Barriers impairing energy-efficient renovation in the Dutch housing sector

Master Thesis (45 ECTS)

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Utrecht University

Supervisor: Dr. Ir. J. Rosales Carreón
2nd supervisor: Dr. G.J. Heimeriks

Geert Sauvé - 3042987
g.g.h.m.sauve@students.uu.nl
Vlierdenseweg 19
5753AA Deurne

Summary

The Dutch government has set energy efficiency goals which at the current pace will not be reached within the defined timeframe. Barriers in the Dutch energy-efficient renovation sector hamper the development of the system. This research identifies the barriers that impair energy-efficient renovation strategies within the Dutch housing stock. A Sectoral Innovation System perspective was used and the analysis was conducted using the functions of innovation systems framework. The data was gathered using a literature review and expert interviews. The functions of innovation systems framework has proven to be a helpful tool in defining a system and identify barriers within that system. Five barriers were identified during this analysis: there is insufficient participation of actors in the diffusion of knowledge regarding energy-efficient renovation; there is a lack of competitive advantages to create a favorable market for energy-efficient renovation; there is a lack of energy standardization and compliance to those standards; public awareness is virtually non-existent; lobbying efforts to increase awareness are in vain. Recommendations that foster the development of the Dutch energy-efficient renovation sector are given.

Keywords: Energy-efficient renovation, energy efficiency, renovation sector, housing sector, barriers, sectoral innovation system.

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1. Introduction

1.1 Background

In the 70's, 80's and 90's there was a growing realization that the temperature on earth was rising (Wigley & Raper, 1987; Hansen & Lebedeff, 1987; Graham, 1995). This led to a large body of scientific research on the anthropogenic impact of greenhouse gasses (Water vapor, Carbon dioxide, Methane, Nitrous oxide, Ozone and CFC's) on the earth's climate as a result of emissions (Stott et al., 2000; Ding et al., 2001; Trenberth, 2001). Literature has shown that different types of impact have occurred in the years during and following that period or will occur in the future, including increase in sea level (Church et al., 2001; Karl & Trenberth, 2003), change in health effects, both beneficial and adverse (McMichael et al., 2006) and increase in extreme weather phenomena (Patz et al., 2005).

According to the IPCC (Susan, 2007) climate change is very likely to increase if the emission levels remain equal or increase compared to the emission levels in 2000. This growing awareness of climate change has led to the increase of climate policy within nations' policy programs. Because climate change is a global problem it is important that nations work together to solve this issue. In 1997 this resulted in the international treaty known as the Kyoto protocol. This treaty states that the participating countries have to decrease emissions as agreed upon in the treaty within two periods, the first before 2012 and the second before 2020 (Carraro, 2000). The main goal of the Kyoto protocol is to reduce the anthropogenic carbon dioxide emissions by setting lower emission levels targets compared to those in 1990 (Kyoto protocol, 1997). The countries that took part in the protocol consisted of annex 1 countries (UN, 2013a) and non-annex 1 countries (UN, 2013b) of the United Nations framework convention on climate change. Annex 1 countries, consisting of developed countries plus economies in transition, set a goal of at least 5% carbon dioxide emission reduction compared to their respective 1990 levels (Manne & Richels, 1998). Non annex countries, often countries in development stages, were often allowed to increase their emission levels to prevent the Kyoto protocol from becoming a growth barrier. The emission levels for non-annex 1 countries was determined on a country-by-country basis. Not all nations involved in the Kyoto protocol have ratified the protocol, but 83 nations have ratified the protocol as of 2013 (UN, 2013c).

As seen in the previous section, a large portion of the countries in the world have decided to enter agreements to reduce the anthropogenic impact of our current energy needs. Most of these agreements focus on greenhouse gas emission reduction, as they are the major impact factor on the ecosystems of the earth, since they are said to be the largest contributors to the rising temperatures on the earth. Climate change mitigation agreements such as the Kyoto protocol generally consist of a set of goals defined for a specific timeframe that need to be met for the agreement to have its desired effect. In the case of the Kyoto protocol, this is at least a 5% emission reduction of greenhouse gasses in the 5-year period 2008-2012. The Kyoto protocol agreement was one of the first large-scale attempts to reduce global emission levels and as such seems to be moderately successful in its task. This is due to the fact that countries that cannot meet their goals have the option to buy 'emission rights' from other countries. Analysis on greenhouse gas emission by countries shows that developed countries are often not reaching their targets without buying extra emission rights. A 2012 analysis showed that the Netherlands is one of these countries not reaching their targets (Verdonk & Wetzels, 2012).

In the years following the Kyoto protocol, the European Union came to the conclusion that at the current rates of reduction it was estimated that it would not be able to reach its targets set for 2020 (European Commission, 2012a). Therefore it proposed a directive on energy efficiency that encouraged member states to take further action. By reducing its energy needs, Europe planned on reaching its goals as set in the Kyoto Protocol in 1997 and the Energy Efficiency Plan in 2011. According to Karl & Trenberth (2003) climate change is caused mainly by anthropogenic influences on the atmosphere which are primarily related to energy use. Therefore it can be concluded that energy use has a direct influence on climate change. The European Commission (EC) breaks down the total energy use into three main categories: Industry, Transport and Buildings. According to the EC, the highest potential in energy savings can be found in the Buildings sector, followed by transport and industry respectively (ibid.; Mickaityte et al., 2008). Based on reports, around 40% of final energy consumption is in houses, public and private offices, shops and other buildings (EC, 2012a; Naess-Schmidt et al., 2011; BPIE, 2010; Mickaityte et al., 2008). The Dutch ministry of the Interior stated that the Dutch buildings account for 30% of the national energy consumption (Ministerie van binnenlandse zaken, 2011).

The Netherlands has a plan to reach certain energy reduction (and pollution reduction subsequently) goals in the period until 2020 (Lente akkoord, 2011). The government has also stated that the built environment in the Netherlands needs to be energy neutral by 2050 (SER, 2013). The 2011 agreement covenant[1] on energy-efficient new buildings states that all the stakeholders need to increase the use of knowledge transfer and incentive programs to increase the use of energy efficiency concepts and techniques (ibid.). It also states that all stakeholders will aspire to build new buildings to a (near) zero-energy building standard (ibid.). Focusing on a (near) zero-energy building standard for new buildings is not the only possible method to reduce energy use in the housing category. Relatively speaking, newly built houses only account for a small percentage of the total Dutch housing stock. The current housing stock is very large, and renovation of it will also lead to a reduction of the total energy use in the housing sector. Since the economic crisis in 2008, banks have been less willing to loan out capital for the building of new homes, resulting in the need to renovate the current building stock. In 2010 Agentschap NL[2] conducted research to assess the relative energy efficiency benefits of new buildings compared to renovation of older buildings, and came to several conclusions. First, buildings that are older (e.g. >20 years) usually have worse energy labels, meaning that they are more fitted for renovation because there are large possible gains in energy efficiency (W/E adviseurs, 2010). Second, the energy usage of a building consists of two major phases, the first being energy used in the actual construction of the building and the second being the energy usage related to the operation phase. The older the building the larger its relative energy consumption (ibid.). These two conclusions show that older buildings have bigger energy saving potential because they are less energy efficient due to less strict building codes at the time they were built and a high relative energy usage during its occupation, compared to the energy necessary to build it. This goes to show that for older buildings renovation is a viable energy efficiency strategy, which is in line with other studies (Kromhout et al., 2007; Jeths & Prendergast, 2009; Ministerie van economische zaken, 2012). The Netherlands is a country leading in voluntary agreements regarding energy efficiency goals (Bertoldi & Rezessy, 2010) and has proven to be a good pilot country when testing the

[1] Government and other relative stakeholders such as building associations and unions list recommendations and guidelines in this agreement. (lente akkoord in Dutch)
[2] A subsidiary of the Dutch ministry of economic affairs partly focusing on sustainability and innovation.

introduction of new products and services (TNO, 2013). However, the Dutch housing sector remains very reliant on fossil fuels for its energy needs compared to other European countries (ibid.).

The total final energy use of buildings in the Netherlands is 30-35% of the national energy consumption (Ministerie van binnenlandse zaken, 2011; Harmelink et al., 2010). A significant reduction in energy use within this sector would therefore also result in a significant reduction in the energy use of the country. In order to be able to make conclusions about the energy efficiency of the Dutch housing stock, it is important to know what the housing stock looks like. Figure 1 shows an overview of the Dutch housing stock by building period. Buildings built before 1995 comprise roughly 85% of the total housing stock. This implies that a large energy savings potential remains untapped in this sector (Sunikka, 2003).

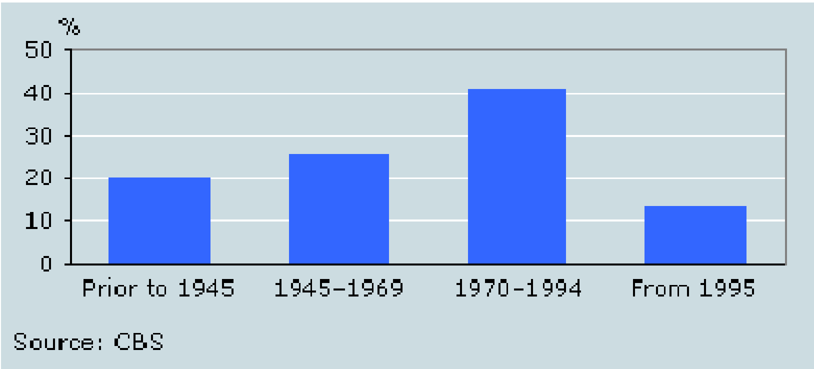

Figure 1: Dutch housing stock by building period (2007)

Because of the old average age of the Dutch housing stock, (energy-efficient) renovation can be deemed an important strategy to reduce the Dutch energy use while increasing quality of housing and health. According to Tofield & Ingham (2012) emphasis within policy should be on energy efficiency within the building stock.

1.2 Problem definition

The European Union (EU) started to expand its policy regarding energy efficiency and energy use in the 2000's with several directives. In 2007 the EU decided on new environmental targets that were more ambitious than those agreed on in the Kyoto protocol. The goal was named the '20-20-20' goal, which refers to the following three goals (European commission, 2011):

1. To reduce energy use by 20% by 2020 through energy efficiency
2. To increase renewable energy use to 20% of total primary energy use by 2020
3. To reduce greenhouse gas emissions by 20% by 2020

In 2011 the EU published an update on the current status of the goals. This update showed that the EU was on track for both goals 2 and 3, but at the current pace was only going to reach half of the energy use reduction (European commission, 2012b). For the second goal national targets were set based on the potential of member states renewable energy production, but that lead to an overall EU increase of 20% in 2020. The third goal was strongly influenced by a directive started in 2005 called the 'European union emissions trading system (EU ETS)', which is a large scale emissions trading scheme that caps the total emissions output and regulates the trading of emission rights in Europe. The ETS does not cover all sectors, excluding sectors such as: housing, agriculture, waste and transport (excluding aviation). The non-ETS sectors comprise 60% of total emissions. Emission targets for non-ETS sectors where set to country-by-country specific targets based on the relative wealth of the member states, ranging from -20% for the richest and +20% for the poorest compared to 2005 (ibid.). For the Netherlands the target for 2020 was set at -16% compared to 2005 (European commission, 2013). According to Harmelink et al. (2010), 40% of the emission reduction is expected to be realized through energy saving in the Netherlands. They also state that the current rate of energy efficiency increase needs to be drastically increased if the Netherlands wants to reach its goals. They have combined international studies to find explanations for barriers that prevent a successful increase in energy reduction for different sectors (de T'Serclaes & Jollands, 2007; Yamamoto et al., 2008; Brown & Whiting, 1997). For the housing sector, three major barriers have been found: 1) Split incentives, where the person that invests in energy reduction is not the person to benefit from its reduction in energy costs; 2) A lack of knowledge about costs and the effects of energy reduction; 3) Energy use plays a minor role in the decision when purchasing appliances and homes compared to aesthetics.

Lanting (2010) states that in the Netherlands there will be a demand for new education and to make better use of communication methods to overcome professional barriers that exist in the building sector. He states that the need for better communication indicates the following problem: Knowledge does not transfer freely and successfully between relevant stakeholders in the energy efficiency related fields of the building sector.

The fact that the Netherlands is not reaching its energy efficiency targets needs to be explored further. As discussed earlier in this section, literature suggests that there are barriers that hamper the further increase in energy efficiency within the housing market. These barriers need to be overcome if the Netherlands wants to reach its longer-term targets regarding emissions and energy efficiency. It was also mentioned that the Dutch housing market is responsible for a large portion of the total energy use in the Netherlands. The risk related to inaction regarding the anthropogenic impact of greenhouse gasses on the climate of the earth are high for the Netherlands, as they have a historical necessity to contain water to prevent floods. Energy reduction has therefore become an important point on the political agenda in the Netherlands and it is important that the energy efficiency goals are met. There is a need for an increase of energy efficiency in the housing sector and there are possibilities for energy-efficient renovation of the Dutch housing stock (see section 1.1). Further exploration of the barriers that hamper the rate at which this energy-efficient renovation takes place in the Netherlands is therefore important. The failure to reach energy efficiency goals have led to the formation of several different organizations, firms and covenants that aim at increasing energy efficiency in the building (renovation) sector. As an example the following covenants have been formed: 'Meer met minder'[3], which is a collaboration between the government and building, installation and energy companies to inform, advise and help customers to increase energy savings. Innovation program 'energiesprong'[4] is a booster that, on behalf of the Dutch government, brings together supply and demand to increase energy-efficient retrofitting. The third one 'Blok voor blok'[5] was created after Dutch minister Donner concluded that the tempo and scale of energy-efficient retrofitting needed to be increased. Blok voor blok brings together the stakeholders for large-scale (2000+ homes at a time) retrofitting projects (Agentschap NL, 2013). These programs were started with the purpose of bringing together different stakeholders by overcoming existing barriers and to increasing the knowledge transfer among stakeholders.

The Dutch renovation sector, as a subsector of the construction sector, is a system in which many different actors work together to adapt dwellings to new needs. In this system (new) technologies and knowledge flow between the actors in the sector with the goal to successfully introduce those products and processes to the market. In other words, innovation plays an important role in the Dutch renovation sector. Therefore, innovation system theory can be used to analyze the system. Wieczorek & Hekkert (2012) suggest the use of systemic instruments in (innovation) systems to improve its functioning. They define the idea behind systemic instruments as: "*Systemic instruments aim to address problems that arise at the innovation system level and which negatively influence the speed and direction of innovation processes".* The goal of this study is to assess problems caused by barriers that hamper the needed increase in energy-efficient renovation in the Netherlands and how to address those problems. The system instruments approach is appropriate because the goal of this study is to analyze shortcomings to the current system and to improve its functioning, similar to the suggested use of the approach by Wieczorek & Hekkert.

In section 1.1 it was discussed that countries have trouble reducing emissions. Additionally, only 1.2% of the housing stock is renovated annually, which is roughly a factor 3 too little to make the energy reduction goals that were set by the EU, and were adopted by the Netherlands (EuroAce, 2013). This indicates that whether the scale is global, continental or even national, countries will often fail to reach the ambitious goals they have set out to reach. Therefore it is necessary that we further explore the barriers that hamper the development of the energy-efficient renovation sector in the Netherlands, in order to help create policy advice that has the ability to strengthen our current tactics to reach the energy efficiency goals we need.

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[3] More with less.
[4] Energy jump.
[5] Block by block.

1.3 Research questions

In this research we are interested in how the Dutch renovation sector functions and which blocking mechanisms hinder the implementation of energy-efficient renovation in the Netherlands. For this, the innovation systems approach will be used in combination with the functions of innovation systems theory. In order to be able to address the problem of barriers within this industry, several research questions need to be answered. The main research question of this research is:

Which barriers impair energy-efficient renovation strategies within the Dutch housing stock?

Like discussed in section 1.2 there is an indication that barriers impair the development of the Dutch energy-efficient renovation sector. Finding the answer to this research question will therefore make it possible to adapt policy to overcome these barriers and help the Netherlands reach their energy efficiency goals. Two sub-questions are created to answer the main research question. Since this research will employ an innovation systems approach it is necessary that structural components of the system are known. These structural components consist of actors, networks and institutions and are mapped to find out what interactions occur within the sector and whether these interactions are barriers. This leads to the first sub-question:

What are the structural components of the Dutch renovation sector?

Mapping the structural components of the Dutch renovation sector is the first step in analyzing the functioning of the system as a whole. In the second step, functions of the innovation system will be assessed to help identify which aspects of the innovation system are carried out strongly and which aspects are carried out weakly. Weak functions within the innovation system can indicate the presence of barriers related to that function. This leads to the second sub-question:

How is the Dutch renovation sector functioning?

This will result in an overview of the weak aspects of the innovation system and provide a basis from which the barriers that hamper the development of the energy-efficient renovation sector in the Netherlands can be deduced.

These two sub-questions will help identify the barriers that are present in the system. Results from this study will add to the research on barriers in innovation systems and give policy makers and market actors a better understanding of the limited renovation rate that can currently be witnessed. Based on the results from this study policy makers can adapt the policy instruments that are currently being used to strengthen the aspects that are indicated to hamper the development of the system.

In the following section the building system will be described, including the subsectors that are under study in this research. In section three the theoretical framework for this study will be addressed, including innovation systems theory and the scheme of analysis to assess the function of the system. In section four the methodology used to answer the research question will be discussed. In section five the results of the study will be presented. Section six and seven will bring the results of this study together in a discussion and the conclusion.

2. Building system

In this section a brief overview of the Dutch building system will be given. The system consists of: *the construction sector*, encompassing all construction efforts in the Netherlands; *the housing sector*, encompassing the Dutch built environment; *the renovation sector*, encompassing all renovation efforts in the Netherlands and its subsector *energy-efficient renovation,* encompassing the renovation efforts that focus on energy efficiency. Each of these sectors will be explained in further detail in the following sections.

2.1 Construction sector

According to Bouwend Nederland, the Dutch construction organization, the construction sector in the Netherlands accounts for 5% of the GDP, worth 53 billion euro. It also employs between 450 and 500 thousand workers, making it one of the biggest sectors in the Netherlands (Bouwend Nederland, 2013a). The Dutch construction sector is regarded as conservative, historically showing relatively low innovation figures (Harkema & Golriz, 2012; Pries & Heijgen, 2005). In 2005 de Jong & Muizer (2005) conducted a study in which they ranked 58 Dutch sectors based on their levels of innovation. The construction sector was ranked 49th in that study. This is also witnessed in the traditional nature of the sector. According to the KVK[6] tender request methods have remained the same for decades and are still largely focused on price; in 2008 85% was based on the lowest price (KVK, 2013). Roughly 30% of the Dutch construction output is in utility construction, roughly 40% of the construction output is in dwelling construction and the other 30% is in maintenance and civil works (ABN, 2013). The financial crisis of 2008 hit the Dutch building sector hard. Since the start of the crisis there have been large scale layoffs in this sector and the building production has been declining ever since. In 2013 the Economical institute for the building sector (EIB) published their yearly expectations and forecasts, which show that the Dutch building sector is still declining in production, with negative forecasts for 2013 and 2014 (Bouwend Nederland, 2013b). They do not expect growth in this sector until 2015 at the earliest, with their forecasts showing growth in production towards pre-crisis levels in 2018.

While the current situation of the Dutch building sector looks bleak, the construction sector and government expect a shortage of skilled workers in the future (NOS, 2013). Therefore they have decided to invest in the building sector to ensure the education of necessary skilled workers and to rehabilitate unemployed people back into the sector. In June 2013 a deal was signed between four major building companies and six housing corporations in the Netherlands to commit to the renovation of 11000 rental houses (Energiesprong, 2013). After this, more companies committed to a large-scale renovation project of 111.000 houses. These companies concluded that the current prices of such renovation projects were too high and that only industrialization (i.e. the development of industry on an extensive scale) would bring costs down, while increasing innovation levels within the sector. This project takes place under the innovation incubation programme ‘energiesprong’[7], directed by the Dutch government. The Dutch government also pledged to change policy to make this project possible.

[6] Kamer van koophandel, chamber of commerce in english.
[7] Energy jump in english

2.2 Housing

In 2012 the Dutch housing stock consisted of 7.27 million dwellings and showed an average annual growth of 0,84% over the timeframe 2006-2012 (Rijksoverheid, 2013a). As discussed in section 1.1 there is a large potential for energy reduction within the Dutch housing stock. The reason behind this is twofold: 1) The total energy use of the Dutch housing stock (7.27 million dwellings) in relation to the total primary energy use of the country is high, accounting for 7.27 million dwellings in need of energy (gas and electricity) it is a large portion of the total energy needs of Dutch citizens: Literature suggests the total energy used by households consists of 30-35% of the total primary energy needs of the Netherlands (Ministerie van binnenlandse zaken, 2011; Harmelink et al., 2010). 2) A large portion of the current housing stock was built in a periods in which energy-efficient building was not addressed on the policy agenda. Figure 2 shows an overview of the percentage of total housing stock per building period, indicating that a large portion of the current Dutch housing stock consist of dwellings built before the 1990s.

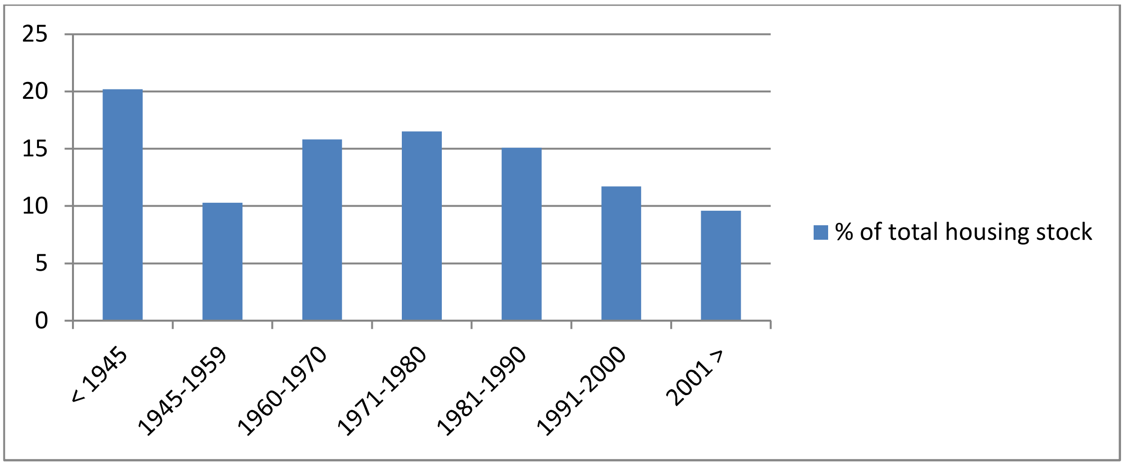

Figure 2: Dutch housing stock (2012) by building period

The energy performance of a dwelling is a calculation based on technical aspects of the dwelling (insulation, boiler type, glazing etc.) that makes it possible to classify the energy efficiency of dwellings (Rijksoverheid, 2013c). In the Netherlands energy performance in newly built dwellings have been included in the building regulations since 1995, with the introduction of the energy performance coefficient (EPC) (FMM, 2009). The Dutch housing stock built before 1995 was therefore not subject to energy performance ratings. Roughly 14% of the Dutch housing stock was built after 1995. This means that 86% of the building stock was built before the implementation of energy performance in building regulations, or 6.25 million dwellings.

In 2008 the Dutch government made the use of energy labels mandatory for rent and sales of houses 10 years or older. The distribution of energy labels per building period is shown in Figure 3. It can be seen that the majority of the dwellings with energy labels C or worse were built in the period before 1990. This confirms the notion that before 1995 energy performance of the housing sector was not an important policy issue.

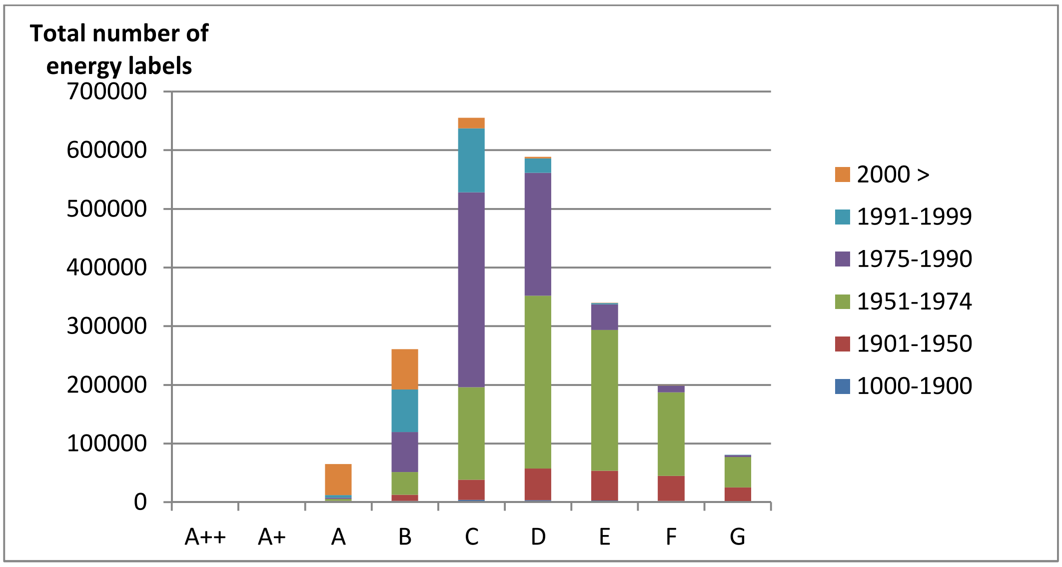

Figure 3: Distribution of energy labels per building period (Senternovem, 2013)

2.3 Renovation

As other industrial sectors, the housing market was strongly influenced by the financial crisis of 2008. In most developed countries dwelling prices dropped and banks were forced to be less lenient when giving out mortgages (Kam, 2009; Nibud, 2013). Figure 4 shows the distribution of market share between newly built and renovation including historical data on the last 10 years and a prognosis for 2013-2014. In the timeframe 2003-3007 the market share of newly built was slightly higher than that of renovation. In terms of total production, both sectors showed a steady increase. In 2008, newly built production drops strongly. Between 2009 and 2012 the production of newly built was relatively stable. The prognosis for 2013-2014 shows a small growth in newly built production again. Production levels of renovation showed only a minor reduction in 2008. In the years 2009-2012 the production remained stable. The 2013-2014 prognosis for renovation shows no significant increase in production. These market changes result in a majority share of newly built production towards a majority share of renovation production in 2008.

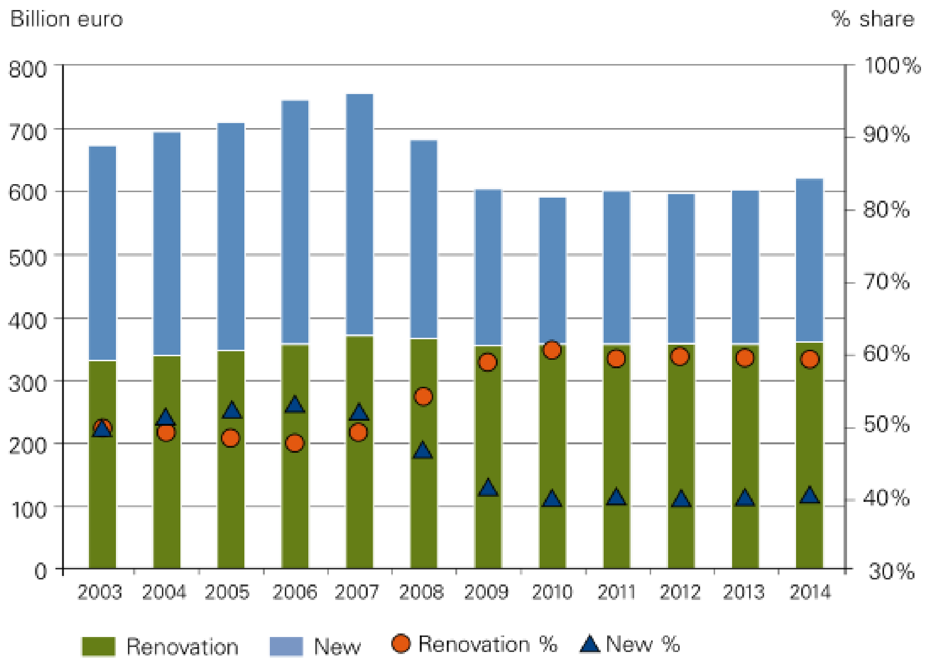

Figure 4: Shift from new buildings to renovation (KPMG, 2012)

KPMG states in their construction sector forecast that these increased share levels of renovation will likely hold for the next few years, since the required dwellings are available but not up to the current needs and sustainability ambitions (KPMG, 2012). This corresponds with the Dutch housing sector, which consists of an aging housing stock that scores badly on energy efficiency (little to no insulation, single glazing, old production techniques used) and healthiness of said dwellings (the use of asbestos, poor ventilation) (see section 2.2). Two points can be discerned from the figure and the KPMG forecast: 1) The total production of the construction sector has decreased since the financial crisis started; 2) Renovation production remained roughly the same in this period. This indicates that investments in the renovation sector are preferable in times of financial instability and uncertainty. KPMG (2013) states that the crisis has strongly effected the construction sector hard in the Netherlands. However, they expect that sustainability ambitions by the government will be an important driver for the growth of this sector.

There are many different reasons to choose for renovation. Renovation encompasses more than trying to improve energy efficiency within a dwelling. The following list gives an overview of possible reasons for renovation:

- Aesthetics: Dwellings have long lifetimes and (new) residents may have different desires than the current aesthetics of a dwelling.
- Repurposing: Old dwellings can be repurposed to fit new needs. An example of this is district Strijp-S in the city of Eindhoven, where former factory buildings are repurposed into lofts and apartments.
- Reconstruction: During the years dwellings can be damaged and may need renovation for its constructional base.
- Space saving: Depending on the location it may be impossible to completely rebuild a dwelling.

- Health improvement: Old dwellings were built in times that building regulations and codes were very different from now and often contain hazardous materials or lack ventilation.
- Energy efficiency: To reduce energy costs, residents have the option to make use of energy-efficient renovation.

This list shows the diversity of reasons for renovation projects, but all reasons have a message in common: Older dwellings do not need to be excluded as habitable, but can instead be the basis for a modernized version of the dwelling that complies with the needs and expectations of the owners. The current yearly production of newly built dwellings is less than 1% of the housing stock (CBS, 2013a) and according to the rijksoverheid (2013d) there is a shortage of available housing. There are three reasons for this shortage: The effect of the crisis on the construction sector, an increase of the population and a decrease in household size. This housing deficit increases the demand for renovation of the current housing stock.

2.4 Energy-efficient renovation

Energy-efficient renovation refers to the renovation of a dwelling with the goal of decreasing its energy use. As discussed in section 2.2, it can be concluded from the energy label data that the majority of the housing stock in the Netherlands scores badly and that indicates a large energy reduction opportunity in the Netherlands. Naess-schmidt et al. (2011) agree that the housing stock is an interesting sector for energy efficiency and also state that "[m]uch evidence has shown that renovating the existing building stock is one of the most attractive and low cost options to reduce CO_2 emissions". They also suggest that the net cost of investing in renovating the existing building stock is not only low, but it is in fact negative. Negative investment costs means that the savings (a reduction in energy costs) are higher than the investment costs, resulting in a net profit during the lifetime of the dwelling. Therefore, energy-efficient renovation is financially interesting, since the (financial) benefits outweigh the costs. Green financing is therefore a low-risk method to ensure large-scale energy-efficient renovation, since the risk of financing such a project can be calculated based on the expected energy reduction and energy cost forecasts. Hermelink & Müller (2011) agree with this and add that deep renovation, energy-efficient renovation that reduces 80-90% of CO_2 emissions is the necessary method if we want to make the long-term goal of an energy neutral built environment (see section 1.1). They state that in all European countries they studied, except the UK, the market conditions are favorable for the investment costs of deep renovation over inaction. This means that the costs for deep renovation of the housing stock is not as high as the total costs of the extra energy needed for a non-renovated house.

There is a wide variety of possible energy-efficient renovation strategies, ranging from large-scale façade renovation to a small-scale condensing boiler (Harvey, 2009; Verbeeck & Hens, 2005; Vreenegoor et al., 2008; Rooijers et al., 2001; Xella, 2013). Often, renovation calls for custom work, as different customers have different needs and budgets, but the products and methods used are generally the same. Listed below are some of the most commonly used renovation techniques:

1) Shell renovation includes methods that improve the energy performance of the shell of a dwelling by reducing the energy loss, such as: 1) *Cavity wall insulation*, in which the wall cavity is filled with an insulating material to prevent energy loss through the shell; 2) *Roof insulation*, which increases the insulation value of the roof by adding/substituting materials; 3) *Floor insulation*, which prevents energy loss through the floor of a dwelling; 4) *Mechanical*

ventilation combined with *airtightness*, which combines the closing of a system (airtight) with a mechanical ventilation system to preserve air movement within the dwelling for health reasons; 5) *Glazing*, which covers the increase of insulation of the glass in the shell of a dwelling (Energy saving trust, 2013).

2) Energy recovery renovation includes methods and products that recover still useable energy from streams that would normally be discarded, such as: 1) *Ventilation heat recovery units*, which recover energy from the ventilated air before it is discarded (NAHB, 2013a); 2) *Heat recovery from water*, which recovers leftover energy from sources such as hot shower water (NAHB, 2013b).
3) Energy generation renovation includes methods and products that generate energy, or take it from sustainable sources, to reduce the need for gas and electricity in a dwelling's energy needs. This includes: 1) *Heat pump*, which exchanges heat/cold with either the air or a geothermal source (NAHB, 2013c); 2) *Solar boiler*, which uses the suns energy to heat water to the wanted temperature (NAHB, 2013d); 3) *Condensing boilers*, which are gas boilers that have high efficiency levels (NEF, 2012).
4) Lastly, there is the strategy to reduce energy use from appliances. Modern society relies more and more on appliances to make lives easier and more comfortable, but all these appliances increase household energy use. By switching to relatively energy-efficient appliances a household can save a good deal of energy. In most developed countries government policy demands the use of labeling, or grading the relative energy efficiency of a product compared to a set standard (Rijksoverheid, 2013b). This is mostly done for appliances such as washing machines, dryers, televisions, and refrigerator. Another energy-inefficient product present in all dwellings is incandescent light bulbs, which lose most of their energy through heat. By switching to compact fluorescent or LED light bulbs a household can save a significant amount of energy (Milieu centraal, 2013).

Recently there has also been new renovation concepts such as the passive house (Schnieders & Hermelink, 2006). This concept consists of a design in which a dwelling can be lived in with a minimal need for heating. For a dwelling to be considered a 'passive house' it needs to satisfy a set of demands that result in a certificate. While this concept can be used for renovation it is more easily applicable to new buildings. There are two reasons for this: 1) A newly built house can be built towards the most favorable direction for maximum heating from the sun; 2) You built from the ground up, this has the advantage that you do not need to keep to the existing structure.

This chapter has shown that energy-efficient renovation is a serious opportunity for the Netherlands to reduce its energy use. It also shows that the Dutch renovation market consists of a wide range of technologies and methods that can be used to reach energy efficiency goals. However, as discussed in section 1.2 these technologies and methods are not applied enough. Because the technologies are available and the possibilities to apply them to the Dutch housing stock already exist it is necessary to better understand where the current system is running into limitations regarding energy efficiency applications. The system as a whole needs to be analyzed and possible bottlenecks need to be identified to better understand how the Netherlands can make better use of the energy-efficient renovation possibilities they have. Without this knowledge the Netherlands will not reach the efficiency targets they have set for themselves. In the following chapter the theoretical background to deal with this problem is explored.

3. Theoretical framework

3.1 System approach

The Oxford dictionary defines a system as "a set of things working together as parts of a mechanism or an interconnecting network; a complex whole" (Oxford dictionary, 2013). Based on this definition it can be said that the Dutch renovation sector can be approached as a system. It is a complex network of actors that compete and work together within the same system boundaries and are therefore also bound by the same institutional rules. Based on policy and projects started in the Netherlands in the last decade, (the implementation of) technological change is one of the spearheads to reach energy goals. Within large systems, such as the Dutch renovation sector, innovation plays an important role. Innovation causes a system to change over time. System innovations are the transitions from one socio-technical system to another (Geels, 2005). In this study system innovation is the transition from renovation to energy-efficient renovation. Within these system innovations, technical innovation provides the system with solutions to ever-changing market demands, such as the need to reduce energy through the application of new methods and technologies. Innovation system theory provides the framework to analyze the relations between actors and institutions regarding these system innovations.

3.2 Innovation systems

The precursor of Innovation systems (IS) theory is the publication of 'the national system of political economy' by Friedrich List in 1841 (Freeman, 1995). This publication dealt with the issue of uneven development of national economies in Europe. List explored how it was possible that Germany overtook England and proposed policy suggestions that could help to promote industrialization and economic growth (ibid.). After this publication, it took more than a century for the term 'Innovation Systems' to be used in scholarly publications. Lundvall (1985) first used the term system of innovation within a basic context of what it meant. This consisted of the notion that within a system there is a vertical division of labor in which multiple actors collaborate and influence each other to transform newly created knowledge into products that reach the market. In the decades following this publication, the concept of IS took off quickly and is now widely used within scholarly publications as well as policy programs. Some of the major contributors to the development of IS theory include scholars such as Freeman (1988; 1995), Lundvall (1988), Carlsson & Stankiewicz (1991) Nelson (1993) and Edquist (1997).

The idea behind innovation systems is that determinants of technological change are not (only) found in individual firms or in research institutes, but also in a broader societal structure in which they exist (Suurs, 2009; Saxenian, 1996). Within IS theory, different system categorizations can be identified: Regional/National Innovation Systems (NIS), Sectoral Innovation Systems (SIS) and Technological Innovation Systems (TIS). These three system categorizations will be discussed below.

3.2.1 Regional/National Innovation System

Regional/national innovation systems have the scope that the first scholars (i.e. Lundvall, 1985; Freeman, 1987) have used, which is a system boundary defined by a geographical area. In the early publications these were limited to nations, hence the name National Innovation System, but later Regional Innovation System was added to this system to show that this type of IS was delineated geographically. NISs explained why certain countries performed better in hi-tech markets than others. Scholars found out that 'technological performance' of an area could be explained based on the societal structure of the technological market. Scholars previously tried to explain the performance through more narrow focus on aspects of that technological market, such as new scientific activities (e.g. invention) or new innovation in basic industries (e.g. iron or engineering).

Over the years there have been several definitions for the different types of ISs that all differ from each other, so there is not one single definition. A definition often used by Metcalfe (1995) is:

'That set of distinct institutions which jointly and individually contributes to the development and diffusion of new technologies and which provides the framework within which governments form and implement policies to influence the innovation process. As such it is a system of interconnected institutions to create, store and transfer the knowledge, skills and artefacts which define new technologies.'

According to Suurs (2009), the NIS approach is often used as a heuristic tool for policy analysis, since its use as a research framework is limited. Its heuristics are used as a starting point to identify sub-systems, actors and institutions relevant to the system in that country. This makes it possible to compare countries based on the structures and knowledge flows. Suurs states that such systems are so massive and complex that it is not possible to analyze interactions properly, because countless actors and institutions are aggregated.

Where the NIS is delineated to the borders among nations, the Regional Innovation System has a smaller geographical scope. When a system under research is so small that the actors, rules and regulations of that region are different from those of the nation, it is better to use the regional approach. An example of this is Silicon valley, a region south of San Francisco, home to a well-known hi-tech center. Silicon valley compromises an innovation system that caters perfectly to the opportunities and needs of hi-tech companies, such as top-level education, high quality of life, the acceptance of failure and the availability of investment capital.

3.2.2 Technological Innovation System

In a TIS the system boundary is (usually) not a geographical area but a technology or a technological field (Carlsson & Stankiewicz, 1991; Jacobsson & Johnson, 2000). The following definition of a TIS by Carlsson & Stankiewicz (1991) is often used:

'A dynamic network of agents interacting in a specific economic/industrial area under a particular institutional infrastructure and involved in the generation, diffusion, and utilization of technology. Technological systems are defined in terms of knowledge or competence flows rather than flows of ordinary goods and services. They consist of dynamic knowledge and competence networks.'

A TIS consists of four components: *actors, networks, institutions* and the *physical structure* in which it is nested. Actors comprise all stakeholders that influence the system under study, such as producers, regulators and consumers. Musiolik & Markard (2011) define networks as follows: *Inter-organizational relationships of firms and other actors whose goals are the achievement common aims. Such networks encompass strategic alliances, working groups of associations, technical committees or project networks*. Institutions can be broken down into two categories: A set of common habits, routines and shared concepts used by humans in repetitive situations (soft institutions) organized by rules, norms and strategies (hard institutions) (Wieczorek & Hekkert, 2012). The physical structure in which it is nested comprises the artefacts and technological infrastructure. According to Jacobsson & Johnson (2000), the technology-specific feature of the systems make the TIS approach attractive when the focus of the enquiry is competition between various technologies to perform a certain function. Coenen & Lopez (2010) state that the TIS approach is equipped to deal with emerging markets.

3.2.3 Sectoral Innovation System

The system boundaries of a SIS are not defined by a geographical area, but are instead defined by an industrial sector. Malerba (2002) is an important contributor to SIS literature and has created the following definition of SIS:

'A sectoral system of innovation and production is a set of new and established products for specific uses and the set of agents carrying out market and non-market interactions for the creation, production and sale of those products. A sectoral system has a knowledge base, technologies, inputs and an existing, emergent and potential demand.'

SIS theory draws from evolutionary theory and IS theory and contains a set of basic elements that define the SIS: *products; agents; knowledge and learning processes; basic technologies, inputs, demand, and the related links and complementarities; mechanisms of interactions both within firms and outside firms; processes of competition and selection; institutions* (ibid.).

Coenen & Lopez (2010) state that if the boundaries in which the selected system operates are limited to a newly-emerging sector, the SIS approach is less ideal, due to considerable technological and market uncertainty. According to Suurs (2009), the structure of a SIS can be seen as a technological regime and helps to explain the differences in the innovative activities of industries across sectors. Since these regimes evolve over time, analysis can give a dynamic perspective, but often this is negated because well-defined industries are chosen as a starting point. Sectoral systems can also be examined both narrow and wide, depending on the specific research goal (Malerba, 2002). When choosing the narrow examination of a SIS one product/technology is the focus, whereas in a wide examination a group of similar products/technologies is the focus.

3.2.4 Innovation system approach

Now that the different innovation system approaches have been described, an analysis must be made to select the most appropriate system approach for this study. Table 1 shows an overview of the system delineation and technological focus for each of the system approaches.

	NIS/RIS	SIS	TIS
System delineation	Geographical region	Sector boundaries	Technology boundary
Technological focus	All technological areas within the system	All technologies relevant within the sector	The one technology under study

Table 1: Comparison overview of innovation systems

In this research the system boundaries are chosen to delineate the Dutch renovation sector. The focus will be on energy-efficient renovation. Meaning that the main delineation of this research is not a geographical one, but rather one based on a set of methods and technologies within an industry. The NIS/RIS approach also encompasses all areas of a system, such as all relevant subsystems and institutions in multiple sectors and technological fields. For these reasons the NIS/RIS approach is not the appropriate system concept for this research. In this study the focus is on the energy-efficient renovation sector, which is a smaller section of the national system. Where the NIS/RIS system approach is not focused enough, the TIS approach is too focused, looking at one specific technology. Section 2.3 and 2.4 show that in energy-efficient renovation several main products are used, but not all these products can be grouped under one and the same technology or technological field. It is therefore not possible to analyze the renovation sector with the TIS approach. Both the NIS/RIS and the TIS approaches did not meet the scope of analysis needed in this research. However, according to Malerba (2002) the scope of the system under study can be determined based on the research goal. In this study that envelops the Dutch renovation sector, including all energy-efficient renovation technologies. Looking back at the definition of a SIS, the system under study here is comparable to the system described: it is a system delineated by an (economic) sector; it covers a range of older (e.g. condensing boiler/insulation) products as well as newer products (e.g. heat recovery units); it comprises a set of agents carrying out market (e.g. competition) and non-market (e.g. social awareness of going 'green') interactions that stimulate the creation, products and sales of those products; it has a knowledge base, technologies, inputs and section 2 has shown that there is a demand for these products. Therefore the SIS approach was chosen as the appropriate system categorization for this study.

3.3 Functions of innovation systems

Hekkert et al. (2007) concluded that the concept of Innovation Systems is a useful heuristic framework, because it helps researchers to better grasp how innovation within systems emerges based on semi-predefined components. Unfortunately, this concept suffers from two major flaws. First, it is static; it focuses on comparing the social structure of different innovation systems, putting less emphasis on the analysis of the dynamics of innovation systems. Second, it lacks sufficient attention for the micro level (i.e. actions of the entrepreneur). The explanatory power of the innovation system approaches are mainly on the macro level (institutions) instead of the actions of the entrepreneur within the system, although the role of the entrepreneur is an essential role in innovation literature. They propose a framework that solves these shortcomings by mapping the activities that take place in innovation systems. This will give them the possibility to analyze the activities that occur within an innovation system and that eventually lead to technological change. The framework they created is called 'functions of innovation systems' in literature. They state that "it focuses on the most important processes that need to take place in innovation systems to lead successfully to technology development and diffusion" (ibid.).

In the last decade there has been an increase in literature about this form of innovation system analysis, focusing on a functional perspective (Markard & Truffer, 2008). Bergek et al. (2005) created a scheme of analysis that uses a set of seven functions that give a researcher the analytical framework to assess what the system under research works in comparison to how it is composed or structured (Markard & Truffer, 2008). Over the years different scholars have given different lists of functions to make such a system assessment possible, but comparing the lists of functions shows that they are very much alike and convey the same core ideas (Johnson, 2001; Bergek et al., 2005; Bergek et al., 2008; Hekkert et al., 2007). Hekkert et al. (2007) give an overview of the definitions of functions by different authors and how those led to the creation of their proposed set of functions. The list of functions used in this study is that proposed by Hekkert et al. (2007) instead of the list of functions as proposed by Bergek et al. (2005) in the scheme of analysis. According to literature (Markard & Truffer, 2008; Bergek et al., 2008) the two lists of functions are different wordings of the same basic functions. Besides that, the set of seven functions has been thoroughly subjected to empirical validation by other researchers (Negro, 2007; Negro et al., 2007; Van Alphen et al., 2007; Van Alphen et al., 2009) and in these studies the proposed list of functions has proven to be a good indicator of the actual processes relevant in the field of sustainable innovation (Suurs, 2009).

These functions will help to assess the system under study. Seeing to what extent the functions are addressed in the renovation sector will help to identify possible bottlenecks in the development of energy-efficient renovation. That will result in the identification of the barriers this study has set out to find. The seven functions will now be further explained.

Function 1: Entrepreneurial activities

Innovation systems and entrepreneurs are inherently bound to each other, since the role of entrepreneurs is to take new knowledge and turn it into new business opportunities. When new knowledge is created in research facilities it is available as a theoretical idea. These theoretical ideas/products are then produced as prototypes and first-generation products that need to be tested in the real world, to assess how the technology behaves once installed. If the real-world behavior of technologies corresponds to the theoretical expectations, this will increase the confidence in that technology. An example is the use of heat pumps for heating/cooling in dwellings whichwas a distinct new method of climate control and first had to prove that it behaved the way researchers indicated. That means that it needed to show it could perform its task (heating/cooling), while using less energy than conventional heaters (e.g. condensing boiler) and be reliable in its use. Entrepreneurial activity comprises all such efforts by entrepreneurs to bring new technical innovations to the market in an attempt to create a market share for that technology.

Function 2: Knowledge development

Knowledge is at the basis of the innovation process and without new knowledge the existing markets will not evolve, which meaning the innovation system reaches a standstill. Once knowledge is created actors must absorb that knowledge to learn new skills and gain competences. Learning is therefore a fundamental process in the innovation system and is not limited to one specific element of the system, such as the technologies that emerge within a market, but also covers the rest of the system. Two types of learning are distinguished here: 1)Learning by searching, which encompasses knowledge creation by means such as research and development. In this system new knowledge is created in research facilities as well as by producers through research and development; 2)Learning by doing, which encompasses (real world) experimentation. This method of knowledge development is more evident in the renovation sector, mainly through the use of technology application in pilot projects (dwellings renovated to high new energy efficiency standards) by entrepreneurs.

Function 3: Knowledge diffusion through networks

Positive interaction between actors is a necessity in any innovation system, as that is what leads to innovations. A relevant form of interaction between actors to stimulate innovation is that of knowledge diffusion (Singh, 2005). Knowledge diffusion between relevant actors is important to transfer knowledge to the right actors within the system. Knowledge diffusion between actors and institutions is important because of standardization, setting long term targets and to match policy decisions with the latest technological knowledge available. In the case of the energy-efficient renovation sector, the government engages in discussion with the housing sector through intermediating organizations such as unions and trade organizations. However, knowledge diffusion through networks can come in many other forms: conferences, (instructional) schooling, collaborations in renovation projects.

Function 4: Guidance of the search

To ensure sufficient resources are available to individual technological options, it is important that specific foci are chose for further investments as resources are limited (Hekkert et al., 2007). This function attempts to guide the system towards a direction of technological change. Guidance of the search can be caused by different elements within the system, such as energy efficiency policy targets set by the government or expectations voiced by technology users. The government has had a direct influence on the Dutch housing sector in the last two decades concerning guidance of the search, as it keeps increasing energy efficiency standards and guidelines. The second aspect of this function is the expectation of the technology users. In this system these are the buyers (housing corporations/households) as well as the people that implement the technologies (construction companies/installers). Willingness by these actors to use the new technologies creates awareness and increases confidence in that technology.

Function 5: Market formation

When new technologies are ready to get to the market they must compete with embedded technologies, giving the new technologies a serious disadvantage to diffuse within the market. To prevent this situation it is important to create an environment in which the new technologies can be tested and expectations about it can grow. A method to do so is to create a niche market in which the technology gets the possibility to mature. This for example can be done by giving the technology a competitive advantage over embedded technologies, such as favorable tax regimes and subsidization. An example of this in the energy-efficient renovation sector is the subsidization of solar panels by the government, reducing the payback period for the panels and the energy price to a level competitive with conventional energy.

Function 6: Resources mobilization

Without the needed resources (financial and human capital) an emerging technology will not reach the market. Capital and skills are necessary within a system to support the emergence of a technology. When there is a lack of available capital the system will not function properly, limiting its development. Resource mobilization is therefore an essential activity in an innovation system. Renovation projects tend to be costly and households/housing corporations usually do not possess the necessary financial capital to finance an entire project. Instead they rely on other actors to supply them with capital in return for interest. Small scale projects (households) mostly use banks to finance, where large projects (housing corporations) are often financed by pension funds or branch-related funds. The other resource, human capital, comprises knowledge and skills possessed by humans in the sector. Human capital can be increased through education and experience.

Function 7: Creation of legitimacy

If a new technology wants to develop within a market it needs to become part of an incumbent regime or overthrow it (Malerba & Orsenigo, 1997). Reaching that goal is not an easy task, because incumbent actors will cause resistance and therefore it is important that social acceptance of a new technology is high. Advocacy lobbies can steer this by creating legitimacy for a new technology and working as a catalyzer. Once the lobby reaches a certain size it will be able to tip the scales towards the emerging technology. The Dutch housing sector can be described as conventional (as the housing stock figures in section 2 suggest), meaning that technologies used in renovation projects have mostly stayed the same in the last few decades. In the case of the renovation sector, new technologies might have to face diffusion barriers. Entrepreneurs, branch-organizations and unions therefore have an important role to create awareness and legitimacy for the new technologies.

3.4 Actors

Within energy-efficient renovation projects four distinct phases can be discerned: planning, designing, realization and completion (Ministerie van BZK et al., 2011). The actors of the industry are usually only active within several phases. Table 2 shows an overview of the actors that are active in an (energy-efficient) renovation project and the phases they are active in. The planning phase encompasses the concretization of needs and possibilities by the involved actors, such as the delineation of the project. In the designing phase the actors will create the technical designs necessary for the project. In the realization phase this design will be applied to the dwelling and actors will realize the project. In the completion phase the realizing actors (and dwelling owner) will deliver the dwelling back to the inhabitant, finishing the renovation project. Sometimes this last step will also encompass the diffusion of technical knowledge to the inhabitant to use the newly installed technical installations.

	Planning	Designing	Realization	Completion
Government/municipality	■			
Housing corporations	■	■	■	
Consultants	■	■		
Financial institutions	■			
Designers		■		
Construction companies			■	
Installers			■	
Households (rental)				■
Households (private)	■	■		■

Table 2: Overview of actors per project phase

Government/municipality: For this actor a distinction needs to be made between two levels of governmental institutions. On the one hand there is the national government that creates policy and sets goals for the future of the nation and on the other hand there is the localized government that is responsible for local planning and permits. Projects need to adhere to national policy and guidelines and therefore the government indirectly influences all phases of a project. However, they only directly influence the planning phase, because local government is responsible for permits. Governments and the renovation sector (unions, associations) engage in discussions when creating new policy/guidelines and municipalities and other actors interact in the planning phases of renovation projects.

Housing corporations: Housing corporations own roughly one third of the total Dutch housing stock (CBS, 2013b). They are therefore an important actor in the Dutch housing sector. These corporations are responsible for building, maintaining and renting out housing. In 2011 they invested 280 million euro in energy efficiency according to sector association Aedes (Aedes, 2012). The average size of housing corporations was 72.5 full-time equivalent (FTE) (ibid.). Depending on the size of the corporation some of the actor functions may be performed in-house, but in general housing corporations interact with all the other actors.

Housing corporations for example influence three of the project phases: they are the clients that decide to perform a renovation project and will be a major influence in the planning and designing phases and to a smaller extent also in the realization phase. In the planning and the designing phase they are responsible for direct input: they have a list of demands (e.g. energy label) they want to be met and what budget is available for the renovation, but besides supervision the actual renovation will be in the hands of other actors.

Consultants: Consultants are professionals that are for hire in the renovation sector. They provide companies/organizations with specific expert knowledge that they lack, usually on a project basis. Consultants offer their knowledge to other actors in the planning and design phases, aiding those actors where necessary. Housing corporations, designers and households are the other actors consultants interact with while planning a project.

Financial institutions: Financial institutions cover all actors that provide capital for renovation projects. These institutions include banks, branch-related funds, pension funds and other (private) funds. Financial institutions provide the needed capital up front, in exchange for interest over the prearranged term of the loan. Therefore they are only active in the planning phase. They interact mostly with housing corporations and households.

Designers: The designers are the people responsible for the structural drawings needed for renovation projects. They possess the structural knowledge needed to reach the specifications set for the renovation and provide other actors with blue prints. They have two types of interaction: 1) With housing corporations and households to design the aesthetics of a renovation project; 2) With construction companies and installers to provide technical drawings and instructions for the construction work.

Construction companies: This group of actors is responsible for the structural renovation work. They do the skilled and labor-intensive work on the structure of a house and can be small in size (<10) to very large (>1000). Depending on the size of the company they are likely to have more knowledge in-house and rely less on external knowledge. They interact with customers (housing corporations/households) during the realization phase as well as work in tandem with installers when working on the same project. As stated before they also interact with designers, as they supply the construction companies with technical instructions.

Installers: Installers are a group that consists of the skilled workers that install and maintain technical installations such as electricity, plumbing, central heating etc. Together with the structural renovation, technical installations are the most important part of energy-efficient renovation. They are active in the realization phase like the construction companies. They interact with them during the realization of renovation projects. They also interact with designers when they get their technical instructions. Depending on the systems installed they may also interact with households to provide information on how to use systems.

Households: This actor consists of rental and private households. The former consists of all houses rented by households (from housing corporations). This group has little influence on renovation, since the house owners have the decision to renovate. In the Netherlands a renter does have the right to object to renovation plans by house owners, because the rent usually increases after renovation. The other households are privately owned housing stock, meaning that they have full control of renovation projects, but are also responsible for their own renovation and financing. Rental households interact with their housing corporation and in some cases with the installers. They are active in the completion phase. Private households interact with municipality (permits), financial institutions (financing), designers (technical and aesthetics), construction companies (structural work) and installers (technical installations). Usually private households are active in all phases except the realization phase.

Now that the theory used is described and the actors in the system under study are defined, the methods used to analyze the Dutch energy-efficient renovation sector can be described. The following section will show how the functions of system innovations theory is applied in this study and how data was gathered.

4. Methodology

The goal of this research was to get an understanding of the barriers that exist in the Dutch energy-efficient renovation sector and that hamper its development. This was done through an analysis of the functions of the system having sectoral innovation system theory as a framework. The spatial delineation of the system under research was the Netherlands. Due to EU policy agreements the Netherlands has to adhere to certain goals set in the past decades, including CO_2-emission reduction and energy efficiency increase (see section 1.1). A literature study and expert interviews were used for data collection and an adaptation of the scheme of analysis as proposed by Bergek et al. (2005) was used in to analyze the functions of the system.

4.1 Operationalisation

The systemic functions discussed in 3.3, need to be operationalized in order to be analyzed. Indicators are defined in this section in order to explain the functioning of each of the system functions as described in section 3.3. Hekkert et al. (2007) apply the systemic functions on a technological innovation system rather than a sectoral innovation system, but literature (Markard & Truffer, 2008; Bergek et al., 2008) states that due to the comparable nature of systemic functions used within literature it can be applied to different types of innovation systems. Indicators were chosen based on functions of innovation systems literature (Bergek et al., 2005; Hekkert et al., 2007; Bergek et al., 2008).

Function 1: Entrepreneurial activities

The system under study consists of a large number of different technologies. Therefore it was needed to see how the industry was behaving with regard to entrepreneurial activities. We defined the following indicators: the number of *new entrants* (Energy-efficient technology specific installers/constructors/consultants) and the *diversification of activities of incumbent actors* (moving from non-energy efficient specific technologies towards energy-efficient renovation by installers/constructors/consultants/housing corporations). *New entrants* are an indication of how many new organizations try to get a position within the system. Entrepreneurial activity within a system can be done by two types of actors, as mentioned in section 1.2: New entrants to the market and diversification of activities by incumbent actors. *New entrants* is therefore an important indicator of the entrepreneurial activities function. This indicator can be defined as: The number of new actors within the energy-efficient renovation sector in the last three years. *Diversification of activities of incumbent actors* is the other indicator of this function. Merriam Webster (2013) defines diversification as *"to change (something) so that it has more different kinds of people or things"*. Therefore *diversification of activities of incumbent actors* is defined as: The change of products/services offered by incumbent actors over the last three years. This indicator has two possible states: an actor either diversified or not.

Function 2: Knowledge development

This function covers what is done within the system to generate new knowledge. Research and development is the main method of knowledge creation and can therefor indicate that there is knowledge creation within the SIS. We defined the following indicators: the amount of *knowledge creation* or the *importance of R&D* within the system. The amount of *knowledge creation* indicates to what extent actors within the system are creating knowledge. If actors show little to no activities regarding R&D, that indicates a low level of knowledge development in the system. *Importance of R&D* is the other indicator that helps analyze the importance of knowledge development in the system. A low score of the importance of R&D by market actors indicates that R&D is not carried out to a high degree. Levels of R&D and innovation can be compared to other sectors to put the figures in perspective.

Function 3: Knowledge diffusion through networks

Understanding how well the knowledge diffuses within a system is important for actors and institutions. We defined the following indicators: the number of *conferences* and *the participation of actors* in the system under research. The conferences can be on any industry important topic that includes multiple actors, such as: Energy saving insulation products/methods (wall cavity insulation, glazing), energy producing methods (solar boilers) or deep renovation tactics. The size of the network explains to what extent actors within the system work together. *Conferences* indicate to what extent actors within the system share knowledge with each other at formal meetings. If actors visit many conferences there is a higher chance of knowledge diffusion than when actors do not take part in conferences. *Participation of actors* is a similar indicator, as it also gives an indication of the knowledge diffusion opportunities an actor participates in. If actors limit knowledge exchange they themselves are also less exposed to new knowledge.

Function 4: Guidance of the search

High expectations about a technology are likely to stimulate the development of those technologies, while low expectations are likely to hamper the development. We defined the following indicators: the *influence of policy targets* set by the government and the *growth potential* of energy-efficient renovation. Energy efficiency targets are usually covered in governmental policy in the form of goals that are set for a specific timeframe. For this study only national targets are considered and can include goals such as the plan to renovate at least 300.000 dwellings a year for two energy label steps in the Netherlands (Rijksoverheid, 2013e). The expectations of professionals regarding growth potential includes interviews of professionals within the system. If important actors have high expectations of products/methods there is a higher chance of its use within the industry. *Influence of policy targets* indicates how the governments ideals for the near future (2020-2050) are adopted by actors. *Growth potential* of energy efficiency in the housing sector indicates what professionals within the system expect of (energy-efficient) technologies. This is also an important element, because actors within the system have to believe in the possibilities that technologies have before they are willing to invest. The influence of policy targets indicates to what extent market actors are guided by the government in their business strategies and the growth potential indicates the expectations of professionals.

Function 5: Market formation

Within the energy-efficient renovation sector subsidization has been an important driver of niche market formation in the future (Duurzaam thuis, 2013). We defined the following indicators: the amount of *competitive advantages* offered within the market and the *presence of standardization* that favors energy-efficient technologies. Competitive advantages offered include various methods that are employed by the government to improve the chances of new products/methods to make it to the energy-efficient renovation market. For example this can be done in the form of subsidizing Photo-voltaics to reduce costs and payback periods or by reducing tax on specific products and services to create a favorable environment for energy-efficient renovation. Standardization that favors energy-efficient technologies can increase the willingness of actors such as housing corporations or installers to move towards energy-efficient renovation methods. If the expectations of professionals within the system do not concur with the expectations and targets set out by the government, the government needs to incentivize actors within the system to increase their entrepreneurial activity. By creating *competitive advantages* offered within the market they can do that. Actors are more likely to enter/invest in a market if there are a high number of competitive advantages. Less than 5 incentives is low, 5-10 is medium and 10+ is high. Another institutional element that can increase this willingness is indicated by the *presence of standardization* that favors energy-efficient technologies. Standardizations gives the energy-efficient technologies an advantage compared to normal technologies and are likely to improve the actors willingness to use them. Standardization is the result of a consensus between actors and standard setting organizations (such as ISO) on a (technical) standard. Standardization can increase the ease of use of technologies due to the fact that actors know what they are working with and how it should perform. Energy standardizations provide homeowners with clear concise information about the energetic performance of products and dwellings.

Function 6: Resources mobilization

By interviewing key actors within the system under research it is possible to get an indication whether new technologies are hampered when entering the market due to the lack of resources available within that market. External financers can add resources to the system that were previously not available. We defined the following indicators: the need for *external resources* and the *availability of capital*. Change within an industry can be held back due to a lack of available capital, be it in the form of finances or human capital (knowledge). New and upcoming markets therefore need access to plenty capital to function properly. The use of new products and renovation methods mean that there is a need for new human capital within the system, but it also means that actors such as installers have to change their working gear to deal with the new products. If there is a lack of capital it is important that there are external resources available. Possible external resources can be knowledge institutes that provide installers/constructors/consultants with the knowledge they need to use new products/methods or banks that provide ‘green’ financing for housing corporations to do large scale energy-efficient renovations to their housing stock.

Function 7: Creation of legitimacy

The performance of the system can also be analyzed through the amount of lobbying advocacy lobbies do. We defined the following indicators: *public awareness* about new technologies and the amount of *lobbying by interest groups* that is done within the system. If there is a lack of public awareness in a new market, there is the chance of it not maturing (quickly enough). Housing corporations for example need to be aware of the possibilities and opportunities there are regarding large scale energy-efficient renovation to make an informed choice about their housing stock. If interest groups lobby they can increase the awareness and create a situation within the system where key actors are informed and convinced to move towards those products/methods.

4.2 Data collection

Two methods of data collection have been used for this research: Literature review and expert interviews. The first method was used to make the structural analysis of the system under research and it was used as a basis for the selection of actors for expert interviews.

4.2.1 Literature study

The first method of data collection was a literature review, used for the structural analysis of the system. Two sources of literature were used to delineate the structural components. The first source is scientific literature review, which has helped to assess what structural components have been analyzed in the available literature on energy-efficient renovation. The literature reviewed was limited to the Dutch renovation sector. One of the reasons to do so was that according to Hekkert et al. (2011) different innovation systems (different localities) may have similar components but can function completely different. Another reason to limit the scope of the search was the fact that the Dutch housing sector is very reliant on fossil fuels and this sector was marked as the sector with the largest energy savings potential (see section 1.3). Different sources for scientific literature were consulted: Web of science, Scopus and Google scholar. The key words used during the web search were: Sustainable renovation (Netherlands), Sustainable retrofitting (Netherlands), renovation (Netherlands), retrofitting (Netherlands), sustainable building etc. The second source of literature was the review of project reports. These consisted of projects carried out within the last five years and often were part of one of the three covenants mentioned in section 1.2: *Meer met minder, Energiesprong* and *blok voor blok*. The other reviewed project reports consisted of renovation projects carried out with no link to the three covenants, but that were found during the literature study.

4.2.2 Expert interviews

The second method of data collection were expert interviews, which were used to gain insights in the system from key actors. According to Ghauri & Grønhaug (2005) a key purpose of qualitative research is to understand and gain insights. They also state that because of the 'unstructured' problems it researches qualitative research tends to be exploratory and flexible. Literature (Bryman, 2008; Walsham, 1995) explains that a researcher can follow different epistemologies to conduct their research. Whereas positivism has an emphasis on the explanation of human behavior, interpretivism has an emphasis on the understanding of human behavior (Bryman, 2008). The goal of this research is to understand what barriers hamper the development of the Dutch energy-efficient renovation industry from a sectoral innovation system perspective. To be able to answer the research questions key actors need to be involved, because they fulfill a vital role within the innovation system. According to Hekkert et al. (2011) it is necessary to involve experts or key actors in the assessment of the functioning of an innovation system, because innovation systems differ by region and experts involved in an innovation system know that system best. The data for the functioning of the SIS was collected through semi-structured personal interviews with key actors in energy-efficient renovation projects. The actors were also asked to score each of the indicators on a five-point Likert scale (1 = very weak and 5 = very strong). The key actors in the Dutch renovation sector that were mentioned in section 3.4 are the actors that were interviewed in this study, with the exception of the households. As mentioned in section 3.4 rental households have almost no influence on the renovation of their dwelling, in contrast to private households. The reason this actor was not involved in this study was the limited accessibility to this group. There is no public database of private energy-efficient renovation projects and companies that are involved in them respect the privacy of their customers. In order to include private households as well as possible the other key actors were asked about their views on the perception of energy-efficient renovation by households. Based on the indicators discussed in section 4.1 a list of questions was created to gather data from the actors within the system. The questions are also adopted from van Alphen et al. (2010), who have created a list of general questions to analyze system functions. The interview guide can be found in appendix A. In section 4.2.3 the experts that were interviewed and the cases that were selected will be discussed.

4.2.3 Case and actor selection

The literature study provided the basis for the case selection in this study. Energy-efficient renovation projects carried out under the *energiesprong* and *blok-voor-blok* covenants are well documented and project descriptions can be found on their respective webpages[8]. Because of the available timeframe and the necessary scope of this research three energy-efficient renovation projects were selected for further analysis. Based on the background and the problem definition of this research the following selection criteria were chosen:

- Project must have been finished recently (3 years or less) or was being executed at the time of the study, to ensure that the data gathered from the project is still relevant.
- The size of the renovation project executed needed to be large. This can be assessed on basis of volume (many small scale renovations) or size (large scale building) as to ensure that all key actors were involved. Case reviews have shown that in smaller renovation projects not all actors determined in the structural analysis are involved, which makes it harder to generalize the findings of those cases.

Based on these criteria a list of 24 possible cases was made. Based on the size, location and project goals the following three cases were selected:

033Energie

A project of the *blok voor blok* covenant in the city of Amersfoort. They have set the goal to renovate 2000 homes, increasing their energy label by two steps or make them label B. They also want to renovate 20 homes to become energy neutral. They want to realize this goal in three years. This project is currently being executed.

De slimme buurt

This *blok voor blok* project is taking place in Den Bosch. Like the project in Amersfoort the goal for the project is to renovate 2000 homes, increasing their energy label by two steps. The households will also be made aware of their energy use by using smart meters. The project is currently being executed.

Eindhoven 3x3 = 9

In Eindhoven another *blok voor blok* project has been started through an organization called 'neighbourhood by neighbourhood'. The goal of this project is to renovate atleast 2000 homes and to inform the people of smart energy efficiency technologies that are available to them.

The blok voor blok project descriptions, as well as the contact list for actors participating in these projects have been publicized by the government (AgentschapNL, 2013). Based on these publications we contacted actors. This resulted in the participation of 8 experts, divided over the following actors: housing corporations (1), consultants (2), financial institutions (1), designers (1), construction companies (2) and installers (1).

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[8] http://energiesprong.nl/blog/category/inspirerende-projecten/woningbouw-renovatie/
http://www.agentschapnl.nl/onderwerpen/duurzaam-ondernemen/gebouwen/blok-voor-blok/projecten

4.3 Data analysis

After the key actors were interviewed the data was analyzed. Bergek et al. (2005) proposed a scheme of analysis that makes it possible to analyze the functionality of a SIS. Figure 5 shows the scheme that was adapted and was used to assess the functionality of the Dutch energy-efficient renovation industry. The functions as seen in Figure 5 were exchanged for those proposed by Hekkert et al. (2007) and the reason for this substitution was given in section 3.3: The list proposed by Hekkert et al. is interchangeable with that proposed by Bergek et al. (2005) and has been applied extensively in the field of sustainable innovation. Using their list of functions over those proposed by Bergek will have no implications, as the list of functions covers the same seven important functions of innovation systems.

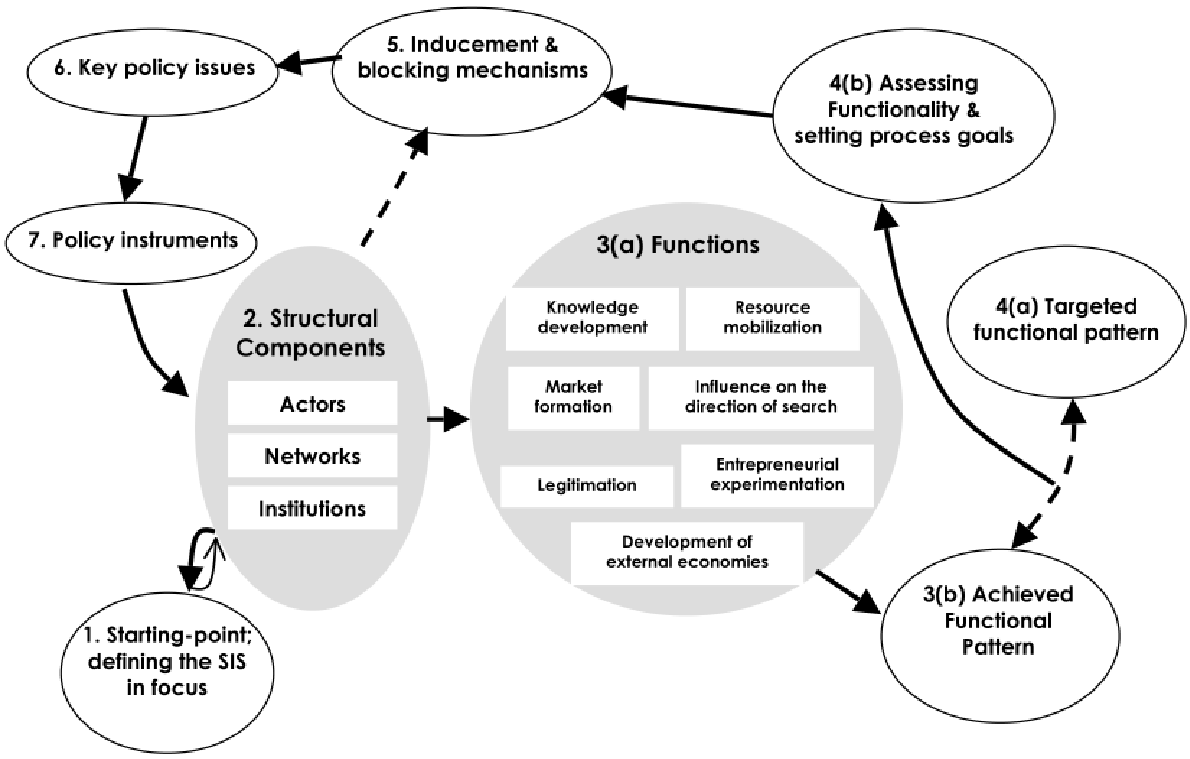

Figure 5: Scheme of analysis for Sectoral innovation systems (Bergek et al., 2005)

Within this research the 7 steps of the scheme of analysis were followed to assess the functioning of the SIS under study. In the first step the SIS under research was defined. In the second step the structural components (actors, networks and institutions) of that system were identified. The third step consisted of mapping the functional pattern of the SIS. For this, an overview was created to what extent functions are currently filled out in the SIS. In the fourth step the functionality as found in step 3 is compared to the targeted functionality to assess how well the SIS is functioning, this assessment is based on the operationalization in section 4.1. In the fifth step mechanisms were identified that induce or block the functionality of the SIS. Steps 6 and 7 consist of identifying key policy issues and finding policy instruments that will help dealing with the hampering mechanisms found in step 5. The resulting policy instruments will be based on the Dutch energy-efficient renovation sector, but they may also prove to be useful in the further understanding of barriers in innovation systems in general. The results are discussed in the chapter 5.

5. Results

In this chapter the structural components of the Dutch renovation sector, as well as the functional analysis of this sector are discussed.

5.1 Structural components

In this section the structural analysis of the Dutch renovation sector is discussed. The structural components consist of three groups: actors, networks and institutions (see section 3.2 and 4.2). This data was gathered from scientific literature, project reports (see section 4.2.1) and expert interviews.

5.1.1 Actors and networks

Due to the size of the sector it is virtually impossible to create a complete overview of all the individual actors and networks that are involved in the Dutch renovation sector. However, the overview created in section 3.4 is as extensive as possible and comprises all actor groups involved in the sector. The overview created in section 3.4 elaborates on all the actors that are present in (large scale) renovation projects. These actors are government/municipality, housing corporations, consultants, financial institutions, designers, construction companies, installers and households. The individual actors that are active in the market range comprise small (<50 employees), medium (50 – 250 employees) and large (250+) enterprises. 42.595 companies were active in dwelling construction in 2010 (CBS, 2012). In 2010 60% of the revenue of dwelling construction was contributed to renovation (see figure 4).

System building, the creation of a system in which new products and technologies can develop and reach legitimacy, is very difficult for single actors to achieve (Musiolik et al., 2012). They therefore stress the importance of cooperation between actors with regard to innovation system building and the important role that formal networks play herein. Important networks that can be discerned in this sector are: Industry associations, e.g. *bouwend Nederland* (building sector), *energie-Nederland* (energy sector) and *UNETO-VNI* (installation sector), promote knowledge diffusion and create commitment to energy efficiency goals. These three associations, in combination with the government, signed a covenant called *meer met minder*. The goal of this covenant is to stimulate investments in energy efficiency measures and through advise and connecting actors; In 2012 KEI, Nicis institute, Nirov and SEV were merged into *platform31*, a knowledge- and networking organization for urban and regional development. Interviewees responded that platform31 has proven to be a helpful organization in the planning phases of *blok-voor-blok* projects. Within these projects actors work together to realize large scale dwelling renovation. Platform31 also created an innovation program called *energiesprong*. This program aimed at creating a large demand and supply of zero energy dwellings by changing the processes and methods within the building sector.

5.1.2 Institutions

In the structural analysis of the Dutch renovation sector, the following institutions were identified: The Dutch building sector has always been very conservative in nature (see section 2.1). During building projects, the promoter will do a tender procedure, for which a large selection of market parties can make an offer. In the current system the tender is usually offered based on the lowest price. “Tender requests are selected based on price” (installer). This has created a mindset in the market that focuses on price, rather than quality. Since energy-efficient renovation technologies and methods are still relatively expensive they are not extensively used in the building sector. Experts think that the creation of renovation concepts that can be applied widely can prove to be an important booster for energy-efficient renovation, “On the current scale we will not reach renovation goals. [Renovation] concepts are rolled out, but it needs to be done on a larger scale” (designer).

In the Netherlands rules and regulations regarding building and renovation are set in *het bouwbesluit* (the building code). This is a collection of minimal technical regulations to ensure safety in buildings. In 1992 the first national version of the building code was introduced, which most recently has been updated in 2012. Within the building code energy efficiency regulations are addressed. Newly built dwellings need to conform to an *energy performance coefficient* (EPC) specified within the *energy performance norms* (EPN). During the last 2 decades the EPC has been increased, forcing newly built dwellings to become more energy-efficient. In 2003 the European Union introduced the *energy performance of buildings directive* (EPBD), which is a guideline to stimulate the energy efficiency of the European housing stock. Based on this directive the Netherlands introduced a mandatory energy labeling system for dwellings that are sold or rented. These energy labels are valid for 10 years and can only be awarded by certified actors. With the latest revision of the EPBD by the EU, the Dutch government has decided to simplify the energy labeling system. In 2014 or 2015 energy labels are expected to no longer be mandatory. According to experts that will have a negative effect on energy-efficient renovation, “Unfortunately [the energy labeling] will be stopped next year […], because the energy efficiency gains can be made in the current housing stock” (Construction company).

5.2 Energy-efficient renovation system functioning

In this section the system functions (see section 3.3 and 4.1) are elaborated on and the results of the study are presented. Each function will be discussed separately. Letters between brackets indicate actors that mentioned the topics that are discussed. The respective actors are: housing corporation (A), installer (B), consultant (C), financial institution (D), construction company (E,F), designer (G) and consultant (H). At the end of the section an assessment of the functioning of the Dutch renovation sector as a whole is presented. This is presented in a table, displaying the actors (the letters match those previously mentioned) and how they scored each indicator. Lastly the average assessment per indicator is presented, as well as the average assessment of the total function.

Function 1: Entrepreneurial activities

Entrepreneurial activity is an important factor in the growth of innovation systems. The development of an innovation system will halt if the actors within the system show no entrepreneurial activity. As mentioned in section 2, the Netherlands has been in a financial crisis since 2008, which has led to a serious decline in the building production of the building sector. This has had a double effect on the entrepreneurial activity in the Dutch renovation sector. First, *new entrants* to the sector have been limited (B,F,G,H). Large (construction) companies generally ignored the energy-efficient renovation market and smaller actors noticed this behavior, leading to the entrance of new actors into niche markets (D,E,F). Experts agreed that the amount of new entrants was weak, “Only some new entrants with specific technical knowledge entered the market” (consultant). Second, *diversification of incumbent actors* was also influenced by the reduction in building production. Because the total investments in the building sector were decreasing, companies shifted their focus towards renovation to increase revenue (E,F). Within the renovation market a distinction needs to be made between the actors that started to focus on energy-efficient renovation and those that kept relying on traditional methods of renovation (C,D,G). Explanations given by the experts included: Lack of interest in energy-efficient renovation (C); Lack of human resources (G); Legal obligation of housing corporations to become more energy efficient (A,H). Some large incumbent actors that remained on the background regarding energy-efficient renovation looked at the business practices of the small actors in the market and learned from them what to do (D).

Interviewees											
Function	**Indicator**	A	B	C	D	E	F	G	H	Indicator average	Function average
F1: Entrepreneurial activity	New entrants	-	2	2	3	3	4	2	2	2.57	2.90
	Diversification of incumbent actors	-	3	3	4	4	3	2	3	3.14	

Table 3: Expert assessment F1: Entrepreneurial activity

The average assessment for the *new entrants* indicator was 2.57, meaning that they rate this indicator between weak and average. In section 2.1 we discussed that the construction sector is strongly influenced by the crisis, which would limit the number of new entrants to the market as can be witnessed. However, because of the projects initiated by the government we expected this indicator to score better. The average for *diversification of incumbent actors* was 3.14, meaning an average fulfillment. Due to a declined production in the construction sector we expected incumbent actors to show a diversification towards energy efficiency, albeit it limited due to the conservative nature of the sector (see section 2.1). Therefore an average fulfillment of this indicator was expected. The average assessment of the *entrepreneurial activity* function of was 2.90, or slightly below average. This data shows that due to the limited number of new entrants to the energy-efficient renovation sector, entrepreneurial activity scores below average.

Function 2: Knowledge development

Without the development of new knowledge there is no innovation possible. As mentioned in section 3.3 there are two types of learning that lead to the development of new knowledge: Learning by searching and learning by doing. Learning by searching is the creation of new knowledge through research & development (R&D). According to the experts the innovations that reached the market have been mostly incremental in kind (E,G,H). They describe the building sector as traditional by nature, meaning that there tend to be little disruptive innovations and product life cycles are long (B,E). The focus of knowledge development should not only be limited to technological knowledge, but should focus more on the creation of process knowledge (F,H). More research regarding chain collaboration needs to be conducted to streamline energy-efficient renovation projects. An expert agreed to this, stating that “[t]hey look at what they can do technically, but they do not look further. And when we talk about chain collaboration, I think a good deal can be gained by looking for an integral approach” (consultant). It was also suggested that the Netherlands, being a knowledge economy, has a responsibility to increase knowledge creation (G). This increase in R&D should be incited by the government instead of market parties. Learning by doing occurs at a decent level in the Netherlands, through the use of pilot projects. Pilot projects are important in the creation of renovation concepts, which will make large scale energy-efficient renovation easier in the near future (F,G).

Interviewees											
Function	**Indicator**	A	B	C	D	E	F	G	H	Indicator average	Function average
F2: Knowledge development	Knowledge creation	-	3	2	2	2	3	3	2	2.43	2.64
	Importance of R&D	-	3	3	3	3	3	2	3	2.86	

Table 4: Expert assessment F2: Knowledge development

The average assessment of the *knowledge creation* indicator was 2.43, meaning they rate this indicator between weak and average. The construction sector in the Netherlands is considered to be conservative, showing low levels of innovation (see section 2.1), which can explain a weak performance of this indicator. *Importance of R&D* was rated 2.86, meaning a slightly below average rating. Experts show that despite the conservative nature of the sector, they expect R&D to be important in the energy-efficient renovation sector. The resulting assessment of *knowledge development* was 2.64, or between weak and average. The low assessment of this function is not unexpected, as literature suggested that innovation in the Dutch construction sector has always been low.

Function 3: Knowledge diffusion through networks

Once knowledge is created it needs to find its way on the market. Knowledge diffusion happens in a myriad of ways. Knowledge regarding technical installations is diffused by suppliers and industry organizations through schooling projects (B,E). Industry wide publications, as well as the internet are increasingly being used as methods of knowledge diffusion in the renovation sector (C,D,E,G). Collaborations during renovation projects was also mentioned as a method of knowledge diffusion (D,E,F,H). Lastly, networking opportunities, such as *conferences* and workshops, are an important aspect of knowledge diffusion in the renovation sector according to the expert. A high number of conferences within the sector has made it difficult for actors to choose which ones they want to attend (C,F,H). Regularly conferences are purely to meet new people and do networking, rather than the diffusion of knowledge (A,E,G). One expert stated "[I] think we talk more there than that we work" (housing corporation). The rate of knowledge diffusion within a system depends partly on the *participation of actors*. Especially in the past the participation of actors in knowledge diffusion was low (A). Currently a change in the participation of actors can be witnessed, due to an increase of chain integration/collaboration on energy-efficient renovation projects (B,C,E,F). There is a role for the government to stimulate these types of collaboration, because it will increase knowledge diffusion as well as the market production as a whole, which leads to lower product costs (F). however, actors remain reserved when it comes to knowledge sharing, because they fear it will cost them revenue (C,D).

		Interviewees									
Function	**Indicator**	A	B	C	D	E	F	G	H	Indicator average	Function average
F3: Knowledge diffusion	Conferences	-	4	4	4	4	5	3	4	4.00	3.36
	Participation of actors	-	3	2	3	3	2	2	4	2.71	

Table 5: Expert assessment F3: Knowledge diffusion through networks

The average of the indicator *conferences* was 4.00, which means strong. This strong score indicates that there are plenty of opportunities for actors to participate in knowledge diffusion. Based on the existence of several trade associations this was expected, because they promote knowledge diffusion. *Participation of actors* was rated 2.71, or between weak and average. We expected a stronger score for this indicator, because the knowledge diffusion opportunities are present. However, this indicator shows that due to several reasons actors do not actively participate in knowledge diffusion. This results in the assessment of *knowledge diffusion* of 3.36, or slightly above average. The discrepancy between the scores for the indicators shows us that the participation of actors should be improved in the energy-efficient renovation sector.

Function 4: Guidance of the search

High expectations of energy-efficient renovation technologies and methods will have a positive effect on market growth. Expectations can be increased by the government, if they create clear targets in their policy. In the Netherlands the government has created energy efficiency targets that have an influence on what actors in the market do (see section 1.1 and 1.2). All interviewed experts said that some form of governmental *policy targets* has influenced their business strategy. Housing corporations have a future legal obligation to increase the energy efficiency of their housing stock and are therefore forced to take that into consideration when renovating (A,H). Housing corporations own roughly 3 million dwellings in the Netherlands, meaning that their move towards energy-efficient renovation will create a large market demand. Policy targets have also influenced actors because it created a market (C,F,G) and it provides resources (C). Unfortunately, the traditional nature of the building sector still limits the effect of policy targets on business strategy, because tender requests are still dominantly decided on pure financial basis (B,E). Expectations by experts are also of importance to the guidance of the search. Disregarding any current socio-economic influences the experts agree unanimously that the growth potential for energy-efficient renovation in the Netherlands is large. Increasing energy costs (C,D,E) and climate problems (G) are driving factors in the growth potential. Growth potential is limited because of a lack of willingness to invest (B,E,F) and due to limited awareness (H).

		Interviewees									
Function	**Indicator**	A	B	C	D	E	F	G	H	Indicator average	Function average
F4: Guidance of the search	Policy targets	-	4	4	4	4	5	4	5	4.29	4.07
	Growth potential	-	4	4	4	4	3	4	4	3.86	

Table 6: Expert assessment F4: Guidance of the search

The average assessment of *policy targets* was 4.29, which means they rate this indicator strong. Based on the literature review we knew that the Dutch government had placed energy efficiency in the housing sector high on the policy agenda. The influence of these policy targets on business strategies of actors in the sector were higher than expected. Energy-efficient renovation *growth potential* was rated 3.86, which is also strong. This indicator was expected to score high, because literature showed the possible energy savings and the investment costs needed. The resulting function average assessment is 4.07, or strong. This strong score indicates that the Dutch government is successfully influencing actors in the sector to increase energy efficiency.

Function 5: Market formation

The right market conditions need to exist for new methods/technologies to make a successful entrance. Creating advantages for these emerging technologies is one method to increase the chances of successful market adoption. Such advantages can come in the form of *institutional incentives*. Subsidies are one of these incentives and is used by the government to create advantages. Several energy efficiency products have been subsidized in the past years, such as photo-voltaics, double glazing and heat recovery systems. The effect of these subsidies is limited, because they create a high demand short-term, but resulted in little to no market demand after the subsidy expired (B,C,E). The government should simplify the incentives system, because the current system is too unclear and confusing to the public (E). The availability is almost always based on a set amount of money, rather than a timeframe, making it hard for people to decide whether to invest (D,G). *Standardization* in favor of energy-efficient renovation is another method of creating advantages for energy efficiency products. In the Netherlands little is done to create this advantage. Building codes and regulations dictate standards and numbers that construction has to be compliant to, but there is little to no monitoring afterwards (B,G,H). Standardization with regard to energy labeling and the strict compliance to this standard is important in the Dutch housing sector. In the current system energy labels are not mandatory, decreasing the value of that standard. Other European countries enforce energy labels in the sales of houses, resulting in the increase of energy-efficient renovation. Linking energy labels to mortgage applications could result in a strong increase in investments, states an expert: "[a] low price for an energy label G house will incentivize the homeowner to improve the energy efficiency of his house" (financial institution).

		Interviewees									
Function	**Indicator**	A	B	C	D	E	F	G	H	Indicator average	Function average
F5: Market formation	Institutional incentives	-	3	2	2	2	2	2	2	2.14	2.14
	Standardization	-	2	3	3	3	1	1	2	2.14	

Table 7: Expert assessment F5: Market formation

The average assessment of *institutional incentives* was 2.14, which is a weak fulfillment. We expected this indicator to be higher, because the government has been actively incentivizing the market to invest in energy efficiency. Apparently the current methods are not best suited to increase investments in energy efficiency. The assessment of *standardization* was 2.14, meaning it is rated weak. Based on literature this was expected, because the Netherlands scores weakly in comparison to other European countries, especially regarding energy labeling compliance. The resulting function average was 2.14, showing that this function lacks within the system. A failure to incentivize actors can be a cause for the low levels of energy-efficient renovation in the Netherlands.

Function 6: Resources mobilization

Without resources an emerging sector cannot mature. Before the financial crisis struck in 2008, the *availability of capital* was not an issue. Financial institutions provided loans and other actors such as housing corporations had sufficient capital to invest in their housing stock. Since then the availability of financial capital has dwindled. Housing corporations are interested in investing in energy-efficient renovation of their housing stock, but are limited in their earning models by the government (A,H). The availability of financial capital for home owners is sufficient, but investments remain at low levels because of two reasons. First, the distribution of capital is limited (C,G). Second, because of the financially uncertain times home owners are wary to invest their savings at this moment (C,E,F). *External resources* could be a solution to increase investments in energy-efficient renovation. The creation of a fund by the Dutch municipalities could incite housing corporations to invest (A,D). The government could also create incentives to attract pension funds (national and foreign) to invest in the Dutch housing sector (A,D).

		Interviewees									
Function	**Indicator**	A	B	C	D	E	F	G	H	Indicator average	Function average
F6: Resources mobilization	Availability of capital	-	3	4	3	3	2	4	3	3.14	2.93
	External resources	-	2	2	2	2	3	3	4	2.71	

Table 8: Expert assessment F6: Resources mobilization

The average assessment of *availability of capital* was 3.14, which means they rate this slightly above average. We expected this value to be lower, because the crisis has decreased available capital. Apparently the capital is there, but the redistribution of that capital is lacking. The need for e*xternal resources* was rated 2.71, which is below average. If capital is available, there is no need for further external resources. The resulting function average assessment is 2.93, or slightly below average. Considering the crisis, this function scored higher than expected. This indicates that the actors in the market are less reserved than the public when it comes to investing.

Function 7: Creation of legitimacy

New emerging technologies need to be socially accepted in order to successfully reach the market. *Public awareness* regarding energy-efficient renovation is very low in the Netherlands, which is agreed upon by all experts. The exposure of energy-efficient renovation in the Netherlands is very weak, especially compared to other countries (G). In Germany there is almost daily exposure to the risks of fossil fuel use, resulting in a public mindset that wants to increase energy efficiency. In the Netherlands only energy companies increase public awareness through marketing, but this information should come from a more credible source such as the government rather than market parties (B,D,G,H). The public needs to see a clear cost breakdown to believe that the investment they make is justified (B,E). Young homeowners also show no interest in investing in energy-efficient renovation, because they do not have savings and do not know how much they can save if they increase their mortgages (E). A large number of *Lobby groups* exists, but because the renovation sector is so diffuse and the groups do not work together they prove to be little effective (B,C,E,H). Due to a lack of transparency the public also distrusts lobby groups (F,G).

		Interviewees									
Function	**Indicator**	A	B	C	D	E	F	G	H	Indicator average	Function average
F7: Creation of legitimacy	Public awareness	-	2	2	1	1	2	2	2	1.71	2.14
	Lobby groups	-	3	3	3	3	2	2	2	2.57	

Table 9: Expert assessment F7: Creation of legitimacy

The average assessment for the *public awareness* indicator was 1.71, meaning that they rate this indicator very weak to weak. We expected this indicator to score below average, but not this weakly. This score indicates that public awareness needs to be improved strongly before investments in energy-efficient renovation will increase. The average for *lobby groups* was 2.57, or between weak and average. Linking this assessment to the weak score for public awareness shows that lobbying efforts are strongly insufficient. The resulting average assessment of the *creation of legitimacy* function was 2.14, or weak. Such low scores are a strong indication that these indicators are barriers in the development of the Dutch energy-efficient renovation sector.

5.3 Sector analysis

The expert data presented in the tables in section 5.2 was used to create a spider diagram of the average function fulfillment in the Dutch energy-efficient renovation sector. Figure 6 shows the seven functions and the average fulfillment for each function.

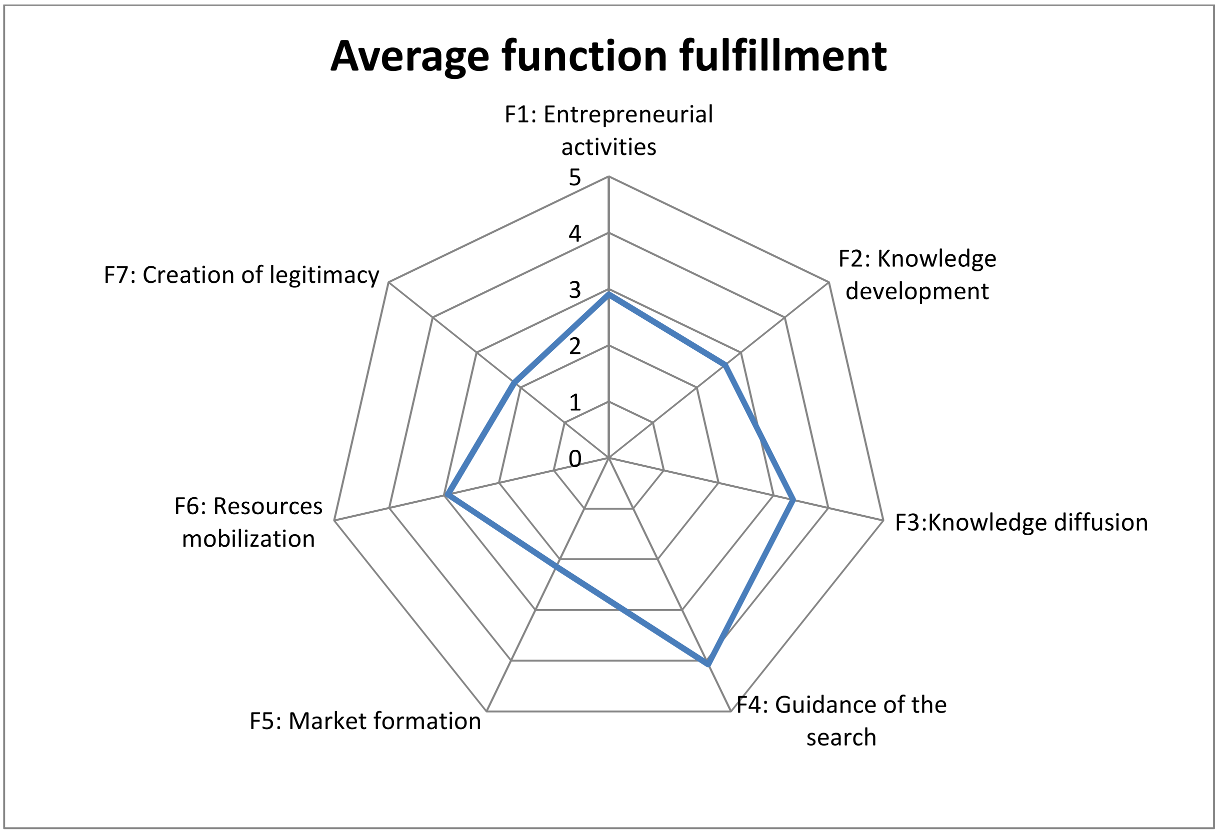

Figure 6: Average function fulfillment, 1 = weak and 5 = strong

Four functions score average to strong: *Entrepreneurial activities, knowledge diffusion, guidance of the search* and *resources mobilization*. In a developing market one would expect entrepreneurial activities to be high, because there will be no lock-in that prevents new technologies and actors from entering. The data does not really show this, but the financial crisis likely has had an influence on entrepreneurial activity. Knowledge diffusion scores slightly above average, but that figure is high due to the strong score for networking opportunities. Participation of actors within the sector is lower than expected and needs to be increased. Most of the experts mentioned 'chain integration' as an important driver of knowledge diffusion in the renovation market. Guidance of the search is fulfilled the strongest in the sector. It shows that in the Dutch system there are high expectations for energy-efficient renovation of the housing stock, strongly influenced by government policy. The mobilization of resources is fulfilled average in the renovation sector. Increasing methods to redistribute available capital for actors to invest in energy-efficient renovation is most important for this function. The experts stated that capital currently is too locked up for large scale investment. Three functions score well below average: *Knowledge development, market formation* and *creation of legitimacy*. Knowledge development was expected to be low, because the Dutch construction sector is very conservative. However, market formation and creation of legitimacy scored unexpectedly low. Market formation is hindered because the current methods the Dutch government employs to stimulate the energy-efficient renovation sector are not proving to be successful. The lack of stimulation to invest in energy-efficient renovation is linked to a lack of energy labeling compliance. Experts state that the government should reward those that want to invest and stimulate those that do not want to invest by increased costs for inaction. E.g. linking energy labels to low interest rate mortgages to stimulate investments. Finally, creation of legitimacy is also strongly lacking in the sector. Public awareness is very weak and lobbying efforts to increase awareness are ineffective according to the experts. All actors involved in the energy-efficient renovation sector should help increase awareness through channels at their exposal. The government should take a leading role in this movement towards mass informing.

The figure above, and the results discussed in section 5.2 have created an overview of the functioning of the Dutch energy-efficient renovation sector. It shows that market formation and creation of legitimacy are the two main bottlenecks in the sector. These results have helped us to answer the research question of this study. In the next chapter the implications and limitations of this study will be discussed, followed by the conclusion.

6. Discussion

This study has identified barriers that hamper the development of the Dutch energy-efficient renovation sector. This was done based on functions of innovation systems theory. This theory has proven helpful in the analysis of innovations systems by identifying the barriers within a system and providing the researcher specific problem areas that can be addressed with policy recommendations. In this study a group of experts from different backgrounds, were interviewed to obtain the necessary data for the functional analysis. The methodology was used to create an overview based on multiple actors, all representing the different actor groups mentioned in section 3.4. This was done to ensure that all the possible actor perspectives within the sector were taken into account. By selecting these experts from the blok-voor-blok projects, we tried to keep project conditions (e.g. organizational structure or method of informing the public) as comparable as possible in order to see if different actors within the projects had similar ideas about the functioning of the system. Data triangulation is a research method that involves the use of different data sources (experts) to increase validity of the research. In this study experts with different backgrounds were interviewed, increasing the validity. While the experts interviewed had different backgrounds, municipalities may have been insufficiently represented. Municipalities were contacted, but showed no interest in participating in this study. However, some experts did provide insights in the participation of municipalities for the blok voor blok projects. They stated that due to limited resources municipalities in general show limited participation in the projects.

The external validity, or to what extend the results can be generalized, is influenced by people, places and times. The sample size for this study was relatively small, but the interview data showed similarities between answers given by interviewees. That is an indication that perspectives represent a similar, but larger, group of actors. However, increasing the number of interviewees could have increased perspectives, especially if actors who are currently not involved in energy-efficient renovation are interviewed. Interviewees were selected from various projects in different cities in the Netherlands. Biased results based on location are therefore unlikely. Time is also unlikely to have influenced the study, since all interviews were carried out in a timeframe of two months. During this timeframe no interfering occurrences were witnessed, such as publications of sudden policy changes.

Most of the energy efficiency and emission goals set by the EU and the Netherlands were introduced in the mid to late 2000s. This is roughly the same period in time in which the financial crisis of 2008 started. Most of the experts interviewed agreed that the crisis has influenced the construction sector and the development of the Dutch energy-efficient renovation sector, partly because it constrained the available capital and partly because it severely decreased the willingness of actors to act in the market. It is therefore difficult to estimate how much the crisis has affected the development of the sector. The effect of the financial crisis has been partially addressed in the indicators for the system functions, but except for the availability of capital no indicators focused on the Dutch economic landscape. Based on the figure in section 2.3 the production of the construction sector shrank a maximum of 14%, of which 1-2% came from the renovation production. This implies that the newly built sector was especially hit by the financial crisis. Also, we think that the worst performing functions in the Dutch renovation sector are not likely to have been influenced by the financial crisis, because the gross of the investments necessary for those functions were made by the government, who have a more resilient financial strength.

One of the data sources were experts, who are all active in their own respective fields. This has the positive effect that their input is very specific for that subsector, resulting in views from different standpoints. In this study this was witnessed in the views of experts that were not related to the financial subsector. They had different opinions on the availability of financial capital and possible solutions than those related to the financial subsector. Another example is the effect of government policy targets on the business strategy of organizations. Actors that were directly related to the rental sector stated that they were forced to focus more on energy efficiency by government policy. However, other actors stated that the policy created a possibility for them. They preferred to focus on the energy efficient side of their business, rather than being forced. It needs to be noted that actors in the rental sector were not against energy efficiency per se, but rather against the constricted options the law provided them to invest in energy efficiency. Since the rental sector comprises more than 2 million dwellings it is essential that the government changes relevant laws that constrict energy-efficient investments (Datawonen, 2011).

Large-scale energy-efficient renovation is not yet occurring in the Netherlands, based on the figures of current renovation production and the opinions of the experts interviewed (see section 1.2). This indicates that this sector is still in the development stage. It is interesting to see whether policy recommendations following from this, or similar, studies have an influence on the system. The functional analysis approach has proven it possible to assess the dynamics of innovation systems by comparing the function of a system at different points in time. Redoing an analysis of the Dutch energy-efficient renovation sector in 5-10 years could show which functions at that time are carried out weakly or strongly. We do not propose to do a longitudinal study, since we did not start this research with that goal. If we wanted to use this research in a longitudinal study we should have focused more on characteristics of the actors, rather than on characteristics of the system. However, conducting a similar study after that timeframe and comparing it with the one in this study will show whether the barriers recognized in this study have been addressed, and whether there are still functions that hamper further development of the system.

Some of the results found may seem counterintuitive. For example, the score of the knowledge development function was 2.64, which is a below average fulfillment. However, we conclude that this functions does not pose a barrier in the development of the Dutch energy-efficient renovation sector. We conclude this, because in section 2.1 we stated that the construction sector in the Netherlands has historically been lacking innovation. We do still think that knowledge development in a developing sector is important, but the importance should be assessed relative to the larger system in which it is situated. That is why we remain confident in system functions theory as a tool to assess the performance of a system. As long as the correct indicators are used to assess the performance of a system, this tool will prove helpful. The vast literature on this theory helps guide to find the correct indicators (see section 3.3).

Harkema & Golriz (2012) suggest that there is a problem regarding attitude that they call 'circle of blame'. This means that actors shift the responsibility of sustainability in the construction sector to other actors. As a result, the homeowner is forced to choose non-sustainable products. Our results showed that the experts we interviewed were not stepping away from their responsibility to invest in energy-efficient renovation, but we do have to note that our interviewees were all active in energy-efficient renovation, thus maybe skewing their attitude slightly.

Lastly, there were some results that surprised us. The weak score for the market formation function was unexpected. The literature review showed that the Netherlands was fairly active in creating institutional incentives to promote energy-efficient renovation. They offered a range of subsidies for energy-efficient technologies. After interviewing the experts it became apparent that actors in the market do not want to rely on these subsidies for the creation of a market. They stated that they would rather have subsidies based on a timeframe, instead of a predefined amount of capital. They also argued that political horizons in the Netherlands caused these subsidies to be too short term, preventing market actors from investing.

7. Conclusion

This study has set out to explore the existence of barriers that hamper the development of the Dutch energy-efficient renovation sector. The energy efficiency goals set by the Dutch government are not met at the current rate. The Dutch housing stock is responsible for a large percentage of the total primary energy use of the Netherlands, which makes the Dutch housing sector an interesting market to make gains regarding energy efficiency. Therefore, in this study the scope of the system was delineated as the energy-efficient renovation sector. Low yearly renovation figures mentioned in the available literature suggested that the sector was not performing on the levels the Dutch government had expected. The functioning of this sector was analyzed using a sectoral innovation system perspective. We used a scheme of analysis that provides a step by step framework to analyze structural components and systemic functions. In section 1 the following research question was formulated: *Which barriers impair energy-efficient renovation strategies within the Dutch housing stock?* Several sub questions were proposed to help answer this research question.

The first sub question is: *What are the structural components of the Dutch renovation sector?* A structural analysis helped create an overview of the actors, networks and institutions apparent in the Dutch renovation sector. The actor groups that are active in this sector are government/municipality, housing corporations, consultants, financial institutions, designers, construction companies, installers and households. These actors are linked together through several networks, mainly trade associations, networking organizations and covenants. The actors and networks are bound by institutions, of which the most important ones are the building code, energy performance norms and the energy performance of buildings directive.

The second sub question is: *How is the Dutch renovation sector functioning?* A functional analysis of the system helped to identify which functions within the system were carried out sufficiently and which functions lack, indicating possible barriers. This functioning of the system was based on the opinions of experts active in the sector. The first function, entrepreneurial activities, showed two faces. New entrants to the market were limited, possibly due to the financial crisis that hit the sector in 2008. On the other hand, incumbent actors have shown a diversification of their activities towards energy-efficient renovation in the last five years. According to the experts there are two reasons this diversification has occurred: 1) Because a decrease in total building production of the building sector forced actors to increase their share of renovation projects; 2) Because there has been an increase in market demand for energy-efficient renovation. Based on the limited number of new entrants and the slightly above average diversification of incumbent actors we concluded that there is an average fulfillment of this function. This signifies that there are gains to be made, but also that they are not direct barriers for the development of the system.

The second function, knowledge development, indicated that knowledge creation in the system is limited. However, experts believe that research and development is not the most important factor for this system to develop further. They state this is so, because technologies and methods used in the building sector have long product life cycles and there is a larger need for new procedural knowledge than technical knowledge. Based on the opinions of the experts on the importance of new knowledge creation we conclude that while this function scores weakly. As discussed in section 2.1, the Dutch construction sector is very conservative and historically has shown weak levels of innovation. Which is why a relatively weak fulfillment of this function does not present a direct barrier, hampering the development of the system. This conclusion is supported by expert opinions that state that the necessary technical knowledge is available.

The third function, knowledge diffusion, was separated in networking opportunities and participation of actors. Networking opportunities, i.e. conferences or workshops, are plentiful in the sector. Experts state that the offer of networking opportunities is so high that they have to decide which opportunities they need to attend. The participation of actors with regard to knowledge diffusion on the other hand is weak to average. Knowledge diffusion outside of the networking opportunities are often limited to the necessary knowledge exchange during projects. We conclude that in total, knowledge diffusion occurs slightly above average. However, there is an opportunity to increase participation by actors, e.g. through chain integration/collaboration.

The fourth function, guidance of the search, is the strongest function in the system. Government policy targets have influenced many of the actors in the market to adapt their business strategies to include energy efficiency. According to the experts this can still be improved if the government creates clearer and longer-term policy. The expectations of professionals regarding the growth potential of energy-efficient renovation is very high. They state that if the government manages to create the right market conditions, energy-efficient renovation will be able to increase strongly in the coming decades. We conclude that this function is carried out strongly and creates no barriers for the development of the system.

The fifth function, market formation, indicated that insufficient competitive advantages have been created for energy-efficient renovation methods and technologies to be successfully adopted in the renovation sector. Most incentives are based on subsidies, which offers only short term market stimulation for the respective technology. Focusing more on long term incentives reduces the dependability on subsidies for investments in energy-efficient renovation. The presence of standardization in the sector is another barrier. According to the experts energy standardization, i.e. energy labeling, should be regulated more strongly and compliance to these regulations should be increased. Currently homeowners are not sufficiently incentivized to invest in energy-efficient renovation. We conclude that this function is weak, while it should be one of the driving forces in the development of an energy-efficient renovation sector. There is a major role for the government to incentivize the actors in the market to invest and decrease energy use. They can do that by creating institutional incentives (e.g. tax benefits, long term subsidies) or by rewarding energy label compliance (e.g. lower interest rates, property taxes).

The sixth function, resources mobilization, indicated a sufficient availability of financial capital in the system. However, according to the expert this capital is partially locked, because private homeowners do not want to risk an investment and financial institutions are reluctant to loan out the needed capital for investments. Stimulating the creation of loans that are linked to increased energy efficiency of dwellings is a method to increase investments in the energy efficiency of dwellings. The need for external resources to further stimulate the sector was rated weak to average. A weak need for external resources signifies that there is sufficient capital available in the market. We concluded that resources mobilization is average in the system, not resulting in barriers.

The seventh and last function, creation of legitimacy, indicated a strong lack of public awareness. All experts agreed that currently there is little to no public awareness regarding energy-efficient renovation. Private homeowners do not know about the options they have to increase energy efficiency through renovation, nor do they know the benefits (financially and physically) that an increase in energy efficiency offers them. Actors on all levels play a major role in improving the public awareness, but the government should take a leading role in this respect because it is trustworthy. Lobbying by the market is being done, but the effectiveness of these activities are very limited. We conclude that public awareness is one of the major barriers to the development of the energy-efficient renovation sector in the Netherlands.

Resulting from the functional analysis of the system we have identified five barriers:

1. There is insufficient participation of actors in the diffusion of knowledge regarding energy-efficient renovation.
2. There is a lack of competitive advantages to create a favorable market for energy-efficient renovation.
3. There is a lack of energy standardization and compliance to those standards.
4. Public awareness is virtually non-existent.
5. Lobbying efforts to increase awareness are in vain.

Based on the indicated barriers we have several policy recommendations. First, the government should increase efforts to unite actors in projects. The covenants mentioned in section 1 are an example to do so. The energiesprong covenant has as a goal to unite market actors to create market demand and to share the project experience with other actors in the sector. For the energiesprong projects they actively search for actors that want to participate. Second, the methods used to stimulate investments in energy efficiency in the housing sector should be reviewed and adapted to include longer-term strategies. Current incentives focus too much on the short term and fail to create the driving force needed to develop renovation methods and technologies on a large scale. Third, a strict energy labeling standard needs to be created and this standard needs to become an important factor in multiple fields. The label should be mandatory when renting/selling a dwellings as well as when applying for a mortgage. If dwellings with worse energy labels receive lower mortgages, homeowners are motivated to invest in energy efficiency. If they do not invest, they risk having to sell for a lower price. Fourth, all actors in the sector need to increase the information diffusion towards the public. The government has a critical role herein, because they can offer the public the needed generic information from a trustable source that incentivizes the public to reach out to other actors for more information. This information should encompass all aspects of energy-efficient renovation, e.g. technical possibilities, health benefits and financing. Fifth, lobbying efforts by lobby groups should be better structured. Currently these efforts are too diffuse, resulting in little effectiveness. If actors within subsectors combine their lobbying efforts through trade associations they can reach a bigger group. Lobbying efforts by the market parties towards the government can also be better structured through meetings on predefined intervals. This can result in quicker responses from the government towards changing market conditions.

Now that we have answered our research question we can offer some suggestions for further research. To further strengthen the structural analysis aspect of this study, a social network analysis can be performed to get a more detailed overview of all the actors and the relations between them. If we want to create a (more) complete overview of this structure it is necessary that the scope of the study is enlarged. In this study blok-voor-blok projects were an important source of project data, but projects outside of the covenants mentioned in section 1.2 can prove to be just as useful in further explaining the links between actors in practice. This will require a large amount of resources, because it encompasses an entire sector, consisting of 100s to 1000s of actors and networks between them. A detailed mapping of this sector could indicate the most important hubs, or central points of networking, which in turn could provide invaluable data on which actors and networks the sector should focus to increase the production of energy-efficient renovation in the Netherlands.

In a future study the sample size of the experts could be increased to increase saturation of actor perspectives in this sector. By increasing the scope outside of blok voor blok projects more valuable data can be gathered. As mentioned in section 6, all the actors that were interviewed were already participating in energy-efficient renovation projects, but there is also a large group of actors that have not done so. It would be interesting to see if their perspectives/opinions differ from those interviewed in this study, and if so to understand why.

To further study the effect of the financial crisis on the development of the Dutch energy-efficient renovation sector we propose to add several indicators to study. One indicator would be the extent of *financial limitations* actors have witnessed regarding the decisions they made. If actors indicate that their decisions were limited by capital, we need to relate the limitations to the financial performance of the organization of the actor. This would be done to ensure that the limitations stem from the crisis, and not from a desire to live beyond your means. Another method would be to study the development of energy-efficient renovation sectors in other countries that have similar economic landscapes. If they prove to have performed better despite similar financial downturns, that could indicate that the financial crisis has had little effect on the development of the sector.

Based on the expert interview data we can conclude that there is an opportunity to further explore several aspects of this system, because these were often mentioned by the experts. Examples include: the importance of chain collaboration within the sector; the effect of the political horizon in the Netherlands, especially regarding long term policy; consistency in rules and regulations for the sector. Based on the expert views, a better understanding of these aspects in relation to the Dutch renovation sector would further help the development of the Dutch energy-efficient renovation sector.

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References

ABN (2013). Visie op bouw en vastgoed.

Aedes (2012). Feiten & Cijfers. Retrieved September 30th 2013, from http://www.aedes.nl/content/elementen/feiten-en-cijfers.xml

Agentschap NL (2013). Blok voor blok. Retrieved august 5th 2013, from http://www.agentschapnl.nl/onderwerpen/duurzaam-ondernemen/gebouwen/blok-voor-blok

Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S., & Rickne, A. (2005). Analyzing the dynamics and functionality of sectoral innovation systems–a manual. In *DRUID Tenth Anniversary Summer Conference* (pp. 27-29).

Bergek, A., Jacobsson, S., Carlsson, B., Lindmark, S., & Rickne, A. (2008). Analyzing the functional dynamics of technological innovation systems: A scheme of analysis. *Research policy*, *37*(3), 407-429.

Bertoldi, P., Rezessy, S. (2010). Voluntary agreements in the field of energy efficiency and emission reduction: Review and analysis of the experience in member states of the European union.

Bouwend Nederland (2013a). Organisatie. Retrieved august 6th 2013, from http://www.bouwendnederland.nl/organisatie

Bouwend Nederland (2013b). Verwachtingen bouwproductie en werkgelegenheid 2013 (EIB). Retrieved November 12th 2013, from http://www.bouwendnederland.nl/nieuws/32873/verwachtingen-bouwproductie-en-werkgelegenheid-2013-eib

BPIE (2010). Cost optimality. Discussing methodology and challenges within the recast Energy Performance of Buildings Directive.

Brown & Whiting (1997). Consumers' attitudes toward energy efficient appliances in the Los Angeles Area.

Bryman, A. (2008). *Social research methods*. Oxford university press

Carlsson, B., Stankiewicz, R. (1991). On the nature, function and composition of technological systems. *Journal of Evolutionary Economics*, 1(2), 93–118.

Carraro, C. (Ed.) (2000). *Efficiency and equity of climate change policy*. Dordrecht: Kluwer academic publishers.

CBS (2012). Bedrijven; naar economische activiteit. Retrieved November 28th 2013, from http://statline.cbs.nl/StatWeb/publication/?DM=SLNL&PA=80233NED&D1=0&D2=475-476,481,493&D3=1-l&HDR=T,G2&STB=G1&VW=T

CBS (2013a). Voorraad woningen en niet-woningen; mutaties, gebruiksfunctie, regio. Retrieved november 12th 2013, from http://statline.cbs.nl/StatWeb/publication/?VW=T&DM=SLNL&PA=81955NED&LA=NL

CBS (2013b). Woningvoorraad naar eigendom; regio. Retrieved September 30th 2013, from http://statline.cbs.nl/StatWeb/publication/default.aspx?DM=SLNL&PA=71446ned&D1=0-10&D2=0,122,245,442,499&D3=a&HDR=T,G2&STB=G1&VW=T

Church, J. A., Gregory, J. M., Huybrechts, P., Kuhn, M., Lambeck, K., Nhuan, M. T., ... & Woodworth, P. L. (2001). Changes in sea level. , in: JT Houghton, Y. Ding, DJ Griggs, M. Noguer, PJ Van der Linden, X. Dai, K. Maskell, and CA Johnson (eds.): Climate Change 2001: The Scientific Basis: Contribution of Working Group I to the Third Assessment Report of the Intergovernmental Panel, 639-694.

Coenen, L., & Díaz López, F. J. (2010). Comparing systems approaches to innovation and technological change for sustainable and competitive economies: an explorative study into conceptual commonalities, differences and complementarities. *Journal of Cleaner Production*, *18*(12), 1149-1160.

Datawonen (2011). Woningvoorraad sociale huursector, 2011. Retrieved December 24th 2013, from http://vois.datawonen.nl/report/cow13_802.html

de T'Serclaes, P., & Jollands, N. (2007). Mind the gap: quantifying principal-agent problems in energy efficiency. *Paris, International Energy Agency and the Organization for Economic Cooperation and Development*.

Ding, Y. D. J. G., Griggs, D. J., Noguer, M., van der LINDEN, P. J., Dai, X., Maskell, K., & Johnson, C. A. (2001). *Climate change 2001: the scientific basis* (Vol. 881). Cambridge: Cambridge University Press.

Duurzaam thuis (2013). Overzicht subsidie duurzaam wonen en duurzaam bouwen. Retrieved December 24th 2013, from http://www.duurzaamthuis.nl/financieel/subsidies

Edquist, C. (ed.) (1997) Systems of Innovation: Technologies, Institutions and Organizations. London: Pinter publishers

Energiesprong (2013). Deal de stroomversnelling: 111000 huurwoning naar energienota=0. Retrieved november 12th 2013, from http://energiesprong.nl/blog/deal-de-stroomversnelling-111-000-huurwoningen-naar-energienota0/

Energy saving trust (2013). Insulation. Retrieved November 13th 2013, from http://www.energysavingtrust.org.uk/Insulation

EuroACE (2013). Renovate Europe. Retrieved December 24th 2013, from http://www.euroace.org/Resources/Projects/RenovateEurope.aspx

European Commission (2011). EU 2011 energy-efficiency measures – 20% reduction by 2020. Retrieved august 1st 2013, from http://ec.europa.eu/news/energy/110622_en.htm

European Commission (2012a): http://www.europarl.europa.eu/ftu/pdf/en/FTU_4.13.3.pdf

European Commission (2012b). The EU climate and energy package – Policies – Climate action. Retrieved august 1st 2013, from http://ec.europa.eu/clima/policies/package/index_en.htm

European Commission (2013). Europe 2020 in the Netherlands. Retrieved august 5th 2013, from http://ec.europa.eu/europe2020/europe-2020-in-your-country/nederland/progress-towards-2020-targets/index_en.htm

FMM (2009). Aanscherping EPC-eisen utiliteitsbouw. Retrieved august 6th 2013, from http://www.fmm.nl/aanscherping-epc-eisen-utiliteitsbouw.2.77132.lynkx

Freeman, C. (1988) 'Japan: A new national innovation system?', in G. Dosi, C. Freeman, R. R. Nelson, G. Silverberg and L. Soete (eds.) Technology and economy theory, London

Freeman, C. (1995). The 'National System of Innovation' in historical perspective. *Cambridge Journal of economics*, *19*, 5-24.

Geels, F. W. (2005). *Technological transitions and system innovations: a co-evolutionary and socio-technical analysis*. Edward Elgar Publishing.

Ghauri, P.N., & Grønhaug, K. (2005). Research Methods in Business Studies (3rd Edition), Prentice Hall: London

Graham, N.E. (1995). Simulation of recent global temperature trends. *Science*, vol. 267, no. 5198, 666-671

Hansen, J., Lebedeff, S. (1987). Global trends of measured surface air temperature. *Journal of geophysical research: Atmospheres*, vol 92, issue D11, 13345-13372

Harkema, S., & Golriz, D. (2012). Sustainable Innovation in the Dutch Construction Industry: Entrepreneurs as Agents of Change. *Available at SSRN 2180509*.

Harmelink, M., Graus, W. H. J., Marsidi, M., Saygin, D., & Worrell, E. (2010). Potentieel voor Besparing en Efficiency van Energiegebruik in Nederland (BEEN).

Harvey, L. D. (2009). Reducing energy use in the buildings sector: measures, costs, and examples. Energy Efficiency, 2(2), 139-163.

Hekkert, M. P., Suurs, R. A., Negro, S. O., Kuhlmann, S., & Smits, R. E. H. M. (2007). Functions of innovation systems: A new approach for analysing technological change. *Technological Forecasting and Social Change*, *74*(4), 413-432.

Hekkert, M.P., Negro, S.O., Heimeriks, G.J., Harmsen, R. (2011). Technological innovation system analysis: A manual for analysts.

Hermelink, A.H., Müller, A. (2011). Economics of deep renovation: Implications of a set of case studies.

Jacobsson, S., & Johnson, A. (2000). The diffusion of renewable energy technology: an analytical framework and key issues for research. *Energy policy*, 28(9), 625-640.

Jeths, R., Prendergast, E. (2009). Hoogwaardige renovatie beter dan sloop. *BouwIQ*, 3, 24-29

Johnson, A. (2001). Functions in Innovation System Approaches. In Paper for DRUID's Nelson-Winter Conference. Aalborg, Denmark.

Jong, J.P.J., Muizer, A.P. (2005). De meest innovatieve sector van Nederland, Ranglijst van 58 sectoren. EIM, Zoetermeer

Kam, C. A. de (2009).Van financiële crisis naar depressie?. Tijdschrift voor Openbare Financiën, 41 (2).

Karl, T.R., Trenberth, K.E. (2003). Modern global climate change. *Science,* vol. 302, 1719 – 1723

KPMG (2012). Kengetallen in de bouw.

KMPG (2013). De bouwsector in crisis heeft nieuwe marktkansen voor het grijpen. Retrieved December 24th 2013, from http://blog.kpmg.nl/de-bouwsector-in-crisis-heeft-nieuwe-marktkansen-voor-het-grijpen/

Kromhout, S., Wilkens, L., Keers, G. (2007). Verbeteren in plaats van slopen: Zes succesvolle voorbeelden van hoe het anders kan.

KVK (2013). Innovatief aanbesteden in de bouw. Retrieved December 26th 2013, from http://www.kvk.nl/lokale-informatie/midden-nederland/sectoren/bouwen-en-ontwerpen/innovatief-aanbesteden-in-de-bouw/

Kyoto protocol (1997). United Nations framework convention on climate change. Kyoto Protocol, Kyoto.

Lanting, R. (2010). Sustainable construction in the Netherlands. TNO, report 9.

Lente akkoord (2011). Lente-akkoord energiezuinige nieuwbouw.

List, F. (1841). *The nationol system of political economy*, http://oll.libertyfund.org/title/315

Lundvall, B. Å. (1985). 'Product innovation and user-producer interaction, industrial development', Research Series 31, Aalborg: Aalborg University Press.

Lundvall, B. Å. (1988). Innovation as an interactive process: from user-producer interaction to the national system of innovation. *Technical change and economic theory*, *369*.

Malerba, F., & Orsenigo, L. (1997). Technological regimes and sectoral patterns of innovative activities. *Industrial and corporate change*, *6*(1), 83-118.

Malerba, F. (2002). Sectoral systems of innovation and production. *Research policy, 31,* 247-264

Manne, A., & Richels, R. (1998). The Kyoto Protocol: a cost-effective strategy for meeting environmental objectives.

Markard, J., & Truffer, B. (2008). Technological innovation systems and the multi-level perspective: Towards an integrated framework. *Research policy*, *37*(4), 596-615.

McMichael, A.J., Woodruff, R.E., Hales, S. (2006). Climate change and human health: present and future risks. *The Lancet*, vol. 367, issue 9513, 859-869

Merriam Webster (2013). Diversification – Definition and more. Retrieved December 1st 2013, from http://www.merriam-webster.com/dictionary/diversification

Metcalfe, J.S. (1995). Technology systems and technology policy in an evolutionary framework. *Cambridge Journal of Economics 19*, 25-46.

Mickaityte, A., Zavadskas, E.K., Kaklauskas, A., Tupenaite, L. (2008). The concept model of sustainable refurbishment. *International journal of strategic property management*, 12, 53-68.

Milieu centraal (2013). Energiezuinige lampen op een rij. Retrieved November 13th 2013, from http://www.milieucentraal.nl/themas/energie-besparen/energiezuinig-verlichten/energiezuinige-lampen-op-een-rij

Ministerie van binnenlandse zaken (2011). Plan van aanpak energiebesparing gebouwde omgeving.

Ministerie van BZK, Ministerie van IM, NEPROM, de vereniging Nederlandse gemeenten, interprovinciaal overleg (2011). De reiswijzer gebiedsontwikkeling 2011: een praktische routebeschrijving voor marktpartijen en overheden.

Ministerie van economische zaken (2012). Nationaal hervormingsprogramma 2012 Nederland.

Musiolik, J., & Markard, J. (2011). Creating and shaping innovation systems: Formal networks in the innovation system for stationary fuel cells in Germany. *Energy Policy*, *39*(4), 1909-1922.

Musiolik, J., Markard, J., & Hekkert, M. (2012). Networks and network resources in technological innovation systems: Towards a conceptual framework for system building. *Technological Forecasting and Social Change*, *79*(6), 1032-1048.

Naess-Schmidt, H.S., Hansen, M.B., Utfall Danielsson, C. von (2011). Multiple benefits of investing in energy-efficient renovation of buildings: Impact on public finances.

NAHB (2013a). Energy and heat recovery ventilators. Retrieved November 13th 2013, from http://www.toolbase.org/TechInventory/techDetails.aspx?ContentDetailID=748

NAHB (2013b). Drainwater heat recovery. Retrieved November 13th 2013, from http://www.toolbase.org/Techinventory/TechDetails.aspx?ContentDetailID=4050

NAHB (2013c). Geothermal heat pumps. Retrieved November 13th 2013, from http://www.toolbase.org/Techinventory/TechDetails.aspx?ContentDetailID=4052

NAHB (2013d). Solar water heaters. Retrieved November 13th 2013, from http://www.toolbase.org/Techinventory/TechDetails.aspx?ContentDetailID=4059

NEF (2012). The national energy foundation – Energy advice – Condensing boilers. Retrieved November 13th 2013, from http://www.nef.org.uk/energysaving/boilers.htm

Negro, S. O. (2007). Dynamics of technological innovation systems: the case of biomass energy. *Netherlands Geographical Studies*, *356*.

Negro, S. O., Hekkert, M. P., & Smits, R. E. (2007). Explaining the failure of the Dutch innovation system for biomass digestion—a functional analysis. *Energy Policy*, *35*(2), 925-938.

Nelson, R. R. (ed.) (1993) National Systems of Innovation: A Comparative Analysis. Oxford: Oxford University Press

Netbeheer Nederland (2013). Infrastructuur. Retrieved july 30th 2013, from http://www.netbeheernederland.nl/branchegegevens/infrastructuur/

Nibud (2013). Nieuwe hypotheeknormen voor 2014. Retrieved November 12th 2013, from http://www.nibud.nl/over-het-nibud/actueel/nieuws/artikel/nibud-nieuwe-hypotheeknormen-voor-2014.html

NOS (2013). 120 miljoen voor bouwsector. Retrieved November 12th 2013, from http://nos.nl/artikel/562275-120-miljoen-voor-bouwsector.html

Oxford dictionary (2013). System: definition of system in Oxford dictionary. Retrieved November 21st 2013, from http://www.oxforddictionaries.com/definition/english/system

Patz, J. A., Campbell-Lendrum, D., Holloway, T., & Foley, J. A. (2005). Impact of regional climate change on human health. *Nature*, 438(7066), 310-317.

Pries, F., Heijgen, P. (2005) Een eeuw innovatie in de bouw. Building Business, april.

Rijksoverheid (2013a). Woningvoorraad naar bouwjaar en aantal kamers. Retrieved august 6th 2013, from http://vois.datawonen.nl/quickstep/QSReportAdvanced.aspx?report=cow13_104&geolevel=nederland&geoitem=1&period=1985,1990,1995,2000,2005,2010,2012

Rijksoverheid (2013b). Wat is het energielabel voor huishoudelijke apparatuur? Retrieved November 13th 2013, from http://www.rijksoverheid.nl/onderwerpen/energiebesparing/vraag-en-antwoord/wat-is-het-energielabel-voor-huishoudelijke-apparatuur.html

Rijksoverheid (2013c). Uitleg energielabel. Retrieved December 16th 2013, from http://www.rijksoverheid.nl/onderwerpen/energielabel-gebouwen/uitleg-energielabel

Rijksoverheid (2013d). Nieuwbouw | Woningmarkt. Retrieved December 24th 2013, from http://www.rijksoverheid.nl/onderwerpen/woningmarkt/nieuwbouw

Rijksoverheid (2013e). Retrieved December 24th 2013, from http://www.rijksoverheid.nl/documenten-en-publicaties/kamerstukken/2013/11/15/kamerbrief-over-energiebesparing-in-de-gebouwde-omgeving-en-het-energieakkoord-voor-duurzame-groei.html

Rooijers, F., Moorman, S., Dulk, F. D., & Buitenhuis, H. (2001). EPL bestaande woningbouw; systematiek. *CE, Delft*.

Saxenian, A. (1996). Regional advantage: Culture and competition in Silicon Valley and Route 128. Harvard University Press.

Schnieders, J., & Hermelink, A. (2006). CEPHEUS results: measurements and occupants' satisfaction provide evidence for Passive Houses being an option for sustainable building. *Energy Policy, 34(2),* 151-171.

Senternovem (2013). Labels woningen [aantal] Nederland. Retrieved august 7th 2013 from http://senternovem.databank.nl/quickstep/QsBasic.aspx?cat_open=energielabels

SER (2013). Gebouwde omgeving is in 2050 energieneutraal. Retrieved December 24th 2013, from http://www.ser.nl/nl/publicaties/overzicht%20ser%20bulletin/2013/themanummer/zuinige-gebouwen.aspx

Singh, J. (2005). Collaborative networks as determinants of knowledge diffusion patterns. *Management science*, *51*(5), 756-770.

Stott, P.A., Tett, S.F.B., Jones, G.S., Allen, M.R., Mitchell, G.J., Jenkins, J. (2000). External control of 20th century temperature by natura land anthropogenic forcings. *Science*, vol. 290, no. 5499, 2133-2137

Sunikka, M. (2003) Sustainable housing policies for the existing housing stock in Europe, *Open House International*, 28(1), 4–11.

Susan, S. (Ed.). (2007). *Climate change 2007-the physical science basis: Working group I contribution to the fourth assessment report of the IPCC* (Vol. 4). Cambridge University Press.

Suurs, R. (2009). Motors of Sustainable Innovation: Towards a theory on the Dynamics of Technological Innovation Systems. Utrecht University

TNO (2013). Naar een toekomstbestendig energiesysteem voor Nederland.

Tofield, B., Ingham, M. (2012). Refurbishing Europe: An EU Strategy for Energy Efficiency and Climate Action Led by Building Refurbishment. Build with CaRe, Norwich.

Trenberth, K.E. (2001). Climate variability and global warming. *Science*, new series, vol. 293(5527), pp. 48-49

United Nations (2013a). List of annex 1 parties to the convention. Retrieved july 22nd 2013, from http://unfccc.int/parties_and_observers/parties/annex_i/items/2774.php

United Nations (2013b). List of Non-annex 1 parties to the convention. Retrieved july 22nd 2013, from http://unfccc.int/parties_and_observers/parties/non_annex_i/items/2833.php

United Nations (2013c). Status of ratification of Kyoto protocol. Retrieved july 22nd 2013, from http://unfccc.int/kyoto_protocol/status_of_ratification/items/2613.php

van Alphen, K., van Sark, W. G., & Hekkert, M. P. (2007). Renewable energy technologies in the Maldives—determining the potential. *Renewable and Sustainable Energy Reviews*, *11*(8), 1650-1674.

Van Alphen, K., Van Ruijven, J., Kasa, S., Hekkert, M., & Turkenburg, W. (2009). The performance of the Norwegian carbon dioxide, capture and storage innovation system. *Energy Policy*, *37*(1), 43-55.

Van Alphen, K., Noothout, P. M., Hekkert, M. P., & Turkenburg, W. C. (2010). Evaluating the development of carbon capture and storage technologies in the United States. *Renewable and Sustainable Energy Reviews*, *14*(3), 971-986.

Verbeeck, G., Hens, H. (2005). Energy savings in retrofitted dwellings: economically viable. *Energy and Buildings 37*, 747–754.

Verdonk, M., Wetzels, W. (2012). Referentieraming energie en emissies: Actualisatie 2012. Energie en emissies in de jaren 2012, 2020 en 2030.

Vreenegoor, R. C. P., de Vries, B., & Hensen, J. L. M. (2008). Energy saving renovation, analysis of critical factors at building level. In *Proc. 5th International Conference on Urban Regeneration and Sustainability* (pp. 653-663).

Walsham, G. (1995). The emergence of interpretivism in IS research. *Information systems research*, vol 6, issue 4, 376-394

W/E-adviseurs (2010). Kiezen voor nieuwbouw of het verbeteren van het huidige kantoor.

Wieczorek, A. J., & Hekkert, M. P. (2012). Systemic instruments for systemic innovation problems: A framework for policy makers and innovation scholars. Science and Public Policy, 39(1), 74-87.

Wigley, T.M.L., Raper, S.C.B. (1987). Thermal expansion of sea water associated with global warming. *Nature, 330*, 127-131

Xella (2013). Energiezuinig bouwen en renoveren: nú doen!

Yamamoto, Y., Suzuki, A., Fuwa, Y., & Sato, T. (2008). Decision-making in electrical appliance use in the home. *Energy Policy*, *36*(5), 1679-1686.

Appendices

Appendix A

General interview

General information

- What is your name?
- What is your function within the company/organization?
- How long have you been with this company/organization?
- What is the size of this company/organization? (People/financials)
- What areas is your company/organization active in?

- How would you describe the Dutch renovation sector?
- What changes within the system would benefit you?

System functions

F1: Entrepreneurial activity

- Has the energy-efficient renovation sector seen (many) new entrants to the sector?
  - If so: what types of products/methods do they often employ, or is there are rather homogeneous distribution of products/methods?
- Do incumbent actors within the housing sector show a diversification towards energy efficiency?
- How would you describe the competitiveness within the sector?

F2: Knowledge development

- To what extent is new knowledge created within the sector?
- Would you say that R&D within this sector is an important element for growth?

F3: Knowledge diffusion

- How often are there conferences within the sector?
- How would you say the participation of actors within the sector is regarding knowledge diffusion?
  - If low: Do you see potential opportunities that would increase intra-network knowledge diffusion?

F4: Guidance of the search

- What governmental policy targets directly influence your business strategy?
- What would you say is the growth potential of energy-efficient renovation methods/products?
- What targets are set by the government?

F5: Market formation

- What institutional incentives are in place to increase energy-efficient renovation?
- How important is standardization within the sector in regard to energy-efficient renovation promotion?
- What competitive advantages are offered by the government?

F6: Resources mobilization

- What is the availability of capital (human, financial) within the sector?
- Do you think there is a need for external resources?

F7: Creation of legitimacy

- How would you say the public awareness of energy-efficient renovation is?
  - Do you see any potential to increase that?
- Do you know of any lobby groups that increase energy-efficient renovation awareness?
  - How big are they and do they have an influence on the system?

- What do you think would be best for the renovation sector to increase energy-efficient renovation?