggest that energy policy embedded in the institutional dimension tends to be the dominant and most frequently cited driving forces of the renewable energy industry (see Table 4-1). However, there are still other systemic driving forces that affect the development of this industry. Both acknowledging and strengthening all systemic driving forces are essential if the aim is to realize the full potential of RETs within a short timeframe. The results of this literature study showed that across the studied cases, actor prevalence as a driving force of RETs appeared to be diversified (Darmani et al., 2014a). In other words, while in some countries actors played a significant role in driving RETs, their contribution was found to be insignificant in others. The actors, among others, are comprised of RES-E investors, on which this thesis focuses particularly.

4.1.2 The assessment of renewable policy instruments: the case of Tradable Green Certificates

Upon highlighting the role of policy instruments as the main driving forces behind the renewable energy industry development, the second literature study of this thesis exclusively examines which policy-instrument outcomes are evaluated for assessing their performance in stimulating larger shares of RES-E (OBJ2). This thesis specifically focused on TGC schemes, which constitute a prevalent policy framework in the European electricity industry and are enacted in Sweden, the empirical setting of this thesis. In European negotiations, TGC schemes have been considered a superior policy framework (Bergek and Jacobsson, 2010) and was a candidate for a harmonized RES-E support scheme (Del Río, 2005).

This second literature study delineated the analyses criteria that researchers have taken to assess the performance of the TGC system. This study featured full-text analyses of 63 papers, from which information on their analysis criteria was extracted. The literature study contributed to the related literature in two ways: 1) it shed light on the main analyses criteria used for assessing TGC systems and summarized their outcomes, and 2) it explored the relative impact of the studies taking each analysis criterion on forthcoming research by analyzing their citation records.

Analysis criteria for assessing the Tradable Green Certificate framework

Using the method discussed in section 3.2, the second literature study of this thesis reviewed the full text of 63 papers. Upon extracting and categorizing the analysis criteria of the 63 papers, the second literature study of this thesis acknowledged the existence of seven distinct analysis criteria used to assess TGC system performance—namely, the economics of investment, the design and effectiveness of TGC systems, comparative analyses of RES-E support schemes, investors’ diversity, TGC systems as a harmonized policy framework (for the European Union), innovation and technical changes, and local preferences. Table 4–2 shows the number of papers that took each of the analysis criteria. Additionally, for each criterion, the cumulative number of citations and the average number of citations per paper are given, to shed light on its relative impact on forthcoming studies.

Table 4–2. Analysis criteria for assessing the Tradable Green Certificates: content and impact

Topic	Number of papers ^a	Cumulative number of citations	Average citation per paper
The economics of investments	37	652	17.62
The design and effectiveness of TGC systems	32	709	22.16
Comparative analyses of RES-E support schemes	25	683	27.32
Investors diversity	13	180	13.85
TGC system as a harmonized policy framework	8	208	26.00
Innovation and technical changes	7	223	31.86
Local preferences	3	60	20.00

^a Note that some papers took several different analysis criteria for assessing TGC system performance. Accordingly, the total number of papers listed in this table is not equal to 63.

As seen in Table 4–2, the literature study found analysis of the economics of investment in RES-E to be the most commonly taken analysis criterion for assessing TGC systems. However, in spite of its popularity, the criterion group has had a limited impact on forthcoming studies, given its low average number of citations per year. Researchers that take this criterion argue that investors in part make investment decisions based on financial reasoning (Reuter et al., 2012; Unger and Ahlgren, 2005), and that policy instruments are crucial because they have an influence on that reasoning (Ericsson et al., 2011; Haas et al., 2011a; Haas et al., 2011b). In TGC systems, RES-E investors can make additional revenue by selling their electricity certificates (Bergek and Jacobsson, 2010) at a market price that is based on supply and demand (Amundsen et al., 2006; Marchenko, 2008; Mitchell et al., 2006; Verbruggen and Lauber, 2009). Accordingly, certificate prices play a deterministic role in the amount of revenue that electricity producers can gain, and certificate price fluctuation is a source of uncertainty inherent in the design of TGC schemes (Agnolucci, 2007; Amundsen et al., 2006; Mitchell et al., 2006). Figure 3–5 in section 3 illustrates trends and volatility inherent in Swedish TGC prices.

The second most commonly taken analysis criterion is to assess the design and effectiveness of TGC systems in producing desirable outcomes (see , Haas et al., 2011b). Given the varied designs of TGC systems as well as the targets set across countries, almost all the papers that took this criterion (30 of 33) were found to assess TGC system effectiveness at the country level. The overall conclusion of these papers tended to be that TGC systems motivate further investments in RES-E, although the investments are predominantly made in mature RES-E types and the system outcomes are not on par with market potentials (Haas et al., 2011b; Verbruggen and Lauber, 2012).

The third most commonly taken analysis criterion is to assess TGC system performance in tandem with other policy support schemes. The studies that take this criterion assess the outcomes of various support schemes by comparing parameters such as installed capacity, production cost, the local market, or interest in the local manufacturing market (Haas et al., 2011a; Kildegaard, 2008; Ringel, 2006). This criterion has had a considerably large impact on forthcoming studies, with a citation record of 27.32 per paper. With this criterion, studies frequently assess the performance of TGC systems in comparison to FIT (e.g., Agnolucci, 2007; De Jonghe et al., 2009; Finon and Perez, 2007; Jaraitė and Kažukauskas, 2013; Johnstone et al., 2010; Ringel, 2006; Verbruggen and Lauber, 2012). Whereas neither TGC nor FIT offers the optimal solution (Finon and Perez, 2007), the FIT framework is often considered a more effective policy instrument in driving RES-E investment (Alishahi et al., 2011; Fouquet and Johansson, 2008; Haas et al., 2011b; Toke and Lauber, 2007). As Fouquet (2008: P. 4085) states, *“the outcome of the comparison of TGC on the one hand and FiT is apparent: end of 2006 a total of 20 GW of RE capacity from wind power alone was installed in Germany, after 15 years of FiT systems. In Great Britain, just 2 GW of RE capacity was installed from wind power, after 17 years of existence of the two major quota and trade mechanisms ever established in Europe”*.

Studies of the fourth most frequently seen analysis criterion examine the diversity of investors in the renewable electricity markets and investigate how the specific designs of TGC systems can affect investment decisions of different kinds of investors. Interestingly, in spite of the considerable number of papers to find the economics of investment to be the main reason behind the investment decisions of RES-E investors, only a limited number of them actually examine the diversity of those investors: 37 papers speak to the economics of investments, but only 13 focus on investor diversity. In this research line, RES-E investor diversity in terms of their market power (Amundsen and Bergman, 2012; Tanaka and Chen, 2013), investment and generation capacity size (Amundsen and Bergman, 2012; Verbruggen and Lauber, 2012), and risk aversion (Fagiani et al., 2013), among other measures, is acknowledged. The results of these studies indicate that TGC systems affect diverse investors in different ways—and that can, in turn, influence TGC system outcomes.

The fifth most commonly taken analysis criterion is seen in papers that investigate the performance of the TGC framework as a harmonized policy solution for the European electricity industry. Notwithstanding their limited number, the papers that take this criterion have had a very large impact on forthcoming studies

(i.e., an average of 26 citations per paper). These papers mostly advise against a harmonized TGC system by raising doubts about the efficiency and effectiveness of such a system (Jacobsson et al., 2009; Toke, 2007; Voogt and Uytterlinde, 2006) and its influence on various national electricity markets in Europe (Del Río, 2005).

The studies taking the sixth criterion examine the extent to which TGC systems induce innovation and drive technical change. The results of these studies form one of the main criticisms behind the technology-neutral design of TGC systems, by showing that the systems do not induce technical changes or innovation effectively (see, Bergek and Jacobsson, 2010; Jacobsson, 2008; Menanteau et al., 2003). In practice, TGC systems encourage investment in mature and low-cost technologies, while new and costly technologies require further support (Menanteau et al., 2003). The importance of this criterion is evident, given its high average number of citations per paper ($N = 31.86$).

The last criterion, used by the least number of papers (i.e., three), explores the influence of local preferences on the outcomes of TGC systems. These papers' findings show that factors such as local community interests in renewable electricity sources (Toke, 2005) or their trust in a policy support scheme (e.g., TGC systems) (Diaz-Rainey and Ashton, 2008) can affect the outcomes of TGC systems.

Overall, the findings of the second literature study of this thesis demonstrate that several analysis criteria have been used to assess TGC system performance. They also reveal that some criteria are more commonly used than others. This means that while certain outcomes of TGC systems have been in spotlight and examined, there are others that need to be considered more carefully before making any conclusions about the policy-instrument outcomes. Particularly pertinent to this thesis's objectives, these findings shed light on the wide gulf that exists between the number of papers that evaluate the economics of investments in RES-E and the number of papers to acknowledge RES-E investor diversity when examining TGC system outcomes. The findings underscore the necessity of further research on RES-E investor diversity. The following steps of this thesis aim exclusively to highlight that diversity.

4.2 Which firms contribute to the transition to a more sustainable electricity industry? The case of Sweden

In this section first an introduction to the development of the renewable electricity industry in Sweden is provided. Next, the results of statistical analyses examining Swedish RES-E investors' characteristics are presented.

4.2.1 Development of the renewable electricity industry in Sweden

Presently, Sweden is identified as a forerunner in renewable electricity production. Both the academic literature and reports indicate that until the late 1970s, Sweden's energy portfolio relied heavily on oil

imports (e.g., Wang, 2006). In the 1970s, Sweden imported 70% of its oil; by 2011, that number was 28% (only 0.5% in the electricity sector), and this reduction is a clear indicator of the country's successful transformation of its energy portfolio (IEA, 2013). This transformation made Sweden famous, on account of its low level of dependence on fossil-based fuels—the lowest level among IEA member countries (IEA, 2013). This transformation was neither easy nor something that happened overnight.

Following the oil shock of the 1970s, Sweden realized that any variation in either the price or quantity of oil could have crucial consequences on the country's energy industry (Löfstedt, 1993). This problematic dependence motivated the Swedish government to restructure Sweden's energy industry.

In Sweden, investment in hydropower had already started, in the late 19th century. Embarking on the ambitious goal of exploiting hydropower's potential, several energy firms were founded (Högselius and Kaijser, 2010). However, the shares of these firms in hydropower generation were minimal, compared to that of Vattenfall. Vattenfall was established in 1909 as a state-owned company to provide Sweden with cheap and clean energy that was generated by the power of large waterfalls that belong to the state (Högselius, 2009). Subsequently, ever since, Vattenfall has played a significant role in the Swedish energy industry, and it is the largest electricity producer in the country (CEER, 2010; European Commission, 2011). With the support of the Swedish government, hydropower produces about 44% of Sweden's electricity (See, Figure 2–2). Nevertheless, further expansion of this power source has been banned by virtue of environmental policies that protect Sweden's remaining rivers (Doherty et al., 2002).

Nuclear power was introduced to the Swedish electricity industry in the mid-1960s (Högselius and Kaijser, 2010), partly to provide an alternative power source (Wang, 2006). In 1972, Oskarshamn 1 was established and became the first nuclear reactor in Sweden (IAEA, 2014). Like hydropower, nuclear power development received support from the Swedish government (Wang, 2006); this support encouraged large Swedish electricity producers like Vattenfall to invest in nuclear power capacity (Kåberger, 2002).

Nevertheless, the development of nuclear power in Sweden has always been a matter of controversy, as its status has remained largely a matter of policy (Vedung, 2001). Since its introduction, various Swedish government parties have held dissimilar opinions about the consequences of nuclear power. In 1970, when the Central Party was in power, the decision was made to phase out this power source by 2010 (Doherty et al., 2002). However, early in 2005, the leader of the Central Party declared that climate change should be prioritized over the decommission of nuclear power. This mindset was strengthened in 2009 by a center-right coalition, which abolished the law forbidding the construction and renovation of nuclear reactors. As a result of a new law approved in June 2010, the reconstruction of nuclear reactors on existing sites was permitted, thus making nuclear power part of the Swedish energy portfolio for “the foreseeable future” (see, WNN, 2014). As of 2014, Sweden had 10 active nuclear reactors producing about 40% of Sweden's electricity (See Figure 2–2) (IAEA, 2014).

With the ambition of finding an alternative to nuclear power production and increase the share of low-emission power sources, investments in renewable power sources in Sweden have been prioritized since 1990 (Wang, 2006). Having environmental laws constricting the expansion of hydropower—as well as a limited number of sunny hours—biopower and wind power remain Sweden’s main renewable power sources.

Biomass expansion started in Sweden as early as the 1970s, in a process labeled the “quiet revolution” (Kåberger, 2002); it had the ambition of reducing the country’s oil dependence. Biomass has grown notably in Sweden, mainly in the form of heat and power production (Swedish Energy Agency, 2005). Jacobsson (2008) shows that the development of biopower in Sweden is in a growth phase, but its induced outcomes are still modest in comparison to its potential. He further explains that this modest development has occurred, first, because many firms consider biopower a by-product of heat generation from biomass sources. Second, there are other energy resources (e.g., natural gas) that are good substitutes for biopower, and third, the current design of the TGC system is supplemented by the generation of windfall profits—something that can draw into question the “legitimacy” of both the TGC system and biopower production in Sweden.

Wind power development in Sweden started taking off in 1990, with the introduction of complementary policy programs (Söderholm et al., 2007). In spite of this long development history and the establishment of supporting policy instruments (i.e., tax incentives, TGCs, and improved permission process), advances in the Swedish wind power subsector are slow and behind those of Denmark or Germany, for example. One reason behind this slow process in Sweden is that the TGC framework is currently the country’s main RES-E policy support scheme. Within this framework, wind power plants are less economically competitive in comparison to other available options, such as biopower (Söderholm et al., 2007; Wang, 2006).

The TGC framework was introduced to the Swedish electricity industry in May 2003 to promote a larger share of RES-E (Bergek and Jacobsson, 2010). The Swedish government initially enacted the TGC framework over the 2003–2010 period (SOU, 2005:33). The target behind the designed TGC system was to add 10 TWh of RES-E to the Swedish electricity industry by 2010, from the 6.5 TWh of RES-E generation in 2002 (SOU, 2001:77). However, in 2012, Sweden and Norway founded a joint TGC market, and it will be in force until 2035; the goal of that joint market is to add a total of 26.4 TWh RES-E to the two countries’ generation portfolios between 2012 and 2020 (Swedish Energy Agency and Norwegian Energy Directorate, 2013).

Figure 4–3 speaks to the development of onshore wind power²⁹ in Sweden (i.e., number of plants and installed capacity) following the introduction of the TGC framework. Looking at the graph, one can see that the number of plants (purple bars) and the installed capacity of wind power (red line) follow the same trend as the certificate prices (two blue lines, with and without a two-year time lag). To understand the significance of the relationship between investments in wind power and certificate prices, a linear regression model was

²⁹ Please note that all the data presented from this point forward pertain to onshore wind power.

used. The model identified a quite-significant relationship between the number of onshore wind power plants and certificate prices with a two-year time lag ($R^2 = 62.1\%$, significant at the 1% level). This significant relationship was also confirmed between the yearly installed wind power capacity and the certificate prices. This further illustrates that the Swedish TGC system has affected investments in wind power—although, these investments are still lower than the wind power potential in Sweden.

The forces within the Swedish TGC framework for RES-E investments were fortified in 2005, when the EU Emission Trading System (ETS) was introduced into European national electricity industries (Wang, 2006). The ETS plays a significant, yet controversial role in the European electricity industry (Richstein et al., 2014; Richstein et al., 2015). The considerable influence of the ETS in Sweden can be seen in the country's electricity price (Jacobsson, 2008). The price of electricity in Sweden was about SEK120/MWh in 2000, but it reached SEK445/MWh in 2006 (Nordpool, 2015). In 2015, the electricity price in Sweden was about SEK287/MWh³⁰ (Nordpool, 2015).

Figure 4-3. Installed capacity and registered number of plants in Swedish onshore wind power industry and yearly average TGC prices (Source: Swedish TGC database and www.skm.se)

4.2.2 Incumbents' reaction to the transition to a more sustainable electricity industry: the case of Vattenfall

In Europe, MNCs are among the powerful firms in the European electricity industry (Stern, 2006) and in a position to influence opportunities within the entire market (see, Cantwell and Janne, 2000). Looking at

³⁰ This number presents the average electricity price of Sweden's four electrical regions (SE1–SE4).

Figure 4–4, one can see that the dominant role of MNCs in the Swedish electricity industry is evident, given their 85% market share in the country’s general electricity production (i.e., the electricity industry involving all energy sources, such as oil, gas, and renewables). This significant market share is managed by five MNCs, which are the incumbents of Sweden’s electricity industry—namely, Vattenfall, Fortum, E.On, Statkraft, and Skellefteå³¹ (CEER, 2010; European Commission, 2011). Nevertheless, in Sweden, these MNCs produce only about 15% of the electricity generated from (onshore) wind power³² (based on data presented in the Swedish TGC database, see Figure 4–5). As discussed earlier, incumbents are results of the regulated European electricity industry, with large amounts of assets in profitable power sources, such as coal, gas, and nuclear power. Based on the path-dependency literature, these assets can demotivate incumbents’ investment decisions to partake in RES-E, which offers marginal profits. The small market shares of Swedish electricity incumbents in RES-E suggest their limited interest.

Figure 4–4. The market shares of Swedish electricity producers in 2010 (CEER, 2010; European Commission, 2011)

Figure 4–5. The market shares of Swedish onshore wind power producers in 2013 based on received certificates for electricity production (Source: Swedish TGC database)

³¹ In the report of the European Commission and CEER, firms with significant market shares are identified as the “main” firms. In this thesis, as discussed, firms with significant market share are referred to as “incumbents.”

³² Please note that all the data presented from this point forward pertain to onshore wind power.

National institutional frameworks that center on sustainability issues challenge the incumbents' limited interests in the renewable electricity industry. Institutions can delimit MNCs' strategic behavior by enacting established policy frameworks; additionally, the norms of local markets can also have this effect. When it comes to the European electricity incumbents, MNCs' strategies with regard to business and operations are not only challenged by the institutional frameworks of their home country, but also those of the host countries into which their business has expanded. In this process, an MNC will need to choose between two options: follow its core strategy, or adapt to localized institutional frameworks (Kolk and Levy, 2001, 2003). The results of prior research indicate that while some MNCs have been inclined to follow their core global strategy (Child and Tsai, 2005; Christmann, 2004; Dowell et al., 2000), others adapt to local institutions (Christmann, 2004; Levy and Kolk, 2002). The results are thus inclusive and can vary in different industrial contexts (Christmann, 2004).

This thesis explores MNCs' choices with regard to a global strategy versus localized strategies to enable understanding of how incumbents react to specificities in national policy frameworks and a social commitment to sustainability transition (i.e., research question 2.1; OBJ3). It did so by undertaking an in-depth longitudinal case study of Vattenfall's market development and operations in Sweden, Germany, and the Netherlands. Vattenfall manages a considerable share of Sweden's electricity market, although its portion of the renewable electricity industry there is moderate. Note that Vattenfall is among the largest wind power producers in Sweden. However, compared to other power sources, its share of wind power generation is still limited (See, Figures 4–4 and 4–5). Below, the results of the case study on Vattenfall operation in Sweden, Germany and the Netherlands are described in details.

Vattenfall's history: Results of the case study

Vattenfall's boom-and-bust cycle (1909–1999)

Vattenfall initiated its operations in Sweden as a state-owned company exploiting large-scale hydropower (Högselius, 2009). Initially, the company built its global strategy and business competencies on cheap, reliable green energy, making itself known for a non-fossil fuel energy-generation portfolio. During that time, the company attempted to further strengthen its reputation by building its brand and initiating the Two Holes in the Wall campaign.³³ Vattenfall, which aims to become one of Europe's leading energy companies and had the goal of achieving an annual profit of 15% from a very early stage (Vattenfall, 2011), identified these competencies as insufficient. To fulfill its goals, Vattenfall had two options: diversify its technological profile, and enter foreign markets (Högselius, 2009). The company aimed for both.

³³Following the deregulation of the Swedish electricity market, Vattenfall felt the need to adopt new approaches in order to compete. The company therefore started the advertising campaign called Two Holes in the Wall to illustrate the daily use of "what comes out of socket holes." Through creative advertisements, Vattenfall increased its customers' confidence and awareness and benefited from the popularity of its campaign both in Sweden and abroad.

Vattenfall's diversification began at a very early stage in the late 1980s, when the company changed its description from *electricity company* to *energy services company* (Vattenfall, 1990). The expansion process, in contrast, lagged behind. It was not until 1990 that the first attempts at internationalization were acknowledged on the company's management board (Högselius, 2009). This process commenced with Vattenfall's expansion in Germany in 1992 with the major aim of increasing its annual sales outside Sweden.

Entering the German market was considered a huge success in the time, and doing so supported the company's strategy of becoming a leading European energy company. The German experience yielded many lessons for Vattenfall. As Levinthal (1991) discusses, accumulated experience and knowledge influence a company's subsequent expansion. But Vattenfall's experience did not accrue overnight. Long, challenging, and controversial processes were undertaken before the company established itself (Högselius, 2009) as Germany's third-largest energy producer (Vattenfall, 2011).

Growth years: Leader in Sweden, opportunist in Europe (2000–2005)

At the turn of the 21st century, Vattenfall's development history in Sweden was an indicator of the company's objective of profiting from clean and cheap energy. This provided Vattenfall with a positive reputation all over Europe (Högselius, 2009). While this reputation was key to successful penetration into foreign markets, it faded when the company took the opportunity to acquire three large coal plants in Germany, a move that seemed reasonable in the context of market timing.

In early 2000, the Swedish energy market had already been in the process of deregulation for almost five years. Deregulation caused a huge shift in companies' mindsets:

- *We tried to gradually understand how the liberalized energy market develops. There was also some headline saying, "Small fish are being eaten by large fish" and the idea was that you need to be big to win and to be influential.* (Manager, Business Environment Analysis, Vattenfall)
- *So the market was deregulated, and I can say that was the biggest motivation for Vattenfall to become international and expand. Deregulation of the market has been a main driver for the last two decades in Vattenfall.* (Director, Strategic Planning & Projects, Vattenfall)

Before deregulation, energy prices in the market corresponded to the sum of regulated costs and a regulated profit margin. After the liberalization of the market, however, this formula changed. Instead, profit became the result of price minus cost. In this new economic context, energy companies could earn profit in any of four ways: (1) investment in production units that were profitable in the existing market structure; (2) divestment of units that were not fully profitable in the new deregulated market; (3) increased electricity demand in the market, leading to profit from a rise in energy prices; and (4) the stabilization of demand for electricity in the market to avoid its price reduction.

As part of the company's global strategy of becoming "*a leading European energy company through growth*" (Vattenfall, 2001), Vattenfall acquired Berliner Städtische Elektrizitätswerke AG (BEWAG), Vereinigte

Energiewerke AG (VEAG), and Lausitzer Braunkohle AG (LAUBAG), three large German coal power plants. The prospect of this acquisition was, for two main reasons, too attractive to resist. First, the energy market had been opened up by deregulation, as just discussed; the acquisition thus provided Vattenfall with an opportunity to expand. Second, through this purchase, the company gained access to a huge profit-making opportunity through these cost-effective production units. This was reflected in the sudden 60% rise seen in the group's net sales by 2002 (Vattenfall, 2002). In addition, Vattenfall believed that this expansion would make it a dominant player capable of influencing policy frameworks in pursuit of its objective.

Interestingly, this controversial contract was signed immediately after the appointment of a new CEO, Lars G. Josefsson, dubbed a climate hero by *Time* magazine (Vattenfall, 2005). It was not until after Josefsson's arrival that Vattenfall reevaluated the consequences of purchasing and acquiring coal power plants and opted to undertake the risk (Högselius, 2009). While this decision was taken in good faith, breaking the non-fossil fuel tradition was inconsistent with the company's heritage. This decision was a conspicuous indicator that Vattenfall's global strategy of growth prevailed over market considerations at a time when concerns about climate issues were first shaping national institutional frameworks.

It was not until 2004 that Vattenfall first expressed formal concerns about the greenhouse effect in its annual report. That the company cited these concerns exactly one year after publishing its corporate social responsibility report in 2003 was no coincidence. In the early 21st century, climate issues were becoming more widely acknowledged in different regions, and concerns were rising about governments' agendas (Kolk and Levy, 2001). This can be traced in Vattenfall's home country, Sweden. The Swedish government decided to enforce the TGC system as of 2003 in order to follow the enacted renewable directives (Wang, 2006).

In Germany, alterations in the regulatory framework were more advanced. The German policy framework has always been a successful example of how institutions can drive renewable technologies forward (Sühlsen and Hisschemöller, 2014). Since 2000, a generous FIT scheme determined by the Renewable Energy Sources Act (EEG) of 2000 was applied in that country, and subsidies were allocated to the generation of electricity from renewable sources (Karakaya et al., 2015; Sühlsen and Hisschemöller, 2014).

On the European level, this evolving market orientation toward a more sustainable energy industry was reflected in the enforcement of ETS in 2005, established by European Directive 2003/87/EC. The purpose behind this policy was clearly to manage and reduce emissions in the various European countries. Nevertheless, ETS not only failed to hinder MNCs such as Vattenfall, E.ON, and EDF, but it actually allowed them to earn huge profits (Sijm et al., 2006). This profit coincided with the initiation of ETS in a test phase (2005–2007). Big energy companies acquired a considerable number of trades free of charge and were allowed to sell them in the market. In addition, these companies benefited from their assets in nuclear plants with no emissions (Sijm et al., 2006). At present, the ETS test phase is over, and a continuous ETS has been established by European Directive 2004/101/EC. But the extensive number of trades in the market has

resulted in a massive decline in the price of trades (Richstein et al., 2014) and, consequently, in a marginal decline in MNCs' profit making.

These new policy orientations and schemes motivated energy companies in both Germany and Sweden to undertake renewable-power projects. The result was a sharp rise in technological changes in these countries. Nevertheless, large utilities such as Vattenfall seemed unwilling to take advantage of these policy changes and invest in RETs. Vattenfall's profitable power-generation portfolio now has a reduced incentive to invest in less cost-competitive RETs.

As a result of a consistent regional market orientation, in 2005 Vattenfall designed a more environmentally friendly global strategic plan that consisted of five main lines, of which the environment formed one (Vattenfall, 2005). Vattenfall's climate-centered strategy became apparent in the company's aim to become "the largest wind-power producer" in Europe (Vattenfall, 2005). Nevertheless, as shown in Figure 4-5, its contribution remained minimal when is compared with the contribution of the group of others.

Rising to the challenge: A squeeze in the European market (2006–2009)

Following Vattenfall's history chronologically since January 2006 reveals dramatic changes in its fortunes. These shifts started that year with a major incident at Forsmark, Vattenfall's nuclear power plant and the largest nuclear facility in Sweden. While the consequences of this incident were considered small scale, some called it pure luck that the problem did not escalate in the same way the Fukushima disaster did (Forsström, 2011). This critical situation became more severe in 2007, when the company's nuclear power stations in Germany, Brunsbüttel, and Krümmel each suffered isolated incidents. These incidents sparked massive criticism of Vattenfall's capabilities (Lewenhagen, 2009). This was to be expected, since one of Vattenfall's main competencies and strengths for its future lay in its nuclear power expertise. Hence, the incidents brought into question the company's main strength. The fallout from these incidents, however, was quite different in Sweden and in Germany, highlighting the varying local institutions in the two contexts.

In Sweden, owing to society's accepting attitude toward nuclear power, the incident at Forsmark caused only minor deviations in public perception. This almost-positive perspective is evaluated annually by authorities in the Swedish energy system. Therefore, none of the active MNCs in the Swedish energy industry with assets in nuclear power were challenged to reconsider their business in that sector. Conversely, public reaction was quite different in Germany. A sequence of accidents, coupled with energy-price hikes, resulted not only in a huge loss in the company's market share in Germany but also in the loss of almost 25,000 customers (Vattenfall, 2007). To regain their loyalty, Vattenfall offered both Swedish and German customers the option selecting their preferred energy sources. While Swedes responded positively to these efforts, however, German customer response was less promising (Vattenfall, 2007).

Consequently, while the company was still benefiting from its profitable energy portfolio, the institutional framework zeitgeist in Germany caused a shift in focus and began squeezing Vattenfall's market share in that country. Local institutions and climate concerns became predominant, and other issues remained secondary.

- *I think Vattenfall learned a lot in Germany, but it was painful. At the beginning, they followed their own strategy by going into that market ... It was reasonable to move into that market and penetrate it. It was close to their home market, [and] it had new providers, but then again, investing in power sources like coal—I'm not sure.* (Head of Policy Analysis Unit, Swedish Energy Agency)

This evolving institutional framework and increase in environmental responsibilities led Vattenfall to enforce its “*Combat Climate Change*” strategic plan in 2007, a strategy that accentuates environmental concerns and new market requirements (Vattenfall, 2008). The company was challenged to adjust its energy-generation portfolio to comply with the new strategic plan. Answering local markets' challenges through a global strategic plan was once again an indicator of Vattenfall's efforts to remain “united.” Hence, Vattenfall did not approach the alternatives only within the boundaries of controversial markets such as Germany. To respond to this challenge, Vattenfall had two strategic options for its technological assets: to profit from its existing emissions-based power-generation portfolio while undertaking carbon capture and storage (CCS) projects, or to replace the “dark side” of its power generation (i.e., assets in conventional power sources) by adding new system capacity or selling property. The company pursued both alternatives, in keeping with the owners' annual 15% profit requirements.

Vattenfall's aim to contribute to the advancement of CCS started as early as 2001, even though the technology still requires further development to reach the commercial phase. The establishment of CCS plants is controversial, and the concept's outcomes currently hinge on opposition from local institutions (discussed further in the next subsection).

The second alternative, investment in new capacity, had historically not been a Vattenfall priority because of existing excess capacity in the European energy market. Therefore, the company invested only marginally in new capacities such as wind power, instead obtaining new capacity through acquisition. Vattenfall's main motives for acquisition were threefold: (1) the possibility of replacing the dark side of its energy-generation portfolio, (2) its original endeavor to grow via market expansion, and (3) the potential of acquiring the competencies required for future growth. With this rationale in mind, Vattenfall acquired Nuon in 2009.

Nuon was founded in 1994–1995 from the merger of several Dutch energy companies. After a failed merger in 2007 with Dutch company Essent, Nuon was looking for a foreign partner to strengthen its position. Vattenfall accomplished this purchase by investing a considerable amount of money in acquiring 49% of Nuon shares (Vattenfall, 2010). The valuation by Vattenfall brought Nuon's enterprise value up to €8.5 billion. This was surprising at the time, since analysts were predicting a much lower bid.

Nuon seemed to have had a technological level that was comparable yet complementary to Vattenfall's. Thus, this acquisition brought Vattenfall a number of competitive advantages. A German newspaper expressed the concerns of its readership, stating, "*This is a big day for the Swedish state-owned company Vattenfall, [but] definitely not a good day for the German customers*" (Wetzel, 2009). Worries were magnified by the European Commission's decision to authorize the acquisition of Nuon only if its German subsidiary was divested.³⁴ Overall, the initiation of this cooperation was expected to increase Vattenfall's capabilities to advance in different technologies, progress that would comply with its new strategic plan. Unfortunately for Vattenfall, this seemingly reasonable investment was doomed to massive criticism and challenges.

Years of reality: Consolidation phase (2010–2013)

The liberalized market (1990–2010) was conceived to create a highly competitive environment with incentives for the development of the renewable energy. Nonetheless, RETs still struggled to compete with cheap coal and gas, especially among large utility companies whose main goal was profit maximization (Fleten et al., 2007; Pettersson and Söderholm, 2009). Since the beginning of 2010, however, Swedish politicians have felt the need for greater input in the energy industry's operation.

- *From 1990 to 2010, we had the liberalized market. But the liberalized market didn't provide enough incentives to transfer toward renewable. Renewable had tough time competing with coal. So now, from around 2010 forward, it's like a regulated market with competition.* (Director of Strategic Planning and Projects, Vattenfall)

Hence, a new orientation evolved within the Swedish energy market, resulting in a market driven by competition and bound by regulation.

- *Ten years ago, we had a few big companies; now we have many small companies ... The landscape is changing.* (Director of Commercial Steering, Vattenfall)

Forecasts of Vattenfall's future status based on the existing competition in its market that fell short of the company's 15% profit target in three successive years led to Vattenfall's latest strategic plan, set forth in 2010. This new approach was launched after the appointment of the company's latest CEO. This was an interesting event in Vattenfall's history, as the company once again undertook a massive change in its global strategy after an alteration in its managerial board. The new strategic plan pursued four main targets: profitability, a core-market focus, concentration on three main products (electricity, heat, and gas), and reduced CO₂ emissions. To achieve these goals, Vattenfall allocated the first four years (2010–2014) to cost consolidation, followed by years of growth (2014 onward) (Vattenfall, 2010).

³⁴ European Commission interference to restrict the power of big utilities is not limited to the case of Vattenfall; it is also evident in the forced decision of E.ON to sell its high-voltage grid. For further information, please refer to Tagesschau (2008).

After 2010, significant changes occurred not only in Vattenfall's case but also in the strategies of MNCs throughout the European energy industry. E.ON announced its strategy of "*cleaner and better energy*" in 2010 to adjust the company's activity to the new market environment. After 2010, the Italian MNC Enel reacted to emerging climate issues by making several strategic decisions that included investment in a new pilot project for smart grids that considered technical aspects of the power produced from renewable energy sources (repubblica, 2011) and investments in CCS technologies to improve the environmental aspects of Enel's fossil-based energy sources (Enel, 2011).

- *Instead of participating in the development of renewable energy, the big companies fought for the expansion of their nuclear power plants and made expensive and risky acquisitions abroad. The management of large utilities had their eyes closed for too long, when they could have foreseen the evolving new energy market. Now they are paying the price for willfully adhering to an outdated business model.* (Based on a study by Greenpeace; our own translation from (Spiegel, 2015))

While Vattenfall's new strategic plan was enforced as a global strategy for this company, it was a conspicuous result of forces being exerted by specific localized institutions. In one of its controversial host countries, Germany, inconsistency in policies with respect to Vattenfall's power-generation portfolio and competencies created several obstacles. Clear examples are policies and regulations concerning Germany's nuclear power plants and the CCS-demonstration projects. Nuclear power was considered a bridge for generating electricity in Germany until renewables became viable. Accordingly, the question whether to shut down nuclear power stations had appeared on Germany's agenda from time to time. Finally, in 2011 the German government decided to close all 17 of the country's nuclear power plants by 2022, at the latest. This decision, enforced only one year after lifetime extension permits were granted to German nuclear power plants (Vattenfall, 2010), conflicted with Vattenfall's competencies and engendered huge doubt around the stability of German regulation. Vattenfall and other utility companies (such as E.ON) with assets in nuclear power disputed this decision and even sued the German government for their incurred loss; the decision, however, was never altered (Spiegel, 2011; Süddeutsche Zeitung, 2011).

- *We continuously bring our competences and facts to the politicians, but still they are more in the driver's seat ... we can't control energy policy.* (Director of Strategic Planning and Projects, Vattenfall).

Other cases of conflict arose as soon as Vattenfall decided to build a CCS-demonstration power plant in Germany. In 2011, the German government refused to endorse the Jänschwalde Project, which was among one of six initiatives funded by the European Union. Cancellation of this project was justified primarily because of the unreasonable continuation of fossil fuel-based production and, second, owing to public concerns and opposition on account of unknown CCS environmental hazards (Reuters, 2011). The company's global strategy, exercised without involving local institutions, led to customer loss and a negative reputation for Vattenfall in Germany. Vattenfall, on the other hand, cited German markets as offering supportive but inconsistent policies, a fragmented customer base, and low value added (Vattenfall, 2010).

In contrast, in the Swedish market the nuclear incidents did not cause a noticeable deviation in government or public perception of nuclear fuel. This positive view toward nuclear power was reflected in the Swedish government's decision to allow replacement of its nuclear power capacity in 2010. This decision was compatible with Vattenfall's general portfolio and activities.

- *In Sweden, there is a questionnaire by the Swedish energy agency, [and] we ask people what they think about different sources of energy every year ... Nuclear power is still accepted. There is no broad opinion for increasing it, but most agree with keeping it.* (Head of Policy Analysis Unit, Swedish Energy Agency)
- *The Swedish system has been built based on cheap energy. So this is one of the advantages of having nuclear.* (Director of Strategic Planning and Projects, Vattenfall)

Vattenfall has always demonstrated a clear interest in old, profitable energy sources, to which about two-thirds of the company's budget is dedicated. This is clear in the case of the Nuon acquisition. Vattenfall's expansion into the Dutch market initially represented a great investment, supported by three main arguments. First, apart from the Netherlands, Nuon also boasted a presence in Germany, Belgium, and the UK. This expanded Vattenfall's customer base. Second, Nuon possessed mainly gas-fired power plants, which offered several core advantages. Gas-fired plants were much cleaner than coal plants and more acceptable to the public. Third, Nuon had the capacity for wind power generation, aligning with Vattenfall's aim of becoming a wind power leader in Europe. This contribution, however, was minimal in the company's overall renewable-power-generation portfolio.

In the fallout following the acquisition, state-owned Vattenfall's purchase of Nuon was dubbed "*Sweden's worst investment*" (Lindvall, 2013). Although the acquisition and loss were blamed on a lack of planning by Vattenfall, they could also be explained by the status of gas in the global energy market. Soon after the acquisition, the massive exploitation of shale gas began in the United States. Consequently, gas quickly became much cheaper, and most power-generation companies in the United States were lured to switch from coal to gas as their main energy source. The surplus of US-produced coal flooded the European market, and coal prices in Europe fell suddenly. Coal energy hence became much more profitable than gas energy, resulting in a loss of value for gas-fired power plants.

- *This is the situation now for Vattenfall. But ... if the Nuon purchase had been successful, no one would be criticizing Vattenfall.* (Head of Policy Analysis Unit, Swedish Energy Agency)

Despite its dominant and stable position in the Swedish energy market, Vattenfall's new strategic plan and concurrent rapid divestments constitute further proof of the company's mistakes in some local markets because of the choice, again, to deviate from local institutions. Vattenfall's divestment from some plants, such as its lignite plants in Germany, can be viewed as a signal that a *united* Vattenfall wanted to center its global strategy on power generation from clean and renewable energy sources (Reuters, 2014b). On the other

hand, if Vattenfall had decided to focus on clean energy production, it is interesting to understand why it opened a brand new coal energy-generation unit in Germany in 2012 (Reuters, 2012).

Global vs. local strategy: What can be deduced from the Vattenfall case?

The findings of this case study suggest that even in the energy industry—which is known to be highly capital-intensive and institution-based (Jacobsson and Bergek, 2011)—the relationship between national institutions and energy companies is not of a one-way variety, dictated by the institutions. Based on this study’s findings, Vattenfall’s decisions can be seen to satisfy its core strategies of growth and profitability, rather than follow various national institutional frameworks. This can especially be seen in Vattenfall’s decision to invest in three large coal-fired power plants in Germany, at the cost of breaking its non-fossil fuel tradition. Similarly, Vattenfall has significant assets in nuclear power, but not comparable assets in wind or solar power in Sweden or Germany. However, as the renewable energy industry matures and environmental concerns mount, the institutions (i.e., both policy frameworks and customer norms) will continue to play a greater and growing role in various national markets (Darmani et al., 2016). Subsequently, institutional frameworks have stimulated more responsive behavior from Vattenfall.

This study’s findings show that restriction policies have been particularly effective in reorienting Vattenfall’s operations and strategies. For example, the decision to phase out nuclear power in Germany affected Vattenfall’s future strategies (or those of E.ON), although supportive policy designs (such as FIT in Germany) did not induce its decisions to invest significantly in renewable sources.

Overall, MNCs such as Vattenfall have evolved in recent years to become more responsive to the emerging sustainability movement as climate-change concerns have mounted. This responsive behavior is not limited to the case of Vattenfall; it can also be seen in the recent decision of E.ON to split its business and undertake two major overhauls. E.ON’s decision aimed “*to focus on its renewable activities, regulated distribution networks and tailor-made energy efficiency services, citing ‘dramatically altered global energy markets, technical innovation, and more diverse customer expectations’*” (Reuters, 2014a: quoting from an online news).

4.2.3 Characteristics of firms in the transition to a more sustainable electricity industry: evidence from the Swedish onshore wind power industry

As discussed in chapter 2, following the market deregulations in the European electricity industry, new entrants have found the opportunity to compete with incumbents. In Sweden, the result of this competition is evident in the momentous market positions of new entrants in the renewable electricity industry (see, Bergek et al., 2013b).

This thesis explored which RES-E investor characteristics—namely, those of both incumbents and new entrants—can lead to their decisions to invest in RES-E (OBJ4). It did so by testing five hypotheses on the relationship between wind power investors’ characteristics—which are embedded in their dynamic

capabilities—and their amounts of (onshore) wind power (in follow is referred as wind power) technological assets.

As explained in the methodology section, a total of 617 firms in the onshore wind power subsector formed the empirical basis for testing the hypotheses. Table 4–3 presents the model estimation results. Overall, the model results confirm the significance of four of five hypotheses, and support the thesis’s earlier assumption that investors with certain characteristics—especially new entrants—invest more heavily in the Swedish onshore wind power (in follow is referred as wind power) subsector. The model tested empirical data as at the end of the 2013; however, the results of the time-specific model—which focused on both 2003 and 2008—are also presented and discussed, in the following section.

Table 4-3. Model results on investor characteristics and investments in wind power

Variable	Model 1			Model 2			Model 3- Time specific model		
	(Control variables: 2013)			(All variables: 2013)			(All variables: 2008)		
	Std. Error	β (Std. β)	Sig.	Std. Error	β (Std. β)	Sig.	β (Std. β)	Sig.	β (Std. β)
1 (Constant)	971.143	27.672	0.977	2616.148	13845.544*	0.000	-3035.450*	0.000	-2389.436*
2 Investment size				0.127	1.130* (0.303)	0.000	1.153* (0.602)	0.000	1.289* (0.563)
3 Investment frequency				885.317	6820.713* (0.460)	0.000	2013.582* (0.411)	0.000	1718.21* (0.613)
4 Management experience				180.584	274.313 (0.051)	0.129	195.472 (0.054)	0.134	272.105 (0.080)
5 Unrelated diversification (Industrial background)				1105.786	3282.796* (0.107)	0.003	296.021 (0.037)	0.318	-65.322 (-0.017)
6 Related diversification (Generation Portfolio)				2359.138	9206.023* (0.134)	0.000	1149.882 (0.062)	0.087	-25.094 (-0.003)
7 Age of investor in wind power industry				90.334	-516.870* (-0.213)	0.000	-98.321* (-0.119)	0.002	25.389 (0.045)
8 Firm age	38.214	-50.702 (-0.050)	0.185	40.192	41.101 (0.040)	0.307	8.770 (0.032)	0.408	-0.906 (-0.008)
9 Number of invested regions	542.349	5506.440* (-0.382)	0.000	840.703	197.085 (0.014)	0.815	146.230 (0.049)	0.335	73.019 (0.059)
R ²		0.144			0.383		0.608		0.822
Adjusted R ²		0.141			0.375		0.599		0.814

* $P < 0.01$ | ^a Pairwise deletion was used.

The results of the linear regression analysis on the thesis model confirmed the validity of the hypothesis regarding the investment experience of wind power investors in Sweden. The hypothesis is restated below:

Hypothesis 1. An investor's investment experience (herein linked to (a) investment size and (b) investment frequency) within a subsector of the renewable electricity industry positively affects its amount of technological assets in the same subsector of the renewable electricity industry.

Hypothesis 1a could not be rejected; this indicates that the investment experience of Swedish wind power investors in relation to their investments size positively influences their asset amounts in the wind power subsector. Hypothesis 1b was not rejected, which means that their investment frequency also positively affects investors' wind assets. Interestingly, investment frequency appears to have a greater effect on investors' technological assets than does investment size (i.e., standard $\beta = 0.30$ and 0.46). The results of the time-specific model show that while the significance of investment frequency has increased through the years, investment size has played a less-influential role in the final wind assets of RES-E investors as time has progressed.

Hypothesis 2 pertained exclusively to testing the role of management experience on the amount of wind technological assets among Swedish investors:

Hypothesis 2. A firm's management experience in a subsector of the renewable electricity industry positively affects its amount of technological assets in the same subsector of the renewable electricity industry.

This hypothesis was rejected. This demonstrates the insignificance of management experience (as it was measured) on the capabilities of firms to acquire higher amounts of wind power assets. The results of the time-specific models suggest that this variable has never played a significant role in the market. One reason could be the definition of management experience as the number of firms a CEO manages concurrently, which excludes breadth of experience within one firm. Another reason behind this insignificant result could be that the CEOs' management experience has not yet had an effect but might have in future. Or that on the contrary the concurrent management of multiple firms has caused inertia limiting the managers' capabilities to explore the emerging opportunities³⁵. As Brailly et al. (2001) on a study on biases and effects of experience illustrate, experts (e.g., managers) can also be delimited by the limited information that they have or be over-confident in their knowledge assets thereby judgments.

The thesis also tested two hypotheses with respect to the industrial profiles of wind power investors:

Hypothesis 3. An investor with capabilities for unrelated diversification (i.e., a diversified industrial background) in a subsector of the renewable electricity industry has a larger amount of technological assets in the same subsector of the renewable electricity industry.

³⁵ For further reading please refer to the literature on serial entrepreneurs.

Hypothesis 4. An investor with capabilities for related diversification (i.e., a diversified generation portfolio) in a subsector of the renewable electricity industry has a larger amount of technological assets in the same subsector of the renewable electricity industry.

The model results rejected Hypothesis 3 on the relationship between firms' capabilities to diversify their industrial background—as a proxy for their unrelated diversification—and their wind assets. The model results showed that investors whose business is dedicated to electricity generation have a higher amount of assets in the Swedish wind power subsector; therefore, it can be concluded that while firms with diversified industrial backgrounds are joining the wind power subsector, electricity producers still comprise a majority of firms (see Figure 4–6). The significance of electricity generators in the wind power industry has increased through the years, according to the results of the time-specific model (compare the standard β values in 2003, 2008, and 2013).

This negative significant result could be explained by the availability of electricity generation firms' complementary resources, for example in terms of knowledge on the electricity system, network connection and access to cheap human capital. Since electricity generation firms are already familiar with the electricity industry this might make them more capable of exploiting available opportunities in the market. However, in future, traditionally non-energy based firms (e.g., farmers or real-estate) might enhance their complementary resources such as their connection to the network, and therefore their contributions to the renewable electricity industry could improve.

Figure 4–6. Contribution of different industries in Swedish wind power industry (source: own elaboration, using data from the TGC database and the Allabolag website)

However, the results do support Hypothesis 4, thus indicating that the investors' capabilities to diversify their generation portfolio—as a proxy for their related diversification—can positively influence their amount of wind power assets. The time-specific model results suggest that the significance of this parameter is increasing (corresponding to standard $\beta = -0.003, 0.062, \text{ and } 0.134$ in 2003, 2008, and 2013, respectively).

Finally, the model results support the assumption that the new entrants hold a higher level of dynamic capabilities, and Hypothesis 5 cannot be rejected. Hypothesis 5 tests:

Hypothesis 5. An investor's age within a subsector of the renewable electricity industry negatively affects its amount of technological assets in the same subsector.³⁶

The model results point to a significant and negative relationship between firm age within the subsector and the amount of wind power assets (See Figure 4–7). Corresponding to the results of the time-specific model, the contributing role of new entrants has increased through the years. This finding is somewhat paradoxical, given Hockerts and Wüstenhagen's (2010) finding that when a market matures, incumbents can overtake emerging new entrants. However, electricity markets are growing, and so this can change in the future.

Figure 4–7. Cumulative installed wind power capacity of incumbents of the Swedish electricity market and others, 1996–2013 (Source: Own elaboration, using data from the Swedish TGC database)

Whereas the model identified a significant relationship between investor firm age within the wind power subsector and the amount of technological assets, the model did not demonstrate any relationship between the investors' general firm age and wind assets (i.e., one of the control variables). As illustrated in Figure 4–8, the investors' general average firm age diverges significantly from their age within the wind power subsector. For example, while municipalities have the oldest average firm age among the other industries that contribute to the Swedish wind power subsector, they are the youngest in the wind power subsector (corresponding to firm age within the subsector). The model results also reject the existence of any relationships between the investors' number of invested electrical regions—which is the other control variable—and their amount of wind power assets.

³⁶ As the development of various renewable electricity subsectors began at different points in time, no proposition is put forward based on differences in RES-E investors' ages within various subsectors.

Figure 4–8. Average of investors' firm age and firm age within the wind power industry among different industries (Source: www.allabolag.se and the Swedish TGC database)

Summary: Onshore wind power investors with dynamic capabilities in Sweden

The results of the linear regression model demonstrated that certain relationships exist between Swedish wind power investors' characteristics and their amount of assets in the onshore wind subsector, while the time-specific model results shed light on the possible trends of those relationships.

On the whole, the results suggest that investors with greater investment experience, as captured through the firm investment size and frequency, have a higher amount of wind power assets. The results of year-specific models reveal that the relationship between investment frequency and wind assets is growing and becoming more significant than investment size and assets. However, in the final year of observation (i.e., 2013), no significant relationship was observed between firm management experience and amount of assets. Concerning the investors' industrial background, the findings illustrate that investors whose businesses are dedicated to electricity generation hold a higher amount of assets in wind and comprise the majority of this power subsector. Conversely, the results do acknowledge the positive relationship between investors' capabilities to diversify their generation portfolio, and their wind power assets. This relationship appears to have become more significant in recent years. Finally, with respect to firm age within the wind power subsector, the results demonstrate the dominance of younger firms in that RET subsector. This further suggests that new entrants have managed to overtake incumbents in the Swedish wind power industry, even though incumbents had an oligopoly in previously regulated electricity sectors.

4.2.4 Firms' heterogeneity in various subsectors of the sustainable electricity industry: evidence from the Swedish wind power, biopower, and hydropower industries

The results of the above analyses demonstrate the relationships between certain characteristics of Swedish wind power investors—which are embedded in their dynamic capabilities—and their amount of wind technological assets. Subsequently, the thesis tested whether those RES-E characteristics differed significantly across various Swedish renewable electricity technology subsectors (Propositions 1–3; OBJ5). Examining those differences, the thesis suggested that the varied costs of RETs are not the only reasons behind uneven competition across renewable electricity technology subsectors, within technology-neutral renewable policy instruments like TGC schemes. In practice, other factors—such as investor heterogeneity with respect to their characteristics—can exacerbate uneven competition.

To explore this heterogeneity, cross-sector comparative analyses were conducted of investors in Sweden that held wind power, biopower, and hydropower assets; these investors comprised 836 firms, and the study period was from 1996 to 2013. Corresponding to Propositions 1–3, the analytical results evidenced this heterogeneity by demonstrating significant differences among investor characteristics. Table 4–4 summarizes the findings of the Kruskal–Wallis pair tests, which indicate that five of the six variables under study differed significantly across the subsectors.

Table 4-4. Statistical results on differences among investors in wind power, biopower, and hydropower

Factors (variables)	Number of available data	Mean (SD)		Column A <i>Kruskal-Wallis Tests</i>		Column B <i>Mann-Whitney tests</i>	
		Sig. ^{a,b}		Chi-Square		Significant paired difference test results ^{a,c}	
		Wind power	Biopower	Hydropower			
1 Investment size (kW)	836	1994.28 (3799.09)	14431.95 (46791.54)	1147.14 (6405.80)	5.78	0.000	B>W>H
2 Investment frequency	836	1.32 (0.95)	1.23 (0.68)	1.17 (0.66)	5.78	0.055	
3 Management experience	791	1.94 (2.65)	1.03 (0.172)	1.31 (1.062)	34.47	0.000	W>H>B
4 Unrelated diversification (Industrial background)	836	0.69 (0.46)	0.06 (0.24)	0.50 (0.50)	156.58	0.000	W>H>B
5 Firm's partnership status	836	0.30 (0.46)	0.69 (0.46)	0.29 (0.45)	62.81	0.000	B>H, B>W
6 Related diversification (Generation portfolio)	836	1.03 (0.20)	1.20 (0.53)	1.12 (0.37)	35.49	0.000	H>W, B>W

^a All numbers are also significant with the Monte Carlo method.^b 0.01 is considered the critical significance-level value.^c All the paired difference tests are significant at the 0.016 level.

The test results indicate that Swedish investors in wind power, biopower, and hydropower differ with respect to their level of investment experience. The results shed light on the possibility of Proposition 1 of this study being true:

Proposition 1. In different subsectors of the renewable electricity industry, investors follow different paths to accumulating experience (herein related to (a) investment size, (b) investment frequency, and (3) management experience), which in turn affect capabilities for responding to changes in the renewable electricity industry.

The results of comparative pair-wise tests demonstrate that investors do differ significantly in terms of investment size, but not investment frequency. The test results identify biopower investors as having higher levels of investment experience with respect to their average investment size, compared to hydropower or wind power investors.

The test results illustrate significant differences among firms of various subsectors, in terms of their management experience. The results identify wind power investors as having the highest level of management experience, in comparison to the other two subsectors. Since the results of the earlier regression modeling did not identify any relationship between the wind power firms' management experience and their amount of assets in that subsector, it is expected that this characteristic plays a very limited role in the other two subsectors.

Regarding the firm characteristics that are associated with their industrial profile, the test results showed significant differences in terms of the firms' industrial background and generation portfolio mix (i.e. a range of renewable energy sources), across the subsectors. The results can be used to examine Propositions 2 and 3 of this thesis:

Proposition 2. In different subsectors of the renewable electricity industry, investors pursue varying paths to industrial diversification, which in turn affect their capabilities for responding to changes in the renewable electricity industry.

Proposition 3. In different subsectors of the renewable electricity industry, investors follow different paths with respect to generation portfolio diversification, which affects their capabilities for responding to changes in the renewable electricity industry.

The results suggest that biopower investors have the highest level of both the strong and weak forms of dynamic capabilities. Table 4–5 provides a taxonomy of the industrial backgrounds of the firms that contribute to Swedish wind power, biopower, and hydropower, and Figure 4–9 illustrates the share of the industries in the various subsectors. This taxonomy further acts as an analogue to the earlier claim of this thesis—namely, that RES-E investors are heterogeneous in terms of their industrial profile.

Table 4–5. Taxonomy of Swedish wind power, biopower, and hydropower investors' industrial backgrounds

Industry	Number of firms		
	Wind power	Biopower	Hydropower
Electricity generation	428	7	54
Electricity distribution	4	4	2
Electricity trading	5	2	3
Heating and cooling	6	36	2
Agriculture	50	13	5
Construction	21	1	2
Municipality	9	7	0
Real estate	24	0	4
Pulp and paper	0	10	5
Waste management	0	18	0
Consultancy	15	0	5
Machinery	7	0	0
Other	48	12	27
Total	617	110	109

Figure 4–9. Number of firms joining wind power, biopower, and hydropower from various industries

As Table 4–5 shows, the contribution of electricity generators to the wind power subsector is more significant than that of biopower or hydropower investors. Looking at Figure 4–9, one can see that while

firms from various industrial backgrounds have joined the wind power subsector, 69%³⁷ of all wind power investors are still firms whose businesses are dedicated to electricity generation. The hydropower and biopower subsectors follow, in that order, the ranking of firms in terms of their contributions as electricity generators, with shares of 49% and 6%, respectively.

The results show that biopower inventors diversified their industrial background more significantly than did the other two subsectors. Looking at Figure 4–9, one can see that the four industries of heating and cooling, pulp and paper, agriculture, and waste management together constitute 67% of all investors in Swedish biopower subsectors³⁸. The results of a comparative study of the partnership status of firms in various subsectors confirm these results. In the biopower subsector—which has the highest level of contribution from various industries—almost 70% of the firms have a parent company. Hydropower and wind power follow next, in terms of this ranking.

Finally, concerning the variable of generation portfolio mix, the test results again demonstrate higher capabilities among biopower investors in diversifying into related fields (See Figure 4-10). Therefore, biopower investors appeared to have the highest level of diversification capabilities, compared to the wind power or hydropower subsectors.

Figure 4–10. Number of firms with and without a parent company active in the wind power, biopower, or hydropower subsector in Sweden (Source: Own elaboration, using data from the TGC database and Allabolag)

³⁷ Figure 4–9 shows stacked percentages, but the numbers in the text are actual percentages. For this reason, they do not align perfectly.

³⁸ The analytical results show that the Swedish biopower subsector considerably benefits from contributions made by the pulp and paper and waste industries, as well as the Swedish heating district system. In practice, firms active in these industries have joined the biopower subsector to improve their production processes and their use of potential biopower fuel. Accordingly, to engage in the biopower subsector, they do not require the same level of diversification capabilities as the other industries. However, as noted in the methodology section, this thesis limits itself to distinguishing between firms with business in electricity generation and those that do not.

Summary: Differences among wind power, biopower, and hydropower investors' dynamic capabilities in Sweden

The results of the paired-difference tests demonstrate that investors build up different levels of dynamic capabilities within or across the wind power, biopower, and hydropower subsectors in Sweden (See the mean, standard deviation, and significance results reported in Table 4–4). The test findings show that in Sweden, biopower investors have a larger average investment size than do those of the other subsectors. The biopower investors also have diversified their industrial background and generation portfolio more significantly than have investors in wind power or hydropower. Accordingly, given the hypotheses of this thesis, Swedish biopower investors have built up a higher level of dynamic capabilities than have those of the other two subsectors. Based on the test results, the Swedish wind power investors only hold a higher level of management experience (one out of six studied variables), which the earlier regression modeling suggested plays an unimportant role. Hydropower investors recorded the lowest ranking in terms of almost all the studied variables, and therefore hold the lowest level of dynamic capabilities in the period following Swedish electricity market deregulation.

Overall, these results suggest that across Swedish renewable electricity technology subsectors, firms follow different investment paths and due to those paths they can respond differently to the sustainability change processes happening in the electricity industry. This partly can explain the mixed outcomes of policy instruments aiming for a larger share of RES-E, specifically technology-neutral renewable electricity policies such as the TGC framework.

5 Conclusions, Implications, and Suggestions for Future Research

This chapter will answer the thesis research questions and outline how the findings of this thesis contribute to both theory and practice. Furthermore, it will offer several policy and managerial implications, based on the research findings. Finally, it will present the limitations of this thesis and discuss how future research can enrich these findings.

5.1 Answers to research questions, and implications

To provide insights into the mixed outcomes of renewable policy instruments in the electricity industry, this thesis examines the following questions:

What are the driving forces behind the development of the renewable energy industry leading to a more sustainable electricity industry?

To answer this research question, two literature review studies were conducted. The first study was conducted using 30 papers that investigate the development and deployment of wind, solar, biomass, and wave energy in EU-7 countries and Ireland. By taking a systemic perspective and drawing on the TIS literature, the findings of that study gave rise to a typology of the driving forces behind the development of the renewable energy industry; this typology consists of 12 different categories that are embedded in four TIS structural elements and a dimension of region.

The empirical findings point to the influential role of all TIS structural elements (i.e., actors, institutions, network, and technology) in the development of the renewable energy industry. The thesis proposed that, notwithstanding the exceptional influence of energy-related policies, other factors play roles in driving emerging renewable energy markets. Identified factors included, actors' economic rationale and their willingness to acquire new competences, actors' change propensity, actors' obligations and set targets, societal preferences and norms, network strengths in terms of both the supply chain and societal networks, technological specifications and infrastructure, and regional attributes. The thesis's results showed that the development of the renewable energy industry cannot be explained as a simple one-way process dictated by policy instruments. In fact, the empirical findings demonstrated that the markets and technologies supported by various and multilateral driving forces appear to be more prosperous in bringing about ongoing sustainability transitions. Hence, focusing solely on policy-based driving forces is insufficient to leverage all the driving forces behind the renewable energy industry development, even if those forces considerably enrich approaches to accelerated RET development.

The second literature study (consisting of 63 academic publications) sheds light on the analysis criteria used to assess TGC system performance. This was done to explore which outcomes of this policy instrument

have been used to assess its success as a driving force. This knowledge also can aid policymakers to put the assessment into perspective, when reevaluating national TGC systems. The TGC framework was selected, because it is a prevalent policy instrument in the European electricity industry, allows free competition among RET subsectors and is currently in force in Sweden, the main empirical setting of this thesis.

The results of this literature study identified seven common analysis criteria; these are the economics of investment, the design and effectiveness of the TGC system, comparative analyses of RES-E support schemes, investor diversity, the TGC system as a harmonized policy framework (for EU), innovation and technical changes, and local preferences. The results showed that some analysis criteria are more commonly taken than others, and this in turn has affected our knowledge of TGC system performance. For example, while several studies assess TGC systems effectiveness in reaching their set objectives, or their influence on the economics of RES-E investments, fewer studies have examined how TGC systems induce technical changes, or motivate a diverse array of RES-E investor groups. This motivated the subsequent steps of this thesis, which was to study diverse RES-E investors in the renewable electricity industry, when the primary motivation was to delineate why policy instruments generate mixed outcomes.

Which firms contribute to the transition to a more sustainable electricity industry?

With firms in the spotlight, this thesis illustrated various groups of RES-E investors compete in the renewable electricity industry. Investor responses to ongoing sustainability transitions in the electricity industry, and policy instruments stimulating a larger share of RES-E differ from one group to another. This thesis especially distinguished incumbents from new entrants. Incumbents were defined as traditional oligopolistic firms of the old regulated European energy markets, whose market shares in energy production remain significant. On the other hand, non-traditional investors—herein referred to as “new entrants”—are firms who joined energy markets mainly after the market deregulation, with motives often different to those of the incumbents.

Given the heterogeneity among RES-E investors, the above question was answered by posing two specific subquestions. The first subquestion addressed only the reaction of incumbents to the sustainability transition in the European electricity industry, while the second subquestion took a more general view and explored the characteristics of RES-E investors (i.e., both incumbents and new entrants) that foster their decisions to contribute to the sustainable electricity industry. These questions were answered as follows.

How do incumbents react to specificities in national policy frameworks and social commitment to sustainability transition?

This thesis investigated the behavior of energy MNCs—as the incumbents of the European electricity industry—to determine if the firms adapted to the prevailing institutional contexts (i.e., national policy frameworks and social commitment) of their host countries or if they followed their core individual business strategies. The empirical findings derived from a case study of the operations of Vattenfall, a well-known

European energy MNC, active in Sweden, Germany, and the Netherlands. Further investigations on other European energy MNCs were conducted to extend and validate the findings of this case study. The case study findings revealed that Vattenfall was more devoted to its core strategies across local markets, and therefore less responsive to the ongoing sustainability changes and the commitment stimulated by local institutions. However, as renewable electricity markets mature, the role of institutions—in terms of both policy obligations and social commitments—becomes more predominant. Subsequently, local institutions challenged Vattenfall's strategies and compelled them to contribute to projects that are compatible with the requirements set by governments, society, and emerging electricity markets (e.g., institutions). This change can also be traced back in the operational histories of the other MNCs, which were studied.

Additionally, the findings showed that, specifically, MNCs' strategies are challenged by restrictive policies. Based on the findings of the Vattenfall case study, this thesis suggested that while MNCs in the European electricity industry do not take advantages of supportive policies, they do react strongly to restrictive policy instruments. These findings have one important policy implications, as follows.

- The market strategies of European MNCs, as the incumbents of the European electricity industry, are more bounded by restrictive policies than supportive policies, the latter of which have a marginal influence on MNC business profitability. Understanding that the companies' market strategies are crucial, since MNCs still handle a majority of the European electricity markets, the full potential of RES-E will not be realized unless this group of firms extensively participates in the renewable electricity industry.

Which characteristics of RES-E investors foster their decision to contribute to sustainability transitions within the electricity industry? How do those characteristics differ across RET subsectors?

Drawing on the theories of dynamic capabilities, this thesis assumed that RES-E investors follow different investment paths through which, they build up certain characteristics that are embedded in their dynamic capabilities. Such characteristics enable firm decisions to invest in RES-E, meaning that they acquire a higher amount of technological assets in RETs. The characteristics studied were investment experience, management experience, capabilities of unrelated and related diversification (i.e., diversified industrial background and generation portfolio, respectively), and the age of a firm within a subsector.

Next, this thesis examined the relationships between the RES-E investor characteristics and their amount of relevant technological assets (i.e., assets in RETs). The results of this thesis's empirical analyses of the case of Swedish wind power investors support the existence of certain relationships between investor characteristics and their amount of onshore wind technological assets. The statistical results suggest that firms with a higher level of investment experience—whose businesses are dedicated to electricity generation but hold a diversified generation portfolio—have a higher amount of assets in the Swedish wind power subsector. The results also showed that investors who joined the Swedish wind power subsector in more recent years hold a

higher share of assets in onshore wind; this suggests that currently, new entrants play more of a leading role in the renewable electricity industry (see also, Masini and Menichetti, 2013; Wüstenhagen and Menichetti, 2012).

The thesis also examined the heterogeneity of RES-E investor characteristics across three Swedish RET subsectors—namely, wind power, biopower, and hydropower. This was done to examine whether investors in different subsectors have different levels of dynamic capabilities. The statistical results showed that biopower investors gain a higher level of investment experience through their investment size; they also diversified their industrial background and generation portfolio more significantly than do those from the other two subsectors. Therefore, the cross-sector comparative study undertaken in this thesis found that in Sweden, biopower investors have a higher level of dynamic capabilities in comparison to wind power or hydropower investors.

Overall, this thesis found that RES-E investors are heterogeneous within and across RET subsectors, and that their characteristics can have an influence on their investment decisions for RES-E. These findings clarify the necessity of tailor-made policies by which to realize the full potential of a sustainable electricity industry. Given investors' different levels of market power (i.e., incumbents vs. new entrants) on one hand, and their varied capabilities and interest in RES-E on the other, policymakers need to understand that taking a "one-size-fit-all" approach will not nurture full RES-E investment potential. Therefore, the findings of this thesis bear the following policy implication:

- Tailor-made policies are essential at both the international and national levels to leverage the cooperation of all potential groups of RES-E investors in the renewable electricity industry.

Assuming the possibility of enhancing investors' characteristics that are embedded in their dynamic capabilities through tailor-made policy instruments, the empirical findings of this thesis give rise to the following policy recommendations.

- The results showed that the cumulative experience of RES-E investors matters. Policymakers can therefore give additional support to projects that can enhance the experience base of investors. One example of such a project is a plant with improved processes (e.g., higher generation capacity or cost efficiency).
- Policymakers can design specific policies for investors from different "industrial" groups.
- Policymakers can encourage a larger share of RES-E by motivating cooperation among investors from different industrial backgrounds or who have a diversified bundle of investments (e.g., a diversified generation portfolio). Through this cooperation, investors can contribute to one another's knowledge and experience bases and enlighten one another with respect to the different approaches through which network members can derive profits.

The findings of this thesis also suggest that new entrants have taken advantage of a unique opportunity and invested remarkably in the renewable electricity markets. This opportunity was made possible partially because the deregulation of the electricity industry has opened market boundaries. In such circumstances, energy producers understand that in current markets, customers can choose freely among electricity providers; therefore, firms need to compete for customers and work to address their expectations. Given the above arguments, the following managerial implications are relevant.

- New entrants are contributing remarkably to the renewable electricity industry. Thus, incumbents should contemplate the significance of these contributions, if they wish to maintain their competitive market positions.
- Soft institutions (i.e., market and societal and customer norms) appear to play a more prevalent role in current national electricity markets than was thought to be the case. This means that firms should thoroughly research the social dimensions of a market before making investment decisions.
- In a deregulated electricity market, parameters such as economies of scale may no longer play important roles. Energy producers may therefore come to reconsider the rationale behind their investment decisions.

5.2 Theoretical contribution

This thesis contributes to theory in the following two ways: first, it develops and presents a typology for the systemic driving forces behind the renewable energy industry development, which deepens the understanding of the TIS development for this industry by shedding light on the factors that can accelerate this development. Second, it incorporates the theories on dynamic capabilities into sustainability transition studies, and proposes a new analytical framework for examining role of firms in markets that are experiencing sustainability transitions.

Typology of the driving forces behind the renewable energy industry development

The TIS perspective, in line with the literature on an industry's life-cycle, explains that to enter a growth phase, a new industry needs to experience the formative phase of development. The formative phase comprises processes such as market formation, firm entry, and institution establishment. After there has been a successful formative phase, an emerging industry can enter the growth phase. Throughout this process, several factors (e.g., driving forces) can act as stimuli in further developing an emerging industry.

This thesis contributed to this line of research by presenting a systemic typology for the driving forces behind the development of the renewable energy industry. The driving forces were found to originate within the structural elements of TIS—namely, its actors, institutions, network, and technology—and also within the additional dimension of region (See Figure 4-1). The empirical data obtained demonstrated that regions

and technologies that encompass various and multilateral driving forces saw more accelerated development in their renewable energy industry.

New analytical framework that combines the dynamic capabilities theories with sustainability transition studies

This thesis made one of the first attempts to incorporate theories on “dynamic capabilities” into studies on sustainability transitions in the electricity industry. The value of incorporating capability-based literature into sustainability transition studies has been highlighted in earlier research (e.g., Markard and Truffer, 2012), although it has seldom been done in the energy literature.

A recent body of literature discusses those RES-E investor characteristics that have an influence on investors’ decisions to invest in the renewable electricity industry (see, Bergek et al., 2013b; Masini and Menichetti, 2012; Schmidt et al., 2012; Wüstenhagen and Menichetti, 2012), and therefore also on their contribution to sustainability transition. This thesis brought new insights into this line of research by incorporating dynamic capabilities theory—a line of theory that suggests that firms with a higher level of dynamic capabilities are better able to adapt to changes happening in a market (Teece, 2007). In line with this literature, this thesis proposed that firms with a higher level of dynamic capabilities are more capable of adopting sustainability changes taking place in the electricity industry. This means that they have a higher amount of REIT technological assets acquired through their investments in RES-E. For exploring RES-E investors’ dynamic capabilities, the thesis assumed that firms follow various investment paths, through which they build up certain characteristics that are embedded in their dynamic capabilities. The empirical findings of this research demonstrate that, indeed, the firm characteristics matter. This thesis investigated those characteristics that are linked to the investors’ experiences and industrial profile.

This thesis hence proposed a new analytical framework by combining dynamic capabilities theory with sustainability transition studies. An analytical framework can allow for the testing of whether investors with higher levels of dynamic capabilities are better able to contribute to a transition to a more sustainable electricity industry. Overall, the proposed analytical framework presents a new way of examining the roles and contributions of firms during sustainability transitions happening in an industry. The proposed analytical framework is applicable, albeit with considerations, to other industrial contexts undergoing sustainability transitions. Researchers in other fields can examine the role of firms in an industry by focusing on their characteristics and estimating their dynamic capabilities.

5.3 Methodological contribution

Sovacool (2014: P.530) highlights the necessity of new methodological approaches in the energy literature by stating that “*energy studies must become more socially oriented, interdisciplinary and heterogeneous. Problem-focused research activities that [...] include diverse actors and mix qualitative and quantitative methods, have a better chance of achieving analytic excellence and social impact*”.

In the past, researchers attempted to analyze the performance of energy-related policies in the development and deployment of RETs. However, to understand how electricity markets function, it has often been the case that too few actors in terms of firms investing in RES-E have been assessed (see, Masini and Menichetti, 2013). The conducted analyses were either qualitative in nature, or used quantitative methods that underrepresent the RES-E investors' heterogeneity. Therefore, many of those analyses did not acknowledge the heterogeneity of firms investing in a single RET subsector, or even across subsectors. This thesis addressed this shortcoming by undertaking a well-focused study of RES-E investors, setting the firm as the unit of analysis, analyzing a broad dataset and applying both qualitative and quantitative methods.

Given the limited number of incumbents in the European electricity industry, this thesis started its investigation by undertaking a case study of Vattenfall, a well-known MNC. Following from this qualitative method, this thesis incorporated several statistical tools to highlight and account for heterogeneity among all RES-E investors groups—including both incumbents and new entrants—in the electricity industry. To do so, this thesis drew several RES-E investor characteristics into the spotlight and offered a measurement method for each. This quantitative method developed within the thesis was used, first, to assess the influence of RES-E investor characteristics on their technological assets, and second, to analyze the extent to which investors differ from one another.

Drawing on dynamic capabilities theory, this thesis specifically examined the investor characteristics that are linked to their investment experience, industrial profile, and age within a subsector. To measure the characteristics, this thesis assumed that RES-E investors could accumulate experience by virtue of their investment size, investment frequency, and management experience. The investors' industrial profiles were captured through their industrial background and generation portfolio mix. This thesis hence proposed a calculation method for each of the characteristics.

The developed method makes an important methodological contribution to the energy literature by proposing a new approach by which to analyze investors. This method specifically contributes to research on the renewable electricity industry, in which investors are relatively large in number and rather heterogeneous. It should be noted that the method developed herein can be applied to other markets that are in flux. Therefore, with some considerations, the proposed methodology can be applied to and tested in other industrial contexts.

5.4 Limitations and future research directions

This thesis sought to identify the driving forces of the renewable energy industry development and to investigate firms' heterogeneity in the renewable electricity industry. However, it is difficult to fully identify and conceptualize within a single work the extensive diversity of the driving forces and heterogeneity of firms—the things from which this thesis's findings derive. Correspondingly, as with other works of original research, this thesis has a number of limitations that speak to several new directions for future research.

Additionally, there were several other interesting research topics beyond the scope of this thesis that would be worth addressing in future studies.

Limitations

First, this thesis aimed at explaining the mixed outcomes of renewable policy instruments for the electricity industry by focusing first on the diversity of the driving forces behind the development of the renewable energy industry and second on RES-E investors' heterogeneity. However, there are other reasons, which if one investigates can further fortify the arguments in this thesis. Examples of such reasons are conflicting policy instruments, lobbying activities, macroeconomic developments, and prices of raw materials to build RETs.

Second, this thesis made one of the first attempts to develop a comprehensive typology of the systemic driving forces of the renewable energy industry development. Therefore, in further research, with a more systematic methodological approach, is needed to more deeply conceptualize the typology's categories, and test this study's findings and extend its arguments.

Third, to explore the reaction of European incumbents to the sustainability transition in the electricity industry, a longitudinal case study was conducted herein on Vattenfall's operations in Sweden, Germany, and the Netherlands. Although several interesting results were drawn from this case, the findings could be enriched and tested by undertaking additional in-depth case studies.

Fourth, a single case within the European electricity industry served as the basis of the empirical context of this thesis, and a majority of the empirical data used herein were obtained from the Swedish electricity industry. This implies that further analysis with the same objective can be brought to bear on other national electricity markets (both in developing and under-developing countries), to bring new insights into this line of research and enrich the presented findings.

Fifth, this thesis modeled the relationship between a selected number of Swedish wind power investors' characteristics—all of which are embedded in their dynamic capabilities—and their amount of technological assets. The characteristics were chosen based on importance, relevance and data availability. This means that there are other characteristics that should be studied, in order to increase understanding of wind power investors in particular and RES-E investors in general. An interesting example of such characteristics could be investors' operational knowledge.

Sixth, to measure RES-E investor characteristics, certain assumptions must be made. For example, this thesis measured a firm's management experience by counting the number of firms that a manager (or management board) was directing simultaneously. However, firm size or an individual's relevant educational background could serve as alternative proxies of management experience. As another example, to measure investor capabilities with respect to unrelated diversification, this thesis distinguished only between firms with an

industrial background in electricity generation and others (binary variable = 1,0). However, each distinct industry needs to possess a varied level of unrelated diversification capabilities, if it is to invest in a renewable electricity subsector. For example, the pulp and paper industry and real-estate companies clearly need different levels of diversification capabilities if they are to invest in the biopower subsector. Therefore, an ordinal variable could be used in place of the binary variable. Overall, the application of other measurement methods could enrich the outcomes and findings of this thesis.

Finally, this thesis applied statistical methods to capture the characteristics of RES-E investors. Although quantitative methods are powerful tools for examining a particular dataset, they fall short in explaining the unique characteristics of included data cases. Likewise, the quantitative findings of this thesis fail to explain details and the particularities inherent in the analyzed data. For example, the results show that younger firms have a higher amount of technological assets in the Swedish wind power subsector, thus suggesting the important role of new entrants in this subsector. However, in reality, some incumbents also invest to a great extent in this subsector. Statistical analyses do not pinpoint those cases; they speak only to overall outcomes. Accordingly, the use of qualitative data can enrich the findings of this thesis's quantitative analyses in developing a more complete picture of what was found.

Future research directions

First, this thesis presented a typology for the systemic driving forces behind the renewable energy industry development; however, it did not study how various groups of actors value one driving force in comparison to another. For example, it is of interest to know whether a firm places more value on the strength of a local network or the technological infrastructure when investing in RES-E. Researching this topic can increase knowledge of the prevailing role of each systemic driving force for RETs.

Second, this thesis selected a number of RES-E investor characteristics and argued that those characteristics can affect the investors' responses to policy instruments that promote a larger share of RES-E. Nonetheless, there are several other important characteristics that can be analyzed and which lie outside the scope of this thesis. Examples of those characteristics are firm reputation or size, operational knowledge, and risk aversion.

Third, there is lack of knowledge of whether RES-E investor characteristics vary among various investor groups or segments. For instance, it is not clear how the experience, risk aversion, or operational knowledge of firms that join the renewable electricity industry from the agriculture, pulp and paper, or electricity generation industries differ from one another. Likewise, in the electricity industry, we do not know whether the risk aversion of new entrants differs significantly from that of incumbents.

Fourth, as a market grows, actors can interact and influence each other. Future studies can explore interactions among actors of different segments, regions, and/or countries, and discuss the consequences of such interactions. As an example, pioneers may interact with laggards and thus fortify their future investment decisions, and this may in turn lead to more accelerated advancement among RETs.

Fifth, this thesis focused on RES-E investors in terms of firms which electricity production is a part of their business. This means that there is still a need to study characteristics of actors who finance investments in RES-E and to examine how those characteristics have changed.

Sixth, in past years, the leveled cost of various RETs has changed massively (e.g., the case of solar PV (see for example, Karakaya et al., 2015)), thus causing welfare loss. It would be interesting to study firms' strategies in dealing with such welfare loss, how welfare loss affects firms' future investment decisions, and whether firms from different groups perceive the significance of such welfare loss differently.

6 Abbreviation

RET	Renewable Energy Technology
RES-E	Renewable Energy Sources-Electricity generation
TIS	Technological Innovation System
TGC	Tradable Green Certificate
FIT	Feed-In Tariffs
MNC	Multinational Companies
ETS	Emission Trading System
EU	European Union
CCS	Carbon Capture & Storage
EU-7 (countries)	United Kingdom, Sweden, Italy, France, Germany, Netherlands, and Spain

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