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University of Oslo

Postboks 1108
Blindern
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Commercializing new renewable energy solutions: Understanding the formative phase of an emerging technological innovation system

- A case study of the Norwegian Research Centre for Offshore Wind Technology

Lene Gjengedal Hansen

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Lene Gjengedal Hansen

E- mail: Lenegjengedalhansen@gmail.com

Telephone: + 47 48 22 22 47

University of Oslo

Innovation and global challenges

Supervisors:

Magnus Gulbrandsen and Olav Wicken

Preface

This master thesis is the final part of the Master in ESST - Society, Science and Technology in Europe at the University of Oslo. The program has duration of 13 months and consists of three intensive semesters. The program has a cross-disciplinary approach involving innovation, technology and culture in society.

This thesis is part of and a contribution to the research project CenSES at the TIK-center at the University of Oslo. The purpose of the research project is to create and preserve knowledge-bases with a focus on transition strategies that enhances sustainable energy systems and a “green” economy.

I would like to also thank all contributors, especially: Alfred Bjørlo, Audun Ruud, Espen Borgir Christophersen, Gard, Hopsdal Hansen, Jan Onarheim, Kjell Eriksson, Markus Steen and Trond Einar Pedersen.

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Lene Gjengedal Hansen

Abstract

New renewable energy (NRE) represents enormous potential and is recognized as a way to fix the increasing demand of energy as well as preserving our climate. However, the sun and the wind come and go, so we need to *control* it. In order to accomplish this, new technological innovation must emerge, which also represents great challenges and large uncertainties. The object of this thesis is to increase the understanding of the formative phase of an emerging technological innovation system studying the Norwegian Research Centre for Offshore Wind Technology (Nowitech). Offshore wind power (OWP) represents a great potential in Norway. A successful establishment of OWP farms is important for the environment, society and to secure future energy supply.

I argue that the energy system is constrained by a national "systemic lock-in". Norway has traditionally had a recourse based economy. Idiosyncratic patterns refer to traditional industries within a country, like the Norwegian fishing and shipping industries which later formed a basis for the petroleum industry. Hence, this in turn can represent a foundation and competitive advantage within an OWP system. The theoretical framework is based on the technological innovation system approach (Bergek et al., 2008). It focuses on the co-evolution of technological innovation, markets and policies that are recognized as key premises for technological innovation systems to emerge and evolve. The framework emphasizes the systemic aspects related to OWP in Norway, whereas the technology is "black-boxed".

The Norwegian energy system is characterized as diverse, but dominated by the petroleum and hydropower industries. Nowitech is defined as a system builder and facilitate knowledge creation and transfer within the system. The OWP system mirrors a strong national offshore industry and is categorized as diverse. Because of this policies and market opportunities are limited in Norway. This drives firms to an "exit" strategy, meaning that they enter other countries with more established markets. NRE policies have characteristics similar to the ideal type of "innovation policy" that favor a neo-classical approach. Hence, the Norwegian OWP system is lagging behind the European race towards a more sustainable economy.

Keywords: Commercialization of new renewable energy; Innovation; Innovation systems; Lock-in; National Innovation System; Offshore wind-power; Path dependency; R&D; Technological innovation system.

Contents

List of tables and figures

Abbreviations

CIC	Committee of Innovation and Commercialization
FME	Centre for Environment-friendly Energy Research
GHG	Green House Gas Emissions
IS	Innovation System
NIS	National Innovation System
Nowitech	Norwegian Research Centre for Offshore Wind Technology
NRE	New Renewable Energy
NTNU	The Norwegian University of Science and Technology
ONWP	Onshore Wind Power
NP	The Norwegian Petroleum Industry Association
OWP	Offshore Wind Power
R&D	Research and Development
RENERGI	The Clean Energy system of the future
RES	Renewable Energy Strategies
RQ	Research Questions
SC	Scientific Committee
SR	Scientific Research
STI	Science, technology and innovation policies
SME	Small and Medium Enterprises
TIS	Technological Innovation System
TTO	Technology Transfer Office, refers to the NTNU Technology Transfer that is the commercialization unit of NTNU

Introduction

The objective of this thesis is to increase the understanding of the formative phase of an emerging technological innovation system (TIS) within offshore wind power in Norway, related to the case study of Nowitech.

It is now 20 years since the first offshore wind power was built in Denmark (Breton and Moe, 2009). It is common to distinguish between onshore wind power (ONWP) and offshore wind power (OWP). ONWP is a relatively mature technology, whereas OWP represents uncertainties and many challenges as a relatively new technology. Both Denmark and the U.K. are key actors within the OWP field which is characterized by policies and an incentive system that support and encourage OWP development (Breton and Moe, 2009).

Norway has traditionally been a natural resource based economy. The establishment of the oil and gas industry in the mid-sixties by the state has strongly influenced the energy system today. This has gained attention within the innovation literature were the phenomena is expressed to have caused a "systemic lock-in" or "path dependency", meaning that prior behavior is decisive for future actions (Narula, 2002, Fagerberg et al., 2009b). Since 2000 the petroleum industry has contributed with 18 – 25,4 percent of the GPD, in addition to being one of the main suppliers globally[1]. The domestic energy supply is mainly delivered by hydropower parks in Norway (Hansson and Øydgard, 2010). Similar to the petroleum, commercialization i.e. a transmission of the ownership of the hydropower parks from the state to commercial firms were restructured in early 1990s. The main argument against new renewable energy (NRE) is that it requires capital intensive investments and that it is not cost effective compared to other energy available energy solutions in Norway.

[1] Website Ministry of Petroleum and Energy (Accessed 4.5.2011) http://www.regjeringen.no/nb/dep/oed/tema/teknologi-og-internasjonalisering-innen-.html?id=86979

This illustrates the unique situation of the energy system which also is referred to as the Norwegian paradox because the potential for more sustainable energy production is vast in comparison with most other countries which leads to a tension between climate and energy policies (Hanson et al., 2011).

In 2008 the climate settlement pushed forward a collective political commitment in Norway. One of the main results was the establishment of the Centres for Environment-friendly Energy Research (FME). One of the eight FME`s was Nowitech. The research center´s goal is to develop and provide pre-competitive R&D that can be facilitated within the OWP system and potentially become commercial products[2]. OWP is a radical innovation because it challenges existing energy systems in Norway, the hydro-power and the petroleum –industry as a potentially new system competing with the same end product; energy. These industries also shape the basis for "idiosyncratic patterns" which represents the foundation for knowledge transfer and contribute to competitive advantage and a position in international markets for Norwegian OWP.

The thesis will pinpoint some of the key challenges for new renewable energy in Norway. The case of Nowitech is used to illustrate how and why. The theoretical framework builds on innovation system literature in order to analyze, capture and discuss relevant issues and the most important findings. The scope of enquiry is the reason why the selected interview objects represents different positions within the new renewable system in Norway, with an emphasis on the OWP field. This is the reason why the thesis is orchestrated with a perspective from "outside – in" instead of the more traditional weight on the case-study unit solely.

NRE refers to energy sources that are not yet facilitated. These potentially new energy systems face different challenges towards adoption in the market and society which is are referred to revers salient. Hence, most new sustainable energy systems is *not* able to compete in the market sphere, in order for them to develop it is a premise that the state interfere or other that the systems receives other forms of support.

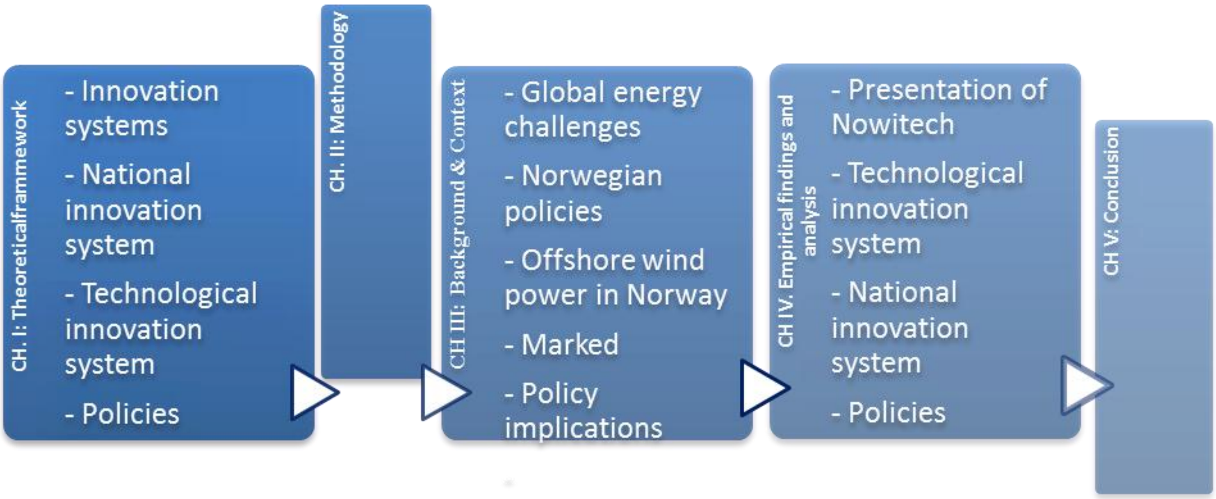
I argue that a "systemic lock-in" within the Norwegian energy system possess great challenges for a formative TIS to emerge. In order to understand the formative phase of OWP in is important to study what occurs in a TIS and how key blocking or inducement mechanisms related to technological innovation may represent a reverse salient (Bergek et al., 2008).

[2] A product refers to both commodities and services SCHIFFMAN, L. G. & KANUK, L. L. 2007. *Consumer behavior,* Upper Saddle River, N.J., Pearson/Prentice Hall.

Thesis outline

The thesis is organized into five chapters. To guide the reader through the thesis, the logical structure and themes in the thesis is presented in the following model.

Figure 1: *Thesis build-up*



Chapter I Theoretical Framework introduces innovation literature related to the systemic approach, the issues of knowledge transfer at several levels and policy aspects. Based on the theoretical review and the case study the research questions (RQ) are derived. *Chapter II Methodology* accounts for the choices that were done before and during the work on the thesis and a theoretical discussion. *Chapter III Background and Context* includes important facts, historical events, policies, market development and other important documents that shed light on renewable energy strategies (RES) and OWP in Norway. Moreover it gives a brief explanation of OWP technology. *Chapter IV Empirical finding and Analysis* introduces the case study, an analysis and a discussion of the RQ`s and an overview of the empirical findings. *Chapter V Conclusion* presents important deductions and discussions for further research.

I. Theoretical framework

The theoretical framework used in this thesis will be explained in this chapter. A socio-technical theoretical approach is used to capture all relevant actors that influence the formative phase in the field of NRE related to OWP (Geels, 2004, 525).

Firstly, I define important denotations used in this thesis. Secondly, I present the innovation discipline and discuss some of the main theoretical approaches within the "innovation system". Thirdly, I present the theoretical framework national innovation system, technological innovation system and policies. These theoretical approaches are supplemented with contributions from academic theories within learning and knowledge transfer as well as other relevant literature from the innovation field. At last, I present the research questions I will enquire in the case study.

Definitions

Innovation origins from the Latin word *innovare* and it is defined as an invention in the first phase towards commercialization (Fagerberg et al., 2006, 5). *Commercialization* is when a product is brought to the market and made profitable. Innovation theory distinguishes between several types of innovation. *Incremental innovation*s refer to a product development or improvement whereas *radical inventions* refer to innovations that occur in the development phase, that are not adapted into existing systems but inaugurated and new (Bijker et al., 1987, 57). *Conventional inventions* are defined as improving innovations that may expand existing systems which dominate the phase of growth and competition (Bijker et al., 1987, 57).

Innovation trajectories to commercialization vary according to what type of innovation it is. *NRE* refers to an exploitation of energy recourses that are inexhaustible and do not damage or have negative effects to the environment (Hansson and Øydgard, 2010, 18). OWP may become a radical innovation because it challenges and is perceived as a threat to existing energy systems. This is because OWP is feeding off the same resources like personnel, expertise, incentives and infrastructure etc. in addition to being a potential competitor in supplying energy to end users. The process of research and development as a resource to achieve relevant knowledge that can facilitate innovations, or selected to be commercialized is recognised as one of the key aspects within innovation literature (Edquist, 2005). This "transformation into knowledge" as Edquist (2005, 190) puts it, places and provides a basis for diffusion and dissimilation[3] of relevant knowledge in the centre of trajectories from scientific research (SR)[4] and R&D to commercialization.

An introduction

Innovation studies began to surface as its own field of research in the 1960s (Fagerberg et al., 2006, 2). The field is dominated by a cross-disciplinary approach echoing the influence innovation has within many disciplines. "*Thus, theories of interactive learning together with evolutionary theories of technical change constitute origins of the systems of innovations approach*" (Edquist, 1997, 7). The establishment of the Science Policy Research Unit (SPRU) at the University of Sussex was the starting point for academia, later followed by a number of research and department was establishments around the twentieth-century (Fagerberg et al., 2006).

A main finding within the field of innovation "is that a firm does not innovate in isolation, but depends on extensive interactions with its environment" (Fagerberg et al., 2006, 20). Several approaches has emerged to increase the understanding of this phenomena which

[3] Refer to a process of becoming less similar DICTIONARY, O. E. 2004. Oxford English dictionary online. *Mount Royal College Lib., Calgary,* 14.

[4] *Scientific research*, is defined as "the human activity directed towards the advancement of knowledge …facts or data…and theories or relationships between facts". NELSON, R. R. 1959. The simple economics of basic scientific research. *The Journal of Political Economy,* 67**,** 297-306..

has led to concepts like “networks” or “systems”(Fagerberg et al., 2006, 20). The systemic approach is regarded as one of the main tools in order to understand these phenomena’s.

In order to understand the advancement of innovation the connections between science and technology is important. The development of science and technology effects and depends on each other, although *how* it occurs changes, the advancement is not an isolated phenomena – by and large we can say that the development of NRE in Norway is dependent on an SR and technological innovation (Mowery and Rosenberg, 1991, 23).

Innovation systems

Innovation systems (IS) literature refers to a specific way to understand a given phenomenon. The approach offers a multitude of theories that systematizes different key factors in relation with the level (macro, meso or micro) and type of innovation (incremental – radical or knowledge-base or commodity) in connection with the phase of development the innovation has reached. Each theory offers frameworks that point out different functions that are vital in innovation trajectories towards commercialization that are applicable to illustrate the development of NRE solutions in Norway.

Fagerberg et al (2009a, Fagerberg et al., 2006) argue that the IS approach is better understood in a historical context, the evolutionary approach. Hence, different ISs co – exist in relation with each other and is affected by their historical paths. This broad approach defines ISs to include all factors that may affect the innovation process, recognizing that we do not know what determinant(s) that potentially is an important factor in the innovation process. Edquist (2005, 183) define “(national) systems of innovations includes all important economic, social, political, organizational, institutional and other factors that influence the development, diffusion and use of innovations”. Fagerberg distinguishes between systems *organizational* and *institutional* components; organizations i.e. formalized structures between actors or players, and institutions i.e. unformulated rules of the game, norms, culture, regulation and laws within the system (Fagerberg et al., 2006, 182). However, the different actors and influences that strengthen and "shapes" the system does not need to be firmly organized (Nelson and Winter, 1982).

Edquist (2005, 190) classify a IS at a more general level as "*the main function - or the overall function - in ISs is to pursue innovation processes i.e. to develop, diffuse and use innovations*". A general definition of a system in this context is a group of components or functions (devices, objects, institutions, organizations or an agents role) working towards a common generic goal or serving an overall mutual purpose by creating, diffusing and utilizing innovative products (goods, services or processes) (Bergek, 2002, Carlsson and Stankiewicz, 1991, Galli and Teubal, 1997).

ISs may be defined in a multitude of ways, yet today there are four theoretical approaches that are frequently used; national, regional, sectoral and technological (Fagerberg et al., 2009b, 5, Carlsson et al., 2002, Carlsson, 2006)

National innovation system (NIS) is limited by national borders, whereas regional innovation system (RIS) narrows down the geographical proximity. Sectoral innovation system (SIS) or TIS emphasizes a specific industry, field or limited to a specific technological artifact.

From here on, the IS literature in the theoretical framework will focus on NIS and TIS. The NIS approach provides a wider approach to understand the premises NRE encounter in Norway. Whereas the TIS approach is a heavily empirical tool that point out important functions that must be present in well performing TIS and it is suited to understand the relation between innovation and technical engineering.

National innovation system

The term "national system" of innovation appeared first in the published book about Japan by Freeman (1987) (Carlsson, 2006). The following year another book on national IS from

(Freeman and Lundvall, 1988) emerged (Carlsson, 2006). The two most influential literature contributions on national IS are Lundvall (1992) as mentioned above, in addition to Nelson (1993) according to Edquist (2005). The two contributions differ in their approaches within the field of studying NISs, which again reflects the two opposite interpretations on NISs today. Whereas Nelson is more focused on the importance of empirical studies, Lundvall emphasizes the theoretical approach (Edquist, 2005, 183).

In order for new ISs to emerge within a national context it is important to reflect on the foundation, potential and obstacles is may present. In addition to frame premises for new renewables within national boarders, it also facilitates the possibility to compare one NIS to another. Based on the characterization that NRE technologies are emerging and challenging the exiting energy systems, national pre-conditions are important to recognize at a national level. The Norwegian idiosyncratic patterns represent national premises for ISs to emerge. Furthermore is creates a basis for transfer of knowledge. Diffusion and transfer of knowledge are key functions for an IS to evolve, especially for R&D within the field of engineering. (Fischer, 2001). These are important factors that will be emphasized in the IS approach as follows.

The NIS approach is suitable to understand why countries do as they do related to national characteristics. Hence, illustrate the trajectories within NRE with a particular emphasis on policies related to R&D and energy.

The NIS in Norway may be described as diverse (Wicken, 2009, 33). This diversity is explained by a historical processes and different paths spinning out from the three most important industrial transformations processes originated from Western history (Wicken, 2009). Competence specific development within the Norwegian energy system poses the possibility of a “lock-in” (Coriat and Dosi, 1998, 104). Hence, in some countries “national champions” closely interaction with the state and have power to influence the system, the economy and policies to their own advantage (Narula, 2002). Introducing radical technological innovations may require a transition within the energy system, a high level recourses and reallocation of them in addition to governance interference. Hence, “national champions” do not want to change their position in the energy market, they can use their power to resist innovations (Christensen, 1997). In this thesis “national champions” refer to major power companies that have co-evolved with the state like Statoil, Statnett and Statkraft etc.

Knowledge transfer and diffusion within a national system

Knowledge creation processes or activities are coupled with uncertainty. This can cause a lack of sufficient information for a foundation to make good strategic choices or rational decision making. However, within a NIS there are some traditional patterns that enhance the probabilities for creation of knowledge in some fields above others. Lundvall (1988, 360 - 361) argue that knowledge transfer is related to “idiosyncratic national patterns”, meaning that national characteristics and industrial traditions facilitates a foundation and potential that may favor some technologies or industries with specific characteristics above others. The distinct patterns of a technological specialization changes steadily over long epochs of time, and are dissimilar from country to country, regardless of the increasing global economy (Narula, 2002). Furthermore, “Idiosyncratic technological capabilities” reflect the difficulty transferring knowledge and technology, whereas some knowledge might be embodied in commodities, others are intangible assets embodied in the work force (Lundvall, 1988). One example is the Norwegian traditions within marine industries that may have benefited the emergence of the offshore oil and gas industry in the mid-sixties. Moreover, Lundvall argues that the most significant limits to international learning and international transmission of technology may be explained by the” limited mobility of labor across national borders…interaction between users and producers who belongs to the same national system may work more efficiently for several reasons" (Lundvall, 1988, 360 - 361). Most important is the common language and cultural proximity which is related to short geographical distance (Lundvall, 1988). More current IS perspectives are associated with the evolutionary and economy view (Nelson and Winter, 1982). The principle that innovation generates economic growth is an argument for a public and active interference by the state.

Spatial proximity[5] and idiosyncratic patterns reflect how firms interact and benefit from exciting knowledge bases within a NIS. Firm's location of R&D is often located close to "home". Production units on the other hand, may be facilitated through and include networks outside of the NIS (Narula, 2002). Narula (2002, 800) argue that there are three strategies a firm can use in respond to a systemic lock – in; *voice*, *exit* or *laissez faire* (Narula, 2002). "Voice" refers to lobbying and allocating recourses to strengthen the power, mainly political, to influence and push the novel IS forward. The "exit" strategy may be used as a respond when the "voice" strategy didn't work, and means that the system or a majority of the actors connect to or enter other NISs where there already are functions present that support the IS. "Laissez faire" is doing nothing or continuing to do the same.

Technological innovation system

Thomas Hughes is recognized as the first to describe a TIS (Carlsson, 1995, 3). Hughes (1987, 53) argues that "*Technological systems solve problems or fulfill goals using whatever means are available and appropriate; the problems have to do mostly with reordering the physical world in ways considered useful or desirable, at least by those designing or employing a technical system*". Carlsson and Stankiewicz (1991, 93) argue that "*A technological system is defined as a dynamic network of agents interacting in a specific*

[5] Referring to space or that the interval of dimension is close. DICTIONARY, O. E. 2004. Oxford English dictionary online. *Mount Royal College Lib., Calgary,* 14.

economic/industrial area under a particular institutional infrastructure and involved in the generation, diffusion, and utilization of technology". The two definitions stresses how emerging NRE systems needs to allocate necessary resources and fulfill "functions" so that the system is able to solve current and future problems and challenges. Hence, a TIS development may be dependent on a multileveled and a social coordination preparing and arranging incentives, policies and markets etc. so that the TIS may emerge. If one part of the windmill doesn't work or if the infrastructure is inadequate, the lagging component is a reverse salient up until it can be solved and altered.

The concept of reverse salient is related to the concept of system. " Reverse salient are components in the system that have fallen behind or are put out of phase with the others" (Bijker et al., 1987, 73). A reverse salient mainly occurs in radical innovations whereas in conservative inventions the reverse salient would already be solved

Hughes (1987, 73) argues that the denotation salient is better suited than "bottleneck". On occasion a reverse salient can be a consequence of radical inventions, because the emergence of new technical systems also is equivalent with complex and enduring alterations that may have caused a new way to meet a perceived need in society.

Scoping down innovation systems

In contrast to the national system approach within IS literature, many contributions narrow down the "IS" approach, to more specific areas like technological, sectorial, regions, products etc. (Edquist, 2005, 183). Carlsson et al (2006, 58) argue that "depending on the purpose of the inquiry, the most useful definition of ISs might not coincide with national borders". The emergence of several published works on these different approaches began in 1988 when some Swedish colleagues started to work on similar technological systems centered on innovations in specific techno-economic parts (Carlsson, 2006, 58). Hekkert et al. (2007)

argue that the emergence of a new IS evolves in parallel with technological development and change. Moreover, that the traditional IS approach is insufficient and primarily emphasize the focus on structural components (Hekkert et al., 2007). The framework that is suggested centers around a number of key processes for a well-functioning IS, these are labeled as "functions of innovation systems" (Hekkert et al., 2007).

The process of technological innovations

The evolutionary approach suggests that the phases of a technological system or the development of innovation, are not sequential or linear, they overlap and backtrack (Bijker et al., 1987) (Fagerberg et al., 2006, Bergek et al., 2008).

Figure 2: *The linear model of innovation*

Source: *(Kline and Rosenberg, 1986, 286)*

The linear model of innovation has been regarded as the main model of innovation since the world war II when it first was introduced in the Vannevar Bush report "Science the endless frontier" (Kline and Rosenberg, 1986, 285, Bush, 1945). Although the model indicates that the sequential process from R&D to commercialization is isolated, Kline and Rosenberg (1986) argue that this merely is a simplification of reality.

The model does not incorporate the market as a factor or as part of the process. The idea of innovation is mostly related to a recognized commercial need, and normally it is through feedback on perceived problems encountered in a specific area that pushes it forward.

This emphasizes the interaction between innovation and market developments, were the TIS to some extent may be argued to co-evolve with the market sphere.

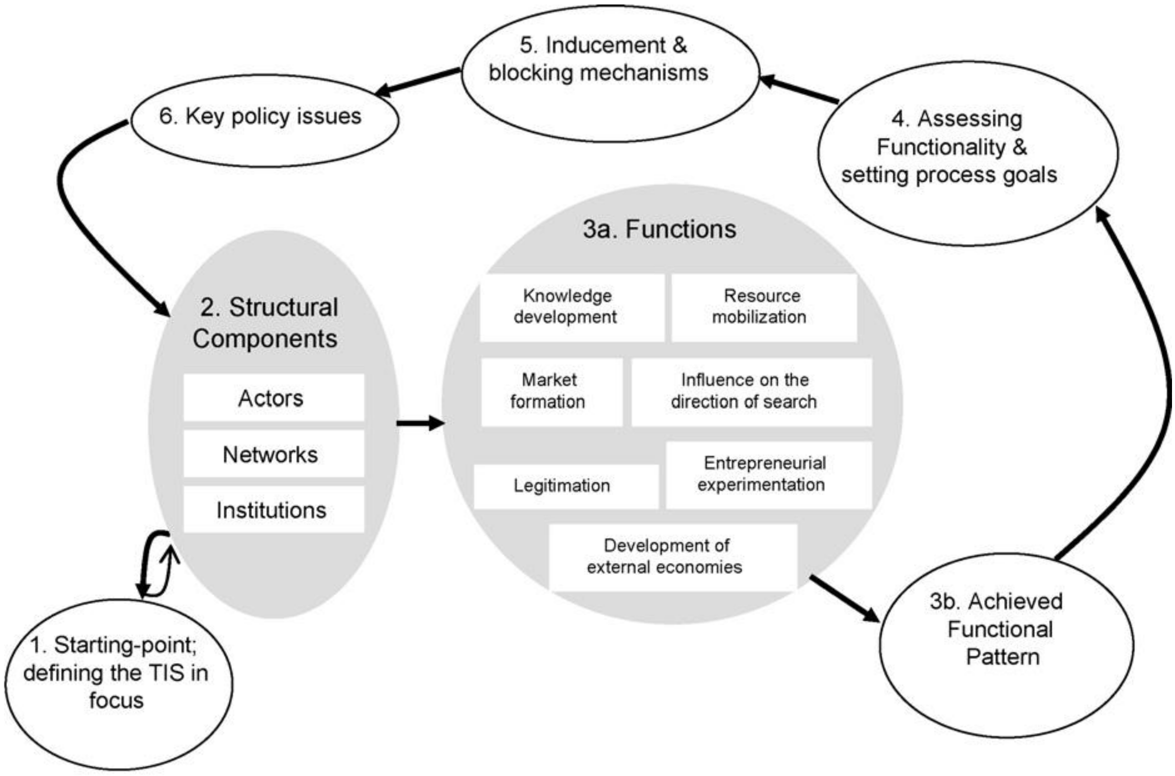
Whereas most innovation literature treats the theories as somewhat static, Bergek et al. (2008) provides a more dynamic approach to analyze a TIS, in which provides a different perspective. TIS is defined as “socio-technical systems focused on the development, diffusion and use of a particular technology (in terms of knowledge, product or both)” were the TIS may be interpreted to part of a NIS (Bergek et al., 2008, 480). What separates the theory from other applicable innovation literature is the relevance it brings to technological innovation development in relation with policy makers, recognizing the interactive and dynamic relationship between the “system builders” and government to a higher extent than other IS approaches like Fagerberg et al (2009b) and others. These factors provide adequate connections to understand the energy system in Norway and may indicate the status of the TISs development. The theory may also indicate what strategic trajectories the OWP system currently are following and to some extent indicate what future strategic choices that can benefit further development.

Technological innovation system functions

Bergek et al (2008) introduce six steps of analyzing (TIS) that are based upon reviews of and related to 20 different concepts of TIS approaches from the innovation literature.

The key proceseses are in sum what represent a functional TIS, and in an analysis of how the TIS is behaving it may point out key challenges and bottleneck that need to be overcomen in order to reach a well function system (Bergek et al., 2008).

Figure 3: *Sheme of analysis of a functional TIS*



Source: (Bergek et al., 2008, 411). The scheme of analysis (adapted from Oltander and Perez Vico, 2005).

The behavior of any defined TIS will probalbly differ from antoher TIS, due to the fact that most patterns doesn`t replicable. The thesis will mainly focus on “3a. Funtions” although the other steps are relevant to increase the compelete understanding of a TIS. In the following the seven functions are presented acordignly to Bergek et al (2008). The limitations are dune because they capture the core of innovation dynamics and provide a good undertstanding of how the OWP operate and what challenges it may experience within the energy system today. Although the other “steps” are not reviewed thuraly in this thesis, these factors are accounted for by other suitable approaches in this thesis.

Risk and uncertainty are key elements in TIS. Bergek et al., (2008) discuss how a well performing TIS is be related to how the functions is carried out. Hence, this underlines how a TIS acts to overcome major uncertainties and reduce risk in order to form a system.

Mapping the functional patterns of the TIS

1. *Knowledge development and diffusion*

At the core of a TIS is the knowledge base. The knowledge development and diffusion describes the performance and evolution of a TIS, and how the knowledge is diffused and interact in the system as well as over time. It distinguishes between different types of *knowledge* and between different types of *knowledge development*.

Cohen and Levinthal (1990) argue that the parallel between a firm's capability to recognize and assimilate new knowledge to its innovative capability correlates with its absorptive capacity. "The ability to evaluate and utilize outside knowledge is largely a function of prior related knowledge " (Cohen and Levinthal, 1990, 128). A firm's absorptive capacity therefore refers to the whole organization, and not the sum of its individual's abilities, but how well the firm is able to exploit it. Hereunder, knowledge transfers and distribution within the firm, and communication between the firm and its environment. Shared expertise and knowledge, like language and symbols, may enforce basic internal communication. However, for a firm to incorporate and acquire specific critical complementary knowledge and complex information, like sophisticated technology, internal experience must occur. Furthermore, the competent staff must be familiar with the idiosyncratic needs of the firm.

Creation of knowledge and transfer is coupled to the organization as a whole i.e. structure, strategy, culture etc. It is an ongoing innovation process that cannot be outsourced to a division or to an external unit (Nonaka, 1994). Nonaka presents the terms explicit and tacit knowledge (Nonaka, 1994, 16 - 17); tacit knowledge i.e. codified knowledge refers to knowledge that can be transferred through language and "digitalized" in data, books etc. Tacit knowledge needs a higher level of involvement and requires a process in order to gain a mutual understanding of the desired knowledge.

2. *Influence on the direction of search*

Bergek et al (2008) suggest that in order for a TIS to evolve, new entrants i.e. firms, organizations, institutions and other actors need to decide to enter it. It also needs to be a pressure or an incentive system making the choice desirable. The function also includes the mechanism and degree of strength of the following qualitative factors; articulated demand, competing technologies and services, belief in the TIS growth potential, policies and incentives in the energy sector, price on electricity and the extent of regulatory pressure. The function measures the variables together, meaning that not all variables need to be present in order for the influence on the direction of search to be positive or negative for new entrants.

A system is dependent on the advocacy and mobilization of new actors, like mentioned earlier. Hughes (1987) refers to these as system builders. “One of the primary characteristics of a system builder is the ability to construct or to force unity from diversity” (Bijker et al., 1987, 52).

3. *Entrepreneurial experimentation*

A TIS evolves with a high degree of uncertainties in its *emerging* phase. The uncertainty is linked to technological development and to the fundamental requirements necessary to be able to develop technologies, markets or applications (Bergek et al 2008) (Rosenberg 1996). However, in order to push forward a TIS`s development, experimentation must be present. Entrepreneurial experimentation in the TIS is recognized through the diversity and number of new entrants, the use and extent of technologies and complementary technologies, and different forms of applications. Although the level of uncertainty may be recognized at a high level in the formative phase, it is also likely to prevail in the next phases at different levels. Furthermore, a decisive role for systems builders is to ensure feedback loops between system performance and goals in order to correct errors in a technological system performance (Bijker et al., 1987, 54). As a system evolves over time and get closer to "momentum" it also becomes less adaptable.

4. Market formation

Market formation life-curves are typically divided into three stages *nursing*, *bridging* and *mature* (Bergek et al., 2008) (Kotler and Keller, 2006). In order to understand the cycle of market formation one must study the *market development* and what *drives* market formation. Here, the important factors to consider are; timing size, type of market, identify the users and consumer behaviors i.e. if possible identify a demand "profile". These factors may be underdeveloped or even none existing for an emerging TIS. Based on this the market formation needs to be accommodated by a formation of organizations and institutions. Hereunder, a premise for markets to evolve is the creation standards (Bergek et al., 2008, Hughes, 1983).

A key challenge for formative or emerging technological system related to NRE solutions is that it in its initial phase rarely is competitive (Mowery and Rosenberg, 1979). In Norway the state has played the role as an interventionist in industry especially since the second world war, this underlines the need for policies and incentives to support *nursing* and *bridging* TIS in small and open economy's (Narula, 2002). The formative phase of a TIS related to NRE policies and state interference may therefore be a premise related to the function.

5. Legitimation

Legitimation refers to the process of making the TIS acceptable and normative to the relevant organizations and institutions. This may occur in relation with upstream or downstream knowledge development of the new technology. The function level and dynamic may be identified by indications like the number of R&D projects, bibliometrics, number of professors and, or patents.

Siddiqui and Fleten (2010) claim that the opposing forces of CO2 emissions have increased and contributed to an acceptance of finding and funding NRE solutions in society mainly related to the marginal social cost of pollution.

6. *Resource mobilization*

For an emerging TIS to develop, it needs to mobilize a variety of resources. The analysis points out the importance of recognizing the level and extent to which the TIS is able to assemble*/competence/ human capital*, *financial capital* and *complementary assets*. The measurement may indicate strong or weak resource mobilization like the infrastructure, number of university degrees, services, etc.

7. Development of positive externalities

Positive externalities refer to economies that have a positive impact on the TIS. This function`s degree of strength is argued to have an impact on the other six functions, and therefore also regarded as an indicator to the overall dynamics within the TIS.

Positive economies are drawn around Marchall`s (1920) three sources of economies "that were external to firms but internal to location" (Bergek et al 2008, 418): *Emergence of pooled markets, emergence of specialized intermediate goods and service providers* and *information flows.* To illustrate the point in question, emerging entrant may decrease the uncertainty by increasing specialized knowledge, information flows, gain political power, gain legitimacy, etc. A system has general thematic inputs and outcomes (Bijker et al., 1987). NRE sources may here have mechanical energy from natural resources as an input and mechanical electricity as an output. Hence, the economies, marked structure and formation of institutions and organizations within the may be argued to co-evolve within the system.

Phase of development

A TIS can be divided into two phases; formative and growth (Hanson et al 2011). In the formative phase the TIS needs to activate central key "functions", assemble actors and networks. Basic pre-conditions and establishing institutions that can facilitate legitimacy in the society is also important. This phase must occur for a TIS to enter the growth phase and it is characterized by a high level of uncertainty, although uncertainty is a staying factor it may decrease in the latter phases. Emerging technologies systems diffuse slowly and it is also related to adaption of NRE solutions. This is viewed in connection with "the fact that new technologies seldom compete well in part has to do with lack of learning processes associated with broader markets and user bases" (Hanson, 2011, 7). The premises for a TIS to evolve as a system can therefore depend on the technological development and diffusion of knowledge, hereunder the education of personnel and the adoption in the market. In this phase the knowledge transfer and diffusion, see function 1, can be dependent on the firms absorptive capacity.

Technological characteristics, phase of development or maturity define the level of proximity to which the process of innovation may occur (Teece, 1986). Emerging TIS, is also referred to as "System builders travel between domains such as economics, politics, technology, applied scientific research and aspects of social change, weaving a seamless web into a functioning whole" (Geels, 2004, 898). System builders or new system may emerge within other system or connect to them (Bijker et al., 1987). Drawing on idiosyncratic patterns this may highlight a preferable RES in order to for relevant for NRE systems in order to gain access and allocate necessary resources so that the premises to evolve are met.

Science, technology and innovation policies

Science, technology and innovation policies (STI) refers to ideal types of explicit policy areas that serve an analytical purpose (Lundvall and Borrás, 2005, 3). In a complex field like the Norwegian policy system, these ideals reflect the policies used to facilitate knowledge production, diffusion, dissimilation and use of SR and technical knowledge to achieve national objectives, related to NRE system.

The OECD document from 1963 prepared by Christopher Freeman amongst others pushed forward a shift regarding how scientific policies turned towards a more economic objective (Lundvall and Borrás, 2005). Lundvall and Borrás argue that present science policy mainly concerns the academic field with the argument that research is important for social and economic usefulness and in a modern society. Moreover that technology policies deals with industry and technology with an emphasis on science based technologies that can contribute to economic growth. However, since the second war II technology has mainly been related to SR. Innovation policy represents two alternative policy paths. The first inspired by a neoclassical tradition were there's no state interference or economic support and the technology or industry must compete and survive in market solely. The latter perspective reflects a consideration that competence is not equally distributed amongst businesses. Hence, that the "failure" might be due to factors beyond the neoclassical principal of market failure, and incorporate linkages or address systemic functions or needs to preserve a desired economic development (Lundvall and Borrás, 2005). Yet, both perspectives accounts for all the aspects of innovation that have an importance for the economy like the process, use and adoption of new technologies.

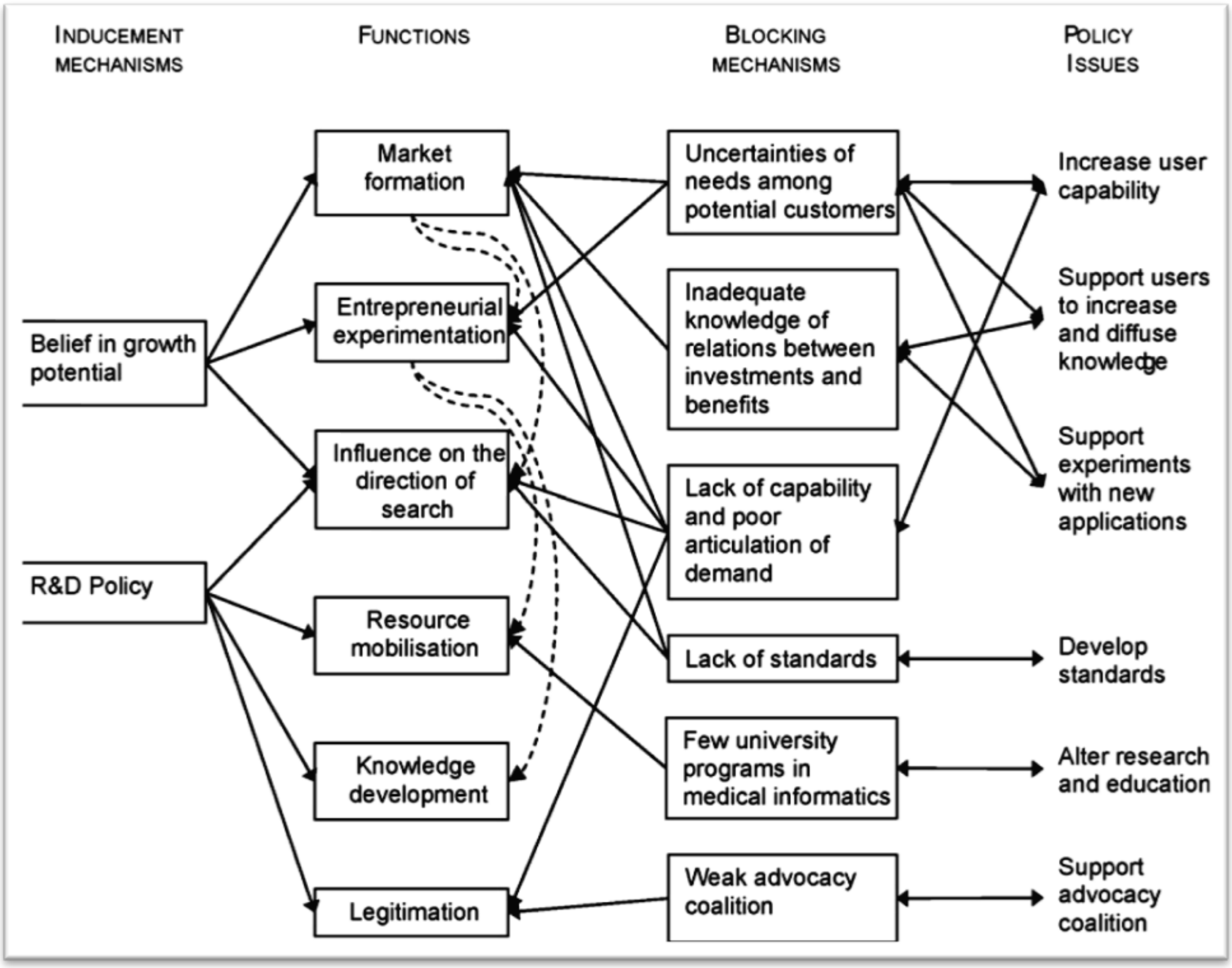
Innovation policy tries to open the "black box" of the innovation process in a systemic way to understand the social and complex processes (Lundvall and Borrás, 2005). Moreover, innovation policy has similar feature to the IS and NIS as discussed above. It revolves at a multitude of levels, both horizontally, vertically and dependent on an organizational development and most importantly an institutional determination and vigor to push forward innovation. Narula (2002) has a similar argument stating that Norwegian firms behavior is determined by an SI which in turn explains why they locate their innovation activities close to home, although they suffer from "systemic lock-in".

The Norwegian IS development has shaped a structure of policies and organizations that offer little support for new, knowledge-intensive sectors (Narula, 2002, Fagerberg et al., 2009a). Hence, the role of the state is argued to contribute to this ineffectiveness (Narula, 2002). Bye et al. (2011) argue that in a small and open economy like Norway, knowledge absorption though international trade represents a more important role to innovation and growth than domestic R&D. Current and persistent policies encounter inefficiencies partly because of the favorable policies or path dependency towards traditional industries (Bye et al., 2011, Fagerberg et al., 2009b). These created innefficiencies can be counteracted by an alternative policy through an export of R&D-based products. This strategy can foster a stimulation of national knowledge spillover and improve absorption of knowledge spillover from foreign countries (Bye et al., 2011). Whereas, science based sectors representing new industries or challenging to the existing ones, that suffers from a systemic lock-in may respond with an exit strategy to evolve.

A strategy describes a plan for how an organization can move from one position to a desired one (Porter, 1996). Porter distinguishes between in house and outside activities, were managers need to make strategic choices. "Operational effectiveness" means that a firm performs an activity better than other firms (Porter, 2002, 11). Hence, there are significant differences between the firms that operate in clusters in contrast to isolation (Porter, 2000b). Firms within a cluster are often more able, faster to recognize market needs from retrieving knowledge from the cluster and actors an advantage in aborting new technological knowledge faster and thereby a higher ability to innovate and (Porter, 2000b, 262) . This reflects an era were the economic geography has altered and diminished the traditional roles of location in technology and competition, however the concentration of interconnected firms have a "growing importance in an increasingly complex, knowledge-based, and dynamic economy" (Porter, 2000a, 15). Yet, in many countries the tradition have been a policy in opposition to cluster (Porter, 1996).

According to Bergek et al., (2008) a TIS can be enhanced by facilitating policies according to a desired development.

Figure 4: *Inducement and blocking mechanisms related to policy issues*



Source: (Bergek et al., 2008, 422)

As an alternative to market failure or reverse salient, the scheme outlines policy tools that indicate how to stimulate the TIS in a desired direction. Further it is pointed out that the relation between innovation processes and government has been highly underestimated, moreover how direct interventions in particular innovations able both well organized and resourceful action to occur (Lundvall, 1988).

Inducement mechanisms are the driving forces in a developing TIS[6]. The blocking mechanisms are strong counterforces that may be regarded as reverse salient. Hereunder, the mentioned element of risk in innovation is always an underlying factor, hence the time leap from the formative phase to mature or more stable systems can take decades characterized by uncertainty. The national trajectory from R&D to sustainable energy systems therefore occur in relation with a policy mechanisms which alter the need for national RES.

ISs are generically open and characterized by the emergence of novel initiatives where a heterogenic selection process of innovations occurs, which is complex and takes place at different levels (Fagerberg et al., 2009a, 4, Fagerberg et al., 2006). The Norwegian Energy policy system related to R&D and commercialization of new technology is characterized as a coevolution between several actors (Bugge, 2010, 20), see *appendix 1*. NRE signifies minor actor in this aspect, hence, it is rather the upstream alliances to the system and how they are incorporated in the RES that constitutes the framework. Yet, strong specializations on non-NRE thereby represent a different set of challenges in Norway compared to other systems.

6 *Function 7* Development of positive externalities is excluded from the figure because it reflects how the six other functions are met within the TIS as mentioned above.

Summary of theoretical framework

The theoretical chapter has discussed several possible angels to inquire different trajectories towards commercialization of NRE in Norway and at different levels. NIS and STI-policies focuses at macro levels where the innovation is limited within national borders. The TIS limits the system and views NRE more at a micro level where the national borders are of less importance, whereas the operational "functions" needs to be present and reverse salinet's resolved in order to for a TIS to function well.

Hence, the linkages between idiosyncratic capabilities, knowledge creation and transfer, development of markets and policies have been emphasized. Moreover, how theses co-evolve and what key premises that need to present for emerging new renewable solutions innovations to evolve.

In relation with the case study and other theoretical contributions within the field this trajectory's are argued to be influenced by a "lock-in" in the energy system. Although innovation is difficult to measure, the thesis will enquire the formative phase in Nowitech and to some extent in field of OWP in Norway. Knowledge creation and development is a premise for a TIS to evolve and is therefore an important aspect. The phase of development may further be indicated by characteristics by location of R&D and formation clusters and experimentation. The operational function of a TIS related to policies may pinpoint main reverse salient and strategies within NRE.

The theoretical framework, discussions and case study represents the foundations from where I have derived the following research questions for further analysis of Nowitech and the energy system related to OWP:

RQ 1: How does Nowitech create and transfer knowledge?

RQ 2: What characterizes the OWP system in Norway?

RQ 3: Does a systemic "lock-in" influence offshore wind power?

II. Methodology

This chapter provides an account for the research design and methods used in this thesis.

Relevance

Literature and research within innovation and renewables related to offshore wind power mostly center on technology development or testing and evaluation on projects. Little research is done on the relation between NRE technology and social aspects to gain a broader understanding. A socio-technical systemic analysis offers an integrated evaluation of the innovation development related to the economy, policies, and marked formation. Bugge (2010, 50 -51) argue that this insight is valuable and relevant in a least three areas:

i. Provide insight and knowledge concerning what and how strategic trajectories new renewables energy systems can develop to reach national policies and NRE targets.
ii. Acquire knowledge regarding the energy systems in Norway within social science related to of the FMEs.
iii. Gain a better understanding of how to unite the spheres of business and market related that may strengthen the meaning behind the FMEs.

The thesis addresses the FME Nowitech and accounts for all three areas to some extent because they naturally overlap.

Justification of design and method

The thesis is a case study of Nowitech related to the current situation of OWP in Norway (Yin, 2009). An explanatory design is used because the thesis seeks to understand “how” and “why” in order to explain the dynamics in the “system” that Nowitech is a part of (Gripsrud et al., 2004). Moreover, the research focuses on contemporary events and does not require control over behavioral events or seek answers to a given problem (Yin 2009, 9 -11). The methodological approach is similar to the grounded theory but due to limited space this is not elaborated in this thesis (Glaser et al., 1968).

The initial object and strategy for collecting data were clear from the beginning, although the research questions have been modified in relation to what has been revealed during the data collection. Hence, during the writing of this thesis I have been given access to new and unpublished data and surveys, which have provided me with relevant information concerning agents in the OWP field. These are used secondary sources and analyzed as documents and given me insight in what kind of resources and “system failures” actors within the OWP field experience.

The thesis is defined as a single-case study of Nowitech, however, the purpose of the case study is not an analysis of the one unit isolated, but within the Norwegian energy system as a whole (Yin, 2009, 18-21).

A single-case design has both weaknesses and strengths compared to other methods (Yin 2009, 53). Compared to multiple-case studies design the rationale can be higher for multiple-case studies were a comparison of several FME`s could strengthen it. On the other side this would be time consuming and it would require a higher extent of recourses and time than the ESST master provides.

Population and selection of sample

The data and sources were selected in relation with the focus on key aspects in the thesis; a TIS in a formative phase, knowledge development and transfer, OWP development in Norway and policy issues in connection with Nowitech. Selection of interviewees was strategically and based on the principle of multiple sources of evidence (Yin, 2009, 114).

The data is divided into primary and secondary sources. Primary sources include interviews and relevant conferences. The interviews used were in-depth interviews and one group interview in Trondheim. The in-depth interviews were chosen to ensure high quality data within the agent`s field of expertise. The group interview was chosen because Nowitech and CenSES operated within the same field and location, and it gave fruitful discussions related to the *interview manual*, see *appendix 2*. A disadvantage was that this interview was more difficult to manage although I had more time available which ultimately strengthened the data. The data could have been enhanced by a larger amount of sources in order to gain a more solid empirical understanding of the case study.

As a part of gaining a better insight and understanding of the current situation of the energy systems in Norway it was important to attend several conferences. Some the conferences I attended was: "Knowledge for the future" held by the Ministry of Education and Research , "The Nordic Energy Summit" held by the financial stock firm First Securities (FS), "Norway's energy challenges" and "Energy systems" both held by the University in Oslo.

Secondary sources consist of; white papers, reports, literature on offshore wind, knowledge transfers and policies regarding energy issues. To secure a high level of academic quality, the scientific publications were chosen by obtaining theoretical contributions with a high number of citations from acknowledged scientific journals and books accepted within the innovation discipline and in relation to the ESST –master program.

Initially I started out contacting NIFU STEP who published the report and evaluation of the FME`s in 2010. This first interview was with Trond Einar Pedersen who was the researcher that analyzed Nowitech and the OWP field in the report. Based on this, selections of other key interview objects were identified within different positions of the NRE field related to OWP.

List of interviewees[7]:

Industry & SMEs
Kjell Eriksson, leader in CIC in Nowitech and Director of the Energy Programme in DNV Research and

Innovation collaborate

Alfred Bjørlo, manager in Måløy Vekst

Research institutes & Universities
Jan Onarheim, vice directior in Centre management and secretary in CIC in Nowitech

Gard Hopsdal Hansen, Post Doc at NTNU, CenSES

Markus Steen, PhD candidate at NTNU, CenSES

Audun Ruud, Researcher at SINTEF

Government & authorities
Espen Borgir Christophersen, senior advisor (Renenergi) The Research Council of Norway

Trond Einar Pedersen, special advisor in The Research Council of Norway

The initial contact with Nowitech was established in an early phase, and I had a good dialog with Nowitech in Trondheim. I spent one day in Trondheim discussing the theme and interviewing. These conversations became directional for a re-evaluation of the main topics of the thesis as well as pinpointing issues in the OWP field and whom I would benefit with talking to.

I established contact with the Ministry of Petroleum and Energy and after several attempts it was not possible to get an interview in person or per e-mail[8]. To strengthen the case study data collection several sources were used; mainly reports, white papers, internal documents and interviews.

[7] A full overview of the interviews, time and place is presented in appendix 3.

[8] The Ministry of Petroleum and Energy responded that the Ministry did not have time or recourses available to answer my questions.

During the writing of this thesis several publications, reports and agreements have been made public. To some extent I have managed to include these events in this thesis, but due to time limitation the latest events have been excluded[9].

The interview

Before every interview it was important that the relevant person was familiar with theme and important aspects and why the interviewee was interesting for the thesis (Punch and Punch, 2005). The interview scheme was open and contained simple questions, rather than complex, to avoid confusions. In order to increase the reliability and cover the main "themes" and objects of the thesis, extra questions were used. Probing questions were used to elaborate on various discussions, and to increase insight within the agents field of expertise.

The *interview manual* was divided into four sections:

1. ***Introduction and background:*** In this first part each person present held a short introduction in an informal tone.
2. ***Definition:*** I asked the interviewee to define "innovation" and "commercialization" to ease the conversation over to the relevant themes and questions. This worked well, and it angled the interview towards main subjects of the thesis and formed a platform for *part 3*.
3. ***Themes and question:*** This was the main part of the interview. The interview manual was organized into themes according to the "functions" from the TIS approach by Bergek et al (2008), see *appendix 2*. To avoid "replication of design", meaning that one questionnaire might not correlate equally well with different interviewees the

[9] A recent and important event was the Norwegian launching of Energy +. The international energy and climate initiative accounts for important questions revolving carbon development and NRE strategies onward in Norway. Website The Norwegian Government (Accessed 12.10.2011) http://www.regjeringen.no/nb/dep/smk/aktuelt/taler_og_artikler/statsministeren/statsminister_jens_stoltenberg/2011/welcome-address-at-energy-for-all-confer.html?id=660288

interview guide was structured in themes offering a good basis for to gather information from different sources and organizing the data afterwards (Yin 2009, 53). Because the interviewees had different background and work in different firms and organizations, many questions were prepared within each theme to capture their perception and knowledge. On this basis, I would still have data that could be compared according to the "themes".

4. ***Wrapping it up:*** In this part last comments and remarks where asked for, and I expressed my gratitude for their contribution.

The interviews lasted from one up to three hours. All the interviews were held at time and a place it suited for the contributor. All interviews were held in Norwegian, which also was the native language for all participators. The interviews were recorded with the permission from each interviewee. Firstly so that it would make it easier for me to concentrate on the subjects and themes, and secondly to ensure and preserve the quality of the data. The data was later transcribed and analyzed according to theoretical framework in order to ensure validity and reliability. Citations from the interviews are my own translations and they were reviewed by the interviewees in order to ensure that the correct meaning was obtained and for permission to publish their statements.

Validity and reliability

The validity and reliability of the results of the interviews were important factors in the planning, executing and gathering of the data material and writing the thesis. Yin (2009, 41) argue for four tests in order to accomplish this:

Construct validity: By using a number of different sources within the OWP field during the data collecting data, I was able to identify correct operational objectives that correlated with similar published literature. A weakness is the number of interviews which could have been higher and from additionally agents within the NRE system.

Internal validity: The crucial point was to recognize all factors that could have an influence on Nowitech to order to achieve valid data, analysis and results in the thesis (Yin, 2009, 42). This is ensured by the analytical strategy through organizing the interview manual according to the theoretical framework and functioned as a tool to analyze the material.

External validity: The number of interviews and concentrated theme reduces the level of generalization to the whole field of OWP or NRE. Yet, because this thesis is a case study, the generalization occurs in relation with a more extensive theory or replication of logic expressed from a variety of sources (Yin 2009, 44). Moreover, in connection with an explorative design the thesis will rather try to pinpoint important issues within the OWP field.

Reliability is ensured though transparent step by step explanations throughout the thesis related to how and what the findings and results are based on. Because the thesis enquires contemporary events the answers and results may change due to future events and therefore reduce the reliability.

Ethical concerns

Ethic is an important aspect when conducting research and submitting the results. To insure this, the ethical principles prepared by The National Research Ethics Committee for Science and Technology (NENT)[10] was safeguarded. This chapter has accounted for these principles by explaining the process and choices behind the method, data collection and analysis. Again, respects to privacy, confirmations, information concerning relevance to the

[10] Website Research Ethics Committees (Accessed 15.9.2011) http://www.etikkom.no/no/Forskningsetikk/Etiske-retningslinjer/Forskningsetisk-sjekkliste/

interviewee, and feedback and permission of direct citations were dune. Hereunder, the transcripts and recordings from the interviews are confidential.

Limitations and theoretical concerns

The theoretical framework is mainly gathered from the IS literature. Hereunder, with a particular focus on the dynamic processes and functional components necessary for a TIS to function well, and relevant theories about knowledge transfer and policies. The thesis focuses on the systemic mechanisms in the case study, whereas the innovation is "black-boxed".

The TIS is a comprehensive theory and it is a result based on reviews of previous scientific work within the innovation literature field. The TIS approach is used in several similar case-studies, comparative case-studies or based on quantitative research within the field of emerging IS and NRE in relation with strategic policy mechanisms (Hekkert et al., 2007, van Alphen et al., 2009, Blomberg, 2008, Suurs and HEKKERT, 2009).

Debates and criticism

IS literature contributes with different approaches to understand phenomena(s) with a "systematic" method, were stagnation or obstacles might be explained in terms of "system failure". Hence, it pinpoints factors or instrumental policy "tools" governments may use as inducements mechanisms in the economy i.e. "system" (into a desired direction). The IS includes evolutionary aspects which may increases the understanding of different paths of behavior.

Strengths of the framework may be that it emphasizes creation of learning, cross-disciplinarity and that it views innovation in a co-evolutionary perspective. It is not linear and includes a holistic perception of the phenomena. Weaknesses can be the weak limitation of "systems" although this also allows one to include factors that are viewed as important.

The innovation systemic approaches represent gap between number of functions and what key functions a system contains of within IS literature. Although different theories recognize a different number of crucial functions, most agree upon that a system consists of actors i.e. persons, initiations or organizations that strategically contributes to reach an overall and unified goal. The different definition of systems reduces the ability for comparative analysis within the field.

Bergek et al (2008) argue that the scheme of analysis is based on reviews and academic results within the system innovation literature and that are synthesized into the functional dynamics, although is regarded as ongoing work rather than finished. This is based on several factors; among them the uncertainty in the term "goodness" of the functional patterns and gaining more empirically based knowledge in order to develop a classification of "archetypal" development paths (Bergek et al., 2008, 424). This may indicate a conceptual disorientation that weakness the strength of the theory. Yet, the IS approach is recognized within the innovation discipline, and by supporting the framework with strong theoretical contributions strengthening the quality.

Whereas a significant amount of literature is based on other cultures and systems like American or Chinese, (Bergek et al., 2008) theory is formulated and based from Scandinavian conditions. This emphasizes the relevance related to NRE solution in Norway.

III. Background and Context

Energy access is an important factor for economic growth. It can be viewed as a premise and input to society where the innovation may be viewed as the "black box" and specific technological artifacts are the output.

This chapter will highlight some of the conditions in society that have been and are important for development of NRE in Norway. In the following selected literature within climate policies, market development and offshore wind power are presented.

Global energy challenges

In the 1970s concerns regarding environmental issues became one of the top three concerns worldwide (Lidskog and Sundqvist, 2002). Environmental pollution is strongly correlated to energy production and usage[11]. Today, politicians and leaders worldwide look to technology developments and innovations as a way to resolve energy and environmental issues. The OECD and EU are pushing forward policies to speed up energy innovation in order to reach the goal of more sustainable future (Kerr, 2010). Offshore wind power is highlighted as one of the most effective solution in order to accomplish this (Martinot et al., 2007).

International climate policies

Norwegian climate policies have been influenced by international policy principles tied to the OECD, United Nations, and the European Commission, whereas it recently has been tied to the EU ETS and Renewable Energy Directives through the EEA-agreement.

[11] Website Statistics Norway (Accessed 10.7.2011) http://www.ssb.no/klimagassn/

The Kyoto Protocol was the first climate agreement in the world, and in 2011 the members included the EU and 192 countries[12]. The Kyoto Protocol was a result of international negotiations in 1997 as well as interconnected to the United Nations Framework Convention on Climate Change (UNFCCC). The main feature of the UNFCCC is that it encourage industrialized nations to reduce GHG emissions, whereas the Kyoto Protocol sets binding goals for its members[13]. According to the Kyoto Protocol Norway can increase GHG emissions by 1 percent compared to the 1990 -level subsequent to other quota mechanisms in the agreement. The most important goal for Norwegian climate policies is that the commitment to the Kyoto Protocol is met[14]. The Norwegian government has facilitated a wide range of means were the most central are directed against the Norwegian business sector including emissions trading, taxes on greenhouse gas emissions, and voluntary agreements (Eskeland et al., 2005, 7). Furthermore, Eskeland et al. (2005, 16) points out that the petroleum industry stands for approximately one third of all GHG emissions in Norway, in relation with countries it is natural to be compared to like Denmark, Great Britain and Netherland. The climate policy instruments towards this industry is therefore of great importance to the overall national GHG emissions and total cost.

Norway is a part of the European energy system though the EEA agreement and collaborative partner in the process of resolving energy and policy issues. Norway has strong relations within the European energy market which is reflected Norway`s position as a

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[12] Website Statistics Norway (Accessed 2.6.2011) http://www.ssb.no/emner/01/klima_luft/kyotoboks.html

[13] GHG emission quotas are decisive for the amount each country can release within the period 2008 -2011. Website UN FCCC (Accessed 9.9.2011) http://unfccc.int/kyoto_protocol/items/2830.php

[14] Source Ministry of the Environment (Accessed 1.8.2011) (2005), *St.meld.21 (2004-2005) Regjeringens miljøvernpolitikk og rikets miljøtilstand*, Miljøverndepartementet, Oslo.

supplier of energy to the European and Nordic -markets with a supply rate of 80 percent of the exported petroleum[15].

The EU targets presented in the framework "Energy 2020 - A strategy for competitive, sustainable and secure energy" pushes forward five strategic points[16] to increase a more sustainable and green economy. The 2020 targets indicate that it will be investment 1000 billion NOK in order to facilitate an installation of 50 GW in European OWP farms[17].

Norway has not finalized the agreement regarding how to decrease greenhouse emissions by 20 percent by 2020 in contrast to most other countries. The respond to how Norway will resolve and meet the 2020 goals was expected to come in the Norwegian white paper "Klimameldingen" last fall. This white paper has been delayed several times and it is uncertain when it will come.

The Government stated in connection with the UN`s report on renewable energy this year the following strategic points for Norway's participation within renewable energy development:

- Norway will especially contribute to an increased exploitation of renewables in developing countries.
- In Norway the impacts will increase renewable power production though small scale hydropower plants.

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[15] Website Ministry of Petroleum and Energy (Accessed 4.6.2011) http://www.regjeringen.no/en/dep/oed/tema/eueos_og_energi.html?id=1005

[16] The five strategic points highlight: employment, 2) R&D and innovation, 3 climate change /energy, 4) education and 5) poverty. The goal of R&D and innovation includes a goal of increasing the investments in R&D/innovation up to 3 % of the GPD. The goal of climate change/energy means a decrease of greenhouse gas emissions of 20 % compared to 1990, where 20% decrease in energy efficiency and 20% from renewable energies (Eu.eu 03.09.2011).

[17] Website Sintef (Accessed 1.10.11) http://www.sintef.no/SINTEF-Energi-AS/Xergi/Xergi-2009/Nr-1---april/Forskningssenter-for-miljovennlig-energi---NOWITECH/

In Norway NRE solutions are generally met with the principle of the "free-market"[18]. Yet, there are some public supports for these energy systems that provides beneficial conditions competing in the open market.

The Norwegian state has particularly, since the World War II, played the role as an interventionist in Norwegian industry and emphasized the importance of support and R&D (Narula, 2002). The STI policies support to innovations mainly focuses on R&D, whereby it is the market mechanisms that decide whether or not it will survive like described earlier, see *Chapter I*. Policies concerning Norwegian energy operate after a principle of cost efficiency that origins from the 1990`s based on when the state agreement that greenhouse emission efforts should be done where the costs were low (Hanson et al 2011). Based on this the policies signalizes that emission reduction efforts should be carried out in other countries where they are more cost-efficient.

In 2010 the Norwegian emissions increased with 4,8 percent[19] . Energy production and usage represents 2/3 of the greenhouse gas emissions, due to the fact that 80 percent of all energy production comes from fossil fuels[20]. In order to preserve our planet many efforts have been taken to reach the international goals; decrease toxic waste, develop CO2 capture and storage and find NRE solutions. Norway has traditionally supported the development of energy systems in developing countries. In 2007 the initiative "Ren energy for utvikling" was established in order to support NRE, which may have a positive impact on the global climate[21]. The initiative includes all aid, bilaterally and multilaterally, that goes to

[18] Website Renewableenergy.no (Accessed 7.8.2011)http://fornybar.no/sitepageview.aspx?sitePageID=1768

[19] Website Statistics Norway (Accessed 10.7.2011) http://www.ssb.no/klimagassn/

[20] Website Ministry of Petroleum and Energy (Accessed 25.8.2011) http://www.regjeringen.no/nb/dep/oed/aktuelt/taler_artikler/politisk_ledelse/taler-og-artikler-av-statssekretar-eli-b/2011/konsekvenser-for-norsk-energipolitikk-og.html?id=644108

[21] Website Ministry of Petroleum and Energy (Accessed 25.8.2011) http://www.regjeringen.no/nb/dep/oed/aktuelt/taler_artikler/politisk_ledelse/taler-og-artikler-av-statssekretar-eli-b/2011/konsekvenser-for-norsk-energipolitikk-og.html?id=644108

development countries under the umbrella "pure energy". Norway is also the biggest supplier of international development of hydro power though the international hydro power association IHA. By setting international sustainability standards in collaboration with authorities, industry, banks and the community, as well as evaluating individual projects objectively. In addition, Norway is a member of several international organizations to push forward usage of renewable energy globally, like the IEA, IRENA, and the OED.

The *Energy21* report published June this year on behalf of the Department of Oil and Energy presented a holistic strategy from R&D and innovation, the energy system value chain to the market sphere. The traditional part of energy system today is characterized by a very low rate of innovation (Moestue and Moengen, 2011). Moreover the report argues that generic national and global targets of a climate friendly energy development cannot be reached without a significantly expanding the resources for R&D. It's pointed out that Norway has advantages within these areas that should be exploited now when the window[22] is open. The RES focuses on six new renewable energy solutions were OWP is described as a comparative advantages for the petroleum and maritime –industry for supply in the fast speeding international market (Moestue and Moengen, 2011). Hereunder, based on experiences from the Climate-settlement in 2009, support for testing and demos are recommended.

The Norwegian energy policies and industry differs from most European countries. Most countries has developed a political understanding for the necessity to shift from fossil fuels over to renewable energy solutions, development of markets and facilitated a framework for sustainable energy systems to emerge and mature during the last two decades (Hansen et al., 2011, 11).The current Norwegian climate policy reflects a diversified system that has not developed a similar shift in energy policies. The less cost effective the greater the

[22] Refers to when it is an advantage to exploit a product, knowledge or similar in order to maximize profit, regarding market development or other crucial factors.

differences in price for emissions of greenhouse gases are, the bigger the administrative costs for each of the instruments (Eskeland et al., 2005, 8). This illustrates how Norway rather supports development abroad rather than altering the national energy system.

Fagerberg (2009b) argues that Norway to a high extent is path dependent. The energy system is dominated by the oil and gas industry. Fossil fuels hold the dominant position in the world and cover 90 percent of total primary energy usage. With today`s production line and technology, the Norwegian petroleum production is estimated to decrease to one third of current production line in 2030[23]. The domination of petroleum power globally is increasingly challenged by a growing need for energy and a global concern for the environmental changes. As a consequence, governments and organizations around the world like the IEA, EU, and the UK are developing RES.

Norwegian policies

The Norwegian policy on new renewable power has similar features as the American power strategy "Bricolage" in the 1980`s (Hanson et al., 2011, 76)[24]. As most countries have had a shift from this, as mentioned above, Norwegian policies stands in stark contrast to countries like Denmark which has clearly demonstrate the benefits economically and environmentally.

The IEA emphasize that most technological innovations need to be pushed forward by R&D and public funding, and a pull into the market though economic and market incentives systems like trading and taxes (Moe, 2010, 5). Obviously, NRE solutions presents a higher costs than fossil fuels, yet, theses can only be reduced through learning, R&D and demonstration (Moe, 2010, 5).

[23] Website Statistics Norway (Accessed 3.4.2011) http://www.ssb.no/emner/10/06/20/rapp_201046/rapp_201046.pdf

[24] The strategy origins from the Denmark and refer to how incremental innovations is shaped with a basis from existing technology.

Innovation Norway and ENOVA are two key public funding organizations' that contribute and facilitate funding in order to achieve economic development, whereas the RCN administrate R&D.

Offshore wind power

In 2009 the Norwegian Government presented a new act on offshore renewable energy[25] . The act itself states in particular that there is a lack of knowledge regarding the possible effects of off-shore wind turbines on fish and marine mammals, and furthermore that potential conflicts must be considered in the planning of new installations.

March 2010 a Norwegian strategy and the "Sea-Energy" act were passed by the Government[26]. The legal act lays the legal basis of NRE production and development on the Norwegian continental shelf. The framework is similar to how the continental shelf was divided into block – areas for exploitation and safeguarding of the oil and gas industry. The appointed directory group Havvind have identified 15 blocks suitable for OWP development[27].

August 2010 Norway and the UK signed the Climate Change and Energy Security. The agreement states that wind energy industry shall exchange of information regarding OWP in North Sea projects[28]. The joint collaboration objective is to strengthen the development of new renewables were challenges and possibilities.

The most exciting technological innovations within the Norwegian OWP system is the successfully installed full-scale demo project Hywind. Statoil is the only Norwegian company that has managed to install a full-scale offshore windmill with real and concrete commercial

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[25] The Norwegian Government, Ot.prp. nr. 107, 2009, Press release 26.06.2009 (Accessed 4.9.2011)

[26] Website Ministry of petroleum and Energy (Accessed 15.9.2011) http://www.regjeringen.no/nb/dep/oed/dok/regpubl/otprp/2008-2009/otprp-nr-107-2008-2009-.html

[27]Website Norwegian Water Resources and Energy Directorate (Accessed 25.9.2011) http://www.nve.no/no/Havvind/

prospects[29]. The project was initiated in 1999 and launched ten years later. The floating wind turbine is now in operation in Karmøy, outside Stavanger. The company's core competence within petroleum was crucial in the development, were they have used an existing technology in new combinations. Public funding though ENOVA contributed with 59 million Norwegian kroner to the overall cost on 400 million NOK.

The two most prominent support programs that promote technological development of NRE are green certificates and "feed-in" tariff systems.

In 2012 the protocol for Green certificates for a joint market between Sweden and Norway will launched (Hansson and Øydgard, 2010). The goal is to increase production of renewable energy up to 26.4 TWH by 2020. Green certificates are technology neutral and therefore also more likely to push forward mature technology. In a common market it has been signalised that Sweden is likely to produce more onshore wind power and bio-mass, whereas Norway is expected to establish several minor hydropower plants and to some extent ONWP (Hansson and Øydgard, 2010).

"Feed –inn" systems are a technology specific funding. It opens up for supporting immature technology which requires a high level of recourses more and low-cost and mature technology less.

Hanson et al (2011) argue Norwegian policies restrict Norwegian offshore wind power development by:

i. Norwegian authorities have to a limited extent supported the power industry in order to innovate or expand the energy production.

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[28] Website Ministry of petroleum and Energy (Accessed 15.9.2011) http://www.regjeringen.no/en/dep/oed/aktuelt/taler_artikler/politisk_ledelse/taler-og-artikler-av-statssekretar-per-r/2010/offshore-renewable-energy-production--po.html?id=620419

[29] Website Statoil (Accessed 9.5.2011) http://www.statoil.com/no/TechnologyInnovation/NewEnergy/RenewablePowerProduction/Offshore/Hywind/Pages/HywindPuttingWindPowerToTheTest.aspx

ii. Technology policy emphasizes radical innovations, also characterized as a “breakout strategy”.

iii. Chose to develop immature technologies, which in turn makes it difficult to commercialize.

Grid system and power balance

The national electricity transmission grid of Norway faces challenges related to an increased future demand and new energy systems. Norway has installed a hydroelectric production capacity 27 million kilowatts that supplies 99 percent of the national consumption[30]. In order to meet the future energy supply needs the current grid is insufficient, and new production of energy solutions like ONWP and OWP in areas that do not have power cables to carry electricity escalate this demand[31]. A joint operation between hydropower parks and wind power offers benefits and may present synergy effects through a possible integration of wind power into the current grid system and the regulatory ability in the grid.

Although, there is neither a demand in the Norwegian market for electric power nor a political will from the Government that encourages any building of OWP farms in Norway, there is support and an elaborated aim that Norway shall produce research and development in order to gain expertise within the field at a high international level[32].

The Norwegian offshore wind power system

There are 359 members connected to the wind cluster associations in Norway[33] mapped in a survey performed this year (Hansen and Steen, 2011). Empirical findings show that OWP is a

[30] Website Global Network Institute (Accessed 5.9.2011) http://www.geni.org/globalenergy/library/national_energy_grid/norway/index.shtml

[31] The Norwegian Government (Accessed 6.6.2011) Ot.prp. nr. 107, 2009.

[32] Website Ministry of Petroleum and Energy (Accessed 5.7.2011) http://www.regjeringen.no/nb/dep/oed/aktuelt/taler_artikler/politisk_ledelse/taler-og-artikler-av-statssekretar-eli-b/2011/konsekvenser-for-norsk-energipolitikk-og.html?id=644108

[33] Referring to the number of members in Arena NOW, Windcluster Mid-Norway, Norwea & Navitas Network

strategic area for 105 out of 184 firms. 51 of these firms have delivered services, whereas some have supplied components to OWP projects and are expecting major future distributions.

A majority of the actors are also suppliers in other offshore industries, mainly within the marine industry and the petroleum industry. This indicates that the field is diversified. Although there is a relative high activity in the OWP field, most of the operating suppliers within offshore use less that 20 percent of their time exclusively on OWP. There are only 18 out of 105 firms that are solely dedicated to OWP. These firms were established less than five years ago and are characterized as new entrants.

Knowledge transfer and recruiting personnel from traditional Norwegian industry is evident and recognized as the main competitive advantage, whereby10 out of 18 managers formerly worked in the oil and gas industry. There appears to be a united normative perception that OWP is an exciting field which offers great challenges, however mainly as a complementary to the petroleum activity. Furthermore, the survey expressed that Norwegian policies are ambiguous and unpredictable, the public system lacks competent people as well as an incentive system. Moreover, normative statements from the survey indicate that the political signals are conflicting and create uncertainty related to the Governments RES and polices.

The energy market

In 2007 the potential for the Norwegian offshore wind power capacity was estimated to be at approximately 13 970 TW/h (Sandgren et al., 2007). In compare, the total domestic energy usage in 2010 was 244 TWh[34]. Most of the underwater conditions in the continental shelf in the North Sea require technology that can handle rough conditions below and above surface. It has not yet been installed any OWP farms in deep sea (Sandgren et al., 2007). Hereunder, the OWP market in Norway is limited compared to the UK and Denmark (Løvdal and Aspelund, 2011).

The Norwegian power production situation today shows that the electricity usage is higher than the production in a normal year, and that Norway needs to import electricity (Sandgren et al., 2007, 58). Hence, an empirical study of the Norwegian electricity production shows that the production capacity has not been expanded after the 1990`s (Hanson et al., 2011), although the support for R&D within renewables has been extended. The energy usage is stipulated to decline due to a departure of energy-intensive industry, however the consumer usage increases. The population is estimated to grow from 4, 8 million to 6.9 million in 2060[35] and from 1990 up to 2010 the average consumer usage has extended with 1percent each year (Hansson and Øydgard, 2010, 46).

The Norwegian future economy is more than likely to rely on other, or additionally, energy resources than oil and gas, since oil and gas reservoirs are not inexhaustible (Fagerberg et al 2008, 13). Hence, for OWP to become profitable in Norway the OWP suppliers need to be ensured a price level at 0.60 NOK or higher[36].

The Norwegian Research Council

The RCN was established with the intention to better coordinate all R&D funding and policy making agencies, in order to improve efficiency and strengthen the connections between applied and basic research. The energy sector is one of RCNs priorities for knowledge building (Taraldsen, 2009). Yet, the direct support from the RCN to industry is only close to 25 percent. Direct funding from Ministries given to larger "national champions" is obvious according to Narula (2002).

[34] Website Statistics Norway (Accessed 9.6.2011) http://www.ssb.no/energiregn/

[35] Website Statistics Norway (Accessed 10.7.2011) http://www.ssb.no/forskning/artikler/2009/6/1244787326.72.html

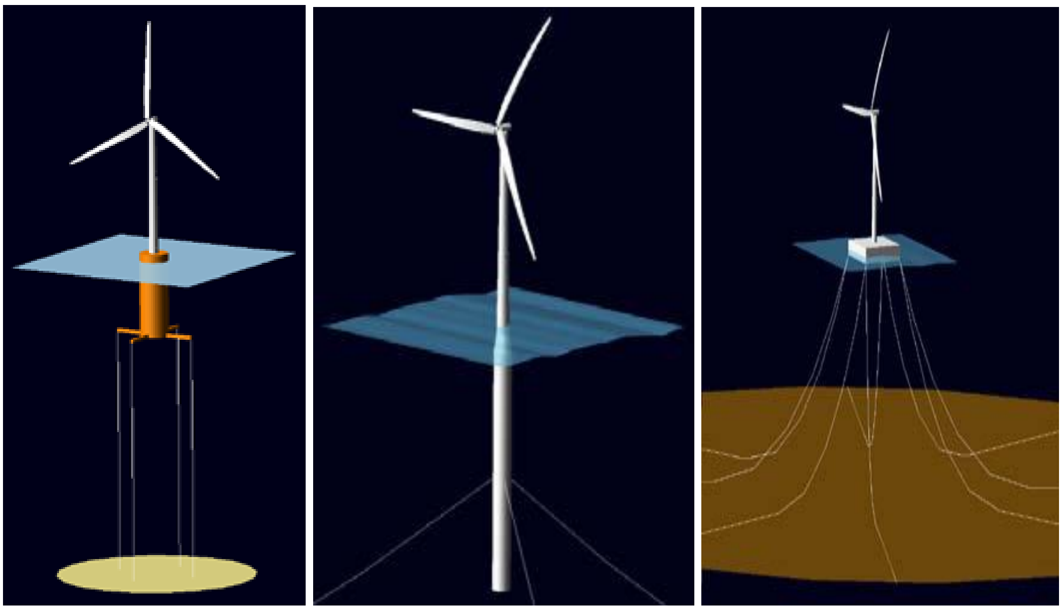
[36] Source Polytech (Accessed 3.8.2011) http://www.polytec.no/wp-content/uploads/POL09037-R001-01.08.09.pdf

In 2008 the Norwegian Research Council (RCN) initiated the FME. The arrangement was a consequence of the climate settlement in 2008. The FME started out with eight centers, but has increased to eleven centers divided into different fields within NRE. The areas include; offshore wind energy, solar energy, energy efficiency, bio energy, energy planning and design and carbon capture and storage.

Explaining the technology

Offshore wind power energy is captured by windmills. The exploitation of power occurs through breaking down the wind, although it is not possible to stop the wind entirely. The wind is slowed down in the air and then spread over to a bigger area than it initially came from. The “Betz-effect degree”, named after Albert Betz who deduced the theory in 1920, represents the theoretically maximum efficiency of wind power which is 16/27 or 0.593 (Sandgren et al., 2007, 4).

Figure 5: *Illustrations of offshore wind turbines*



Source: (Jonkman et al., 2010, 6)

This illustration shows offshore wind turbines with different sub-structures; jacket, mono-pile, and floating spar. Offshore windmills consist of a few technical components similar to the onshore windmills. The main components are; a tower, wings with three blades, generator, transformation and a house for the machine. The windmill has a turbine that produces wind (eclectic) energy when the wings rotate.

IV. Empirical findings and analysis

This chapter outlines the empirical findings based on interviews and documents. The chapter is divided into three sections related to the intersection between the theoretical framework, defined research questions and empirical findings. Hence, the analysis will focus on systemic aspects and "black-box" the technological artifact.

Firstly, the case study is presented. Secondly, the RQ`s are inquired and discussed under the subtitles: *Technological innovation and learning*, discussing *RQ 1*: How does Nowitech create and transfer knowledge?, *Market development* analyses *RQ 2*: What characterizes the OWP system in Norway? and *Policy implications* inquires *RQ 3:* Does a systemic "lock-in" influence offshore wind power? Thirdly, a summary of all empirical findings is presented according to Bergek et al., (2008) which refers to *Chapter I,* and section *Mapping the functional patterns of the TIS.*

Presentation of the case study

Centre for Environment-friendly Energy Research

In 2009 the Research Council of Norway (RCN) established eight FMEs. The FME is a time – limited initiative with a framework of eight years and administrated by the RCN. The centres mission is formulated to contribute to technology and knowledge development that can be facilitated within the energy industry (Forskningsrådet.no). Two generic goal were central in the selection of applications "relevance and potential for innovation and economic value, and scientific quality"(Forskningsrådet, 2011). The selected research center's shall focus upon long term and concentrated research within selected challenges related to energy and environmental issues at a high international level (Forskningsrådet, 2011). Hence, it is a requirement that they corporate with relevant industry partners (Forskningsrådet, 2011).

In 2009 the first eight centers were established; Centre – International CCS Research Centre**,** Centre for Environmental Design of Renewable Energy, Bioenergy Innovation Centre, Norwegian Centre for Offshore Wind Energy (NORCOWE), Nowitech, The Norwegian Research Centre for Solar Cell Technology SUbsurface CO2 storage, and The Research Centre on Zero Emission Buildings. In 2011 the FME was extended with additionally three centres within social science; Centre for Sustainable Energy Studies (CenSES), Strategic Challenges in International Climate and Energy Policy and Oslo Center for Research on Environmentally friendly Energy (Forskningsrådet, 2011).

In 2010 a report on the FME`s innovation and commercial strategies was written by NIFU on behalf of RCN. The analysis found that Norwegian actors within the OWP field almost entirely export technology mainly because there are no demand or market for OWP in Norway (Bugge, 2010).The report emphasizes that this happens because the present hydro power production and capacity satisfy the energy demand in Norway. Additionally, the incentive system does not support the new OWP technology sufficiently (Bugge, 2010).

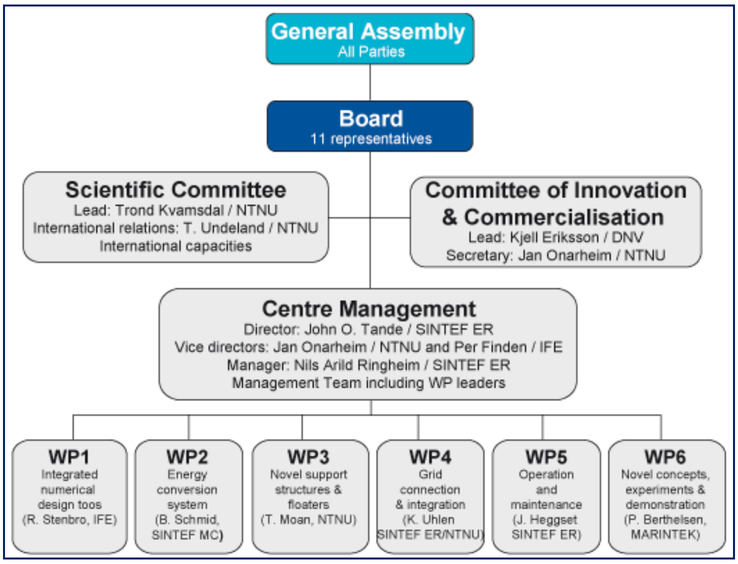
Norwegian Research Centre for Offshore Wind Technology

Nowitech is located in Trondheim and has a budget of 320 million NOK[37]. Nowitech's core areas of research facilitate precompetitive R&D to gain knowledge and find solutions that will push forward and commercialize OWP[38]. In order to reach this goal, the center works toward developing new technology and solutions which in turn may benefit the OWP industry as a whole. This means that the OWP wind mills must become cost effective and sustain Norwegian offshore conditions. Nowitech focuses on bottom fixed and floating wind turbines that can be facilitated 30 meters and below, the sea surface. In addition the center aims to

[37]Website The Research Council of Norway (Accessed 5.3.2011)
http://www.forskningsradet.no/servlet/Satellite?c=Nyhet&pagename=energisenter%2FHovedsidemal&cid=1253952435986

contribute with education and expertise within the field through post-doc and Ph.D. programs (Bugge, 2010). NTNU, SINTEF and Institute for Energy Technology (IFE) were the initiators and the foundation for the establishment of Nowitech. Nowitech draws on these in terms of solid knowledge bases, networks and reputation.

Figure 6: *Organizational structure of Nowitech*



Source: (Forskningsrådet, 2011)

Nowitech is organized with a Committee of Innovation and Commersialisation (CIC) and a Scientific Committee (SC) in addition to the board and centre management. R&D activities are organized in six defined work packages that mirror the value chain within the OWP field.

[38] Website Sintef, Annual report 2010 Nowitech (Accessed 4.4.2011) http://www.sintef.no/project/Nowitech/Publikasjoner/Annual%20Report%202010_NOWITECH.pdf

Technological innovation and learning

Knowledge development and diffusion represent a key function for formative TIS. Nowitech's activities related to knowledge transfer are as follows; workshops, creating meeting arenas though arranging seminars and other activities, newsletters[39], CIC meetings, integration activities within the WP`s, intranet, and publications. Commitments and IPR are automatically set by the consortia agreements formulated by the RCN[40].

Creation and transfer of knowledge are ongoing processes that are synthetized within the whole organization which is a premise for technological innovation to occur. Nowitech has a well-defined research base within offshore development. Nowitech states that R&D occurs in connection with actors whom represent a cross-disciplinary field, co-evolves within industrial clusters and work to provide different arenas where Nowitech and the industry may interact.

Three important findings that characterize Nowitech based on all interviews related to knowledge creation and transfer are that Nowitech holds an important role generator of new knowledge from existing knowledge bases, a facilitator of learning arenas and as an educator of future personnel,. These aspects will be discussed consecutively.

Generating knowledge

"Wind technology comes from the oil industry and the shipping industry" (Onarheim 2011). All interviewees stated that the advantage Norway has within existing branches represents the basis for transferring knowledge from existing knowledge bases over to OWP technology. The technical OWP innovation draws on specific engineering specialization that is already well developed related to more mature offshore technology. Although, these national

[39] Nowitech publish four newsletters each year.

[40] Website Sintef (Accessed 4.4.2011) http://www.sintef.no/project/Nowitech/FMEvind_final.pdf

specializations represent benefits and provide competitive advantages within the NIS, several agents expressed that this is merely providing Norway with a better starting point.

Norwegian idiosyncratic patterns, from the shipping and petroleum industries, provide the Norwegian OWP system with a competitive advantage. Nowitech`s existing networks and knowledge bases though NTNU, SINTEF and IFE is the foundation for knowledge transfer from traditional offshore industries to OWP. This is illustrated by how the center is reorganized with a CIC in addition to the SC that ensures both basic and applied research quality.

In the consorter agreements between Nowitech and partners, all requirements, legal, IPR, are defined. The partners also select which WP(s) they want to participate in. Though, all partners have access to internal documents and results through internal web-rooms. Moreover, Nowitech and DNV express that although the R&D results primarily are exclusive for formalized partners, the possibility for knowledge transfer to actors outside the organization is only prevented by a time lag. *"Everything that is produced and created in connection with the FME – is legally open for everyone to use – also to the commercial results"* (Onarheim 2011).

Nowitech has organized their work-packages related to the value chain. The scientific research is then encompassed in workshops for industry partners[41]. This is the formal meeting arena Nowitech arranges where new research is presented and participating industry partners may present reverse salient (Onarheim 2011). In the WPs creation of knowledge is organized, monitored and supervised. *"To have two committees in addition to the board is interesting because it gives the board an excellent opportunity to balance things, if we get this one and not the other it would have been quite short term, and if we had this one and no activities here*

[41] Nowitech holds approximately two times workshop-seminars a year.

you would kind of lose the firms interest and maybe a lot of the relevance as well" (Onarheim 2011).

One of the main features of Nowitech's is how the organization structure firmly echoes the importance of relevance. *"We are trying to have an agenda that emphasize relevance – we take these (work-packages) in for a discussion and scientific quality to see how it's going – This way you get a nice balance"* (Onarheim 2011). An example of how Nowitech share ongoing creation of tacit knowledge and transfer it is explained by DNV, one of the industry partners: *"Nowitech are developing new methods for how to analyze and design wind turbines; new ways to connect the windturbines to the grid, so it's not only new "heads" that spins out of Nowitech – it's also methods and knowledge that we can use"* (Eriksson DNV 2011).

The focus on relevance in the WPs contributes to reduce *risk* through making sure that industry partners have an incentive to stay, participate and contribute with resources. Through R&D of a high relevance to ongoing industry and research Nowitech maintain an attractive partner and position in the system (Onarheim 2011). This is important to get access to perceived problems i.e. reverse salient in ongoing OWP construction in addition to insight in SR. Moreover it may be considered as a mean in the trajectory towards commercialization of OWP and strengthen legitimacy for relevant firms.

Development of technological innovation and commercialization

Nowitech own evaluation of progress from R&D to commercialization in 2010 was evaluated this year[42].

[42] The evaluation was initiated in relation with the established CIC, and it is the first evaluation of its kind performed in Nowitech.

Figure 7: *Evaluation of relevance and scientific content*

WP task	Industry relevance feedback	Scientific feedback
Task 1.1 Code development	green, green, yellow, yellow	yellow
Task 1.2 Wind, waves and ocean current	green, green, green, yellow	green
Task 2.1 Rotor blades	yellow, yellow, yellow, yellow	green
Task 2.2 Generators	green, green, yellow, yellow	green
Task 3.1 Bottom-fixed support structures	green, green, green, green	green
Task 3.2 Floating support structure	green, yellow, yellow, yellow	green
Task 3.3 New coatings	green, yellow, yellow, yellow	green
Task 4.1 Internal electrical infrastructure for offshore wind farms	green, green, yellow, yellow, yellow	green
Task 4.2 Grid connection and control	green, green, green, yellow, yellow	green
Task 4.3 Market integration and system operation	green, green, green, green, yellow	green
Task 5.1 Maintenance strategies	green, green, green, green	green
Task 5.2 Surveillance and condition monitoring	green, green, green, yellow	green
Task 5.3 Production and maintenance of materials and coatings	green, green, green, yellow	green
Task 5.4 Experience/data	green, green, green, yellow	red
Task 6.1 Development of advanced control system	yellow, yellow, yellow, yellow	green
Task 6.2 Assessment of alternative and novel design concepts	green, green, yellow, yellow	green
Task 6.3 Experiments and demonstration	green, yellow, yellow, yellow	green

Source: Nowitech 2011

The figure shows how industry partners evaluate the relevance for industry in each WP to the left column and the Nowitech's own evaluations of relevance in the wright. Green equals high industrial relevance, yellow equals medium industrial relevance and red equals no industrial relevance[43]. Nowitech SC expresses that most of the WPs involves integration of existing technology, which is argued to be expected in the startup phase of the projects.

"My impression is that some of the WPs are very good and relevant whereas others are less relevant" (Christophersen 2011). Out of 17 tasks related to six WPs the perceived degrees of relevance differ. The industry relevance feedback expresses a majority of eight tasks to be of "high relevance", six to "medium relevance" and three is divided equally between high and medium relevance. The scientific relevance feedback shows fifteen tasks as "high relevance", one tasks of "medium relevance" and one task to be of "no industrial relevance". The results are conflicting regarding task 5,4 and correlates in task 5,1.

[43] The number of scores differs in the left column according to how many partners that are involved in each WP. The codes of development were based on an "open source" in relation with the programing style. WP 1 did not have a clear annual work plan related to these issues.

Nowitech`s hold on the market sphere is coupled to development in other NIS`s. The technological innovation on deep sea sub-structures can facilitate great potential for both Nowitech and the Norwegian OWP system. As stated by DNV; *"There is a critical window right now where there is a lot of action"*. The quote underlines the rapid development that are occurring in other NIS`s. Because these systems also are emerging – it presents good time-window for Nowitech and other Norwegian firms to take position.

Absorptive capacity

The parallel between a firms capability to absorb knowledge based on prior knowledge is mirrored in Nowitech`s WPs. The industry partners that participate also have the resources to perform in house R&D. The general participation rate is approximately 50 percent (Eriksson 2011).

Big international firms are to a higher extent able to absorb knowledge from Nowitech's scientific work than SMEs (Christophersen 2011) (Steen 2011) (Hansen 2011). *"For firms that are faced with quarterly accounting and a bottom line focus – it's not always easy to prioritize resources to work with research – this is a problem for Nowitech as well"*(Onarheim 2011). The argument support that champions have greater resources to facilitate more R&D within the firm and develop expertise within the system. As stated by the RCN; *"The bigger the firm is, the more long-term R&D is possible… it`s said that one cannot absorb external R&D results if one doesn't have an internal R&D department*".

A firms absorptive ability, capacity and shared expertise and knowledge, may indicate why the participation rate correlate with the size of the industry partners. The national champions Statkraft, Statoil and DNV are the industry partners with the highest attendance rate at Nowitech's WP meetings, see *appendix 5*.

An educator

"The most important channel to spread knowledge is through the students" (Onarheim 2011). Nowitech emphasizes that in order for a system to evolve the expertise must also be integrated within the industry. Without a relatively high number of people in the work force the ability to facilitate OWP in Norway is viewed as a reverse salient. Transferring tacit knowledge though interactions within the WP`s and partners is organized though education programs specifically aimed at master levels, Ph.ds and though exchange programs with collaborating universities, see *appendix 4*.

Nowitech explains that they organize intensive students - industry collaborations. The MSc engineers from NTNU receive an idea from an industry partner that the students shall bring up a plan for commercializing. Additionally, in 2010 the board decided to strengthen a cross-disciplinary approach to the WP`s. One million NOK was allocated within the organization. *"It provides an opportunity to approach different problems from several aspects…we have ended up with a two days seminar with all our scholarship recipients and supervisors where we can structure and go through the sort of problems you need to comprehend"* (Onarheim 2011).

The emerging TIS has an insufficiency of specific knowledge or sophisticated technology, which is typical in a formative phase and underlines the importance of education. The theoretical framework has argued that in order for absorptive capacity and transfer of tacit knowledge to occur, it requires a high level of involvement and cultural similarities within a firm (Cohen and Levinthal, 1990, Nonaka, 1994). The human resources are on this basis the most significant premise for *future* development whereas the researchers and PhD students represent the key means in Nowitech to able transfer of tacit knowledge (Ericsson 2011) (Onarheim 2011).The role Nowitech holds as a facilitator for future personnel within the OWP system illustrates how a future components in the TIS are safeguarded (Bijker et al., 1987).

Creating learning arenas

The knowledge field as a whole is still emerging, in a formative phase, implying that net-works and alliances are yet not stabilized (Bergek et al., 414). These unformulated components or informal networks within a system emphasize that Nowitech`s function as a meeting arena is strong and important, as stated by Måløy Vekst; *"The most important aspect with Nowitech is how they have functioned as a "coupling point" for a small industry cluster in Måløy and the big actors abroad"* (Bjørlo 2011).

Nowitech`s peruse in allocating resources both organizational and institutional are most clear in how it seek to strengthen key functions through experts by collaborations with other universities and try to lobby sub-systems, such as industries that do not have direct linkages to their core activity. Two of the interviewees expressed how informal networks are important for developing OWP innovation (Bjørlo 2011) (Onarheim 2011). These activities occur between different domains with the aim to push forward OWO within the NIS. Hence, these features support the definition of Nowitech as a systems builder (Geels, 2004). However, Nowitech states that little efforts are made to lobby political arenas i.e. "voice strategy" in favor of OWP due to limited recourses (Narula, 2002).

Hereunder, although the system is diversified there are several actors, networks and clusters working towards commercializing of OWP in Norway which in fact is the premise and the foundation of a TIS (Bijker et al., 1987). Nowitech is characterized as a system builder based on the role it holds within the system (Hanson et al., 2011).

Market Development

The Norwegian Offshore Wind Power System

In the formative phase of a TIS, system builders may not have tight interaction between its components, nor orchestrated or intended and not in the sense that they necessarily work towards a mutual goal. Hence, what characterize this phase it is a high level of uncertainties. As stated by CenSES; *"It's apparent that they (actors in the OWP system) relate to a very uncertain market, uncertain policies and uncertain technologies in connection to which way the technological development will have in future markets"*.

Teece (1986) argue that maturity and features related to the technology define the degree to which an innovation process can be internalized. Although the OWP system is characterized to be diverse and with a high level of uncertainty there are 359 actors related to the OWP system in addition to slow influxes of emerging entrepreneurs (Onarheim 2011). Furthermore, Nowitech has 33 consortium partners, see *appendix 4*. *"In Norway there are quite many of the power companies that are involved in both centers (Nowitech and Norcowe). The companies are similar because it is mainly through hydro-power that they have gained a solid financial position that able them to invest and increase their interest to take part of the development – it is possible that things happen that increases the price on electricity, which is a premise in order to meet the required return – which again need to happen in order to accelerate offshore wind as a relevant option in Norway. There is an underlying understanding that taking part in this is very smart"* (Pedersen 2011).This illustrates that although not all actors within the system have the same level of commitment or recourses – the interest and perception of the OWP potential are great and involve a relatively high number of actors. Based on Nowitech`s evaluation of relevance in the WPs, technological development as whole is immature and not ready for commercialization in Norway. Norwegian conditions on the continental shelf require technological innovations that are stable in rough waters. Compared to Great Britain's OWP Park in Doggerbank, the winds are stronger and the sea-shells are deep bellow surface which requires more stable wind turbines and substructures.

R&D are mainly situated close within the NIS (Narula, 2002) . Moreover, the diversity may also suggest the wide range of activities within the value chain in contrast to more specific targets on a few key areas. Empirical finding showed that all respondents believed that OWP would benefit from reducing areas of scope to a few key areas in order to gain competitive advantage internationally.

Idiosyncratic patterns are the foundation for knowledge transfer. Industry-specific characteristics within OWP IS are similar to traditional offshore industries in Norway, this indicates that the OWP system benefits from idiosyncratic patterns (Narula, 2002, 796). All interviewees expressed that OWP innovation and development especially benefit from knowledge bases from the marine-industry and petroleum-industry. The OWP system have close relation with these offshore industries which also is reflected through recruiting of personnel and knowledge transfer from existing knowledge bases within marine technology and oil- industry that is applied or *transferred* over to OWP (Bjørlo 2011, Onarheim 2011) (Christophersen 2011).

Clusters and experimentation

In a technological systemic view the OWP system can be defined as an industry with industry specific proximity in contrast to geographical limitations in the NIS. However, there are strong clusters and R&D appears to be located within the system (Narula, 2002). Due to the fact that OWP development is strongly related idiosyncratic patterns, it pushes forth new industrial linkages and actors operating in the renewable power from the traditional energy system i.e. clusters.

Clusters within the OWP system and research environments indicate that developed technologies exist and that relations between existing and new entrants are increasingly forming what may be seen as an emerging OWP system in Norway (Hanson et al 2011). The Norwegian energy system has 100 years of experience within hydro power and 40 years of experience within the petroleum industry which forms clear idiosyncratic patterns for NRE and OWP in Norway[44].

The lack of OWP parks or demo parks in Norway constrains the development because it prevents agents within the system from experimenting and improving the technological innovation. *"Without demo parks you don't have any references that can able actors to position themselves. The political environment doesn't recognize this as something important"* (Onarheim 2011). The opportunity to show actors and investor in other NISs the quality of Norwegian OWP decreases, also because demo-projects in others NISs restrict foreign actors to participate (Bjørlo 2011). Although some projects are granted by the NVE they are not yet initiated due to considerations of appeal or economic conditions[45]. This reduces the opportunity to supply products mainly for SMEs within the NIS, whereas national champions like Statoil already holds a strong position needed to join big projects like Doggerbank in the UK.

To this day, all demo projects or prospects of commercialized offshore windmill parks, floating or stabile, are not sufficiently supported either by the state though an incentive system nor from firms investing in building in Norway. Initially Nowitech was part of the Demo 2020 which is still in the planning process and not moving ahead. On this basis Nowitech has developed informal contact with intent to precede a collaboration forwarding a demo park in Scotland. The Norwegian OWP actors are inhibited by not having a "trial and error phase" given by demo-projects (Bjørlo 2011, Ruud 2011).

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[44] Website Ministry of petroleum and Energy (Accessed 2.10.2011) http://www.adeb.no/viewfile.aspx?id=3594

[45] Website NVE (Accessed 15.9.2011) http://nyfornybar.no/

Nowitech participation in and effort towards realizing Demo 2020[46] has been unsuccessful (Onarheim 2011). The RCN explains that *"it needs a huge amount of subsidy beyond ENOVA and Innovation Norway –and when it comes to production support there`s the new electricity certificates – it's not suitable"* (Pedersen 2011). The lack of will to invest may be seen in parallel with the limited market in Norway. Nowitech is currently facilitating existing and new networks to build a demo park outside the NIS. *"Now, we are trying to look into the possibility for a demo-program were Norway participate and utilize Scottish subsidy opportunities – founded on a research collaborative on wind and smart grid"* (Onarheim 2011). The OWP system appears to experience a pull towards other more developed markets outside the NIS.

Exit strategy

"The end users are always in the international market" (Bjørlo 2011).

There are limited opportunities for supply in the home market which leads to an "exit" to other NIS`s where there already exists a developed OWP system.

The OWP system patterns show a clear and dominating trend of an "exit" strategy in the Norwegian OWP NIS (Narula, 2002). The development is limited by policies and influenced by the market within the NIS. In parallel to this, system builders act on the key reverse salient of price effectiveness, through an exit strategy to countries where incentive systems makes OWP more profitable. For national champions that already are located in foreign NIS`s an exit strategy becomes a matter of operation effectiveness, were the conditions for OWP becomes decisive for where development occur. DNV states how this influences their business; "*DNV has 250 people who work with wind energy, 10 of them are in*

[46] The initiative is in cooperation with the clusters Arena NOW in the west of Norway and Arena Wind in the Central Norway, which both organizes relevant companies within the industry and is funded by the IN

Norway, and the rest in Copenhagen, USA and in Asia, naturally, because that's where the clients are" (Eriksson 2011).

The Norwegian OWP system is characterized as diverse and the limited market within the NIS causes an exit strategy. As stated by Eriksson (2011) in DNV; "*I think it's possible to create a market for export of offshore wind technology. Norway has is in a way sufficient electricity supply…the ones which really needs these windturbines are Great Britain and Germany. If you look at Great Britain – they are going to install approximately ten thousand offshore windturbines the next ten years…that's where the markets are. One need to develop the niches where Norway has a competitive advantage and support the establishment of the export – industry".*

A technological system can also have sub-systems as part of a novel system, trying to penetrate the energy system according to Hughes (Bijker et al., 1987). Yet, the OWP system appear to consist of two main groups; established firms from the energy system and firms with similar industry specific characteristics like shipyard firm such as Bur and Easyform (Bjørlo 2011). In this context the formative phase of TIS are more related to an international proximity were innovation, knowledge exchange and development occurs without national boundaries, but rather through international networks and markets related to the technical artifact (Lundvall, 1988). Aker Verdal is an example of how actors in the OWP system transfer knowledge from the petroleum business to deliver components to the OWP system in other NIS`s.

The OWP field presents high level of uncertainty especially for SMEs. This shows the importance of how bigger actors that have resources push forward development in the NIS

(BUGGE, M. 2010. *FoU for en grønn energisektor: analyser av innovasjons- og kommersialiseringsstrategier i åtte FMEer - forskningssentre for miljøvennlig energi,* Oslo, NIFU STEP.)

and allocating resources from the NIS to other markets. This again benefits the NIS though spillover effects on the SMEs

Exit strategy - becoming part of, and embedded, in another NIS requires resources to create new networks which are time consuming (Narula, 2002). As expressed by Sintef, it is he current market structures that reflect the development in the OWP field. The weak opportunities within the NIS and the strong incentive systems in external NIS, attracts Norwegian OWP actors. Måløy Vekst explains how the international markets are fast speeding ahead and represents a positive impact within the NIS; *"Basically it is the international markets (that influence direction of search) but mainly via the Norwegian market that is of great importance. Actors like Statoil are concerned about bringing Norwegian industry along – all the way"*.

Nowitech states that they increasingly are altering an "exit" strategy through networking collaborations outside the NIS, especially towards Scotland. The establishment of contacts and uncertainty related to safeguard R&D are some of main reasons why Nowitech and firms localize R&D close to home (Onarheim 2011). Yet, the generic goal of RES poses a conflicting issue within the system. As emphasized by the RCN; *"On the one hand – we are supposed to be best in offshore wind, on the other hand we are not supposed to do it at home"*.

Policy Implications

Policy mechanisms

“Countries with great natural resource wealth tend nevertheless to grow more slowly than resource-poor countries” (Sachs and Warner, 2001). NRE policies have developed inducement mechanisms through legal acts, interconnected networks, strategies and means. However, DNV expresses that the Norwegian policy development is lagging behind other countries that work hard to reach the EU 2020 targets whereas Norway not yet has reached an agreement regarding reduction of GHG emissions. NRE policies and measurements are argued to be developing more slowly in Norway, also compared to countries that it is natural to be compared with. As stated by the RCN; “*What characterizes research on new renewable in Norway the last five years is that it have gone straight to the sky – and the FME´s are a part of this –but it’s not followed through by an incentive system. In some projects there are given financial subsidy….when it comes to funding production there´s “feed-in” tariffs – in Norway it`s only 3 to 5 cents per kWh – in some cases it works, like for bioenergy – not that this makes it profitable – there’s not an incentive system that facilitate investments compared to other countries that are under pressure due to shortage and high prices that have systems – its (R&D) not followed up whit means in Norway – it’s an interesting situation with the significant hydropower, oil and gas – the political strength and the position of the ones who decide – you can in a way say that its like that – that they work against new renewable energy*”.

A formative or an emerging TIS is rarely competitive. This emphasizes the premise that sustainable energy solutions rely on state interference, especially in a small and open economy like Norway. Since the climate settlement in 2009 the state support of R&D has increased and strengthened the position of NRE solutions. These policies draw parallels to the first step of linear model of innovation “research” (Kline and Rosenberg, 1986). The next steps in the linear model “development”, “production” and “marketing” are not strongly supported by the state. Hence, these may be viewed to fall under an innovation policy with a neo-classical approach were the innovation is left over to the market mechanisms deciding whether or not it has the right to be "born" and "survive"(Lundvall and Borrás, 2005).

Technology policies are to some extent supporting OWP innovations, although most means favors more extreme innovations like Hywind. Because OWP technology mainly is based on mature technology from the ONWP, the marine - and petroleum-industry, the formative OWP system is offered relatively limited support exceeding R&D. *"We have incentives in Norway today through the Norwegian Research Council, ENOVA and Innovation Norway which are oriented at technological development in Norway – but there's not an incentive system for production – these subsidies for offshore wind power – in England you have these - there you get a revenue from the sales and an additional income from the state that makes it profitable. In Norway we don't have this today and therefore it's not profitable"* (Christophersen 2011).

The linear model illustrates two points based on the weak support beyond the first step of "research". Firstly, the state may currently facilitate a policy that fall under the ideal type of "Science policies" were the state are sequentially following up this step when the technology has reached a phase of maturity. Secondly, mature OWP technologies that are ready to be commercialized alter an exit strategy due to a limited market within the NIS. The state interference has to some extent addressed inducement mechanisms such as R&D policy and blocking mechanisms like "support of experiments with new applications" through ENOVA and support systems; "feed-in" tariffs and "green" certificates (Bergek et al., 2008). Yet, the OWP system may be suffering from a low "belief growth potential"(Bergek et al., 2008). The RCN states; *"I believe that it (offshore wind power) can be big in Norway the day production don't need to be subsidized"*.

The Norwegian energy paradox influences the development in Nowitech as well as the OWP system. The interview from DNV expresses that the policies are conflicting; *"My perception is that there are political signals saying that the climate is important – that Norway is an energy nation where you have good technology – however I do think that one mix the role of energy producer and exporter with the role as technology producer and exporter. It may take some time before electricity from offshore wind becomes a reality in Norway however that should not stop us from exporting technology for offshore wind and renewable energy. In that sense I think we should be a bit clearer on what "Norway as an energy nation" really means".*

It may be argued that Norway suffers from path dependency or systemic "lock-in" within oil and gas. This might cause a limitation within NRE development were the ideal type of innovation policy based on cost efficiency becomes an argument for why Norway do not change its energy development like comparative countries like Denmark, Germany and the UK do.

Off-shore wind power

"When people talk about offshore wind power in Norway one tend to mix energy and supply issues together with production – and that are two separate discussions" (Ruud 2011). Policy makers often treat the debate of offshore wind power as an issue of energy power, electricity demand or as an environmental issue. *"Summing-up I`m missing is a more clear distinction between renewable power production in Norway versus renewable energy technology export. We have the opportunity to do both but the means and way to success are very different"* (Eriksson 2011). The market structure illustrated a diverse system that facilitated an "exit" strategy in the OWP system. Hence, a holistic RES necessary doesn't need to be at the expense of an exit strategy.

In 2010 the State Secretary Per Rune Henriksen said *"In order to build a sustainable industry, we need a market big enough for the industry to capitalize on technology development. Today the Norwegian market for offshore wind technologies is still at an early stage. To obtain economies of scale and to reap the benefits from a wider customer base, I think the industry is wise to seek business opportunities abroad*"[47]. Yet, based on inquires in this study there`s clearly a common perception that the policies are unclear. *"So what I`m missing is a clearer discussion concerning power production in Norway versus technology export"* (Eriksson 2011). The argument illustrates that the current policies are perceived as inexact. Moreover, several actors stated that that there is a need for a holistic national strategy for the OWP in Norway (Bjørlo 2011) (Eriksson 2011) (Hansen and Steen 2011). This alters the discussion in terms of where the political responsibility lies. Furthermore, how does OWP fit in a national strategy more explicitly than today? The interviews and survey performed in 2011, see *chapter III*, states that the Norwegian Government do not take account of these issues, which again are crucial for decision making for an OWP agent or firm. Additionally, unclear RES and internal overlapping in the Ministries related to responsibility creates challenges for how to operate effectively to inducement and blocking mechanisms in the TIS. These arguments also correspond and pinpoint the issues related to the Norwegian paradox.

Reverse salient

"When a reverse salient cannot be corrected within the context of an existing system, the problem becomes a radical one, the solution of which may bring a new and competing system"(Bijker et al., 1987, 75). A new system can also be altered when and if an identified "presumptive anomaly" occurs. In retrospect, the global lack of energy may be defined as a reverse salient that was altered into a new NRE system like in the UK, Denmark, Germany,

[47] Website Ministry of petroleum and Energy (Accessed 15.9.2011)
http://www.regjeringen.no/en/dep/oed/aktuelt/taler_artikler/politisk_ledelse/taler-og-artikler-av-statssekretar-per-r/2010/offshore-renewable-

and China amongst other nations. Hence, these new radical system may be viewed as more efficient and satisfactory than in Norway where NRE systems to a higher extent compete and try to become a part of the existing energy system.

"As long as the marginal cost is significantly higher than other types of electricity power production - and wind power is today considerably higher whereas hydropower is cheapest - and coal – well, then it doesn't form a foundation for heavy investments in it as long as the support regime isn't better – therefore - one rather chose to invest in demos in Scotland or elsewhere – but why this isn't done? Some believe that it isn't a sensible use of limited funds" (Ruud 2011). The inquiry showed a uniformly perception that the reverse salient is couplet to cost-efficiency, both from an innovation policy perspective and from a firm perspective.

Pushing forward a new direction to the debate that OWP is as a matter of technological and industrial development may lead to a more fruitful debate, that allows policy makers to address OWP and creating an incentive system that facilitate a platform for Norwegian R&D and industry to develop OWP technology for end users in countries where OWP has a strong incentive system and a high demand. The time "window" for Norway to enter the international OWP market is limited, and stresses the importance of more clear state policy. *"I think it's possible to create a market. Norway has is in a way sufficient electricity supply…the ones which really needs these windmills are Great Britain and Germany. If you look at Great Britain – they are going to install approximately ten thousand windmills the next ten years…that's where the markets are. So if one is to develop a Norwegian industry, one should develop those (specific branches) that can be exported – were Norway has competitive advantage and facilitate means that able an establishment of the export – industry"* (Eriksson 2011).

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energy-production--po.html?id=620419

The potential for a well-organized and a development of a Norwegian export system that supplies markets in other NIS`s indicates a high belief in the OWP system. The current "exit" strategy support the trend of how the OWP system is connecting to other NIS.

All the interviewees expressed that the key reverse salient within the TIS is related to that the price level is not competitive (All interviews 2011). The estimated price level of OWP maximize the values chain profit, which in turn is not competitive with other energy sources in Norway.

Offshore wind power and future prospects

The energy system in Norway is characterized by a high level of state interference. The limited market and policies may weaken the OWP system. The Governments polices influence SMEs though a weak incentive system and uncertainty which makes it difficult for SMEs for example to get approved loans from the banks (Bjørlo 2011).

Nowitech is not directly affected by a limited market in relation with R&D and results, although it's expressed that the research center would benefit from a parallel development within the NIS (Onarheim 2011). "*So this is different from the Norwegian oil industry were you had the continental shelf and a home market*" (Onarheim 2011). Nowitech expresses that compared to the policies that enabled the energy system to emerge related to the petroleum industry benefited from a development at all levels in value chain. Furthermore, the state interference in the sixties that supported the energy system may, in an evolutionary perspective, have parallel interests in the energy system today. On this basis, it may function as opposite forces i.e. blocking mechanisms. Although the RCN establishment of the FME`s is a sign of a strong obligation to NRE, the case study has to some extent revealed that this development mainly is associated with key persons with political power.

Norway is experiencing an increasing governance of GHG emission and RES. International climate agreements are under continuous negotiations and pushes forward a more green and sustainable development. These have an impact on Norwegian policies mainly through the EFTA agreement. "*I believe that the EU will decide more in the following years regarding how Norwegian energy policies will look like"* (Christophersen 2011).

RES has traditionally focused on a price effective support which has led to more funding of NRE solutions mainly in developing countries. Norwegian policies appear to be heterogeneous within the field. It is a premise for OWP to become cost effective compared with other energy solutions within the energy system i.e. market in order to be facilitated in the Norwegian energy market. This perspective is interesting in two ways. Firstly, because the energy challenges are global and environmental friendly technological innovations and knowledge should be transferred internationally in order to resolve the generic goal in which some national collaborations agreements are trying to facilitate. Secondly, national initiatives and investments within the field are also likely to include an economic agenda in order to gain competitive advantages, were actors seek to safeguard their technological development and knowledge which pinpoints why R&D is located within the NIS.

Summary of empirical findings

The interviews and data gathering allowed to answer and present empirical findings related to each function according to Bergek et al.,(2008). To summarize this chapter a brief captivation of empirical findings are presented to illustrate the development in the OWP TIS related to the case study. In the end of the summary a figure illustrates the degree of development in each “function” that are needed for a TIS to evolve well (Bergek et al., 2008), see *Chapter II Figure 3*.

Function 1: Knowledge development and diffusion: The case study found that Nowitech has a high level of knowledge creation and transfer through several types of activities: conferences, workshops, intranet, PhD programs, publications as well as the organizational structure. The SC and CIC appear to function as means to balance applied research i.e. for business and market development and preserve basic research quality. The core knowledge creation is tied to the center although it also benefits from a high level of interaction with formal and informal organizations and institutions within the NIS and in other NISs. Nowitech’s competence is regarded to be at a high international level. Moreover, all interviews expressed that Nowitech benefit from NTNU and Sintef in terms of network and reputation. Hence, these founding fathers also lay the foundation for knowledge transfer and specialization within Nowitech.

Function 2: Influence on direction of search: The consortium agreement between the RCN and Nowitech presents the framework from which Nowitech utilize its activities. The framework is based on the application to the FME. This legal agreement is decisive in Nowitech’s direction of search because it describes how SR shall be conducted in the WPs. Nowitech and DNV stated that the partners have some positive influence through bringing experienced from operation OWP parks abroad inn to Nowitech. However, the RCN, industry partners and Nowitech stated that the long term research projects and granted PhDs are forces that incline the opportunity to change direction rapidly and thereby limit influences from the environment.

Function 3 Entrepreneurial experimentation: The emergence of new entrepreneurs effect the OWP system i.e. network Nowitech is a part of. It is mainly the national champions that dominate OWP activity although there are slow influxes of new actors. Nowitech experience little experimentation with complementary technologies beyond the WP areas.

Function 4 Market formation: The Norwegian market is limited, although the potential is great. The market formation is characterized by the emergence of OWP clusters and it is diversified. Clusters are a feature within the OWP system, especially through minor industry areas along the coast line. Hence, the lack of infrastructure, incentives and a clear national strategy constrain the market development. Foreign NISs facilitate incentive systems that attract firms to develop a national OWP market, whereas Norwegian policies are developing slowly which may cause the OWP NIS to be lagging behind other NIS`s. Two important empirical findings are that Nowitech is not directly constrained by the market size in Norway, although the OWP development system is limited by it, hereunder especially SME`s (All interviews 2011). In sum, the market formation is underdeveloped and in a *nursing* stage.

Function 5 Legitimation: Nowitech has as a FME center a high level of legitimacy because of the connection between the RCN and the Norwegian Government. The interviews showed a unified agreement stating that the national support is limited and not holistic whish illustrates a dualistic position were the state encourages both NRE and the petroleum industry. This points out one of the reason why there is a high level of uncertainty within the OWP system. Legitimation is a crucial premise for further development. Currently the support tends to be dependent on key persons.

Function 6 Resource mobilization: The most important resource in Nowitech is the human resources. People within the organization in addition to connected agents both at an organizational and institutional level.

The following figure illustrates a brief empirical summary of the current development in Nowitech according to the function as a formative TIS actor related to "functions". The levels (Low, Medium and High) indicate the level or perceived degree of development within each function.

Figure 8: *Development of functions in the technological innovation system*

Level:	Function 1	Function 2	Function 3	Function 4	Function 5	Function 6	Function 7
High	X						
Medium		X				X	X
Low			X	X	X		

Source: Based on empirical findings

Function 7Development of positive externalities: The overall function of the TIS echoes a TIS in a formative phase. The trend shows a low degree of development in functions of the OWP system in Norway. The technological artifact is immature and not ready for commercialization. R&D activities are mainly located within the NIS, although there are tendencies of a pull towards other NISs also here. A high level of activity is mainly related to firms that are exporting products to other NISs i.e. an "exit" strategy. These are formatting in cluster that might push forwards OWP innovation in Norway. Political signals are mixed and offer little stability within the system.

V. Conclusion

The thesis has presented and discussed different aspects concerned the formative phase of TIS related to OWP. The Norwegian RES and policies are dominated by the Norwegian paradox and a neo-classical innovation policy.

Nowitech has through strong networks, expertise and a cross-disciplinary approach shaped a research center that influence and plays an important part in OWP field in Norway. Hence, it links other actors together in a system with weak organizational and institutional structure. Is may indicate that institutions and organizations to low degree are professionalized within the TIS.

Main discoveries

RQ 1: How does Nowitech create and transfer knowledge? Nowitech holds an important role in the system beyond its core R&D activity. Hence, this role appears to be dualistic, on the one hand Nowitech is a system builder creating strong learning arenas, networks and meeting arenas. On the other hand, Nowitech is an education venue for future personnel. Hence, the level of activity in Nowitech is high does not reflect the OWP system as whole.

The limited OWP market has little impact on Nowitech`s core function directly. However it limits Nowitech indirectly through a weaker interaction and co-evolvement with the industry, less feedback and reduced learning through “trial and error” with the technology.

RQ 2: What characterizes the OWP system in Norway? The OWP system is characterized as diverse at horizontal- and vertical – level. The diversity appears through weak formation of institutions and organization in the OWP system like policies, infrastructure, market formation etc. This is not rare due to the fact that system is in a formative phase. However, the TIS evolves despite of weak developed functions and are appear to be adjusting to these through adopting an “exit” strategy.

Idiosyncratic patterns provide a competitive advantage foremost from the shipping and petroleum industries. These also form the basis for knowledge transfer and the establishment of firms within the system. The trends show slow influxes of new entrepreneurs which may reflect a slow development in Norway.

RQ 3: Does a systemic "lock-in" influence offshore wind power? NRE policies are characterized as heterogeneous and policies executed are described as ideal type of a neo-classical "innovation policy". The incentive system related to OWP is underdeveloped compared to other countries it is natural to compare Norway with, like Denmark, Germany and the UK. However, international agreements push forward RES and may be seen as a "pull". The RES policies are unclear and how Norway strategically will meet the EU GHG targets may present a decisive factor for how technological development related to new renewable in Norway will progress in the coming years.

The OWP system currently features a high level of uncertainty related to technological development, policies, markets and incentive system. Nowitech is emerging an "exit" strategy, and thereby following the trend within the OWP system.

Final remarks

The case study contributes to the field with a systemic approach and combining TIS, systemic lock-in, policies and competitive strategy. The thesis has discussed and illustrated the connection between these issues and how they may add a perspective to the development of a sustainable and economic development in Norway.

Existing research emphasize that Norway should focus on new forms of collaborations between existing environments and new ones were the goal is to balance the exploration of new knowledge and an exploration i.e. commercialization of it (Bugge, 2010). Further Bugge argue that the current situation is influenced by the key reverse salient; cost-efficiency related to other available energy sources in Norway. This thesis joins this argument although it's pointed out the initiative behind the FME should be followed up with a national strategy and policy instruments to a higher extent.

NRE solutions presents a more "green" and sustainable economy. Innovation and development of technology related to Norway`s idiosyncratic patterns and access to natural recourses represents a great potential, as stated by the RCN ; *"it rests a responsibility on us regarding the environment as well as energy supply, not only to Norway but also the energy security for our neighbor countries".* Energy security is increasingly becoming an important issue globally. Norwegian technological development may contribute to this through interconnected collaborations, whereby Norwegian policies need to facilitate a foundation for NRE systems to emerge. It appears that although national RES are present, these are not clear enough or practical oriented in such a manner that it strengthens both SMEs and national champions to shape a system in Norway. Hence, these arguments do not necessarily mean that Norwegian STI-policies should develop OWP-parks in Norway. The policies could also strengthen the system by facilitating means to support OWP as an export industry.

The window for facilitating technological innovation and research with commercial aims are lagging behind leading European countries. Hence, due to available natural resources' and idiosyncratic patterns it would be natural for Norway to take a position within this field.

Further research

Throughout the writing of this thesis several interesting finding were identified. One of the findings indicated a low feedback loop between RCN as an administrator and Nowitech. The case study found that there were conflicting perceptions and expectations in terms of achieved phase of development, position and that the IPR as formulated in the consortium agreement limited commercialization. The RCN stated that IPR did not limit the opportunity to exploit technological innovations commercially, whereas Nowitech expressed that the formulated IPR made it difficult to create spin-off firms or other forms form of commercial activity. These aspects have not been accounted for in this thesis and it would be interesting to examine these issues in further research related to an evaluation the FME`s.

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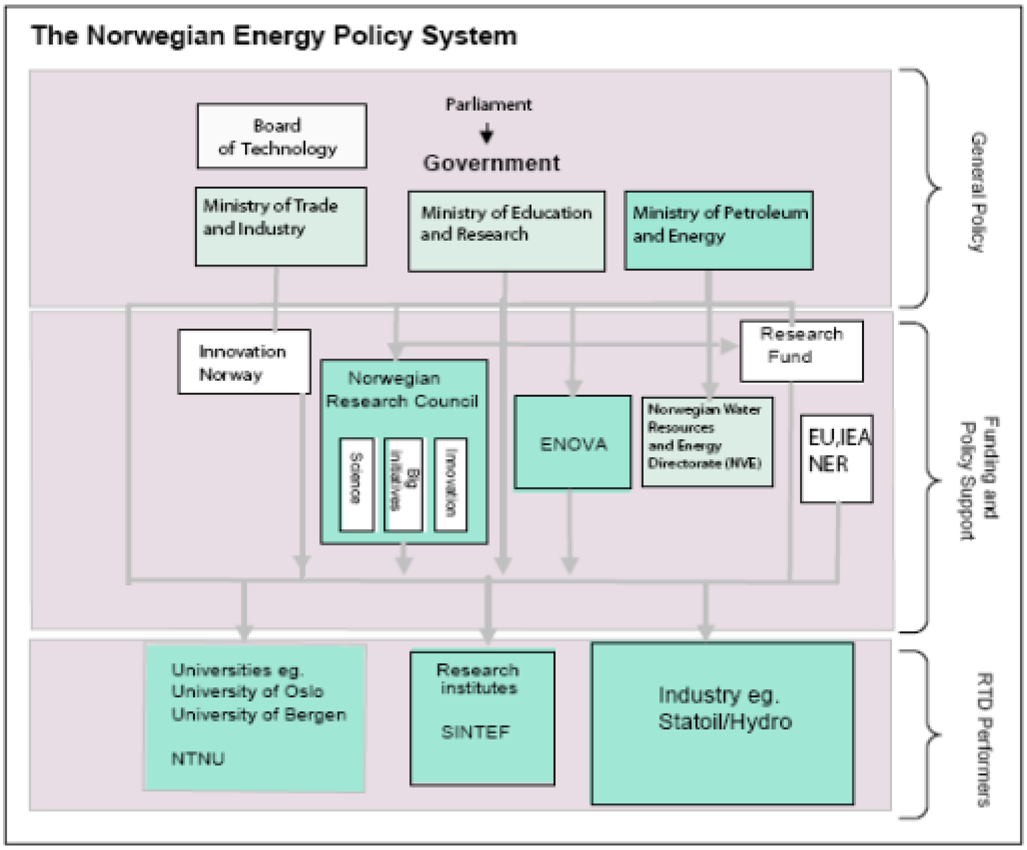
Appendix

Appendix 1: The Norwegian Energy Policy System



Source: Klitkou et al 2008 in Bugge et al.,2010

Appendix 2: Illustrating themes and issues in the interview manual

1. knowledge devopment and diffusion	Tacit and explicit knowledge
	Absorptive capacity (cross diciplinary activities)
	Network and collaboration
2. Influnece on the direction of search	*Power and influence*
	Market mechanisms
	Policies and legal acts
3. Entrepreneurial experimentation	*The emergence of new entrants*
	Complementary technologiies
4. *Market formation*	Trends and development
	OWP- market potential
	Market position
5. Legitimation	*Driving forces*
	Political signals
6. *Resource mobilization*	Human capital and other resources
	Performance and result requirements
7. Development of positivie externalities	The emergence of new entrants
	Complementary technologies

Appendix 3: Interviews

Kjell Eriksson, Nowitech, DNV	09.08.11	Oslo
Alfred Bjørlo, Måløy Vekst	13.06.11	Oslo
Trond Einar Pedersen, Forskningsrådet	20.06.11	Oslo
Jan Onarheim, Nowitech, NTNU	26.05.11	Trondheim
Gard Hopsdal Hansen CenSES, NTNU	26.05.11	Trondheim
Markus Steen, CenSES, NTNU,	26.05.11	Trondheim
Audun Ruud, SINTEF	14.06.11	Oslo
Espen Borgir Christophersen, Forskningsrådet	17.06.11	Oslo

Appendix 4: NOWITECH PARTNERS

The NOWITECH Consortium Partners in 2010 are listed below:
The Host Institution: SINTEF Energy Research
Research Partners:
Norwegian University of Science and Technology (NTNU)
Institute for Energy Technology (IFE)
Norwegian Marine Technology Research Institute (Marintek)
Stiftelsen SINTEF (SINTEF)

Industry partners:
Aker Solutions
Devold AMT AS
Det Norske Veritas AS (DNV)
DONG Energy Power AS
EDF R&D Division
Fugro OCEANOR AS
GE Wind Energy (Norway) AS
Lyse Produksjon AS
NTE Holding AS
SmartMotor AS
Statkraft Development AS
Statnett SF
Statoil Petroleum AS
TrønderEnergi Kraft AS
Vestas Wind Systems AS
Vestavind Kraft AS
In addition NOWITECH has agreements on cooperation with the following associate partners:

Associate research partners:
Massachusetts Institute of Technology (MIT), USA
National Renewable Energy Laboratory (NREL), USA
Risø-DTU, Denmark
Fraunhofer IWES, Germany
University of Strathclyde, UK
TU Delft, Netherlands

Associate industry partners:
Innovation Norway, Enova, NCE Instrumentation, NORWEA, NVE,
Energy Norway, Navitas Network

Source: Nowitech annual report 2010[48]

48 Website Sintef ()http://www.sintef.no/project/Nowitech/Publikasjoner/Annual%20Report%202010_NOWITECH.pdf

Appendix 5: Industry partners attendance at Nowitech's meetings

Partner	GA	Board	WP1	WP2	WP3	WP4	WP5	WP6	CIC	SC
Aker Solutions										
Det Norske Veritas	X	XX	**		XX	X	XX	**	XX	
Devold AMT				X						
DONG Energy Power	X		X		XX			X	X	
EDF R&D	X		*					*		
Fugro OCEANOR		X	X						X	
GE Wind Energy (Norway)	X					X	X		X	
Lyse Produksjon	X		X		X			X		
NTE Holding	X	X					XX		X	
SmartMotor				X						
Statkraft Development	X	XX	XX		XX	XX	X	XX	XX	
Statnett SF	X					XX				
Statoil Petroleum	X	XX	XX		XX	X	XX	XX	XX	
Trønder Energi Kraft	X									
Vestas Wind Systems	X	XX								
Vestavind Kraft			X*		X	X		X*	XX	

X = Participated on meeting (X = one meeting, XX = two meetings)

* = Partner did not have the opportunity to participate on industry meeting, but has communicated suggestions previous to the meeting

(blue box) = Not relevant

Source: Nowitech annual report 2010[49]

[49] Website Sintef ()http://www.sintef.no/project/Nowitech/Publikasjoner/Annual%20Report%202010_NOWITECH.pdf