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The Danish Innovation System and International Embeddedness

A Case Study of the cleantech project Zira Island

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Executive summary

Based on the conceptual framework of the innovation system approach, this thesis explores the embeddedness of the cleantech construction project, the Zira Island, in the surrounding national-, regional-, and sectoral innovation systems. The Zira Island was originally a rocky, deserted island off the Azerbaijani coast but due to the two Danish companies, Rambøll and BIG Architects, it may well become a 1,000,000 square meter role model for sustainable urban development. Cleantech innovation thus represents a way of innovating for a sustainable growth model.

Companies are embedded in complex webs of interactions and the Zira project is developed between in interactions through informal relations with reciprocity and feedback mechanisms in loops. The interactions and relations are mainly based on non-market collaboration characterised by a high degree of trust and through which the knowledge elements are transferred.

The case findings show that BIG and Rambøll are influenced by the surrounding innovation systems in a variety of ways. As regards regional and sectoral innovation systems neither Rambøll nor BIG are officially members of such systems as e.g. Copenhagen Cleantech Cluster. However, the companies are arguably influenced by the more indirect effects of being situated in proximity to a large range of cleantech companies and research institutes geographically within the region. Concerning the influence of the European innovation system, the case findings do not indicate any significant and distinctive influence. The answer to the research question is to a large degree, that the Zira project can be explained by embeddedness in the Danish national innovation system. However, even though *a large degree of exports* and *international interaction* are characteristics of the Danish innovation system, they also indicate that the international embeddedness of the Zira project paradoxically can be partly explained by the project's embeddedness in the Danish *national* innovation system. This can somewhat be accounted for by the *small open economy* argument that the openness of a small economy can be explained by the small size of the domestic market and that they depend on foreign markets to grow and be competitive. The case findings indicate that international embeddedness does not discard the importance of national innovation systems – and they will remain important with the increasing globalisation and changing context.

Three possibly system failures in the Danish innovation system have appeared in this thesis: inefficient and sporadic network activities; bureaucracy and ignorance about the offers in the Danish innovation support system; and lack of access to financing. These system failures all call for policy intervention in order to mitigate the problems. But the most crucial challenges for Danish innovation policy in the future will be to establish a new policy construct which encompasses the blurring of interactions and relations across sectors, technologies, company type and size, geographical borders and public-private status.

Table of contents

1 Introduction

Globalisation brings changes and challenges to innovation systems in both the industrialised and developing countries. The Asian countries have entered the global innovation scene and the Western countries' positions have been challenged. The globalization processes have increasingly started to change from international exploitation of nationally produced products to global generation of innovation. These new patterns indicate that interdependence and interaction are increasingly important words. The patterns of innovation activities are shifting and so are the boundaries between local, national, regional and global innovation (Altenburg et al. 2006, Chaminade and Vang 2006, Parthasarathy and Aoyama, 2006 in Borrás, Edquist, & Chaminade, 2008). The distribution of roles in the world economy thus seem to be changing.

Besides the changing patterns in the globalisation processes, we are facing challenges without precedent in the new *post-crisis* world and in addition to the financial crisis the climate crisis is one of the critical issues. Joseph Stiglitz recently stressed the need for channelling innovation towards environment and saving of resources (Stiglitz, June 2010) as an answer to the challenges the world's governments are currently facing. At the same occasion Robert Solow further stressed the necessity of allocating resources to the institutions which generate innovation (Banerjee, Dasgupta, Maskin, Mirrlees, & Solow, June 2010). The current way that the world's economies are managing pressing issues and organising the innovation systems are therefore increasingly subject to change.

Both the global innovation scene's changing distribution of roles and the pressing climate and financial issues are changing the conditions for and in the Danish innovation system. According to Katzenstein (1985), small economies such as Denmark tend to be more globalised and more dependent on the outside world than large countries because small economies for instance have limited commercial outlet domestically and therefore have a large degree of export. Denmark is furthermore characterised by early support to specific sectors and industries with public technology procurement along with other demand-side measures, such as regulation. One of the industries whose establishment and growth has been highly influenced by the factors above is the cleantech industry.

As a result of the climate threats, untenable energy consumption aggravated by the population explosion and consequently the growing interest in sustainable development, Danish cleantech has become an important industry and a promising growth industry both nationally in Denmark and abroad. Cleantech represents more efficient and cleaner technologies, which are the key to efficient energy use – a prerequisite for a sustainable energy policy in e.g. Denmark. Stern (2008) argues that emission reduction must include a large spectrum of CO2 emitters and not only focus on one or two of the emission culprits. The cleantech industry accommodates reductions of the damaging outcomes of all the culpable energy emitters and the cleantech technologies range from waste treatment,

sustainable energy production- and use to business models, which provide long-term solutions to the climate challenges.

Since energy-related cleantech activities constitute the majority of Danish cleantech activities, the 1,000,000 square meter sustainable building project, Zira Island, in Azerbaijan is used as the case in this thesis. The Zira Island project is being developed and built by two Danish companies, Rambøll Denmark and Bjarke Ingels Group, who envision transforming the rocky, deserted island off the Azerbaijani coast into a model for sustainable urban development with zero carbon footprints. This vision makes the project interesting in the context of the climate crisis and political focus on sustainable energy: "In a society literately built on oil this will serve as a showcase for a new way of thinking sustainable planning" the project director has stated in an interview (Lars Ostenfeld Riemann in Etherington, 2009). Innovation and development in cleantech is thus a way of channelling innovation towards environment and saving resources. Moreover, it is interesting to investigate the competitive advantages of the Zira project and the Zira company consortium in order to open up for a discussion of how the competitiveness of the project and companies has been impacted by the Danish national innovation system. This can further be a starting point for a discussion about Denmark's role when the innovation activities and the distribution of roles in the world economy are changing. And in continuation hereof a discussion of whether a small open economy's national innovation system, which is open and export focused, will remain important with the increasing globalisation.

With this in mind the following broad research question has been generated:

How can the Zira project be explained by
embeddedness in the Danish national innovation system?

1.1 Specification and delimitation of research area

To specify the research question above in more detail, this thesis examines the sustainable building project, the Zira Island, by analysing the relations and interactions among the three Danish companies in the Zira company consortium, Rambøll, BIG and Pihl, and between these companies and the innovation systems they are part of. The innovation system focus is primarily on the Danish system but Copenhagen Cleantech Cluster, as an example of a regional and sectoral innovation system, and the European innovation system are also included. In order to be able to answer the general research question above, two further and more specific questions, which also constitute two different levels of the analysis, are asked:

1. *Organisational and micro level*: How are the relations and interactions between the organisations in the Zira company consortium influencing the innovation processes in the project?
2. *Institutional and meso level*: How are the organisations and the innovation processes in the Zira project influenced by the innovation systems that they are part of?

This thesis thus tries to unravel whether the Zira project can be explained by the institutional set-up in Denmark and the extent to which Denmark is a prerequisite for existence of the Zira project. The focus of this thesis is thereby to identify characteristics and competitive advantages of the Zira companies and identify areas for Denmark to address in order to be innovative and competitive in the future. There is currently an emphasis on comparing and benchmarking innovation systems and their components (e.g. through the European Innovation Scoreboard and the Global Competitiveness Index). According to Lundvall (2004) this generalising of best-practices undermines that systems are unique and elements can therefore not be copied from one system to another. Therefore this thesis takes a strong focus on identifying specific national Danish characteristics.

While the cleantech industry has strong prospects of solving some of the highly debated climate issues and is a means to achieving the energy policy objectives of the Danish government, it is also a promising industry in Denmark. According to Lundvall (2004) firms belonging to different sectors and industries contribute to the innovation processes in different ways and they have different relations and interactions with their environments. In order to produce adequate conclusions and avoid misleading generalisations the focus of this thesis is therefore narrowed down to a single case study of the Zira Island project within the cleantech industry.

According to Edquist (2001, 2004, 2005), we have limited knowledge about what determines innovation and the activities in the innovation systems. In order to assess the determinants of innovation in the Zira project, the relations and interactions in the project are analysed. In an attempt to increase the knowledge about the activities in the innovation system, the following three activities are focused on due to their relevance and centrality for the case: enhancing networking and linkages; facilitating the creation of positive external economies, cooperation and knowledge spill-over; and facilitating financing.

1.2 Structure of thesis

The thesis is structured as follows: The succeeding chapter 2, the conceptual framework, serves the purpose of laying out a conceptual framework for this thesis and highlight relevant points and requirements that the analytical framework should address, as well as providing definitions of the concepts used. Chapter 3 outlines the methodology of the thesis, specifies the philosophical assumptions and the approach upon which the research is based, and clarifies the empirical approach

of data collection and its reliability and validation. Chapter 4 and 5 serve as the starting point for the analysis and discussion: Chapter 4 provides an overview of the Danish innovation system, the changing context of globalisation and a brief outline of the European innovation system in relation to the cleantech industry, while chapter 5 provides an overview of the Danish cleantech industry and Copenhagen Cleantech Cluster. The following analysis in chapter 6 deals with the innovations in the Zira project, the characteristics of the companies in the Zira company consortium involved in the project, and the relations and interactions influencing the innovation processes. Chapter 7 discusses the degree to which the Zira project and the Zira company consortium are institutionally embedded in the Danish national innovation system, while chapter 8 clarifies and elaborates on the system failures identified in the analysis, discusses the role of policy and whether the Danish national innovation system is going to remain important. Lastly, in the conclusion chapter, an answer to the research question is provided, and implications for policy and further research are put forward.

2 Conceptual framework: the innovation system approach

The conceptual framework firstly gives a brief survey of some of the most widespread, traditional models of the innovation process. Secondly the innovation system approach is assessed with the purpose of establishing an analytical framework for later use in this thesis. It is outlined how the strengths of the system of innovation approach counter the traditional models' weaknesses. Thirdly the role of innovation policy and justification of such an intervention within the innovation system framework is assessed. Fourthly a brief account of network theory perspectives is provided before the research gap, which this thesis aims at incipiently filling in, is identified. This chapter serves the purpose of justifying the choice of the innovation system approach as framework for this thesis. It furthermore serves to highlight relevant points and requirements that the analytical framework should address and include.

2.1 Traditional economic theory and innovation analysis

The traditional model of the innovation process is constituted by the neo-classical scholars. In the traditional model the first step in the innovation process is the generation of new knowledge and the model is founded on the Pareto optimality and equilibrium between supply and demand of knowledge. The goal of public intervention is to offset the market failures that obstruct this Pareto optimality (Borrás, 2008). The neo-classical approach has been criticised of being too static, linear and too focused on a utopian Pareto optimality (Borrás et al., 2008). The innovation system approach breaks with this by viewing the market and innovation processes as dynamic, joint learning processes embedded in social, economic and political institutions and without an optimality-oriented utopia. The notion of vertical interaction and innovation as joint process are also present in Porter's industrial cluster concept (1990), where the focus is on interconnectedness of companies, suppliers, supporting organisations, and the institutional setup within a specific industry and physically present in a particular area. Furthermore, it is present in the triple helix model put forth by Etzkowitz and Leydesdorff (2000), where the analysis is focused on the relationships between government, industry, and academia to assess the degree of collaboration in the innovation processes between companies and knowledge institutes in a specific geographical region.

2.2 The Innovation system approach

The *innovation system* (IS) approach has existed for more than two decades in its earliest versions, since Freeman (1982, 1987), Lundvall (1985, 1992) and Nelson (1993). However, as these authors also agree, the idea of a system of innovation goes back to Friedrich List's notion of *The National System of Political Economy* (1841) (Freeman, 1995). During the last decades the approach has been widely disseminated in academic contexts as well as a framework for innovation policy (C. Edquist,

2001) and it has been adopted in the World Bank, the EU-Commission, OECD and UN affiliated institutions as well as policy makers in some of the largest countries in the world (e.g. the US, Japan and China) (Lundvall, 2005).

The definition of *innovation systems* used in this thesis (Table 1) indicates that the innovation systems approach is concerned with the determinants of innovation rather than their outcomes (C. Edquist, 2001).

Table 1: Innovation system terms

- *Innovation system:* "the determinants of innovation process, and is formed by all important economic, social, political, organizational, institutional, and other factors that influence the development, diffusion, and use of innovations."
- *Constituents of ISs*: Components and relations among the components.
- *Main components in ISs*: Organisations and institutions.
- *Organisation:* Formal structures that are consciously created and have an explicit purpose. They are the players or actors.
- *Institutions:* Sets of common habits, norms, routines, established practices, rules, or laws that regulate the relations and interactions between individuals, groups, and organisations. They are the rules of the game.

Source: (C. Edquist, 2001; C. Edquist, 2004; C. Edquist, 2005)

The crucial question is to identify the important factors and parameters, the activities or determinants and functions, in the systems (C. Edquist & Hommen, 2008b).

According to Ingelstam (2002) and Edquist (2005), a system consists of two kinds of entities: components and the relations between these. The system approach aims at capturing the interactive aspects of the innovation processes and encompassing the complex relations and interactions in both the formal and informal institutional setups (Borrás et al., 2008).

2.2.1 Taxonomies of innovation

In order to identify the determinants and boundaries of the innovation systems, we need to have a definition of innovation. Innovations can be defined as "new creations of economic significance normally carried out by firms (or individuals). They may be brand new, but are more often new combinations of existing elements" (C. Edquist, 2001). Different kinds of innovation can have

different determinants as well as consequences and it is thus important to distinguish the innovations (C. Edquist, 2004).

As Table 2 shows, innovations can be *product* innovations (*what* is produced), which encompasses goods (material) and services (intangible) and innovations can be *process* innovations (*how* goods and services are being produced), which can be technological (material) or organisational (intangible) (C. Edquist, 2001; C. Edquist, 2004; Fagerberg, 2005).

Table 2: Innovation taxonomies

	Product innovation	**Process innovation**
Material	Goods	Technological
Intangible	Services	Organisational

Based on Edquist (2001, 2004).

Another classification of innovations is based on Schumpeter's work. This is a classification of innovation into *radical* or 'technological revolutions', which require new, very different knowledge and *incremental* innovations or 'marginal' innovations, which build on existing knowledge. Innovation is a continuous process (of improvements and iterations) and is often the result of a long process with many interrelated innovations (Fagerberg, 2005). According to Lundvall et al (1992) it is a general conception that incremental innovation has a cumulative impact that is just as significant (if not more) than that of radical innovation.

2.2.2 Strengths of the innovation system approach

Today we know that companies do not innovate 'in isolation'. The IS approach has been essential to the attainment of this knowledge and our understanding of the importance of institutions in the innovation processes (C. Edquist, 2001). No matter how essential the approach has been, it still both has strengths and weaknesses. In the following section the strengths of the IS approach will be outlined (the weaknesses will be outlined later).

Innovations are generally seen as being based on learning and it is a strength of the IS approach that it places *innovation and learning processes at the centre of focus* (C. Edquist, 2001).

The approach emphasises interdependence and non-linearity (C. Edquist, 2001). Learning does not happen in isolation in the individual organisation but between organisations in interactions through complex relations with reciprocity and feedback mechanisms in many loops. Innovation is thus based on interactive learning, which is contrary to the linear model of innovation, where science is the basis for innovation and an increase in the scientific inputs will cause the number of innovations as well as technologies to increase (OECD, 1997).

The IS approach furthermore adopts a holistic and interdisciplinary perspective when trying to include all important determinants of innovation (C. Edquist, 2001).

The approach also employs historical and evolutionary perspectives and renders the notion of optimality or the ideal irrelevant because no systems have been going through the same evolution and has the same historical characteristics. Innovation processes are path-dependent and have certain trajectories and different institutional set-ups with different features (Borrás, 2008; C. Edquist, 2001; Fromhold-Eisebith, 2007). This is very important for the understanding of innovation processes and the formulation of innovation policies. Because of this evolutionary character of the innovation processes and because innovations happen all the time everywhere in the innovation system, the system never achieves equilibrium.

The approach can encompass both product and process innovation and not only technological process innovation, which traditionally has been the main focus for innovation studies {{61 Edquist, Charles 2001}}. This use of a comprehensive innovation concept is reflecting the current development, where non-technological forms of innovation are becoming increasingly more important and area of attention.[1]

The approach emphasises the role of institutions and they are considered to be crucial elements in all versions of the SI approach. The institutions shape (and are shaped by) the actions of the organisations and the relations between them (C. Edquist, 2001).

According to Edquist it is due to these strengths that the SI approach has become essential for the understanding of innovation processes in innovation systems today (C. Edquist, 1997; C. Edquist, 2001).

2.2.3 Components

In the SI literature there is agreement that the main components of the innovation system are *organisations* and *institutions* (Borrás et al., 2008; C. Edquist, 1997). There is a conceptual confusion among scholars about the meaning of these components and a specification of the components' meaning is therefore given in Table 1. In addition to specification of organisations and institutions, Borrás (2008) makes a further division of the institutional set-up and divides it into two categories: *formal* institutions and *informal* institutions. Formal institutions are the explicitly formulated rules of the game, while the informal institutions are the norms, customs, routines and worldviews characteristic of the components in the system. The innovation systems are strongly characterised and influenced by both the formal and informal institutional set-up that forms the system (Borrás et

[1] This increasing importance of non-technological innovations can e.g. be illustrated by the increased focus on service innovation in the new EU Strategy 2020.

al., 2008). This also relates back to the SI approach's rejection of optimality and the ideal model of a system.

2.2.4 Relations between components

The relations between the components in the system and between the components and activities are important when we want to understand and explain innovation processes (C. Edquist, 2005). The focus on the relations between components is a major advantage of the innovation system approach but according to Edquist (2001) this is also a challenge since our knowledge about the relations is scarce. These relations between components can take three forms: Interactions between *different organisations*, interactions between *organisations and institutions* and interactions between *different institutions*.

The interactions between different organisations in the NIS approach can take two forms. The first, the *market relations*, coordinate transactions, such as selling and buying, between the organisations. The second interaction is the *non-market relations*, which are based on collaboration, knowledge elements and mediating the relations between the components (C. Edquist, 2001).

The relations between organisations and institutions are important. Institutions provide the incentives and obstacles influencing the activities that the components perform (C. Edquist, 2005). These relations are a two-way relationship: organisations are influenced by institutions and 'embedded' in an institutional environment (e.g. the legal system, norms or standards) but the institutions are also 'embedded' in the organisations (e.g. company specific rules) (C. Edquist, 2005).

2.2.5 Knowledge spill-over and knowledge flows in innovation systems

In the innovation system approach, knowledge flows and knowledge spill-over play an important role because of the approach's focus on the linkages and relations between the components as a key to technology performance (OECD, 1997). According to the OECD (1997), there are many channels in an innovation system through which knowledge can flow, but there are four basic knowledge flows:

1) *Interactions among enterprises*
2) *Interactions among companies, universities and public research laboratories*
3) *Diffusion of knowledge and technology to companies*
4) *Movement of personnel*

According to the OECD (1997), one of the most important knowledge flows is the flow resulting from technical cooperation between companies as well as their informal interactions. The NIS approach is in line with this but includes institutions as a component and therefore stresses that the flow of technology and information between people, businesses and institutions are key to the innovation process (OECD, 1997).

2.2.6 Functions and activities

The *main function* of a system of innovation is to "pursue innovation processes i.e. to develop, diffuse and use innovations" (C. Edquist, 2005) and the *activities*, which are the same as the determinants of the main function and are those factors that influence these innovation processes. The function of the system was not addressed systematically by the early SI scholars but this theoretical gap has been approached by scholars such as Xielin Liu and Steven White (2001), Johnson and Jacobsson (2003), and Rickne (2000) in the early 2000s.[2] There are significant similarities between the different scholars' lists. However, due to the lack of established knowledge about the functions, there is no agreement as to which functions and activities that the system of innovation must contain. Based on the lists mentioned above, Edquist (2005) has however put forward a list of activities that he expects will be most important in SIs (see appendix 13.5). Lundvall (2004) however questions Edquist's attempt to create rigour in the SI approach by creating a list of the most important activities, while saying that list easily could be expanded with equally important activities. As specified in section 1.1, this thesis nevertheless focuses on three of the activities in the lists mentioned above.

2.2.7 Relations between components and functions

As mentioned, the tasks performed by the components (organisations and institutions) vary among the different systems of innovation. This is also the case with the functions, which can be performed by different organisations in different institutional contexts. As regards *functions and organisations*, different organisations can perform and fulfil each function (e.g. research). The relationship between *functions and institutions* is not as direct and the institutions do not fulfil any functions – they influence how the organisations perform them (C. Edquist, 2001; C. Edquist, 2005).

2.2.8 Boundaries of innovation systems

The distinction between what is inside and what is outside the system is crucial and the boundaries therefore need to be defined. The external boundaries of the system are however difficult to identify because system boundaries today cross the national borders and the organisations in the system operate across the national borders in an international context. Nevertheless, if we want to study the

[2] Research, Implementation, End-Use, Linkage and Education (Liu, X. & White S., 2001 in C. Edquist, 2005).
To create 'new' knowledge, to guide the direction of the search process, to supply resources, to facilitate the creation of positive external economies and to facilitate the formation of markets (Johnson A. & Jacobsson S., 2003 in C. Edquist, 2005).
Create human capital, create and diffuse technological opportunities as well as products, incubate in order to provide facilities etc., facilitate regulation for technology, materials and products, legitimize technology and firms, create markets and diffuse market knowledge, enhance networking, direct technology, market and partner research, facilitate financing, create a labour market that new technology based firms can utilize (Rickne 2002 in Edquist, 2001).

system it is necessary that we identify the boundaries of it (C. Edquist, 2005). In order to identify the *spatial* boundaries of the system, there are three variants of the SI approach: *National* innovation system (NIS), *regional* innovation system (RIS) and *sectoral* innovation system (SIS). As Edquist (1997) argues, these approaches can be viewed as complementing each other rather than excluding each other.

Defining the boundaries in terms of *activities* is another way to delimit the innovation system within a NIS, RIS or SIS and deciding which parts to include (C. Edquist, 2005).

2.2.9 National Innovation Systems

The initial innovation system approach was based on a *national* notion. National innovation systems – and an understanding of them – are crucial for an understanding of national competitiveness and competitive advantage (C. Edquist, 2001). NISs are the result of historical processes and innovation policies are part of the complex interactions that shapes the system (Borrás, 2008). The national innovation systems are fruits of a country's history and have evolved in specific trajectories created by decisions and occurrences in the institutional setup.

2.2.10 Regional innovation systems

Innovation system literature that focuses on *regional* innovation systems has developed rapidly since the mid nineties (Cooke, 1996; Maskell and Malmberg, 1997). As regards RIS, it is challenging to define what to include in the region. The RIS boundaries should be defined on the basis of coherence (as e.g. a minimum level of learning spill-overs, skilled workers and a minimum level of collaborations between organisations between the organisations) in the region and not administrative boundaries (C. Edquist, 2001). The boundaries of regional innovation systems are regions within countries or across national borders. RIS can be defined as "a complex in which firms and other organisations [...] are systematically engaged in interactive learning through an institutional milieu characterised by embeddedness" (Cooke et al. 1998, p. 1581 in Fromhold-Eisebith 2007). Fundamentally, there are two kinds of actors whose interaction forms RIS. Firstly, businesses in a region's most important industrial clusters (including customers and suppliers). Secondly, research and higher educational institutions, technology transfer agencies, training organisations, business organisations, financial institutions etc.

2.2.11 Sectoral innovation systems

Brechi and Malerba (1997) developed the notion of the sectoral system of innovation in the mid 1990s. A sectoral innovation system is a system constituted by parts of a RIS or NIS and it is delimited to a specific technology field or product area as well as a geographical delimitation (C. Edquist, 2001).

2.3 Innovation policy

Innovation policy can be defined as "actions by public organisations that influence innovation processes, i.e. the development and diffusion of (product and process) innovations" (Borrás et al., 2008). Through the second half of the 20th century, there has been a gradual transformation in the cognitive paradigm in the policy area (Borrás et al., 2008): In the 1940s-60s the focus was on science and knowledge production (science policy). In the 1970s-80s the focus changed to technology development (technology policy) and since the early and mid 1990s, the focus has been on innovation policy (Lundvall & Borrás, 2005 in Borrás 2008). These changes show the general paradigmatic transformations of the contents and rationales behind policy initiatives. With the focus on science policy the perception of innovation was linear. Through the historical steps, this perception has changes to a more interactive view of innovation and today the policy instruments are not only focused on producing science but also on creating linkages and absorptive capacity (Lundvall, 2005). Innovation policy thus goes beyond science and technology and e.g. includes various areas such as infrastructure, education and R&D and tools such as demand-side instruments. According to Borrás (2008) it is problematic when e.g. the Varieties of Capitalism literature treats innovation policy as an *exogenous factor* not included in the innovation process and innovation system equations. Borrás argues that innovation policy is rather an important variable in the equation together with other complex interactions in the innovation system (Borrás, 2008).

2.3.1 When is innovation policy justified?

The question of when public intervention and innovation policy are justified and what should be undertaken by the state on the one hand and the market and companies on the other, depends on two conditions according to Edquist (2001). Firstly, "the market mechanisms and firms must fail to achieve the objects formulated" (Borrás et al., 2008; C. Edquist, 2001; C. Edquist & Hommen, 2008b). A problem should exist in the sense that the companies and the market are not automatically achieving the politically determined objectives. Secondly, "the state and its public agencies must also have the ability to solve or mitigate the problem" (Borrás et al., 2008; C. Edquist, 2001; C. Edquist & Hommen, 2008b). Innovation policies should not substitute what the private organisations do but should rather ()complement it – and be a midwife (Borrás et al., 2008; C. Edquist & Hommen, 2008b).

In order to mitigate the problem it is necessary to know its causes. These causes or 'system failures' are "deficiencies in the functioning of the system or functions that are missing or inappropriate" (C. Edquist, 2001). There exist four main categories of system failures where the elements are either missing or inappropriate: functions, organisations, institutions and interactions.

Because of the evolutionary individual national characteristics and path-dependency of innovation processes, policy-makers need to have an understanding of these and take them into account when formulating policies. However, this context-based perspective limits the degree to which policy lessons can be drawn from comparisons with other countries. Imitation and institutional borrowing (copying institutions) are common in innovation policy formulation (C. Edquist, 2001) and therefore Lundvall & Borrás (1997 in Edquist and Hommen, 2008) argue that it must instead be a matter of institutional *learning* because the innovation policies need to be adapted to the local contexts. According to the IS school there is thus no single optimal model of institutional set-up or of innovation processes and the *one-size fits all* approach should therefore be avoided in innovation policy.

2.4 Criticism of the innovation system approach

Despite the large diffusion of the innovation system approach, the approach has weaknesses important to have in mind.

The innovation system approach is marked by *conceptual confusion*. Scholars use the framework concepts in different and inconsistent ways, which entails "unclarity and fuzziness" (C. Edquist, 2001; C. Edquist, 2004). An example of this is the use of the term *institution.* Scholars do not give the term the same meaning and use it both as a description of organisational actors (e.g. companies, universities and public innovation policy agencies) and as a description of institutional rules (e.g. sets of common habits, routines and laws).

A further confusion is the *confusion of the functional boundaries* of the innovation system. It is still unclear what to include in the system (C. Edquist, 1997) and scholars have deliberately not given any indications for this.

An additional weakness is that we generally *do not yet have enough knowledge about the determinants of innovation* (C. Edquist, 2001).

According to Edquist (2001), the early writings on the approach somewhat *neglects other kinds of learning processes than those leading to innovations in direct and immediate ways* and that it partly *neglects individual learning in the form of education*. Even though this lack has been somewhat counterbalanced more recently, it is still a weakness and we do not know much about the relations between the different kinds of learning and the way they affect the IS.

Edquist furthermore directs our attention to the *lack of a 'theoretical' component about the role of the state* in the approach. This is an important lack because the state and the state agencies are essential determinants in the system of innovation e.g. in their capacity of law makers of innovation policies (C. Edquist, 2001).

A final weakness outlined by Edquist is that the *SI approach is not a formal theory* because the relations between the variables are not described in a rigorous manner and the functional boundaries of the system are vaguely defined. The IS approach is thus what Edquist calls a "conceptual framework" (Edquist 1997 in C. Edquist, 2001).

To facilitate the later analysis of the interactions between the companies and their interactions, linkages and networks with other organisations in the innovation system, the IS framework is supplemented with the network perspective and business network perspective below.

2.5 Network perspectives

The network perspective focuses on firm behaviour in the context of inter-organisational and interpersonal relationships. This view argues "…that organizational boundaries incorporate both formal and informal relationships" (Coviello & Martin, 1999). Studies show that "…knowledge-based firms, when compared with traditional companies, invest more time in networking and also build more focused networks" (Johannisson, 1998).

A business network extends "…without limit across market, industries and national boundaries (…) Every business firm and every business relationship is embedded in an unbounded network structure" (Forsgren & et al., 2005). In the knowledge-based company, the 'production' is embedded in people's use of their knowledge, but also very much in these people's "…interaction in the market" (Johannisson, 1998), their ability to obtain knowledge and contacts. This stresses the importance of the employee's personal networking skills.

2.6 Conclusion – and research gap

The traditional models of innovation processes are too static and focused on a utopian Pareto-optimality. The SI approach counters these weaknesses by: placing innovation and learning processes at the centre of focus; emphasising that innovation is an interdependent and non-linear process, which happens in interactions; adopting a holistic and interdisciplinary perspective; employing a historical and evolutionary perspective that makes room for viewing the innovation processes as path-dependent and developing system specific trajectories; encompassing different kinds of innovations; and emphasising the role of institutions.

The SI approach acknowledges that there are functions that the market cannot handle sufficiently. Therefore Edquist (2001), Edquist & Hommen (2008) and Chaminade & Edquist 2006) argue that public intervention and innovation policy are justified when a system failure, constituted by a problem that the companies and the market are not able to solve, exists and the state and public agencies have the ability to solve the problem.

In order to facilitate the later analysis of the interactions between the companies and their interactions, linkages and networks with other organisations (i.e. knowledge institutes) in the innovation system, the IS framework was supplemented with the network perspective and business network perspectives, which draw on theories of social exchange and resource dependency and sees the company as an actor in a context of inter-organisational and inter-personal relationships.

The SI approach and network perspectives constitute the conceptual framework for this thesis. The weaknesses of the SI approach on the other hand draws attention to a research gap that deserves more attention.

2.6.1 Research gap

As established above, we have limited knowledge about the activities, functions and determinants of innovation. Furthermore our knowledge about the relations between the components in the innovation systems is neither sufficient. This is the case for both the relations among companies and between companies and institutions (policies).

The SI literature is from the late 1990s and mid 2000s and since then, the increasing globalisation has changed the context companies operate in. This context has increasingly become international and more complex for the companies and consequently, it is evident to assess the implications this changed context have for the IS approach.

3 Methodology

In this section it will be outlined how the research is undertaken, including the theoretical and philosophical assumptions upon which the research is based, and the implication of these for the method adopted. Firstly, the methodological approach is elaborated including specifications of the philosophical assumptions, a description of the research object, specification of the research approach and research strategy. Secondly, the empirical approach of data collection and its reliability and validation is clarified. Thirdly, the implications of the research approach are outlined and discussed before the conceptual and analytical framework is introduced.

3.1 Methodological approach

3.1.1 Research philosophical stance

The research philosophy is marked by an interpretivist approach. With point of departure in the case study, a better understanding of the meaning of the opinions expressed by the interviewees in the conducted interviews is sought. According to interpretivism, "…the social world of business and management is far too complex to lend itself to theorising by definite 'laws'" (Saunders, Lewis, & Thornhill, 2003). As Remenyi (Remenyi (1998) in Saunders et al., 2003) states, there is a necessity to discover "…the details of the situation to understand the reality or perhaps a reality working behind them."

3.1.2 Nature of the research object

The research object of this thesis is the Zira Island, which constitutes an informative case within the Danish cleantech industry. The case is analysed within the conceptual framework of the innovation system literature in order to answer the research question. This thesis explores the interactions, relations and activities in the Zira project – between the three Danish companies in the Zira consortium – and the influence of the innovation systems that surround them. A further introduction to the case will be given in chapter 6.

3.1.3 Research approach

My research involves an empirical investigation of the innovation processes surrounding the Zira Island, and encompasses descriptive, explanatory and exploratory aspects. The first part of the project had a very *descriptive* approach: gathering data to construct an overview of the Danish innovation system, and the Danish cleantech industry and the Zira Island project. The approach to this data was *deductive:* a series of assumptions about the nature of the object studied, i.e. some biased ideas about the embeddedness of the Zira Island in the Danish national innovation system

were in mind before commending the data gathering. Additionally, this might have caused some bias in the data collection. As the case organisations and interviewees were approached, a more *exploratory and explanatory* approach was applied by looking deeper into the issues which arose and the causes for the organisations' behaviours.

3.1.4 Research strategy

The research strategy is an in-depth single case study with the specific case of the Zira Island. As the strategy for the selection of samples and case, the information-oriented selection was chosen. In the information-oriented selection, the purpose is to maximise the utility of information from small samples and single cases. The case is selected on the basis of expectations about its information content (Flyvbjerg 2004) and accessibility. Furthermore the case was selected because it constitutes a contemporary phenomenon in a context where the boundaries between this phenomenon and context are not clearly evident (Yin, 1984).

3.2 Empirical approach

The data collection method consists both of primary data and secondary data. The primary data is based on company publications and interviews with key persons.

3.2.1 Interviews

Because the arguments of this thesis are largely based on the interviews conducted, it is important to be aware of the advantages and disadvantages of this approach. Semi-structured interviews were found most appropriate and within this framework, open, specific and closed questions were asked within themes adjusted to the specific interviewee and organisation. The semi-structured approach was chosen due to its more dynamic nature and furthermore the questions were of a character that required personal contact rather than written questionnaires. The explored themes varied from interviewee to interviewee and were adapted to the themes and the specific role each interviewee had/has in the Zira project or innovation system.

The interviews were conducted in Danish as this is the mother-tongue of both the interviewer and all of the interviewees. By doing this, misunderstandings stemming from the use of a foreign language were avoided. Furthermore, the interviews were recorded in order to be able to focus on the dynamics of the interviews while conducting them and avoid a process of decontextualising the conversations. This also facilitates a more accurate analysis and allows direct quotations.

For the research of this thesis six informants have been interviewed:

The Zira project:

- Geert Stryg, Senior Project Director in Rambøll Denmark
- Kai-Uwe Bergmann, Project Manager and Associate Partner in BIG

Copenhagen Cleantech Cluster (CCC):

- Nicolai Rottbøll Sederberg-Olsen, Head of Secretariat
- Michael Johansen, Project Development Manager

Danish Agency for Science, Technology and Innovation, Ministry of Science, Technology and Innovation (DASTI):

- Thomas Alslev Christensen, Head of Department
- Jan Windmüller, Head of Section

These six informants have been chosen with snowball sampling, which relies on referrals from an initial subject (Lars Ostenfeld Riemann, Service Area Director in Buildings & Design at Rambøll) in order to generate additional subjects and on the basis of their relevance for the thesis: the representatives from the Zira project have been chosen because of their high degree of knowledge about all aspects of the project; the representatives from CCC have been chosen because of their specific insight into the cleantech industry; and the representative from DASTI have been chosen because of their involvement in the development of the Danish *Innovation Action Plans* and their exhaustive knowledge about the Danish innovation system in combination with their specific knowledge of the Danish innovation schemes. The interview guides can be found in appendix 13.1, 13.2, 13.3 and 13.4.

3.2.2 Secondary data

In addition to the primary data, the data collection method also consisted of secondary data of both qualitative and quantitative nature such as data from the academia about the conceptual framework and perspectives that are being used; statistics from Statistics Denmark, the European Innovation Scoreboard, the Global Competitiveness Index and Copenhagen Cleantech Cluster; articles; industry- and government reports. Despite the fact that the information from the secondary data was originally collected for a different purpose than this thesis, Saunders et al (2007) argue that this data often has a high degree of quality and is valuable when carrying out research in a specific field.

Furthermore various conferences and seminars e.g. about project management in the Zira project, the

Danish and European innovation system, cleantech and innovation in the post-crisis context[3], have been attended in order to get an insight into the research object and its context.

3.2.3 Reliability

Reliability is the "…degree to which data collection method or methods will yield consistent findings, similar observations would be made or conclusions reached by other researchers or there is a transparency in how sense was made from the raw data" (Saunders et al. 2003: 488). The reliability of the research for this thesis is ensured by providing the recordings on the CD-ROM at the back of the thesis. Furthermore, direct quotes from the interviews are used in order to ensure that the interpretations of the data are correct. While the characteristics of the semi-structured interview i.e. lack of standardisation may be problematic for the reliability of the data, the findings stemming from the interviews are not necessarily meant to be reproduced as they reflect a specific time and situation when the research was undertaken. The reliability of the research is furthermore sought ensured by *data triangulation* where identical findings are expected to be the same in different contexts and several data sources therefore are used. As mentioned this is sought achieved by interviewing key persons in the Zira project from both Rambøll and BIG as well as two representatives from DASTI and CCC and additionally, these more subjective statements are combined with the statistical data and theory.

3.2.4 Validity

Validity refers to "[t]he extent to which research findings are really about what they profess to be about" (Saunders et al. 2003: 492). The semi-structured interview paves the way for a meticulous discussion of issues, which allows the issue to be covered from different angles and consequently a higher level of validity.

3.3 Implications of the research approach

The chosen research strategy of a single case study makes it challenging to generalise on the basis of the findings in this thesis (Flyvbjerg 2004). However, with the interpretivist perspective the purpose is not to draw universal generalisation and statements from the single case study of the Zira project due to the highly context-dependent character of the findings. In addition to this, Flyvbjerg (2004) states that "…one can often generalise on the basis of a single case, and the case study may be central to scientific development via generalisation as supplement or alternative to other methods"

[3] Attended seminars and conferences: *Managing Projects Across Boundaries* 2009, Dansk Projektledelse; *ABCDE* conference, the World Bank, *Europe INNOVA Annual Partnering Event 2010,* EPISIS INNO-Net and Europe INNOVA,; and *Innovation camp,* Energy Crossroads.

(Flyvbjerg 2004: 425). This is supported by Yin (1984, 1994) who argues that theory-related analytic generalisation can be made on the basis of the case study.

Case studies are also criticised for containing a subjective bias towards verification; an inclination to validate the researcher's preconceived beliefs (Flyvbjerg 2004). In response to this, Flyvbjerg argues that "…the case study contains no greater bias towards verification of the researcher's preconceived notions than other methods of inquiry" (Flyvbjerg 2004).

3.4 Conceptual an analytical framework

The innovation system approach is suitable as the framework for this thesis, rather than e.g. the traditional economic theories and TMH model because the IS framework emphasizes the institutional embeddedness and at the same time allows for analysis that focuses on what happens between all the determinants of innovation in the system; it allows for a *micro* analysis of the innovation processes in the firms and a *meso* analysis of the political environment surrounding the companies. In order to strengthen the micro-level analysis the IS framework is supplemented with network theory perspectives.

4 Danish innovation system

In this chapter the characteristics of the Danish national innovation system are outlined and examined firstly, with a focus on the historical trajectories and secondly, on the current state of the innovation system and the activities influencing innovation. The impact of globalisation on the Danish innovation system is then assessed before the innovation policies in Denmark and the European innovation system are briefly elaborated on.

4.1 The Danish National Innovation System

Denmark has a long tradition of an industrial focus on agriculture and Denmark's process of catching up with the leading industrialised economies in the late 19th to the early 20th century was highly influenced by early specialisation in agriculture and services (Christensen et al. in C. Edquist & Hommen, 2008a). Partly due to this early specialisation, Denmark developed strong low and medium tech industries especially within food. However, the previous relative high share of Danish manufacturing value-added within especially low-tech but also within low-med tech is decreasing: from 1990 to 2000 Danish *low-tech* manufacturing value-added (as a change in percentage share) has decreased from -4.7 to -6.8, while *low-med tech* has decreased only little from 0.9 in 1990 to 0.3 in 2000, *med-tech* has increased slightly from 1.1 to 1.5. At the same time *high-tech* value-added has increased from 2.7 to 5.0 (C. Edquist & Hommen, 2008a). The most important high-tech industries in Denmark are pharmaceuticals and the medical industries (Christensen et al. in C. Edquist & Hommen, 2008a).

Clusters have played a role in the more recent development of Danish industries. After Michael Porter used Denmark in his *Competitive Advantage of Nations* study in the early 1990s Denmark adopted the cluster concept and focused on clusters based on resource/competence areas such as construction, food, bio-health and IT. Today, however, the national cluster initiatives have been substituted by cluster initiatives at the regional level, i.e. Copenhagen Cleantech Cluster (Christensen et al. in C. Edquist & Hommen, 2008a). Public technology procurement (along with other demand-side measures, such as regulation) has played an important role in the cluster initiation and development (C. Edquist & Hommen, 2008a). Furthermore, the Danish clusters (e.g. wind energy, water supply and wastewater treatment, and the medical and pharmaceutical industries) can be linked to public utilities and services (Christensen et al. in C. Edquist & Hommen, 2008a). This indicates that there are correlations and spin-offs resting on public demand-side measures and the Danish welfare state model.

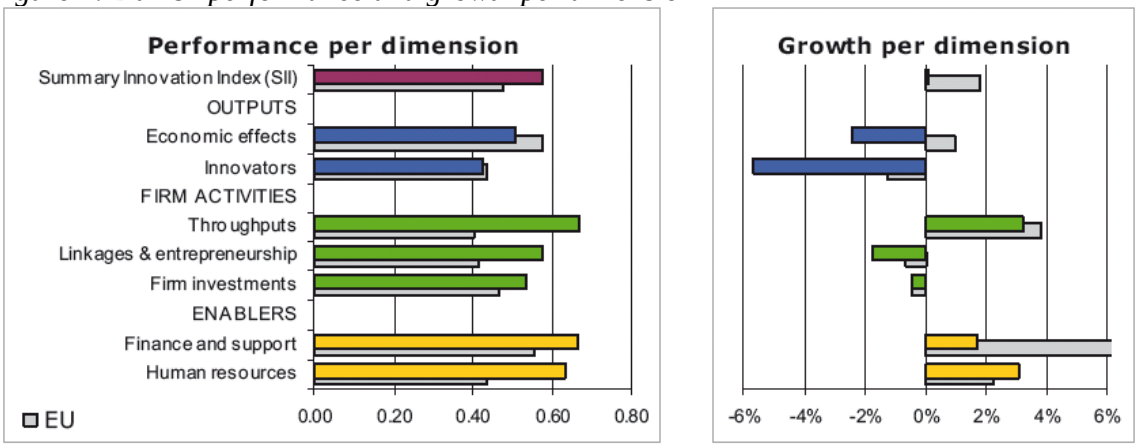
The Danish welfare state model has fostered a relative equal income distribution and social cohesion together with a labour market labelled the *flexicurity model*, which provides a sizeable degree of

flexibility for employees, businesses and industry in combination with a great sense of security for the individual citizen (Christensen et al. in C. Edquist & Hommen, 2008a). The Danish welfare model and the high degree of security is also one of the reasons for a high degree of trust in Denmark. These trust relations play an important role in both facilitating the exchange of information in the economy as well as in establishing strong personal relations and networks locally (Campbell & Pedersen, 2007; Hall & Soskice, 2001; Maskell. P.). This means that there is a large degree of informal networks and collaborations between the Danish companies and institutions.

According to the recent European Innovation Scoreboard report (European Commission, 2010b), Denmark is the economy performing worst of the 5 innovation leaders[4] and Denmark's innovation performance has worsened from 2008 to 2009 (see appendix 13.6 *Summary innovation performance EU27 Member States*).

Denmark is one of the innovation leaders among the countries in the European Innovation Scoreboard analysis and its innovation performance is above the EU27 average. However, as Figure 1 below shows, the total growth rate is close to zero and far below the EU27 average of almost 2 %.

Figure 1: Danish performance and growth per dimension



Source: European Innovation Scoreboard (EIS) 2009) (European Commission, 2010b p. 6) (a description of the indicators can be found in appendix 15.7)

As Figure 1 shows, Denmark performs well in Human resources, Finance and support, and Throughputs, relatively well in Firm investments and Linkages & Entrepreneurship and relatively poorly in Innovators and Economic effects, where Denmark is below the EU average (see appendix 13.6 *Summary innovation performance EU27 Member States* for a comparison with the other EU countries).

[4] The EU innovation leaders are: Sweden, Finland, Germany, the United Kingdom and Denmark, with an innovative performance above the EU27 average (European Commission, 2010b).

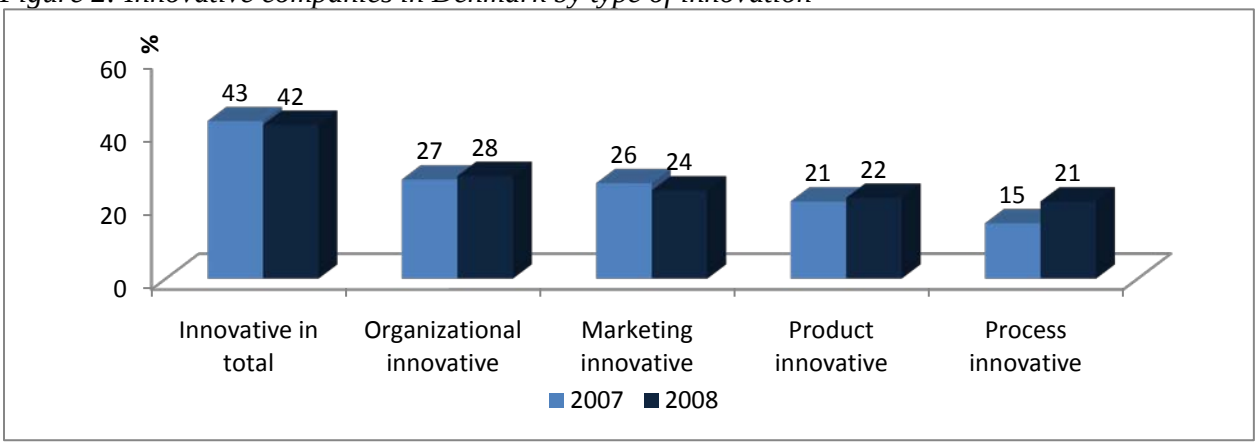
As the *Growth per dimension* graph in Figure 1 shows, Denmark is an innovation leader but is stagnating with an overall innovation dimension growth close to 0 %. Denmark only has a growth rate higher than the EU average in Human resources. While Denmark performs well in Human resources, Finance and support, and Throughputs, it is also these dimensions that have the most growth – in fact; they are the only dimensions with a positive growth. Performance in Firm investments, Linkages & entrepreneurship, Innovators and Economic effects has decreased, especially as a result of decreases in Innovative SMEs collaborating with others (-8.0%), SMEs introducing product or process innovations (-5.7%), New-to-market sales (-7.7%) and New-to-firm sales (-8.5%) (European Commission, 2010b). However, the worsening of the indicators can also be linked to the financial crisis and e.g. following lack of finances for innovation and companies' restraint as regards new initiatives, innovations and collaborations. The Global Competitiveness Index shows a similar picture: in this index, Denmark has fallen from a third place in 2008-2009 down to a ninth place in 2010-2011, which means that Danish competitiveness is worsening in the measures included in the index.

According to Christensen et al. (2008) Denmark's geographical proximity has given rise to spill-overs and spin-offs, which characterise innovation in Denmark. Innovation in Denmark is characterised by a majority of SMEs majorly undertaking incremental innovation interconnected with *learning by using* and *learning by interacting* (Christensen et al. in C. Edquist & Hommen, 2008a) and consequently a large degree of open/user-driven innovation. The Danish flexicurity model has for many years been supporting and fertilising this interactive learning and innovation in Denmark.

Community Innovation Survey 2 and 3 (CIS2 and CIS3) point to that Danish firms are reasonably innovative but that there is a variance between sectors: the highly innovative sectors are manufacturing and knowledge-intensive business services, while the Danish finance and trade sectors are much less innovative and lag far behind other small open economies (like Sweden, Finland and the Netherlands) (Christensen et al. in C. Edquist & Hommen, 2008a). According to Christensen et al. large firms in Denmark are more frequently innovative than the small firms and a recent study from the Danish Agency for Science, Technology and Innovation shows that 22% of the SMEs undertake R&D in 2008, while the corresponding figure for large companies is 46 %. Furthermore, the study shows that in 2008, 42 % of the Danish SMEs were innovative while this percentage is much higher for the large companies (71 %). However, when calculated as the number of product innovations per employee, the small firms are actually more innovative than the large (Christensen et al. 2004 in C. Edquist & Hommen, 2008a).

Figure 2 below shows that from 2007 to 2008 more than one in five (22 %) have introduced new products or services but the figure also shows that Danish product innovation has stagnated with only 1 % increase in the same period.

Figure 2: Innovative companies in Denmark by type of innovation

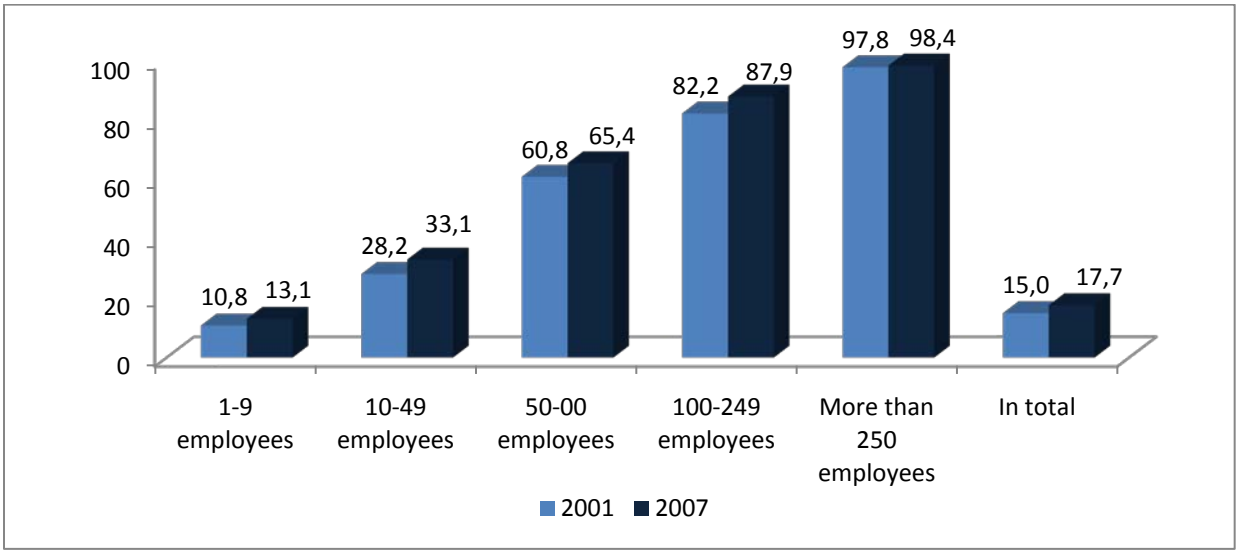


Source: based on data from Statistics Denmark (Forsknings- og Innovationsstyrelsen, July 2010).

As regards process innovation, Figure 2 shows that 21 % of the companies have undertaken new processes, which is an increase of 6 % compared to the previous period. 28 % have organised the organisational procedures in new ways (an increase of 1%) and more companies have thus been organisational innovative than they have been innovative in other ways. The process innovation and organisational innovation of the Danish companies is crucial for the companies' competitive advantage and that they undertake these kinds of innovation means that they keep adapting to their contexts and competitors' levels (Christensen et al. in C. Edquist & Hommen, 2008a).

As shown in Figure 1, Denmark is well above the EU average in human resources. This can be explained by a large degree of highly educated employees and secure labour market. But as Figure 3 below shows it is mainly in the large companies with 100 or more employees that the higher educated are employees. The figure furthermore shows a small increase in the number of highly educated employees in the Danish companies from 2001 to 2007.

Figure 3: Higher educated (tertiary education) employees in the companies
Share of companies with highly educated employees in percent



Source: Statistics Denmark

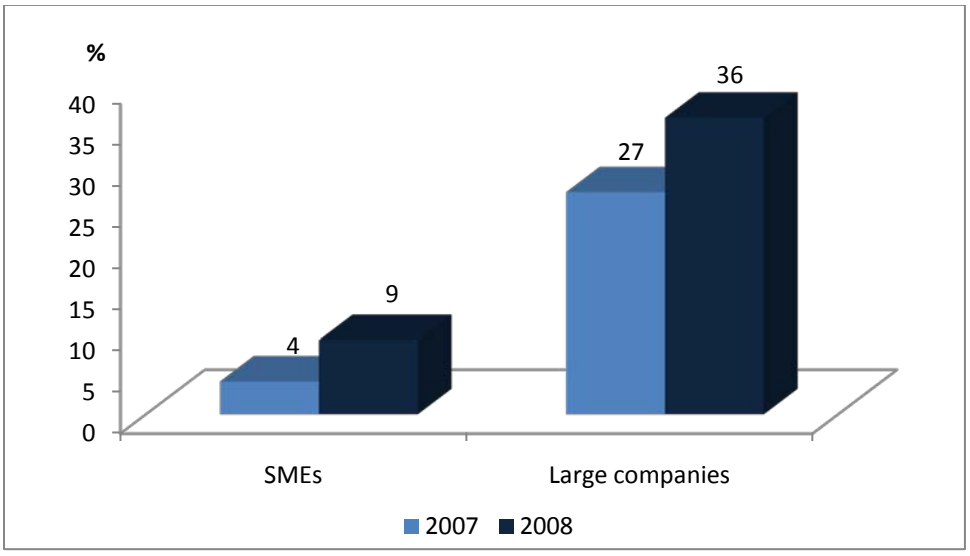
In 2008, half the Danish companies participating in a government analysis, perceived the lack of qualified labour as a barrier for private research and development. In 2009 this figure was 18 % and in 2010 only 10 % (Forsknings- og Innovationsstyrelsen, July 2010). A decrease in this figure supports the strong position of Danish Human Resources in the European Innovation Scoreboard analysis in Figure 1.

According to the Danish Agency for Science, Technology and Innovation (DASTI), cooperation between companies and knowledge institutes increases productivity. R&D-active companies cooperating with knowledge institutes have productivity per employee, which is 15 % higher than R&D-active companies *without* this cooperation. An analysis by Centre for Economic and Business Research at Copenhagen Business School (published May 2010) documents that companies which cooperate with universities, GTS-institutes and other knowledge institutes on R&D in an innovation consortium[5] experience a significant higher value increment than the companies, which do not have the cooperation and the difference is approximately DKK 20 million (Forsknings- og Innovationsstyrelsen, July 2010).

Figure 4 shows that there is a large difference between SMEs and large companies as regards cooperation on both R&D and innovation with knowledge institutes. 9 % of the SMEs cooperated with a knowledge institution on innovation in 2008, while the number was 36 % for the large companies. In total the cooperation between corporations and knowledge institutes is increasing.

[5] See appendix 13.13 for a description of DASTI's Innovation Consortia Scheme

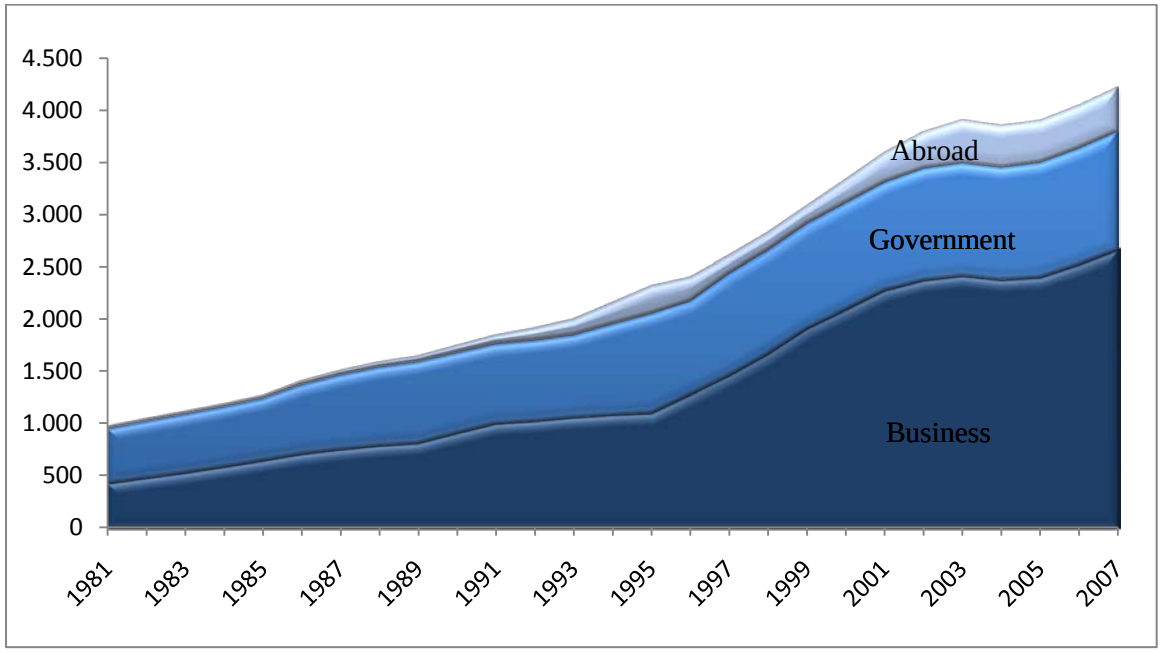
Figure 4: Cooperation between companies and knowledge institutes



Source: based on data from Statistics Denmark (Forsknings- og Innovationsstyrelsen, July 2010).

The financing of innovation and innovation processes is a key activity in a system of innovation (Edquist & Hommen, 2008). Funding facilitates the commercialisation of knowledge and its absorption in the innovation system. As seen in Figure 5 the industry has been the largest source of financing in Denmark for almost two decades. According to OECD data, the proportion of the Danish public funding of R&D is lagging far behind our the neighbouring countries (out of Germany, Sweden, Denmark, England, Norway, Estonia and Italy, only Sweden has a lower public R&D share than Denmark). However, as new figures from Statistics Denmark show, government research and development spending increased with almost 30 % from 2007 to 2008 and for the first time, Denmark thus spent 3% of GDP on R&D (Ministry of Science and Technology, 2010).

Figure 5: Gross Domestic Expenditure on Research and Development (GERD)
Million 2000 dollars, constant prices and PPP



Source: OECD Statistics Directorate, 2010

The business world's R&D percentage of GDP is expected to increase almost 2.2 % in 2010. In 2009 the companies did not reduce their research expenditures as expected but increased it (an increase between 4.5 - 6.5 %). At the same time, GDP dropped 5%, which overall will increase the percentage of GDP used on private research investments (Forsknings- og Innovationsstyrelsen, July 2010).

As regards the intramural R&D in Denmark (all the expenditures for R&D performed in Denmark) (see appendix 13.8 *Intramural R&D in Denmark*), which totalled DKK 43 bn. in 2007, business enterprise constitutes 61% (26.2 bn.), while public funding constitutes only 26% (11.2 bn.) and funds from abroad only 9.7% (4.7 bn.). This shows that domestic business enterprises source most of the R&D performed in Denmark.

Of intramural R&D financed abroad (R&D in Denmark financed by institutions abroad) (see appendix 13.9 *Intramural R&D financed abroad by number of persons engaged in Danish industry*) it is mainly the large companies with 500 or more employees, which have R&D financed by institutions abroad. This indicates that the large companies are more internationally linked than the smaller companies.

The extramural R&D in Denmark (all R&D expenditures spent outside Denmark by domestic institutions) (see appendix 13.10 *Extramural R&D in Denmark by industry and firm size*) amounted to DKK 7.9 bn. in 2006. The manufacturing industry buys most R&D abroad and within manufacturing it is mostly the high-tech companies. The R&D performance abroad is mostly from

other enterprises rather than from the companies' own enterprise group or from public institutions. This indicates that the Danish companies which finance R&D abroad, mostly interact with other companies outside their own international concern. It is mostly the large firms with 1,000 or more employees that have a large degree of domestically financed R&D abroad. The small companies with 1-29 employees however also finance a relative degree of R&D abroad. It is thus mainly the largest and a few of the smallest companies, which are involved in R&D abroad. This could indicate that it is the large companies that can afford this, while the small companies engage in R&D activities related to start-ups.

According to numbers from DASTI, Danish companies' investments in R&D abroad have averagely increased 22% yearly in the period 2002-2008. During the same period, both Danish and foreign investments in R&D in Denmark have on average increased 7.1 % every year. Danish companies' investments in R&D abroad thus has a yearly growth rate three times as large as the investments in R&D in Denmark and the tendency is thus that the Danish companies' purchases of R&D abroad have increased more than the overall investments in R&D in Denmark[6] (Forsknings- og Innovationsstyrelsen, 2010d).

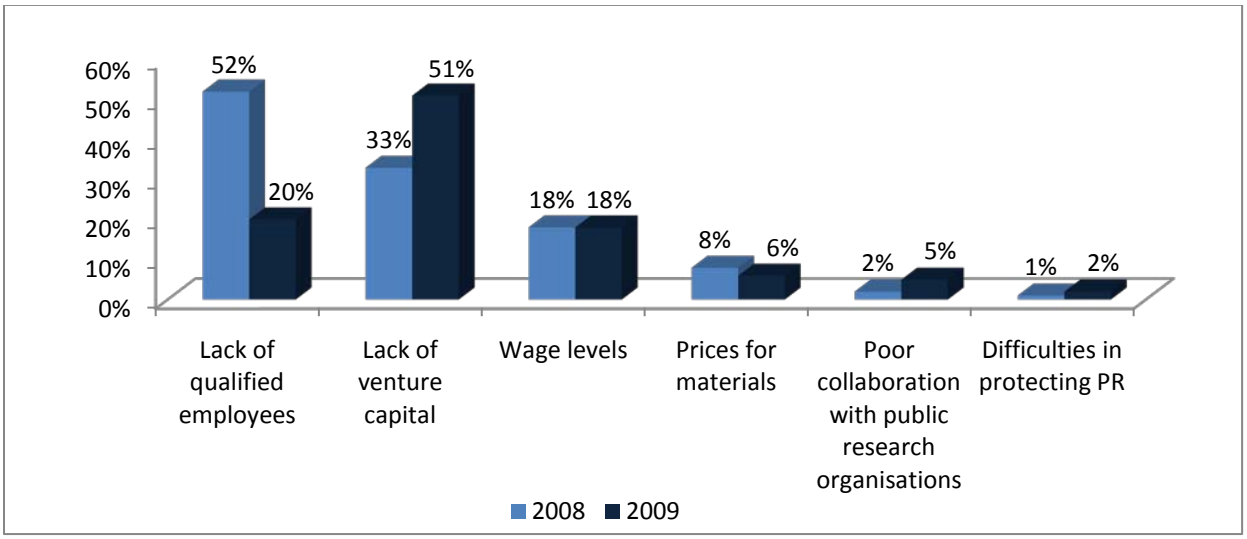
Danish companies investments in R&D abroad supports Katzenstein's (1985, 2006) small open economy argument that small open economies interact with companies abroad, which indicates involvement of Danish companies in networks abroad.

A lack of capital is however an issue for Danish companies. The percentage of companies which identified the lack of venture capital as the main barrier to R&D&I[7] increased 5 percentage points from 2009 to 2010 (from 29 % to 34 %) (Forsknings- og Innovationsstyrelsen, July 2010). As Figure 6 shows, *Lack of qualified employees* was the most significant barrier to R&D and innovation before the financial crisis, while the second most significant barrier was *Lack of venture capital*. However, during the financial crisis in the spring 2009 this picture has turned upside down so that *Lack of venture capital* was indicated as the most significant barrier.

[6] In 2008 Danish companies' purchases of R&D abroad constituted 0.44 % of GDP in Denmark. This means that 22 % of the companies' overall R&D investments are undertaken abroad. This equals DKK 7.7 bn. (Forsknings- og Innovationsstyrelsen, 2010d).

[7] Research & Development & Innovation

Figure 6: Barriers to R&D and innovation - before and during the financial crisis



Note: Enterprises were permitted to indicate up to two barriers

Source: (Danish Technological Institute, 2009 in Christensen, May 2010)

The Danish industrial sector is characterised by a large degree of exports and internationalisations. This export specialisation has traditionally been in low-and med tech industries but this picture is increasingly changing. In Edquist (2008) it can be seen that from 1990 to 2000 Danish low-tech manufacturing exports have decreased from -4.3 to -6.1 (change in percentage share), while low-med tech has increased a little from -2.0 in 1990 to -1.3 in 2000, med-tech has decreased from 1.7 to -0.1 but high tech has increased from 4.6 to 7.5 (C. Edquist & Hommen, 2008a). It is thus both in manufacturing value-added as shown above and in exports that high-tech outpaces low-tech and med-tech in growth rates.

For decades, Danish production has been under pressure from countries competing on low wages and higher production levels. As a consequence, the Danish companies have moved all or part of their production abroad (mainly to Eastern Europe and Asia), while they have kept their R&D activities in Denmark (Forsknings- og Innovationsstyrelsen, July 2010). As it can be seen in appendix 13.10 on *extramural R&D in Denmark*, this picture is, however, changing and companies are increasingly moving the research activities abroad as well. The most dominant impacts of globalisation in relation to innovation activities will be outlined briefly below.

4.2 Globalisation and the changing context

As mentioned, globalisation brings changes and challenges for innovation systems in both industrialised and developing countries. Generally, there are three forms of globalisation of innovation (Archibugi and Mitchie, 1995 in Borras, Edquist, & Chaminade, 2008, Gries & Naud, May 2010): “the international exploitation of nationally produced innovation; the global and techno-

scientific strategic alliances and collaborations between firms; and the global generation of innovations (global distribution of innovation activities)" (Archibugi and Mitchie, 1995 in Borrás et al., 2008). According to several scholars (Altenburg et al. 2006, Chaminade and Vang 2006, Parthasarathy and Aoyama, 2006 in Borrás et al., 2008), the new entrants engaging in innovation are beginning to go from competing on costs and low cost labour to competing in knowledge (Borrás et al., 2008). This is supported by the picture we see in Denmark with the companies' increasing generation of the knowledge intensive R&D activities abroad. This means that the Danish innovation is therefore not nationally produced and internationally exploited, as it was the case previously, but rather globally generated. As a result, the boundaries between local, national, regional and global innovation are shifting and partly erased (Borrás et al., 2008) and as Borrás (2008) argues, this new global context creates big challenges for policy makers as regards the nature and types of strategic choices. The increased globalisation thus also has consequences for policy. The innovation policy choices made, and the rationales behind them, thus become even more important when the innovation activities are global. However, it also creates possibilities. The increasing internationalisation of innovation activities enables other countries to reap the benefits and externalities that one country's firms produce. New possibilities for knowledge spill-over and identification of existing knowledge is accordingly facilitated, which in turn facilitates the combinations of existing knowledge and incremental innovation which are Denmark's characteristics. The intramural R&D in Denmark financed abroad and the extramural R&D in Denmark indicate that Danish companies are increasingly taking advantage of the possibilities that globalisation has opened up for. The openness of the Danish economy, which was established above, however also makes it particularly vulnerable to the global changes (Borrás, 2008).

4.3 Innovation policies in Denmark

In the late 1980s, strategies for improving Denmark's competitive position in the global economy became the motto of Danish industrial policy and innovation has been central of these strategies since (Borrás, 2008). The Danish Council for Technology and Innovation (DCTI) (whose main task is to promote growth and innovation in Danish industry) under the Danish Agency for Science, Technology and Innovation (DASTI) is in charge of "initiatives for promoting innovation and dissemination of knowledge between knowledge institutions and enterprises" (The Danish Agency for Science, Technology and Innovation, 2010) (see appendix 13.11 for DCTI's vision and mission as stated in the 2010-2013 Action plan).

In 2007 the focus on innovation in Denmark – rather than only science and technology – was intensified and became more visible with DASTI's *2007-2010 Innovation Action Plan*. The efforts of the action plan have recently been evaluated and in July 2010 the *2010-2013 Action Plan* was

published. The action plan sets out to contribute to an increase in the companies' cooperation with universities, and the Approved Technological Service Institutes (GTS institutes) further spur private research, development and innovation. The national parliament of Denmark and the Danish Government have set aside more than DKK 3.5 billion for the initiatives in period 2010-2013 and the action plan present more than 50 specific initiatives that are implemented towards 2013 (appendix 13.12 shows DCTI's focus areas and measures as stated in the 2010-2013 Action plan).

In 2007 the Danish Government presented a strategy and objectives for preparing Denmark for the future. This globalisation strategy aims at accomplishing *world top level education; strong and innovative research; more high-growth start-ups; and renewal and innovation* in order to attain *strong competitive power* and *strong cohesion* (The Danish Government, 2006)(The Danish Government, 2006). The implementation of this strategy indicates that the Danish Government acknowledges the aggravating situation described above in the indexes on Denmark's innovation performance and competitiveness. In response to the global context's rapid development the Denmark has furthermore taken a broader perspective on innovation policy and following implemented new and experimental instruments (Borrás, 2008). One of these new initiatives is DASTI's *Innovation Consortia Scheme* (see appendix 13.13 for a description of the scheme), which was created to improve the interaction between companies and knowledge organisations and has been very successful in achieving this. One of the focal points of DASTI's work is the *collaboration between research institutes and the companies*, which is the first focus area (see appendix 13.12). Secondly, the focus is on creating *access to the high skilled workforce*; thirdly, *technological services;* and fourthly, on the *commercialisation of research.* The action plan thus undertakes to cover the whole 'innovation supply chain' from initiation facilitated by provision of technological services, high skilled employees and network programmes promoting collaboration, to the commercialisation of the research. This also proves that Danish innovation policies acknowledge that Danish innovation is interactive and caused by a variety of factors and interactions between various actors; contrary to the linear model of innovation, where science is the basis for innovation and an increase in the scientific inputs will cause the number of innovations as well as technologies to increase.

DASTI is promoting the interactive innovation by focusing on creating collaboration between the knowledge institutes and companies: "The focus is on creating synergy between research institutions and companies - it is the main core of innovation promotion system" (Christensen, Personal communication, August 8, 2010) Thomas Alslev Christensen, Head of Department at DASTI states. Furthermore, Thomas Alslev Christensen states that the collaboration initiatives are "an attempt to leverage research and combining methods" (Christensen, Personal communication, August 8, 2010), which in turn are initiatives for investing in the Danish knowledge society by facilitating the creation

of knowledge and diffusion of the existing knowledge. “Companies may well benefit from the same knowledge - they do not need to compete but can collaborate on using this knowledge” (Christensen, Personal communication, August 8, 2010).

In the action plan, there also is a strong general focus on supporting and strengthening the SMEs and getting them to collaborate on using and producing knowledge. This indicates a Danish innovation political acknowledgement of the large impact such a focus can have when the majority of Danish enterprises are SMEs.

In the 2010-2013 Action plan the focus has slightly been changed. According to the Head of the Department in DASTI, Thomas Alslev Christensen, the main change is that the international focus has been strengthened and DASTI e.g. pays companies from abroad for participating in innovation projects with Danish companies and research institutes. The international focus increases the Danish companies’ possibilities of ’tapping’ into the knowledge resources abroad. As mentioned above, new possibilities for knowledge spill-over and identification of existing knowledge is facilitated with the increasing globalisation and internationalisation, which in turn facilitates the combinations of existing knowledge and incremental innovation which are Denmark’s characteristics. In relation to this, Thomas Alslev Christensen states that “research is global” (Christensen, Personal communication, August 8, 2010). It is thus an important step DASTI has taken when increasing the focus on the Danish companies’ and research institutes international cooperation.

4.4 Innovation policies in the EU

In addition to the national Danish initiatives and policies, EU policies and goals are also influencing the Danish innovation system. Along with the member countries’ implementation of a wider perspective on innovation policy, the EU has launched several major initiatives in this direction. For example, the ERA (European Research Area) and the Lisbon Strategy were launched in 2000 with the aims of facilitating the flow of research and innovation across national borders (European Commission, June 2010) and to coordinate national economic policies (European Commission, March 2010). Overall, the purpose of these actions is to make Europe the most innovative and competitive region in the world by means of social cohesion and coherence. The EU can be defined as a *supra-national* innovation system that influences the national innovation systems (across national boundaries) but which also is influenced by the member states: “The Seventh Framework Programme is also part of the Danish innovation system, because we are helping to support it… We help fund some programs, which Danish companies can apply for” (Windmüller, Personal communication, August 8, 2010). In order to provide active support and facilitate the support that Danish researchers and companies can get form the EU, DASTI has implemented schemes which advice the interested parties on how to apply (e.g. Eurocenter).

The EU initiatives and programmes which, among others, are directed at cleantech companies are elaborated on later in chapter 8.

4.5 Conclusion

Innovation in Denmark has been characterised by small and medium sized enterprises, incremental innovation and interactive learning based on the 'flexicurity model'. The sectors with the largest number of innovative firms are manufacturing and knowledge-intensive business services. Low and med-tech manufacturing are dominant but while the manufacturing value-added of low-med tech and med-tech respectively have decreased and increased only slightly, the value-added for high-tech almost doubled from 1990 to 2000. Clusters have also played a role in the more recent development of Danish industries and public technology procurement (along with other demand-side measures, such as regulation) has been important drivers for these. The clusters of competence can furthermore be linked to public utilities and services, which indicates that there are correlations and spin-offs resting on public demand-side measures and the Danish welfare state model. The Danish welfare model and the high degree of security is also one of the reasons for a high degree of trust in Denmark. These trust relations play an important role in both facilitating the exchange of information in the economy as well as in establishing strong personal relations and networks locally. Denmark's geographical proximity has in addition given rise to spill-overs and spin-offs, which characterise innovation in Denmark.

Danish companies' export and internationalisation oriented focus supports the *small open economy* argument of a large degree of international interaction of these economies. However, the openness and the small size of Denmark make the country vulnerable to changes in international markets. Globalisation has changed the innovation processes and Danish companies have started to move their knowledge intensive R&D activities abroad in addition to their production and this new global context creates big challenges for policy makers as regards the nature and types of strategic choices.

DCTI and DASTI play important roles in promoting innovation and disseminating knowledge between knowledge institutions and enterprises in Denmark. In the new 2010-2010 action plan, there is a strong focus on collaboration, knowledge diffusion implementing an international aspect. In addition to the national Danish initiatives and policies, EU policies and objectives are influencing the Danish innovation system – and the Danish innovation system is influencing the European. The EU has launched several major initiatives in this direction. For example, the European Research Area and the Lisbon Strategy.

On the basis of the presented description of the Danish national innovation system, the next chapter outlines the Danish cleantech industry.

5 Industry description

According to chief economist in UNU-WIDER, Tony Addison, our present growth model is untenable. In the new *post-crisis* world the challenges we are facing are without precedent (Addison, June 2010) and besides the financial crisis, the climate crisis is one of the critical areas. There is an increasing consciousness about and will to 'fight' the climate changes and climate and energy issues have become increasingly more important on both the European and Danish policy agendas.[8] More efficient and cleaner technologies (cleantech) are the key to efficient energy use – a prerequisite for a sustainable energy policy. Improving e.g. the energy efficiency of buildings will reduce the global energy consumption significantly, consequently also reducing CO2 emissions (Energy Map, 2010a; Energy Map, 2010b), and is thus a means to achieve the policy objectives of the Danish government as well as the EU. Cleantech is generally presented as one of the largest and most promising growth areas both in Denmark and abroad is cleantech (Brøndum & Fliess et al., Oktober 2009)(Brøndum & Fliess et al., Oktober 2009)

. But what has driven this growth of the cleantech industry? Whether this central role of cleantech has been caused by the political focus on climate and energy issues or whether it is caused by completely different factors, will be examined in this section. After having provided an overview of the Danish national innovation system above, this chapter surveys the Danish cleantech industry, its sector affiliations, export orientation, growth and growth obstacles, collaboration and funding. Furthermore, the chapter assesses whether Danish cleantech is driven by policy and lastly a description of the Danish cleantech cluster organisation, Copenhagen Cleantech Cluster (CCC), is provided.

According to a report on the Danish cleantech industry, the cleantech industry exists because of a political interest, consumer interest and the increasing interest from and requirements to the business world in sustainability (Brøndum & Fliess et al., Oktober 2009). Along with increases and fluctuations in the oil prices, the climate crisis has been one of the most important reasons for the increasing focus on a sustainable development and accordingly cleantech. This is the main reason why cleantech is called 'the industry of the future'.

[8] Examples of the presence of energy and climate issues on the policy agenda are the Danish government's action plan for promoting eco-efficient technology, *Danish solutions to global environmental challenges* (July 2007) and e.g. the strategy paper *Energy Policy for Europe* which was adopted by the European Council in 2007.

Table 3: Cleantech definitions

- Cleantech: Includes products, services or processes across existing industries that create value using limited or no non-renewable resources and which generates significantly less waste than conventional offerings. Cleantech comprises new technologies and related business models that provides long-term solutions to the ecological and global challenges (Brøndum & Fliess et al., Oktober 2009; Copenhagen Cleantech Cluster, 2010b; The Cleantech Group LLC, 2010) (see appendix 13.14 for outline of cleantech segments).
- Cleantech company: A cleantech company either "produces and/or uses renewable energy and/or materials, reduces the use of natural resources by exploiting resources and/or energy more efficient, reduces harm caused by fossil fuels [or] reduces pollution problems through products, processes and/or consultancy. Cleantech companies offer better solutions than existing traditional technologies and reduce adverse effects on the environment" (Brøndum & Fliess et al., Oktober 2009).

The Danish cleantech field is characterised by small companies; approximately 75 % of all Danish cleantech companies have 50 employees or less. But besides this undergrowth of SMEs, there are also a number of large companies with more than 500 employees in Denmark.

5.1 Sector affiliation

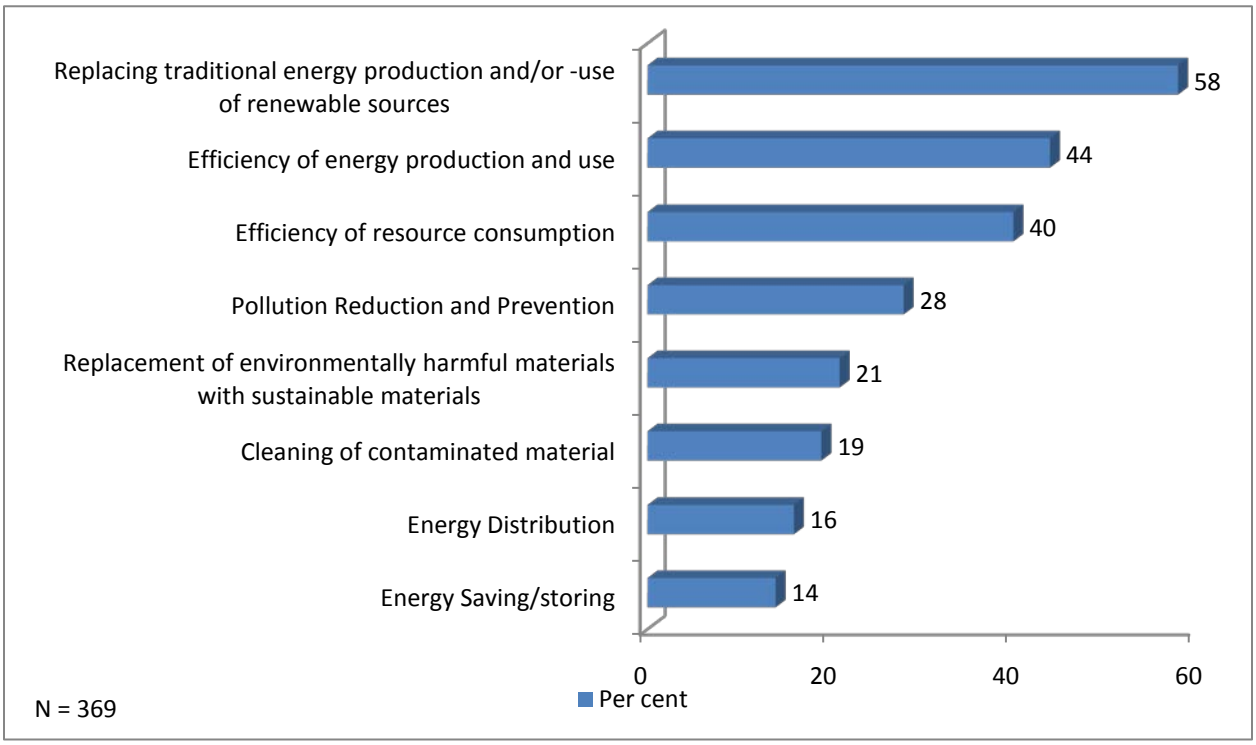
The cleantech industry in Denmark is constituted by approximately 820 cleantech companies (Brøndum & Fliess et al., Oktober 2009) but because the industry moves across traditional industry divisions (see appendix 13.14 for outline of cleantech segments) it is a comprehensive task to estimate the composition and size of the industry. This is also why Nicolai Sederberg Rottbøll, Head of Secretariat at CCC, defines cleantech as a mindset rather than an industry: “Cleantech lies in many different companies. If you look at industry statistics you are taken for a ride, because you can not go out and find that "this is cleantech"” (Sederberg Rottbøll, Personal communication, 28 August 2010). The cleantech companies are mainly found within *Industry* and *Energy* but also the industries *Construction* and *Service* are significant. Within service it is mainly consultancy firms and especially consultative engineers.

The cleantech companies in Denmark are represented within all the cleantech areas (Figure 7) but the energy-related cleantech activities (mainly *Replacing traditional energy production and/or - use of renewable sources*) constitutes the majority. The Danish cleantech field is thus deeply rooted in the

energy related area but at the same time with a broad array of companies in the remaining cleantech areas.

Figure 7: Cleantech companies by main cleantech area

(With the possibility of multiple areas per company)



Source: (Brøndum & Fliess et al., Oktober 2009)

Figure 7 shows that Danish cleantech is a mixed bunch with activities in a wide range of areas. The cleantech areas are also constituted by a wide range of different activities and companies. The largest field of activity, *Replacing traditional energy production and/or -use of renewable sources*, is e.g. encompassing bioethanol, wind power, solar power etc. Among the growth companies[9] 54 % have their main operations within this field and among the Rising Stars[10] it is 43 %. As regards the Danish heavyweights,[11] 32 % have this field as their main cleantech activity. That there is a majority of growth companies in this field indicates that it is the most dominant growth area. For all three categories of companies, *Efficiency of energy production and use* is also a significant field of activity. However, only 14 % of the growth companies and 14 % of the Rising Stars have their main

[9] A *growth company* is defined as having more than 10 employees and more than 50 % growth the last three years. 28 growth companies are identified in the Danish cleantech industry (Brøndum & Fliess et al., Oktober 2009).
[10] A *Rising Star* is defined as having *less* than 10 employees and more than 50 % growth the last three years. 44 companies identified (Brøndum & Fliess et al., Oktober 2009).
[11] A *Danish heavyweight* is defined as a Danish company having more than 500 employees in Denmark

activities in this field, while as many as 32 % of the Danish heavyweights primarily operate in it. This refers to the more mature and established character of this field.

5.2 Export orientation and growth

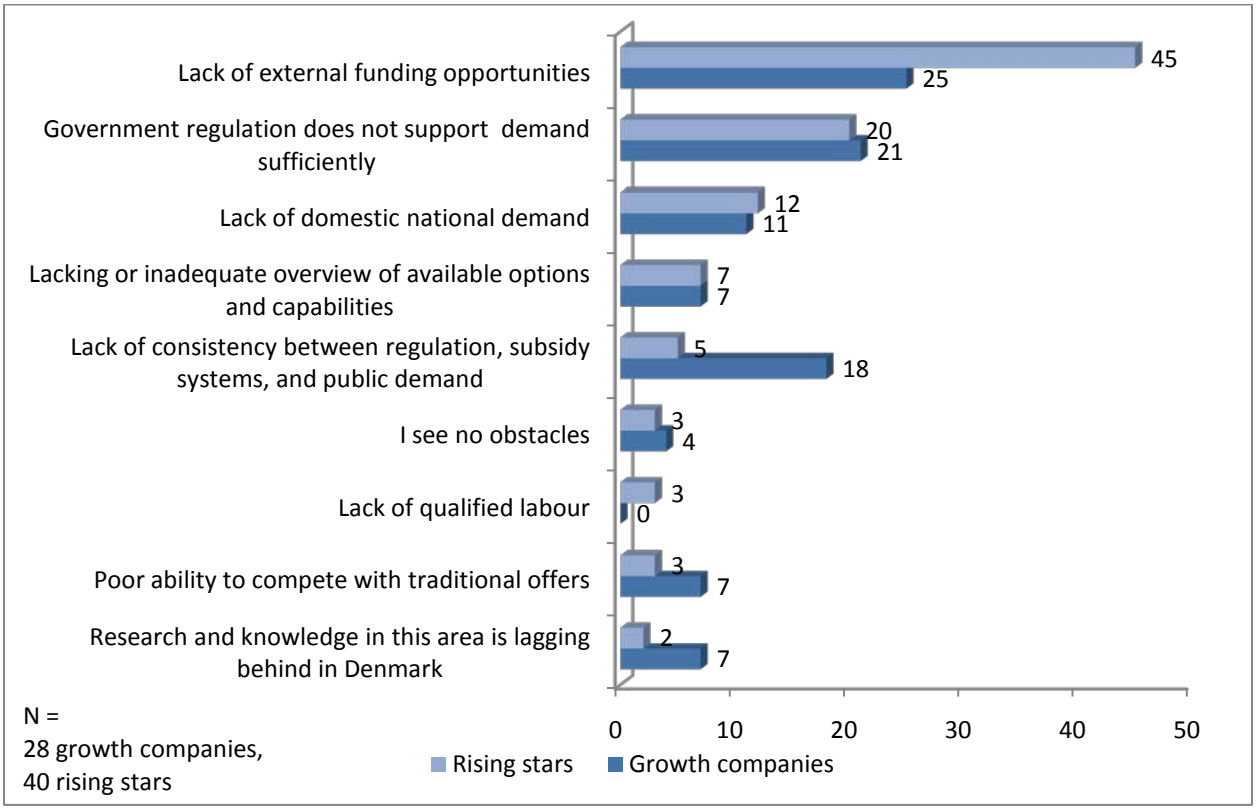
The Danish cleantech companies are export-oriented[12] and measured in GDP Denmark is one of the world's largest exporters of cleantech (Brøndum & Fliess et al., Oktober 2009). The weighted average of the mean value of each cleantech category shows that an average Danish cleantech company has an export share of 33.5 % (an average Danish company has an export share of approximately 10 %[13]). Exports of energy and environmental technologies constitute an export of DKK 64 bn., which is 11% of total exports. The neighbouring countries and the rest of Europe are the most significant export markets (Ministry of Foreign Affairs of Denmark, 2010a). This large export share can to some degree be explained by the small size of the Danish domestic market and the limited commercial outlet for cleantech solutions in Denmark. This indicates that the Danish cleantech products and solutions generally are in demand abroad, that Denmark has a global position of strength pro tem and that Danish cleantech companies are highly involved abroad. The growth companies in the industry export more than the rest of the companies.

The large majority of the Danish cleantech companies have no or few employees abroad. But if they do, they generally have more than 1.000 employees abroad (Brøndum & Fliess et al., Oktober 2009). This indicates that it is mainly the large cleantech companies that have a presence abroad. The Danish cleantech industry's international openness furthermore supports the small open economy argument and the view that Denmark is largely dependent on and embedded in foreign markets.

In a progressing growth area such as Danish cleantech, it is interesting to look at the characteristics for the growth companies in particular – even though they do not necessarily experience high growth tomorrow just because they have done so today. More than 85 % of the cleantech companies have achieved more than 10 % growth the last three years, 40 % have had a growth rate of more than 25 % while nearly 20 % have had more than 100 % growth the last three years. Only 10 % of the Danish cleantech companies do not experience growth (Brøndum & Fliess et al., Oktober 2009). Danish cleantech is thus a growth area. However, the cleantech industry also experiences obstacles to further growth and 25 % of the cleantech growth companies in the Danish report view the *Lack of external funding opportunities* (Figure 8*)* as the main obstacle to further growth. The additional challenges are public authorities in the form of *public regulation* and a *lack of coherence between regulation, subsidy systems, and public demand*.

[12] 4 out of 10 cleantech companies have an export of more than 25 %. More than 20 % of the companies have an export of more than 75 % (Brøndum & Fliess et al., Oktober 2009).
[13] Based on data from Statistics Denmark in (Brøndum & Fliess et al., Oktober 2009)

Figure 8: Main obstacles to further growth, indicated by cleantech growth companies and rising stars[14]



Based on data from (Brøndum & Fliess et al., Oktober 2009)

For the *Rising Stars* among the Danish cleantech companies the main obstacles to further growth are *Lack of external funding opportunities* (45 %) and secondly that *Government regulation does not support demand sufficiently* (20 %). The same picture appears for the growth companies with 25 % and 21 % respectively, but these companies do also, to a large degree, experience that the *Lack of consistency between regulation, subsidy systems, and public demand* (18 %) is a significant obstacle for further growth. The latter is also identified as being the main obstacle for the Danish heavyweight companies.

Almost 9 out of 10 of the Danish cleantech companies wish to or need to enter into a development oriented cooperation partnerships. Only 15 % of the cleantech companies indicate that they do not

[14] A Rising Star is defined as having less than 10 employees and more than 50 % growth the last three years (Brøndum & Fliess et al., Oktober 2009).

cooperate with knowledge institutes. Almost half of all cleantech companies cooperate with a GTS institute[15] and more than 40 % cooperate with Risø DTU[16] (Brøndum & Fliess et al., Oktober 2009).

5.3 Financing and funding possibilities

Innovation has always been associated with a high degree of risk (Stiglitz, June 2010). Especially during and after the financial crisis this is a major problem for innovation and entrepreneurship. Lack of bank credit following the crisis caused a lower number of startup companies as well as the reduction of innovative initiatives (Gries & Naudé, May 2010). According to the Danish state investment fund, *Vækstfonden,*[17] the financial crisis has entailed more risk aversion among investors. This can damage the cleantech area as the lack of venture capital may come to threaten the development of new technologies and value added (Vækstfonden in Brøndum & Fliess et al., Oktober 2009).

Apart from the private business sector funding and the Danish public sector funding the European Union is also funding opportunities for Danish cleantech companies.

There are numerous funding possibilities for cleantech R&D through EU initiatives (See appendix 13.15 *Cleantech R&D funding possibilities through the EU*). One of the most prevailing initiatives is the European Council's Competitiveness & Innovation Programme (CIP), which in particular aims at aiding European competitiveness and innovation, and ensuring sustainable, balanced economic growth. According to the EU, the program will also encourage increased use of renewable energy and energy efficiency. CIP has a total budget for 2007 - 2013 of over € 3.6 bn., of which 60% will go to the Entrepreneurship and Innovation Programme (EIP) and 20% to the program for Intelligent Energy in Europe (IEE). Two of the Entrepreneurship and Innovation Programme's aims, which should be highlighted in the context of this thesis, are: support for improving innovation policy and eco-innovation (European Commission, 2010a). These aims are planned to be achieved through support of transnational networks of various actors and through fostering innovative firms, benchmarking and sharing best practices. The EIP programme illustrates a focus on establishing international collaboration between companies in the member states. The Intelligent Energy Programme (IEE) supports specific projects, initiatives and best practices. Specifically, they support training in new energy-saving building techniques, focuses on improving the efficiency of support

[15] There are currently nine Approved Technological Service Institutes (GTS). The GTS institutes are public utility organizations run by private companies and organizations that collect, build and develop technological skills and disseminate this knowledge to the Danish industry. They are also bridges to knowledge institutes at home and abroad (Forsknings- og Innovationsstyrelsen, 2010c).

[16] The Danish National Laboratory for Sustainable Energy at the Technical University of Denmark – (DTU)

[17] Danish state investment fund which aims to create new growth companies by providing venture capital and competence.

devices for electricity generation from renewable energy and helps cities in Europe to develop more energy efficient and cleaner transport (European Commission, 2010a). The programme has € 730 million of funds available between 2007 and 2013 and it is the objective that the programme will help achieve the EU's climate change and energy targets. Ending on this note leads us on to the next section about cleantech as a policy focus.

5.4 Cleantech as policy focus

As mentioned in the introduction to this chapter, Denmark as well as the rest of the world, is facing some great growth challenges. On one hand, it is necessary to create growth when having to sustain our affluence and prosperity. On the other hand, we are facing considerable challenges concerning creating a sustainable growth, where affluence goes hand in hand with energy and eco-friendly solutions. Cleantech can play a central role in reconciling these two requirements for future growth. Cleantech products and solutions are seen as a prerequisite for creating environmental sustainability, and in many countries, cleantech can also constitute a part of the foundation for future economic growth (Brøndum & Fliess et al., Oktober 2009).

In the Danish government's 2007 action plan *Danish solutions to global environmental challenges*, the government's main objective was: "to strengthen, renew and focus efforts to develop and apply eco-efficient technologies so that Denmark and Danish enterprises can continue their central role in solving the world's most pressing environmental problems through technological innovation" (The Danish Government, July 2007). This indicates a strong political focus on and support to eco-efficient technologies as a part of the solutions to the problems Denmark faces. The manifold funding possibilities mentioned briefly in the section above indicate that energy – and thereby cleantech – is an important focus for policy. This importance of cleantech as a policy focus is also supported by Copenhagen Cleantech Cluster.

5.5 Copenhagen Cleantech Cluster

"Because of the oil crisis in the 70s it was decided that Denmark should be independent of oil. Then they began to scale up biomass and rebuild our power plants to it and it suddenly creates a market opportunity for e.g. Novo Zymes" Michael Johansen, Project Development Manager in Copenhagen Cleantech Cluster states (Johansen, Personal communication, 27 August 2010). This quote illustrates that the Danish cleantech industry was highly driven by political decisions. CCC was established by pulls from the bottom and up: in Copenhagen Capacity a cleantech section was established because there was a desire from the stakeholders' side and an identified need for it. "[...] they looked at the attractiveness and the argument in Danish cleantech. And there is plenty of [cleantech] tradition in Denmark, but the collaboration was surprisingly poor and poorly coordinated" (Sederberg Rottbøll,

Personal communication, 28 August 2010). A potential for improving the collaborations and interplay was thus identified and the official Danish cleantech cluster organisation CCC was established. The organisation aims to "develop one of the world's leading and most renowned cleantech clusters, creating superior value for the cluster companies and the research environment and to differentiate themselves by connecting cleantech technologies and players across sectors and value chains" (Copenhagen Cleantech Cluster, 2010a).

As mentioned in the framework section, the interactions between organisations in the NIS approach can take two forms. The first, the *market relations*, coordinate transactions, such as selling and buying, between the organisations. The second and most interesting one in this respect is the *non-market relations*, which are based on collaboration, knowledge elements and mediating the relations between the components. CCC is facilitating these non-market relations the cross-sectoral cooperation between the organisations in the cluster.

CCC has five focus areas within which they operate: *Facilitation* (communication and coordination), *Matchmaking* (partnerships and network), *Test and Demonstration* (Proof of Concept), *Innovation & Entrepreneurship* (support for start-ups) and *International outreach* (knowledge transfer and collaboration) (Copenhagen Cleantech Cluster, 2010a). The most interesting of CCC's objectives in relation to this thesis is that the cluster organisation aims at attracting foreign companies to the cluster, establishing collaborations with 15 international cleantech clusters and to create 30 new collaborations between companies and research institutions (e.g. start-ups or joint research applications/projects) (Copenhagen Cleantech Cluster, 2010a). This indicates a very strong focus on international outreach and matchmaking. The cluster is making the collaboration and networks between the organisations operating in the cleantech industry more tangible by organising and framing the interactions (Copenhagen Cleantech Cluster, 2010a). CCC also points out that the international perspectives for Danish cleantech are substantial: "We, in Denmark, are so small that we are deeply dependent on the international cooperation. Cleantech will not be solved by individual countries; it will be solved through cooperation" (Sederberg Rottbøll, Personal communication, 28 August 2010)(Sederberg Rottbøll, Personal communication, 28 August 2010).

5.6 Conclusion

More efficient and cleaner technologies are the key to efficient energy use – a prerequisite for a sustainable energy policy which is so debated at present. The cleantech industry exists because of this political interest, consumer interest and the increasing interest from and requirements to the business world in sustainability. Climate and energy issues have become increasingly more important on both the European and Danish policy agendas. This might be the reason why climate technology is the fastest growing export sector with a growth last year at 19% or approximately four times the

growth in the average export. The Danish cleantech companies are highly export-oriented and Denmark is the EU's largest exporter of energy technology, relatively speaking. The Danish cleantech industry is characterised by relatively few large companies and a large group of innovative cleantech SMEs.

Danish cleantech is a mixed bunch with activities in a wide range of areas and the industry moves across traditional industry divisions. The energy-related cleantech activities (mainly *replacing traditional energy production and/or - use of renewable sources,* which e.g. encompasses bioethanol, wind power, solar power) constitute the majority of Danish cleantech but there is a broad array of companies in the remaining cleantech areas. The cleantech areas themselves are also made up by a wide range of different activities and companies. Danish cleantech is a growth industry however, the cleantech industry experiences obstacles to further growth and view the *Lack of external funding opportunities* as the main obstacle. Among the Danish cleantech companies there is a very strong wish and need to enter into development oriented cooperation partnerships and almost half of all cleantech companies cooperate with Danish knowledge institutes. As regards funding, there are many funding possibilities for cleantech companies both in private business sector funding, national public sector funding and within the EU frameworks.

Copenhagen Cleantech Cluster (CCC) is playing a role as facilitator of both the market and non-market relations between the cleantech companies, funding opportunities and knowledge institutes; and facilitating cross-sectoral cooperation. The CCC is making the collaboration and networks between the organisations operating in the cleantech industry more structured by organising and framing the interactions.

In the following chapter, the sustainable construction project, Zira Island, which is a cleantech endeavour will be analysed.

6 Case study: Zira Island in Azerbaijan

Located within the bay of Azerbaijan's capital city Baku, the 1,000,000 square metre master plan of the Zira Island will include seven residential developments based on the shapes of the famous seven mountain peaks of Azerbaijan and housing for 10.000 people. Originally, the island was a rocky, deserted island off the Azerbaijani coast but in the future, it may well become a model for sustainable urban development.

Having provided a general introduction to the Danish national innovation system and the cleantech industry, this chapter addresses sub-question 1: How are the relations and interactions between the organisations in the Zira company consortium influencing the innovation processes in the project? The chapter firstly provides a descriptive overview of the case study. Secondly the chapter analyses the activities, interactions and relations between the organisations by addressing the type of management and leadership; the technologies utilised; the type of innovation; the knowledge generation and the innovation process; the employees as carriers of knowledge; the relations and interactions influencing knowledge and capabilities; the characteristics and competitive advantage of the companies; the project as a sustainability role model; the commercial outlet in Denmark; the demand-side factors and the political context.

6.1 Description of project

The project was initiated by an Azerbaijani holding company, Avrosity Holding, but it is two Danish companies, Bjarke Ingels Group (BIG) and Rambøll Denmark that have created and collaborated on the master plan for the project. The large engineering, design and consultancy company, Rambøll, with more than 8.000 employees worldwide, and the Copenhagen-based architectural firm, BIG, with 90 employees, are among the most active Danish companies within energy, environment, and climate initiatives (Energy Map & Climate Consortium Denmark, 2010). Apart from Rambøll and BIG, the company consortium behind the project consists of a third Danish company, Pihl, which will be responsible for the logistics of the construction work (and has thus not been involved in the project yet).

The whole project started when Ole Gammelgaard, a Danish salesman in the oil industry, came into contact with an apartment complex developer in Baku. At that time, almost everything in Azerbaijan was being built by Turkish and Korean firms and the Azerbaijani developer found this to be uninteresting and similar to everything else. The developer had heard that Danes are good at design and therefore asked Ole Gammelgaard if he knew someone in Denmark whom he could talk to. Ole Gammelgaard cooperated with Rambøll in the oil industry in Esbjerg and contacted Lars Ostenfeld Riemann, who had just become Service Area Director in Buildings & Design at Rambøll. Lars Ostefeld Riemann and Rambøll accepted the project, a contract was made and a program put together for the Azerbaijani developer who was invited to Denmark. The need for an architectural firm in the project was accommodated when Rambøll introduced the Azerbaijani developer to the "dynamic architectural firm" Bjarke Ingels Group (BIG Architects) as Senior Project Director at Rambøll Denmark, Geert Stryg put it; "…and then we show you something about what we do in Denmark" {{80 Stryg, Geert Personal communication, 12 May 2010}}. The BIG Project Manager and Associate Partner, Kai-Uwe Bergmann, and Lars Ostenfeld Riemann knew each other beforehand but the two companies had not previously collaborated on so extensive projects. According to Kai-Uwe Bergmann, Rambøll's project proposal to BIG was a hand being lent from a large company to a SME.

After the visit, the developer was completely taken back and amazed. He had seen BIG's project called "The Mountain" at Ørestaden, which resembles mountain peaks, and was determined to get something like that – just bigger {{80 Stryg, Geert Personal communication, 12 May 2010}}. And there the project started. Rambøll and BIG have travelled to Baku several times since and developed the initially fluffy idea of an apartment complex that was supposed to be build in the middle of Baku to suddenly being a project four times as big and on an island in the bay (Stryg, Personal communication, 12 May 2010). The vision for Zira Island is to create an island 100% independent of external energy resources (Avrositi Holding, 2010).

The project started with Rambøll, then BIG was included, and at some point the scale of the project had increased so much that Avrositi Holding could not command it[18] and Rambøll therefore suggested that Avrosity Holding should include Pihl. Rambøll has previously had good experiences with Pihl during the construction of the Opera House in Copenhagen. According to Rambøll this project was a textbook[19] example of fast, efficient construction and required tough management together with an extremely good cooperation between the companies. "And so we thought, this we

[18] Avrosity Holding normally entrusts all the planning and control of a project to a construction company and says "build it and call when you're done" (Stryg, Personal communication, 12 May 2010).
[19] "The opera is the world record in rapid construction of an opera" (Stryg, Personal communication, 12 May 2010).

can market to our customer in Azerbaijan" {{80 Stryg, Geert Personal communication, 12 May 2010}} and Pihl was following included in the project. Pihl thus became the third company in the Zira consortium because of prior good cooperation experiences with Rambøll. The three companies have worked on the project for a couple of years but the Zira project, however, also got hit by the financial crisis and during the summer of 2009, when the money had to be raised, the necessary investments could not be found. At present, the construction of the project is therefore on standby and the next step to be taken is feasibility studies {{80 Stryg, Geert Personal communication, 12 May 2010}}.

6.2 Management and leadership

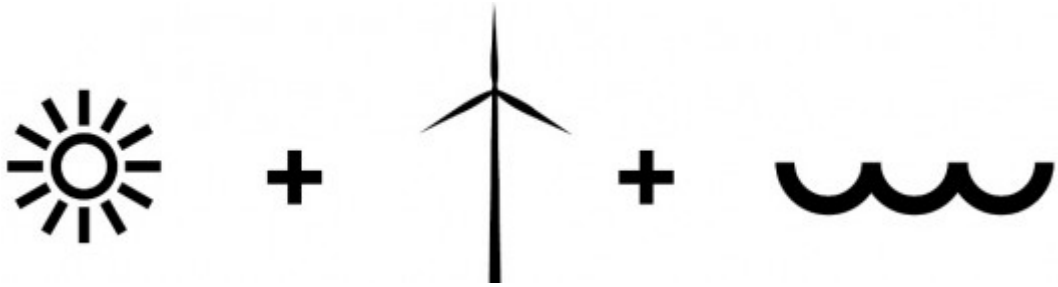
The core team of the project is constituted by 8 employees from both Rambøll, BIG and Pihl. The companies in the consortium have decided that the lead-role and management change as the project unfolds: BIG is taking control in the beginning, then it moves on to the engineers at Rambøll and then to the contractors in Pihl with the execution of the project. According to Rambøll, this means that the best equipped company heads the project in the phase concerned. Three companies' willingness to give up the lead-role and concomitant 'power' illustrates a certain degree of trust between the companies.

The holding company, Avrositi, is not involved in process of developing the project but make decisions based on the material presented to them by BIG and Rambøll {{80 Stryg, Geert Personal communication, 12 May 2010}}. During the initial phases – and after propositions from BIG and Rambøll – two requirements arose from the client's side: firstly, that the project would mirror the mountain landscape in Azerbaijan[20] and secondly, that it should be CO2 neutral (Bergmann, Personal communication, 8 July 2010) (the reason for the CO2 neutrality requirement is dealt with in more detail later in paragraph 6.11).

6.3 The technologies and their Danish trajectories

The company consortium behind the project aims at making the island completely independent of external resources (Avrositi Holding, 2010) and broadly speaking deploys three resources (sun, wind and water) to achieve its vision.

[20] Azerbaijan is known to be the Switzerland of Central Asia (Bergmann, Personal communication, 8 July 2010)



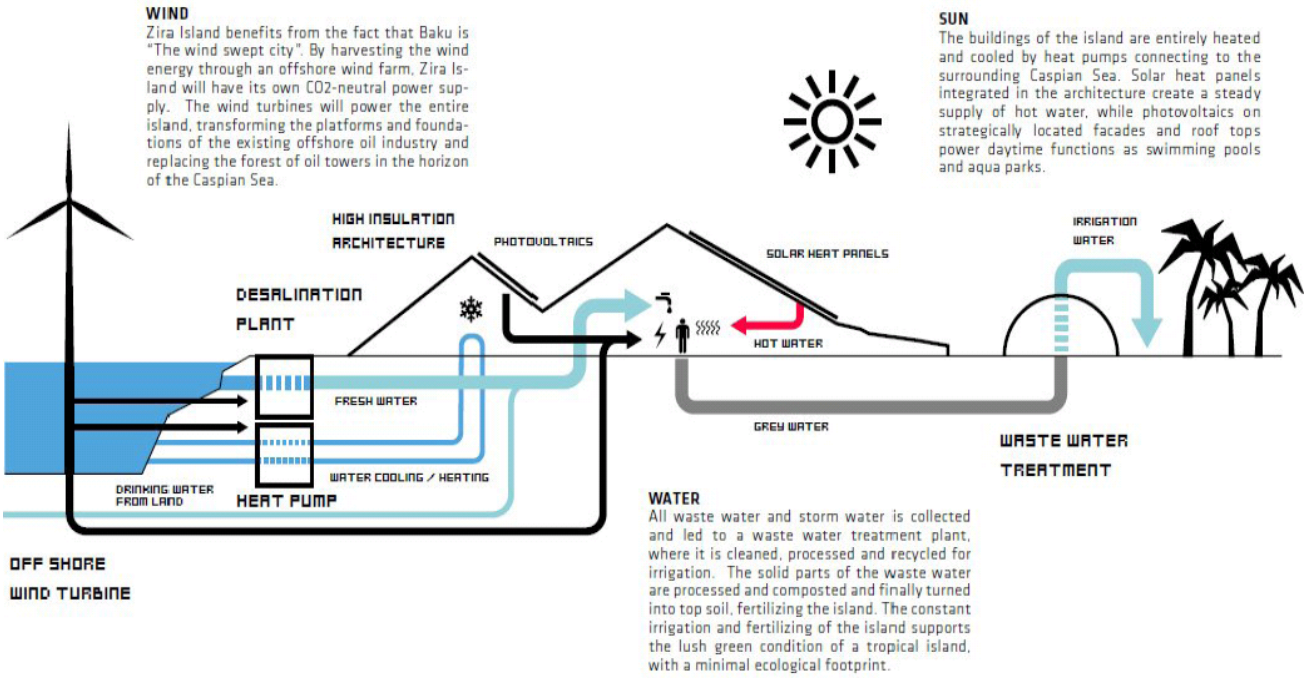
Bjarke Ingels, Founding Partner of BIG: "This new architecture not only recreates the iconic silhouettes of the seven peaks, but more importantly creates an autonomous ecosystem where the flow of air, water, heat and energy are channelled in almost natural ways" (Etherington, 2009). Using the typology used both by Copenhagen Cleantech Cluster and Brøndum & Fliess (Brøndum & Fliess et al., Oktober 2009) (in chapter 5: Industry description), the cleantech technologies in the Zira project fall into three areas. The main area for the project is *replacing traditional energy production and/or -use of renewable sources.*[21] In the Zira project this area comprises the main technologies: solar energy, photovoltaic cells, off shore wind power, and wave power. As shown in figure 7 (*Cleantech companies by main cleantech areas* in chapter 5) this cleantech technology area is the most significant in the Zira project but it is also the largest field of activity[22] for the majority of the Danish cleantech companies (58 % of the Danish cleantech companies operate in this field).

The Zira project also utilises technologies from the second largest cleantech area in Denmark, *efficiency of energy production and use*[23] (44 % of the Danish cleantech companies operate in this field). Within this area, the Zira project encompasses intelligent and zero energy construction and low energy in building (Brøndum & Fliess et al., Oktober 2009).

Thirdly, the planned use of wastewater and rainwater collection and treatment technologies represents yet another cleantech technology type in the project: *cleaning of contaminated material*[24] (which is the 6th largest in Denmark and 19 % of the Danish cleantech companies operate in this field).

[21] This cleantech area is also called *Renewable energy* (see Appendix 13.14)
[22] In terms of the number of companies working in this area.
[23] This cleantech area is also called *Intelligent Energy* and *Energy Efficiency* (see Appendix 13.14)
[24] This cleantech area also falls into the segment *Environmental technologies* (see Appendix 13.14)

Figure 9: Sustainable technologies in the Zira project



Source: Lars Ostenfeld Rieman, Rambøll, presentation at Managing Projects Across Boundaries seminar, 2009

The companies in the Danish cleantech industry operate in a wide range of technology areas and a range of these areas and technologies are brought into play in the Zira project but mainly within the areas *Replacing traditional energy production and/or -use of renewable sources* (Renewable energy), *efficiency of energy production and use* (Intelligent Energy and Energy Efficiency) and *cleaning of contaminated material* (Environmental Technologies). While these technologies are some of Rambøll's core competences (Rambøll Denmark A/S, 2010), they are also some of Denmark's most widespread and largest cleantech areas and technologies. Wind energy and wastewater treatment for instance are Danish core competences (Vindmølleindustrien, 2010), for which public demand, public technology procurement and regulation have been crucial driving forces (Christensen et al. in C. Edquist & Hommen, 2008a). These technologies' origin can thus be traced back to policy decisions and occurrences in the Danish institutional trajectory and it is thus not a coincidence that these technologies are among Rambøll's core competencies, neither that it is these technologies that the Zira company consortium are 'exporting'.

In order to achieve the zero carbon footprint, the project thus includes technologies, energy sources, knowledge and fields from several of the different cleantech areas as well as construction and architecture. This combination of technologies and knowledge from different areas and inter-sectorial cooperation is characteristic for Danish cleantech (Copenhagen Cleantech Cluster, 2010a; Sederberg Rottbøll, Personal communication, 28 August 2010) and for Denmark. Rambøll and BIG are not

100% cleantech companies, but in Denmark, it is typical that companies that operate within cleantech also have other core activities and this facilitates the inter-sectorial cooperation.

6.4 Type of innovation

Zira Island is an innovation in Schumpeterian terms: '*new combinations' of existing resources* (Fagerberg, handbook of innovation: 5). All the employed knowledge has existed within Rambøll and BIG before the Zira Island project was initiated: "We have tried everything, so we have a lot of experience and knowledge internally in the company" (Stryg, Personal communication, 12 May 2010). It is not a brand new innovation but a combination of existing elements in new ways, as Edquist (2001) states that innovation often is. "In Rambøll we e.g. have some employees, who are good at solar energy, windmill farms and monorails so it is just about pulling these competences into the project" {{80 Stryg, Geert Personal communication, 12 May 2010}}.

Using the other classification of innovation based on Schumpeter's work and used in the conceptual framework chapter (chapter 2), the Zira project is thus an *incremental* innovation build on existing knowledge (contrary to *radical* innovation based on new, different knowledge). The use of existing resources and incremental innovation means that the company consortium has not needed to generate new (and expensive) knowledge and technologies for the project. The combinations of existing knowledge required for incremental innovations are facilitated through networks and cooperation – companies, research institutes and employees need to be able to identify where the existing knowledge can be found, in order to identify where it can be used for their own innovative development. The Zira project was facilitated through networks and cooperation. Rambøll asked BIG to be a part of the project because Rambøll knew of BIG's qualifications and competences. The two companies have not collaborated on projects previously but the identification of BIG as a potential partner was facilitated by the geographical proximity of the two companies, which are both located in the Copenhagen region.

6.5 Knowledge generation and the innovation process

The innovation process in the Zira project has not been controlled and ideas have been generated along the way (Stryg, Personal communication, 12 May 2010). According to Geert Stryg, Rambøll is characterised by conservatism and this is expressed in the project's innovation process: "BIG has been good at launching crazy ideas, then we have done everything we could in order to shoot them down in the pipeline. But we have accepted some of the ideas" {{80 Stryg, Geert Personal communication, 12 May 2010}}. The engineers at Rambøll are not that good at generating ideas – for them it is all about screws and bolts. But, "especially on the infrastructure, town planning and supply, we have been pretty good at coming up with some exciting new projects. It's been pretty fun.

So we have certainly been able to offer something different" {{80 Stryg, Geert Personal communication, 12 May 2010}}.

The combinations of the different qualifications and strengths in Rambøll and BIG are advantageous for the companies because it gives them a competitive advantage and furthermore makes them capable of including all aspects of a project; what Rambøll calls 'thinking things through' and 'thinking laterally' across sectorial boundaries.

Internally in Rambøll there is a focus on combining knowledge across the company for facilitating innovation.[25] This combination of knowledge is the same process that happens between Rambøll and BIG. Being innovative by combining existing knowledge is thus a characteristic of innovation generation by the companies both internally and in cooperation with external partners. The idea generation in BIG is however more characterised by diversity and multi-cultural inputs. "We have almost 100 people here, we come from 20 countries...We just produce idea after idea. So it is a hodgepodge of concepts. And thus an evolution where the strongest ideas are coming forward and the weakest ideas are shot down" (Bergmann, Personal communication, 8 July 2010).

The project has thus not developed in isolation in an individual organisation or in accordance with the linear model of innovation, where science is the basis for innovation and an increase in the scientific inputs will cause the number of innovations to increase (OECD, 1997). Rather, the project has developed between organisations in interactions through relations with reciprocity and feedback mechanisms in many loops (C. Edquist, 2001), both as regards the initial development of the technologies used in the Zira project and the project development itself.

The companies have participated with highly different knowledge, qualities and competences. The diversity and supplementation indicate that both Rambøll and BIG have provided equally value-adding knowledge activities. The equal relations might also explain why the consortium is characterised by trust in other companies' competences and accordingly is able to continually shift the lead-role.

6.6 Employees as carriers of knowledge

Employees are important as carriers of knowledge: "The labour force is important. When you move to another company, you have knowledge that you take with you. So labour in fact carries enormous amounts of knowledge" (Christensen, Personal communication, August 8, 2010). The workforce furthermore acts as 'knowledge diffusers' when they facilitate the use existence of specific knowledge in other contexts. It is a believe in the Danish Agency for Science Technology and

[25] An example of this is Rambøll's *Innovation Portal:* the employees can write their good ideas, and then the innovation manager looks them over and they elect the best idea of the year

Innovation that a basic core of the innovation system is to help invest in the knowledge society and to help scatter this knowledge using interaction and networking (Christensen, Personal communication, August 8, 2010). In the Zira project, it has largely been the employees from Rambøll and BIG, who have driven the process and the employees have played a large role as carriers of knowledge –in particular different expert knowledge (on e.g. photovoltaic cells or space syntax methods for analysing spatial configurations), that in combination can create a monumental project as the Zira Island. This knowledge carried by the employees is generally *tacit knowledge*. According to the OECD, the movement of people and the tacit knowledge they bring with them is a key knowledge flow in NISs. "...the skills and networking capabilities of personnel are key to implementing and adapting new technology" (OECD, 1997). The knowledge flows in the Zira project are characterised by tacit knowledge and informal exchanges of between the actors in the project. There are no formalised knowledge transfer systems.

As mentioned in the *conceptual framework* chapter, there are many channels in an innovation system through which knowledge can flow. The basic knowledge flows focused on in this chapter are the relations and interactions between the components in the Zira project, which will be analysed below.

6.7 Relations and interactions influencing knowledge and capabilities

The SI approach stresses the importance of analysing the relations and interactions between the components, which is important in order to understand and explain the innovation processes that take place in the system. This paragraph looks into the relations and interactions influencing knowledge and capabilities in the Zira project: firstly, the relations and interactions between the companies in the consortium and secondly, between the companies and public institutions.

The interactions and relations in the Zira consortium are of a *non-market* character and are based on collaboration and knowledge elements (C. Edquist, 2001). This means that the interactions and relations are mainly based on collaboration and that the knowledge elements are transferred through these non-market relations and interactions. When Rambøll involved BIG in the Zira project, it was a hand being lent form a large company to a SME. This was driven by 'network-mindedness' of an individual employee, Lars Ostenfeld Riemann, who is "a person who seeks new relationships and networks" (Bergmann, Personal communication, 8 July 2010). This illustrates how informal employee networks and personal contacts can determine partnership creation between companies and is supported by network theory (Johannisson, 1998).

The interactions in the company consortium are thus motivated by facilitating the day-to-day associations and avoiding conflicts between the companies: "We simply have to get aligned and coordinate... it is of course essential that we appear as a team when we are in Azerbaijan" {{80 Stryg, Geert Personal communication, 12 May 2010}}. Geert Stryg furthermore points out that this might

be a Danish characteristic because of the small Danish market. “It perhaps characterises the Danish market. We are such a small market and at some point you need to work together again, so everyone has an interest in making it work” {{80 Stryg, Geert Personal communication, 12 May 2010}}. In the Zira project the interactions and relations are of an informal character. The personal relationships thus count e.g. because the employees from different companies will probably have to collaborate on several occasions. Because the relationships are informal, the more informal knowledge transfers play a central role. As mentioned, they do not have codified knowledge transfer systems but the knowledge rather flows informally between the employees in Rambøll and BIG. Therefore it is important for the two companies to establish good and trustful relationships to each other so the knowledge will flow unhampered.

In the Zira project, collaboration between the companies in the consortium has been favourable in other ways than knowledge transfers. Seen as cooperation between a large company and a SME these advantageous effects become apparent. BIG is a small company with 30 employees, but through collaboration with Rambøll, they have benefitted from the administrative resources (such as e.g. legal advice) that the larger company holds internally. This illustrates the beneficial effect of cooperation between small and large businesses. In addition to the administrative resources, the smaller company can also draw on the larger company’s experience when cooperating. In the Zira project this e.g. means that BIG would not make the mistake of putting up parasols and palm trees on windy balconies because Rambøll knows that this does not work. There are also more indirect outcomes of the collaborative company activity in the Zira project. BIG is renowned for avant-garde architecture, but in order to realise their projects the BIG architects need to be able to incorporate the necessary technologies. Cooperation with Rambøll, which possesses a large degree of the technological knowledge BIG needs, enables BIG to identify and adapt the useful technologies.

In relation to the Zira project, there has not been any direct cooperation between the Zira consortium and public research (or other research institutes). OECD studies on national innovation systems however show that public research is mostly important as an indirect source of knowledge and not as a direct source (OECD, 1997). Given the indirect character of this knowledge, it is difficult to say whether public, indirect research has been utilised in the generation of knowledge and development of technologies within the Zira consortium companies prior to the Zira project initiation. The diffusion of indirect knowledge to the Zira companies is also related to the small open economy argument. The small size of Denmark might have facilitated the diffusion of the indirect knowledge and thus have strengthened the indirect effects of the public research for the Zira companies. Furthermore, the large degree of trust and the smaller industries with close relationships and interaction can have played a role in diffusion of indirect knowledge to the Zira companies.

As the paragraphs on the relations between the components in the Zira project indicate, the networking activities between the companies in the consortium have been very sporadic. But despite the sporadic nature of the network activities between the companies in the Zira consortium, network has been and is essential for the companies. These findings support the network perspectives, which underlines that formal and informal relationships are important.

6.8 Characteristics and competitive advantage of the companies involved in the project

In the interview conducted with the Rambøll and BIG patterns in the characteristics and competitive advantages emerged: thinking things through, thinking laterally and creativity were dominant.

6.8.1 Thinking things through

According to Rambøll Project Director Geert Stryg, Rambøll is a very conservative company, which thinks things through and has a focus on quality and value-adding. In the interview with Rambøll, the project director compiles these qualities into what he calls the 'Nordic approach' (Table 4).

Table 4: Azerbaijan and the 'Nordic approach'

"And there's a funny story in relation to Azerbaijan because the old beautiful waterfront in the capital Baku is initiated by the Nobel brothers. So if you are tall, blond and coming somewhere from up here [Scandinavia], you are by definition a friend… Therefore we have done a lot in order to sell this 'Nordic approach', which means that you build quality, you're building something that is nice and thought through. That you are building something that can last and something to suit the climate it is in. And we have had many funny comments, because when we come down and present, they often say "shut up, you've thought of everything!" Many other places in the world you do what you have to, but it is not certain that it is linked to the architectural design or is realistic so that the contractor can actually build it."
Geert Stryg, Senior Project Director, Rambøll Denmark A/S, May 12, 2010

This Nordic Approach is thus synonym with quality and well thought out projects. As could be seen in chapter 5, the Danish cleantech companies are largely oriented toward quality (only 16% of businesses have cost reduction as a key competitive strategy). As Table 4 illustrates, the focus on quality, also applies to the firms in the Zira consortium. These qualities and 'The Nordic Approach' are the reason why the holding company initially contacted the Danish companies and the approach thus constitutes a competitive advantage for Rambøll, BIG and Pihl in Azerbaijan.

The companies involved in the project also define this as a holistic approach to the project: "Our competitive advantage is that we are 'thinking' all the way around the project. We believe that we are

better at working and planning holistically than many of our competitors abroad" {{80 Stryg, Geert Personal communication, 12 May 2010}}. This also relates to the companies' activity and their ability to combine solutions in complex situations with diverse needs and requirements. The quote below in Table 5 illustrates how this competence is a competitive advantage in competition with foreign companies.

Table 5: If you don't think things through, parasols and palm trees will fall off the balconies

"We have an example of an apartment complex that has been built with super apartments and delicious huge balconies, on a hill in the outskirts of Baku. And it looks real nice on the drawings with outdoor Jacuzzi and large parasols and palm trees. But when you lift such a balcony up 150 meters above the ground, the wind will be strong and all the parasols and palm trees they blew down. It is simply not thought through... But they just don't discover that before the parasols are blown down. *We feel that in our end of the world you cannot live with something like that. We're very spoiled in Northern Europe and we do not live with errors. So we are forced to think all around on all projects. 'Oops's' are not very acceptable."* Geert Stryg, Senior Project Director, Rambøll Denmark A/S, May 12, 2010

In Denmark we would not live with parasols and palm trees falling off balconies because our welfare level is so high says Rambøll Project Director Geert Stryg. "No matter how low-paid you are no one in Denmark would live in an apartment where parasols and palm trees are blown down" {{80 Stryg, Geert Personal communication, 12 May 2010}}. "So we'll have to be very careful and meticulous - it is a specific Northern European and Germanic thoroughness phenomenon" {{80 Stryg, Geert Personal communication, 12 May 2010}}. As the Zira companies illustrate, Danish companies have therefore developed competences to comply with this.

6.8.2 Thinking laterally and interdisciplinary

The Nordic Approach of thinking all the way around projects also indicates that the companies are very capable of thinking *laterally* and *interdisciplinary* across sectors and knowledge fields. A sustainable construction project such as Zira encompasses a wide range of technologies and competences which are outside the remit of the individual engineer or architect. In order to provide a well thought through project to the client, they are therefore compelled to think laterally. The comprehensive and exhaustive master plan of the Zira project, which encompasses such a wide variety of technologies requiring a wide variety of competences, indicates that the Zira is very capable of thinking laterally and implementing knowledge and resources from different disciplines. It furthermore indicates that Rambøll and BIG complement each other due to their differences; they are

capable of dealing with a complex situation and cover many different, well thought out aspects in the Zira project.

6.8.3 Creativity

Rambøll and BIG are different companies and bring different qualities to the Zira project. BIG is a creative, innovative and playful company, which was asked to join the Zira project because they have a reputation of being dynamic, innovative and creative. Concerning BIG's competitive advantages Associate Partner Kai-Uwe Bergmann states: "We do what we do. There are some people who are attracted by our thinking, our design. We analyse very carefully, and we spend a lot of time understanding the context we work in: understanding the developer's dream, understanding what is required by the authorities and understanding the users' needs. Then we take these three things… and we try to get these three things to 'talk' together in an architectural project where all three say YES. That is what we can!" (Bergmann, Personal communication, 8 July 2010). This approach has made the Zira project unique because it enables the consortium to combine the traditional Azerbaijani building tradition with groundbreaking Danish architecture, cleantech technologies that do not utilise oil and requirements from authorities. The Zira Island does not resemble ordinary residential developments but is shaped like the seven famous peaks of Azerbaijan. The unusual Zira master plan is an example of unconventional and different thinking. As the Zira project illustrates, this is well received abroad and when the Zira developer, Avrosity Holding, saw BIG's building "the Mountain" at Amager in the initial phases of the project they liked the creative and untraditional approach. The Zira consortium has been able to understand situations where the developer has visions, the users have needs, and the authorities requirements – and following solve them with creativity. The idea behind the project is so unique because it is enables the project of combing Danish architecture with cleantech in an oil producing country, with a famous national symbol (the seven mountain peaks), requirement and demands from the client and authorities. The project therefore has a possibility of being a role model for other zero carbon footprint constructions.

6.9 Sustainability role model

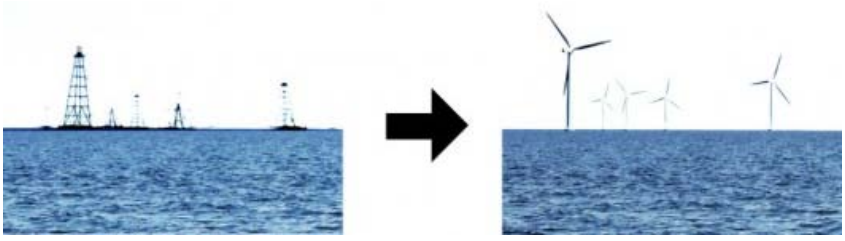
Even though the Zira project is not a radical innovation based on new knowledge, its cumulative impact might still be significant (Lundvall, 1992) and the project is envisioned to be a sustainable model for urban development. "By help of the wind, the sun and the waste the Island will produce the same amount of energy as it consumes. In a society literately built on oil this will serve as a showcase for a new way of thinking sustainable planning" (Lars Ostenfeld Riemann in Etherington, 2009). With the Zira project, BIG and Rambøll have a possibility to be sustainable urban development pioneers and role models, which also makes it attractive for them to be part of it. It is furthermore an opportunity for the companies to engage in an international project.

6.10 Limited commercial outlet in Denmark

The companies in the Zira project engage in this international project because of the market and demand. In Azerbaijan there was demand and initially available funding and therefore it is in Azerbaijan that Rambøll, BIG and Pihl have the possibility of constructing such a large and expensive *role model project*. As mentioned, it was because of employee networks that Rambøll initially got involved in the project and likewise because of network that Rambøll involved BIG and Pihl. But it was due to demand for Danish architecture and the Nordic Approach in combination with demand for sustainability (as a result of increasing oil prices) that the project was engineered. This is also stressed by Michael Johansen from Copenhagen Cleantech Cluster when he states that "there is just limited commercial outlet in Denmark, so if you want to be a large company you are forced to orient yourself internationally" (Johansen, Personal communication, 27 August 2010). Thus even though the Zira consortium might have wanted to construct as extensive a zero-energy role model project in Denmark, there has just not existed an outlet for it and they have to oriented themselves abroad.

6.11 Demand-side factors, market influences and sustainability in the project

While there is a significant commercial outlet for the Zira companies and cleantech abroad, Danish cleantech has also largely been driven by domestic factors. The cleantech industry has been driven by politics, consumer interest, an increasing number of sustainability and responsibility requirements on companies along with the climate crisis. But what determined the focus on sustainability in the Zira Island? Azerbaijan is an oil producing country and the Azerbaijanis basically pump up the oil just outside the door and equip everything with oil and petroleum. The population in Azerbaijan is buying oil for a low price in comparison with what it can be exported for. This means that it is more profitable for Azerbaijan to cut down its own oil consumption and instead export the oil. Rambøll and BIG recognised this issue and concomitant possibilities, and suggested to the Azerbaijani client that the project should be CO2-neutral and self-sufficient. They suggested to reframe the energy consumption and told the client: "if we do not use oil, you can sell it and get the money" {{80 Stryg, Geert Personal communication, 12 May 2010}} and the client accepted the CO2-neutral project. "The developer is not building a sustainable island because they are 'green at heart' – it is 'cool business'" {{80 Stryg, Geert Personal communication, 12 May 2010}}. There was thus absorptive capacity for sustainability in Azerbaijan because it is interesting for them commercially.



The CO2-neutrality aspect of the project is thus highly related to the demand-side factors and market influences and therefore, the activities in the development of the project have fluctuated with the oil prices (see appendix 13.18). When the Zira consortium initiated the project, oil cost $140 a barrel, which was in fact a boom. As mentioned, people in Azerbaijan pay a very little percentage of the real oil prices for the oil they consume. Hence, if Azerbaijan can get the 10.000 people that will be living on the Zira island to use renewable energy and reside in zero-energy buildings, they can sell the oil on the market and get full price. "So it is a business mindset - and not "oh, it must be so nice and CO2 neutral!"" (Bergmann, Personal communication, 8 July 2010). This dependency of the oil prices means that the holding company's commitment to the project is unsteady and the project is therefore on hold at the moment. No matter what drove the projects CO2-neutral vision, the project is a possibility for Rambøll and BIG to brand themselves and the Danish cleantech 'core competences' and for the project to become a sustainability role model.

6.12 The political context

Neither the Danish government nor government agencies have been directly involved in the project or provided support. Rambøll did however ask a ministry department for advice concerning corruption but they found the consultancy so poor that they went to London to get adequate guidance {{80 Stryg, Geert Personal communication, 12 May 2010}}. BIG has furthermore previously attempted to get public support and investigated the innovation support opportunities but came up against a brick wall. According to BIG, the reason why there is not any public resources funding the project is that the Danish public funding system is so bureaucratic and difficult to see through. "…there are several of these situations where you, as a private company, have an idea, you will find support and there are resources out there for it, but the bureaucracy is just so heavy" (Bergmann, Personal communication, 8 July 2010). As regards the Zira project, BIG states that "there was nothing in the Danish society, for instance the Danish innovation fund, which facilitated the project and the innovations. We have not received advice and we have not received interest" (Bergmann, Personal communication, 8 July 2010).

Regional innovation systems do not seem to have had a significant influence on the Zira project. Neither Rambøll nor BIG are for instance members of Copenhagen Cleantech Cluster. However, it is still of importance that all three companies are headquartered in the Copenhagen area since this is likely to have enhanced their knowledge of each other and their skills. As argued, the companies might have been influenced by the more indirect effects of being situated in proximity to a large range of cleantech companies and research institutes in geographically within Copenhagen Cleantech Cluster.

Concerning the local Azerbaijani political context, the Azerbaijani government has an interest in the project. Earlier there have been 7 attempted projects on the Island, where Zira is now planned – but they "have been rejected at the highest level of government" Geert Stryg says. The Zira project has been presented to the Azerbaijani President and due to its visionary character, it has been granted permission to be build on the island {{80 Stryg, Geert Personal communication, 12 May 2010}}. According to Geert Stryg, the Azerbaijani government sees the Zira project as "a possibility for Azerbaijan to rebrand itself" {{80 Stryg, Geert Personal communication, 12 May 2010}} and that is why the Danish company consortium has been granted permission to construct their Zira project.

Concerning the European political influence on the project, there has not been any according to the Zira company consortium. The consortium has not received financial support nor drawn on knowledge from European experts because all knowledge came from within the companies in the consortium and indirectly from Danish public research because the companies are situated in Denmark {{80 Stryg, Geert Personal communication, 12 May 2010}}.

6.13 Conclusion

The company consortium behind the Zira project aims at making the island completely independent of external resources. This CO2-neutrality aspect of the project is highly related to the demand-side factors and market influences – the focus on zero-energy was determined by commercial interests. However, this provides BIG and Rambøll with a possibility of being sustainable urban development pioneers and role models.

The Zira project is characterised by combinations of technologies and knowledge from different sectors and knowledge areas. The project is unique because it combines the traditional Azerbaijani building tradition with groundbreaking Danish architecture, cleantech technologies that do not utilise oil and accommodations of authorities' requirements. The project is a '*new combination' of existing resources*, which was facilitated by the geographical proximity of Denmark, the relations characterised by trust and prior cooperation. The project is developed between organisations in interactions through informal relations with reciprocity and feedback mechanisms in many loops. The interactions and relations are mainly based on collaboration and that the knowledge elements are transferred through these non-market relations and interactions. The small size of Denmark might have facilitated the diffusion of the indirect knowledge and thus have strengthened the indirect effects of the public research for the Zira companies. The Zira project furthermore indicates positive effects of collaboration between large companies and SMEs.

In the analysis characteristics and competitive advantages emerged. Firstly, thinking things through: The companies' competitive advantage in the Zira project is their holistic approach. The Danish or "Nordic approach" is both cost-competitive and quality competitive with foreign companies.

Secondly, it was indicated that an ability to think laterally and interdisciplinary is a significant characteristic. Thirdly, creativity emerged as a characteristic: The Zira consortium has been able of understanding situations where the developer has visions, the users have needs, and the authorities have requirements – and turning them into a groundbreaking creative architectural project.

The companies might have been influenced by the more indirect effects of being situated in proximity to a large range of cleantech companies and research institutes in geographically within Copenhagen Cleantech Cluster even though they are not formally members. Concerning the European political influence on the project, there has not been any according to the Zira company consortium.

The next chapter utilised and elaborates on the findings of this chapter and discusses the degree to which the Zira project and the Zira company consortium are institutionally embedded in the Danish national innovation system.

7 Discussion I: The case in relation to the Danish national innovation system

Utilising and elaborating on the findings and conclusions of chapter 6, this chapter discusses the degree to which the Zira project and the Zira company consortium are institutionally embedded in the Danish national innovation system. The historical and evolutionary perspectives of the innovation system approach, which views the innovation processes as path-dependent over time and with certain trajectories and different institutional set-ups (Borrás, 2008; C. Edquist, 2001) makes it intriguing to assess whether there is a correlation between the Zira consortium's characteristics and the Danish innovation system. Can we actually explain the Zira project by embeddedness in the Danish national innovation system? Or should it rather be explained by other factors, such as globalisation, the increased demand for international competencies and multicultural employees?

7.1 Institutional embeddedness of the Zira project

The Zira project's vision is a zero carbon footprint and energy self-sufficiency. Given the strong foothold of the Danish cleantech industry and drive power of the public technology procurement and alongside the public utilities and services which drove and facilitated the emergence of Danish cleantech, the Zira companies' focus on sustainability does not appear coincidental. The decisions made in the 70s concerning Danish independence of oil for example led to the emergence of fertile ground and market opportunities for BIG and Rambøll decades later. The history and trajectories outlined in chapter 4 and 5 enabled the Zira companies' cleantech focus and the companies in the consortium are thus following the Danish trajectory (C. Edquist, 2001; C. Edquist, 2004).

Concerning knowledge generation and knowledge transfer, the Zira project is characterised by *new combinations of existing resources*, which have been facilitated through the networks and cooperation. Denmark's geographical proximity has given rise to spill-overs and spin-offs and facilitated the gradual combinations of existing knowledge in the project. As the case illustrates, Denmark's relatively small size facilitates the identification of external knowledge and labour skills. As Geert Stryg from Rambøll stated, this means that it is easier to identify the people and knowledge you need, when you are based in a small country such as Denmark, where people often know each other in the industry they operate in. This argument can however be questioned by the increasing international mobility of labour, which hampers the identification of knowledge and competences. However as the case exhibits, the geographical proximity to some degree counters this hampering and it is of importance that all three Zira companies are headquartered in the Copenhagen area since this is likely to have enhanced their knowledge of each other and each other's skills. As argued, the companies might have been influenced by the more indirect effects of being situated in proximity to

a large range of cleantech companies and research institutes in geographically within Copenhagen Cleantech Cluster. Hence, there is a certain degree of regional embeddedness of the Zira project.

The three most significant cleantech technology areas utilised in the Zira project are some of the largest fields of cleantech activities among the majority of the Danish cleantech companies and while these technologies are some of the Zira companies' core competences, they are also Danish core competences whose origin can be traced back to policy decisions and occurrences in the Danish institutional trajectory. It is thus not a coincidence that these technologies are among the Zira companies' core competencies. Besides engaging in the most dominant cleantech areas in Denmark, the Zira companies share several characteristics with the general Danish cleantech company: large export share, network-oriented, activities in a wide range of areas (not necessarily having cleantech as their core area) and moving across traditional industries. The project is reflecting tendencies and characteristics of the Danish cleantech tradition (and hence the Danish innovation system).

In the interview with Rambøll, the project director stressed that the 'Nordic approach' which involves quality, thoughtful solutions and unique designs, is Danish companies' main competitive advantage. As argued, the Danish society has generated this quality consciousness and meticulousness and it can be argued that the Zira company consortium is institutionally embedded in the Danish innovation system.

In addition to the Nordic Approach and quality consciousness, the Zira project illustrated that the companies are good at thinking cross-disciplinary and laterally; linking e.g. wind energy, Danish ground-breaking architecture, and engineering. Project Development Manager at Copenhagen Cleantech Cluster Michael Johansen stresses the value of this lateral and interdisciplinary way of thinking: "what we have observed is that Denmark and Scandinavia are good at thinking laterally. Wind technologies for instance spawned a number of other skills and suddenly a smart grid[26] was needed to manage this growing energy level. Cleantech is about thinking laterally" (Johansen, Personal communication, 27 August 2010). Thinking projects laterally and interdisciplinary is thus a cleantech characteristic as well as a Danish characteristic as argued earlier. This also links to the '*new combinations' of existing resources*, which is prevalent in the Zira project as well as in the majority of Danish companies.

Denmark is renowned for design and creativity and is often branded on this[27] in relation to export and FDI. Denmark's reputation of being a design country was also partly the reason why Rambøll and BIG got the Zira project. Rambøll did initially get involved in the Zira project because the

[26] Smart grid is cleantech technology and a power grid that uses digital technology to deliver electricity
[27] An example of this is the official website of Denmark (Ministry of Foreign Affairs of Denmark, 2010b)

Azerbaijani holding company, Avrosity Holding, had a positive impression of Denmark, Danish design and architecture.

As a conclusion to the discussion above, it can be argued that the Zira project and the Zira company consortium's competences/qualities can largely be explained by embeddedness in the Danish national innovation system. However, the international orientation of the Zira consortium and the analysis findings supporting the small open economy argument, allude to a need for an international angle in order to put a sufficient answer to the research question forward.

7.2 International embeddedness of the Zira project

Because of the limited commercial outlet in Denmark, the Danish cleantech companies are highly dependent on export. This limited commercial outlet, in combination with international employee networks and international demand, have led to an internationalisation of the Zira project as well as the Danish national innovation system. The organisations have taken advantage of the opportunities that have been opened up by economic globalisation. Because there was an Azerbaijani commercial interest in zero-energy, BIG and Rambøll have a possibility of being sustainable urban development pioneers and role models with the Zira project.

Even though BIG Architects is a SME, they have approximately 20 nationalities employed. This alludes to significant international influences. The knowledge and networks that the employees in particular are carriers of, strengthens the companies' competitive advantage. The flexibility of the workforce however also causes problems. The tacit knowledge that the employees carry is difficult to transfer and effective transfer of tacit knowledge generally calls for extensive personal contact and trust. Hence, the mobility of the workforce poses challenges for management in companies concerning managing the knowledge or codifying it in order to keep it in the company.

Because of the international mobility and the movement of labour, the nature of corporate networks has consequently become more international - and composed by diverse knowledge. This is also the reason why the diverse workforce fosters creativity in BIG as well as in the collaboration between Rambøll and BIG. "Labour in fact carries enormous amounts of knowledge. If you are familiar with the existence of specific knowledge you can then use it in other contexts" (Christensen, Personal communication, August 8, 2010). These processes can be described as knowledge spill-over since the employees who come from other companies pass on some of the tacit knowledge they possess to their new workplace.

In combination with the factors above the *large degree of exports* and *international interaction* of the Zira companies suggests a certain degree of international embeddedness of the Zira project.

The discussion above also points to implications. It might be argued that Denmark is missing out on knowledge and resources because of the international embeddedness of the Zira consortium companies. The implications of policy are outlined and discusses in chapter 11 (*Implications for policy*).

7.3 Conclusion

As discussed above, the Zira companies have been influenced by the institutional system in Denmark. The companies and their characteristics can partly be explained by this and the Danish trajectories, history and tendencies. The Zira project and the company consortium can furthermore partly be explained by the indirect effects of being situated in proximity to a large range of cleantech companies and research institutes in geographically within Copenhagen Cleantech Cluster. Hence, there is a certain degree of regional embeddedness of the Zira project.

The Zira project is thus embedded in the Danish national innovation system in a variety of ways and while the Danish innovation system has affected the Zira project and the companies in the Zira consortium to a large degree, their characteristics can only to a certain degree be explained by embeddedness in the Danish national innovation system. International embeddedness is also part of the explanation due to dependency on international markets, demand and export, the international mobility of the labour force and international spill-over of knowledge due to the informal networks that the companies are part of.

Derived from this discussion the next chapter discusses the role of national innovation policy and whether the Danish national innovation system is going to remain important despite the international embeddedness and increasing globalisation.

8 Discussion II: The role of (national) innovation policy

On the basis of the findings in the analysis and the discussion in chapter 7 this chapter discusses the relations between the companies in the Zira consortium and policy. Firstly, the system failures identified in the analysis of the Zira case are clarified and elaborated on and it is perfunctorily assessed what the state and the public agencies are doing to mitigate and solve these problems. Secondly, the role of policy is discussed and on the basis of this and the conclusion of chapter 7 it is thirdly discussed whether the Danish national innovation system is going to remain important.

8.1 System failures and the role of policy and formal institutions

The innovation system approach draws our attention to possible systemic failures, which impede innovation in an innovation system. As mentioned in the section on the conceptual framework used in this paper, the justification of public intervention and innovation policy depends on two conditions: firstly, the market mechanisms and companies must fail to achieve the politically determined objectives and secondly, the state and the public agencies must have the ability to solve the problem (C. Edquist, 2001). As mentioned in chapter 4 the Danish Government has presented a strategy and objectives for preparing Denmark for the future[28](The Danish Government, 2006) and in addition, the European Research Area and the Lisbon Strategy are aiming at facilitating the flow of research and innovation across national borders and coordinating national economic policies respectively. The case however indicates that these politically determined objectives are not achieved by the market and companies. The case study in combination with the description of the Danish cleantech industry, thus draws our attention to three possibly system failures in the Danish innovation system, in particular: inefficient and sporadic network activities; bureaucracy and ignorance about the offers in the Danish innovation support system; and lack of access to financing.

8.1.1 Inefficient and sporadic networks

The matchmaking in the Zira project initialisation phase was very sporadic, which underlines that the network activities in Danish cleantech can be optimised, streamlined and systematised to allow companies greater insight into each other's technologies, knowledge, and competences. Copenhagen Cleantech Cluster has outlined this matchmaking problem as a significant issue for Danish cleantech and in addition, DASTI has identified and acknowledged this as a system failure in the Danish innovation system and in order to remedy this, they have a strong focus on matchmaking activities, creating networks and cooperation.

[28] This globalization strategy aims at accomplishing *world top level education; strong and innovative research; more high-growth start-ups; and renewal and innovation* in order to attain *strong competitive power* and *strong cohesion* (The Danish Government, 2006).

As outlined in chapter 2, Edquist (2005) states that "Networking though markets and other mechanisms, including interactive learning between different organisations (potentially) involved in the innovation processes" is one of the important activities in the system of innovation. As found in the analysis, the combinations of existing knowledge required for incremental innovations is facilitated through networks and cooperation – companies, research institutes and employees need to be familiar with the existing knowledge and where to access it, in order to identify where it can be used for their own innovative development. The findings in the analysis therefore support the importance of networking as an activity in the innovation system – both nationally and internationally. However, as the case findings show, the networks are largely inefficient and sporadic. This implies that there is a need for more efficient and structured network and innovation policies which facilitates such schemes.

8.1.2 Bureaucracy and ignorance about public offers

The companies in the Zira consortium have very limited knowledge about and familiarity with the possibilities available through the public institutes such as DASTI, public policy innovation support and development schemes. And in combination with this ignorance, the case indicates that bureaucracy is an obstructing issue. In the World Economic Forum's "The Global Competitiveness Report 2010-2011" *Inefficient government bureaucracy* is ranked as the fourth most problematic factor for doing business in Denmark (Brøndum & Fliess et al., Oktober 2009), which supports the case findings and the indication that there is a need for more transparency and facilitation of the access to the institutes and the support schemes.

8.1.3 Lacking access to financing

The Zira consortium does not have insight into the funding opportunities available. In relation to finance, the Zira project is an example of that it is largely private companies who pay for innovation in Denmark. According to Edquist (2005), "financing of innovation processes and other activities that can facilitate commercialisation of knowledge and its adoption" is an important activity in the innovation system and the lack of funding and impeded access to financing is thus problematic for innovation in Denmark. Out of the 139 countries in the World Economic Forum's "The Global Competitiveness Report 2010-2011" Denmark is lagging far behind in the financial market development. Denmark is ranking as number 28 in *Availability of financial services*, number 29 in *Venture capital availability* and ranks as low as number 60 in *Financing through local equity market* (World Economic Forum, 2010). Furthermore, the same report shows that *Access to financing*[29] is

[29] *Access to financing* accounts for 21.5 percent of the responses (*Tax rates*, which was rated as the most problematic factor for doing business in Denmark, accounts for 24.7 percent).

the second most problematic factor for doing business in Denmark.[30] This is also supported by *Figure 2* in chapter 5 where it can be seen that the main obstacle to further growth, indicated by the Danish cleantech growth companies and rising stars, is *Lack of external funding opportunities*. The case findings, which show that neither Danish nor European organisations have been involved or given financial support to the Zira project, also substantiate this. BIG has previously used many resources in attempts to get funding for projects but without results. The lack of available financing is thus a system failure in the Danish innovation system.

8.2 Are national innovation systems going to remain important?

As Freeman (1995) already stated in the mid 1990s it is tempting to agree with Ohmae (1995) and his claim that nation states are becoming obsolete and increasingly being replaced by regional economies and institutions. Since many institutions in various sectors either are or act trans-nationally, Nelson and Rosenberg (1993) also question whether a *national* system concept makes any sense - a problematic that only has become more pertinent over the years. The international embeddedness of the Zira project could seem support these arguments at first glance. However as stressed earlier, Zira project is both internationally embedded *and* nationally embedded Previously it was only the production that was outsourced but concurrently with the companies' realisation of the increasing possibilities in innovation systems around the world, activities and networks are also increasingly being internationalised as the Zira project illustrates.

Despite these trends, which challenge the coherence of *national* systems (Hommen & Edquist, 2008), the case findings in this thesis support Lundvall's (2009) argument that national systems still play an important role in supporting and leading the innovation and learning processes. One reasons for this can be exemplified by the following statement made by Rambøll Project Director Geert Stryg: "It means a lot that the companies in the consortium are Danish. Then we have no cultural hassle but have defined roles" (Stryg, Personal communication, 12 May 2010). This indicates that similar innovation system backgrounds facilitate the processes in the project.

The case however shows that international embeddedness does not exclude national embeddedness: The Zira companies are both nationally embedded and influenced by Danish trajectories and the acceleration of national specialisation patterns but at the same time they are internationally embedded, dependent on foreign demand and knowledge spill-overs from international networks.

[30] From a list of 15 factors, respondents were asked to select the five most problematic for doing business in their country and to rank them between 1 (most problematic) and 5 (World Economic Forum, 2010).

In literature there are several conflicting arguments concerning the future role of national innovation systems in relation to globalisation. However, the findings of this thesis indicate that national innovation systems still play an important role.

8.3 Conclusion

The case indicates that the politically determined objectives in the Danish globalisation strategy are not achieved by the market and companies. The case study in combination with the description of the Danish cleantech industry, thus draws our attention to three possibly system failures in the Danish innovation system, in particular: sporadic network activities; bureaucracy and ignorance about the offers in the Danish innovation support system; and lack of access to financing. These system failures all call for policy intervention in order to mitigate the problems.

The case findings support the argument that national systems still play an important role in supporting and leading the innovation and learning processes and that national innovation systems will continue to play an important role. The case however shows that international embeddedness does not exclude national embeddedness: The Zira companies are both nationally embedded and influenced by Danish trajectories and the acceleration of national specialisation patterns but at the same time they are internationally embedded, dependent on foreign demand and knowledge spill-overs from international networks.

Having outlined and discussed the identified system failures, the next chapter concludes the thesis and the consecutive chapter 11 outlines the implications for policy derived from the case findings and the identified system failures.

9 Conclusion

This concluding chapter provides an answer to the research question: *How can the Zira project be explained by embeddedness in the Danish national innovation system?* In order to answer this question, the two sub-questions will firstly be approached.

How are the relations and interactions between the organisations in the Zira company consortium influencing the innovation processes in the project?

As the case analysis in this thesis shows, companies are embedded in complex webs of interactions. The project is developed between the organisations in interactions through informal relations with reciprocity and feedback mechanisms in many loops. The interactions and relations are mainly based on collaboration and transferring of knowledge elements through these non-market relations and interactions characterised by a high degree of trust. The Zira project furthermore indicates positive effects of collaboration between large companies and SMEs.

How are the organisations and the innovation processes in the Zira project influenced by the innovation systems that they are part of?

The case findings show that BIG and Rambøll are influenced by the surrounding innovation systems in a variety of ways. As regards regional and sectoral innovation systems neither Rambøll nor BIG are for instance officially members of such systems as e.g. Copenhagen Cleantech Cluster but the companies are arguably influenced by the more indirect effects of being situated in proximity to a large range of cleantech companies and research institutes geographically within the cluster. Concerning the influence of the European innovation system, the case findings do not indicate any significant and distinctive influence. The case findings moreover show that the Zira project is largely influenced by the national Danish innovation system but addressing *how* leads us on to the overall research question.

In order to approach the overall research question of *how the Zira project can be explained by embeddedness in the Danish national innovation system*, and give a nuanced but clear answer to the sub-questions, the characteristics of the Zira project identified in chapter 9 and the characteristics of the Danish national innovation system as identified in chapter 7 are juxtaposed in the table below.

Danish national system of innovation characteristics	Zira project characteristics	Is the Zira project institutionally embedded in the Danish NIS?
Majority of SMEs	The Zira project indicates positive effects of collaboration between large companies and SMEs.	-
Incremental innovation and	All the employed knowledge has	Yes

combinations of existing knowledge	existed within Rambøll and BIG before the Zira project was initiated.	
Interactive learning and learning by doing	The Zira project is characterised by interactive learning. The degree of learning by doing has not been assessed.	Partly
Knowledge spill-overs play an important role	The Zira project builds on combinations of existing knowledge from different sectors and knowledge areas.	Yes
Low and medium tech specialisation	The Zira project comprises both med- and high-tech.	Partly. However this answer is ambiguous: While low-and med tech are the largest areas of specialisation, high-tech specialisation is increasingly important in Denmark
Large degree of export and internationalisation	The Zira companies have a strong international focus.	Yes
Large degree of international interaction	The Zira companies have a large degree of international interaction through informal networks and international projects.	Yes
Small size of domestic market	The small size of the domestic market has caused e.g. the high-tech companies to focus on larger, international markets.	Yes
Public demand-side measures as important drivers for industries and technologies	The main cleantech technologies in the Zira project are Danish core competences driven by public demand-side measures.	Yes
Public procurement, regulation and demand as important drivers for creation and development of clusters	The Zira project is not involved in CCC, however, CCC is largely influenced by public demand-side measures and the Danish institutional trajectory. The Zira companies have arguably been highly influenced by the indirect knowledge in the region.	Partly
The industry is the largest source of financing	The Zira project is 100% financed by private sources of finance.	Yes
High level of trust facilitating the exchange of information	The informal networks in the Zira project have been facilitated by the high level of trust between the companies.	Yes
Relations by formal contracts and numerous informal networks and cooperation	The Zira project was initiated because of informal networks.	Partly

The table above shows that the answer to the research question to a large degree is that the Zira project can be explained by embeddedness in the Danish national innovation system. However, even though *a large degree of exports* and *international interaction* are characteristics of the Danish innovation system, they also indicate that the international embeddedness of the Zira project paradoxically can somewhat be explained by embeddedness in the Danish national innovation system. This can partly be accounted for by the *small open economy* argument that the openness of a small economy can be explained by the small size of the domestic market and dependence on foreign markets for achieving growth and be competitiveness. In continuation of this it was discussed whether Denmark's national innovation system will remain important with the increasing globalisation and changing context. The case findings indicate that international embeddedness does not discard the importance of national innovation systems – and these still play an important role.

In addition to the table above, the case findings show that the three dominant characteristics in relation to the Zira companies' competitive advantage were also caused by embeddedness in the Danish innovation system: Firstly, the companies' competitive advantage in the Zira project is their holistic, quality conscious approach "Nordic approach." Secondly, it is an ability to think laterally and interdisciplinary across sectors. Thirdly, it is a sense of creativity and the companies' understanding of complex situations where the developer has visions, the users have needs, and the authorities have requirements – and turning these into a groundbreaking, creative architectural project.

The case indicates that the politically determined objectives in the Danish globalisation strategy are not achieved by the market and companies. The case study in combination with the description of the Danish cleantech industry thus draws our attention to system failures in the Danish innovation system, in particular: inefficient and sporadic network activities; bureaucracy and ignorance about the offers in the Danish innovation support system; and lack of access to financing. These system failures all call for policy intervention in order to mitigate the problems. Below, the case findings' implications for policy and further research will be outlined.

10 Implications for policy

The findings in this thesis have implications for policy. As briefly touched upon in the framework chapter, there are however notions to keep in mind regarding lessons for policy. The analytical base for innovation policies can be a combination of general insights into what constitutes good practice in the light of the global contexts and with specific insights into the Danish innovation system characteristics (Lundvall & Borras, 2005). Regarding lessons for policy Hommen and Edquist (2008) emphasise the necessity of understanding the appropriate pitfalls and to identify the transferable best practice models. Direct imitation or institutional borrowing of such models is rarely successful and the Danish context must therefore be understood and respected. Lundvall et al. (2006) argue that an innovation system perspective helps avoid this naïve borrowing across national borders (Lundvall, Pataparong, & Vang Lauridsen, 2006). Undertaking a case study and deriving specific findings and implications furthermore enables an avoidance of the pitfalls of blind institutional borrowing – a case study embraces the specific Danish context. Overall, the case finding show that the most crucial challenge for Danish innovation policy in the future will be to establish a new policy construct which encompasses the blurring of interactions and relations across sectors, technologies, company types and sizes, geographical borders and public-private status. The more specific implications for policy that can be drawn from this thesis are fivefold:

1 More focus on facilitating knowledge transfers and spill-overs
2 Facilitate collaboration between SMEs and larger companies
3 Establish various effective, structured networks and matchmaking schemes
4 Facilitate the interactive learning and incremental innovation
5 Enhance the global orientation of innovation policies

11 Implications for further research

If the time frame for the research conducted in relation to this thesis had been different and allowed for more in-depth research, the presented analysis and evaluations might have been more nuanced. Further research could encompass an in-depth analysis of how the state and public agencies are mitigating and solving the existing system failures. Furthermore, an extensive and through micro analysis of numerous case studies can be undertaken in order to assess the degree to which the Danish companies are undertaking international collaborations, the characteristics of such endeavours and the consequences. At a macro-level this might lead to an analysis and discussion of the extent to which national innovation systems are being eliminated by global innovation systems. Given the international characteristics and orientation of the Zira companies and the Danish

cleantech industry, this thesis could also serve as a starting point for an analysis and evaluation of the degree to which the Danish innovation policies are too nationally focused.

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13 Appendix

13.1 Interview Guide: Rambøll Denmark A/S

Interview with Geert Stryg, Senior Project Director in Rambøll Denmark, 12 May 2010

Zira Island projektet generelt og de involverede parter:

- Hvordan blev projektet startet? Hvem fik ideen? Hvorfor?
- Hvem er parterne i projektet?
    - Hvem er klienten/ investorer?
    - Private aktører:
    - Offentlige aktører (fx videnscentre som DTU):
- Hvilke teknologier bliver brugt?
- Hvad er status på projektet pt.?
- Hvordan bliver projektet finansieret?
- Hvordan fik Rambøll kontrakten? ('Headhuntet' eller udlicitering?)
    - Hvad er jeres motivation for at være med (udover penge)?
- Hvad karakteriserer Rambøll?
- Hvad er Rambølls bidrag til projektet?
    - Hvad tror du det er, at Rambøll kan?
        - Specifikke Rambøll egenskaber?
        - Specifikke danske egenskaber?
- Hvordan ser Rambølls Zira-arbejdsgruppe ud?
  Har I jeres egne ansatte med derned eller hyrer I også lokalt?
- Fortæl mig om de andre parter og hvordan/ hvorfor de er involveret?
- Hvordan er forholdet/ sammenhængen imellem de involverede parter?
    - Hierarki? Magtforholdene? Sociale relationer? Bedre forhold til nogle end andre?
    - Projekt struktur
      (tegning/diagram af projektet og hvordan aktørerne er forbundet og arbejder sammen).
    - Hierarki imellem parterne?
    - Hvem koordinerer projektet and hvordan? Hvordan er rollerne blevet fordelt? (officielt eller uofficielt)
    - Arbejder virksomhederne som 'én unit' eller flere selvstændige?
      (er det 'Zira Projektet lavede dette' eller 'Rambøll lavede dette'?)

Industrien:

- Hvordan vil du beskrive industrien, som omgiver Zira projektet?
- Er der nogen fællesnævnere for de involverede parter?

Innovation og idé-generering i projektet

- Hvordan blev/bliver innovation (nye ideer) genereret og faciliteret i projektet?
    - Hvem er kommet med ideerne?

    - Er der nogle interdisciplinære/ imellem virksomhederne teams som er etableret til at generere ideer/ skabe synergi og arbejde sammen? Eller er det ' hver virksomhed kommer med deres egne ideer'?
- Kunde-dreven innovation: Hvor meget har kunden deltaget i udviklingen og stillet krav til projektet? Er der kommet brugerdreven innovation ud af det?
- Hvordan har I fået den viden, som er brugt i projektet?
    - Er det *ny viden*, som I og de andre parter er kommet op med?
    - *New in the world* (patenter)*? New in the region/country, new in the sector, new in the company?*
        - *Radikal innovation?* Eller en *radical technology shift* i en moden industri*?*
    - Eller *ny kombination af viden*?
- Hvordan genererer og tilegner I jer den viden, som I bruger i projektet? Vidensoverførsel/ vidensdeling, patenter
    - Genererer I selv viden? Har I fået patenter?
    - Samarbejder I med vidensinstitutioner (som fx DTU eller udenlandske universiteter og forskere?) eller andre virksomheder?
        - Er den viden lettilgængelig?

Innovations politikker:

- Hvad er det for en politisk kontekst, som omgiver projektet?
    - Lokale myndigheder
    - Danske myndigheder
    - EU myndigheder
- Hvilke faciliterende eller begrænsende faktorer for projektet er der i dette politiske miljø?
    - Hvad gør jeres arbejde lettere?
    - Hvad begrænser og indsnævrer jeres arbejde?
- Hvilke innovationspolitikker (Danske eller Europæiske) har en positiv effekt på jeres projekt, projekt deltagelse, projekt planlægning, projekt design?
    - Hvilke har en negativ effekt?
        - Hvad har I brug for i en innovationspolitik? Hvilken form for innovationspolitik ville facilitere jeres arbejde og deltagelse i international projekter?
- Hvordan trives Rambøll i det politiske miljø, som projektet er i?
    - Har Rambøll fordele?
    - Eller ulemper?
- Har Rambøll fået offentlig støtte for at blive en del af projektet og i løbet af processen?
    - Er der nogen fremmende initiativer fra regeringen, ministerier eller EU?
- Hvordan påvirker '*spillereglerne'* (fx patent love) Rambøll og jeres arbejde?
- Har I lobbyet for at blive en del af projektet - og i løbet af processen?
    - Hvis ja, hvordan?

Network og samarbejde:

- Hvilke barrierer har der været for Rambølls arbejde og projektet som helhed?

    - Bureaukratiske (lovgivning og politikker)?
    - Kulturelle?
    - Samarbejde?
    - Praktiske (visa, forsikring, ansvar/forpligtelser)?
- Hvad har gjort jeres arbejde og samarbejde nemmere?
    - Bureaukratiske (lovgivning og politikker)?
        - Offentlig støtte (fra den danske regering, EU, Aserbajdsjan)?
    - Kulturelle?
    - Samarbejde?
    - Praktiske (visa, forsikring, ansvar/forpligtelser)?
    - Clusters?
    - Internationalt samarbejde?
- Hvad har faciliteret netværket af virksomheder og institutioner, som Rambøll samarbejder med om Projektet?
- Hvad har virket i processen?
  (Samarbejder, måder at gøre ting på, *best practices*, fordeling af roller)
- Hvordan sikrer I, at de ideer der opstår og skabes i netværket af virksomheder i projektet ikke blive udnyttet og kopieret (kontraktuelle forhold)?
- Hvad er der kommet ud af projektet indtil videre? Hvad har Rambøll (og projektet) opnået indtil videre?
  Hvordan og hvorfor vil det blive en succes?
  Vil det være 'nyt i verden'/ er det nyt og banebrydende?

Yderligere:

- Har der været nogen problemer og større udfordringer? Hvem? Hvordan er de blevet løst?
- Hvad ville I gøre anderledes?
- Hvem ville videre være interessant for mig at snakke med? Tlf. nr.

13.2 Interview Guide: Bjarke Ingels Group (BIG)

Interview with Kai-Uwe Bergmann, Project Manager and Associate Partner in BIG, 8 July 2010

Zira Island projektet generelt og de involverede parter:

- Hvordan blev projektet startet? Hvem fik ideen? Hvorfor?
- Hvem er parterne i projektet?
    - Hvem er klienten/ investorer?
    - Private aktører:
    - Offentlige aktører (fx videnscentre som DTU):
- Hvilke teknologier bliver brugt?
- Hvad er status på projektet pt.?
- Hvordan bliver projektet finansieret?
- Hvordan fik BIG kontrakten? ('Headhuntet' eller udlicitering?)
    - Hvad er jeres motivation for at være med (udover penge)?
- Hvad karakteriserer BIG?
- Hvad er BIGs bidrag til projektet?
    - Hvad tror du det er, at BIG kan?
        - Specifikke BIG egenskaber?
        - Specifikke danske egenskaber?
- Hvordan ser BIGs Zira-arbejdsgruppe ud?
  Har I jeres egne ansatte med derned eller hyrer I også lokalt?
- Fortæl mig om de andre parter og hvordan/ hvorfor de er involveret?
- Hvordan er forholdet/ sammenhængen imellem de involverede parter?
    - Hierarki? Magtforholdene? Sociale relationer? Bedre forhold til nogle end andre?
    - Projekt struktur
      (tegning/diagram af projektet og hvordan aktørerne er forbundet og arbejder sammen).
    - Hierarki imellem parterne?
    - Hvem koordinerer projektet and hvordan? Hvordan er rollerne blevet fordelt? (officielt eller uofficielt)
    - Arbejder virksomhederne som 'én unit' eller flere selvstændige?
      (er det 'Zira Projektet lavede dette' eller 'BIG lavede dette'?)

Industrien:

- Hvordan vil du beskrive industrien, som omgiver Zira projektet?
- Er der nogen fællesnævnere for de involverede parter?

Innovation og idé-generering i projektet

- Hvordan blev/bliver innovation (nye ideer) genereret og faciliteret i projektet og i BIG generelt?
    - Hvor kommer nye ideer fra? (Arkitektskolen, museer etc.)
    - Hvem er kommet med ideerne?

        - Er der nogle interdisciplinære/ imellem virksomhederne teams som er etableret til at generere ideer/ skabe synergi og arbejde sammen? Eller er det ' hver virksomhed kommer med deres egne ideer'?
- Kunde-dreven innovation: Hvor meget har kunden deltaget i udviklingen og stillet krav til projektet? Er der kommet brugerdreven innovation ud af det?
- Hvordan har I fået den viden, som er brugt i projektet?
    - Er det *ny viden*, som I og de andre parter er kommet op med?
    - *New in the world* (patenter)*? New in the region/country, new in the sector, new in the company?*
        - *Radikal innovation?* Eller en *radical technology shift* i en moden industri*?*
    - Eller *ny kombination af viden*?
- Hvordan genererer og tilegner I jer den viden, som I bruger i projektet? Vidensoverførsel/ vidensdeling, patenter
    - Genererer I selv viden? Har I fået patenter?
    - Samarbejder I med vidensinstitutioner (som fx DTU eller udenlandske universiteter og forskere?) eller andre virksomheder?
        - Er den viden lettilgængelig?

Innovations politikker:

- Hvad er det for en politisk kontekst, som omgiver projektet?
    - Lokale myndigheder
    - Danske myndigheder
    - EU myndigheder
- Hvilke faciliterende eller begrænsende faktorer for projektet er der i dette politiske miljø?
    - Hvad gør jeres arbejde lettere?
    - Hvad begrænser og indsnævrer jeres arbejde?
- Hvilke innovationspolitikker (Danske eller Europæiske) har en positiv effekt på jeres projekt, projekt deltagelse, projekt planlægning, projekt design?
    - Hvilke har en negativ effekt?
        - Hvad har I brug for i en innovationspolitik? Hvilken form for innovationspolitik ville facilitere jeres arbejde og deltagelse i international projekter?
- Hvordan trives BIG i det politiske miljø, som projektet er i?
    - Har BIG fordele?
    - Eller ulemper?
- Hvilke faktorer er relevante for at I kan være innovative? (fx innovationskonsortieideen, det danske uddannelsessystem etc).
    - Har BIG fået offentlig støtte for at blive en del af projektet og i løbet af processen?
    - Er der nogen fremmende initiativer fra regeringen, ministerier eller EU?
- Hvordan påvirker '*spillereglerne'* (fx patent love) BIG og jeres arbejde?
- Har I lobbyet for at blive en del af projektet - og i løbet af processen?
    - Hvis ja, hvordan?

Network og samarbejde:

- Hvilke barrierer har der været for BIGs arbejde og projektet som helhed?
    - Bureaukratiske (lovgivning og politikker)?
    - Kulturelle?
    - Samarbejde?
    - Praktiske (visa, forsikring, ansvar/forpligtelser)?
- Hvad har gjort jeres arbejde og samarbejde nemmere?
    - Bureaukratiske (lovgivning og politikker)?
        - Offentlig støtte (fra den danske regering, EU, Aserbajdsjan)?
    - Kulturelle?
    - Samarbejde?
    - Praktiske (visa, forsikring, ansvar/forpligtelser)?
    - Clusters?
    - Internationalt samarbejde?
- Hvad har faciliteret netværket af virksomheder og institutioner, som BIG samarbejder med om Projektet?
- Hvad har virket i processen?
  (Samarbejder, måder at gøre ting på, *best practices*, fordeling af roller)
- Hvordan sikrer I, at de ideer der opstår og skabes i netværket af virksomheder i projektet ikke blive udnyttet og kopieret (kontraktuelle forhold)?
- Hvad er der kommet ud af projektet indtil videre? Hvad har BIG (og projektet) opnået indtil videre?
  Hvordan og hvorfor vil det blive en succes?
  Vil det være ’nyt i verden’/ er det nyt og banebrydende?

Ydeligere:

- Har der været nogen problemer og større udfordringer? Hvem? Hvordan er de blevet løst?
- Hvad ville I gøre anderledes?

13.3 Interview Guide: Copenhagen Cleantech Cluster

Interview with Nicolai Rottbøll Sederberg-Olsen, Head of Secretariat, and Michael Johansen, Project Development Manager, August 27 2010

Hvad karakteriserer Copenhagen Cleantech Cluster (CCC)

- Vil I definere cleantech som en industri eller sektor?
- Hvad har drevet opstarten af CCC?
- Er CCC politisk drevet?

Karakteristika af dansk cleantech:

- Hvad er cleantech drevet af? I hvor høj
- Hvordan er situationen for dansk cleantech i dag?
- Hvad er det Danmark kan i forhold til cleantech?
- Hvad afgør at danske cleantech virksomheder er innovative (og vækster)? Hvad influerer processerne?
- Hvordan ser finansieringen af dansk cleantech ud?

Netværk og samspil:

- Hvilken rolle tildeler I netværk i innovation og vækst?
- Hvad gør CCC for at støtte dette samspil?

Internationale perspektiver og eksport:

- Hvad er de interntationale perspektiver i jeres netværk og matchmakingordninger?
- Hvad er resultaterne af jeres matchmaking og international outreach aktiviteter?
- Hvad er årsagen til, at danske cleantech virksomheder eksporter so meget?

Forholdet til staten:

- Hvordan ser CCC statens tiltag og indsats?
- Hvordan er forholdet og samarbejdet imellem staten og CCC?
- Hvad faciliterer eller begrønser CCCs arbejde?
- Er der noget institutionelt set der faciliterer jeres arbejde i Danmark?
- Er der noget politisk set, som I godt kunne bruge mere af?
- Hvilken politisk kontekst omgiver sektoren?

Politiske behov:

- Hvad er der brug for i en innovationspolitik, som fremmer cleantech?

13.4 Interview Guide: The Danish Agency for Science, Technology and Innovation

Interview with Thomas Alslev Christensen, Head of Department and Jan Windmüller, Head of Section, 8 August 2010

Hvad karakteriserer DK NIS?

- Hvordan vil I beskrive den danske IS?
    - Hvad er vigtigst?
    - Hvordan er relationerne mellem aktørerne?
- Hvad gør Danmark konkurrencedygtig?

Hvad karakteriserer de danske innovationspolitikker?

- Hvad er det for en 'system failure' I løser? Hvad er det for nogle problemer I hovedsagligt addresserer? Hvad er jeres vigtigste opgave/formål?
    - Hvad er årsagerne til problemet?
        - Hvordan analyserer I årsagerne til problemet? Hvad er det for en tilgang I har til innovationspolitik?
- Hvordan bliver policies til?
- Hvem influerer innovation policies i danmark?
- Hvordan er processen?
- Hvad facilierere og hæmmer jeres arbejde?
- Hvordan er jeres relation/samarbejde/ dialogen med erhvervslivet, academia etc.?
- Hvordan bliver jeres arbejde modtaget?

Fokus på sektorer

- Har I fokus på specifikke sektorer? Hvilke? Hvilke sektorer er mest konkurrencedygtige?

Hvad ser I som det største problem for innovation/ det mest innovationshæmmende i DK?

- Hvad er jeres udfordringer nu?
- Hvad er jeres vigtigske opgave for fremtiden?
    - For DK innovationspolitik
    - For DASTI
- Hvad bliver den største innovationspolitiske udfordring for fremtiden?

Innovationsplanerne

- Hvad har I lært af 2007-2010 planen?

Benchmarking og imitation

- Hvilken rolle spiller benchmarking i DK innovationspolitikker?
- Lærer I af andre lande og "låner" (imitation) innovationspolitisketiltag?

Internationalisering

- Hvordan har globaliseringen påvirket de danske innovationspolitikker?
- af innovationskonsortierne + innovationsnetværk?

- Hvad gør den danske regering og de danske offentlige institutioner for at støtte de danske virksomheder i deres arbejde og derved gøre det nemmere for dem at arbejde i den nye globale kontekst?

Competitive advantage of the Danish companies

- Hvordan spiller det danske innovationssysten (NIS, SIS og RIS) ind på konkurrenceevnen?
- Er der nogle faktorer i det danske samfund og innovationssystem, som skaber og præger virksomhederne i en betydelig grad?
- Hvad er danske virksomheders konkurrencemæssige fordel?
- Nu siger virksomhederne i min case, at deres konkurrencemæssige fordel i forhold til udenlandske konkurrenter bl.a. er, at de er meget kvalitetsbevidste og tænker holistisk på et projekt. Er I enige i dette generelt set? Hvad gør I for at fremme dette?

Culture

- Hvad i den danske kultur influerer (faciliterer eller er en hæmsko) for innovationen?

The political context

Local context – Denmark

- Hvordan influerer den politiske kontekst generelt de danske virksomheder og deres innovation?

EU context

- Hvordan har EU influeret jeres arbejde?
- Er der et spændingsfelt og modstridende politikker mellem jer og EU?

Lobbyisme

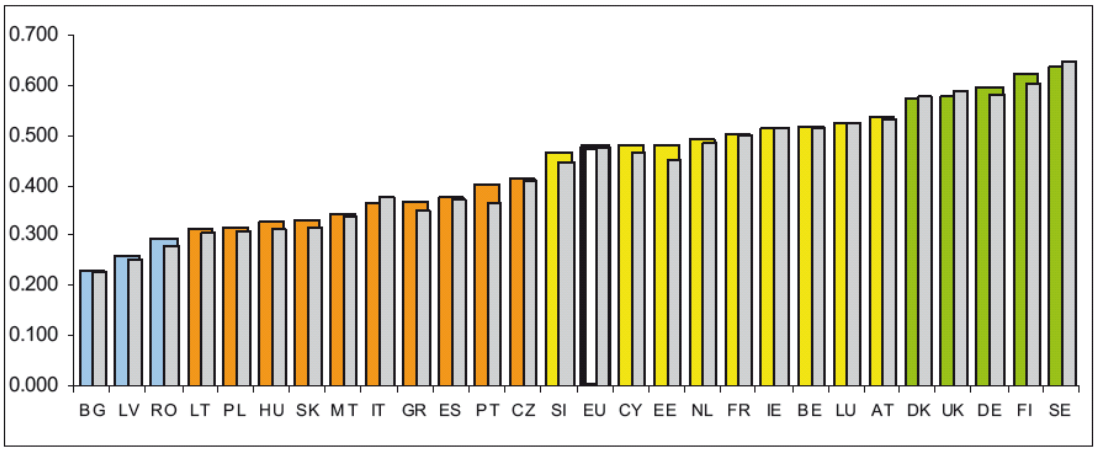
- Bliver DASTI influeret af lobbyister?

13.5 Important activities in systems of innovation

1. Provision of R&D, creating new knowledge, primarily in engineering, medicine, and the natural sciences.
2. Competence building in the labour force to be used in innovation and R&D activities.
3. Formation of new product markets.
4. Articulation of quality requirements emanating from the demand side with regard to new products.
5. Creating and changing organizations needed for the development of new fields of innovation.
6. Networking though markets and other mechanisms, including interactive learning between different organizations (potentially) involved in the innovation processes.
7. Creating and changing institutions that influence innovating organizations and innovation processes by providing incentives or obstacles to innovation.
8. Incubating activities for new innovative efforts.
9. Financing of innovation processes and other activities that can facilitate commercialization of knowledge and its adoption.
10. Provision of consultancy services of relevance for innovation processes.

Source: (C. Edquist, 2004; C. Edquist, 2005)

Summary innovation performance EU27 Member States (2009, Summary Innovation Index)



Note: The Summary Innovation Index (SII) is a composite of 29 indicators going from a lowest possible performance of 0 to a maximum possible performance of 1. The 2009 SII reflects performance in 2007/2008 due to a lag in data availability.

The grey coloured columns show 2008 performance as calculated backward from 2009 using the next-to-last data for each of the indicators. This 2008 performance is not identical to that shown in the EIS 2008 as not for all indicators data could be updated with one year. The difference between the columns for 2008 and 2009 show the most recent changes in innovation performance.

Source: European Innovation Scoreboard (EIS) 2009) (European Commission, 2010b).

13.6 Definitions of indicators (European Innovation Scoreboard 2009)

	Indicators	Numerator	Denominator	Reference year	Source
1.1.1	S&E and SSH graduates per 1000 population aged 20-29 (first stage of tertiary education)	Number of S&E (science and engineering) and SSH (social sciences and humanities) graduates at first stage of tertiary education (ISCED 5)	Population between 20 and 29 years	2006 (2005 for GR, TR; no data for LU)	Eurostat
1.1.2	S&E and SSH doctorate graduates per 1000 population aged 25-34 (second stage of tertiary education)	Number of S&E (science and engineering) and SSH (social sciences and humanities) graduates at second stage of tertiary education (ISCED 6)	Population between 25 and 34 years	2006 (2005 for GR, IT, IS; no data for LU)	Eurostat
1.1.3	Population with tertiary education per 100 population aged 25-64	Number of persons in age class with some form of post-secondary education (ISCED 5 and 6)	Population between 25 and 64 years	2007 (2006 for IS)	Eurostat
1.1.4	Participation in life-long learning per 100 population aged 25-64	Number of persons involved in life-long learning. Life-long learning is defined as participation in any type of education or training course during the four weeks prior to the survey	Population between 25 and 64 years	2007 (2006 for SE, UK, IS, CH)	Eurostat
1.1.5	Youth education attainment level	Number of young people aged 20-24 years having attained at least upper secondary education attainment level, i.e. with an education level ISCED 3a, 3b or 3c long minimum	Population between 20 and 24 years	2007 (2006 for IS, NO, CH)	Eurostat
1.2.1	Public R&D expenditures (% of GDP)	All R&D expenditures in the government sector (GOVERD) and the higher education sector (HERD). Both GOVERD and HERD according to the Frascati-manual definitions	Gross Domestic Product	2008 (2007 for GR, TR, RS; 2006 for CH)	Eurostat
1.2.2	Venture capital (% of GDP)	Venture capital investment is defined as private equity being raised for investment in companies. Management buyouts, management buyins, and venture purchase of quoted shares are excluded. VC includes Early stage (seed + start-up) and Expansion and replacement (expansion and replacement capital) capital	Gross Domestic product	2007 (2005 for SK; no data for BG, EE, CY, LV, LT, LU, HU, MT, SI, TR, IS) Two-year averages are used (cf. EIS 2008 Methodology Report)	EVCA / Eurostat
1.2.3	Private credit (relative to GDP)	Claims on the private sector by commercial banks and other financial institutions that accept transferable deposits such as demand deposits (line 22d of IMF International Financial Statistics)	Gross Domestic Product (line 99b of IMF International Financial Statistics)	2007 (2006 for RO, IS)	IMF
1.2.4	Broadband access by firms (% of firms)	Number of enterprises (excluding the financial sector) with 10 or more employees with broadband access	Total number of enterprises (excluding the financial sector) with 10 or more employees	2007 (2006 for IS; 2005 for CH)	Eurostat
2.1.1	Business R&D expenditures (% of GDP)	All R&D expenditures in the business sector (BERD), according to the Frascati-manual definitions	Gross Domestic Product	2008 (2007 for GR, TR, RS; 2004 for CH)	Eurostat

	Indicators	Numerator	Denominator	Reference year	Source
2.1.2	IT expenditures (% of GDP)	Total expenditures on IT. IT expenditures capture hardware, software and other services. The data cover the total market, including expenditure of the public and private sector (enterprises, as well as those of individuals and households)	Gross Domestic Product	2006 (no data for CY, LU, MT, TR, IS)	EITO / Eurostat
2.1.3	Non-R&D innovation expenditures (% of turnover)	Sum of total innovation expenditure for enterprises, in national currency and current prices excluding intramural and extramural R&D expenditures	Total turnover for all enterprises	2006 (2005 for CH; 2004 for DE, GR, FR, IT; no data for LV, AT, FI, UK, IS)	Eurostat
2.2.1	SMEs innovating in-house (% of SMEs)	Sum of SMEs with in-house innovation activities. Innovative firms are defined as those firms which have introduced new products or processes either 1) in-house or 2) in combination with other firms	Total number of SMEs	2006 (2005 for CH; 2004 for DK, GR, FR, IT, SE, NO; no data for LV, LU, MT, SI, UK, IS)	Eurostat
2.2.2	Innovative SMEs collaborating with others (% of SMEs)	Sum of SMEs with innovation co-operation activities. Firms with co-operation activities are those that had any co-operation agreements on innovation activities with other enterprises or institutions in the three years of the survey period	Total number of SMEs	2006 (2005 for CH; 2004 for GR, FR, IS, NO)	Eurostat
2.2.3	Firm renewal (SMEs entries + exits) (% of SMEs)	Sum of the number of births and deaths of SMEs. Only SMEs with at least 5 employees and who are active in NACE classes C, D, E, G51, I, J and K are included	Total number of SMEs	2005 (2004 for CZ, IT, LU, HU, NL, PT, SK, FI, CH; 2003 for SI; 2002 for LT; 2001 for NO; no data for BE, BG, DK, DE, IE, GR, FR, CY, MT, AT, PL, TR, IS)	Eurostat
2.2.4	Public-private co-publications per million population	Number of public-private co-authored research publications in the Web of Science database. The definition of the "private sector" excludes the private medical and health sector. Publications are assigned to the country/countries in which the business companies or other private sector organisations are located	Total population	2006 Two-year averages are used (cf. EIS 2008 Methodology Report)	Thomson Reuters / CWTS
2.3.1	EPO patents per million population	Number of patents applied for at the European Patent Office (EPO), by year of filing. The national distribution of the patent applications is assigned according to the address of the inventor	Total population	2005	Eurostat
2.3.2	Community trademarks per million population	Number of new community trademarks. A trademark is a distinctive sign, identifying certain goods or services as those produced or provided by a specific person or enterprise	Total population	2007	OHIM / Eurostat
2.3.3	Community designs per million population	Number of new community designs. A registered Community design is an exclusive right for the outward appearance of a product or part of it, resulting from the features of, in particular, the lines, contours, colours, shape, texture and/or materials of the product itself and/or its ornamentation	Total population	2007	OHIM / Eurostat
2.3.4	Technology Balance of Payments flows (% of GDP)	Royalty and license fees, receipts (Balance of Payments, current US$) plus Royalty and license fees, payments (Balance of Payments, current US$)	Gross Domestic Product (current US$)	2006 (2005 for AT; 2004 for TR; 2003 for SK; no data for DK)	World Bank

	Indicators	Numerator	Denominator	Reference year	Source
3.1.1	SMEs introducing product or process innovations (% of SMEs)	Number of SMEs who introduced a new product or a new process to one of their markets	Total number of SMEs	2006 (2005 for CH; 2004 for GR, FR, MT, NO; no data for IS)	Eurostat
3.1.2	SMEs introducing marketing or organisational innovations (% of SMEs)	Number of SMEs who introduced a new marketing innovation and/or organisational innovation to one of their markets	Total number of SMEs	2006 (2004 for BE, GR, ES, FR, IT, SK, NO; no data for LV, SI, FI, SE, IS, CH)	Eurostat
3.1.3	Resource efficiency innovators, unweighted average of the following 2 indicators:				
	• Reduced labour costs (% of firms)	Number of innovating firms who replied that their product or process innovation had a highly important effect on reducing labour costs per unit of output	Total number of innovating firms	2006 (2004 for BE, DE, IE, GR, FR, IT, SI, IS, NO; no data for UK, CH)	Eurostat
	• Reduced use of materials and energy (% of firms)	Number of innovating firms who replied that their product or process innovation had a highly important effect on reducing materials and energy per unit of output	Total number of innovating firms	2006 (2004 for BE, DE, IE, GR, FR, IT, SI, SE, IS, NO; no data for UK, CH)	Eurostat
3.2.1	Employment in medium-high & high-tech manufacturing (% of workforce)	Number of employed persons in the medium-high and high-tech manufacturing sectors	Total workforce	2007 (2006 for HR, IS)	Eurostat
3.2.2	Employment in knowledge-intensive services (% of workforce)	Number of employed persons in the knowledge-intensive services sectors	Total workforce	2007 (2006 for HR, IS)	Eurostat
3.2.3	Medium and high-tech manufacturing exports (% of total exports)	Value of medium and high-tech exports	Value of total exports	2006 (2005 for TR)	Eurostat
3.2.4	Knowledge-intensive services exports (% of total services exports)	Exports of knowledge-intensive services are measured by the sum of credits in EBOPS (Extended Balance of Payments Services Classification) 207, 208, 211, 212, 218, 228, 229, 245, 253, 254, 260, 263, 272, 274, 278, 279, 280 and 284	Total services exports as measured by credits in EBOPS 200	2006 (2005 for IE, FI; no data for ES, FR, IT)	Eurostat
3.2.5	New-to-market sales (% of turnover)	Sum of total turnover of new or significantly improved products for all enterprises	Total turnover for all enterprises	2006 (2005 for CH; 2004 for GR, FR, SE, IS, NO)	Eurostat
3.2.6	New-to-firm sales (% of turnover)	Sum of total turnover of new or significantly improved products to the firm but not to the market for all enterprises	Total turnover for all enterprises	2006 (2005 for CH; 2004 for GR, FR, SE, IS, NO)	Eurostat

Source: (European Commission, 2010b)

13.7 Intramural R&D in Denmark (million DKK), 2007

2007: Sector of Performance	Total intramural R&D:	Total intramural R&D			
Source of funding	Million National Currency	Business enterprise	Government	Higher education	Private non-profit
Intramural R&D	43,205.6	30,028.0	1,416.0	11,552.6	209.0
Business enterprise	26,166.4	25,854.0	8.4	246.6	57.4
Government	11,218.3	745.0	1,174.1	9,259.9	39.3
Direct government	4,083.8	745.0	1,174.1	2,125.4	39.3
General university funds	7,134.5	..	..	7,134.5	..
Higher education	113.6	..	0.0	113.6	0.0
Private non-profit	1,533.9	98.0	86.1	1,256.7	93.1
Funds from abroad	4,173.4	3,331.0	147.4	675.8	19.2
Foreign Business Enterprises	2,991.9	2,893.0	8.0	90.5	0.4
Enterprises within same group	..	2,428.0	..	..	..
Other business enterprise companies	..	465.0	..	..	..
Other National Governments	26.3	..	9.0	17.3	..
Private non-profit	201.0	201.0	..	..	..
European Commission	612.5	140.0	82.3	383.9	6.3
Not elsewhere classified	341.7	97.0	48.1	184.1	12.5

Source: Statistics Denmark, Dansk Center for Forskningsanalyse

13.8 Intramural R&D financed abroad by number of persons engaged in Danish industry, 2003 and 2005

	Percentage share of intramural R&D financed abroad		Percentage of total intramural R&D financed abroad	
	2003	*2005*	*2003*	*2005*
Total in million DKK	*2,997*	*2,956*		
Persons employed			..	..
Total	100	100	12	11.4
1 to 9	1	0.8	2.8	3.4
10 to 49	5.6	6.5	6.3	6
50 to 249	13.6	11.6	10.6	9.4
250 to 499	6.7	1.6	6.5	2.1
500 to 999	24.1	22.7	16.7	19.6
1000 and more	49	56.8	14.8	13.2

Source: Eurostat and Statistics Denmark, Dansk Center for Forskningsanalyse

13.9 Extramural R&D in Denmark (million DKK), by industry and firm size, 2006

	Total	*of which:*		
		Same enterprise group	Other enterprises	public institutions
Total	7,885	1,548	2,756	80
By industry				
Manufacturing	4,893	1,107	2,437	66
Of which:				
High tech	4,448	1,013	2,422	58
Medium tech	90	52	2	1
Low tech	354	41	13	7
Knowledge intensive services	586	121	12	1
Other services	2,406	321	308	13
By firm size				
1 to 29	1,743	64	561	17
50 to 249	1,264	386	149	21
250 to 999	1,115	380	124	10
1000 or larger	3,763	705	1,936	32

Source: Statistics Denmark, Dansk Center for Forskningsanalyse

13.10 DCTI's vision and mission (the 2010-2013 Action plan)

Vision: Create an innovative nation	Mission: Getting innovation goals
That Denmark can legitimately call itself an innovative nation by 2020. Private and public production and service companies should again be among the most competitive and innovative in the world. The Council wishes to contribute to solving major societal challenges and support the development of new forms of innovation in Danish industry through widespread use of new knowledge and technology.	DCTI's mission is to: • Initiate and facilitate business-relevant research at Danish universities together with technology, new knowledge and applied research at the Approved Technological Service Institutes (GTS institutes) • Provide a good framework for collaboration, knowledge dissemination and sharing of knowledge between knowledge institutions and enterprises • Enable the commercialisation and exploitation of knowledge and research • Increase the international cooperation on knowledge and technology for the benefit of Denmark.

Source: Translated from (The Danish Agency for Science, Technology and Innovation, 2010)

13.11 DCTI's focus areas and measures (the 2010-2013 Action plan)

Focus area 1	Focus area 2	Focus area 3	Focus area 4
Collaboration between business and research	Access to high skilled workforce	Technological services	Commercialisation of research
Measures: National Competence and Innovation Networks Innovation projects: • Innovation Consortia Scheme • Innovation voucher scheme • New forms of collaboration	**Measures**: • Knowledge Pilot scheme • Industrial PhD scheme	**Measures**: • Nine Approved Technological Service Institutes (the GTS-institutes)	**Measures**: • Proof of Concept • Innovation Incubator scheme • Technology transfer activities

Cross-disciplinary efforts				
Evaluation and impact measurement	Service innovation and the public sector	Future production in Denmark	Internationalisation	SME Strategy

Source: Adopted from (Christensen, May 2010; The Danish Agency for Science, Technology and Innovation, 2010)

13.12 DASTI's Innovation Consortia Scheme

In the innovation consortia these actors cooperate on a project financed by the DCTI. According to DCTI and DASTI the innovation consortia are, among other things, catalysts for several new initiated innovation projects. DCTI and DASTI state that the innovation consortia lead to a significantly higher gross profit (compared to a control group of companies that have not participated in the consortia); they lead to a clearer understanding, within companies, of their own technologies and new uses for existing technologies; they result in greater use of knowledge from university research, greater focus on business needs from the Approve Technological Service Institutes (GTS) and universities; and a better ability for the participating companies to collaborate and network externally (with both research organisations and other enterprises (Forsknings- og Innovationsstyrelsen, 2010a; Forsknings- og Innovationsstyrelsen, 2010b).[31]

[31] These outcomes of the innovation consortia are highlighted on the basis, that they have received the highest response rate in DCIT and DASTI's own evaluation of the innovation consortium system's effects (Forsknings- og Innovationsstyrelsen, 2010b).

13.13 Energy and environment technologies (EnergyMap)

	Technologies
Renewable Energy*	Biofuel Technologies
	Biogas
	Biomass
	Geothermal Energy
	Hydropower
	Other Renewable Energy Technologies
	Photovoltaics*
	Solar Thermal Energy*
	Waste Incineration
	Wave Power*
	Wind Power*
Energy Efficiency*	Building Materials*
	Chemical and Biological Technologies
	Circulator Pumps
	Cooling/ Refrigeration
	Fire Fighting
	Industrial Equipment and Processes
	Lighting
	Low-Energy Buildings*
Efficient Energy Production	Carbon Capture and Storage
	Combines Heat and Power Plants
	Efficient Gas Furnaces
	Efficient Natural Gas Technologies
	Efficient Oil Extraction
	Energy-Efficient Power Plants
	Fuel Cells
	Heat Pumps
	Micro Combined Heat and Power Plants
	Other Efficient Energy Production Technologies
Infrastructure and Energy Carriers	District Heating and Cooling
	Energy Systems and Planning
	Hydrogen-Related Technologies
	Other Infrastructure/ Energy Carrier Technologies
	Pipes, Hoses and Cables
	Power Electronics and Electronic Devices
	Specialised Containers
Intelligent Energy*	Intelligent Buildings*
	IT Systems
	Other Intelligent Energy Technologies
	Plug-in and Electrical Vehicles

	Smart Grid
Environmental Technologies*	Air Quality
	Flue and Waste Gas cleaning
	Other Environmental Technologies
	Process Optimisation
	Resource Efficiency
	Soil Quality
	Substitution of Hazardous Chemicals
	Waste Utilisation
	Water Quality and Treatment*
Climate Adaptation	Agriculture and Food Security
	Coast Protection
	Drought Mitigation
	Flood Management
	Other Climate Adaptation Technologies
	Sewerage

The technology areas and technologies marked with * are used in the Zira project.

Source: (Energy Map & Climate Consortium Denmark, 2010)

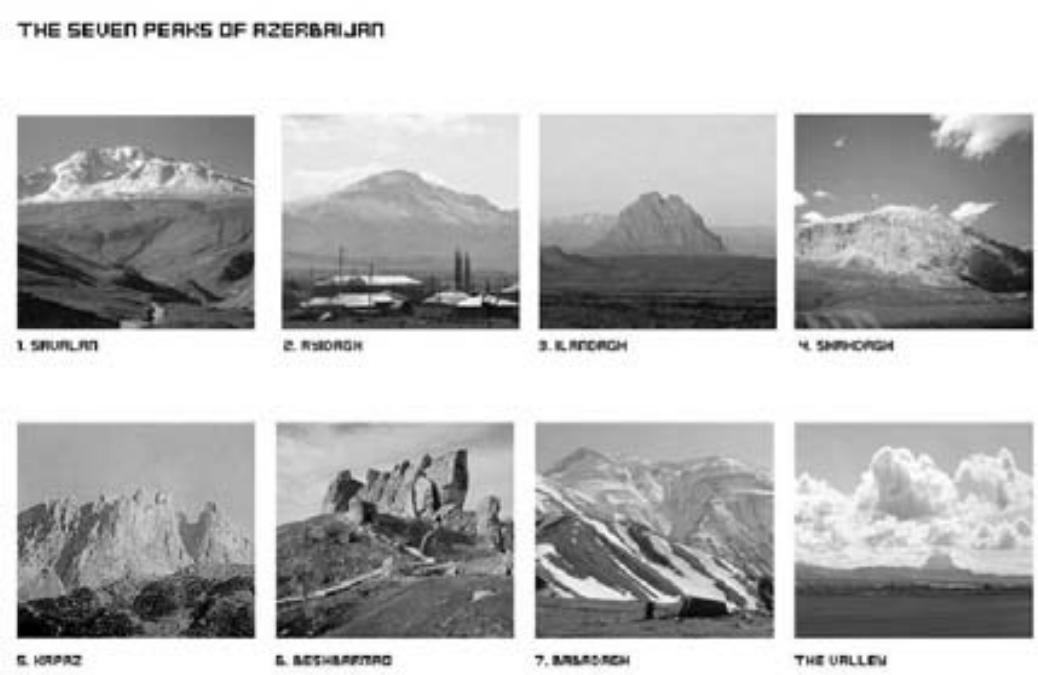
13.14 Cleantech R&D funding possibilities through the EU

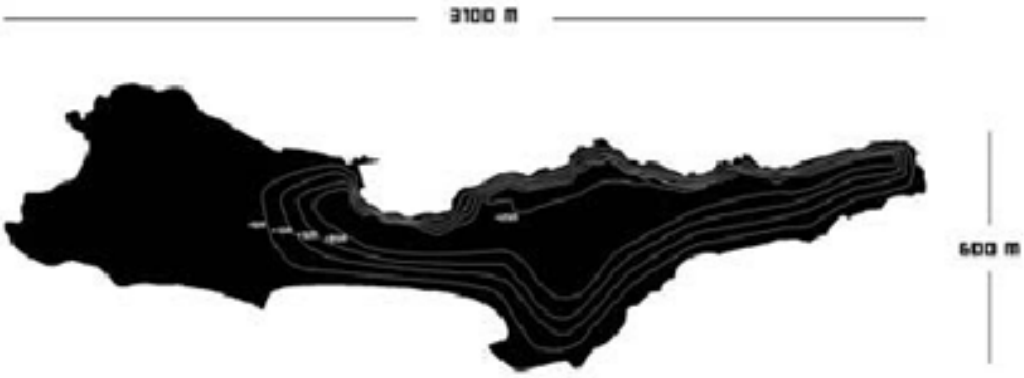
Competitiveness & Innovation Framework Programme (CIP)
Competitiveness & Innovation Framework Programme (CIP) With small and medium-sized enterprises (SMEs) as its main target, the CIP supports innovation activities (including eco-innovation), provides better access to finance and delivers business support services in the regions
Seventh Framework Programme
The EU's Seventh Framework Programms for research (FP7) give out more than 50 billion Euro for research in the period 2007 to 2013
Eurostars
Eurostars is a funding possibility for SMEs involved in research and development
Life+
Life+ is a European funding programme supporting environment and natural environment protection
Marco Polo II
Marco Polo II is a European funding initiativ supporting projects that reorganises cargo transport from trucks to trains or ships
Nordic Environment Finance Corporation (NEFCO)
NEFCO finances investments and projects primarily in Russia, Ukraine, Estonia, Latvia, Lithuania and Belarus, in order to generate positive environmental effects of interest to the Nordic region
Nordic Innovation Center (NICe)
The Nordic Innovation Center is governed by the Nordic Council of Ministers and is an instrument for promoting innovation within environmental technologies

Source: (DI - Organisation for erhvervslivet, 2010) and the European Commission

Note: The accessibility has however not been assessed and whether they would be beneficial for the Danish cleantech projects and cleantech companies.

13.15 The Zira project

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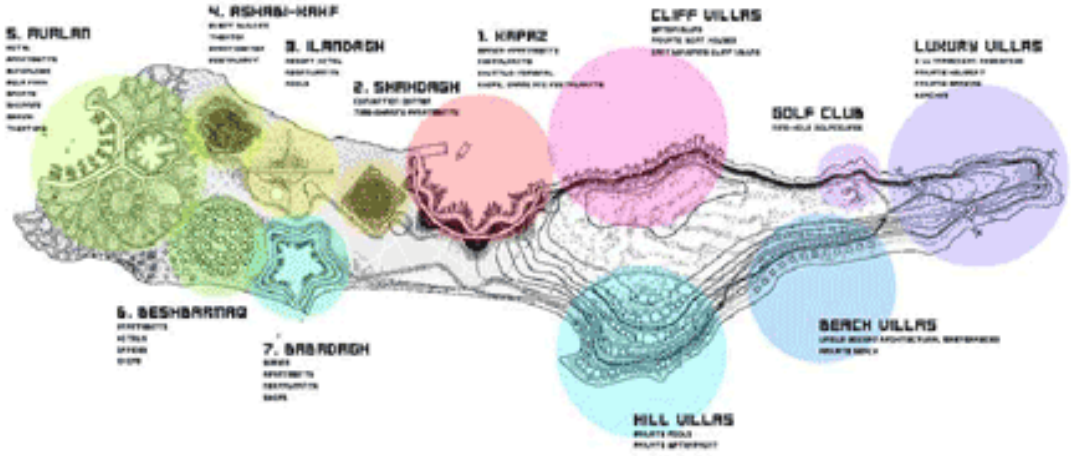
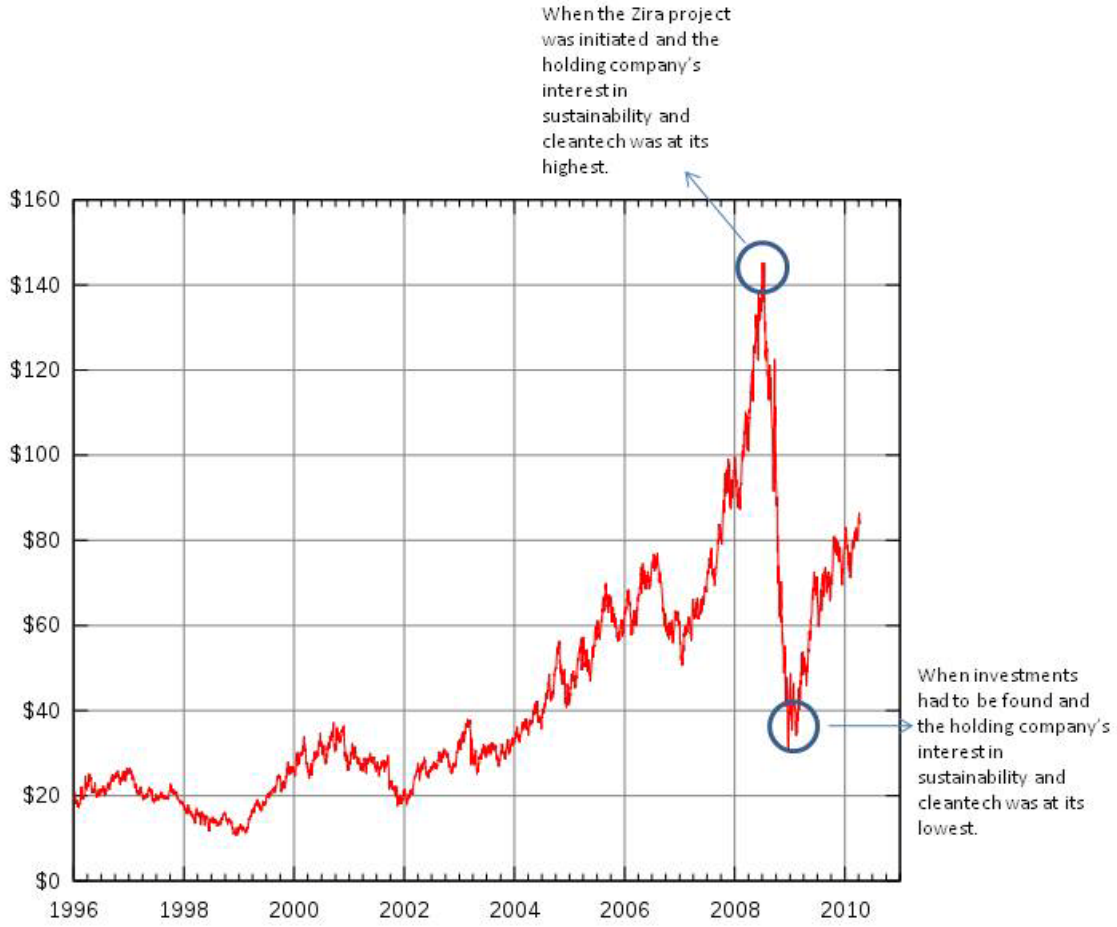

4. ASHRAF-KHAF
5. AURAN
3. ILANDARH
1. KAPAZ
CLIFF VILLAS
LUXURY VILLAS
2. SHAHDARH
GOLF CLUB
6. BESHBARMAQ
7. BARADARH
BEACH VILLAS
HILL VILLAS

13.16 Cleantech technologies in the Zira project

Sun	Wind	Water
"The buildings of the island are heated and cooled by heat pumps connecting to the surrounding Caspian Sea. Solar heat panels integrated in the architecture create a steady supply of hot water, while photovoltaics on strategically located facades and roof tops power daytime functions as swimming pools and aqua parks."	"Zira Zero Island benefits from the fact that Baku is "the city of wind". By harvesting the wind energy through an offshore wind farm, the island will have its own CO2-neutral power supply. Further by locating the wind turbines on sea, it transforms the existing offshore oil industry's platforms & foundations in Baku into a more sustainable future of wind turbine platforms."	"Waste water and storm water is collected and led to a waste water treatment plant, where it is then cleaned, processed and recycled for irrigation."

Source: BIG – Bjarke Ingels Group

13.17 Fluctuating oil prices and the Zira project



Y-axis: Dollars per barrel for NYMEX sweet light crude WTI X-axis: year