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Sustainable energy in North-Brabant
towards a wider adoption through SME entrepreneurs

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Sustainable Energy in North-Brabant

Towards a wider adoption through SME entrepreneurs

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Abstract

In this research barriers to sustainable energy in North-Brabant are evaluated with a focus on entrepreneurs who offer solutions on sustainable energy and that operate in the region. It was found that the most dominating type of barriers were of financial-, institutional/regulatory- and informational nature. According to researchers of innovation systems, the degree of entrepreneurial activities is a good indicator of how good the system is. Several activities exist that in turn affect these entrepreneurial activities and have been called innovation functions. The province and other stakeholders in the search for more sustainable energy in North-Brabant will do well by focussing on the innovation functions that affect the dominating barriers, particularly the resource mobilization, guidance of the search, knowledge development and knowledge diffusion.

"Busca un buki boso lesa"

Luisa Avelina Rasmijn Kock †

This was an often used saying by my grandma when as a kid together with cousins and friends we were doing things that she considered rather unproductive. It is in the language of Papiamento and means literally: go find yourselves a book to read.

Preface

This master thesis was written as part of the final assignment for the MSc program Innovation Management at the University of Technology in Eindhoven. It was conducted at the group of Technology, Innovation and Society which is part of the school of Innovation Sciences.

It has been a great challenge to tackle such a broad topic, as is sustainable energy and I will admit that it has actually helped shape my career plans significantly. In retrospect it is interesting to note how the focus on energy subjects during my previous study of mechanical engineering slowly grew towards a deep interest in sustainable energy ultimately leading to this thesis.

I would like to express my gratitude to both my supervisors, A.J.D Lambert and J.M.N van Kasteren for their always constructive critique and their patience. Furthermore also a special thanks to my family, especially my parents, sister and aunt "Theré" who always supported me through all the years of being a student. Lastly but not least I would like to thank my friends both in the Netherlands as those abroad for their words of motivation and the many occasions of long-lasting discussions on the subject of sustainable energy.

Andrew E. Rasmijn, 29 November 2010

Summary

Introduction

In recent years the topic of sustainability and especially sustainable energy has become a "hot topic" in many countries. While many would agree on the importance of generating and transporting energy in a sustainable manner in order to protect the environment it is the dramatic peak in oil prices during 2006/2007 that contributed to the increased interest. It showed how sensitive many countries' economies actually are to fluctuations in oil prices. In the Netherlands this is also the case and a quick scan on the internet will reveal countless activities and efforts both within the research as in the practitioner's communities.

In the Dutch province of North-Brabant there is also attention to sustainable energy. Recently the energy agenda for 2010-2020, *Energie transitie als kans voor innovatie en duurzaamheid*, was published. In the agenda the case is made for the potential economic benefits for the province that the transition towards sustainable energy systems can bring about. The knowledge oriented nature of the province is presented as one of the main driving factors behind this transition. There is definitely no lack of good intentions but the reality shows however that there is still a long way to go before sustainable energy technologies become more widely adopted. One important group related to this but which is rarely given attention is the group of SME entrepreneurs. In this study the focus lies on these entrepreneurs who sell sustainable energy technologies and offer related services like advice and installation.

Research questions

Sustainable energy systems can be seen as innovation systems and innovation is one of the important requirements for the energy transition to take place. Without entrepreneurs however there can be no innovation systems. This also includes those operating at the SME level. In the Netherlands there is a considerable capacity for knowledge creation. This knowledge however does not seem to sufficiently reach the implementation stage where entrepreneurial activities can lead to a wider adoption of innovation systems. One of the goals of this study is to better understand the factors that slow down the adoption of sustainable energy technologies in North-Brabant and to contribute to knowledge on how to overcome these barriers, particularly with the focus on SME entrepreneurs. The main research questions are thereby formulated as follows:

Research Question 1: *What are the barriers for sustainable energy deployment in North-Brabant?*

Research Question 2: *What can be done to help entrepreneurs in overtaking the barriers to the adoption of sustainable energy systems in North-Brabant?*

These questions are answered through a set of sub-questions by looking at barriers to sustainable energy that have been documented in literature, and through communications with experts and a group of entrepreneurs that operate in North-Brabant. Findings from innovation systems theory form the framework in which the second question is answered.

Theoretical background and research framework: Innovation functions

In the fourth national environmental policy plan (NMP4), presented in 2001 by the Dutch government it is argued that fundamental change is necessary in the economic, technological, socio-cultural, and institutional fields for the transition towards more sustainable energy systems to become possible. Two key terms used in this plan are that of transition and system innovation. Theories behind these two terms form the groundwork for research on socio-technical change which is what a transition towards sustainable energy actually is. Within the research of innovation systems several approaches have been adopted though the years, e.g., national systems of innovations, regional systems of innovation, technological innovation systems and sectoral systems of innovation. For the study of socio technical change it is the technological innovation system approach that appears to be the favorite among scholars. The other approaches are considered too broad and complex to allow for practical implications. Scholars have therefore come up with the concept of innovation functions where it is posited that there are activities or events that affect innovation systems. One of the recent sets of functions is the following:

1. Entrepreneurial activities;
2. Knowledge development;
3. Knowledge diffusion through networks;
4. Guidance of the search;
5. Market formation;
6. Resource mobilization;
7. Creation of legitimacy

These functions do not necessarily affect an innovation system individually but they interact with each other. Positive interactions are called virtuous cycles. Negative interactions on the other hand are called vicious cycles.

Barriers

Sustainable energy is a broad subject which is why a distinction was made between barriers to energy efficiency and barriers to renewable energy separately. This is an often used “break down” of the sustainable energy subject among scholars and practitioners. The barriers were categorized in the following set of barriers:

1. Market barriers/ failures (MB);
2. Economic and financial constraints (EFB);
3. Institutional and regulatory barriers (IRB);
4. Technological barriers (TB);
5. Lack of awareness and information (informational barriers: IB);
6. Behavioral barriers (BB)

Research into literature and experts showed that all of the barrier categories were present for both the areas of energy efficiency and renewable energy. However the financial-, institutional/

regulatory- and informational barriers were the most prevalent. Inquiry with regional entrepreneurs produced similar results.

Recommendations

Recommendations from this study stem from the second research question which focused on what should be done to help the entrepreneurs overcome the barriers that they encounter in their field. This will also contribute to the provincial goals of increasing the amount of sustainable energy in North-Brabant. First of all the use of the innovation functions as a policy assessment tool can help policymakers get a view on how “healthy” the transition towards more sustainable energy is in the province. These would make for great research topics for the universities in the region, further building on the creation of knowledge that is so important in North-Brabant.

The diffusion of knowledge needs to be closely guided to ensure that the right type of information is available to the right recipient at the right time. A more central way of communicating with the different groups of interest might be interesting. This is not the sole responsibility of the province but of the entrepreneurs themselves should also get involved.

Continuing on the involvement of the entrepreneurs, they can form coalitions to better interact with the province and reach potential markets more effectively, something that proved highly successful in Germany. Also instead of relying too much on subsidies, more creative financial alternatives should be explored. Performance based contracting and third party financing, “green loans” are possible solutions.

Table of contents

1. Introduction

1.1 Background

Sustainable energy is probably one of the most important categories in the concept of sustainable development. Few other activities affect the environment, and therefore humans, as the constant increase in energy consumption (Omer, 2008). Just like sustainable development, sustainable energy lacks a single widely accepted definition. Part of the difficulty with this is because of the many discussions on what should be accepted as sustainable energy, e.g., nuclear power, biomass crops cultivation. Some recent definitions are:

1. *Energy that indefinitely endures the type and level of energy services provided and has an extraction, transformation, transportation, and consumption process that is benign to humans and ecosystems* (Jaccard, 2005)

2. *Energy from an energy system that is cost-efficient, reliable, and environmental friendly while making optimal use of local opportunities* (Alanne and Saari, 2006)

3. *Energy from renewable sources, with zero or at least no 'new' CO_2 emission during generation* (Ministerie van Economische Zaken [MEZ], n.d.)

From these definitions it is notable how the definition by the Dutch ministry of economic affairs only includes energy from renewable sources. It would appear that measures for energy efficiency are not considered at all as being part of sustainable energy in the Netherlands. This is interestingly in contrast with the concept of Trias Energetica (discussed in chapter 2) which is widely accepted in the Netherlands. The concept of Trias Energetica is even advocated by NL Agency (formerly SenterNovem), which is a sub-division of the ministry of economic affairs. It is also interesting to note that more subsidy funds in the Netherlands are allocated to renewable energy technologies than to energy efficient measures. In general however scholars and professionals in the Netherlands and also internationally seem to favor the notion that sustainable energy comprises both efficient energy systems and renewable energy. While defining such a concept (or rather achieving more general consensus) could prove to be difficult it is an even more difficult task to achieve the actual adoption of sustainable energy systems. This is the main underlying theme for this study.

The concept of "sustainable energy" has been getting an increasing amount of attention over the years in the Netherlands, not just because of the environmental benefits but also because of the potential economic benefits and job creation opportunities. In the Fourth Dutch National Environmental Policy Plan (NMP4) it is recognized that fundamental change is needed at the technological, economic, socio-cultural and institutional levels (VROM, 2001). These types of changes would have to come about through long transitional periods leading to new energy systems. Energy policy in the Netherlands is the responsibility of the ministry of economic affairs.

The targets that have been set by the government for 2020 are mostly in line with the goals at the European level. The "schoon en zuinig" programme states three main targets (VROM, 2007) for sustainable energy:

- The reduction of greenhouse gasses, namely CO_2 emissions by 30% by 2020 relative to 1990;
- Increase the annual energy savings from 1% to 2% (note: it was unclear how these values were to be understood;
- Increase the share of renewable energy to 20% of total energy consumption.

As of 2009, the share of renewable energy in the total energy consumption in the Netherlands was approximately 3,8% (CBS, 2010). While there has been a steady increase during the years (see table 1.1) there exists skepticism as to whether the targets for 2020 can be met. According to a joint study by Planbureau voor de leefomgeving and the Energy Research Centre of the Netherlands these targets will most likely not be met despite the relatively positive effects of the policies by the government (PBL, 2010).

Table 1.1: Percentage of consumed energy from renewable sources (CBS, 2010)

Year	1990	1995	2000	2005	2006	2007	2008	2009
%	0.6	0.7	1.2	2.4	2.7	2.8	3.3	3.8

North-Brabant

In line with the national ambitions, sustainable energy is also on the agenda in the southern province of North-Brabant. In the strategic goal "*Klimaat en duurzame energieopwekking*" the province calls for a decrease of dependence on fossil fuels and having a sustainable energy supply in the future. This strategic goal is part of a programme called "*Schoon Brabant*" which aims at offering people the opportunity to live in a clean and healthy environment (Provincie Noord-Brabant, 2007). In the recently published energy agenda for the province, "*Energie transitie als kans voor innovatie en duurzaamheid*" provincial officials reiterated the province's role as that of an organizer that oversees initiatives, connects related parties with each other and brings down barriers for the diffusion of sustainable energy (Provincie Noord-Brabant, 2010).

The transition towards sustainable energy systems in North-Brabant is seen as an opportunity for economic benefit for the province and those who live and work there; especially given the amount of knowledge and business activities that are present in the region, i.e., universities, high tech firms, automotive and manufacturing/process industries. One group that is at the forefront of the adoption of sustainable energy technologies but is rarely given attention is the group of entrepreneurs who have those technologies or related services in their business portfolio. Entrepreneurs come in different types and their business can include large and/or small and medium enterprises (SME). In this study the focus will be on the entrepreneurs from SME's who sell sustainable energy technologies and offer related services like advice and installation.

1.2 Entrepreneurial activities

In the recent energy agenda for North-Brabant (Provincie Noord-Brabant, 2010) entrepreneurs are mentioned as part of the stakeholders who can help with knowledge generation and diffusion. They play an important role as the direct links between developers and end users of sustainable energy technologies. It was found through contact with entrepreneurs that operate in North-Brabant that according to them there are still many issues to be resolved for North-Brabant to experience a wider adoption of sustainable energy technologies. The stimulation of entrepreneurial activities (other than developers) should perhaps also become an important topic for provincial authorities. As Hekkert and Negro (2009) put it, without entrepreneurs there would be no innovation systems. This should apply to both those who develop the technologies as those who sell and install them. The role of entrepreneurs is of high importance for the diffusion of sustainable energy solutions. In their study on innovation systems Hekkert and Negro (2009) found through an assessment of cases in the Netherlands and Germany that technology diffusion correlated closely with entrepreneurial activities. This would make the amount of entrepreneurial activities a suitable indicator for the "health" of an innovation system. By creating a climate in which entrepreneurs can thrive, sustainable energy solutions should experience a more rapid diffusion. This would not only lead to the province being a step closer to the energy targets for 2020 and 2040 but it would also create new knowledge to be fed back to developers, researchers, manufacturers and policymakers.

1.3 Scope and research questions

Despite a seemingly growing interest in sustainable energy things are slow to get started and entrepreneurs are not happy with the current situation. In her research Negro (2007) found that while in the Netherlands a lot of activities occur to create knowledge and share this knowledge, little is done to stimulate entrepreneurial activities. One of the goals of this study is to get a better understanding of factors that stand in the way of adoption of technologies that would otherwise enable a more sustainable energy system for North-Brabant, particularly for entrepreneurs who are offering sustainable energy solutions to businesses and private users. The first research question (RQ1) is thereby formulated as follows:

RQ 1: *What are the barriers for sustainable energy deployment in North-Brabant?*

By knowing what is holding back the adoption of sustainable energy the province, interest groups and entrepreneurs can work better toward overcoming them. The topic of sustainable energy however is broad and barriers can be formulated in different ways, depending on who is experiencing them. In order to answer the first question a couple of sub-questions are analyzed in the remainder of this report. These sub-questions (SQ's) also give structure to the barrier identification part of this study.

SQ 1.1: What is a practical and clear way to break down the concept of sustainable energy technologies into clear and groups or sectors?

SQ 1.2: How can the barriers best be grouped into a clear set of categories?

SQ 1.3: What are the critical barriers-types for sustainable energy in North-Brabant according to existing knowledge?

SQ 1.4: What do the entrepreneurs who operate in North-Brabant themselves experience as barriers to a wider adoption of sustainable energy technology?

SQ 1.5: Does the experience from entrepreneurs coincide with existing knowledge?

The first research question and sub-questions comprise the first part of this study and are essentially descriptive in nature. The second part is more prescriptive by looking at what can be done about the barriers.

RQ 2: *What can be done to help entrepreneurs in overtaking the barriers to the adoption of sustainable energy systems in North-Brabant?*

The notion of transition management and particularly innovation systems has been widely embraced in the Netherlands by the government and interest groups. The Dutch government even established a platform called “energie transitie” or “energy transition” with the goal of promoting innovations on sustainable energy in different societal domains. The second research question is analyzed via findings from innovations system theory. Just like with the first research question the second question is assessed through some sub-questions.

SQ 2.1: What does recent theory tell us about innovation systems?

SQ 2.2: How does the recent theory about innovation systems relate to the findings from the first research question?

1.4 Relevance of research

Decision- and policy makers have to deal constantly with a large amount of information. Based on information that they are able to gather or come across they take decisions that affect the community on several levels (social, economical, cultural, environmental), sometimes for many years. They have to deal with conflicting expert views on issues and many times decisions are made only to be retracted afterward after protests from interest groups. The case for wind turbines in North-Brabant is a good example for this. While having a though job their decision influence not only the citizens but also the entrepreneurs.

Entrepreneurs are essentially on of the few groups that are in direct contact with end users. Since the transition towards a new energy system means that sustainable energy systems will have to be adopted by end users, whether these are businesses or private customers, it is evident that entrepreneurs form an important sub-group of stakeholders in the road towards a more sustainable energy system. This study aims to contribute to the body of knowledge about generation on sustainable energy adoption, particularly for North-Brabant and fits within the “*Klimaat en duurzame energie*” strategic programme and studies by TELOS Brabant at achieving a climate neutral Brabant by 2040.

1.5 Structure of the report

The research questions will be addressed in the remainder of this report. Chapter 2 starts by discussing transition theory and system innovation. In chapter 3 the framework for the research is provided by discussing specific parts from theory that are used: barrier types and innovation functions. The research method is discussed in chapter 4. In chapter 5 through 7 the actual barriers are discussed. Barriers that have been identified through existing literature are discussed in chapter 5 and 6 with a distinction being made between energy efficiency and renewable energy. The experiences from entrepreneur are discussed in chapter 7. The 8^{th} chapter discusses where attention is needed for a wider adoption of sustainable energy technologies. The 9^{th} and last chapter summarizes the main conclusions of this report and presents recommendations.

2. Theoretical Background: Transitions and Innovation Systems

2.1 Introduction

The fourth national environmental policy plan (NMP4), presented in 2001 by the Dutch government, mentioned that optimization of existing policies alone is not enough to meet targets for sustainable energy. In the plan it is argued that fundamental change is necessary in the economic, technological, socio-cultural, and institutional fields (VROM, 2001). One of the key terms used in this plan is that of transition. According to Kemp and Loorbach (2005) the concept of transition was widely accepted by the Dutch government because of its flexibility. The focus on innovation and learning combined with long term thinking would allow the different ministries to pursue their own agenda without some kind of rigid control. Another important term in the NMP4 is that of system innovation. It is argued that the transition towards sustainable energy will have to come about through system innovation and not so much through incremental system improvement. This chapter discusses the concepts of transitions and system innovation and is mainly related to the second research question of the study.

2.2 Transitions

The use of renewable energy and more efficient technologies has steadily increased over the years, but the consumption of energy from fossil fuels has been growing at a much faster pace (Jefferson, 2008). The current fossil fuel energy system, with its well developed technologies and established infrastructure, is expected to remain the dominant system for some decades. The shift towards a more sustainable energy system will therefore be a long and complex process which requires large structural change. In literature this shift is often referred to by energy transition. Transitions theory deals with the process of change or innovation in a wide array of economic, sociologic, and technological research. Rotmans and colleagues (2000) give the following definition:

A transition is a long term, gradual or continuous, social transformation process typically of technological, economic, ecologic, social-cultural, and institutional nature.

Transitions are typically slow and can easily last one or more generations. They can be seen as a combination of related/interacting changes and are thus not caused by a single innovation (Rotmans et al, 2000).

2.2.1 Transition management

Full control of transitions is practically impossible because of their complex nature. According to Rotmans and colleagues (2005) however, it should be possible to at least influence the speed and direction in which the transition progresses. The Dutch government has adopted the concept of transition management to deal with this problem. The direct goal of transition management is not to achieve a transition but rather to expose underlying complexities so that transition processes can be better understood (Ibid). This is to minimize failures like those that happened in California during the 1980s where attractive subsidies led to wide deployment of wind projects. The

technology was not fully developed and soon enough technical failures started to show, leading to costly repair or maintenance, and decommission of many installations.
An important aspect of transition management is the need to state transition goals without being tied to technical solutions right from the start. Other solutions might appear during the transition process and policies might have to be adapted along the way, hence some degree of flexibility is required. These goals can be stated in the form of positive visions for the future (Kern and Smith, 2008). Wide acceptance of these goals by several actors is an important prerequisite for legitimacy and to help increase the development, support, and financing for transition processes. Developers should also get the opportunity to experiment with different potential solutions in niches, from which insights can be gathered about the technologies and relevant practices (Ibid). Eventually winning solutions should emerge in an evolutionary manner. Rotmans and colleagues (2000) summarize transition management with the following main characteristics:

- Long term thinking should influence short-term policy (*e.g. positive visions for future*);
- Aiming for learning processes;
- Several options should to be kept open;
- Participatory decision-making between relevant actors;
- Transition process works in more than one domain with several actors;
- Focus towards system innovation next to system improvement.

Supporters of transition management see it as a promising approach towards a sustainable energy system but there are difficulties as well. According to Jänicke (2008), developers tend to favor existing successful technologies or systems. This will mostly lead to optimization of the current system instead of structural change. Jänicke (2008) also contends that structural change will lead to a decrease in business for companies that refuse or fail to modernize. Regulations towards structural change can thus lead to resistance from these so called modernization losers. Shove and Walker (2007) note on the importance that has been given by scholars to participatory processes in the transition management concept and argue that these can actually also hinder transitions. Actors with deeply vested interests can refuse to support certain policies thereby decreasing the legitimacy of one or more transitions. Kern and Smith (2008) warn about the incumbent energy firms in the Netherlands becoming too dominant in the energy transition process, thereby hindering the true purpose of transition management. Rotmans (2005) argues that the consensus searching nature of the Dutch democracy has not been able to tackle long persisting problems and thus might hinder transition processes.

2.2.2 Multi-level perspective

One of the main characteristics of transition management according to Rotmans et al (2000) and mentioned in previous section is that the transition process occurs through different domains and includes several actors. The multi level perspective is an analytical framework designed to deal with this and revolves around the so called socio-technical regimes (See figure 3.2). These are established and shared routines, regulations, and standards among different groups in the community. Dominant technological systems are found within these socio-technical regimes. Changes from within the regime tend to be incremental, aimed at system optimization, and ultimately focused on the continuation of the regime (Geels, 2002). Next to the socio-technical regime there are the socio-technical landscape and technological niches. The landscape consists of factors that are external or not directly affected by technology, e.g., politics, wars, culture, normative values, and environmental problems. These factors are difficult to influence and generally take decades to change. While change from within the regime tends to be incremental, radical change comes from the technological niches. Within the niches novel technologies can be protected from the competition at the regime level and are given room for development (Geels, 2002; Shackley and Green, 2007). Novel technologies typically have a hard time entering the socio-technical regime, which is why it is often stated that regimes tend to protect themselves.

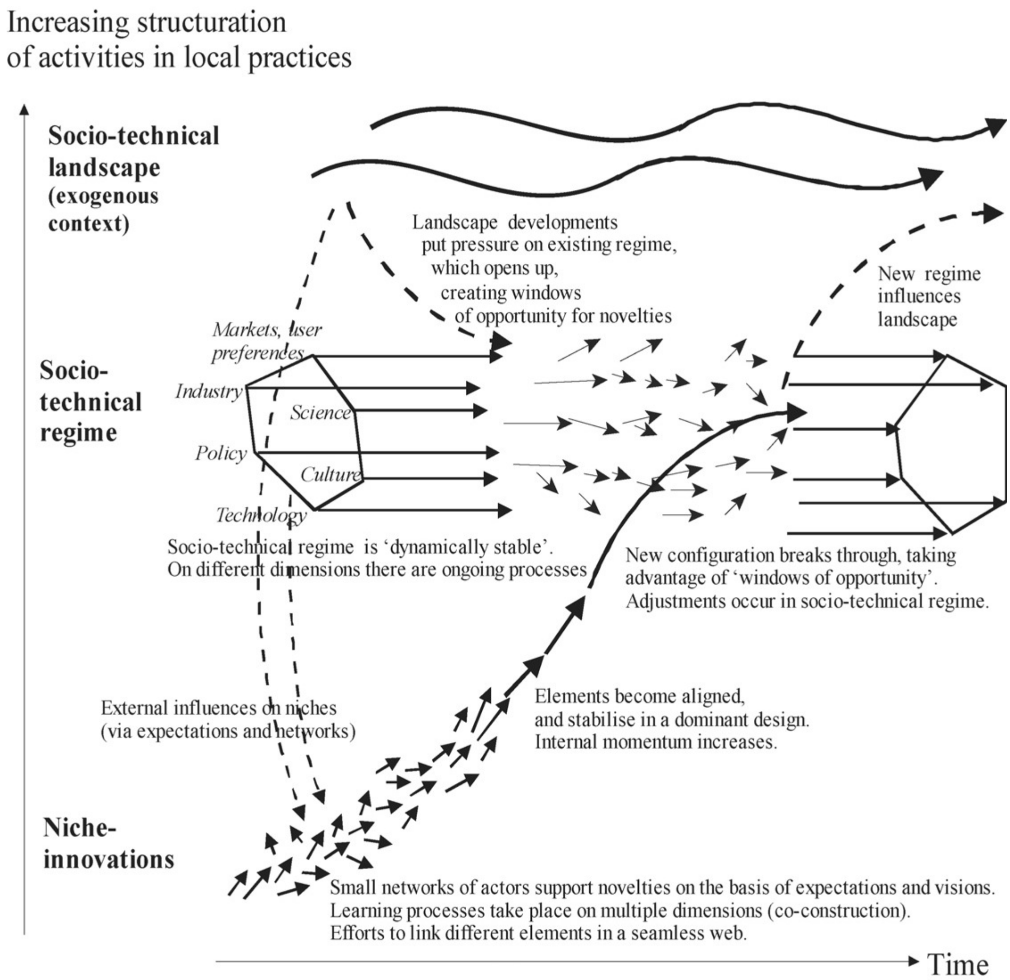

Figure 2.1: Multi-level perspective on transitions (Source: Geels and Schot 2007)

While popular among scholars, the multi level perspective is not without its critics. Genus and Coles (2008) note on the difficulty to generalize among different cases in the multi level framework. Analyses of transitions are heavily dependent on case characteristics and the boundaries chosen by the researcher. Smith and colleagues (2010) similarly note on the need for a more standard way to map transitions so that relevant theory can be generated. They also argue that most studies focus on how the regime operates but that little attention is given on how to destabilize them. Hommels et al (2007) question how much novel technologies should actually be protected in niches and argue for an early exposure to the competition in the regime. By doing so, novel technologies might have a better chance of adoption instead of being protected too much and failing due to mismatch with the regime.

2.2.3 Types of transitions

According to theory, transitions depend on the nature of interaction between the three levels in the multilevel perspective. Geels and Schot (2007) propose five different types of transitions, as a further refinement of the multi level perspective. They also include the case when there is no interaction and the regime remains stable

1. Reproduction

When there are no changes coming from the niche or the landscape level, the existing regime will remain stable. Innovations or improvements happen in a rather incremental way instead of radical break troughs. In this state the regime is only reproducing itself.

2. Transformation

Transformational change is triggered by moderate pressure or interventions from the landscape level; e.g., government, special interest groups, or cultural shifts. If actors in the socio-technical regime notice these pressures and act upon them it may lead to new movements and practices within the regime. This type of transition does not include interactions with the technological niches.

3. De-alignment/re-alignment

De-alignment occurs when the dominance of a particular technology within the regime is destabilized due to changes from the landscape level. If there are no "ready to use" replacements from the niche level, a period of re-alignment will follow. During this period different technologies compete with each other. In the end a leading option emerges becoming the dominant technology or system.

4. Substitution

Substitution is triggered by the similar circumstances as with de-alignment/re-alignment. The difference is that under technological substitution there is the availability of a well developed technology at the niche level. The uncertainty within the regime enables its entrance and replacing the old dominating technology.

5. Reconfiguration

In a reconfiguration path there is system change coming about trough innovations in different but interconnected technologies. When the regime adopts one technology it may lead to experimentation and set of new combinations of technologies and practices.

6. Sequence of transitions

When there is disruptive change coming from the landscape level, there is the possibility that a transition starts with a certain path but shifts to other paths along the process. The ongoing phase out of the incandescent light bulb in many countries can potentially trigger a sequence of transitions. The disruption in this case is the phase out enacted by governments and its effect on the market. Consumers will have to look for other alternatives. With alternatives that are readily available like the compact fluorescent light bulbs or energy saving halogen lamps there will probably be an initial case of substitution. There is however also another option in the form of LEDs which are more expensive but consume less energy and have a greater lifespan than the other alternatives. Further development of the LED could make the technology more competitive leading to a period of de-alignment and re-alignment.

Shackley and Green (2007) argue that in the future, the most likely types of changes for energy systems will be the de-alignment/re-alignment and reconfiguration pathways. Due to the local nature of sources, each region will likely adopt the system that works best for them. It is unlikely that a single technology for energy generation (e.g. solar PV, or wind turbines) will replace the current dominant regime.

2.3 System Innovation

System innovation is considered an important property of transition management (Rotmans et al, 2000, VROM, 2001) and has been a widely accepted as a method to understand what drives innovations and how they affect economic growth (Bergek et al, 2008; Chang and Chen, 2004; Sagar and Holdren 2002). A transition can consist of several system innovations. The literature on innovation systems is extensive and diverse. A literature review by Carlsson (2007) has shown that the four most widely researched concepts for innovation systems are the national systems of innovations, regional innovation systems, sectoral systems of innovation, and technological systems. The following section discusses these systems.

2.3.1 National systems of innovations

According to Lundvall (1992), it was Freeman (1982) who probably used the concept national systems of innovation (NSI) for the first time in an unpublished paper for the OECD. Other scholars picked up the concept soon after. The first definition given by Freeman (1987) was that NSI constitutes the network of institutions in the public and private sectors whose activities and interactions imitate, import, modify, and diffuse new technologies. According to Lundvall (1992), definitions for NSI can be classified into both narrow and broad definitions. In the narrow definition of an NSI, the system consists only of organizations and institutions that are directly involved in search and exploration activities towards innovations. This would be the case in R&D departments, universities, and other technical institutions. The broad definition system includes institutional structures and economic systems that influence creation, diffusion, and exploitation of innovations.

The system boundaries for the NSI are typically the national borders. The reasoning behind this is that individuals within a geographical area tend to share cultural, historical, and linguistic traits (Lundvall, 1992). These traits affect the way how firms are organized, relationships between them, role of the public sector, institutional setup of the financial sector, and the R&D intensity of organizations. These aspects are crucial in how the innovation system performs. Chang and Chen (2004) question this reasoning since countries have become more cultural diverse and firms more internationally active. According to Carlsson (2006) the level of internationalization of innovations has increased over the years but found that many of these innovations are still embedded in the national innovation systems.

2.3.2 Regional systems of innovation

The concept of regional innovation systems (RSI) emerged in the late 1990s when the importance of the local nature of managerial and technical skills, accumulated tacit knowledge, and spillovers became more prominent (Chang and Chen, 2004). A regional system of innovation is similar to NSI in terms of its geographical location as system boundary. Authors often cite the Silicon Valley in California as an example of the RSI. There is no general accepted definition for RSI, and the scale of this system differs considerably in literature. Some authors have used cities to delineate a system, metropolitan regions, more localized forms like districts within cities, or more aggregate forms like the NUTS classifications by Eurostat (Doloreux and Parto, 2005). Cooke and his colleagues (1997) defended the notion of RSI by arguing that delineating an innovation system by national borders could lead to a system that is rather too complex and difficult to understand. Individuals in a nation may very well live in the same country but still have very different cultural backgrounds or even languages, e.g. Flanders and Wallonia in Belgium, or the Basque country in Spain. Politics, culture, and economic factors can push two regions from the same nation into different development paths. This is why a small geographical distance and shared cultural traits between a firm and actors in its network is one of the important aspects of RSI. Even when firms become more global and modern technologies make it easier to communicate there will still be certain type of information exchange that is best achieved through "face to face" interaction (Maskell and Malmberg, 1999).

2.3.3 Technological innovation systems

At the end of the 1980's scholars started to work on the concept of technological innovation systems (TIS). They contended that national boundaries may not be the most optimal option for demarcating an innovation system (Carlsson, 2006). TIS is increasingly being picked up by scholars to study the diffusion of innovations, particularly the processes of socio-technical change (Hekkert and Negro, 2009). Carlsson and Stankiewicz (1995) defined a technological system as a network of agents interacting in a specific economic and industrial area under a particular institutional infrastructure or set of infrastructures and involved in the generation, diffusion, and utilization of technology. This definition is similar to the ones maintained for NSI except for the system boundaries. While national borders influence the exchange of knowledge in the NSI, in TIS this exchange revolves around the technology itself. This would imply that a NSI might include several TIS or that they could cross into different NSI. According to (Chang and Chen (2004), the knowledge network is mainly the result of technology interdependence between firms and other institutions. This is one of the more notable elements from TIS.

2.3.4 Sectoral systems of innovation

If TIS revolves around a particular technological system, then sectoral systems of innovation (SSI) encompasses a set of interrelated technological systems. Breschi and Malerba (1997) define SSI as a group of firms active in developing and making a sector's products and in generating and utilizing a sector's technologies. These firms interact through cooperation or competition, or even both. Malerba (2002) adds the notion of interaction with non-firm organizations in a definition for SSI, making his view of the concept similar to NSI and RSI.

The national system of innovation has been studied the most out of the four systems, but according to Markard and Truffer (2008) this has to do with the concept being developed earlier than the others. Some researchers have stated that the approaches are totally different from each other (Breschi and Malerba, 1997) while others see them as subsets of each other. Doloreux (2002) for example notes that the difference between NSI and RSI can be difficult to grasp. Chung (2002) has argued about the possibility to join several RSI and also SSI together to form a new NSI, and according to Carlsson (2006) it should be possible to view NSI as an aggregate of a set of TIS, RSI, and SSI. Similarities among the four concepts are the aspects of knowledge and learning, and the importance of networks to diffuse innovations (systems approach). Another commonality is the inconsistency among definitions. According to Chang and Chen (2004), this is one of the major challenges in innovation systems research. Generalization is difficult because results and recommendations are based on different inputs. Innovation system studies have been criticized for their lack of practical guidelines for firms, individual entrepreneurs, and policymakers to work with (Chang and Chen, 2004; Hekkert et al, 2007; Bergek et al, 2008). The TIS however has more recently been argued to allow for more practical implications since it focuses on a specific technology and is therefore less “abstract” than the other three systems.

2.4 Conclusion

In this chapter two key concepts from the fourth national environmental policy plan were discussed, transitions and system innovation. Both are widely referred to, not only in academic literature but also in energy policies. The multi level framework has become an important object of research in the study of transitions, by positing how the technological landscape and the technological niches affect the dominant socio-technical regimes. While it is popular among scholars there are also critics of the multi level perspective. They argue primarily about the lack of empirical evidence. Supporters of the multi level perspective also acknowledge that further refinements are necessary. System innovation is seen as an important prerequisite for transitions since further system optimization alone is not expected to bring about the necessary fundamental change. Studies on system innovation focus mostly on four types: NSI, RSI, TS, and SSI. Critics contend that there is a lack of practical guidelines. In the next chapter, a further refinement on system innovation is discussed which has recently been proposed by scholars.

3. Research Framework

3.1 Introduction

The previous chapter dealt with theories behind transition management and innovation systems which are used by scholars to describe the transition toward sustainable energy technologies. In this chapter three concepts are discussed which have been used to provide structure in this study and serve as a framework for the research. When working with a topic as diverse as sustainable energy structure becomes very important. The Trias Energetica framework and barrier categories from literature lend themselves well for structure in the identification part of the research. Different types of barriers have different implications when dealing with them so it is essential to know what kind of barriers one is dealing with. Both transition management and system innovation theories have been criticized for lacking practical implications to users. One possible way of dealing with this is by using the so called innovation functions. Hekkert and colleagues (2007) argue that innovation functions allow for a better understanding of what brings about technological change in innovation systems. They see these functions as complementary to the concept of innovation systems. These innovation functions are used in the analysis part of the research.

3.2 Trias Energetica

The Trias Energetica is a popular guiding principle towards reduction of the use of fossil fuels and increasing the share of renewable energy. Lysen originally introduced the concept by the name of Trias Energica at a conference about solar energy in 1996 (Lysen, 1996). He argued that countries should stop waiting for a breakthrough in renewable energy technology and start integrating more efficient measures and clean use of energy in their energy policies. The Trias Energica was adapted into a strategy with emphasis on the order of the steps and coined Trias Energetica by C. Duijvestijn from the Delft University of Technology (Trias Energetica, nd). This concept proposes a process of three subsequent steps to achieve a sustainable energy system:

1. Reduce energy consumption by avoiding waste and implementing energy-saving measures;
2. Increase the use of sustainable energy sources;
3. Produce energy from fossil fuel as efficient as possible to meet the remaining demand.

According to the framework, the first step towards sustainable energy systems is by saving energy through the use of more efficient methods, materials, appliances, and systems. Technologies for this step are in general in a very mature state of development and many times readily available. The second step is to use sustainable or renewable energy sources as much as possible. When the first two steps are not enough to satisfy the energy demand, then traditional fossil fuels should be used as efficiently as possible to generate and supply energy. Trias Energetica has been widely accepted among companies that have businesses related to sustainable energy. Some companies or groups even use it as a form of marketing tool to show their commitment to sustainability.

Overall, two themes can be seen in the Trias Energetica which is that of energy-saving/efficiency and that of renewable energy. Scholars and practitioners when talking about sustainable energy generally follow this distinction. This is also the case in this study where barriers to energy efficiency and renewable energy are discussed separately.

3.3 Barriers

Several types of barriers to the penetration of sustainable energy technologies have been listed in literature. Some have broad descriptions while others are more case specific. Being able to categorize the barriers is helpful, since dominant types of barriers can be revealed. It is not within the scope of this study to uncover or suggest new categories since these have already been extensively studied and documented in literature. Table 3.1 shows some examples where it can be seen that categories identified by different authors tend to be similar to each other and will sometimes show overlap. In this study the set of barrier categories as proposed by Reddy and Painuly (2004) are used. The authors supply clear descriptions for their barriers while others only give some examples or use fewer categories making their description rather broad.

Table 3.1: Types of barriers as used by different authors

Painuly 2001	Bachhiesl 2004	Beck and Martinot 2004	Reddy and Painuly 2004	Mirza et al 2009
Market failure/ imperfection	Economical barriers	Market performance	Market barriers/ failures	Market-related barriers
Market distortions	Innovational barriers	Costs and pricing	Economic and financial constraints	Fiscal and financial barriers
Economic and financial	Technological barriers	Legal and regulatory	Institutional and regulatory barriers	Policy and regulatory barriers
Institutional	Social barriers		Technological barriers	Institutional barriers
Technical			Lack of awareness and information	Technological barriers
Social, cultural, and behavioural			Behavioral	Information and social barriers
Other barriers				

Barriers by Reddy and Painuly (2004):

1. Market barriers/ failures

Sometimes there are technologies that might appear cost-effective and reliable but do not break in to the market. Factors leading to this are typically referred to as market barriers. Some typical examples of market related barriers are uncompetitive market prices, lack of competition, lack of infrastructure, and established regimes of conventional energy.

2. Economic and financial constraints

Investment costs related to more sustainable energy options tend to be high when compared to the established technologies and have long payback periods. This might scare investors away. Furthermore small scale users typically have lower incomes making them hesitant to make the investments. This is most unfortunate since the cumulative energy savings between them can be significant.

3. Institutional and regulatory barriers

The institutional and regulatory barriers are institutional structures/mechanisms, policies and practices (or lack of them) that act as barriers to a sound adoption of more sustainable technologies and practices. Typical examples are the lack of incentives, lack of participation of relevant actors in decision making, complicated procedures, and lack of or unfavorable legislation to support more sustainable energy.

4. Technological barriers

Technological risks or barriers are related to the technical performance and reliability of the individual technologies. These risks depend on the maturity of the technology and also sometimes on the site where it is installed. Some examples of technological barriers are the lack of qualified personnel, lack of standard codes or certification, existing infrastructures that do not enable optimal use of sustainable energy technologies and insufficiently developed technologies.

5. Lack of awareness and information (informational barriers)

An important part of adoption of more sustainable energy technologies, measures, and practices is the availability of information. Being able to understand and compare technologies is very important since there are many solutions available and many times a high degree of customization is needed. If potential users are not sure about the benefits or if information is difficult to find, they will probably choose to continue using conventional energy systems. Investors might also not be interested if they are unsure whether the technology will actually work.

6. Behavioral barriers

The decision to adopt a technology depends on the adopter's perception about it. Even if the technology itself has clear and proven benefits in terms of its performance there may be barriers that depend on human nature. Aesthetic considerations, resistance to change, cultural factors are typical behavioral barriers.

3.4 Innovation functions

In chapters 1 and 2 it was mentioned how according to the fourth national environmental policy plan; system innovation will play an important part in the energy transition. The main goal of system innovation is to develop and diffuse innovations (Hekkert et al, 2007). A logical step after identifying barriers to innovations toward sustainable energy is to consider how to overcome these barriers. Some authors have argued that innovation system theories are lacking in this department. According to Chang and Chen (2004), innovation system approaches lack predictive tools and do not provide clear guidance for firms and policymakers. Bergek (2008) makes a similar statement that the theory behind innovation systems does not provide practical guidelines. Hekkert and colleagues (2007) argue that the studies on innovation systems focus mainly on the inner structures of systems and that the activities outside of the structure deserve more attention.

These activities that Hekkert and colleagues (2007) refer to have been called functions of innovation systems. According to Johnson and Jacobsson (2000), every innovation system serves a set of functions. The better these functions are fulfilled, the better the innovation system performs. There have been a number of different studies on such system functions e.g., Johnson and Jacobsson, (2000); Johnson, (2001); Bergek et al, (2008); Rickne, (2000); Hekkert et al, (2007); Edquist, (2004). Hekkert and Negro (2009) assessed the set of functions as proposed in Hekkert et al (2007) for validity through a historical event analysis of different events in Germany and the Netherlands. These functions are discussed below.

1. Entrepreneurial activities

Entrepreneurial activity is crucial to the success of any innovation system. The goal of this function is to translate knowledge into business opportunities (Suurs et al, 2009). Hekkert and colleagues (2007) compare entrepreneurs with experimenters who bear the risk of testing new possibilities on the market. When entrepreneurs try certain technologies in the market they engage in interaction with costumers, government, suppliers and even competitors. A lot of useful information can be collected from these interactions that can help clarify uncertainties about how the combinations of technological knowledge, applications, and markets go together.

2. Knowledge development

The creation of knowledge is also important to an innovation process. The development of knowledge is dependent not only on universities and research organizations but also on entrepreneurs. They can provide feedback loops to researchers and designers. Hekkert and Negro (2009) argue that the creation of insights into the fit between technologies, business practices, and regulations is also very important to the innovation process. Knowledge is not limited to knowing how new technologies work. It also includes knowledge of the existence of certain technologies, both new and existing ones. According to Hekkert and Negro (2009) a lot of novel technologies are actually combinations of existing technologies.

3. Knowledge diffusion through networks

People and organizations create networks in order to facilitate exchange of knowledge (Carlsson and Stakiewics, 1995). Such networks can give access to knowledge from other actors or they may lead to new business opportunities by revealing existing problems with other actors. According to Hekkert and Negro (2009), knowledge diffusion is very difficult to map. One could measure the number of workshops, conferences related to a specific technology, or network size and intensity but still not get a grasp of the actual level of diffusion.

4. Guidance of the search

Knowledge is gathered trough learning and by doing. There is however a certain need for guidance. Policy goals, preferences in society, or even stating expectations for a particular technology are examples of how search for knowledge can be guided. If for example the government states the goal of increasing energy efficiency for lighting systems by a certain percentage, it sends a message not only to those directly related to the technology but also to developers in the built environment. By having clear messages about the direction in which the market is to grow, developers and entrepreneurs will know better how to allocate their resources. Hekkert and Negro (2009) found in their analysis that frustrations among entrepreneurs were mostly because of rapid shifts in guidance instead of the problems with technology or finding investment capital.

5. Market formation

It is important for emerging technologies to be able to compete with existing ones. Due to the regime protecting itself, as was discussed in chapter 3, there will be a need to create markets for these promising technologies. Possible options are to create niche markets in which these technologies can be developed and demonstrated or to give these technologies a temporary advantage; e.g. favorable taxing, or consumption quotas (Hekkert and Negro, 2009).

6. Resource mobilization

Resources, be it financial, material, or human, are necessary as a basic input to the activities in an innovation system. In their studies Hekkert and Negro (2009) have found that reluctance by private investors in the Netherlands many times was directly related lack of, or unstable support from the government. This might have been due to lack of or unstable guidance (Function 3).

7. Creation of legitimacy

When new technologies or practices appear, they will encounter a certain amount of resistance to change. The regime will try to protect itself. If developers can prove the benefits related to the new technology, its legitimacy will increase and attract entrepreneurs. The more entrepreneurs are attracted, the bigger the chances to become part of the regime or to even overthrow it. Lobbying and giving advice are examples of how to create legitimacy.

These functions can individually affect the innovation system but they can also do so through their interaction with each other. According to Jacobsson and Bergek (2004), when there is positive interaction, functions will reinforce each other resulting in an accelerated innovation process. This is called a virtuous cycle. Suurs and colleagues (2009) refer to this process as cumulative causation. The opposite can also occur where the interaction actually slows down the innovation process. This is called a vicious cycle. The topics in the previous paragraphs were intended to help give form on the barrier identification. The innovation functions on the other hand are used in the analysis part of this study in chapter 8.

3.5 Conclusion

This chapter started by briefly discussing the Trias Energetica which is a framework towards a more sustainable energy system. It proposes a set of subsequent steps towards a sustainable energy system which has been widely accepted by users in the field. Then different barrier categories as they are found in literature were discussed. An extensive review of studies on such categories was not considered necessary for this study since it was found that many of the categories researchers propose are similar or overlap. The topics from paragraphs 3.2 and 3.3 give form onto the first part of this study which is the identification of barriers. First the distinction between energy efficiency and renewable energy is made and secondly barrier categorization becomes possible. A logical step after identifying barriers to innovations is to consider how to overcome them. In the Netherlands, the concept of innovation systems is widely accepted as a way to bring about fundamental change towards a sustainable energy system. Critics however contend that innovation systems lack practical guidelines on how to deal with difficulties regarding the diffusion of innovations. Scholars have therefore proposed the concept of innovation functions as tools to help shape and guide the innovation process. Fulfillment of these functions should lead to more penetration of innovations, particularly due to positive interactions between the functions. These interactions are called virtuous cycles.

4. Method

4.1 Introduction

The previous chapters presented the research question and theoretical basis for this study. This chapter discusses the approach behind this study. Given the nature and scope of the research questions a qualitative approach was chosen. According to Strauss and Corbin (1990), qualitative studies are useful to gain in-depth understanding of problems which are difficult to analyze quantitatively. Findings from such type of research can subsequently lead to variables to be tested quantitatively in further studies.

4.2 Type of research

Research is often categorized as being exploratory, descriptive, or explanatory (causal) (Yin, 1994). Exploratory research is used to gather initial knowledge about a problem or situation and is considered many times as a prelude to a more structured type of research. Descriptive research is more structured with clearly defined problems, and pre-specified methods for collecting data. Explanatory goes further by trying to explain why certain events occur and thus to determine cause and effect relationships between variables. This study is primarily exploratory in nature. There have been no (recent) inquiries into the barriers for sustainable energy specifically in North-Brabant and it thus lays the groundwork for understanding the existing barriers in North-Brabant, particularly for SME entrepreneurs. The approach followed has been that that of a case study. Yin (2003) contends that this type of approach can be used when there is a broad research topic instead of a narrowly defined topic, complex situations are to be studied instead of just isolated variables, and when the researcher needs to deal with multiple sources from which to collect information. All of these apply to this study.

4.3 Barrier identification

This study follows the framework for barrier identification as suggested by Painuly (2001). He argues that before starting to look for barriers it is important to select renewable energy technologies (RET) with adequate potential; i.e., searching for barriers to the diffusion of hydro energy in a region without water resources would be meaningless. After the selection of suitable RET's, multiple sources should be used to identify relevant barriers. Literature is the most accessible and flexible way to look for barriers, especially case studies. Site visits can also help the researcher get a better understanding for the technologies being studied. The difficulty with site visits is that these are not always possible, especially in the case of this research where the study covers a broad set of technologies/sectors. Painuly (2001) recommends interaction with stakeholders since these are the ones dealing with the different technologies and experiencing the effects of the barriers. Typical stakeholders are actors from the industry, policymakers, non-governmental organizations, and professional institutions. Mcormick and Kåberger (2007) propose a similar approach by using studies from literature, interaction with actors from the industry, and by conducting workshops with users. This is basically the same as with Painuly (2001) with the exception from the site visits. While Painuly specifically used RET's as the unit of analyses it can be used for energy efficiency measures/ technologies as well. Given the scope and time constraints only literature and interaction with stakeholders were used as sources to identify barriers. Conducting site visits would have been unfeasible for all cases. The followed framework consisted of the following steps:

1. Literature survey about potential efficiency measures/RET's
2. Selection of the units for analysis in the fields of efficiency measures and RET's;
3. Literature survey into barriers for each case;
4. Interaction with stakeholders

In this study information on barriers was gathered by means of an extensive desk research and personal communications. Scientific articles, studies from government and non government groups, presentation sheets, conference proceedings, company reports, and documents summarizing provincial meetings were the main sources of information for the desk research. This phase of the research gave important leads for personal communication with persons or groups of interest. Entrepreneurs that provide sustainable energy solutions in North-Brabant were approached for their take on barriers to their business as follow up on the barriers that were identified in the first phase of barrier identififcation. A total of 34 entrepreneurs or companies were contacted. From this group 12 cooperated. Respondents were either the director or head of sales for the company.

4.4 Quality of the results

Collecting and using data from different sources can be advantageous to understanding the problem being investigated. The use of the desk research format allows for a lot of flexibility. It can be conducted at any given time the information is readily available. However by relying on information that has been gathered by others there is a risk of using data that is incorrect, outdated or incorrectly interpreted. One strategy to assure data credibility or "truth value" is member check or informant feedback, (Baxter and Jack, 2008; Yanow and Shwartz-Shea, 2006). With member check the researcher basically checks if his or her interpretations of collected data are correct by asking the source. In line with this member checking process, data from personal communications where checked by getting back to the source to assure that their statements were correctly interpreted. Also any ambiguities that were encountered in literature were addressed as much as possible with the original authors or people who are authoritative on the subject. These personal communications were very beneficial since many times they led to new insights, sources, or re- evaluation of data that proved to be outdated. Another strategy was the use of multiple sources to crosscheck the validity of barriers. This is also called triangulation of data.

4.5 Conclusion

This study can be characterized as exploratory. No recent studies on barriers has been conducted with North-Brabant as the system boundary. Several sources of evidence were used from which to collect data which is one of the characteristics of the case study approach. The following chapters present the barriers to diffusion for relevant options within the domains of energy efficiency and renewable energy in North-Brabant and barriers as experienced by SME entrepreneurs.

5. Barriers to Energy Efficiency

5.1 Introduction

In the Netherlands there has been a steady increase in the energy demand over the years. Population growth, increased wealth, and more industrialization are the main factors contributing to the rise in energy demand. Despite this increase there is significant opportunity for energy savings (SenterNovem, 2009a). Energy efficiency can lead to a decrease in actual energy demand and is therefore an important part of the energy transition. According to the Trias Energetica framework (Chapter 3), the decrease of demand through more efficiency is the first step to be taken towards a more sustainable energy system. This chapter discusses some key sectors on their status and barriers to energy efficiency. Table 5.1 gives an overview of these sectors and their respective share in the total energy consumption in North-Brabant. For each sector a list of barriers were identified through literature review and personal communications with relevant actors and corresponding authors of several articles and reports.

Table 5.1: Sectors and their energy consumption

Mode	Consumption (PJ)	%
Residential buildings	67	17
Public/utility buildings	73	18
Agriculture	27	7
Industry	147	37
Transport	83	21

Adapted from "*Energiek Brabant: Een scenariostudie naar de energievoorziening van Noord-Brabant in 2040*" by H. van Kasteren, W. Konz, P. van Schijndel, R. Smeets, C. Wentink, 2008, Tilburg: TELOS brabants centrum voor duurzame ontwikkeling P. 10.

5.2 Built environment

5.2.1 Status

The built environment is one of the most energy intensive sectors in North-Brabant. In 2008, the energy consumption in residential buildings accounted for 17% of total energy use while in public and utility buildings it was 18% (table 5.1). Taken together this means that the built environment accounted for up to 37% of the total energy use. Options for saving energy in the built environment are fairly mature in terms of development and can lead to significant cuts in energy consumption. These measures are typically found in the areas of insulation, climate systems, building control/automation, materials, solar screens, heated water, and lighting. According to a study by ECN, the most unused potential for energy saving in the Netherlands lies in this sector (Menkveld et al, 2005).

Residential Buildings

There is significant potential for overall energy saving measures in this sector if proper advantage is taken of the maturity of existing technologies. Despite the possibilities, improvements in energy efficiency are slow to catch on in North-Brabant (Provincie Noord-Brabant, 2009a). An example is the case of thermal insulation. A large number of houses in North-Brabant lack proper thermal insulation. Almost 25% of them have no roof insulation at all (Ibid). The province is trying to motivate the adoption of energy efficient technologies through the Brabant Bespaart programme. Homeowners can get €500 subsidy for the installation of energy efficient measures or renewable energy technologies. They also offer low interest loans of up to €10.000. Other forms of loans also exist; e.g., groen lenen, and duurzaamheidslening.

Public/utility buildings

Buildings destined for commercial, civil, and governmental use are usually categorized as public buildings. North-Brabant is pursuing more energy efficiency in public buildings by offering subsidies to businesses that install energy saving measures (Provincie Noord-Brabant, 2009b). Businesses can also apply for low interest loans intended for investments in energy saving measures.

5.2.2 Barriers

Despite of all the existing possibilities, deployment is not as widespread as might be expected for the available and in many cases well proven technologies. Few projects are implemented, mostly due to financial and organizational reasons (SenterNovem, 2009b). Email conversations with policy advisors in North-Brabant (Brabant Bespaart) led to similar findings. Financial reasons appeared to be one of the most encountered hurdles in this sector, both for firms as for the individual consumer. As an example they mentioned how real estate corporations lack the necessary liquid assets to make investments. This is not only the case for North-Brabant but also for the rest of the Netherlands where major corporations are having difficulties (Quintis, 2009). This lack of liquidity has been caused mainly by the economic situation during the last couple of years, which has led to stagnating sales (Bijsterveld, 2009). A study by Waarborg-fonds Sociale Woningbouw (WSW) revealed that up to 65% of investments by corporations in the Netherlands depend on sales (WSW, 2009). The same study also suggests that the financial difficulties for corporations might have also been due to sales prognoses that were too positive, leading to an increased number of projects (Ibid).

Another barrier that the policy advisors in North-Brabant recognize is the uncertainty about the benefits from energy efficiency measures, especially among homeowners or renters. Because of this they are less likely to make the investments. A study by SenterNovem among groups of apartment owners supports this statement (SenterNovem, 2008a). Adding to the uncertainty is the complex process to implement efficiency measures. When there are many actors involved, the planning and implementation process can be very complicated. There are not only technical and financial issues, but also judicial implications, e.g. lack of clarity on who has to pay for what in shared areas in a building, or what to do when not every member of the concerning party agrees with the needed investments. Because of these issues people might give up on energy efficient measures. It was also found that for the consumer it is most attractive if one party takes care of the organization and planning in the form of a total package (SenterNovem, 2008).

New buildings benefit the most from sustainable energy technologies but developers in turnkey projects tend to be heavily cost minded. They tend to look for the least costly solutions. Many times energy costs will be less of a concern in these settings (TNO, 2008). According to the

Milieu- en Natuur Planbureau (MNP) it appears that aesthetical considerations and building traditions are still more heavily favored than sustainability (MNP, 2008). Financial backing programs can be an important incentive; however these are mostly only available for owners. Table 5.2 presents barriers that were identified through personal communications with policy officials in North-Brabant and literature search.

Table 5.2: Barriers energy efficiency in built environment, MB: market barriers, EFB: economic and financial barriers, IRB: institutional and regulatory barriers, TB: technical barriers, IB: informational barriers, BB: behavioral barriers

Barriers	MB	EFB	IRB	TB	IB	BB
Uncertainty regarding benefits of new technologies	●			●	●	
Increase in rent and service costs is unpopular among tenants		●				●
Real estate corporations lack liquid assets for extra investments	●	●				
Opportunity is bounded/limited to maintenance and renovation moments for existing buildings				●		
Characteristics of existing buildings limit possibilities				●		
Multiple parties involved (inhabitants, owners, home corporations, government, and utility companies) slow down or limit implementation			●			
Only the availability of subsidies will entice house owners to invest in energy saving measures		●				●
Split incentives between tenants and landlords		●				
More energy efficient appliances means extra upfront costs		●				
Payback period is perceived as too long	●	●				●
Project developers are risk averse due to claim culture and consequently stick to proven technologies		●		●		●
Lack of common knowledge among involved actors					●	

5.3 Industry

5.3.1 Status

North-Brabant is a highly industrialized region, especially in the manufacturing sector. The energy consumption in the industrial sector takes a share of 37% of total consumption in North-Brabant (table 5.1). The extent of potential savings for 2020 differs considerably in literature as research groups have come up with different numbers as noted by van Kasteren and colleagues (2008). The general consensus remains though that significant savings can be achieved in this sector with current technologies. In industrial settings these savings can be attained in two broad areas: the building envelope and the installations.

Building envelope

Just like in the built environment, a well insulated building envelope is an important aspect of its energy saving potential. It controls the energy flow between the interior and exterior of the building. Typical energy saving measures in this category are similar to those for buildings in the built environment, e.g. air leakage mitigation, insulated glazing, passive light, and the insulation of walls, floor, and roof. Just like in the built environment, the difference between existing and new buildings is an important factor for the impact that modifications will have. New buildings will benefit more from the measures.

Installations and equipment

Most improvements regarding energy consumption in this sector are possible by using installations that are more efficient (Kasteren et al, 2008). In pilot projects by SenterNovem savings of at least 30% were achieved by using more efficient lighting systems and heating (Energiegids.nl, 2008a). More efficient machines and a more task specific choice in parts like, motors, pumps, compressors, boilers, heat exchangers and bearings can also lead to significant cuts in energy consumption (IEA, 2007a). According to the Dutch chemical industry association VNCI, energy savings from 10% up to 70% can be achieved for rotating equipment (VNCI, 2008). Brammer, a European manufacturer of parts for industrial machinery conducted a survey in 2008 among its customers which included those in the Netherlands. The results showed that companies do take energy saving into consideration but that they lack up-to-date knowledge about the possibilities. Only a small part of respondents actually took retooling or revisions of machinery parts into their plans (Energiegids.nl, 2008b).

Combined heat and power (CHP) also has considerable potential for North-Brabant according to a study by TNO (as cited in SER Brabant, 2008) but it warned that other potentially more efficient measures should be considered first. A study by ECN suggest that the benefits from CHP might turn to be less than current projections if optimal energy saving is achieved with more efficient machines and heating systems (Menkveld et al, 2005).

An approach that can lead to energy saving but requires changes of a more fundamental nature is process intensification. With process intensification, solutions are sought to make industrial machinery smaller, cleaner, safer, and more energy efficient (Reay, 2008). Some of the equipments in industrial processes are based on technology of more than 50 years old which have been optimized through the years. New ways of conducting these processes are necessary. An increase in process intensification in the Dutch industrial sector is one of the main targets of the Dutch Platform for Chain Efficiency.

5.3.2 Barriers

Many times companies do not know of all the possibilities that are applicable in their respective fields (Menkveld et al, 2005; Energiegids.nl, 2008b). Especially SMEs might need support in order to make the right choices (Kasteren et al, 2008). This lack of knowledge seems to be the main barrier in this field according to the International Energy Agency (IEA, 2007a). Based on several studies they conclude that this lack of awareness exists not only among managers and workers in the industrial sector but that it is also present among suppliers and consultants.

An interesting barrier as noted by Almeida et al (2003) is the difficulty for engineers to convince decision makers of the benefits of technological investments. While their plans are technically sound they might not able to totally convince financial managers or other decision makers. In the Netherlands this also seems to be the case. Ideas from the "workfloor" do not reach the managers (Ypma, 2009a). Next to the lack of skills by the engineers to convince decision makers there appears to be a lack of interest or commitment among higher management in many companies. Even when action is taken to save energy, it is treated as a project (with a start and finish) rather than a continuous process that is part of the daily activities. Many times such projects end up being outsourced (Ibid). Cost wise, outsourcing can be attractive but the chance to make energy efficiency something inherent to the company is lost.

A study on process intensification by the Platform for Chain Efficiency identified potential barriers at many levels. Next to high financial and technical risks, their results suggest that there is insufficient knowledge among process engineers and lack of awareness of the benefits among managers (Platform Keten-efficiency, 2008).

In general, companies in the Netherlands would benefit greatly by just applying best practice guidelines for their respective working field. This could lead to 35% of saved energy costs (Ypma, 2009a). Table 5.3 summarizes barriers for more energy efficiency in the industrial sector.

Table 5.3: Barriers energy efficiency in industry, MB: market barriers, EFB: economic and financial barriers, IRB: institutional and regulatory barriers, TB: technical barriers, IB: informational barriers, BB: behavioral barriers

Barriers	MB	EFB	IRB	TB	IB	BB
High investments combined with short payback period expectations	●	●				
Companies do not apply best practices					●	●
Importance of more efficiency not equal among all levels of company			●		●	●
Energy experts in companies typically do not have enough decision making power			●			
Engineers are unable to convince decision makers or financial managers of benefits			●		●	
Lack of knowledge about both existing and up and coming possibilities					●	
Risk averseness due to high focus on reliability leads to new technology not being picked up easily	●			●		●
Over-engineering or sizing of components due to standard used large safety margins or lack of knowledge about particular mechanical loads				●	●	
Split budgets		●				
Companies treat energy use as a private matter, thereby minimizing knowledge diffusion			●		●	●

5.4 Agriculture

5.4.1 Status

The agricultural sector in North-Brabant is responsible for around 7% of the total energy consumption in the province (table 5.1). Within this sector it is the greenhouse subsector that consumes the most energy. Up to 85% of the agricultural energy consumption can be allocated to greenhouse farming (Kasteren et al, 2008). In 2005 the total area being used for greenhouse farming was 1135 hectares; by 2009 it had increased to 1393 hectares (LEI Wageningen UR and CBS, 2005, 2009). It is expected that this subsector will grow steadily in the coming years (Wetzels et al, 2007; Provincie Noord-Brabant 2008a). The province wants to have 1800 hectares of specially designated land by 2020 (Provincie Noord-Brabant, 2006). Energy costs for greenhouse farming are relatively high, sometimes taking up more than 20% of the total process costs (Wetzels et al, 2007). Important parties in the sector and the government are envisioning climate neutral and possibly even energy producing greenhouses after 2020 (Stichting Natuur en Milieu and LTO glaskracht, 2007).

Energy in the greenhouses is used for heating, cooling, CO_2 fertilization, and lighting. Especially heating is an important part of the cultivation process making the total operational costs highly dependent on natural gas prices. Solar and geothermal energy, and also biofuels are considered as viable sustainable alternatives. Particularly geothermal energy appears to enjoy renewed interest in the Netherlands (TNO, n.d.) According to Bakker and Campen (2007) it can be effectively used in the greenhouse farming subsector. The topic of geothermal energy is discussed further in chapter 6. Trends in research for more energy efficiency also show that there is growing attention to process control optimization and decision making tools for farmers (Dieleman and Marcelis, 2007).

5.4.2 Barriers

According to Wetzels and colleagues (2007), it appears that the potential of current technologies in the greenhouse sector has been used for the most part. Significant energy savings will depend on new technologies, most of which are still in the development phase. Modifications to greenhouses are difficult to plan given production intensity in the Netherlands. In contrast to other countries, greenhouses are used almost all year long. A perfect moment to invest in new and more efficient technologies is during large-scale maintenance or replacements of greenhouses. A typical greenhouse is replaced once in approximately 15 to 20 years. This minimizes the possible moments to deploy new technology on a “larger scale” (Wetzels et al, 2007; Femke Pullens, personal communication, October 7, 2009). According to Femke Pullens, a specialist on sustainability and licenses for Zuidelijke Land en Tuinbouw Organisatie (ZLTO), there is a lack of information on the part of the farmers. The effect of the economic recession has also had its negative effects. Farmers even have difficulty to invest in regular activities like maintenance or small to midscale replacements of installations. Table 5.4 presents barriers to more energy efficiency in the agricultural sector.

Table 5.4: Barriers energy efficiency in agricultural sector, MB: market barriers, EFB: economic and financial barriers, IRB: institutional and regulatory barriers, TB: technical barriers, IB: informational barriers, BB: behavioral barriers

Barriers	MB	EFB	IRB	TB	IB	BB
High upfront investments and economic downturn	●	●				
Risks related to measures		●		●		
Lack of knowledge					●	
Modifications to greenhouses are difficult to plan and limited to when greenhouses are to be replaced	●					
No more significant energy saving potential with current technologies				●		
New technologies are still not showing the desired results				●		

5.5 Transport

5.5.1 Status

The Dutch government is focusing on four paths towards a sustainable transport sector: hybrid and electric transportation, deployment of biofuels, hydrogen as a fuel, and more intelligent transport systems. Since 2005 provincial authorities began to more formally embrace biofuels in North-Brabant (Van der Laak et al, 2007) and currently there are several refueling locations, mainly for bio-ethanol and natural gas in the province. There is also an increased interest in electric cars and the local authorities have announced the intention to promote the production of such vehicles and also to provide the necessary infrastructure (Provincie Noord-Brabant, 2008a, 2009). Current goals are to introduce electrical vehicles in the public transportation sector and to have 200.000 electric vehicles by 2020.

Table 5.5: Energy consumption in transport sector

Mode	End use	Consumption (PJ)	%
People	Car	43.9	57.9
	Train	0.6	0.8
	Bus	0.5	0.7
Cargo	Road	29.3	38
	Train	0.1	0.1
	Waterways	2.7	3.5

Adapted from "*Energiek Brabant: Een scenariostudie naar de energievoorziening van Noord-Brabant in 2040*" by H. van Kasteren, W. Konz, P. van Schijndel, R. Smeets, C. Wentink, 2008, Tilburg: TELOS brabants centrum voor duurzame ontwikkeling P. 47.

The transport sector is responsible for around 21% of the total energy use in North-Brabant (table 5.1). Within this sector two categories clearly stand out: the transportation of people by car and transportation of cargo via roadways (table 5.5). The biggest potential for energy savings and CO_2 emission mitigation lies therefore with innovations in these two segments. The results will depend on the type of transportation. For the short and medium term substantial improvements are expected in the transport sector due to technological advancements like sustainable biofuels, better information and communication technology, higher penetration of hybrid vehicles, and otherwise more efficient internal combustion engine vehicles (ECN, 2009). Solutions for the long term, like electric and hydrogen fueled cars are still in early development phases and require massive modifications in infrastructure.

6.5.2 Barriers

Promising technologies are still in early development or demonstrative phases. Massive change is needed in the infrastructure to enable the diffusion of these technologies. Other technologies or fuels that can be deployed on a wide scale manner may pose benefits for the short term but become unattractive in the medium and longer term. An example of this would be the case of compressed natural gas (CNG). There has been a recent rise in popularity of CNG but with more stringent EURO norms CNG might become less attractive in the near future (ECN, 2009). The question then arises of how much to invest in such a technology. Most barriers to wider penetration of more sustainable transport systems appear to be of technological and financial nature. Table 6.6 presents barriers that have been identified for energy efficiency in the transport sector.

Table 5.6: Barriers energy efficiency in transport sector, MB: market barriers, EFB: economic and financial barriers, IRB: institutional and regulatory barriers, TB: technical barriers, IB: informational barriers, BB: behavioral barriers

Barriers	MB	EFB	IRB	TB	IB	BB
Lack of clear plans on provincial level			●		●	
High purchasing costs for existing options	●	●				
Lack of incentives	●	●	●			
Technologies that are mature and available for widespread deployment are not long term oriented				●		
Promising technologies for the long term are still in early development phase				●	●	
Most technologies require massive system innovation	●		●	●	●	

5.6 Conclusion

In this chapter barriers to energy efficiency have been mapped for the following sectors: built environment, industrial sector, agricultural sector and the transport sector. From the overall results it can be seen that the financial-, institutional and informational barriers stand out among the barrier types. These dominating barriers differ per sector as each sector has their own characteristics like level of maturity and users. An example for this would be the contrast between the built environment and the industrial sector. In the built environment it is particularly the barriers of financial nature that present the biggest hurdle to energy efficiency while in the industrial sector it is rather the institutional-, Informational- and behavioral barriers that dominate. The lesser presence of financial barriers in the industrial sector could be because the larger capacities for making investments. The built environment includes a lot of private households where the investments are more difficult to be made. In the agricultural sector it is the market-, financial- and informational barriers that appear to pose as the major barriers. Modifications to for example the greenhouses depend on select occasions and furthermore there seems to be a lack of information on the part of the farmers. For the transport sector the barriers are somewhat more evenly distributed with the exception of behavioral barriers. This sector is still in the development phases thereby explaining the lack of dominating barriers.

6. Barriers to Renewable Energy

6.1 Introduction

There is considerable interest for energy from renewable sources in the Netherlands. According to the VNO-NCW there is more attention given to renewable energy compared to efficiency measures even when the technologies for efficiency are in a more mature phase than those for renewable energy (Weijer, 2009). In 2009 the share of renewable energy grew from 3.3% to 3.8% of total energy consumption. This was mainly due to an increase in the generation of electricity from renewable sources which comprised 9% of total Dutch electricity consumption. In 2008 it was 7.5% (CBS, 2010). This chapter discusses energy sources and technologies for renewable energy that have or might have any significant importance for North-Brabant: biomass energy, wind energy, solar energy, and geothermal energy. Other techniques that have little or no potential are not discussed, e.g., tidal power, wave energy, hydro energy. Just like in chapter 5, first an overview is given of the status of the technologies and then the barriers are discussed. One of the goals for the province is to increase the share of locally generated renewable energy in order to be less dependent on imports and energy from fossil sources.

6.2 Biomass

6.2.1 Status

Biomass is used to produce energy trough different types of techniques; e.g., combustion in dedicated power plants, gasification, and digestion. Biomass can also be used for co-firing at coal power plants. This process is not discussed in this report. The use of biomass for energy has not been as successful in the Netherlands as in countries like Denmark or Germany. Negro and colleagues argue that technical difficulties, problems in finding end-uses for the by-products, and the lack of consistent regulations led to the closing of many biomass power plants during the 1990s, including gasification plants in Helmond, Breda, and Tilburg (Negro et al, 2007).
Despite the failures during previous years, biomass is considered to have significant potential in the short term as a renewable energy source (Van Kasteren et al, 2008; Raven, 2004). Up to 18% of all Dutch agricultural companies and 20% of all cattle-breeders are situated in North-Brabant (Provincie Noord-Brabant, 2009c). Processes for biomass combustion, whether done locally at home or in power plants, and anaerobic digestion are the most mature for deployment. Other methods like gasification are still in the early phases of development (IEA, 2007b). In a study for SenterNovem, Koppejan and colleagues expect waste streams, particularly agricultural manure, to be the most important biomass sources for the Netherlands by 2020 (Koppejan et al, 2009).

Anaerobic (co-)digestion

Anaerobic digestion is the decomposition of organic waste material in a zero-oxygen environment with biogas, and digestate (liquids, fibrous materials, sludge) as resulting (by)-products. Biogas is used to produce electricity or heat and as biofuel for vehicles. Typical feed-materials are agricultural waste like crop residues and cattle manure, organic waste from households and industry, and dedicated or residual energy crops. The process is called co-digestion when more than one feed-material is used. Anaerobic digestion of manure produces less foul odors in

comparison with traditional aerobic composting if the process is designed adequately (Smet et al, 1999; Holm-Nielsen et al, 2009) and less sludge compared to other aerobic processes (Ward et al, 2008). The by-products of the anaerobic process can be used as soil fertilizers after post treatment (Abdullahi et al, 2008; SenterNovem, 2006a).
The significant presence of the farming sector in the province results in large amounts of agricultural manure and organic waste making it an interesting source for bioenergy. According to the Raad Landelijk Gebied, these are the sources with the most potential for North-Brabant (RLG, 2008). Provincial authorities regard the further development of anaerobic digestion as having a higher importance than further development of biomass combustion (Provincie Noord-Brabant, 2008b).

Combustion

The most widely used form of biomass conversion to produce energy is combustion. Feed-materials for combustion are organic waste from the agricultural sector, wood waste from industry, and animal waste. According to Hermkens, organic waste and wood chips both have high potential as a biomass source for combustion in North-Brabant (Hermkens, 2006). The process is done in midsized to large biomass burning plants, furnaces for heating of large buildings, and home furnaces.

Combustion power plants

After many years of stable electricity production at biomass burning plants there was an increase of 62% from 2007 to 2008. The heat production on the other hand did not grow at the same pace as electricity. Most of the new installations did not include CHP. According to a study by the CBS this was mainly because the SDE subsidies focused only on electricity generation (CBS, 2008). Some examples of midsize waste burning plants in North-Brabant are the power plant in Cuijk which produces 25 MWe and the recently built power plant in Moerdijk with a capacity of 36,5 MWe.

Furnaces for heating at companies

The majority of furnaces in this sector are used at wood processing plants and in the furniture industry. These sectors have been fairly stable when it comes to the heat generated. The agricultural sector however seems to be catching up. Since 2004 the installed heating capacity in this sector increased by 94% in 2008 (CBS, 2008).

Home furnaces

Home furnaces account for 5% of the total renewable energy in the Netherlands (CBS, 2008). There are three types; traditional open fireplace, insert fireplace, and stand alone furnaces. This sector has remained practically stable over the last 10 years.

6.2.2 Barriers

Anaerobic digestion

The production of both electricity and heat from anaerobic digestion has increased during the last years, particularly in the agricultural sector. According to Biogas Branche Organisatie however, projects still face many constraints and even get cancelled because they failed to get subsidies. Consultancy firm and developer of sustainable projects E Kwadraat Advies cite the uncertainty around regulations as the main barrier to a wider deployment of the technique (Faber, 2009). Studies on the potential for digestion in North-Brabant suggest that barriers to diffusion are mainly financial factors, uncertainty regarding the technology and its byproducts, and unclear government policies (SenterNovem, 2006a; SenterNovem, 2006b).

According to a study by Rabobank, up to 75% of digestion installations in the Netherlands operated with financial losses in 2008 (as cited in Faber, 2009). Upfront investment costs for digestion are high and the raw material costs tend to be higher in the Netherlands than in other countries like Belgium (Faber, 2009). The current subsidies are not enough for the process to be financially feasible. Even when the ministry of economic affairs increased the subsidies for 2010, they still are less than what has been advised by ECN and KEMA (Vermaas, 2010).

Another barrier is the difficulty to sell the digestate (Ibid). While there should be no discussion about the potential of using the digestate as soil fertilizer, farmers are still very reluctant about this (J.B. Holm-Nielsen, personal communication, July 15, 2009). There are high costs associated with the disposal of waste or surplus manure. The allocation of subsidies to projects via a lottery procedure has also been criticized. According to E Kwadraat Advies and the "Biogas Branche Organisatie", this lottery eliminates the opportunity to control for projects with fewer chances for success. Barriers to a more widespread deployment of anaerobic digestion are summarized in table 6.1.

Table 6.1: barriers to digestion, MB: market barriers, EFB: economic and financial barriers, IRB: institutional and regulatory barriers, TB: technical barriers, IB: informational barriers, BB: behavioral barriers

Barriers	MB	EFB	IRB	TB	IB	BB
High investment costs		●				
Low subsidies	●	●				
Uncertainty regarding policies			●		●	
Difficult to sell digestate	●	●				
Foul odors in direct proximities to digestion plant can lead to protests, e.g., Cleanergy in Wanroij				●		●
Safety concerns by some farmers					●	●

Combustion

Combustion for the many small to midsize scale plants have similar barriers to deployment as digestion. The main problem remains that initial investments are high. Potential users depend largely on subsidies for the project to be financially feasible. The government has followed the advice by the ECN regarding the amount of subsidies. Those for the small- and midsized plants however are below the amount that was calculated by ECN. In 2008, hundreds of projects were cancelled due to insufficient funds and especially because of the subsidy regulations (DHVN, 2008). Barriers for biomass combustion applications are presented in table 6.2.

Table 6.2: barriers to combustion of biomass, MB: market barriers, EFB: economic and financial barriers, IRB: institutional and regulatory barriers, TB: technical barriers, IB: informational barriers, BB: behavioral barriers

Barriers	MB	EFB	IRB	TB	IB	BB
High investment costs		●				
Low subsidies	●	●				
Uncertainty regarding policies			●		●	
People tend to favor solar collectors, and biogas for heating instead of the use of biogas					●	●
Biomass is the least popular source of renewable energy among general public					●	●
Increasingly tighter regulations on emissions can make furnaces financially unattractive		●	●			

6.3 Wind energy

6.3.1 Status

There are different ways to exploit the power of wind; e.g., windmills, wind powered water pumps, and with turbines. In this study only the conversion to electricity by means of turbines is considered. Wind energy is one of the fastest growing energy systems in the world (Kubiszewski et al, 2010). This is due to several factors; e.g., highly fluctuating prices for fossil energy sources, increasing demand for energy from sustainable sources, and maturity of the technology. For the Netherlands wind energy next to bio energy is seen as the most promising technological option to reach the goals set by the government regarding renewable energy for 2020 (Junginger et al, 2004). There are generally three types of turbines; off-shore turbines, on-shore turbines, and small wind turbines. For North-Brabant only the on-shore and small turbines are of any practical interest given its geographical location. According to Van Kasteren and colleagues (2008) up to 428 MW could be generated in North-Brabant in present times given the current technology and characteristics of the region. In line with the national BLOW agreement, North-Brabant set a target to have a minimum of 115 MW of installed wind power capacity by 2010 (Provincie Noord-Brabant, 2002). At the end of 2008 the installed turbine capacity was at 65 MW with 55 turbines.

6.3.2 Barriers

Surveys conducted by VROM suggest that between 70 to 90% of the Dutch public supports more deployment of wind energy. However, when presented with the prospect of having turbines installed in their neighborhood this positive attitude tends to change (VROM, 2009). According to consultancy firm Bosch & Van Rijn (2008), this is the main barrier to more wind energy in the Netherlands. People are afraid of visual and noise annoyances, and also fear devaluation of their property. This has led to well organized protests against wind turbines. In 2005 a group called Platform tegen windturbines campaigned against plans for wind turbines in the municipality of Boxmeer and were successful in getting the plans cancelled (De Gelderlander, 2009). More recently, plans for turbine placement in the municipality of Bernheze were cancelled after

protests from local citizens and lack of suitable locations due to the presence of the military airport (Wind Service Holland, 2009). In the small town of Made plans were also scrapped after local politicians decided against those plans (Ibid). Support from the local governments tends to correlate highly with the level of public support of local citizens.
Another factor influencing decisions of local governments seems to be lack of information (Bosch & Van Rijn, 2008). The extensive arguments available both for and against wind turbines make the creation of an objective opinion difficult. Getting the necessary permits is also very slow. It can thus take many years before turbines are actually installed (Ibid). In the covenant “Sector Akkoord Energie 2008-2020” between government and energy sector a faster permit granting process was stated as one of the prerequisites to achieve current targets set for wind energy in the Netherlands (Ministry of Economic Affairs, 2009).
The limited availability of suitable land is also a barrier to more wind energy. The Netherlands is a densely populated country. This shows in the “wind energy density” where the country ranks as number five in the world with 95 watt per capita (Welch and Venkateswaran, 2009). Typical areas considered as viable for turbine placement are large agricultural lands and/or industrial zones. Even in those places it will not always be possible to install turbines. An example would be a recent feasibility study by SenterNovem (2009c) that probed the potential for wind turbines around waste water treatment plants in North-Brabant. Several factors where found to make the deployment of wind energy difficult; e.g., air traffic, high voltage lines, communication ray-paths, main transport roads, environmental concerns, and cultural/historical concerns. This shows that a less populated area does not automatically translate to suitable land for wind turbine deployment. With current trends it is unlikely that the target set in North-Brabant for 115 MW by the end of 2010 will be met. Typical barriers for more wind energy are summarized in table 6.3.

Table 6.3: barriers to wind energy, MB: market barriers, EFB: economic and financial barriers, IRB: institutional and regulatory barriers, TB: technical barriers, IB: informational barriers, BB: behavioral barriers

Barriers	**MB**	**EFB**	**IRB**	**TB**	**IB**	**BB**
Visual annoyance to neighboring inhabitants	●					●
Noise annoyance to neighboring inhabitants	●		●		●	
Potential harm to birds				●		●
Limited available land	●			●		
Long process before actual implementation			●			
Technical/geographical/cultural/historical/safety characteristics of potential locations	●		●			●
Well organized local public resistance						●
Lack of objective information					●	●
Performance of small turbines differ considerably per manufacturer				●		

6.4 Solar energy

6.4.1 Status

Energy derived from the sun is by far the largest source of renewable energy available. While it is considered an option of growing potential in Brabant (SER Brabant, 2008); its share in the energy mix has been minimal. Even when added with other sources such as wind, nuclear, and hydropower its share barely reaches 2% (Van Kasteren et al, 2008). In 2009 provincial authorities took steps towards the establishing of a “solar cluster” where knowledge organizations, industry, and entrepreneurs work together in order to promote the development and diffusion of solar energy technologies (Provincie Noord-Brabant, 2009d). At the national level there are no specific goals set for solar energy (Milieu- en Natuur Planbureau, 2008).
There are many conversion techniques to harness the energy from the sun for electricity or heating purposes, each in different stages of maturity. Other techniques like solar energy for chemical processes fall outside the scope of this study and are not discussed in this report. Technologies for electricity generation are the solar photovoltaic systems (PV), concentrating solar power (CSP), solar updraft tower (also called solar chimney), and thermo- generators. Solar PV and SCP are the most developed solar based technologies for electricity generation. For heating purposes solar energy can be put to practical use through solar collectors, solar ponds, thermal mass for heat storage, and also the already mentioned CSP. In the Netherlands only the PV (photovoltaic) systems and solar collectors are eligible for subsidies. The remainder of this paragraph discusses these two techniques.

PV technology

PV technology has some attractive characteristics. It enables modular installation, low maintenance, and creates no noise unlike other renewable energy technologies. Furthermore solar panels typically have a long lasting product lifetime. Countries like Germany and Japan have experienced a wide diffusion of PV technology due to significant support from their respective governments. The German high feed-in tariffs and long term commitment to these tariffs were the main reasons to the increase in installed capacity (Jacobsson and Lauber, 2006). In Japan, the large upfront capital subsidies and tax deductions have been the main drivers for the wide adoption (Shum and Watanabe, 2009). In the Netherlands the government is waiting for more improvements through research and development before committing to more ambitious subsidies. According to the ministry of economic affairs funds are better spend on technologies that are more cost effective (Ypma, 2009b). The province commissions EMG (economie, beleid, en grotestedenbeleid) and R&M (ruimte en milieu) have made similar statements. According to them, PV technology is not apt yet for large-scale subsidies to promote mass deployment. The Netherlands is clearly waiting for more cost effectiveness instead of resorting to heavy financial push like in Germany. In 2008 the province decided to continue with existing subsidy programs until PVs become more cost competitive, something that they expect to take between 10 to 15 years.

Solar collectors

In contrast to PV technology, solar collectors are in a more mature phase of development. Available systems can generally be considered as reliable (Philibert, 2006; SenterNovem, 2008b). Wide scale deployment has not happened yet in the Netherlands (Milieu- en Natuur Planbureau, 2008). Since the heating demand is significant in North-Brabant this technology can be a viable solution and implemented on a much shorter time frame than PV technology (Van Kasteren et al, 2008). The introduction of a subsidy program for solar collectors/boilers in 1991 led to an increase of boiler installations, peaking in 2002 with 10035 newly installed units. In contrast there were just over 1000 installations in 1991 (SenterNovem, 2008b). The program was cancelled in 2003. The new program (energieprestatie-regeling or EPR) excluded new building projects, which is the primary deployment sector for solar collectors/boilers. Between 2003 and 2006 the Netherlands was the only European country showing a declining trend in newly installed thermal capacity (Ibid). In 2006 the decline was at 27% in terms of newly installed thermal capacity from the previous year while countries like Germany, France, and Belgium were experiencing increases of above 50% (ESTIF, 2006). The Dutch market showed signs of picking up again from 2007 onwards (ESTIF, 2007, 2008, 2009). SenterNovem attributed this to higher natural gas prices and increasing environmental consciousness. Subsidies have been available again since 2008 trough the program for sustainable heat or “subsidie-regeling duurzame warmte bestaande woningen”. The program’s goal was to give new impulse to not only solar collectors but also heat pumps and micro-CHP at home. In 2008 there were 7284 new unit installations and until the third quarter of 2009 up to 8066 new units had been installed, suggesting a new increasing trend (CBS, 2010b).

6.4.2 Barriers

PV technology

While PV panels are already finding deployment to some extent, for most people or businesses it is not affordable without or even with the available subsidies in the Netherlands. Subsidies in North-Brabant are available as part of the “Brabant Bespaart” program. The program however is aimed at energy saving measures in general and the amount of money is limited. PV technology therefore has to compete with other, possibly more mature technologies. The critical prerequisite for mass deployment is that costs have to be competitive (Sinke, 2009). PV panels are tied to high production and transaction costs. Solar PV energy is discrete and decentralized by nature. The custom application nature of the technology makes the offering of standardized solutions difficult which would otherwise benefit mass deployment (Shum and Watanabe, 2008). Table 6.4 summarizes the barriers that appear to stand in the way of mass deployment of PV energy applications.

Table 6.4: barriers to solar PV, MB: market barriers, EFB: economic and financial barriers, IRB: institutional and regulatory barriers, TB: technical barriers, IB: informational barriers, BB: behavioral barriers

Barriers	MB	EFB	IRB	TB	IB	BB
Large upfront investment needed for purchase and installation		●				
Feed-in cap for "small PV" treats better performing systems the same as systems with less performance thereby potentially limiting the incentive to maximize electricity generation	●	●	●			
Limit to amount of subsidies issued			●			
Lack of integral approach regarding the procedure of getting subsidies can be seen as cumbersome since there are many parties involved			●			●
No long term security of subsidies and the partial feed-in payback	●	●	●			
Low PV cell efficiencies				●		
Limits posed by buildings				●		

Solar collectors

The decreasing trend between 2003 and 2006 in the deployment of solar collectors/boilers has been attributed to the cancellation of the technology specific subsidy in 1999. The EPR that came afterwards did not have the intended effect for this particular technology. One of the barriers in this sector seems to be the lack of knowledge on the part of installation companies (MNP, 2008; SenterNovem, 2008b). According to the Milieu- en Natuur Planbureau, the years of decreasing sales might have taken away the motivation of installation companies to keep their knowledge about the technology up to date (MNP, 2008). A growing market would entice installation companies to keep themselves informed on the latest developments about the technology. SenterNovem contends that the somewhat conservative culture within the installation companies can lead to a case of slow knowledge acquisition on the latest developments and possibilities with the new solar collectors and boilers (SenterNovem, 2008b). Another major barrier is the long payback period. On average a payback period of at least 14 years can be expected (Ibid). Especially the private consumer might find this to be too much and become thus less interested in this option. Barriers to solar collectors are presented in table 6.5.

Table 6.5: barriers to solar collectors, MB: market barriers, EFB: economic and financial barriers, IRB: institutional and regulatory barriers, TB: technical barriers, IB: informational barriers, BB: behavioral barriers

Barriers	MB	EFB	IRB	TB	IB	BB
Long payback period		●				
Solar collectors are not "popular" among public	●				●	●
Lack of knowledge among installation companies				●	●	
Uncertainty regarding continuity of subsidies		●	●			
Uncertainty regarding amount of energy saved				●	●	●

6.5 Geothermal energy

6.5.1 Status

Geothermal energy is the heat or power derived from the heat stored beneath the earth's surface. According to Dutch NGO "Stichting Platform Geothermie", water of at least 70° Celsius can be found in the Netherlands at depths of around 1800m which can be used for heating purposes in buildings (Stichting Platform Geothermie, 2008). The first deep geothermal installation went online in 2007, providing heat to the greenhouses at a tomato farm in the town of Bleiswijk. The same farm announced it was drilling another well in 2008 which increased the interest by other farmers. In 2009 the government introduced a type of insurance to help investors in case the drilled wells fail to deliver the expected heating capacity. Up to 85% of the drilling investments can be reinstated. The Rabobank also offers an additional insurance of up to 10% of the drilling investments. According to Lockhorst and Wong (2007), there are aquifers in North-Brabant with temperatures reaching well above 100° Celsius. As of October of 2009 there were 12 license applications for deep drilling in North-Brabant (Van Heekeren, 2009).

6.5.2 Barriers

Despite the increased interest, compared to surrounding countries with virtually the same type of soil, development in deep geothermal energy has been rather modest according to Van Heekeren and colleagues (2005). Geothermal energy requires high initial capital investment. Drilling costs are in the range of €1000 per drilled meter. If the drilling misses the aquifer, or if these do not have the heating capacity that was expected it could even lead to bankruptcy. While the government introduced the insurance backup, the total budget allocated to this backup allows for at most just 5 projects a year (Stichting Platform Geothermie, 2009). Furthermore the total allowed insurance budget per project is limited to a maximum amount of €5.950.000. Some users might therefore opt for shallower drilling instead of drilling deeper where typically higher temperatures are found (Gram, 2009). The insurance backup for failed projects has also been criticized for being too strict. Permit seekers need to state beforehand the heating capacity they expect with 90% of probability based on statistical data. In places with well known aquifers this should not be a problem. However in locations with highly varying heat capacities per aquifer, the statistical data will lead to low expected capacities. This makes the project unattractive for the permit seeker (Verheul, 2009). Barriers to the diffusion of geothermal energy are summarized in table 6.6.

Table 6.6: barriers to geothermal energy, MB: market barriers, EFB: economic and financial barriers, IRB: institutional and regulatory barriers, TB: technical barriers, IB: informational barriers, BB: behavioral barriers

Barriers	MB	EFB	IRB	TB	IB	BB
High upfront investment costs related to drilling process	●	●				
Geological risks				●	●	
Long permit seeking process			●			●
Several permits needed			●			
Upper limit to amount of insurance might entice users to opt for shallower drilling instead of going deeper where higher temperatures are available	●	●				●
Total insurance budget not enough for all license applications		●				

6.6 Conclusion

In this chapter barriers to renewable energy technologies were discussed for the following: biomass as resources for renewable energy, wind energy, solar energy and geothermal energy. From the overall results it can be seen that the financial-, institutional and informational barriers stand out among the barrier types just as was the case with energy efficiency barriers. The major barrier among these appears to be the financial barriers, mostly related to the high upfront costs. Surprisingly for wind energy there were no clear barriers that could be directly categorized as financial barriers. Financial difficulties for wind energy like long payback periods are rather due to low performance.

7. Barriers as experienced by entrepreneurs

7.1 Introduction

In chapters 5 and 6 barriers for solutions to energy efficiency and renewable energy technologies were discussed. These barriers were identified through the review of existing studies, articles and reports on hindrances to sustainable energy and through personal communications with policymakers and interest groups. In order to get a more complete picture and in line with the main goals of this study, entrepreneurs that operate in the region were also consulted on the subject. In this chapter the results of personal communications with the entrepreneurs for the province of North-Brabant is therefore discussed based on the barrier categories that were discussed and used in previous chapters. The entrepreneurs were asked about what they encounter as barriers to the part of their business that deal with solutions regarding sustainable energy. Their take on the barriers is also compared to what has been found in chapters 5 and 6.

7.2 Perspectives from entrepreneurs

As was already mentioned in chapter 5, from 34 entrepreneurs or companies that were contacted 12 cooperated. Respondents were either the director or head of sales for the company. Only companies that operate in North-Brabant were contacted. In this section the results are discussed through the barrier categories from Reddy and Painuly (2004) which were introduced in chapter 3 and the results are summarized in table 7.1. The list of companies that responded are shown in appendix 1.

1. Market barriers/ failures

One respondent noted that subsidies and their requirements sometimes are made in cooperation with local energy suppliers. This could potentially lead to market imperfections, something that Kern and Smith (2008) also warned against where incumbent firms in the Netherlands might become too powerful and end up hindering the energy transition. Another market barrier was suggested to be the "relatively" lower costs of energy for some businesses which makes the installation of for example PV panels, wind turbines or solar boilers not attractive. The benefits would not pay off. A certain critical point regarding the energy consumption would need to be crossed for the system to become viable.

2. Economic and financial barriers

All of the respondents included barriers of economic or financial nature in their answers. The way that it was perceived however was somewhat varied among the respondents. To some it was clear that the high initial investment costs and related long payback periods put a big hurdle in front of people who are thinking about possible investments. Others put the blame on the lack of sufficient subsidies. One respondent thought that actually the subsidies were not the optimal solution and suggested that better suited financing could fare much better:

"While many people see sustainable energy as important a climate seems to have been cultivated where sustainable energy is perceived as viable only with the help of subsidies. I would rather see some kind of special financing for sustainable energy instead of the subsidies (particularly in

times of cost cutting/crisis). This makes it possible for more people to participate. This kind of financing should also be explained in a clearer way to the customers than how it is done now by for example the Stimuleringsfonds Volkshuisvesting Nederlandse Gemeentes (SVN)"

3. Institutional and regulatory barriers

The barriers in this category are institutional structures, mechanisms, policies and practices that actually slow down the diffusion of sustainable energy technologies. The majority of barriers that fell into this category had to do with the subsidies. Again almost all of the respondents mentioned the limited subsidies as a barrier. Subsidies are bounded to upper limits on capacities of systems and the lottery system was perceived as unfair. Another hindrance was found to be what the respondents perceived as a lack of clear direction by the government. Their views change too often and therefore entrepreneurs or customers become unsure about making large investments. One respondent compared it with a stop and go cycle kind of situation where for example at one particular moment the government is granting subsidies and announces support for it while later they announce that subsidies should be minimized. The long or sometimes difficult process for customers to get permits is also seen as a barrier.

4. Technological barriers

Except for one respondent (nr. 5 in table 7.1) there were not many barriers that could be included under the category of technological barriers. It appears that the technology advancements have come a long way, especially for energy saving measures. Most difficulties were actually about the location where the systems had to be installed. For PV panels it makes little sense to install them where there are many trees or surrounding buildings, or sometimes people are actually worried about the mechanical stress by the installations on the buildings' roof. Also the available space was a concern not only because it may pose limits on the installations but also on future projects that may have nothing to do with energy, e.g. a roof dormer. The only barrier that was mentioned with a direct relation to technology was the high customization factor with most systems thereby affecting the price and applicability.

5. Lack of awareness and information

Perhaps even more important than the financial barriers are the informational barriers. The lack of information was not perceived by the entrepreneurs among customers alone but also among other entrepreneurs and decision makers from government. One respondent suggested that that the lack of proper marketing or awareness by the customers about proper companies that offer solutions is a bigger hurdle than the high prices. The massive amount of information on especially the internet makes it difficult for the customer to decide which companies are good or not:

"In reality there are companies that go into the sustainable energy business without proper certifications and knowledge trying to sell solutions in the off the shell style. This diminishes optimal advice and installations which can reflect badly on the market"

Another respondent concurred with the lack of proper marketing by stating about how many customers think that sustainable is still expensive. With proper design and financial backing like subsidies or loans the system can provide energy that is cheaper than what is available from the net, some people just do not know about the available subsidies. The government, interest groups and companies could do better by publishing more success stories in the media instead of technical brochures. It was also suggested that the constant news in the media about the next breakthrough slows the diffusion:

"Stories in the media about the next big breakthrough where afterwards nothing really happens affects the market negatively, some people might actually see this as a reason to not undertake steps"

Companies like those operating in the building sector also seem to lack up to date information on what is available which is unfortunate since this is one of the two sectors where the most energy is consumed (see chapter 5).

6. Behavioral

Sometimes the decision to adopt a technology simply depends on what the potential user thinks about it. Sometimes there is just no interest. Aesthetical consideration also seems to play a role according to some of the respondents. The case for windturbines is a good example where many times community's band together to protest against the turbines and manage to influence the decision makers. Perhaps partly related with the financial barriers is the fixation of people on the more "standard" payback periods of 3 to 7 years. Also it was mentioned that people tend to be focused on maximizing the subsidies and forget about optimizing their energy systems.

Table 7.1: barriers according to entrepreneurs; MB: market barriers, EFB: economic and financial barriers, IRB: institutional and regulatory barriers, TB: technical barriers, IB: informational barriers, BB: behavioral barriers, Resp.: respondent number

Resp	Barriers	MB	EFB	IRB	TB	IB	BB
1	Lack of right information rather than crisis or high investments					●	
	Problem with separating good from bad companies which has become difficult due to growth on the internet	●				●	
	Companies go into the sustainable energy business without proper certifications and knowledge			●	●		
	Incentives like subsidies from government should be tied to proper certified companies		●	●			
	Lack of information in the building sector					●	
2	Government lacks continuity/ clear direction	●		●			
	People who are not clients or not interested lack up to date information					●	●
	Stories in the media about the next big breakthrough	●				●	●
	Investments only if the economic benefits are very large		●				

Table 7.1 barriers according to entrepreneurs continued: MB: market barriers, EFB: economic and financial barriers, IRB: institutional and regulatory barriers, TB: technical barriers, IB: informational barriers, BB: behavioral barriers, Resp.: respondent number

Resp	Barriers	MB	EFB	IRB	TB	IB	BB
3	Majority of population do not know that solar electricity can be equal or cheaper than energy from the net					●	
	Potential customers do not have the money or are not interested to invest in such systems		●				●
4	Problems with correct calculations regarding payback period		●				
	Problems with financing: increased risks		●				
	No consistency from government on policies, no clear direction			●			
	High research costs		●				
	Long processes e.g. permits, subsidies etc: weigh heavy on especially small businesses			●			
5	High initial investment costs		●				
	Lottery for subsidies is unfair			●			
	Uncertainty if its really the right time to invest	●					●
	Aesthetic considerations	●					●
	Once installed, other options are not possible anymore				●		
	Mechanical stress on the roof				●		
	Fitting of solar panels with the current system				●		
	Lack of sufficient space				●		
	Location or orientation of building not optimal e.g. shadows, buildings, trees				●		
6	High degree of customized solutions				●		
	Limitation of available subsidies		●	●			
7	Local energy companies might have too much say in the process of subsidies			●			
	The impression exist that sustainable energy could only be profitable with subsidies	●					●
	Subsidies are limited hence the budget is used up rather fast		●				
	Subsidies are mostly unknown or are known late with people					●	
	People tend to be focused on subsidy maximization instead of optimization of their energy system				●		●
	Communication from the government or groups is not optimal					●	
	Subsidy process leaves a lot of potential adopters out due to limitedness			●			

Table 7.1 barriers according to entrepreneurs continued: MB: market barriers, EFB: economic and financial barriers, IRB: institutional and regulatory barriers, TB: technical barriers, IB: informational barriers, BB: behavioral barriers, Resp.: respondent number

Resp	Barriers	MB	EFB	IRB	TB	IB	BB
8	Constant changing of direction or lack of it by the government makes entrepreneurs uncertain about making investments			●			
9	Payback periods are too long		●				
10	Investments are too high		●				
	Subsidies are limited while there is a large demand		●	●			
11	Lack of clear pricing		●				
	Limited subsidies		●	●			
	Peoples expectation for payback periods is too short		●				●
12	Unreasonable requirements/limits on subsidies			●			
	Lack of knowledge on the part of decision makers				●	●	

7.3 Existing knowledge on barriers and input from entrepreneurs

It appears that what the entrepreneurs experience as barriers or hindrances to their businesses regarding sustainable energy technologies correlate in most cases with the results in chapters 5 and 6 except for the technological barriers. This was less a factor (with the exception of one respondent) than what would have been expected based from the results in chapters 5 and 6. The institutional, financial and informational barriers seem to be the leading factors that slow down the adoption of more sustainable energy technologies; this is also the case for both energy efficiency and renewable energy technologies. The common found barrier among many of the respondents was that the subsidies are too little and that the local government lacks direction.

7.4 Conclusion

In this chapter the results from inquiries with entrepreneurs that operate in North-Brabant were presented. The results are close to the information that was collected from existing knowledge about barriers to energy efficiency and renewable energy technologies (chapters 5 and 6 respectively). The dominant barriers for the entrepreneurs appear to be the institutional, financial and informational barriers.

8. Towards an increased adoption

8.1 Introduction

The identification of barriers is an important part of the road towards increasing the adoption of sustainable energy technologies. It is however also important to look on how to actually guide this adoption process. Province authorities mention in the latest energy agenda for Brabant about the high risks for SME's (Provincie Noord-Brabant, 2010) and recent studies on innovation systems agree on the importance of entrepreneurial action for the adoption of innovations. It would be right to argue that due attention to this group is therefore necessary by the relevant stakeholders, i.e., province, research organizations, interest groups and the entrepreneurs themselves. From the energy agenda it is very clear that for the moment the majority of the focus is on knowledge development. This fits with transitions theory which advocate that several options be left open to expose complexities related to different innovations. This however could at the same time be the very one thing that slows down the adoption of sustainable energy technologies. Perhaps Lysen was right in advocating a focus on implementation instead of waiting on the next breakthrough (Lysen, 1996). After all, there will always be "the next big breakthrough". By focussing on implementation, knowledge can be gained too through the experiences with the technologies for sustainable energy that have been implemented. The main goal that this study tries to contribute to is the increase in entrepreneurial activities regarding sustainable energy technologies. This should lead to more sustainable energy technologies being adopted. In this chapter this topic is discussed through the lens of the innovation functions that were discussed in chapter 3. These functions are not just for analysis of the current situation of sustainable energy but can also be used as a sort of guide on critical events/activities that need to take place.

8.2 Entrepreneurial activities

Entrepreneurs are an important ally in the quest for wider implementation of sustainable energy technologies. Entrepreneurs are not only those that develop the technologies but also those that have to sell/install these to customers. According to Hekkert and colleagues (2007) the function of entrepreneurial activities is primarily influenced by how the other functions are fulfilled. It is therefore more helpful to look at the other functions and how they affect entrepreneurs and their customers.

8.3 Knowledge development

According to Negro (2007) the Netherlands scores well on knowledge development when it comes to innovations. In North-Brabant there are several institutions present that can drive this function. The recent energy agenda for Brabant (Provincie Noord-Brabant, 2010) is mainly focused on activities that contribute to this function, e.g., creation of think thanks, bringing stakeholders together and knowledge creation through pilot projects. For the type of entrepreneurs that are targeted in this study the value of knowledge creation lies mainly in the opportunity to know about what is available in terms of technological solutions for end users, financial constructions and regulatory issues. Also an important aspect of knowledge for entrepreneurs is to know where there might be potential customers. These could be interesting topics for projects at the regional universities as they encompass not only the technological field but also topics of economical, financial and social nature. If the province manages to execute its plans as presented in the energy agenda then this function should perform well. The next innovation function (knowledge diffusion) goes hand in hand with knowledge development.

8.4 Knowledge diffusion though networks

Closely related to knowledge creation is the actual diffusion of this knowledge to relevant actors. As was mentioned in the previous paragraph, the province wants to promote the diffusion of knowledge by bringing stakeholders together and creating think tanks. It will be important that this is well coordinated to ensure that that the right recipients are able to have access to this knowledge. Knowledge should also not remain restricted to the scientific community but attention should be given to the translation towards practice. At the moment there is a lot of knowledge present but it seem to be highly fragmented with occasional news bits on internet pages or printed media. Especially with regulatory and financial issues there are several sources on the internet which could confuse those who are looking for information. Also knowledge is not only for the entrepreneurs. For potential customers/users this was one of the major barriers that was identified: lack of information on the part of potential end users. Sometimes end users make wrong assumptions about a technology that ends up in them not adopting it (e.g., solar PV). More central locations where information is communicated could help with this. The province or for example TELOS Brabant will do well by facilitating the building of networks between stakeholders to exchange knowledge on these topics but attention needs to be paid to supplying this knowledge in an effective manner.

8.5 Guidance of the search

Of all the functions it is perhaps within this category that the biggest barrier lies. Entrepreneurs argue that there is no clarity on the direction in which the government wants to go, including the provinces. Furthermore it is argued by the entrepreneurs that the subsidies are not allocated fairly. They contend that with the lottery style allocation potentially under-skilled companies are put at the same level as those who are more adept with giving advice and installing the sustainable energy technologies. In the latest provincial energy agenda from 2010 there are a lot of intentions mentioned or potential activities to be undertaken but most of the direction given is in abstract terms. There is no concrete plan of action. The province will do well by stating how they will facilitate entrepreneurs who want to operate in the region and by applying a more stringent allocation procedure for subsidies. On the other hand it can be advantageous for the entrepreneurs themselves to band together in order to supply relevant feedback to the provincial authorities. This could send clear messages to the province and lead to better guidance.

8.6 Market formation

If the amount of applications for subsidies in 2010 was of any indication it would appear that there is indeed enough opportunities available in the market. In 2010 for example there were around 52,000 applications for subsidies regarding solar PV for both large- and small scale installations (SenterNovem, 2010). The market appears to exist but is not effectively reached. Barrier assessment suggests that this is mostly due to institutional/regulatory barriers, financial barriers and informational barriers. While the province offers itself as a potential "first launch" customer it will do better by providing an effective guidance of the search and resource mobilization. Through these two other functions it will be much easier to fill the function of market formation.

8.7 Resource mobilization

Resources can be of financial, human and material type. For entrepreneurs it is essentially the financial resources that pose difficulties. Several options are possible for this function. The subsidies have been a proven and time tested method but lately it does not seem to be executed effectively. It would be easy to argue that the amount of funds available for subsidies needs to be increased and if this was possible for the short to mid term it would definitely serve its purpose. However for the long term this may not be the best option for market creation since the ultimate goal is to make sustainable energy technologies competitive on the market. Perhaps making more funds available for more "green loans" would be a better option, especially if one takes the total amount of subsidy applications for 2010 into account.

On the part of the entrepreneurs themselves the performance based contracting concept might be an interesting option. It has been a proven method especially in the U.S.A and is slowly gaining interest in Europe. The principle behind performance based contracting is that the amount of money saved on the energy bill goes to the entrepreneur or service provider until the project has been paid for. Many times these are done in cooperation with third party financing. The customer keeps paying a fixed amount of money during that time. The incentive for the customer is then that they do not have to make high initial investments and for the entrepreneur the incentive will be to save as much energy as possible given that this will increase his profit. The main drawback is that people are fixated on standard payback period of 5 to 7 years while for energy projects these tend to be longer.

8.8 Creation of legitimacy

Legitimacy for an innovation system can lead to better institutional interest and eventually a more effective guidance of the search. The province has several areas of interest regarding sustainable energy, i.e., solar PV, biobased economy, electrical transport, heating, energy efficiency in the built environment, wind power and decentralized energy systems. Entrepreneurs can do best by banding together on one or more of these areas and form coalitions with clear standpoints in order to influence provincial authorities. In Germany it was possible for these coalitions to influence the government which led to elimination of institutional barriers and thus more guidance of the search (Hekkert and Negro, 2009). Perhaps one of the first goals of such coalitions could be the introduction of a quality mark that indicates a high degree of excellence by the entrepreneur/service provider. An important function that is related to this would then be the knowledge diffusion which should make sure that customers get to know about the quality mark.

8.9 Interaction between functions

According to Hekkert and colleagues (2007), functions will seldom work alone and there is a big chance that it will be connected to other functions. In their research on cases for biomass technology adoption in the Netherlands and Germany Hekkert and Negro (2009) found that most sets of interacting functions start with the guidance of search. This can potentially trigger other functions. When these interactions interact positively with each other this is called a virtuous cycle. When the influence on each other is negative it is called a vicious cycle. These type of cycles cannot be forecasted and they can alternate with each other. It is the task of the stakeholders to monitor the progress (or lack of it) and take action. The initiative should not always lie with the provincial authorities but the entrepreneurs themselves should also become more involved. By forming strong and well organized coalitions they can exert influence on policy makers thereby influencing the guidance of the search. Better guidance could translate itself into more legitimacy among researchers, developers, customers and financial institutions. This could set of more resource mobilization and market creation. When there is enough market available for a service and suitable financial options become available entrepreneurs can see this as a sign to take action.

8.10 Conclusion

By using the innovation functions as a sort of guidance on the type of activities that need to take place barriers to more sustainable energy technology adoption can potentially be relieved. The great thing about an approach that involves the innovation functions is that by working on a function it is possible to affect many barriers at the same time instead of just focusing on one particular barrier. If for example an effective system is set up for information diffusion this could take care of informational barriers but also behavioral barriers since one's behavior is closely related to the information that is available. Also by working on functions other functions can be triggered (virtuous cycles) thereby influencing even more types of barriers. It should be noted that the initiative should not only lie with the province but also with the entrepreneurs.

9. Conclusions

9.1 Introduction

This study set out to look into the barriers that stand in the way for more sustainable energy in North-Brabant and it incorporated insights from innovation systems theory to generate recommendations. In previous chapters the results from literature study and communications with relevant stakeholders were presented. In this chapter the main results are summarized by specifically answering the research questions and the related sub-questions. Recommendations are made and limitations of this study are highlighted.

9.2 Results

In order to come to an answer for both the main research questions a set of sub-questions were analyzed first. These are discussed below together with the main research questions.

SQ 1.1: What is a practical and clear way to break down the concept of sustainable energy technologies into clear and groups or sectors?

By looking into what is mostly used in literature it was found that distinction is made between energy efficiency and renewable energy. Within the field of energy efficiency it would have been impractical if not impossible to work with a list of technological solutions given the broad scope of this study. It was therefore chosen to analyze this part of sustainable energy by looking at sectors rather than at individual technologies. For the renewable energy technologies however it was possible to look at the renewable energy sources themselves. Some were left out because they have no significant meaning for North-Brabant, e.g., wave power or hydro-energy. These distinctions are also customary in both scientific and professional literature.

SQ 1.2: How can the barriers best be grouped into a clear set of categories?

A review through literature resulted in insights into the types of barriers that scholars typically use. It was found that while the numbers differed there was a lot of similarities between barrier types but not all authors would give a clear description of what would fall under these categories. This was important for this study because a lot of barriers that were found would be stated differently by their sources. It was thus necessary to do some categorization. The barrier set from Reddy and Painully (2004) were both extensive enough but also well explained which is why their set of barriers was used.

SQ 1.3: What are the critical barriers-types for sustainable energy in North-Brabant according to existing knowledge?

All of the barrier types were present but the financial-, institutional and informational barriers were the dominating types according to results from literature reviews and personal communications with policy makers and interest groups.

SQ 1.4: What do the entrepreneurs who operate in North-Brabant themselves experience as barriers to a wider adoption of sustainable energy technology?

The entrepreneurs experience a lot of financial barriers for the customers paired with institutional barriers. They criticized the government for a lack of clear guidance. There is a big enough potential market but the subsidy funds are too low. It was even suggested by some entrepreneurs that more "green loans" would fare much better for adoption instead of subsidies. Also many times potential customers are not well informed and tend to keep on waiting for the next big breakthrough.

SQ 1.5: Does the experience from entrepreneurs coincide with existing knowledge?

Pretty much the same types appeared to dominate among the entrepreneurs compared to what was found in the literature review and personal communications. The institutional and financial types seemed to be the major ones with informational coming in second. It is noteworthy to mention that technological barriers were not as present as one would have expected them to be. Perhaps this was because SME entrepreneurs deal with technologies that are already past the initial development stages where technological challenges tend to happen the most.

Having answered the sub-questions it becomes possible to answer the first research question:

RQ1:	*What are the barriers for sustainable energy deployment in North-Brabant?*

In chapters 5 through 7 the barriers are discussed. From the results it appears that while all barrier categories are present the financial-, institutional- and informational barriers pose the biggest hindrance to a wider adoption. A strategy at the provincial level to address these barriers would be appropriate.

The second part of the research is more prescriptive in nature and deals with what can actually be done to overcome the barriers that have been found in the first part of the research. In order to come to these implications insights from innovation systems theory and in particular the innovation functions were consulted. First two sub-questions were assessed.

SQ 2.1: What does recent theory tell us about innovation systems?

It has been argued by several scholars that existing approaches related to innovation system theory lack practical implications. Some authors have therefore come up with a new approach that focuses on activities that need to take place for an innovation system to succeed. These have been called innovation functions. These functions are 1.Entrepreneurial activities; 2.Knowledge development; 3.Knowledge diffusion through networks; 4.Guidance of the search; 5.Market formation; 6.Resource mobilization and 7.Creation of legitimacy. By fulfilling these functions a strong basis can be created for an innovation system to thrive. In the Netherlands this approach has been used to study the adoption of biomass digestion technologies. It has been found that in the Netherlands there is a high focus on knowledge creation but that there is difficulty to successfully commercialize innovations.

SQ 2.2: How does the recent theory about innovation systems relate to the findings from the first research question?

From the barrier assessment it was found that the institutional-, financial- and informational barriers dominate among the barrier types. These are directly related to the innovation functions Guidance of the search, Resource mobilization and Knowledge development/Knowledge diffusion respectively. When functions interact with each other it has been found that most of the time this interaction starts with guidance of the search. This can potentially trigger other functions to be filled. Some of the entrepreneurs mentioned that the lack of clear direction by the government was the biggest barrier, even more so than the financial barriers. If the latest energy agenda for North-Brabant is any indication of the direction in which the province will be going then there will be focus on all of these functions.

This brings us to the second research question:

RQ2:	*What can be done to help entrepreneurs in overtaking the barriers to the adoption of sustainable energy systems in North-Brabant?*

For the North-Brabant there are seven paths of interest:

1. Solar-PV;
2. The biobased economy;
3. Electric transport/intelligent transport system;
4. Sustainable heat;
5. Energy efficiency in the built environment;
6. Wind energy;
7. Decentralized networks

First of all by applying the innovation function concept to each of these paths the province can have a tool for analyzing the status of the transition in North-Brabant. The province is doing well by trying to set some clear paths in which it wants to go. This is actually part of the guidance of the search and is one of the innovation functions that the province can directly influence. In the energy agenda entrepreneurs are mentioned but no distinction is made into what kind of entrepreneurs is meant. Further attention to them will not only strengthen the guidance of the search but potentially also other functions. The entrepreneurs should therefore be included in the process around the paths of interest for North-Brabant.

The province wants to put a lot of focus in knowledge creation and diffusion. Especially the diffusion part needs to be closely guided in order to ensure that the right type of information is available to the right recipient at the right time. These recipients are not only the entrepreneurs but also potential customers/adopters. A more central way of communicating with the different groups of interest might be interesting. As of now there is already a lot of knowledge available but these tend to be highly fragmented. This of course is not the sole responsibility of the province but of the entrepreneurs themselves as important stakeholders.

The entrepreneurs can form coalitions in order to better interact with the province and reach potential markets more effectively. This has been highly successful in Germany. Also some entrepreneurs are worried about the quality that is given to customers. This could be a first goal for the formation of coalitions: communicating about the quality of their work to customers. Instead of solely competing with each other a situation of co-opetition should be reached in order to create a larger market. This is when competitors also cooperate with each other (Garcia and Velasco, 2004).

The limited amount of subsidies is a case for concern for many entrepreneurs. If more subsidies can be attained it will be very welcome but perhaps thinking creatively could provide a much more long lasting solution. Performance based contracting and third party financing, "green loans" are all possible solutions.

In the end regarding the SME entrepreneurs the main goal is to increase their activities. The more entrepreneurial activities the healthier the innovation system is expected to be.

9.3 Limitations and implications for further research

Despite the apparent correlations between barriers found in literature and through personal communications with experts and the entrepreneurs there are still some limitations to the results from this research. One of the first limitations is the relatively low response rate under the entrepreneurs. Despite showing a high degree of similarities with existing knowledge on barriers there were still only 12 companies that responded from the 34 that were approached. A higher response rate would have provided a more complete picture of the situation for North-Brabant.

Another limitation is the broad scope that was maintained for this study. In a future research further in depth analysis can be undertaken by looking at the seven paths of interest separately and how the innovation functions perform for each path. This could yield recommendations that are more practical which is the main goal of the theory behind innovation functions.

One last limitation is the qualitative nature of the study. Again by focusing on the seven paths of interest that the province presents in the energy agenda more thorough analyses become possible. Quantitative data on for example the amount of a certain technology that has been sold will reveal what customers are buying the most and could give stakeholders an indication where to put more attention.

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Appendix 1: List of entrepreneurs/companies contacted

DEGOTECH Zonne-energie BV, (South-Holland)

De Solarshop Systeemhuis, Maastricht (Gelderland)

Draaistroom Nederland BV, Veghel (North-Brabant)

EnergieWonen BV, Almere (Flevoland)

ESDEC BV, Deventer (North-Holland)

R&R Systems BV, Gemert (North-Brabant)

Rome Energy solutions bv, Rossum (Gelderland)

Re-source Energy, Helmond (North-Brabant)

Sollect BV, Waalre (North-Brabant)

Intersolar BV, Eindhoven (North-Brabant)

Leudal Duurzame Systemen BV, Hulsberg (Limburg)

Megens van Bergen Technische Installaties BV, Ravenstein (North-Brabant)