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Analysis of Energy Transition Pathways in the Residential Sector of the Built Environment: A Sectoral Country Comparison

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DEPARTMENT OF EARTH SCIENCES
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Content

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Abstract

An energy transition is currently taking place in many European countries. Existing studies comparing countries' energy transition pathways are limited in scope and lack a strong theoretical foundation. This thesis addresses the lack of theoretical framework-based approaches by applying a sectoral analysis framework, identifying the main factors facilitating or hindering the sustainable energy transition in several countries, and the significant differences between them.

The research focused on four countries; the Netherlands, Denmark, Germany and the United Kingdom and was limited to the residential sector of the built environment. It included the three dominant housing types: social rental; private rental; and homeownership. Data was clustered along the four dimensions of the sectoral analysis framework, identifying: (1) actors, interactions & networks; (2) the institutional or legal framework; (3) the technological framework; and (4) market demand. The same process was repeated for each of the countries, forming a detailed overview about their chosen energy transition pathways. A number of interviews were conducted to gain further insight into country-specific factors.

With respect to *actors, interactions and networks*, this study has found that strong ties and cooperation between ministries and departments is an important factor facilitating policy success, with departmental fragmentation or competition posing a significant barrier. In terms of the *institutional framework* policy stability, clear targets and long-term policy framework are all factors for policy success. Conversely, frequent changes to existing policies, non-binding goals and the absence of a long-term framework are all seen as barriers for a sustainable energy transition. Looking at the *technological regime*, this study found countries with active support for renewable energy technologies have a higher share of renewable energy than countries where the choice of technologies is largely market-based. Past technological choices and existing energy-infrastructure were found to influence transition pathways and can be both a positive or negative factor. Lastly, with respect to *market demand*, the existence of a standardised housing stock was found to be a potentially significant factor for the upscaling of innovative initiatives. The existence of a large and fragmented (private) rental sector and high interest rates on financing products were found to be further barriers for the energy transition in the residential sector.

This thesis has identified obstacles matching those in previous studies and introduced a number of factors facilitating policy success. It has made a first step in overcoming the lack in theoretical framework-based approaches in energy transition analysis future studies can build on.

Keywords: Sustainable Development, social sciences, energy transition, residential sector, built environment

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Summary
In recent years, environmental issues have increasingly come to the forefront in policy-making, with the global community committing itself to preventing dangerous climate change. One of the key components of climate change action is reducing global energy demand, which has increased greatly over the past century. With energy-use in buildings accounting for around forty per cent of final energy consumption in the European Union, policy-makers in many countries have recognised the potential for energy-savings in this sector. Many governments have now formulated policies to accomplish an energy transition, introducing policies to increase energy efficiency and promote renewable energy technologies. Previous studies into the energy transition pathways of different countries have often been limited in scope, focusing on a relatively small number of issues and are conducted on an ad-hoc basis, without a strong foundation in theory. This thesis attempts to fill some of the gap in theoretical research by using a sectoral analysis framework. The objective of the study is to compare and contrast the energy transition pathways in the residential areas of a number of European countries and to identify the important factors underlying policy success or failure.

This thesis used a sectoral analysis framework to examine the energy transition pathways in the Netherlands, Denmark, Germany and the United Kingdom. These countries are all subject to the same environmental regulations of the EU and have comparable climatic conditions. The analysis was limited to the residential sector of the built environment and included the three dominant housing types: social rental; private rental; and homeownership. The study made use of a wide range of qualitative and qualitative data and interviews were conducted to gain a better understanding of country-specific factors. The information collected was clustered using the four dimensions of the sectoral analysis framework, identifying: (1) actors, interactions & networks; (2) the institutional or legal framework; (3) the technological framework; and (4) market demand. By repeating the in-depth analysis of the four dimensions for each of the countries, a detailed understanding was formed about the chosen energy transition pathways, allowing a comparison between them to be made.

When put together, the country profiles paint a picture of the energy transition pathways followed by the four countries, highlighting the key differences in their trajectories and policy instruments used. The discussion explains the differences between countries for all four dimensions at the hand of a number of key parameters. In terms of *actors, interactions and networks*, the study focused on the parameter 'cooperation vs fragmentation' and found that strong ties and cooperation between ministries and departments is an important factor facilitating policy success, with departmental fragmentation or competition posing a significant barrier. In terms of the *institutional framework*, the parameters were 'soft power vs hard targets' and 'policy stability'. Results indicate policy stability, clear targets and long-term policy framework are all factors for policy success. On the contrary, frequent changes to existing policies, non-binding goals and the absence of a long-term framework are all seen as a barrier for a sustainable energy transition. Looking at the *technological regime*, the parameters set were ‘technological preferences’ and ‘path dependency’. This study found that those countries with active support for renewable energy technologies had a higher share of renewable energy than countries where the choice of technologies was largely market-based. Past technological choices and existing energy-infrastructure were found to influence transition pathways and can be both a positive or negative factor. Lastly, with respect to *market demand*, the parameters focused on ‘potential for large-scale renovation’, ‘fragmentation of the housing market’ and ‘access to financial means’. Findings indicated that the existence of a standardised housing stock can be a significant factor for the upscaling of innovative initiatives. The existence of a large and fragmented (private) rental sector and high interest rates on financing products were found to be further barriers for the energy transition in the residential sector.

The obstacles listed in this research match those identified in previous studies. In addition, it has introduced a number of factors that may contribute towards policy success. It has found that policies and technologies favoured by national governments are very different and often depend on national contexts. While it may not be possible to copy successful policies directly from other countries, policy-makers can learn from experiences in other countries. This thesis has made a first step in trying to overcome the lack of theoretical framework-based approaches to energy transition analysis. Future studies could build on the findings of this report.

Keywords: Sustainable Development, social sciences, energy transition, residential sector, built environment

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List of Abbreviations

BMUB	Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (Germany)
BMWi	Federal Ministry for Economic Affairs and Energy (Germany)
BPIE	Buildings Performance Institute Europe
BZK	Ministry of Interior and Kingdom Relations (Netherlands)
CBS	Statistics Netherlands
CCS	Carbon Capture and Storage
CHP	Combined Heat and Power
CIEP	Clingendael International Energy Programme
CMA	Competition and Markets Authority (United Kingdom)
CPB	Bureau for Economic Policy Analysis (Netherlands)
DCLG	Department for Communities and Local Government (United Kingdom)
DECC	Department of Energy & Climate Change (United Kingdom)
Defra	Department for the Environment, Food and Rural Affairs (United Kingdom)
DERA	Danish Energy Regulatory Authority
DTI	Department of Trade and Industry (United Kingdom)
ECN	Energy Research Centre of the Netherlands
ECO	Energy Companies Obligation (United Kingdom)
EEG	Renewable Energy Act (Germany)
EnEV	Energy Saving Ordinance (Germany)
ENS	Danish Energy Agency
EPC	Energy Performance Certificate
EU	European Union
EZ	Ministry of Economic Affairs (Netherlands)
FiT	Feed-In Tariff
GDHIF	Green Deal Home Improvement Fund (United Kingdom)
GW	Gigawatt
IEA	International Energy Agency
IenM	Ministry for Infrastructure and Environment (Netherlands)
IS	Innovation System
Kebmin	Ministry of Climate, Energy and Building (Denmark)
KfW	German Development Bank
kWh	Kilowatt-hour
MEP	Environmental Quality of Electricity Production (Netherlands)
$MtCO_2$	Metric tons of carbon dioxide
Mtoe	Million tonnes of oil equivalent
MW	Megawatt
NEEAP	National Energy Efficiency Action Plan
Ofgem	Office of Gas and Electricity Markets (United Kingdom)
PBL	Environmental Assessment Agency (Netherlands)
PJ	Peta-Joule
PV	Photovoltaics
RE	Renewable Energy
REB	Regulating Energy Tax (Netherlands)
RVO	Netherlands Enterprise Agency (Netherlands)
SER	Social and Economic Council (Netherlands)
TPES	Total Primary Energy Supply
VAT	Value Addded Tax

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1. Introduction

In recent years, environmental issues have increasingly come to the forefront in policy-making, both on the national and international level. These issues include a wide range of challenges, from rising sea levels to biodiversity loss and extreme weather events. Over the last two decades, efforts to fight climate change have taken flight and the international community has committed to reducing greenhouse gas emissions by 2020. One of the key components of climate change action is reducing global energy demand. Global energy use has greatly increased over the last century, largely driven by a rising population, industrialisation and economic growth. With large amounts of greenhouse gas emissions resulting from the production and consumption of energy, energy policy plays a crucial role in achieving the formulated ambitions.

In March 2007, the European Union (EU) launched the “2020 Climate and Energy Package, which was adopted in its final form in 2008 and introduced what has now become known as the 20-20-20-targets: by 2020, to reduce greenhouse gas emissions by 20 per cent, increase energy efficiency by 20 per cent, and to reach a 20 per cent share of renewables in total energy consumption in the EU (**Council of the European Union, 2008**). In its Roadmap for moving to a competitive low economy in 2050, the EU furthermore agreed to reduce its domestic emissions by 80 per cent by 2050 compared to 1990 (**European Commission, 2011**). National governments, too, have sought to address environmental issues. The British government, for example, adopted a Climate Change Act in late 2008, setting the world’s first legally binding climate change target, establishing a carbon budget for 2050 that is at least 80 per cent lower than the 1990 baseline (**Crown, 2008**). The energy policies of EU Member States today are often guided by three core objectives; (1) sustainability, (2) affordability, and (3) reliability, or security-of-supply (**European Commission, 2006**), with safety sometimes being added as a fourth objective (**DECC, 2011a**).

With around forty per cent of final energy consumption, buildings in the EU are accountable for a large share of total energy use, and thirty-six percent of greenhouse gas emissions originates from houses, offices, shops and other buildings such as schools and hospitals (**European Commission, 2013**). This energy use is associated with the so-called building envelope, including building components such as walls and roofs and the energy used for heating and cooling of the building, and the “internal load”, the energy used for e.g. lighting and appliances. In 2013, the residential sector alone accounted for 26.8 per cent of final energy consumption, second only after transport (31.6%), as illustrated in Figure 1. With the continuing expansion of the built environment and ownership of energy-consuming (e.g. ‘smart’) products, building emissions will almost certainly continue to grow (**IEA, 2010**). Given the significant share of energy consumption of this sector, now and in the future, considerable potential exists for energy savings and/or a reduction in greenhouse gas emissions.

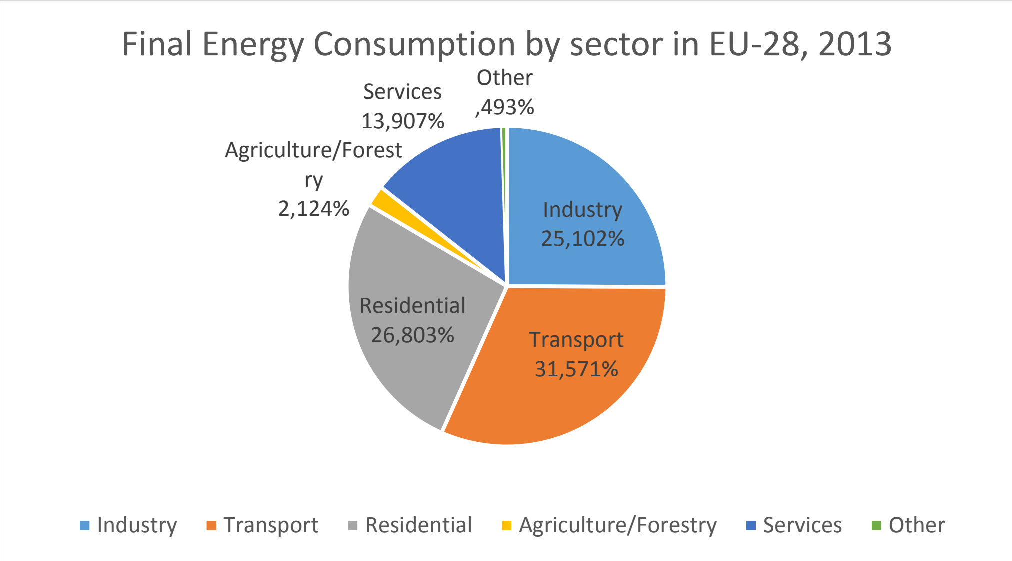

Fig. 1: Final Energy Consumption by Sector in EU-28, 2013 (Source: Eurostat, 2015)

Members of the European Union have recognised this potential and recently introduced new rules on building- and product requirements. The 'Energy Performance of Buildings Directive[1], for example, requires all new buildings to be nearly zero-energy by the end of 2020 and introduced a mandatory energy performance certificate for all buildings within the EU. Given the long lifetime of buildings, however, changes in the building stock generally proceed only slowly. The future building stock will thus largely consist of buildings that are here today. Yet a large share of existing buildings was constructed prior to the introduction of formal energy performance requirements (**BPIE, 2014**). The energy performance of these buildings is far below those constructed to today's standards. The low retirement rate of residential buildings is seen as a significant constraint, particularly in reducing heating and cooling demands (**IEA, 2010**). Tuominen et al. **(2012)** estimated the housing sector offers an energy-saving potential of around 27 per cent by 2020. The EUs Energy Efficiency Directive[2] recognises the energy saving potential of existing buildings and requires EU countries to draw-up long-term national building renovation strategies.

A wide range of technologies that can reduce CO_2 emissions in both new and existing buildings are already available, at or near the stage where they are economically viable (**IEA, 2010; Faber & Hoppe, 2013**). This includes insulation measures, renewable energy technologies such as solar-PV and biomass boilers and other energy saving technologies such as combined heat and power (CHP) and heat recovery ventilation.

1.1 Problem definition

Despite receiving increased attention and policy support in recent years, the prevailing renovation rate is estimated to be around 1 per cent (**BPIE, 2011**), insufficient to reach the full potential of improvements before the end of the century (**BPIE, 2014**). Furthermore, previous studies have identified important obstacles preventing the adoption of sustainable energy technologies, causing the adoption levels of these technologies to remain low despite strong policy support in their favour. They include: frequent changes to the regulatory framework (**Tuominen et al., 2012; Negro et al, 2012**), conservatism of the housing sector (**Kieft et al., 2013**), the dominance of established actors and technologies (**Negro**

[1] Directive 2010/31/EU, OJ (2010) L153/13.
[2] Directive 2012/27/EU, OJ (2012) L 315/1

et al, 2012), difficulty for households to obtaining the necessary loans or mortgages (**Faber & Hoppe, 2013**) and the so-called split incentive, where landlords have no incentive to invest in energy efficiency measures from which tenants enjoy the benefit (**ibid**). Significant differences between countries can be observed, whether in the size and structure of its housing market, institutional characteristics, or technological preferences. Little research has been done, however, into the chosen energy transitions pathways of different countries, or how they compare to one another. While a number of studies comparing energy policy experiences or the building sector in different countries exist (e.g. **CIEP, 2013; Ecofys, 2012; Kieft et al., 2013**), they are often limited in their scope and ambition and lack a strong theoretical foundation.

1.2 Research question

The situation described above leads to three important questions. First, what are the factors behind policy-success and -failure for the sustainable energy transition in the residential sector of the built environment in each of the countries included in this study? Second, what significant differences can be observed between the different countries? Thirdly, how can one account for these differences, and what lessons can be learned from them?

1.3 Research objective

The objective of the study is to compare and contrast the energy transition pathways in the residential areas of a number of European countries. By doing so, the study aims to contribute to a better understanding of the important factors underlying policy success or failure. While the study does not make recommendations on what would be the preferred course of action for the various actors involved, a number of important lessons are drawn from the findings of this research.

Furthermore, this study contributes to existing work in this field in that it – for the first time – seeks to apply a comparative method, using a theoretical framework-based approach to make an extensive and in-depth country comparison. Moreover, the strong theoretical and systematic structure of the case study allows going beyond the cases, enabling a number of hypotheses on the connections between energy transition pathways and “policy success” for further study to be formulated on their basis.

1.4 Thesis outline

The next section briefly outlines the scope and delineations of the study presented in this thesis and explains the chosen research method in greater detail. The research process and consecutive analysis are based on the ‘sectoral analysis framework’, originally developed by Malerba (**2002**) and later used by Faber & Hoppe (**2013**). With the delineations of innovation systems determined by the analytical purpose and chosen research question of each study, this thesis has adapted the framework to better suit the purposes of the research. This theoretical framework will be discussed further in the third section of this thesis. Sections four to seven present detailed country profiles for each of the four countries included in the study, constructed through exhaustive collection and interpretation of primary and secondary data. The profiles are structured along the four dimensions identified by the sectoral analysis framework; actors, interaction & networks; the institutional framework; technological framework; and market demand. Section eight subsequently offers an in-depth analysis of some of the key parameters, evident in the country profiles and influencing the various energy transition pathways followed. The final section (section 9) offers some concluding remarks and suggestions for further analysis.

2. Methods

2.1 Selection of countries

This study has selected the Netherlands, Denmark, Germany and the United Kingdom for closer analysis. As members of the European Union, all four countries are subject to the same European environmental regulation and they have comparable climatic conditions. Part of the study presented in this thesis was performed at the Scientific Council for Government Policy in the Netherlands. For this reason, the Netherlands has been considered as the baseline country for the analysis presented in this paper. Denmark was included for its high levels of policy ambition, large share of wind in the energy mix, and relatively high standard of the housing stock. Germany was included for its high ambition, large number of energy cooperatives, relatively old housing stock and large private housing market. Lastly, the United Kingdom was included for its highly centralised power production, high levels of homeownership, and a relatively aged housing stock compared to the other three. In the case of the UK, it was important to make a distinction between the central government and its four constituent parts: England, Wales, Scotland and Northern Ireland. While most matters are in the hands of the UK government, others – such as building regulations – are devolved to the national governments. Where required, this thesis will make a clear distinction between the UK and its members. Together, the similarities and differences allow for an interesting comparison to be made between the selected countries.

2.2 Boundaries of the study

Firstly, the analysis was limited to the residential sector of the built environment, thereby excluding offices and utilities. As the non-residential sector is highly heterogeneous, for example in terms of usage pattern, energy intensity and

construction techniques (**BPIE, 2011**), it does not easily lend itself to general comparisons. Secondly, when discussing energy efficiency, the focus was on the building itself, rather than on appliances and transport as the use of these may vary strongly between households. Thirdly, the study considered three housing types: social rental, private rental and homeownership. Together, these are the most common housing types. Other forms of housing (e.g. communes), making up a negligible share of residents, are therefore excluded from the study. Fourthly and finally, energy improvements in the housing stock consist of two separate elements: lowering the energy use on the one hand, and the use of sustainable technologies on the other. The study therefore focused on these two aspects.

2.3 Data collection

The early exploratory phase of the project focused on mapping the various environmental- and energy policies of a large number of European countries. The aim was to get a broad overview of the current state and ambition of the energy transition across Europe. Important data sources during this stage included (national) reports, press releases and newspaper archives. Once the final four countries had been selected, the focus shifted to the large scale collection of secondary data for each of the countries included. The study was largely based on qualitative data, in particular official policy documents, national legislation and independent reports. Quantitative data, primarily in the form of statistics from national statistics offices, was collected to complement quantitative data.

Throughout the research process, a number of discussions took place with individuals and organisations with relevant expertise in one or more of the countries or subject matters, both in the Netherlands and abroad. The knowledge and experience shared in these meetings often served to clarify the author's understanding of the literature or country-specific factors. The results of these meetings have not been used directly in this report. A list of organisations interviewed is included in Appendix 1.

2.4 Framework for analysis

In order to be able to compare and describe the transition processes in the four countries studied, the collected information was clustered using a 'sectoral analysis framework' discussed in more detail in section three. This framework distinguishes four important dimensions: (1) actors, interaction and networks; (2) the institutional or legal framework; (3) the technological framework; and (4) market demand. A sectoral analysis using the four dimensions was subsequently carried out for each country, providing the reader with an in-depth understanding of the different energy transition pathways followed and its various constitutive elements. All four dimensions demonstrated certain distinguishing characteristics and significant differences. Section eight will offer a detailed discussion of the following key parameters.

2.4.1 Actors, Interaction and Networks

Significant differences in institutional set-up and interaction between actors tasked with the energy transition can be observed across the four countries. The first section of the discussion highlights one key parameter in particular, i.e. 'cooperation vs fragmentation'. While some countries display strong signs of cooperation, or even integration between actors, institutional-, other countries are characterised by strong departmental- and sectoral fragmentation. This part of the analysis thus aims to uncover a number of potential institutional factors behind policy success and/or failure.

2.4.2 Institutional Framework

Another important difference can be observed with respect to the policy instruments favoured by governments of the selected countries. The second section discusses two parameters in more detail. Firstly, it will take a closer look at the preference for 'soft power' vs 'hard targets'. While some countries have laid out specifically the means through which they intend to reach the targets proposed, others choose to focus on the end, rather than the means through which they are to be achieved. A critical question at this point is whether the difference is likely to significantly affect policy-success.

The second parameter of the regulatory section is that of 'policy stability'. While some countries appear to have a consistent and stable long-term policy framework, other countries have experienced more frequent policy changes. While changes may be necessary to ensure the (cost-) effectiveness of chosen policies, policy instability may also result in a loss of confidence by investors or citizens. This part of the discussion thus focuses on the effects of policy stability (or instability) observed in the four countries.

2.4.3 Technological Regime

In terms of the technological framework, the discussion provided in this thesis again focuses on two core parameters. Firstly, this particular section examines differences in terms of technological preferences. While some countries predominantly focus on existing technologies, others place a strong emphasis on innovation. In doing so, this part attempts to uncover the rationale behind the technological focus adopted by the four countries and offer some insights into their effectiveness.

Technological preferences expressed by the various countries can be based, at least in part on 'path dependency', where technological choices made today are dictated by historical developments, technical compatibility and existing industrial networks (**Åhman & Nilsson, 2008**). The second parameter thus focuses on this path dependency, determining to what extent the policies of the countries included in the study are based on existing infrastructure and industry.

2.4.4 Market Demand

The final section of the discussion focuses on a number of key parameters for the housing sector. The first parameter takes a closer look at the housing stock itself, determining the potential for large-scale renovation of existing buildings in the four countries. As the four countries differ fundamentally in the composition of their existing housing stock and regulation of the housing market, this potential may similarly differ from country to country.

Secondly, the discussion focuses on the fragmentation of the different national housing markets, specifically taking into account important elements arising from 'ownership vs. renting' and 'the private rental sector vs. social housing'. It is important to examine in what way these forms of ownership influence the shape and pace of the energy transition in each of the four countries.

As a final parameter, a closer look is taken at the 'access to financial means' available to households. This includes both the financial position of households and support mechanisms offered through government policies.

3. Theoretical Framework

This thesis focuses specifically on the residential sector of the built environment. This sector, however, is by no means homogeneous and includes a wide range of actors (e.g. governments, landlords, tenants, and homeowners), types of ownership, and extensive legislation. Without any form of analytical framework including these various constitutive elements, it is difficult, if not impossible, to form a comprehensive understanding of the housing sector. To this end, a number of previous studies, many of which have focused on innovation, have adopted a sectoral systems approach to identify the specifics of their respective sectors. Some of these will briefly be mentioned below.

The study presented in this thesis aimed to build on these existing studies by adapting the sectoral innovation approach developed used by Faber & Hoppe (2013), stripping it down to a more descriptive framework better suited for the purposes of the research undertaken in this thesis. In doing so, the sectoral analysis concept served as an important means to structure the search and collection of information, forming the foundation for the subsequent country profiles presented in sections 4-7.

3.1 Innovation system approach

The innovation system (IS) approach was originally developed in the nineties in order to analyse relations between producers, users, governments and institutions surrounding system innovations (**Lundvall, 1992; Edquist, 2005**). It directly challenged the dominant neo-classical paradigm prevalent at the time, which highlighted market-failure as the main factor stifling innovation, instead focusing on other system failures (**Negro et. al., 2012; Faber & Hoppe, 2013**). These factors may include matters such as knowledge basis, limited interaction between the parties involved, technological opportunities, and demand conditions (**Oltra & Saint Jean, 2009**) and are sometimes referred to as the "social fabric" that shapes these developments and within which they are rooted (**Archibugi et al., 1998**).

Four main IS-approaches have been identified (1) national systems of innovation, (2) regional systems of innovation, (3) sectoral- and (4) technological systems of innovation (**Edquist, 2005; Schrempf et al., 2013**). Where national and regional systems of innovation approach use geographical delineations to define their system boundaries through a spatial dimension, the sectoral and technological innovation approach focus on a certain sector of the economy (including various technologies) or a certain technology spanning multiple sectors (**ibid, p.4**). As this thesis focuses specifically on the residential sector of the built environment, a sectoral innovation system approach was considered most suitable in this case.

3.2 Sectoral system of innovation

The concept of sectoral innovation systems was developed mainly by Malerba. A sectoral system of innovations is defined as "*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 sales of those products*" (**Malerba, 2002**). Sectors are defined as "*a set of activities which are unified by some related product groups for a given or emerging demand and which share some basic knowledge*" (**ibid, 2005, p.65**). Considering studies using a traditional 'market structure and innovation' approach as being insufficiently dynamic and one-dimensional, Malerba instead argues sectors undergo important transformations over time and that sectoral systems are thus "a collective emergent outcome of the interaction and co-evolution of its various elements over time" (**2002, p.251**). As the various elements of the system influence each other, the system is turned into a dynamic, rather than static, whole (**Kieft et al, 2013**).

One of the advantages of adopting a sectoral systems view, according to Malerba, is that it allows "*a better understanding of: the structure and boundaries of a sector; the agents and their interactions; the learning, innovation and production processes; the transformation of sectors and the factors at the base of the differential performance of firms and countries in a sector*" (**2002, p.248**). In this theory, sectoral systems are based on three building blocks: (1) knowledge and technologies, (2) actors and networks, and (3) institutions (**Malerba, 2005; Schrempf et al., 2013**). While demand is not referred to as a key building block by Malerba, other scholars specifically include this fourth element (e.g. **Faber & Hoppe, 2013**).

A number of previous studies have used a sectoral innovation approach to describe technological change (**Hekkert et al, 2007**), the diffusion of renewable energy technologies (**Negro et al, 2012**), the development of low-emission vehicles in the French automotive industry (**Oltra & Saint Jean, 2009**), the energy transition of the Dutch housing sector (**Hoppe & Faber, 2011**), or energy efficiency improvements in the built environment (**Faber & Hoppe, 2013**). While the first two studies provide a clear theoretical framework and literature reviews, the latter three aim to specifically apply this sectoral innovation system approach in practice. None of these studies, however, have thus far attempted to make a cross-country comparison of (the energy transition in) the built environment.

3.3 Four dimensions of sectoral innovation systems

Although each of these studies offer a somewhat adapted version of the same system of innovation, **Hoppe & Faber (2011)** have perhaps created the most practical framework to use when attempting to analyse sectoral patterns. Used to identify and assess systemic barriers preventing energy efficiency improvements in the Dutch housing sector, their sectoral innovation system distinguishes four dimensions: (1) Actors, interactions and networks; (2) the institutional dimension; (3) the technological regime and; (4) market demand (ibid, p.21). Their aggregation of the four dimensions is reflected in Fig.1.

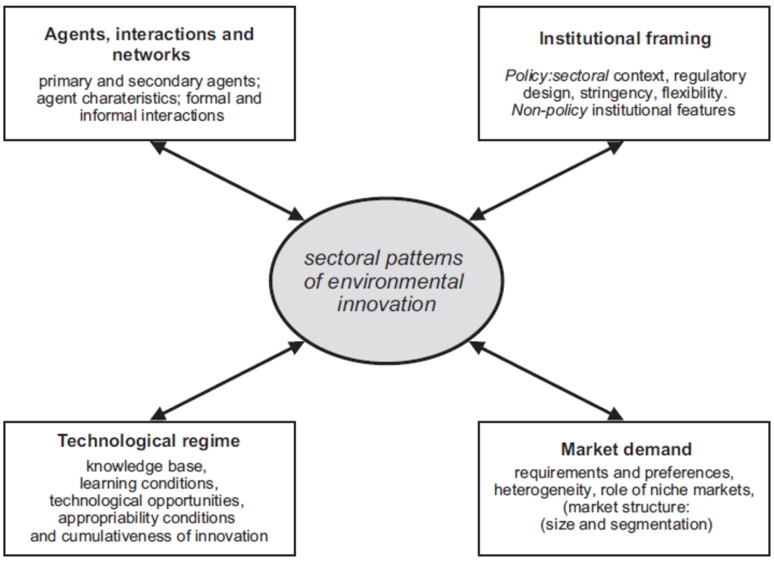

Fig.2: Dimensions of Sectoral Patterns of Environmental Innovation and their interaction (Source: Faber & Hoppe, 2013).

Agents, interactions and networks describes the main actors in sectoral innovations and the interactions between them, forming the sectoral structure. Agents include primary actors – the main actors performing core innovative activities, experiments and capacity building – and secondary actors, accounting for supporting measures. (**Faber & Hoppe, 2013**). These interact through various processes, such as communication, exchange, cooperation, competition and command (**Malerba, 2004**).

The *institutional framework* includes both policy- and non-policy aspects. Formal rules can include specific laws and regulations. National institutions can include i.e. the patent system, property rights or antitrust regulations (**Malerba, 2005**), but can also be specific to one particular sector. Non-formal rules include elements such as norms and values, routines, established practices and common habits (**Malerba, 2005**; **Faber & Hoppe, 2013**). As these unwritten rules are often not directly visible to agents other than those concerned, non-formal rules can sometimes be difficult to identify from those 'outside' the circle yet prohibit successful innovations in an established market by newcomers.

The *technological regime* is concerned with the specific knowledge base, technological opportunities and inputs (**Malerba, 2005**), and particularly with the dynamic relationships between them. A better understanding of this knowledge base and the learning processes behind innovations can shed new light on the sources of innovation and the direction of the resulting technological developments (**Oltra and Saint Jean, 2009**). The technological regime is considered a major source of transformation and growth, and "may set in motion virtuous cycles of innovation and change" (**Malerba, 2005, p.66**). Large investments in one technology, for example, may render investments in another economically unviable. Four factors in particular define a technological regime (**Malerba & Orsenigo, 1997; Faber & Hoppe, 2013**):

(1) The knowledge base, referring to the nature of the knowledge (generic vs. specific, complex vs. simple, tacit vs codified) and the means of knowledge dissemination and communication;
(2) The technological opportunity conditions;
(3) The appropriation of innovations, referring to the possibilities of protecting innovations from imitation or copying (patents) and of making profits; and
(4) The cumulativeness of innovations, including the learning processes, determining how future innovations are likely to build upon current ones.

Finally, *demand* focuses on differences in the preferences of consumers and producers (**Malerba, 2005**; **Malerba et al., 2007**; **Oltra & Saint Jean, 2009**), stemming from factors such as asymmetry in information or skills, constraints in opportunity, or heterogeneous intrinsic motivations (**Faber & Hoppe, 2013**). When strong enough, consumer preferences cannot only survive, they can create important niche-markets or even displace the established technologies and radically change the market. Such (niche)-markets could stabilise by users themselves or through active support by governments.

3.4 Adapted framework for international comparison

The framework presented in the previous section was developed mainly to examine innovative activities. While innovation is certainly one important element of the energy transition in the residential sector, it is not the focal point of the study. The concept and its four constituting dimensions nevertheless offer a useful point of departure for the analysis undertaken in this thesis. The model of Faber & Hoppe, if stripped down to a more descriptive framework, allows for the examination of the four elements in detail for each of the countries examined, providing useful structure for the research process. The uniformity of the research method and consistent repetition for each country subsequently allows for a more reliable comparison to be made in the final section of this paper. The four adjusted dimensions are as follows;

Agents, interactions and networks aims at identifying the most important actors related to the energy transition. These include the relevant ministries, (non-) governmental organisations and a wide range of private companies such as landlords, industry, energy companies, and financial institutions. By mapping the various agents for all countries, some of the differences in the institutional set-up between these countries will become apparent. Although the study has aimed to identify the most important agents, it does not attempt to cover all of them. The division between primary- and secondary agents and the models of interaction between them is of lesser importance than their initial identification.

The formal aspect of the *regulatory framework* in this paper is limited explicitly to the sector-specific government regulation related to the energy transition in the built environment, most specifically with respect to energy efficiency and renewable energy technologies. Any other formal relationship or institution is specifically excluded from this analysis. The non-policy aspect covers some of the major institutional features that, although they may not be immediately evident from formal policy outcomes, may serve as important indicators for an actor's overall motivation or decision. These may include issues such as dominant country-specific values, routines, and practices. No attempt has been made to provide an in-depth analysis of all the agents involved, as this would be beyond the scope of this project.

Whereas the *technological regime* commonly describes the *dynamic* links between its constituent elements, this thesis offers a static overview of the technological regimes in the four countries. As such, this section offers the most 'dressed-down' application of the IS-model, simply providing an overview of the general technological environment. A basic description of the current energy-system, technological focus, strategies and preferences allows the reader to sketch a picture of the current technological environments of all four countries discussed. From this, it becomes apparent that the current technological regimes and outlook for future developments are different in all four countries. This paper does not concentrate on the learning processes, nature of knowledge or the easiness with which firms are able to innovate.

Finally, while *demand* usually focuses on individual consumers, firms, agencies, and social factors, each with their own characteristics, this paper largely focuses on aggregate demand through a description of the structure of the housing- and property market. This includes the size, segmentation and quality of the existing housing stock, demographics and economic factors. While individual preferences and niche-markets are recognised as important elements of this dimension, they are not discussed at length.

4. Sectoral Analysis the Netherlands

Today, the Netherlands is considered one of the most fossil fuel- and CO_2-intensive economies among IEA member countries with (**IEA, 2014**). Due to the relatively energy-intense industry, including (petro)-chemical industry, iron- and steel industry and agriculture, fossil fuels currently account for more than 90 per cent of the energy mix. The country predominantly relies on its natural gas deposits to meet domestic energy needs and has formulated the ambition to become Northwest-Europe's gas-hub.

With respect to the built environment, the residential sector in 2012 accounted for 16.9 per cent of total final energy consumption and 10.2 per cent of greenhouse gas emissions (**ibid**). Initially fuelled by concerns over security-of-supply, and later by concerns over the environment and climate change, energy efficiency has played an important role in Dutch energy policy since the 1970s, resulting in significant improvements in the (thermal) quality of the Dutch housing stock. Dutch renewable energy policy has rapidly developed since the Third White Paper on Energy in 1995. However, the country currently lags behind its renewable energy targets, and frequent changes to the regulatory framework appear to do little to inspire confidence amongst investors and citizens. While initially considered as one of the frontrunners in international efforts against climate change, the Netherlands appears to have lost its initial advantage.

In 2013, an energy agreement was concluded between over forty representative organisations, including governments, business and scientists and is currently the main policy-instrument to boost sustainability in the Netherlands. The Agreement aims to achieve 1.5 per cent annual energy savings, a total of 100PJ by 2020 and has a strong focus on innovation (**SER, 2013**). A number of programmes and initiatives have been developed to encourage energy-renovations in the Dutch housing stock.

4.1 Actors, Interactions & Networks

The Netherlands have a constitutional monarchy and bicameral legislature. The country has a long tradition of multi-party, or coalition, governments. For legislation to pass in both chambers, a simple majority of the number of votes is required. The current minority-Government is made up of the liberal party (VVD) and Labour Party (PvdA) and relies on the support of three opposition parties to pass its legislation through both chambers.

Responsibility for the energy transition in the built environment is divided between several ministries. Firstly, responsibility for overall energy policy and innovation lies with the Ministry of Economic Affairs [*Economische Zaken, or EZ*]. Responsibility for climate, the environment, spatial planning, and water lies with the Ministry for Infrastructure and Environment [*Infrastructuur en Milieu, or IenM*]. Thirdly, the Ministry of Interior and Kingdom Relations [*Binnenlandse Zaken en Koninkrijksrelaties, or BZK*] is responsible for housing and energy efficiency in the residential sector. The Ministry of Finance, finally, is tasked with the overall budget, financial policy, and taxation, thus fulfilling an overarching role. These ministries rely on a number of agencies for support, which include the Netherlands Enterprise agency (RVO), the Bureau for Economic Policy Analysis (CPB), and the Dutch environmental Assessment Agency (PBL).[3]

[33] RVO provides support to entrepreneurs involved in sustainable, innovative and international businesses. CPB conducts independent research and focuses on climate change, energy security and regulation of the energy market. PBL is tasked with the examination and evaluation of environmental policies, future trends, social issues, and the identification of strategic options. PBL

The Social and Economic Council of the Netherlands [*Sociaal-Economische Raad*, or *SER*] is one of the main advisory bodies to the Dutch government, giving advice on (inter)national social and economic policies. The SER consists of three groups, each with 11 members and they are; employers' representatives, union representatives and so-called crown members or independent experts. The SER played a facilitating role in the Energy Agreement of 2013 and is currently responsible for monitoring process towards achieving the goals set out by all parties to this Agreement.

Another knowledge- and network organisation is 'Platform31' – created as the result of a merger of a number of previous organisations. Platform31 has its own research programme and supports a range of innovative experiments in the built environment. It operates a number of programmes, including *Energiesprong*, an innovation-programme for the residential sector and commissioned by the Dutch ministry BZK, that aims to increase both supply and demand for energy-neutral buildings, incl. residences, offices, schools and healthcare providers. The organisation depends largely on subsidies from the government and contributions of partner organisations (incl. municipalities).

The Dutch construction sector is highly fragmented, with nearly 100,000 companies in 2008 (**Santema et al., 2010**). While the construction market consists of a large number of small companies – 80 per cent of all companies in the industry only consist of one or two people – almost a third of market share is attributed to the ten largest construction companies (**ibid**) which compete for the large contracts. In most cases, the clients commissioning new housing in large numbers are project developers and housing corporations (**Hoppe & Faber, 2011**).

A large number of energy companies buy energy from the grid and supplies it to the final customer. The gas-network is operated in a similar fashion. Currently, there are forty-nine companies with a permit to supply electricity in the Netherlands, and forty-nine companies with a permit in the gas-market – often, but not always the same companies as in the electricity-market. The Authority for Consumers and Markets (ACM) is tasked with ensuring competition and safeguarding consumer protection.

The Netherlands have a large social housing sector, with a large number of social housing corporations representing around 33 per cent of total housing stock in 2012 (**Vandevyvere & Zenthöfer, 2012**). While originally strongly regulated by the Dutch government, after years of deregulation in the 1990s, housing corporations are now financially independent privatised companies (**ibid**). The private rental sector is small in comparison to other countries. A number of social housing sector reforms have been put forward recently, including proposals that will move some social renters into the private sector, and proposals to stimulate the setting-up of housing co-operations.

4.2 Institutional Framework

While energy has been an important policy issue in the Netherlands during the post-second world-war period, it was not until the oil-crisis in the 1970s that the Dutch government formulated its first integral energy policy, the White Paper on Energy or *Energienota*, in the spring of 1974 (**de Jong, 2005**). Increased energy efficiency and the diversification of energy sources became key concerns of Dutch energy policy at this time. An in-depth investigation of Dutch energy policy since 1974 is well beyond the scope of this paper and would replicate already existing work in many ways. Interesting books by authors such as Noud Köper (**2008; 2012**) and organisations like the Clingendael International Energy Programme (**de Jong,**

often works in cooperation with the Energy Research Centre of the Netherlands (ECN), a large Dutch energy-research institute.

2005) offer a comprehensive analysis of this topic, often supplemented by insights of some of the important individuals personally involved in these processes at the time. It is difficult, however, to fully grasp the energy market of today without some overview of historic developments. The two tables in Annex II list the most important 'energy efficiency' and 'sustainable energy' policies for the residential sector since that first White Paper. Focusing on today's state of affairs, this section will discusses in more detail the current energy-efficiency and renewable energy policies.

4.2.1. Energy efficiency

As demonstrated in Table 1 of Annex II, energy efficiency targets have been different in their formulation and their level of ambition over the last four decades. Overall, however, they characterise the importance attached to energy efficiency by consecutive Dutch governments throughout most of this period. The gradual introduction of stricter insulation standards and building performance requirements on the one hand, has aimed to ensure that new buildings are constructed to a high energetic standard. Information campaigns, subsidy schemes and the introduction of energy labels and performance requirements for various electrical appliances on the other, have aimed to also improve the energy performance of existing dwellings.

Energy efficiency targets

Throughout the 2000s, the energy efficiency target has regularly been revised to factor in changes in government priorities and economic growth scenarios. Where the energy report of 2002 stipulated that energy-efficiency should improve by 1.3 per cent per annum, or as much as required to meet the CO_2-target required under the Kyoto protocol, the programme *´Schoon en Zuinig´* [Clean and Efficient] of 2007 saw ambitions increased to 2 per cent per year over the 2011-2020 period. The Coalition Agreements of 2010 and 2012 make no mention of a national target, only stating existing policies should be continued and intensified (**Regeerakkoord 2010; Regeerakkoord 2012**). As part of the EU's 2020 Climate and Energy Package and Energy Efficiency Directive 2012/27/EU, however, the Netherlands has an indicative national energy efficiency target of 1.5 per cent. The Energy Agreement for Sustainable Growth concluded in 2013 included that same target.

Energy efficiency programmes

A range of programmes have been initiated in recent years. In 2008, a joint initiative between construction-, installation- and energy companies resulted in the voluntary agreement *'Meer met Minder'* [More with Less], together with the Ministries of Economic Affairs and VROM (now IenM). In the agreement[4], the signatories committed to realising additional energy-savings of at least 100PJ by 2020, improving the energy performance of at least 500,000 existing homes and other buildings by a minimum of 2 steps on their energy-label each year until 2011. A 2012 evaluation by PBL concluded that the pace of energy-savings lagged far behind the original goals, quoting reasons hindering investments by homeowners in particular as being the difficulty in financing the necessary investments; long return-on-investment periods, having other financial priorities; and other issues such as practical inconvenience (**Elzenga & Kruitwagen, 2012**). The Agreement was renewed in 2012, with at least 300,000 such renovations to be undertaken each year, allowing for additional measures if this result is not being met (**BZK, 2012**). This commitment was reaffirmed in the 2013 Energy Agreement.

In 2012, BZK initiated the pilot project *'Blok voor Blok'* [Block by Block]. The €5.75 million project is aimed at market-

[4] Staatscourant, 2008, Nr.29.

parties, housing corporations, municipalities, provinces and other parties involved. It started with a 2-year phase, in which thirteen local projects received funding for energy-efficiency measures (**RVO, 2014**). To be eligible, a project has to include at least 2,000 homes and have to improve their energy-label by two steps on the energy-label, or acquire a B-rating within three years. Rather than taking place on an individual household level, renovations under this scheme include entire streets, apartment buildings and other housing complexes, thus reducing the cost-per-unit and leading to more energy-efficiency savings. The main goal of the first phase was to gain knowledge and experience before an eventual country-wide introduction (**BZK, 2011**). An evaluation report by RVO published in July 2014 found that until then, around 15,000 homes had been made energy-efficient, with a further 3,700 renovations foreseen. With the project now finished, it concluded that while this integral approach to large-scale energy-savings proved possible in the social rental-sector, the same approach could not be replicated for owner-occupied dwellings (**RVO, 2014**). Homeowners were found to have a desire for more tailored solutions where they can determine if, when, and what measures he or she wants to take (**ibid, p.18**). The business-case of the large-scale approach was thus found not found to be profitable for this group.

2013 Energy Agreement
The conservation of energy is one of the key pillars of the 2013 Energy Agreement concluded between over forty organisations, including businesses organisations, employees' organisations, nature- and environmental organisations and governmental organisations. In the Agreement, the signatories express the shared goal of achieving saving 100PJ in terms of final energy use by 2020, ultimately striving towards an energy-neutral built environment in 2050 (**SER, 2013**). Apart from the built environment, it includes actions for industry, business and the agricultural sector, although it is not specified as to how energy-savings are to be divided across the different sectors. In addition to the measures listed in Table 1, the signatories strive to reach an average A-label for buildings by 2030. A strong emphasis is placed on informing and creating awareness among consumers, with all homeowners and tenants/landlords receiving an indicative energy-label in 2014/2015. A number of 'sustainability shops' have opened up across Dutch cities, where citizens can get free information on energy-saving topics. Smart-meters are currently being rolled out across the Netherlands. The Energy Agreement specifically leaves open the option of additional actions to reach the 100PJ goal, incl. fiscal- or non-voluntary measures and like those before it, the Agreement remains based on the principle of voluntary agreements, thus depending on the good will and efforts of all those involved.

Renovation schemes
At the request of BZK, Platform31 has initiated the innovation programme *Energiesprong*, running until the end of 2015. The programme supports a number of innovation-projects aimed at creating demand and supply for energy-neutral buildings, including homes, offices and health-care facilities. Current projects in the residential sector include *´Stroomversnelling Huurwoningen*', where four building companies and six housing corporations have agreed to renovate 11,000 rental homes to an energy-neutral standard by December 2016 without (substantial) rises in housing costs for tenants. The costs of the renovation are to be covered through significant reductions in monthly energy bills. If the results are considered satisfactory, another 100,000 homes are to follow between 2017 and 2020 (**Stroomversnelling.net, 2013**). If successful, this approach could help overcome the split-incentive between

landlords and tenants. A similar programme for privately owned homes (*'Stroomversnelling* Koopwoningen') has recently been given the green light.

In 2013, as part of wider housing-market reforms, a so-called revolving fund for energy-saving measures has been established with the Dutch government contributing €150 million and another €450 million made available by private parties. The scheme offers low-interest loans for energy-saving measures in existing dwellings and is intended to provide a boost to employment in the construction- and installation sectors (**BZK, 2013a**). Around half of the €600 million fund is reserved for housing corporations (**BZK, 2013b**). Another €150 million energy-saving fund (*Nationaal Energiebespaarfonds*) specifically aimed at owner-occupiers was established in that same year (**BZK, 2013c**). Pick-up of the scheme has been limited so far, with 699 loan-applications received, in the first three quarters of 2014 (**Cobouw.nl, 2014**). With only 398 loans valued at a total of less than €5 million granted, results have fallen short of the 5,000 applications expected over 2014 (**CDA.nl, 2014)**.

Level of ambition

In a report published in October of 2011, the Netherlands Court of Audit concluded that while Dutch energy-saving policy had been more ambitious than that of the EU until 2010, this was no longer the case under the new cabinet Rutte I (**Algemene Rekenkamer, 2011**). More importantly, however, it found that Dutch achievements had systematically trailed behind the expressed ambitions since 1995, due to the fact that "expectations and responsibilities have not explicitly been agreed and recorded, causing ambiguity as to who was responsible to compensate lower-than-expected results with extra policy" (**ibid, p.29, translated**). A report published by PBL in December 2014 concluded that current policy stimuli, the creation of favourable finance conditions and increased education, are insufficiently strong to move homeowners into adopting more energy-saving measures (**Vringer et al., 2014**). More binding measures may thus be required to attain the desired goals.

4.2.2. Renewable energy

During the 1970, alternative energy sources did not yet play a significant role in Dutch energy policy. The future potential of renewable energy technologies such as solar-, wind, and geothermal energy is openly recognised in the White Papers of 1974, and '79 and considerable attention went out to research and development of these technologies. The emphasis nevertheless very much remained with natural gas from the northern Province of Groningen, coal and nuclear energy during this decade. In 1986, the government initiated the Integral Programme Wind-energy (IPW), aiming to have installed 100 to 150MW wind-energy in the Netherlands by 1990. In addition to this target, a number of subsidy-schemes were put in place around this time, with CHP, wind-turbines and solar-boilers considered the most important technologies (**EZ, 1990**)

Renewable energy targets

A list of sustainable energy targets and the policy instruments used since 1990 can be found in Table 2 of Annex II. The Third White Paper on Energy of 1995 (**EZ, 1995**) included a specific target for renewable energy, set at 10 per cent of total energy use in 2020, with an interim target of 3 per cent in 2000. Policies to further the penetration of sustainable energy were to be directed primarily at electricity production, so that around 17 per cent of the electricity supplied would have to come from sustainable resources (**ibid**). The 2007 Coalition Agreement and '*Schoon en Zuinig'*-programme announced to increase existing targets to 30 per cent CO_2-reduction and 20 per cent sustainable energy in 2020 (**VROM, 2007**). Voluntary agreements between the government and parties from the built environment, energy companies, industry, the transport- and agricultural sector were central to this approach and there was a strong focus on already existing technologies as well as innovation.

Three years later, however, the 2010 Coalition government made a stark U-turn,
substantially scaling back ambitions to 20 per cent CO_2-reduction and 14 per cent renewable energy in 2020, in line with its EU obligations (**EZL&I, 2011**). It argued a hasty roll-out of renewable energies would lead to unnecessarily high social costs (**ibid, p.3**). The cabinet announced a major review of the stimulation policy for renewable energies, Civil society was to be the lead actor in the transition process, with the government assuming the role of facilitator. Innovation was to be the main focal point of Dutch energy policy, with strong support for those technologies which offer large potential in the long term (**ibid, p.16**). Nuclear energy and CCS were to play an important role in the future energy mix. The current VVD/PvdA government largely continues on the path set out by the VVD in its previous term, keeping the target steady at 14 per cent renewables by 2020 Innovation, and a strong focus on future technologies remain core elements of Dutch energy policy. Existing policies are directed mainly at the energy-sector and industry, often through voluntary agreements between government and business. Nevertheless, a number of important policies directed at citizens exist.

Renewable energy programmes

In 1996, the government introduced a regulating energy tax (REB) on natural gas, electricity and mineral oils, aimed at reducing CO_2-emissions and furthering energy-savings.[5] A regressive tax rate applies to natural gas and electricity, with the tax rate decreasing as the amount of energy used increases. Energy-intensive industry and companies thus pay less, on average, than households. Electricity generated through renewable resources is currently exempt from the REB, and a lower rate applies to members of an energy cooperation or owner's association delivering to its own members (**Belastingdienst.nl, n.d.**). While 'green elecriticy', electricity from renewable resources bought from the grid, was initially exempt from the REB, this exception was removed in 2004. As of January 2013, households and businesses are required to pay an additional levy on natural gas and electricity-use through the *Opslag Duurzame Energie* (ODE), similarly based on a regressive system, the revenue of which is used to stimulate the production of renewable energies.[6]

A law on the Environmental Quality of Electricity Production (MEP) went into effect in July of 2003. Aimed at stimulating the production of clean and sustainable energy, the MEP provided subsidies to electricity-producers with wind-, solar- water-power, biomass and CHP.[7] Feed-in tariffs per kWh varied per technology and were determined on an annual basis and the scheme was open to all producers. In 2006, the scheme was closed with immediate effect, arguing that the goal of 9 per cent of electricity generated sustainably in 2010 would be met with the actions taken so far. A report by the Netherlands Court of Audit, however, was more critical about the effectiveness and consistency of the MEP, and found that ultimately, uncontrollable budgetary costs associated with the open-ended arrangement were an important factor in the termination of the scheme (**Algemene Rekenkamer, 2007**). In 2008, the MEP was replaced by the SDE, where the government, for a pre-determined period, paid producers the difference or a part thereof, between the average cost-price and relevant average-market price of

[5] Staatsblad, 1995, Nr.662.

[6] Staatsblad, 2012, Nr. 673.

[7] Staatsblad, 2003, Nr.235.

renewable electricity or gas.[8] Unlike the MEP, the SDE was not an open-ended arrangement, with a subsidy-ceiling set for each category of production-installations, determined on an annual basis. The SDE was open to all producers, incl. business, (non-)profit organisations and citizens. In 2011, the SDE was radically reformed. Whereas the SDE focused on two goals; roll-out of sustainable energy and innovation, the new SDE+ would focus on an efficient roll-out of these technologies so as to reach the 14 per cent European target (**EZL&I, 2010**). The scheme is financed through the ODE and one subsidy-ceiling is established for all technologies, with a maximum subsidy of 15 ct/kWh. The SDE+ is no longer available to citizens. In 2012 and 2013, however, €22 million and €30 million respectively were made available to consumers in the form of solar-panel subsidies, with all available funding exhausted by August 2013. No new national subsidies have been made available since then, although some subsidies are available on a municipal or provincial level.

Feed-In-Tariffs

Under certain conditions, households are able to feed-in renewable energy not directly used into the electricity grid. If consumers produce more electricity than they use, their energy company is obliged to pay for the difference, with rates varying per provider. Rates vary between € 0.07 and €0.092 per kWh, depending on the energy provider. Private parties who deliver energy to their energy suppliers are considered entrepreneurs for tax-purposes and are required to pay VAT over their income if the payable amount exceeds €1,345 per calendar year. A smart meter is required to deliver energy back to the grid.

In order to stimulate the uptake of decentralised energy production by private individuals, the 2013 Energy Agreement announced that as of January 2014, a tax-discount of 7,5ct/kWh would be introduced for renewable energy produced through cooperatives or owners' associations and used by small-scale users of which both members and installations are within a certain postal-code area or surrounding postal-codes (**SER, 2013**). In practice, however, the scheme is proving too complicated, with low or even negative annual returns in some cases, and return-on-investment periods are too long to persuade citizens to make the initial investment. A formal evaluation of the scheme is expected in the spring of 2015.

Reaching the 14%-target

Despite initially high ambitions, the share of renewable energy stood at 4.5 per cent in 2014, unchanged from the year before and at one of the lowest levels in the EU (**CBS, 2014**), with a relatively small impact by household investments. While the production of solar-energy doubled for the third year in a row in 2013, it only accounted for 0.4 per cent of total electricity use in the Netherlands in that same year, compared to 5 per cent in Germany (**ibid**). On the one hand, the 2013 Energy Agreement focuses its efforts on the development of centralised and large-scale technologies, including onshore-wind energy (6000MW/54PJ in 2020), offshore wind-energy (4450MW) and biomass (25PJ). On the other, it also strives to obtain 40PJ from diverse, mostly decentralised, forms of sustainable energy by 2020 (**SER, 2013**). To this end, the government and other parties have agreed to solve organisational bottlenecks, ensure an adequate legal framework, and to create fiscal incentives. These measures should result in one million households and/or small-and-medium-sized enterprises generating a "substantial part" of their own energy-needs through decentralised renewables (**ibid, p.79**). Currently, the proposed measures remain rather vague and undefined and it is highly questionable whether they will be sufficient to motivate

[8] Staatsblad, 2007, nr.410.

homeowners to invest in renewable energy technologies.

In September 2014, PBL concluded that the current energy-innovation policy focuses primarily on reaching the 2020 target, without sufficient regard for the development of innovative options for the period thereafter (**Ros & Boot, 2014**). Together, ECN and PBL, in the first interim-report of the Energy Agreement estimated that, with current policies, the share of renewable energies will lie somewhere in a bandwidth of 9.1 to 11.1 per cent (**ECN, 2014**). If currently intended measures are implemented, the estimated share will rise to 12.4 per cent, with a bandwidth of 10.5 to 13.0, nevertheless falling short of the 14 per cent European requirement. A further intensification thus appears to be required. A mandatory minimum share of renewables in the energy-mix has actively been considered by consecutive governments, but never been implemented.

4.2.3 Non-policy

The Netherlands has regularly been characterised by its relative instability and criticised for its "policy discontinuity" (**IEA, 2014, p.108**). It could even be argued that, at times, the government has been a hindrance, rather than a stimulant of change as the discontinuity caused by consecutive subsidies for solar-panels did more to upset the market than it did to further it (**e.g. Köper, 2012**). Frequent changes in government have been accompanied by almost just as frequent changes in the direction of its energy policies. The free market ideology, a key element in Dutch energy policy since the 1990s, has come under significant pressure in recent years as energy- and climate policy have increasingly become entangled. While some parties argue that changes are inevitable and necessary for the transition-process to stay on course, others argue that the constant policy changes do little to provide the sense of security and confidence in government needed to attract (foreign) investment. Predominantly focused on short-term objectives, consecutive Dutch governments have largely failed to formulate a credible long-term strategy integrating renewable, climate and energy efficiency objectives.

One element that has been crucial to Dutch energy policy from the very beginning, however, is the strong influence of the so-called 'polder-model'. With a few exceptions, the Dutch government customarily seeks support from a broad range of actors representing the various business, societal, and environmental interests. While this consensus-approach does usually result in a wide base of support for the proposed goals, it does not always result in the most ambitious targets.

4.3 Technological Regime

According to 2014 IEA data, the total primary energy supply (TPES) of the Netherlands stands at 78.6Mtoe, made up primarily of natural gas (41.7%), oil (39.4%), and coal (10.4%) (**IEA, 2014**). TPES per capita, with 4.7toe, lies slightly above the IEA average of 4.5. Electricity is largely generated through the use of natural gas (54.4%) and coal (26.6%), with biofuels and waste taking up 8.7 per cent, wind at 4.9 per cent and nuclear at 3.8 per cent. With a share of 44.6 per cent, industry accounts for a large share of total final energy consumption. It is followed by the commercial and services sector and residential sector, accounting for around 19.9 and 16.9 per cent respectively. When looking at the CO_2-emissions per sector, the residential sector accounts for 10.2 per cent of greenhouse gas emissions in the Netherlands, ranking below power generation (30.8 per cent), manufacturing and construction (23.3), transport (18.7) and services (10.5) (**ibid**).

Natural gas is crucial to meeting the energy and heating needs in most Dutch households. Almost all household are equipped with highly efficient (HR) and modern gas-fired boilers and around one-third of power-use is generated using natural gas. A recent study commissioned by the Netherlands Enterprise Agency (RVO) estimated that around 600,000 – or just under 8 per cent – of all Dutch households are connected to a district heating network, roughly half of which are operated by one of the large heating distribution companies (**DHC Holland, 2014**). While the majority of electricity used was produced using natural gas between 2000 and 2010, the use of coal has increased significantly in recent years due to its low prices on global markets. Today, about one-third of power-use is generated using natural gas (**ECN, 2014**). Around half of the Dutch power supply is generated by CHP, in around 4,500 plants, fired up to 90 per cent by natural gas (**IEA, 2014**). The low price of coal has resulted in a number of clean gas-powered stations being taken offline in favour of more polluting coal-fired plants in recent years.

The current government is supportive of offshore CCS; the 2013 Energy Agreement even refers to CCS as being "inevitable" (**SER, 2013, p.98**). A Rotterdam Capture and Storage Demonstration Project (ROAD) is set to start capturing the CO_2-emissions of a new power-plant and another demonstration project in the Dutch North-Sea is in operation since 2002.

Nuclear energy does not offer a significant contribution to the Dutch electricity-mix at this time. The only existing nuclear power plant in Borssele accounted for around 2.9 per cent of total electricity production in 2013 (**CBS.nl, 2014**). While consecutive governments have generally looked favourable on the construction of new nuclear power plants, the decision has been postponed until the next government on a number of occasions. While two companies, Delta & RWE/Essent, had plans to construct a new nuclear power plant in Borssele, both parties have decided to postpone their applications in light of the current economic climate. With several political parties in favour of new nuclear energy capacity, the topic remains on the political agenda at this time.

Technological preferences

Of the two Dutch parties currently in government, the VVD in particular does not wish to express a preference towards any of the renewable energy technologies, instead leaving it to the market to determine which energy source is fit for the future. The website of the government lists wind-energy, bioenergy, solar-energy, green electricity and geothermal energy as the most important sources of sustainable energy in the Netherlands, in that particular order, with a limited role for technologies such as water-power, "blue" energy (generated through contact between sweet- and salt water) and ambient heat (**Rijksoverheid.nl, n.d.**). In the fall of 2014, the Minister of Economic Affairs presented a revised offshore wind-strategy, withdrawing permits for nine smaller windfarms previously issued and replacing them instead with three sites closer to the shore, arguing the existing plans are overly expensive. While the new plans are thought to be €4.2 billion cheaper, it is likely to cause further delays and does little to change the image of a wavering and indecisive central government.

While a strategic reserve model was developed in 2003, there has not yet been a need for its activation.

4.4 Market Demand

The Dutch housing market has a number of distinguishing features when compared to the other three countries.

It has been argued that since the post-World War II reconstruction years, the building process can be characterised by "rationalisation and standardisation" (**Rakhorst, 2008, p.150**). Emergency housing had to be constructed in a short timeframe in order to meet the enormous housing shortage caused by the war. Private commissioning for new housing and self-build projects are relatively uncommon in the Netherlands to this day, with the majority of new housing demand being developed by a small number of project developers and housing associations (**Faber & Hoppe, 2013**). Overall, the Dutch building sector is often characterised as being conservative, with limited room for new technologies and innovative experiments, largely as a result of existing vested interests (**ibid**). In recent years, however, innovation has become a key buzzword in the sector, with companies competing for contracts in a slow market.

Table 3: Statistics Housing Market the Netherlands

Building Types (%)	
Detached Houses	16.0
Terraced Houses	61.2
Multiple-family	18.4
Other	4.4
Housing Types (%)	
Social Rental	31.0.
Private Rental	9.0
Ownership	60.0
Other	-
Empty	-
Age Housing Stock (%)	
<1919	6.9
1919-1945	13.9
1946-1970	27.0
1971-1980	17.0
1981-1990	15.4
1990-2000	12.0
2000>	7.9

Source: BZK (2013d)

With over 60 per cent of all dwellings, terraced houses are typical of the Dutch urban landscape. Most of are standard housing concepts built in large volumes by the project developers and housing associations, with residents having little to no say throughout the construction process (**Hoppe & Faber, 2011; Kieft et al, 2013**). As described previously, the housing stock is generally deemed to be of a good energetic standard. Most houses are insulated to a high energetic standard and nearly all households make use of relatively new, high-efficiency boilers to meet their heating needs. Nevertheless, a number of important steps continue to be to further improve the thermal quality for owner-occupied and rental housing.

Housing market

The share of homeownership is relatively high in the Netherlands, with around 60 per cent of Dutch dwellings being privately owned. The active stimulation of homeownership for both low- and high income households has been a central part of government policy in the decades leading up to the 2008 crisis. The social rental sector nevertheless continues to play an important role, with almost one-third of all Dutch residents living in housing supplied by one of the housing corporations. The private rental sector is significantly smaller than those in Germany and the United Kingdom. Tenants' rights are well-protected in the social rental sector, with maximum rents set at €710.68 as of January 2015. The government determines with which percentage the rents are allowed to rise each year.

Throughout the last decades, Dutch governments have actively stimulated homeownership. Through fiscal stimuli, people were encouraged to make the switch from renting to owning their own property, resulting in a highly dynamic housing market. The financial crisis of 2008 has had a significant impact on the Dutch housing market, with housing prices dropping by more than 20 per cent since their peak in 2008, nearly 30 per cent in real terms (**Gelauff et al., 2014**). At the same time, it has become increasingly difficult for prospective buyers, particularly young entrants into the housing market, to access the required funding, with banks hesitant to provide the necessary credit. As a result, tenants are often unable to move from the rental sector to the property market. While there are signs the housing market may be recovering, progress is still fragile. One cause of continued concern for the Dutch housing market is the high level of household debt, with many homes considered to be “under water”, i.e. with a higher mortgage than the value of the home. Unable to move without residual debts, this group is limiting movement on the housing market.

In recent years, the social housing sector has been plagued by a number of scandals, with a parliamentary enquiry into the matter concluding that, since liberalisation of the sector in the 1990s, social housing corporations could be blamed for excessive and imprudent risk-taking, failing leadership, financial mismanagement, even self-enrichment, fraud and embezzlement (**Tweede Kamer, 2014**) It further concluded corporations should focus on its core activity of providing affordable housing to people with low incomes who are not able to do without support (**ibid, p.176**). People with higher incomes are expected to move into a growing private rental sector. Most of these reforms were agreed on by the Government and constructive opposition in the ‘Housing Agreement of 2013’ (*Woonakkoord*). The Agreement capped rent increases at 1.5 to 2 per cent (above inflation) per annum for people with an income of up to €43,000 and at 4 per cent (above inflation) annually for people with incomes exceeding this amount. The idea is that this will provide the needed impetus for the private rental market to grow and stimulate the wider housing market. Foreign investment in this sector is actively encouraged.

Access to finance

Homeowners may be eligible for finance through a national ‘energy savings loan’ (*Energiebespaarlening*) or regional/local ‘sustainability loan’ (*Duurzaamheidslening*). Interest rates for the former are tax-deductible and vary around 2.6 to 3.3 per cent, while interest rates for the latter are at least 0.5 per cent after a discount of 3 per cent. Although interest rates are low, so far pick-up of the scheme by homeowners appears limited.

Demographic challenges

The Netherlands will be facing significant demographic challenges over the coming decades. The urban area known as the “Randstad” includes the four largest cities in the country – Amsterdam, Rotterdam, The Hague and Utrecht – and is home to more than one-third of the total population. The population in this part of the country is expected to grow steadily during the first half of this century, so that new developments continue to be economically viable and indeed necessary in this area while peripheral parts of the Netherlands will face a decline in the number of residents (**de Jong & van Duin, 2012**). A strategy has been developed in which new developments in some of these areas can only take place when existing properties are demolished. Ageing of the general population and changes in household structures are further expected to significantly change the demand for housing in the future.

5. Sectoral Analysis Denmark

In international comparisons, Denmark is often hailed as one of the world's frontrunners in terms of renewable energies, energy efficiency and the fight against climate change (e.g. **IEA, 2011**). Danish energy consumption has remained constant since the 1980s, despite its economy growing by almost 80 per cent over the same period, and CO_2-emissions have actually reduced over the same period (**ENS, 2012a**). The country has a large and well-developed district heating sector, with a strong emphasis on the cogeneration of heat and electricity and renewable energies account for 29 per cent of gross energy consumption (**Statistics Denmark, 2014**).

With respect to the built environment, the residential sector in 2010 accounted for 31 per cent of total final energy consumption, about 83 per cent of which was related to the heating of households (**Gram-Hanssen, 2013**). At the same time, the residential sector accounted for only 6 per cent of greenhouse-gas emissions, due in part to a large share of emissions in electricity and heat generating sectors at 47 per cent (**IEA, 2011**).

Since the 1970s, Denmark has introduced strict building requirements and a number of ambitious measures aimed at stimulating energy efficiency improvements and the use of renewable energy technologies in its housing stock, consciously coupling the energy renovation of buildings with general maintenance and repairs. Consecutive governmental agreements have been concluded with broad parliamentary involvement and support. In 2011, Denmark published the 'Energy Strategy 2050', setting itself the goal of becoming completely independent of fossil fuels by 2050.

5.1 Actors, Interactions & Networks

The Kingdom of Denmark is a constitutional monarchy, consisting of five regions and ninety-eight municipalities. It has a unicameral national parliament in which most post-war governments have been minority coalitions supported by outside parties. From April 2009 until September 2011, Denmark had a right-wing coalition cabinet. Following 2011 elections, a new left-wing coalition of the Social Democrats, Danish Social Liberal Party and Socialist People's Party took office. Since 2014, a new cabinet was formed with the former two parties remaining.

The main ministry responsible for the built environment is the Ministry of Climate, Energy & Building or *Klima, energi- og bygningsministeriet* (kebmin), established in November 2007. Previously, energy had been part of the Ministry of Transport and Energy (2005-2007) and Ministry of Environment and Energy (1994-2005) and in 2011 building policy was added to the Ministry's tasks. Since this time, building-, energy- and climate policy are thus all brought under the umbrella of one single ministry. The Ministry of the Environment [*Miljøministeriet*] is responsible for "administrative and research tasks in the areas of environmental protection and planning (**Miljøministeriet, n.d.**). Both ministries rely on a number of agencies for support.

The Danish Energy Agency (ENS) works under the auspices of kebmin and is responsible for matters relating to energy supply and consumption, a reduction of carbon emissions, and Danish building policy (**ENS, n.d.**). The Danish Electricity Saving Trust is an independent trust, similarly operating under the umbrella of kebmin, promoting energy savings and energy efficiency. The Agency for Spatial and Environmental Planning is part of the

Ministry of the Environment and tasked with determining the overall planning-framework.

A Knowledge Centre for Energy Savings in Buildings (*Videncenter for energibesparelser i bygninger*) was established as part of the energy policy agreement of 21 February 2008 (**Danish Government, 2008**). Its members include amongst others, the Danish Technological Institute, Aalborg University and the Technical University of Denmark and its objective is to ensure greater awareness in the construction sector of how energy savings in buildings can be achieved. It focuses primarily on the construction industry, rather than consumers or individual homeowners. It operates under the umbrella of ENS (**Danish Government, 2012**).

With the 2014 Climate Change Act, Danish Parliament also established an independent, academically based 'Climate Council'. It will include members with expertise in a number of climate-relevant issues and is scheduled to commence work on January 1st, 2015, or as soon as possible thereafter. Its tasks include the analysis of the potential transition pathways to a low-emission society, including the choice of measures, and the submission of (scientific) recommendations to the Minister for Climate, Energy and Building on climate change initiatives (**kebmin, 2014**).

The electricity- and natural gas grid are owned by Energinet.dk, an independent but state-owned company under the auspices of kebmin. Energinet.dk is tasked with development of the main infrastructure, the creation of objective and transparent conditions for competition, guaranteeing the long-term security of supply, and the support of "eco-friendly power generation" (**Energinet.dk, n.d.**). According to the European Commission, in 2010, two-thirds of all electricity was produced by two companies: Dong Energy and Vattenfall, the remainder being provided by a large number of smaller companies including energy cooperatives and municipal companies (**European Commission, 2012**). Some of the companies (69 net-companies, 27 traders and 14 production companies) are represented by the Danish Energy Association, a commercial organisation managed and financed by its members. The Danish Energy Regulatory Authority (DERA) and Energy Supplies Complaint Board are tasked with overseeing the Danish electricity, gas- and heating markets district heating sector, as well as the handling of complaints.

Local authorities are important as they are responsible for the development of heating plans and the expansion of district heating. The government considers them to be central to the more decentralised energy system of the future (**Sperling et al., 2011**). Denmark's largest district heating plants are owned by large energy companies, while a mix of production companies, municipalities and cooperative societies own and operate the smaller plants (**ENS/DBDH, n.d.**). Both the production- and network companies of district heating are monopolies and regulated as non-profit undertakings by DERA (**DERA, n.d.**).

The Danish construction industry can be characterised by a relatively large fragmentation of actors. In 2012, Denmark had a total of over 31,000 construction companies, employing almost 120,000 people full-time (**Statistics Denmark, n.d.**). Around 48 per cent of companies had no employees, and a further 44 per cent employed between 1 and 9 people (**ibid**). In the post-war period, the Danish construction sector was characterised by a rationalisation of the building process (**Kristiansen et al., 2005**), and in the nineties, it was said to have been defined by issues of "low productivity, poor innovation, poor collaboration and organizational fragmentation" (**Jensen et al, 2011**).

Finally, energy cooperatives play a particularly important role in Danish energy policy. Local ownership of wind turbines in particular has played an important role in the development of the wind energy market and a large share of Danish turbines are owned by private households (**Meyer, 2004; Mendonça et al., 2009**). The interests of owners of turbines and others interested in wind-energy are represented through *Danmarks Vindmølleforening*, an association with around 4,400 members and 3,700MW of installed capacity at the end of 2013.

5.2 Institutional Framework

Denmark has a long history of energy- and building policies which really took shape following the oil-crises of the 1970s at which time over 90 per cent of all the energy supply consisted of imported oil (**ENS, 2012a**). Reducing the dependence on imported fossil-fuels has been paramount to Danish energy policy ever since, and improved energy efficiency and the promotion of renewable energy technologies have been two important elements to achieve this goal from the outset (**Togeby et al, 2009**). Security of supply and the continued affordability of energy in the future – rather than environmental concerns – appear to have initially been two main drivers behind the wider energy transition. In 1979, the Danish government first introduced building regulations which included a minimum requirement for energy consumption for new buildings. They have been tightened a number of times over the years and, since 2006, include provisions on the renovation of existing buildings (**Gram-Hanssen, 2013**). Denmark first introduced Energy Performance Certificates (EPC) for buildings as early as the 1990s, well ahead of most European countries (**Hamilton, 2010**). As an in-depth discussion of all policy initiatives since the 1970s would go beyond the constraints of this analysis, this section chooses to focus on the most important policies introduced in the last ten years.

5.2.1 Energy efficiency

According to the 2006 IEA country review, Denmark has played a "pioneering role" in energy efficiency due to a concerted effort by the government, rather than inherent characteristics of the country itself (**IEA, 2006**). Since the mid-1970s, the government has introduced strict codes for buildings and appliances, public campaigns on energy use, an extensive district heating/CHP network and negotiated agreements with industry. The country has extensive legislation in place to deal with the energy efficiency of new buildings and taken various actions aimed at increasing energy efficiency in existing buildings.

2005 Action Plan

In June 2005, the Danish Government presented the 'Action Plan for Renewed Energy Conservation' (**ENS, 2005a**). Superseding the 2001 'Natural Gas and Energy Savings Agreement' – which first established energy saving targets for individual sectors, including households (**IEA.org, 2013**), the Action Plan introduced an energy-saving target of 7.5 PJ annually over the 2006-2013 period. The various actors in the energy sector, including electricity- and natural-gas companies, district heating companies, oil networks and the distribution companies were made responsible for achieving a significant part of the increased energy savings, at a rate of 2.95PJ per annum. District heating providers have separate, individual targets (**Hamilton, 2010**). The energy-saving obligation was set as a voluntary sector agreement between kebmin and industry and is expressed as first years' savings, thus not considering the length of time during which the energy is saved (**ibid; Togeby et al., 2009**). Overall, the Agreement specifically prioritises a market-oriented approach, focusing on large, profitable energy savings using mechanisms that can realise the savings at low costs. Activities are based largely on individual and easy-to-treat measures, rather than a whole-house retrofit strategy and “deep renovation”. The Action Plan further tightened energy requirements for new builds by around 25 per cent as of 2006, with similar changes foreseen by 2010 and 2015. In relation to already existing homes, the Action Plan introduced specific requirements (e.g. minimum energy-performance) for major renovations to the existing building stock such as changes to roofs, windows and boilers. In 2006, the existing EPC-scheme was streamlined and brought in line with the European Directive 2002/91 on the Energy Performance of Buildings and changes to the labelling scheme are explained in detail in the ‘Act to Promote Energy Savings in Buildings’ of 2005 (**ENS, 2005b**).

2008 Energy Policy Agreement
The February 2008 ‘Agreement on Danish Energy Policy for 2008 to 2011’ set the target of reducing total energy consumption by 2 per cent in 2011 and 4 per cent in 2020, compared to 2006 consumption-levels and to increase the share of renewable energy to 20 per cent of gross energy consumption in 2011 (**Danish Government, 2008**). The energy-savings obligation of energy companies was raised to 5.4 PJ per annum from 2010 onwards. Energy requirements in the building code were tightened, with energy consumption of new buildings to be cut by 25 per cent in 2010, followed by another 25 per cent in both 2015 and 2020, for a total reduction of 75 per cent in 2020. DKK 20 million was set aside annually over the 2008-2011 period for campaigns promoting energy efficiency in buildings. The agreement also saw the establishment of the Knowledge Centre for Energy Savings in Buildings. Contributing only 9.5 per cent of annual residential energy savings in 2008, insulation made up a small share of energy-saving efforts, with companies focusing on less expensive measures instead (**Hamilton, 2010**). Since 2010, building regulations hold that, where part of the house (e.g. the roof) is renovated, this should be done in line with the latest standards if there is no architectural-, economic- or moisture technical argument against it (**Gram-Hanssen, 2014**).

2012 Energy Agreement
The 2012 Danish Energy Agreement includes a number of important measures to further promote energy efficiency, amounting to a 12 per cent reduction in gross energy consumption by 2020 compared to 2006 (**ENS, 2014a**). Firstly, the Agreement raised the energy company obligation further, to 10.7 PJ per year in the 2013-2014 period, and 12.2 PJ per annum over the 2015-2020 period (**Danish Government, 2012**), translating to annual energy savings of 2.6 per cent of final energy consumption (excl. transport) in 2013 and 2014 – compared to 2010 – rising to 2.9 per cent from 2015 to 2020 (**kebmin, 2012**). Secondly, the Agreement announced a comprehensive strategy for energy renovation of the existing building stock and pledged DKK 30 million (€4 million) to support renovations, with DKK 20 million (€2.7 million) assigned to the Knowledge Centre for Energy Savings. Finally, the parties agree on implementing an energy-saving package designed to promote energy efficiency in the private rental sector. As part of this package, following renovations, landlords will be allowed to charge a higher rent increase than under existing rules, provided this is economically viable

From 2015, low-energy class buildings – with energy consumption reduced 50 per cent compared to 2006-levels – have become a legal requirement for new buildings. A ‘building class 2020’ has already been developed, under which energy consumption is reduced by 75 per cent compared with the 2006-level (**ENS, 2014a**). This building class will remain voluntary until 31 December 2018 for publicly owned buildings and 31 December 2020 for private buildings, after which point it will become the new legal requirement.

Renovation schemes

A 'Strategy for energy renovation of Buildings' was adopted by the Danish Government in May 2014. The Strategy contains a list of twenty-one initiatives to stimulate the renovation of the existing Danish building stock and combined, these measures are expected to reduce net energy consumption for heating and hot water by 35 per cent in 2050 compared to current levels (**Danish Government, 2014**). Initiatives are aimed at (1) all building segments – including the upgrading of energy standards for the building envelope and installations, improved information and communication and the advancement of financing frameworks for energy renovation; (2) single family homes; (3) multi-family residences, offices and public buildings; and (4) strengthening competences and innovation (**ibid**). While the Strategy continues to hold energy savings can be achieved best and most economically when renovations are carried out in conjunction with general building renovations such as conversion, extension and ongoing renovation/maintenance, it does aim to ensure that more 'deep' energy renovations such as insulation are carried out.

In its 2013 Growth Plan, the Danish Government proposed a new Danish energy-savings concept, the so-called Green Housing Contract (*Grøn Boligkontrakt*), launched in all municipalities in mid-2014 (**ENS, 2013**). The purpose of the scheme is to make homeowners aware of the benefits of energy renovations and its potential for investment, bringing forward energy renovations that would otherwise not have been undertaken for another few years by making the process more simple and straightforward for homeowners. As part of the *Grøn Boligkontrakt*, a 'one-stop-shop' has been established from which homeowners receive free and impartial advice on which options are suitable for their homes. Green Housing Contract will automatically inform homeowners when they receive an offer and inform them of which loans, grants and/or subsidies are available. The service is also tasked with the follow-up, post-renovation (**Grønboligkontrakt.dk, n.d.**).

5.2.2 Renewable energy

While renewables played a negligible role in total Danish energy supply in the 1970s, by 2010, renewable energy accounted for around 20.7 per cent of TPES and 33.5 per cent in electricity generation (**IEA, 2011**). With little hydropower resources, Denmark has actively stimulated the development of biomass, CHP and its domestic wind-energy market. In the 'Energy Strategy 2050', the Government has expressed its ambition to make Denmark independent of fossil fuels by 2050, increasing the share of renewable energy to 33 per cent by 2020 (**Danish Government, 2011a**). Since 1998, a Public Service Obligation (PSO) is charged onto consumer's energy bills to cover the costs of public service obligations, including subsidies for renewable energy, grants for decentralised cogeneration and R&D into sustainable energy production and energy efficiency.

In 2005, the Danish Ministry for Transport and Energy published its 'Energy Strategy 2025'. The Strategy projected that by 2025, more than 36 per cent of Danish electricity supply would originate from renewables, with wind making up the lion-share of the increase compared to 2003 (**Danish Ministry for Transport and Energy, 2005**). The Strategy strongly focused on the use of markets, holding that a market-based approach would be far more cost-effective than a "politically forced increased use" (**ibid**). Nevertheless, renewable energy was promoted directly, through direct production-subsidies, exemptions from energy taxes and indirectly, through CO_2-taxes and allowances on other forms of energy.

Heat Supply Act
In the same year, the government passed the 'Heat Supply Act of 2005'. In accordance with this Act, local authorities are required to approve proposals for collective heat supply, including district heating to new areas (**kebmin, 2010**). It contains a general framework for the expansion of district heating networks, promoting the most economic and environmentally friendly use of energy for heating and hot water supplies to buildings. While projects under 25MW do not require approval under the Electricity Supply Act, they do require approval from the District Council, which needs to ensure they are included in the spatial planning (**ibid**). The District Cooling Act of 2008 allows Local Authorities to establish and operate district cooling operations, which similarly require approval from the District Council (**ibid**). A Planning Act is in place to ensure that planning is coordinated and takes into account all factors, including local interests and the protection of nature and the environment. While electricity-generating renewable energy installations smaller than 10MW do not require approval under the Electricity Supply Act, they do need to fulfil the requirements of local authorities' spatial planning rules.

Promotion of Renewable Energy
The 2008 'Promotion of Renewable Energy Act' aimed to stimulate the production of energy from renewable energy sources and included a number of measures to promote the expansion of primarily wind energy, both onshore and offshore (**ENS, 2008**). The Act sets out a clear regulatory framework for onshore wind-turbines and contains four new schemes aimed at fostering public uptake- and acceptance of onshore wind.

(1) Any person wishing to erect a wind-turbine is to hold a public meeting to explain the consequences for surrounding real properties, located within a distance of up to six-times the height of the planned turbine. Where the erection of turbines higher than 25 meters is found to lead to loss of value to real property, the person erecting the turbine shall bear the costs of this loss;
(2) Any person who erects one or more onshore turbines of at least 25m in height is required to offer at least twenty per cent of ownership shares to any person over 18 years with a permanent residence within 4.5km from the site of the installation prior to commencement. The offer for sale of ownership is to be made public through "conspicuous advertising in local newspapers" (**ibid, Art.15.4**);
(3) Subsidies (0.004 DKK/kWh) are available for initiatives to promote local acceptance of new onshore wind turbines connected after February 2008.
(4) The Act guarantees loans for wind turbine owners' associations to finance preliminary investigations (incl. location, technical and financial aspects) and to prepare applications (**ibid, Art.21**). The Act also provides detailed feed-in premium tariffs for wind, biomass, biogas and other forms of renewable electricity production.

The 2008 Energy Agreement included additional measures, setting aside DKK 30 million for a two-year period to strengthen information campaigns, labelling and limited grant schemes to replace individual oil burners with heat pumps. The Act specifically targeted heat consumers outside areas connected to the district heating system. A further DKK 25 million per year was made available over a four year period as a subsidy for small renewable energy technologies such as solar- and wave-power. (**Danish Government, 2008**). The 2010 Finance Act allocated DKK 400 million (€53.5 million) for the scrappage of inefficient oil-fired boilers, complemented by a subsidy for the purchase and installation of an energy efficient heating system (**Ministry of Finance, 2009**).

The 2012 Energy Agreement, setting out Danish energy policy over the 2012-2020 period, left support for onshore wind turbines connected to the grid from January 2014 unchanged. Owners of wind turbines will continue to receive a fixed premium of 25 cents/kWh (€0.03) for the first 22,000 full load hours, reduced if the market price exceeds 33 cents/kWh and completely withdrawn if the market price of electricity is 58 cents/kWh or higher (**Danish Government, 2012**). Rates for solar-energy are set at DKK 0.60 (€0.08) per kWh. The Agreement also phases out oil-boilers in existing buildings, from 2013 prohibiting the installation of oil- and natural gas-fired boilers in new buildings and, from 2016, the installation of oil-fired boilers in existing buildings in areas where district heating or natural gas are available as an alternative. DKK 42 million (€5.6 million) was made available to promote initiatives for energy-efficient alternatives, including heat pumps, solar, and solar-heating (**ibid**). In addition, the Agreement announced a strategy for smart grids to be able to deal with the increased share of wind-power and increased integration with the German grid and introduced a "security of supply tax" on fossil fuels and biomass – to counter decreasing existing tax revenues from fossil fuels and finance some of the measures introduced in the Agreement.

Long-term goals

In 2011, the Danish government published a long-term energy strategy, the 'Energy Strategy 2050' in which it expressed the ambition of becoming completely independent of coal, oil and gas, creating an energy and transport system without fossil fuels entirely (**Danish Government, 2011a**). Key elements of this strategy are: the electrification of heating including district heating and individual heating systems; an increase in electricity from wind-power; efficient use of biomass and biogas to cover a large share of CHP production; solar-PV; renewables-based district heating and individual heating; and finally, widespread use of intelligent energy systems. Existing electricity- and heat production capacity based on fossil fuels (incl. district heating) will gradually be converted to renewable energy when they are worn out. The Strategy also includes measures to convert heating by oil and natural gas to district heating, heat pumps and other renewable forms of renewable energy such as solar heating, including a ban on the installation of oil furnaces in existing buildings from 2017 and a ban on installing oil and natural gas furnaces in new buildings from 2012 (**ibid**).

5.2.3 Non-policy

There are a number of important non-policy aspects. Firstly, it is particularly noteworthy that these energy agreements are passed, not only with the support of the parties in government, but also with the support of a large number of the opposition parties. The 2012 Agreement was received with support from four main opposition parties, and only one party voted against the 2008 Agreement. There thus appears to be wide political consensus on the path taken by consecutive governments. Progress has furthermore remained constant, with limited changes to the trajectory followed, despite the different political orientations of consecutive Governments. Following the 2011 election, a shift took place from a centre-right to a centre-left Government and this does appear to have had an influence on discourse. Whereas the centre-right government placed a strong emphasis on cost-minimisation and budget-neutral solutions, the new left-wing coalition has somewhat shifted the emphasis towards cost-efficiency, where "the financing requirement will primarily be covered by households and enterprises" (**Danish Government, 2011b**). Secondly, Denmark's latest National Energy Efficiency Action Plan (NEEAP) was regarded to be of "extraordinary quality", explicitly linking national energy efficiency polices to the development of the independence from fossil fuels target by 2050 (**Schüle et al, 2013**). Overall, Danish energy efficiency and renewable energy policies appear to be well thought-out, and have been an example to policy-makers from the European Union and across its Member States.

Whereas other countries focus on deep renovations and 'deep'-renovation strategies, Denmark's strategy has largely been directed towards individual measures, undertaken in tandem with general maintenance or home-renovations and 'easy-to-treat'-measures with the lowest costs. It has been argued, however, that the renovation rate to date has been too low, with many existing dwellings still lacking sufficient energy efficiency (**Gram-Hanssen, 2014**). The 'one-stop-shop' established in 2014 could be a useful instrument in picking up the rate of renovations.

Finally, while wind-energy policy has been very successful in Denmark to date, and the legislation for onshore wind-turbines introduced with the 'Promotion of Renewable Energy Act' in 2008 may have contributed to the large public acceptance of onshore wind-energy, a couple of developments may be cause of concern for the future. Firstly, due to the currently low market-price of electricity per kWh, wind-energy policy is currently under pressure, leading the Climate and Energy Minister Petersen to announce that the cost of wind energy needs to drop in order to be competitive, or the government will no longer continue the construction of wind farms (**The Copenhagen Post, 2014a**). It is unclear whether this would jeopardize progress on current targets. Secondly, as more and more wind-turbines are installed across Denmark, and turbines becoming increasingly tall as a result of technological developments, it is unclear what the consequences will be on public acceptance of windmills in the Danish landscape.

5.3 Technological Regime

According to 2010 IEA estimates, Denmark's total primary energy supply amounted to 19.7Mtoe, about a quarter of that of the Netherlands (**IEA, 2011**). The country remains dependent on fossil fuels for most of its energy needs, with 38 per cent originating from oil, 22 per cent from gas, and 20 per cent from coal, with only 17 per cent coming from biofuels. While electricity generation also relied heavily on coal (44%) and gas (20%), renewables contributed a significant share, with wind accounting for 20 per cent of electricity and biofuels for 19 per cent. With 31 per cent each, the transport and residential sector are the primary consumers of energy in Denmark, followed by industry (18%) and the commercial- and agricultural sector (20%) (**ibid**). When looking at greenhouse-gas emissions by sector, the electricity and heat-generation sector accounted for 47 per cent of all greenhouse gas emissions, far more than transport (28%), industry (8%) and the residential sector (6%) combined.

Unlike the high share of fossil fuels may suggest, Denmark has been experiencing a remarkable turnaround in its energy use in recent years. At the start of the 1990s, electricity production was almost entirely dependent on coal, with other types of fuel only accounting for 8.7 per cent of consumption (**ENS, 2012b**). Coal remains an important resource for the country's electricity production today. According to data from the transmission systems operator Energinet.dk, around 2,500MW of the current total 7,000MW capacity is coal-fired (**State of Green, n.d.**), with another substantial amount of capacity delivered by oil- and gas-fired plants, sometimes in combination with coal (**Energinet.dk, 2014, Annex I**). The 2014 report expects total centralised- and decentralised capacity to decline to between 4,700MW and 5,400MW in 2021, despite an expected increase in electricity demand, with coal-fired capacity brought down to around 700MW. To achieve this, some of the existing capacity is expected to be mothballed, while other plants will be converted to run on partially or entirely on biomass. Sufficient back-up capacity appears to be in place as a result of these plans (**ibid**). The expansion of wind-power and conversion of CHP-plants to biomass are estimated to result in around 71 per cent of electricity consumption to come from renewables in 2020 (**ENS, 2014b**).

Since the 1980s, the Danish energy generation-system has gradually been decentralised (**ENS, 2014a**), with a large number of small CHP-plants, wind-turbines and biogas-capacity built across Denmark. Local stakeholders and authorities, particularly municipalities form the backbone of the energy transition in Denmark. Municipalities have formal planning authority of wind power and usually manage district heating. The central government sets the overall policy framework, designing, guiding and supporting local energy planning (**Sperling et al., 2011**).

Heating systems in households

Until the mid-1980s, most Danish households made use of oil-fired boilers. Since then, the number of district heating and natural-gas installations has increased significantly. At the start of 2013, 62.1 per cent of the 2.75 million heating installations in Denmark were district heating installations, 15.4 per cent natural gas boilers, only 12.5 per cent oil-boilers, and the remaining 9.9 per cent was made up of other installations such as heat pumps, electric heating, and wood fired boilers (**ENS, 2012b**). Outside areas supplied by district heating or natural gas, heating continue to be based mainly on oil (**ENS, 2010**). Many oil-fired boilers are approaching their technical end-of-life and homeowners are encouraged to switch to more energy-efficient heat pumps or district heating (**ENS, 2014a**). Around half of all district-heating customers are said to now have smart meters installed in their homes, with which they can read their consumption in cubic meters and MWh (**ibid**). Overall, Danish homes are considered to be of a good standard, scoring well on European statistical housing quality indicators.

Combined heat and power

A large share of district heating is produced in combination with thermal electricity generation, 73.0 per cent in 2012. In doing so, it uses the large amounts of heat generated through the thermal production of electricity more effectively. The greatest contribution to district heating comes from large-scale CHP units (44.5%). In total, large-scale and small-scale CHP units produced 72.6 per cent of all district heating in Denmark, with the remainder from units exclusively producing district heating. CHP units used coal as the primary fuel (24.3%), followed by waste (17.5%), biomass (16,8%) and natural gas (13.0%) (**ibid**). A significant decline in conventional decentralised capacity is predicted as a result of changes to existing subsidy schemes, reducing capacity by half in East-Denmark between 2017 and 2020 and one-third in West-Denmark over the same period, with further reductions expected to take place between 2020 and 2025 (**ENS, 2014a**). Some of these decentralised plants will be converted to biomass while others will most likely be shut down completely. While the use of coal as fuel was originally scheduled to be banned in Denmark by 2030, the Climate and Energy Minister recently announced to be investigating the phasing-out of coal in just ten years' time (**The Copenhagen Post, 2014b**).

Technological preferences
Renewable energies are key to Denmark's energy strategy and the country has had a longstanding focus on wind energy. In January 2014, the installed generating capacity totalled to approximately 4,800MW, of which about 1,142MW was located offshore, 130MW in coastal areas and 3,530MW of land-based turbines (**Energinet.dk, 2014**). Currently, the wind energy market supplies over 20 per cent of Denmark's energy needs and the goal is to increase this share to at least 50 per cent by 2020. Other technologies such as solar- and wave power are regarded as "valuable supplements" in *Our Future Energy*. The *Energy Strategy 2050* further stresses the need to use already existing/proven technologies, rather than pinning its hopes on new developments, particularly in the period leading up to 2020.

In 1985, one year before the nuclear disaster in Chernobyl, Danish parliament passed a resolution excluding the construction of nuclear power plants in Denmark. Today, no nuclear power is generated in Denmark as a result, although it is imported from neighbouring countries. Overall, the government has adopted a positive – though cautious – approach to carbon capture and storage, arguing in the Energy Strategy 2050 that while "CCS technology is not yet commercially viable […] there is no reason to exclude this technology from being part of the Danish energy system at a later date" (**Danish Government, 2011a**). The first European CCS-pilot plant was opened at the Elsam coal-fired power station near Esbjerg in Denmark in March 2006 and a regulatory framework is in place, in accordance with EU rules on CCS. For the time being, however, there is little (political) activity on this topic and there currently appear to be no further projects planned

5.4 Market Demand

There are a number of important elements characterising the Danish housing market. Firstly, Denmark has a comparatively large share of detached houses, versus a low share of terraced or semi-detached homes (the 0 per cent by BZK is questionable, data from the Danish 2014 Statistical Yearbook would put the figure closer to 14.5 per cent) (**Statistics Denmark, 2014**). Secondly, the country has a high rate of social rental homes when contrasted to the other countries. Of particular interest is the large share of non-profit dwellings where low- and middle income households receive subsidised housing. The ratio of ownership vs. rental sector is about 50-50. Finally, around 75 per cent of the residential building stock was constructed before 1979, when the Danish building requirements were tightened for the very first time (**Thomsen et al., 2009, p.3**).

Table 4: Statistics Housing Market Denmark

Building Types (%)	
Detached Houses	59.2
Terraced Houses	0.0
Multiple-family	27.6
Other	13.2
Housing Types (%)	
Social Rental	48.7[9]
Private Rental	-
Ownership	50.5
Other	0.8
Empty	n.a.
Age Housing Stock (%)	
<1919	19.7
1919-1945	16.1
1946-1970	26.4
1971-1980	16.6
1981-1990	9.1
1990-2000	5.4
2000>	6.7

[99] Specified further as: 19.8% privately-owned, 41.5% non-profit, 13.6% Limited Liability Companies (LLCs) & cooperative societies, 15.8% housing societies, 3.6% public authorities, and 5.7% other or not-stated.

Sources: BZK (2013d); Statistical Yearbook Denmark (2014)

Household finances

With a share of over 30 per cent, living expenses take up a large percentage of disposable income (**BZK, 2013d**). Furthermore, the share of households spending more than 40 per cent of income on living expenses (incl. energy) is, with 62.8 per cent, by far the largest of the countries studied – the UK being a distant second with 47.6 per cent (ibid). Despite having high living costs, Denmark is said to have one of the lowest levels of fuel poverty in the EU (**Thomson & Snell, 2013**). It is argued, however, that research on the topic has been limited in Denmark (**Nierop, 2014**) and the country does not currently have an official definition of the term.

Denmark has one of the highest levels of 'green taxation' in the developed world, constant at around 4 per cent of annual GDP over the last thirty years (**Larsen, 2011**). It consists of three elements; energy taxes, taxes on motor vehicles, and environmental taxes. Although renewable energies were exempted from green taxation until the Energy Agreement of 2012, they are now included in the 'security-of-supply tax' mentioned above. Although no measurements of the exact influence of these taxes on energy consumption are available, the Danish Energy Agency is confident that they "have had a big influence" on consumers' behaviour (**ENS, 2012a**).

In 2011, the ratio of household debt to net disposable income was 330.8 in Denmark, down from an all-time high of 355.6 in 2009 but well above the OECD-average of 135 per cent and that of countries like Germany (108.8) and the United Kingdom (155.9) in the same year (**OECD, 2014**). While the Danish Central Bank argues there is no cause for concern as the debts are matched by "substantial assets" (**Danmarks Nationalbank, 2014**), it has prompted warnings from organisations such as the OECD and IMF. These concerns are strengthened further by uncertainties surrounding the Danish property market. In 2014, the Economist reported the share of Danish mortgages with long interest-only periods stood at 57 per cent, up from only 10 per cent a decade earlier (**The Economist, 2014a**). With some of these interest-only periods ending in the near future (typically ten years into the loan), monthly costs are expected to increase substantially for these homeowners, up to six times their current monthly payment (**The Copenhagen Post, 2013a**). Questions remain over their ability to repay or refinance these loans, with the number of homeowners unable to pay their mortgages reported to be increasing (**The Copenhagen Post, 2013b**). In February 2014, the Directorate-General for Economic and Financial Affairs of the EU published a report claiming that "the macroeconomic challenges in Denmark no longer constitute substantial macroeconomic risk" and the stability of the financial sector seemed guaranteed as a result of adjustments of the housing market (**European Commission, 2014**). Nevertheless, in September of 2014, the government announced a set of measures to address continued concerns, limiting sales of interest-only and adjustable mortgages and restricting the amount banks can refinance.

Access to finance

Financing-options are available to those households and individuals wishing to invest in energy efficiency and renewable energies. Subsidies and tax-deductions are available for a wide range of energy improvements. Additional financing options are available in the form of loans. G*røn boligkontrakt* offers loans up to DKK 250,000 (€33,000) at fixed or variable rates through Nordea Finance, with interest rates ranging from 6.7 to 9.6 per cent (**Grønboligkontrakt.dk, n.d.**). The height of these interest rates, coupled with already high levels of household debt, may be an important barrier preventing individuals from taking out a loan to invest in energy efficiency and renewable energy technologies.

6. Sectoral Analysis Germany

Today, the German term *Energiewende* has become internationally synonymous with the energy transition. With the nuclear phase-out and emphasis on renewable energies, Germany is often cited as being one of the front-runners of climate change policy in Europe. The Energiewende is high-up on the political agenda and attracts frequent media attention.

With respect to the built environment, the residential sector in 2011 accounted for 25.4 per cent of energy consumption and 11.9 per cent of greenhouse gas emissions (**IEA, 2013**) and together, public and private buildings are estimated to use around 40 per cent of total energy consumption for heating, hot water needs and lighting (**Bundesregierung, n.d.**).

The government has expressed its intention to achieve a near-energy neutral building stock by 2050 and introduced a variety of policies to try and achieve this. Two elements in particular make up the cornerstone of German policy; the expansion of renewable energy on the one hand, and increased energy efficiency improvements on the other. While significant achievements have been made to date, some important issues remain.

6.1 Actors, Interactions and Networks

As Germany is a federal state, power is divided between central government (Bundesregierung) and the regional states through Articles 70-82 of the Basic Law for the Federal Republic of Germany.[10] The federal government has exclusive jurisdiction over nuclear energy, but powers are shared with respect to nature conservation and landscape management, for example. While recognising the important role played by regional governments, this country profile largely focuses on federal policy and legislation so as to provide an overview of German policy as a whole.

The responsibility for the energy transition in the built environment lies primarily with two federal ministries, the Federal Ministry for the Environment, Nature Conservation, Building and Nuclear Safety (*Bundesministerium für Umwelt, Naturschutz, Bau und Reaktorsicherheit* – or *BMUB*) and the Federal Ministry for Economic Affairs and Energy (*Bundesministerium für Wirtschaft und Energie* – or *BMWi*) [11]. Ties between the two ministries are strong. They are in continuous contact and work together on strategic issues and documents. The Federal Environment Agency (*Umweltbundesambt*, or UBA), the main environmental protection agency, is tasked with gathering data in relation to the environment, makes projections and provides the relevant federal bodies with policy advice.

The KfW is the German government-owned development bank. Originally established in 1948 to finance the post-war reconstruction in Germany, the bank now stimulates issues such as development finance, project finance and provides credits to private individuals for e.g. home renovations and student-loans. Through a number of government programmes, the bank offers low-interest loans for energy-renovations of existing buildings and the construction of new energy-efficient homes [*KfW Förderprogramme für energieeffizienten Bauen und Sanieren*] (**BMUB, 2014a**).

[10] Revised version published in Federal Law Gazette, 1949, Part III, classification number 100-1, as last amended by the Act of 11 July 2012 (Federal Law Gazette, 2012, Part I p.1478).

[11] BMUB in its current form was established in Dec. 2013, when "Buildings" were added to the existing responsibilities. Before this, the Ministry was referred to as 'BMU'.BMWi, previously known as the Bundesministerium für Wirtschaft und Technologie, was renamed to include energy-issues at the same time.

The Federal Network Agency for Electricity, Gas, Telecommunications, Post and Railway [*Bundesnetzagentur*] is responsible for supervising energy supply network operators safeguarding competition and compliance with regulations(**Bundesnetzagentur, n.d.**). In addition, the *Bundesnetzagentur* is responsible for expansion of the electricity grid's infrastructure that needs to be increasingly capable of dealing with the inclusion of renewable energy into the grid.

Together, four big energy companies (RWE, E.ON, EnBW and Vattenfall, also referred to as '*Die Großen Vier*'), in 2010 held a 43.6 per cent share of the energy market, a considerable drop from 53.9 per cent in 2004 (**BDEW, 2013**). A multitude of smaller operators active in the German energy market are gradually increasing in number and importance. These include smaller (local) energy companies, energy cooperatives and a growing number of individuals who are able to feed their surplus energy back into the grid.

While Germany has a large rental market, there are few social housing agencies remaining since the privatisation of the rental market. Over 84.6 per cent of residential buildings is owned by individuals (**Statistische Ämter des Bundes und Länder, 2014**), resulting in a high fragmentation of actors in the residential sector. Construction and/or renovation in the residential sector often takes place through local companies in case of single-family homes, or bigger interregional companies for multi-family homes. Large-scale new-build projects are often divided into smaller parts for different companies.

6.2 Institutional Framework

Like the other countries, Germany also has a long-standing history in terms of national energy policy. The country introduced its first thermal insulation ordinance [*Wärmeschutzverordnung*] in 1977, which was subsequently renewed in 1984 and 1995, and replaced by the first energy-saving ordinance in 2002. In its 2010 Energy Concept, the Federal Government has committed to reducing primary energy-use in buildings by as much as 80 per cent by 2050 (**BMU, 2010**). After renewable energies, energy efficiency is now seen as the "second pillar" of the energy transition in Germany (**BMWi, 2014**a).

Looking at alternative forms of energy, Germany has actively promoted the production of renewable electricity within its borders, particularly since the introduction of the 'Electricity Feed-In Act' [*Stromeinspeisungsgesetz*] in 1991. Under European commitments, by 2020 at least 18 per cent of total final energy consumption is to come from renewable energy sources[12], translating to a 35 per cent share in electricity consumption (**IEA, 2013**). This section will in turn discuss Germany's current energy-saving and renewable energy policies.

6.2.1 Energy efficiency

In 2002, the first Energy Saving Ordinance (*Energieeinsparverordnung, EnEV*) came into force, merging and replacing two previous ordinances, the Thermal Insulation Ordinance (WSchV) and Heating Appliances Ordinance. It has been amended on a number of occasions, first in 2004, then in 2007, 2009 and most recently in May 2014. The latest amendment partly serves as the implementation of EU Directive 2010/31/EU, on the energy performance of buildings.[13] The EnEV sets requirements for the primary energy demand of new buildings, through heat insulation standards of the building envelope and through energy efficiency requirements for energy systems (e.g. heating or cooling systems, ventilation and light). The latest version includes a number of important amendments. From 2015, homeowners are no longer allowed to use

[12] EU Directive 2009/28/EC

[13] Bundesgesetzblatt (Federal Law Gazette), 2013, Teil I, Nr.67

oil- or gas-heating boilers installed before January 1, 1985. Boilers installed after 1985 have to be replaced after 30 years (Art.11). The energetic standard for new-builds will be increased as of January 2016, through around 25 per cent stricter requirements on annual primary energy demand and a 20 per cent increase in the thermal insulation of the building envelope (**BMUB, 2013**). Responsibility for enforcement of the Ordinance lies with the federal states.

Energy efficiency programmes

In 2007, the coalition government of CDU/CSU and SPD introduced the Integrated Energy- and Climate Programme (IEKP), aimed at further expansion of renewables and increasing energy efficiency. The programme includes a renovation programme (*CO_2-Gebäude-sanierungsprogramm*) and Renewable Energies Heat Act (*EEWärmeG*) aimed at increasing the share of renewables used for heating from 6 per cent recorded in 2006, to 14 per cent in 2020 (**BMWi, 2007**). The renovation programme is the centrepiece of the German central Government's energy-saving measures (**Bundesregierung, n.d.**). Recognising that existing measures were insufficient to reach the formulated goal, the federal government reinforced the CO_2-building-renovation programme to include support for two KfW-support proframmes: '*Energieeffizient Bauen'*, aimed at builders of new properties, and '*Energieeffizient Sanieren'*, aimed at homeowners to stimulate energy-renovations of existing buildings. Through these programmes, private persons and businesses are eligible for low-interest loans (from 1 per cent annual interest), with a value of up to €75,000 for private persons. Between 2006 and 2011, the Federal Government allocated around €7.8 billion to the CO2-renovation programme, reportedly triggering around €94 billion worth of investment from the market, enough to construct or renovate 2.7 million homes (**BMVBS, 2013**). By the end of 2014, this number was reported to have increased to over 3.8 million (**BMWi, n.d.**). On-site renovation advice ["*Vor-Ort-Beratung"*] is currently available for owners and tenants of existing dwellings for buildings constructed before January 31, 2002, with BMWi paying up to 60 per cent of the costs of the advice (**BMWi, 2015**).

In 2010, the Government, now made up of CDU/CSU and FDP, presented an Energy Concept (*Energiekonzept*) formulating scenario-based guidelines for a clean, reliable and affordable energy supply. The concept sets out a number of goals for (1) the reduction of greenhouse gas emissions, (2) further expansion of renewable energies, and (3) increased energy efficiency (**BMU, 2010**). Section E of the *Energiekonzept* – on energy renovations of existing buildings and energy-efficient construction – sets out the central goal of achieving a next-to-neutral building stock by 2050, where buildings have a limited energy requirement and the remaining demand is to be met through renewable energies (**ibid**). To achieve this, the government sets out the goal of doubling the annual renovation-rate from 1 to 2 per cent, with an evaluation of the policy scheduled in 2020. The German Institute for Economic Research (DIW Berlin) has estimated that the most recent savings are insufficient, with the current rate of refurbishments remaining below the target level, and argues that more "clear and reliable framework conditions are needed" to increase the renovation rate (**Blazejczak et al., 2014, p.14**).

Speaking at an Energiewende conference in Berlin in November of 2014 the State Secretary at BMWi, Rainer Baake, stated that energy efficiency will come to the forefront more in the future. In December 2014, BMWi published the long-awaited National Action-Plan for Energy Efficiency (NAPE), tying together the goals, instruments and responsibilities in one clear document. Immediate actions in the action-plan include tax-incentives for energy-renovations and further strengthening of the renovation programme (**BMWi, 2014a**). An overarching renovation strategy [*Energieeffiziensstrategie Gebäude*], describing the renovation requirement in the total building stock, and measures to attain the goals set out, is currently being developed and expected to be announced in November 2015 (**BMWi, 2014b**).

Targeting the split-incentive

In May 2013, the government introduced changes to the existing landlord/tenant laws (*Mietrechtsänderungsgesetz*). Under the new rules tenants can no longer claim rent reductions for inconveniences such as noise caused by energy-efficient modernisation of the property during the first three months of construction, to make the process easier for landlords. Landlords still carry the costs for renovation, however. Tenants on the other hand, experience the benefits of improved insulation and modern heating systems through lower heating costs, reducing their overall cost-of-living. The new changes allow landlords to increase the rent following energetic modernisation, adding 11 per cent of the costs to the annual rent.[14] Tenants must accept the renovations, unless they are able to successfully claim financial hardship, in which case the interests of tenants on the one hand must be weighed against those of the landlord, energy efficiency and climate protection on the other. Tenants have a one-month period after the initial announcement to make public any such hardship, after which modernisation cannot be stopped on these grounds. The German Rental Association or *Deutscher Mieterbund* (DMB) strongly criticised these changes, announcing they contributed to little more than an abolition of tenants-right and that the measures would fail to meet the goal of improving the renovation-rate (**DMB, n.d.**).

[14] Bundesgesetzblatt, 2013, Teil I, Nr.13

6.2.2 Renewable energy

As early as 1991, the German government adopted the "Electricity Feed-In Act" [15], in German *Stromeinspeisungsgesetz,* obligating electricity providers to purchase the renewable energy produced in their area of operations at a set price, with rates varying from 65 to 90 per cent of the average tariff for final customers (**Lipp, 2007**). In 2000, this was followed and replaced by the first *Erneuerbare-Energien-Gesetz* (EEG), or Renewable Energy Act. The EEG regulates the preferential treatment of the supply of electricity from renewable sources into the German energy grid, and guarantees producers fixed feed-in tariffs. The goal of the Act[16] is to enable the sustainable development of the energy supply and significantly increase the share of renewable energies in Germany. Adjusted several times since its introduction the EGG remains the main policy-instrument for renewable energy.

The Renewable Energy Act

Rather than expressing compensation in terms of average tariffs, new rates are determined for each technology and fixed for 20 years. The amount of remuneration for each technology is set out clearly in Art.4-8, with each one receiving a different guaranteed price based on the costs of generation for that specific technology. Remuneration-rates are set at 8.9 ct/kWh for onshore wind in the first five years, then going down to 4.95 ct/kWh, and 9.23 ct/kWh for solar-PV. As of January 2016, only production capacity of under 100MW will be considered small-scale, a considerable drop from the current level of 500MW. The tariffs are lowered regularly to encourage increased efficiency. Following the 2014 revision[17], the EEG

[15] Bundesgesetzblatt, 1990 Teil I, Nr. 67, Seite 2633
[16] Bundesgesetzblatt, 2000 Teil I, Nr.13, Seite 305
[17] Bundesgesetzblatt, 2014, Teil I, Nr.33, Seite 1066

now aims to reach 40-45 per cent renewable electricity by 2025, and up to 55-60 per cent in 2035. To cover the costs of the scheme, consumers are required to pay a surcharge (a so-called *EEG-Umlage*) on their electricity consumption. Since its introduction, the surcharge has increased from 0.19 cents/kWh to 6.24 cents/kWh in 2014 (**Mayer & Burger, 2014**). This charge in considered a tax, not a subsidy, as they are paid for entirely by consumers, thus avoiding breaking EU-regulation on state-support and competition.

The 2009 revision[18] introduced a special compensation for energy-intensive companies (Section 2, Art.40-44), reducing energy costs for these companies and railways to ensure their continued international competitiveness. In 2012, the Bundesnetzagentur published an evaluation of the compensation-mechanism regulation in which they expressed their concern over the privileged status of these companies, arguing that while they used 18 per cent of total energy consumption in 2012, they only paid 0.3 per cent of the total surcharge (**Bundesnetzagentur, 2012**). The distribution of costs between energy-intensive industry, consumers and small-and-medium sized enterprises continues to be a contentious issue at the time of writing.

The Renewable Heat Act

Another important policy is the previously mentioned *EEWärmeG*[19], aimed at stimulating the production of heat from renewable resources. The Act obligates owners of newly constructed dwellings with a surface of over 50 square-meters to obtain a share of the building's energy needs from renewable sources (Art.3), ranging from at least 15 per cent when using solar to 50 per cent for geothermal and ambient heat (Art.5). The obligation could be avoided in a number of circumstances, e.g. when at least 50 per cent of heating is derived from CHP or when the building's energy efficiency-level is at least 15 per cent higher than the EnEV requirements (Art.7). Regional states are further reserved the right to introduce a similar renewables obligation for the use of renewable energies in already existing buildings.

6.2.3 Non-policy

The previous section already touched upon some important issues. Overall, the government is taking a pro-active role in the energy transition and built environment. Consecutive governments have set out clear policies and regulatory frameworks and regularly revised them to tackle important issues. Germany has pursued an integrated overall strategy and from the onset, it has recognised the need to link renewable energies to increased energy efficiency in its policies. Despite changes in Government, no radical policy-shifts have taken place. CDU/CSU have been one of the leading parties throughout the time period investigated, a fact that has most likely had a positive impact on policy stability. **Lipp** (**2007**) identified potential factors for the success of renewable energies as being: the successful role the feed-in-tariff has had in terms of installed capacity, the policy's success in job creation, and the institutional arrangements – with the renewable energy portfolio in the hands of the BUMB.

There are, however, some important concerns. Firstly, consumers have so far carried the costs of the EEG, with heavy industry exempted from much of the surcharge (**IEA, 2013; The Economist, 2014b**). In September 2014, the newspaper *Frankfurter Algemeine* published answers from the Government to the Greens, acknowledging that since 2008, the costs for consumers had gone up by 38 per cent, while industry only paid an extra 13-15 per cent and energy-intensive energy had actually seen its energy-costs lower by around 1 per cent (**Frankfurter Algemeine, 2014**). The advantaged position of industry has come under increasing pressure in recent years, igniting

[18] Bundesgesetzblatt 2008, Teil I, Nr.49, Seite 2074
[19] Bundesgesetzblatt, 2008, Teil I, Nr.36, Seite 1658

a strong political debate in Germany about the costs of the Energiewende. Secondly, despite large sums of money invested by the Government, the renovation rate remains below the 2 per cent target. Furthermore, it has been noted that, instead of undertaking deep renovations, building owners focus on the urgent minor repairs as a result of which renovation will need to take place again in the near future (**Energytransition.de, n.d.**).

In addition to the cost-related issues, (renewable) energy policies have created a number of significant grid-related problems. These will be discussed in more detail under the technological regime.

6.3 Technological Regime

With over 170GW of installed capacity in 2011, Germany has the largest electricity market in Europe (**IEA, 2013**). The power-sector is heavily dependent on fossil-fuel powered power stations such as coal-, brown-coal, gas-plants, and nuclear power-plants. With a share of 45.1 per cent, coal is the most-used source for electricity generation, followed by nuclear energy (17.9%), and natural gas (13.9%) (**Weiß, 2013**). In January 2014, the Financial Times reported that in 2013, the use of brown coal for electricity production had risen to its highest level since German reunification in 1990 (**Financial Times, 2014a**). A recent report by the Climate Action Network furthermore mapped the 30 most CO_2-polluting thermal power plants in the EU, dubbed the "Dirty 30", and found that the UK and Germany each have nine of the most polluting plants in Europe, with two plants reaching places two and three respectively (**Climate Action Network, 2014**). The report also found that, due to the relatively low price of coal compared to gas, many of the EU's coal-fired plants are running at full or near-full capacity. A number of cleaner gas-fired power plants have permanently or temporarily been taken offline in recent years. Renewables nevertheless played an important role in electricity generation, particularly wind (8.1%), biofuels and waste (7.3%), solar (3.7%), and hydro (2.9%) (**ibid**).

The nuclear phase-out

In 2000, the German government announced its intention of phasing-out nuclear energy in Germany, the so-called *Atomausstieg*, or nuclear phase-out, over a thirty-two year period. Following the Fukushima nuclear disaster in March of 2011, the German government announced a three-month moratorium on eight nuclear power plants. In June of the same year, the German Bundestag voted on the thirteenth amendment of the Atomic Energy Act, with a vast majority (513 out of 600 votes cast) in favour of speeding up and completing the nuclear phase-out by 2022. RWE and EON have both taken the federal government and several states to court to demand compensation for the three-month shutdown of some of their nuclear facilities and are suing for damages caused by the nuclear phase-out.

It has been argued that the decline of nuclear energy "has left a gap that only fossil fuels could fill quickly" (**Financial Times, 2014a**). The 2013 IEA Report noted that, in one of the biggest waves of investment since the post-war reconstruction, several large new coal-fired power plants are currently under construction, with a technical lifespan until at least 2050 (**IEA, 2013**). A Greenpeace report illustrates how, in the past few years, German companies like Vattenfall, E.ON and RWE have invested in large new coal-fired power plants (**Dallos, 2014**). Agora Energiewende, a think-tank concentrating on the electricity sector in Germany, argues that, rather than constituting a 'Coal Renaissance', the wave of investment is largely the result of a favourable market environment in 2007/2008 and an inability or reluctance of developers to cancel projects in light of changed circumstances (**Graichen, 2013**). Nevertheless, large investments made by the major energy companies and long technological lifespans of the new production capacity are likely to lead to pressure on the decision-making process.

Citizen-led growth of renewable energy
Alongside these developments, the share of renewables in the energy-mix has increased rapidly in recent years. The Feed-in-Tariffs have proven highly successful in stimulating the pick-up of these measures and are often cited internationally. Where renewable energies accounted for 5 per cent of energy produced in 1999 – hydro-power making up about 80 per cent of this –this share had increased more than four-fold to 20.5 per cent by 2011 (**Weiß, 2013**). In 2013, renewable energies accounted for 25.3 per cent of gross electricity-use (**AGEB, 2014**). The EEWärmeG discussed previously aims to achieve similar progress in relation to heat production. The German government considers solar- and wind-energy as the main energy-carrier technologies on which to focus, with biomass, hydropower, and geothermal energy considered valuable additional elements.

Out of the 73GWh renewable energy capacity installed in 2012, around 47 per cent originated from citizen-led initiatives (**Agentur für Erneuerbare Energien, 2013**). About 2000,000 members hold shares in 800 renewable energy cooperatives, 90 per cent of which are private citizens and participate with an average of €3000 (**Wieg, 2013**). Together, they produced around 580 million kWh of clean energy (**ibid**). For this reason it has been argued that it is not the traditional energy providers, but private citizens, farmers, and energy cooperatives who form the backbone of this part of the Energiewende. Germany's Federal Building Law, while allowing local communities to define certain zones for wind-energy parks, forbids them to refuse wind turbines altogether on their territory (**Jobert et al., 2007**). This could be an important factor in fostering local social acceptance among the area's residents.

Technological difficulties
The rapid diffusion of renewable energies in the German energy grid has not come without its share of problems. There is currently an overcapacity on the German energy market, with the large energy providers heavily invested in fossil fuels. RWE in particular, appears to be struggling in the current market-place, recording a loss of €2.76 billion in 2013, its first full-year loss in 60 years. The traditional business-model of the big energy companies is under significant pressure and several energy companies have (temporarily) taken production capacity offline. The cheap price of coal, as compared to gas, has meant that more coal was used for the production of electricity, causing German CO_2-emissions to increase in both 2012 and 2013, despite a mild winter in the latter year (**Umweltbundesamt, 2014**). Furthermore, the large inflow of RE's at certain times has led to instability in the German grid during these peak-times, putting a downwards pressure on already-low prices. Exports to neighbouring countries such as France, the Netherlands and Poland have increased recently in recent years, effectively causing German consumers to pay for this through the EEG-Umlage. This in turn has led to the closing of much cleaner gas-fired facilities in the Netherlands and increased the risk of blackouts due to oversupply in countries like Poland. To guarantee continued grid-stability in the face of increasing shares of renewables, the federal government has made plans to modernise the electricity-network, with investments totalling an estimated €10 billion over the next ten years.

Germany is currently in danger of missing its 40 per cent greenhouse gas emission reduction target by 2020. While voices, even within the government, have gone up to withdraw the target, the Climate

Package decided on by the Cabinet in December 2014 continues to uphold this figure (**BMUB, 2014b**). It is unclear whether Germany can meet its CO_2-reduction targets under the current conditions without nuclear energy or CCS. The power of approval or rejection lies with the *Landesbehörden*, the authorities of the individual states. According to the German Energy Blog, the issue had been "hard fought over" between states with potential storage sites, but opposed to CCS, and states that favour testing the technology (**German Energy Blog, n.d.**). Overall, public support for CCS appears to be lacking, and projects have proven costly, rendering it unlikely Germany will be able to rely on CCS to meet its shorter-term climate targets.

Electricity market reform

An active discussion is currently taking place on the design of the German electricity market. In July of 2014, the BMWi published two studies discussing the design of the energy market, one dealing primarily with the current "Energy-Only Market" (EOM), and the other discussing the possible introduction of so-called "Capacity Reliability Mechanisms" (CRMs) where the operators of power-plants are provided with a minimum payment in return for guaranteeing a minimum level of capacity. While this discussion remains open, the overall conclusion of these reports was that, for now, the current EOM remains sufficiently able to guarantee security-of-supply for end-users and that capacity mechanisms are not suitable for achieving secondary goals such as the reduction of CO_2-emissions or a lowering of prices for consumers (**R2B, 2014**).

6.4 Market Demand

The housing market is characterised by a large degree of stability. Contrary to that of other countries, it came through the crisis and its aftermath relatively unscathed. The country has a relatively low rate of homeownership when compared to the other countries. Viewed from a historical context, the post-war reconstruction effort saw the large-scale construction of social housing projects to provide affordable shelter to large scores of people who had been displaced during the war (**Voightländer, 2009**). Strict rent controls were imposed to ensure they demanded a rent based on costs. This strong emphasis on protection of the tenants by law is still present in post-liberalisation rental policies today. Furthermore, through the system of *Bausparen* in Germany, banks are often only permitted to lend out 80 per cent of the value of the property, the remaining 20 per cent having to come from savings. Overall, this is a solid financing system and while there are some signs to suggest that house prices in the biggest cities are overvalued by as much as 25 per cent (**Financial Times, 2014b**), there does not appear to be a housing market bubble in the German market. Overall, there is a relative long-term price stability, with house prices remaining relatively flat in Germany over the 2000-2006 period, while booming in countries such as the UK and Spain (**Voightländer, 2012; Just, 2008**).

Table 5: Statistics Housing Market Germany

Building Types (%)	
Detached Houses	28.8
Terraced Houses	16.1
Multiple-family	53.6
Other	1.6
Housing Types (%)	
Social Rental	n.a.
Private Rental	48.8
Ownership	40.8
Other	2.2
Empty	8.6
Age Housing Stock (%)	
<1919	14.4
1919-1945	13.6
1946-1970	46.3
1971-1980	-
1981-1990	13.2

1990-2000	9.2
2000>	3.3

Sources: BZK (2013d); BMVBS (2013) [20]

[20] Bundesministerium für Verkehr, Bau und Stadtentwicklung, since December 2013 Bundesministerium für Verkehr und Digitale Infrastruktur (BMVDI)

Housing market

In a report on the housing- and real estate market in Germany, the BMVBS characterises the housing- and real estate market to be a key pillar behind the economic power of Germany, (**BMVBS, 2013**). It further notes that around half of private household capital is invested in real estate. Private persons own around 84.6 per cent of residential buildings and 58.4 per cent of dwellings (**Statistische Ämter, 2014**). This is reflected in the rental sector, where small-scale providers control around 61 per cent of all rental properties (**BMVBS, 2013**). Following the construction-boom in the first half of the 1990s, a reduction in construction activity has taken place. While intensified by the economic crisis between 2007 and 2009, a trend-break is now clearly visible with construction activity increasing in some parts of the country as a result of an increase in demand. Demographic prognoses, however, predict a substantial negative population growth over the course of the next 50 years, coupled with a rise in the share of elderly people (**ibid; BZK, 2013d**) and these are likely to have important implications on future policy.

The housing stock

A 2011 census found that the majority of the 18 million residential properties are single-family homes, accounting for around 65 per cent of buildings, another 17 per cent are made up of two-family homes and the remainder consist of three residences or more (**Statistische Ämter, 2014**). Large multi-family buildings (made up of seven or more homes) only accounted for around 6 per cent of total building stock. The census also found residential buildings in former East-Germany to be older on average, and that buildings constructed between 1950 and 1989 consisted of an average of 3.6 homes, compared to 2.1 homes in the west of the country. Thus, some distinctions between east and west continue to be visible in some respects.

Around three-quarters of the building stock is estimated to date from before 1978, when the first Heating Act (*Wärmeschutzverordnung*) was introduced (**BMVBS, 2013**). While some of these homes have been renovated over time, the energetic standard is often below today's norms. In 2013, German homes largely relied on gas (49.2%), heating-oil (28.8%), and district heating (12.9%), and to a smaller extent on electricity (5.3%) (**Statista, 2014a**). A large percentage of oil- and gas heaters was installed between 1991-1997 (43.9 per cent and 49.6 per cent respectively), and 1998-2010 (32.1% and 34%) (**Statista, 2014b**). While the quality of the housing stock is regularly said to be of a good standard, sufficient room for improvement thus remains.

Household finances

Figures by the Federal Statistical Office (*Statistisches Bundesamt*) show that on average, the share of household income spent on housing, energy, and maintenance equated to about 34.4 per cent of consumer expenditure (**Alter et al., 2013**), with 75.8 per cent of households considering these living expenses some or a large financial burden. Energy-poverty does appear to is increasingly become a concern for many German households. Figures by the Government show that the share of energy-poor households increased from 13.8 to 17 per cent between 2008 and 2011 (**Der Spiegel, 2014**), about one-in-six of all German households. Prices have increased sharply since 2000, with the price of electricity (199%) and gas (177%) nearly doubling between 2000 and 2013 (**Deutsche Umwelthilfe, 2013**).

Wage-increases have failed to keep up with increased prices, placing a particularly high burden on already struggling lower-income households. Energy companies who have failed to redistribute falling purchase prices for electricity over the last six years to their end-consumers. This issue could become more important in the coming years.

7. Sectoral Analysis United Kingdom

Originally the home of the industrial revolution, the UK has relied heavily on fossil fuels for most of its energy needs. Today, as the result of its large financial- and services sector, coupled with a low share of energy intensive industry, energy use per unit of GDP in the United Kingdom is one of the lowest among IEA member countries (**IEA, 2012**). Characterised by a strongly liberalised market, with a strong focus on cost-effectiveness and competitiveness, the UK has laid out plans to become a low carbon country (**HM Government, 2009**).

With respect to the built environment, the UK has one of the oldest building stocks in Europe. In 2010, the residential sector accounted for 32 per cent of total final energy consumption and households were responsible for around 17 per cent of greenhouse gas emissions (**IEA, 2012**). Final energy consumption in this sector actually increased by 2 per cent since 2005 and is considerably above the 20 per cent EU average.

In 2008, the UK adopted the Climate Change Act, introducing a long-term framework, setting out a legal commitment to reduce greenhouse gas emissions by at least 80 per cent below 1990 levels by 2050, as well as an interim target of 34 per cent reduction by 2020. Upon taking office in 2010, Prime Minister David Cameron announced the intention that his Coalition Government would be the "greenest government ever" (**Cabinet Office, 2010**). A wide range of measures are in place with respect to energy efficiency and renewable energy in the residential sector, inluding the so-called "Green Deal" and "Energy Company Obligation". At the same time, however, the government heavily cut back on energy efficiency measures and is at risk of falling behind on its 15 per cent renewable energy target by 2020 (**EEA, 2015**). Furthermore, the government is facing significant resistance from at home, over its controversial promise to go "all out" on fracking, and from abroad as Austria has lodged legal proceedings against the European Commission over a £17.6 billion subsidy for a new nuclear power station, something which it considers to be illegal state aid (**The Guardian, 2015**). Taking all these factors into account, the energy transition in the UK certainly warrants closer scrutiny.

7.1 Actors, Interactions and Networks

Like the Netherlands and Denmark, the United Kingdom is a constitutional monarchy with a bicameral legislature. The political system consists of multiple parties, with the Conservative Party and Labour Party being the dominant political parties. At time of writing, the country had a coalition government made up of the Conservatives and Liberal Democrats. While some powers have been devolved to the governments of Scotland, Wales and Northern Ireland, others remain based in Westminster. Scottish Parliament, for example, has the power to make laws concerning the environment and housing, while energy issues are reserved for UK Parliament.

The energy transition in the built environment mainly involves three separate ministries: The Department of Energy and Climate Change (DECC) is the main ministry responsible for energy- and climate change policies and the energy infrastructure, including renewable energies. The Department for the Environment, Food and Rural Affairs (Defra) is responsible for policy and regulations on sustainable development and the green economy. Finally, the Department for Communities and Local Government (DCLG) carries responsibility for the English housing market, including the rental sector, building regulations and increased energy efficiency. Her Majesty's Treasury is the government's finance ministry, overseeing economic policy and government spending. Each of these departments is supported by a number of agencies and public agencies, ranging from eight for DECC to as much as thirty-five for Defra. Most of the regulatory power lies with the central government, with limited responsibilities devolved to local councils.

In November 2012, the UK Government set up a Green Investment Bank, investing an initial £3.8billion of public funds, using this money to "back green projects on commercial terms and mobilise other private sector capital into the UK's green economy" (**UK Green Investment Bank, 2014**). Investment sectors include offshore wind, energy efficiency, waste and bioenergy, and "others" – such as CCS, marine energy and biofuels – that the Bank currently monitors but does not expect to "make any significant investments in projects in the near term" (**ibid, n.d.**). Solar-energy is thus not considered a commercial investment opportunity.

National Grid, a privately-owned company, owns and manages the electricity grid in England and Wales while Scotland has its own network. The UK's energy suppliers use this transmission grid to deliver electricity to its customers. Six providers, the so-called 'Big Six' (British Gas, EDF Energy, E.ON UK, npower, Scottish Power, and SSE) currently hold a dominant position on the UK's electricity market. The Office of Gas and Electricity Markets (Ofgem) is a non-ministerial government department tasked with protecting the interests of both existing and future electricity and gas consumers. As allegations of price-fixing have regularly surfaced in recent years, Ofgem has referred the retail energy market to the Competition and Markets Authority (CMA) to "establish if there are market failures which are having an adverse effect on competition" what impact the "incumbency" has on competition and whether coordination has taken place between the six large suppliers (**Ofgem, 2014a**). Initial findings by the CMA suggest no wrongdoing by the big energy firms (**CMA, 2015**). Nearly one thousand renewable energy companies are represented in the Renewable Energy Association.

The construction industry is characterised by a high degree of fragmentation and low levels of innovation (**Department for Innovation & Skills, 2013**) and counts over 280,000 businesses and 2.93 million jobs. The construction of private housing was reduced significantly by the 2008-crisis.

Following privatisation, only a small social-rental sector remains in the UK, with housing allocated according by local councils. Social housing is owned by registered providers, often local authorities or non-profit housing associations. While commercial organisations are entitled to build and manage social housing, this is not currently common practice. Social housing is regulated and DCLG oversees the correct implementation of the rules. A number of private landlord-, tenant- and homeowner organisations represent the interests of these various groups.

A number of non-governmental and charitable organisations such as Carbon Trust, Energy Saving Trust, UK Green Building Council, and Greenpeace UK are working with governments, businesses, other organisations and households, offering their expertise and advice on a range of issues such as increased energy efficiency and carbon reduction.

7.2 Institutional Framing

As was the case in other European countries, the oil-crisis of 1973/74 had an important impact on British society, raising the status of energy policy in the UK and leading to the establishment of a separate government ministry for energy issues, the Department of Energy (**Pearson & Watson, 2012**), thereby moving responsibility away from the

Department of Trade and Industry (DTI) that had been responsible for energy policy until that point. The department was abolished in 1992 following the privatisation of gas and electricity, when its main energy functions were transferred back to DTI and market regulation was passed off to Ofgem (**ibid**). The current Department for Energy and Climate Change was established in 2008 to "take the lead across government for tackling climate change and securing clean, safe and affordable energy for the UK", bringing energy- and climate policy together in one department (**Cabinet Office, 2009**). In compliance with EU Energy Efficiency Directive 2012/27/EU, the UK released its first National Energy Efficiency Action Programme in April 2014. This document details the progress made on energy efficiency, and current actions being taken to realise its ambitions.

A recent book titled 'The Energy Security-Climate Nexus', argues UK energy politics is characterised by internal tensions and three different, sometimes contradictory, perspectives on energy: a security of supply perspective, climate change perspective, and a pro-market perspective (**Kuzemko, 2013**). Where both Conservative and New Labour politicians have previously actively sought to remove energy from politics, making it an 'economic' subject and normal commodity product (**ibid, p.48**), a series of events has highlighted market failures and the vulnerability to an unstable foreign supply. This tension is clearly visible throughout the policy and non-policy dimension.

7.2.1 Energy efficiency

The first building regulations for new buildings were introduced in the Building Regulations of 1965, prior to the establishment of the new Department of Energy. The Building Regulations of 1976 first introduced requirements for energy conservation in existing homes and stricter standards have been introduced on several occasions over the years. The Building Act 1984 remains the primary legislation under which Building Regulations and other (secondary) legislation are being made in England and Wales. Scottish building regulations are set out in the Building (Scotland) Act of 2003. Consecutive amendments to the Building Act of 1984 have gradually introduced stricter standards over the years.

Building regulations consist of thirteen parts (A-P), where Part L is of particular relevance as it covers the conservation of fuel and power in new (L1A) and existing dwellings (L1B), as well as other buildings (L2A and L2B). The latest version of L1B was published in 2010 (**HM Government, 2010**), with further amendments coming into force in 2013 and 2014. Listed buildings, monuments and dwellings in designated conservation areas are exempt from these energy efficiency requirements only to the extent that compliance with requirements would "unacceptably alter the character or appearance" of the dwelling (**ibid, p.8**). Building standards are set to be "progressively tightened" in the move towards the introduction of a Zero Carbon Homes Standard for new homes by 2016 (**Committee on Climate Change, 2014**).

Building standards new homes

In its 2006 consultation document 'Building a Greener Future', the UK Government announced the introduction of a 'Zero Carbon Homes Standard' for all new homes from 2016 (**DCLG, 2006a**). At the same time, it published a 'Code for Sustainable Homes', a voluntary set of standards for new homes. The code provides nine measure of sustainable design, ranging from energy/CO_2, the use of materials, and waste during the building process to the health and well-being of the workers on site and management. It uses a 1 to 6-star rating-system. The definition of a Zero Carbon Home, when first introduced, was a home achieving Level 6 of the Code for Sustainable Homes and included emissions from regulated energy use (e.g. space heating, hot water) and unregulated energy (e.g. appliances and cooking). The 2011 budget watered down this commitment by excluding unregulated energy use from the definition (**HM Treasury, 2011**), which account for between a third and half of household emissions.

Building standards for new homes were to be progressively tightened in the run-up to the Zero Carbon standard; first to a 25 per cent improvement in the energy performance requirement in 2010, to 44 per cent in 2013, and finally, towards zero carbon in 2016, where annual net carbon emissions from energy use in the home would be zero (**DCLG, 2006a**). The original definition suggested a 70 per cent reduction in emissions compared to current homes through high energy efficiency and on/near-site renewables, with the remaining 30 per cent supplied by directly connected renewables. The coalition government watered down the 70 per cent requirement, aiming at "striking a balance between zero carbon goals and the stimulation of growth in the house building industry" and introduced the concept of 'Allowable Solutions', off-site options for carbon reductions (**House of Commons, 2013**). In 2013, the UK government made a number of amendments to Part L of the Building Regulations, watering down non-residential improvement commitments down from 20 to 9 per cent and requiring non-domestic buildings to follow the Zero Carbon standard from 2019, three years later than originally proposed so as to "reduce unnecessary burdens on industry" (**HM Government, 2013a**).

A document accompanying the Queen's Speech of 2014 confirmed that the government continues to be committed to implementing the standard for homes from 2016, but added that small sites – the definition of which is yet to be concluded but may include all sites below 50 homes – will be exempt from the zero-carbon requirement (**Queen's Speech, 2014**). This could potentially exempt a large number of dwellings. The Government's policy towards new homes thus appears to be wavering, and consecutive amendments to the original proposals will most likely result in less emissions reductions being achieved overall.

Policies for existing homes

With respect to already existing homes, the UK government has in recent years in simultaneously introduced a range of policies to stimulate reductions in energy use among households. In 2011, The UK Government launched the Green Deal Programme and Energy Companies Obligation (ECO) to replace the previously existing 'Carbon Emissions Reduction Target' (CERT) and 'Community Energy Saving Programme' (CESP)[21]. At the time, then Climate Change Minister Greg Barker announced the scheme would be "the biggest home improvement programme since the Second World War shifting our outdated draughty homes from the past into the future" (**DECC, 2011b**). ECO places a legal obligation on the large energy suppliers to deliver energy efficiency measures to domestic energy users and reduce overall emissions, through the Carbon Emissions Reduction Obligation – focusing in particular on solid wall insulation and hard-to-treat cavity walls. An initial emissions-reduction target was set of 20.9Mt CO_2 by March 31, 2015, with an additional 6.8 MtCO_2 to be saved through the Community Obligation, directed at low-income areas (**Crown,**

[21] The CERT (2008-2012) required all domestic energy suppliers with over 250,000 customers (the "Big Six") to reduce the CO_2 emissions of households, usually through the installation of insulation (**DECC, 2011c**). The CESP (2009-2012) was a policy specifically targeting the most deprived, i.e. low income areas across Great Britain, requiring gas- and electricity suppliers and electricity generators to deliver energy saving measures equating to 19.25m tonnes CO_2 in households in these areas by December 2012 (**Ofgem, 2013a**).

2012). The programme is designed in such a way that individual customers do not pay for the renovations directly, with costs being passed on to all consumers through their energy bills. At the end of 2013, the Government lowered the Carbon Emissions Reduction Obligation target for March 2015 by thirty-three per cent, to 14 $MtCO_2$ (**DECC, 2014a**) in an attempt to bring down energy bills for consumers. While a formal evaluation is not expected until after the end of the first period, ECO has been criticised by industry for being overly expensive, and by energy poverty groups as not doing enough to help those most in need. The scheme has been extended to March 2017 and the revised regulations will consider "easy to treat" measures such as standard cavity wall and loft insulation and district heating to be eligible under the scheme (**ibid, 2014b**).

Green Deal programme

Through the 'Green Deal' scheme, households can pay for energy-saving improvements such as insulation, double glazing, and the installation of a new boiler or microgeneration, such as solar-panels by taking out a loan, with the loan being repaid through savings on energy bills (**ibid, n.d.**). To be eligible for these loans, households must undergo a so-called Green Deal Assessment in which homeowners receive an EPC-rating for their home, assessment of their energy use, and a recommendation of which improvements could carried out. The "Golden Rule" is that the costs of renovation must always be less than the expected savings from the retrofit (**ibid, 2011c**). The assessment must be carried out by a certified Green Deal assessor, who must notify customers of their fee in advance, typically costing between £75 and £125. If households choose to have energy-saving measures installed, financing instruments are available.

A Green Deal Finance Company (GDFC) was set up as part of a new financing framework which lends money to so-called Green Deal Providers. There are currently over fifty such companies. Consumers cannot borrow directly from the GDFC and interest rates are around 9 per cent. Furthermore, the loan is attached to the property, not the individual, so that anyone moving into a property having undergone a Green Deal renovation will have to take over the loan. In addition to these loans, households may be eligible for an "incentive payment" through the Green Deal Home Improvement Fund (GDHIF). The Government launched the scheme in May 2014 in order to boost the Green Deal programme, the pick-up of which had been considered disappointing up until then. As part of the GDHIF, households would be able to claim back up to £7600 for energy efficiency improvements on their home.[22] On July 24, 2014, DECC promptly closed the scheme to new applicants due to overwhelming public demand, indicating that the £120m available had been depleted. In December, DECC released the first £30m of the £100m second phase for the GDHIF. Of this, £24m was reserved for solid-wall insulation, and the remaining for energy efficiency upgrades. Households can claim for a maximum of £5,600 (**DECC, 2014c**). Just a day after re-opening the budget, the government was again forced to close the scheme to applications to the budget earmarked for solid wall insulations as the budget had been depleted.

The Green Deal has widely been critiqued. A recent report by Members of Parliament judged the scheme a "disappointing failure in its first eighteen months" (**House of Commons, 2014a, p.3**). Uncertainty and insecurity, a lack of flexibility and clarity, frequent changes and high borrowing costs were identified as important barriers for successful

[22] £1000 for installing two measures from an approved list, up to £6000 for installing solid wall insulation, up to £100 for their Green Deal Assessment and up to £500 to those who bought a property in the 12 months prior to the application (**Gov.uk, 2014**).

implementation (**ibid**). By the end of August 2014, 326.884 Green Deal Assessment-requests had been lodged, with 940.000 measures installed in around 778.000 properties, 98% of which was delivered through ECO (**DECC, 2014d**). From those households that had lodged for an Assessment, only 4.737 actually had a Green Deal plan in progress, 2.092 of which were 'live' in that they had all measures installed (**ibid**). While hailed as a success by Under Secretary of State for Energy & Climate Change, Amber Rudd, others critiqued the stop-and-start nature of government policies, noting that these are not helpful to industry and left many people out of pocket after having paid £100 for a Green Deal Assessment. The future of the Green Deal looks uncertain, as Energy Secretary Ed Davey confirmed a review into its future would be taking place (**DECC, 2015a**).

In an encouraging sign that the Government is serious about improvements to the quality of the existing building stock, regulations were introduced in February 2015, banning landlords in England and Wales from renting out F- and G-rated homes from January 2018 and making it illegal for landlords to "unreasonably refuse consent to requests for energy efficiency measures" from their tenants from April 2016 (**ibid, 2015b**).

7.2.2 Renewable energy

The UK government introduced a Feed-in Tariffs (FiTs) scheme in April 2010. Under this scheme, organisations, businesses, communities and individuals generating low-carbon electricity (e.g. solar PV, wind) with 5MW or less installed capacity, or Micro-CHP with a total installed capacity of 2kW or less, receive payments for the generation and export of renewable and low carbon electricity (**Ofgem, 2013b**). Ofgem is responsible for administering the scheme. Due to spiralling costs, the Government conducted a comprehensive review of the original scheme, introducing a system of quarterly degressive tariffs from November 2012 (**DECC, 2012**). While one tariff is set for the energy you generate, another is set for each unit exported back to the grid and rates are fixed for a maximum of twenty years. Until the end of June 2015, rates are set at €0.085/kWh and €0.067/kWh respectively for solar energy, €0.20/kWh and €0.067/kWh respectively for wind, and €0.19/kWh and €0.067/kWh for micro-CHP. While rates are determined every three months, once a generator has registered for FiTs, their generation and export tariff will be fixed for as long as the installation is eligible. The electricity supplier pays the generator on a quarterly basis and they are funded through the electricity bills of their customers. Until the second quarter of year five of the FiT scheme, solar-PV accounted for 81.4 per cent of installed capacity (2,356.7MW) with wind a distant second at 260.5MW (**Ofgem, 2014b**).

Renewable Heat Incentive

In April 2014 the UK Government launched the Domestic Renewable Heat Incentive (RHI), a financial incentive to encourage a switch to renewable heating systems (**ibid, 2014c**). The programme works in tandem with the Green Deal programme and applicants are required to have had their homes assessed and found sufficiently insulated. Owners of newly built homes are explicitly prevented from making use of this scheme, as these are covered by stringent building requirements - self-builders excluded (**DECC, 2013a**). Those joining the scheme receive quarterly payments for seven years, ranging from 7.3p/kWh for air source heat pumps to 19.2p/kWh for solar-thermal (**Ofgem website, 2015**). The scheme is managed through 'degressive' tariffs as a pre-set level of spending is reached (**DECC, 2013b**). If the first trigger is hit, the tariff for that technology is reduced by 10 per cent; if a second trigger – a so-called "super trigger" is hit, the tariff will be reduced by 20 per cent. While no cap has been placed on the budget to prevent a run on available funds, it is not ruled out if degression is not sufficiently able to control expenditure.

7.2.3 Non-policy

Faced by an economic and financial crisis, the current Coalition government has placed the issue of 'austerity' high on the political agenda. Aimed at building a leaner, more efficient state, public spending has been under pressure across the board. Climate and the environment are no exception. The UK's 2010 Spending Review delivered cuts to DECC's core budget of 30 per cent in real terms by 2014-2015 – over half of which is made up of nuclear decommissioning costs each year – and overall resource savings of 29 per cent at Defra in real terms by the same time (**HM Treasury, 2010**).

From 2012-2014, Owen Paterson was Secretary of State for Environment, Food and Rural Affairs. During this time, Paterson's views on climate change were questioned repeatedly and he openly opposed the construction of onshore wind-farms. After leaving this post, Paterson spoke out against what he called the "Green Blob", a "mutually supportive network of environmental pressure groups, renewable energy companies and some public officials" (**Paterson, 2014**). Michael Fallon, Energy Minister at DECC from 2013-2014 was recorded speaking out against strong environmental and climate change commitments (**The Guardian, 2013**) and Cameron himself was rumoured to refer to environmental policies as "green crap". While these views may not be representative for government policy, they are at noteworthy from the "greenest Government ever" (**While, 2013**).

Perhaps as a result of these tensions, the Government has repeatedly been criticised over U-turns, poor policies, and unlawful actions. An example of this is that the UK Government is currently said to be lobbying the European Commission to keep open the Aberthaw coal-fired power plant in south Wales, despite its nitrogen oxide emissions being five times over the new legal limit set by the EU (**The Guardian, 2014**), leading environmental groups to question the Government's environmental commitments. In another illustration, four of the major British solar companies have recently sought judicial review of a government proposal that would halt a subsidy scheme for solar energy from April 2015, two years earlier than planned (**UK Reuters, 2014**). This follows a ruling by the High Court one month previously, which ruled that solar installers were given insufficient notice of cuts to feed-in-tariffs (**ibid**). The European Commission has recently begun infraction proceedings against the UK because of inconsistent or missing data in its proposals for emissions reductions.

7.3 Technological Regime

Since industrialisation, the United Kingdom has relied heavily on fossil fuels for large shares of its energy supply. After the closure of most of the mines in the 1980s, the country experienced a strong shift into other fossil fuels for its energy needs, particularly natural gas. In 2012, around 26Mtoe of gas was used to meet domestic heating needs in the UK, around three-quarters of the total energy used for heating, with solid fuels (incl. renewables) accounting for no more than 5.0Mtoe, or 14 per cent of the total. Similarly, gas was used to meet nearly 78 per cent of hot water needs (**DECC, 2014d**).

The UK economy has a relatively low carbon intensity, or energy use per unit of GDP, almost 30 per cent below the EU average (**IEA, 2012**). This is explained mainly by a large share of the services sector in the UK economy, at around 78 per cent of GDP, and the relatively small share of energy intensive industry.

Technological preferences

The Coalition Government has indicated its intention to focus on the successful development of three low-carbon technologies in particular; renewable energy, nuclear, and CCS (**ibid**). DECC's Renewable Energy Roadmap published in 2011, sets out a number of targeted, practical actions aimed at accelerating renewable energy in the UK and achieving the 15 per cent 2020 target (**DECC, 2011d**). The Roadmap identified onshore and offshore wind, marine energy, biomass heat and electricity, heat pumps and renewable transport as those technologies with the biggest potential. By the 2013 update, solar PV had been included in the list of key renewable energy technologies (**DECC, 2013c**). Provisional 2013 figures demonstrate renewable energies accounted for 5.2 per cent of final energy consumption (**ibid, 2014e**) and the UK is one of the global leaders in the offshore wind-market, with more capacity deployed than any other country (**ibid, 2013c**). The Government's support for onshore windfarms, however, currently looks less stable with many MPs opposing wind farms in their constituency. The Conservative Party promised to end onshore-wind subsidies following a 2015 election victory.

Particularly interesting in the debate is the continued importance of nuclear energy in the UK, especially when seen in light of developments in other European countries after the Fukushima disaster. In the 2013 Nuclear Industry Strategy, the UK Government expressed its wish to see the successful delivery of industry's planned delivery of at least 12 new reactors at five sites by 2030, representing around 16 GW of energy (**HM Government, 2013b**), extending the operating period of some existing plants, while safely decommissioning others. Part of the explanation for this continued reliance on nuclear energy lies with the ageing and fragile electricity system. Several coal- and gas-fired power stations are currently out of action due to maintenance while other nuclear- coal fired plants have recently been retired. A further fall in installed capacity is predicted in the next few years (**Ofgem, 2014d**), sparking fears over possible blackouts in the coming winters.

Electricity market reform

The UK is currently in the process of introducing important electricity market reforms to deal with these challenges. This reform is made up of two mechanisms: Contracts for Difference (CFD) and a Capacity Market. Under CFD, when selling energy, generating parties are paid the difference between the price reflecting the cost of investing in certain low-carbon technologies and the average market-price for electricity (**DECC, 2014f**). When the market price exceeds the strike price, the generator is required to pay back this difference. On the one hand, this mechanism provides more certainty to electricity providers investing in low-carbon technologies by increasing price stability while protecting consumers on the other hand, who do not have to pay higher support costs when electricity prices are already high. The aim of the Capacity Market is to secure sufficient reliable generating capacity to meet peak demand by providing a regular retainer payment to reliable forms of capacity (**ibid.**). All capacity providers are able to compete for these capacity rights at auction, which serve as a back-up when demand is high or supply low. Capacity agreements are offered to investors of both existing and new capacity four years ahead of the year it must be delivered, thus providing certainty over future revenues. Providers will face a fine if they cannot provide the energy when needed. The first capacity auction took place in December 2014, with 49.3GW of capacity sold at 19.40 £/kWh (**ibid, 2015c**).

Shale-gas

Attention for shale-gas has greatly increased in the UK, both by supporters and opponents of the technology, since David Cameron announced the Government’s intention to go ‘all-out’ on fracking in January 2014. The 2014 budget implemented a tax allowance for the exploration of onshore oil and gas (including shale-gas) in the UK, reducing the tax rate on profits from 62 per cent to 30 per cent in recognition of the “challenging nature of these developments” and companies will receive an allowance equating to 75 per cent of capital spend on these projects (**HM Government, 2014**). In addition, the Government amended trespass-laws, allowing companies to drill below 300 meters under private land without the homeowner’s consent, despite over 99 per cent opposing the proposal in response to a public consultation by the Government (**DECC, 2014g**).

7.4 Market Demand

The housing market in the UK has a number of distinguishing characteristics.

Table 6: Statistics Housing Market in the United Kingdom

Building Types (%)	
Detached Houses	25.8
Terraced Houses	59.3
Multiple-family	14.7
Other	0.2
Housing Types (%)	
Social Rental	17.8
Private Rental	17.7
Ownership	64.2
Other	0.3
Empty	-
Age Housing Stock (%)	
<1919	17.0
1919-1945	17.0
1946-1970	21.0
1971-1980	21.8
1981-1990	20.0
1990-2000	-
2000>	-

Sources: BZK (2013d); gov.uk (n.d.).

Looking at the residential sector, the UK has one of the oldest building stocks in Europe (**IEA, 2012**), with 75 per cent of non-domestic buildings constructed before 1985, and nearly one-third before 1940 (**DECC, 2011e**). Overall, the UK has a high share of terraced houses, making-up almost 60 per cent of the total housing stock. Similarly, the level of homeownership is substantial at over 64 per cent. Since market liberalisation and the privatisation of large swathes of the housing stock, the private rental sector has steadily increased in size and importance. In 2012-2013, the private rental sector overtook the social rental sector and became the second largest form of tenure in England (**DCLG, 2014a**). Although there is currently no form of rent-control in the private rental sector, the recent rise in rent levels, as well as a focus on reducing Government expenditure on Housing Benefits has led to a call for the reintroduction of private sector rent control (**House of Commons, 2014b**).

Housing market

The housing market is characterised by considerable tensions, with property values rapidly increasing in some parts of the UK, particularly around London. A shortage of affordable housing, coupled with strong demand is fuelling fears of a new property bubble and puts the first step on the property ladder out of reach for potential homeowners, particularly first-time buyers (**Savills, 2013**). This has already led to the identification of ‘Generation Rent’, a group of 20-45yr olds without the prospect of owning their own home in the next five years (**Jessop & Humphrey, 2014**). A ‘help-to-buy’ and ‘shared ownership’ scheme have been introduced in England, under which first time buyers and homeowners looking to move are eligible for government assistance in buying their own home.[23] It is estimated, however, that at the end of 2014, the 'Help to Buy'-scheme had contributed to average house prices rising by £46,000 in 18 months, leaving over 250,000 renters priced out of a new home, compared to 31,000 profiting from the scheme (**Telegraph, 2015**).

In 2013, changes in Government housing benefit came into force, under which tenants in the social rental sector are required to pay an "under-occupancy penalty" where they are deemed to have at least one spare bedroom (**DWP, 2012**). The goals of this policy is to firstly contain the costs of housing benefits, and secondly, to encourage mobility within the social housing sector by providing people an incentive to move to "more suitably sized accommodation"(**ibid**).

Energy poverty

Despite having some of the lowest gas- and electricity prices in the EU, and relatively high household incomes, the UK has the highest rate of fuel poverty out of 13 Western European countries (**Association for the Conservation of Energy, 2013**). Since late 2013, fuel poverty is measured through a 'Low Income High Costs'-definition, which considers a household to be poor if: (1) the required fuel costs are above the national median level, and (2) if they would spend that amount, they would be left with an income below the official poverty line (**DECC, 2014h**). Previously, it was only held that people considered to live in fuel poverty if they spent more than 10 per cent of their income on fuel "to maintain an adequate level of warmth" (**UK Parliament, n.d.**). According to official estimates, around 2.28million people, or 10.4 per cent of English households are currently in fuel poverty, down 5 per cent compared to 2011 (**DECC, 2014h**). Estimates by the Association for the Conservation of Energy (ACE) and the Energy Bill Revolution, using the original definition put this number at 4.82million households in England at the start of 2014, up 13 per cent compared to the previous year and 6.59 million households in the UK overall (**Association for the Conservation of Energy, 2014**).A report by the Living Wage Commission puts the number of people in poverty at 13 million people, 6.7 million of them from working households (**Living Wage Commission, 2014**).

The apparent paradox of low energy prices and relatively high household incomes versus high energy poverty can at least in part be explained by the poor standard of the existing housing stock. Particularly private renting is said to be "associated with uncertainty and lack of quality" (**Gardiner, 2014**), and is the sector with the largest percentage of properties – at 13.5 per cent – with F- or G energy performance ratings of (**British Property Federation, 2013**). The English Housing Survey over 2012-2013 found that properties in the social rental sector, those owned by local authorities, and newer properties were more energy efficient than properties in the private rental sector, owner-occupied, and pre-war dwellings (**DCLG, 2014b**). In 2012, 4.9million dwellings, or 22 per cent of all dwellings, did not meet the 'decent homes standard' (**ibid, 2014a**). This standard holds that homes are to meet a statutory minimum standard for housing, be in a recent state of repair, have reasonably modern facilities and services, and provide a reasonable degree of thermal comfort (**ibid, 2006b**). While this number represents a significant drop from the 35 per cent recorded in 2006, considerable room for progress remains.

[23] Under help-to-buy, prospective homeowners need to bring in a 5% deposit, the government will lend out 20% (no fees in the first five years) and the remaining 75% is borrowed from commercial lenders. An increasingly popular alternative is 'share ownership', provided through housing associations, in which private citizens buy a share of the home and pay rent on the remaining share.

Household finances

The high cost of living in the UK may be an important barrier hampering the spread of sustainable energy technologies. While annual publications by the Office for National Statistics have recorded a consistent decline in household's real wages since the economic downturn in 2008-09, the longest sustained period since 1964 (**Taylor, et al., 2014**), the average energy bill has increased by about 75 per cent between 2004 and 2010 (**British Property Federation, 2013**). Consumer gas prices have risen by over 120 per cent since 2005 (**Fuel Poverty Advisory Group, 2013**). Similarly, other consumer prices in the UK, e.g. for education, health, communication and transport have experienced some of the highest increases of four countries, particularly education which has become more than twice as expensive since 2005 (**Eurostat, 2014**).

8. Discussion

When put together, the profiles of the examined countries paint an interesting picture of the energy transition pathways followed by the countries included in this study. The goals and targets set out by each of these countries vary greatly, as do the trajectories and instruments favoured by policy-makers in each of them. While each country faces different barriers for a sustainable energy transition in their residential sectors, both as a result of historical developments and present-day policies, it is nevertheless possible to make a valuable comparison between them. The second section of this thesis briefly outlines a number of key parameters for each of the four dimensions distinguished in the sectoral analysis framework. The discussion provided in this section will revisit each of these parameters, highlighting the different barriers and the most important differences observed between the four countries.

8.1 Actors, Interactions & Networks

Significant differences are observed in the institutional set-up and the interaction between the various actors involved in the energy transition in each of the countries studied. The key parameter used to identify these differences is 'cooperation vs. fragmentation'. This can in turn be divided into: (a) 'institutional cooperation vs fragmentation'; (b) 'departmental fragmentation vs cooperation'; and (c) 'sectoral fragmentation vs cooperation'. The discussion below focuses primarily on the first two dimensions. As a more in-depth examination into the building sector would be required to make a qualified statement regarding the sectoral dimension, the discussion limits itself to more general observations on this subject. Table 7 summarises the most important findings for each country.

Table 7: Cooperation vs. fragmentation

The Netherlands	Institutional fragmentation; departmental compartmentalisation; limited fragmentation construction sector;
Denmark	Institutional cooperation; widespread political consensus; fragmented construction sector;
Germany	Institutional & departmental cooperation; strong interdepartmental ties; fragmented construction sector;
United Kingdom	Institutional fragmentation; departmental compartmentalisation; fragmented construction sector;

An important difference is observed between the institutions tasked with the energy transition in the various countries. In the Netherlands, responsibility for the energy transition is divided over several ministeries; the Ministry of Economic Affairs (energy), IenM (environment) and BZK (housing & energy efficiency residential sector). Cooperation between these ministries – or even between different departments within the same ministry – has at times been difficult. Energy policy in particular has been a contentious issue, with frequent tensions arising between environmental and economic departments of the different ministries and levels of cooperation have at times depended on the personal relations between (high-ranking) individuals. As a result of these factors, the system in the Netherlands is characterised by a high degree of institutional- and departmental fragmentation. In the private sector, only a handful of construction companies compete for large building contracts, often commissioned by large social-housing corporations. Overall, however, the Dutch building sector is highly fragmented, with a large number of smaller contractors and installation companies.

In Denmark, since 2007, the Ministry of Climate, Energy and Building (kebmin) is the single ministry responsible for energy-, energy and building policy, making it unique amongst the countries examined in this case study. The Ministry for Environment is responsible for administrative and research tasks relating to environmental protection and planning. Tasks and responsibilities are thus clearly divided, with kebmin the clear authority for energy- and climate policy. As agreements are concluded with the support of both the government and a great majority of opposition parties, decisions on the desired energy transition pathway appear to be taken with widespread political consensus. The Danish construction sector is characterised by a relatively large fragmentation of actors.

In Germany, responsibility for the energy transition lies primarily with BMUB (building & environment) and BMWi (energy). Ties between the two ministries are strong, with both parties cooperating on the drafting of strategic documents and policies. One possible explanation for these strong ties may be that both ministries, in its current form, were only established in December 2013 and they are still adapting to their new roles. Future developments will thus tell whether this is a permanent feature. The construction industry is highly fragmented, with construction mainly taking place through local- or larger interregional companies, and large projects often divided between companies.

In the UK, the responsibility is spread over DECC (energy & climate change), DEFRA (environment) and DCLG (housing market). Like in the Netherlands, frequent tensions have arisen between environmental- and economic considerations, with energy policy long considered a purely economic subject that should be left to the market. Clear signs of intra- and interdepartmental disagreements have been visible, strengthened by frequent tensions between the 'green agendas' of the Conservative Party and Liberal Democrats, as well as public statements against environmental policies by prominent government ministers. The construction industry in the UK is highly fragmented, with a large number of companies competing for contracts.

8.2 Institutional Framework

When looking at the institutional frameworks and policy instruments favoured by each of the four countries, a number of other significant differences become apparent. This section specifically focuses on two key parameters: 'soft power vs. hard targets' and 'policy stability'. Table 8 and 9 offer a brief summary of the main characteristics for each country.

Table 8: Soft-power vs hard targets

The Netherlands	Bottom-up decision-making process; voluntary private sector agreements; non-binding goals
Denmark	Mix of top-down decision-making and voluntary private sector agreements; binding targets
Germany	Top-down decision-making process; binding-targets
United Kingdom	Top-down decision-making process; binding targets

The Netherlands has a number of distinguishing characteristics. The Dutch decision-making process is often referred to as the 'polder-model', a consensus-driven decision-making process with a strong emphasis on soft power, in which political- and societal actors work together to agree on policies on a range of issues, including energy efficiency- and renovation targets. The outcome of this process is often in the form of a *covenant*, or voluntary agreement between government, industry and other societal actors (e.g. social housing associations) for a specific period. The 2013 Energy Agreement for Sustainable Growth is a prime example of the Dutch approach, bringing together a range of actors from local, regional and central government, employer's associations and trade unions, environmental organisations and other actors in civil society. As a positive effect of such an approach, decisions reached can generally count on widespread support from the majority of the actors involved. However, with the large number of stakeholders involved, the process can result in significant trade-offs to meet everyone's needs or expectations just to keep sufficient actors on board. This process thus does not necessarily lead to the formulation of ambitious policies. While energy efficiency targets are fairly average, they are by no means exceptional and renewable energy targets in particular can only be considered as very low in comparison to those of countries such as Denmark and Germany.

Generally, the voluntary agreements in the Netherlands are of a non-binding nature, making it difficult to hold any single party accountable if the desired goals are not met at the time the agreement comes to an end. Overall, achievements have systematically trailed behind ambitions, both with respect to energy efficiency- and renewable energy targets, which can at least in part be ascribed to the fact that responsibilities have not explicitly been agreed and recorded. The energy transition in the Netherlands still appears to be guided more by the vision rather than the goals, at least when seen in light of a post-2020 framework. The Netherlands is required to reach a share of 14 per cent renewable energies by 2020 under its European commitments. However, being now only five years away from this point, a recent study by PBL and ECN found that it is unlikely current efforts will be sufficient to fulfil this requirement.

Danish energy policy has a longstanding tradition of voluntary energy-saving agreements with the energy sector. The targets set can by all accounts be regarded as ambitious, at 2.9 per cent per year from 2015 to 2020. The research carried out as part of this study could not find any significant opposition to the energy-saving requirement. On the other hand, Denmark's energy efficiency and renewable energy targets are clear and ambitious. Mandatory energy requirements have been tightened by 50 per cent compared to 2006-levels, with a further 25 per cent in 2020 and the government has introduced a strict framework for the environmentally friendly heating of buildings, banning oil- and natural gas-fired heaters in areas where district heating is available as an alternative. Denmark furthermore set up an exemplary regulatory framework for the expansion of onshore wind-energy, aimed at fostering public uptake and acceptance of wind-turbines in the Danish landscape. Together, the combination of voluntary agreements and clear policies aimed at achieving the hard targets appears to be paying off, as Denmark is considered one of the frontrunners in Europe in terms of energy efficiency and renewable energy.

Like Denmark, Germany has formulated ambitious policies on energy efficiency and renewable energies, the term *Energiewende* having become internationally synonymous with the energy transition across the globe. Unlike Denmark and the Netherlands, however, policy-making remains predominantly the result of top-down processes, with limited examples of voluntary agreements between government and private sector parties. The country has formulated clear and binding energy efficiency- and renewable energy targets. The German Feed-In-Tariff system has been crucial in expanding the uptake of small-scale renewable energy production. Energy efficiency achievements, however, continue to lag behind ambitions. A clear strategy for the energy renovations of buildings is expected by November 2015. While ambitious, the German approach appears to be more tempered than that of Denmark, choosing for example to gradually phase out oil-fired boilers and those older than thirty years.

In the 2008 Climate Change Act, the United Kingdom has committed to reducing its greenhouse gas emissions by at least 80 per cent below 1990 levels by 2050. This legally binding commitment is the main foundation on which the UKs climate- and energy policies are currently based. The UK, like Germany, can be characterised by its largely top-down decision-making process. Over the years, the UK has regularly tightened building regulations and energy performance requirements, ultimately leading to the introduction of a Zero-Carbon-Homes standard from 2019 onwards and achieves to promote the uptake of renewable energy technologies through a Feed-In-Tariff system. Like Denmark, the country introduced an Energy Companies Obligation, requiring energy companies to deliver energy efficiency measures to domestic energy users. Introduced at the start of 2013 to replace to previously existing schemes, the agreement has not been concluded on a voluntary basis but places a legal obligation on the 'Big-Six' energy providers to deliver these measures.

Table 9: Policy stability

The Netherlands	Frequent changes to policies & targets; large number of different consecutive programmes; no credible long-term policy framework
Denmark	High rate of stability policy framework; clear long-term policy framework
Germany	High rate of stability policy framework; existing policies regularly revisited and made up-to-date; clear long-term policy framework
United Kingdom	Frequent changes to policies; binding targets watered down; clear long-term policy framework

One of the important barriers hindering a successful energy transition in the Netherlands appears to be the lack of policy stability and continuity. When looking at energy efficiency and renewable energy policy over the past thirty years, for example, one finds that targets and instruments used have fluctuated greatly depending on the political- and economic situation at any specific time. Consecutive governments, which have often represented shifting political tides not only change the rhetoric of the energy transition, but also its shape, direction and ambition. Taking the share of renewable energy as an example, the target was lowered substantially from achieving 20 per cent sustainable energy by 2020 in the 2007 Coalition Agreement, to no more than 14 per cent in the Coalition Agreement three years later. Whereas the 2007 programme '*Schoon en Zuinig*' of the Christian Democrats, Dutch Labour Party and ChristenUnie focused strongly on the importance of existing technologies, post-2010 programmes under the political leadership of the conservative-liberal VVD have instead focused on innovation and the development of future technologies.

Various programmes have been developed and implemented in rapid succession over the years. While there has been a wide range of pilot-programmes, relatively few of them have been translated into policies after their completion. For this reason, it could be argued that while pilots are considered to be 'sexy', policies are not. Furthermore, very few programmes have survived in their original form and a number of successful and widely popular polies have been reversed, often on short notice, due to overwhelming success and higher-than-expected costs. Frequent changes to the policy framework further do little to promote the necessary confidence with investors and citizens. While it could reasonably be argued that changes are inevitable and indeed necessary to keep the transition process on course, overall it appears that the lack of stability has hampered the energy transition in the Netherlands to date. Finally, the Netherlands currently does not have any long-term policy framework covering the post-2020 period, thus providing little clarity on the shape and form of the transition-process beyond five years' time.

In many ways, Denmark can be considered the opposite of the Netherlands. While the country has a similar multi-party system, it demonstrates a high policy stability and changes in government have only had a limited impact on policies. As agreements are concluded with the support of both the government and a great majority of opposition parties, elections have not substantially impacted the course and direction of policies in the Danish energy transition. While some changes in discourse have been visible – the centre-right government focusing on cost-minimisation and budget-neutrality, whereas the new left-wing government focuses more on cost-efficiency – they have not had a significant impact on Denmark's ambitions and targets. Overall, both energy efficiency and renewable energy targets have been remarkably consistent over time. Building requirements have regularly been tightened since the 1970s, and the Public Service Obligation and subsidy-schemes for renewable energies have only experienced minor adjustments since their introduction. Finally, Denmark has established a clear long-term policy framework, publishing its 'Energy Strategy 2050', in which it expressed the goal of becoming completely independent of coal, oil and gas, as early as 2011.

Germany is similarly known for its high policy stability. While the country also has a multi-party system, the Christian-Democratic CDU/CSU and Social-Democratic SPD have played a dominant role in German politics, resulting in a political system far less fragmented than that in the Netherlands. The dominance of these political parties can be considered an important stabilising factor for climate- and energy policies. It has been argued that the country has experienced particular political stability since Angela Merkel took office in 2005. Germany further has a number of longstanding policies, particularly with respect to renewable energies. The country introduced a Feed-In-Tariff system in 1991 which, although revised on several occasions, remains the main policy-instrument for the promotion of renewable energy in Germany today. The costs for the EEG are distributed to energy consumers through a surcharge on their energy use. Since 2008, the costs for consumers have increased rapidly for citizens, while energy-intensive industry saw its costs reduced slightly over the same period. The overall rise in costs of the Energiewende, coupled with the advantaged position of industry, may pose an important threat to German energy policy-stability in the future. Finally, in 2010 the Federal Government adopted the 'Energy Concept', establishing the guidelines for a long-term energy pathway to 2050. The strategy contains a number of clear and measurable goals but leaves sufficient flexibility for technological and economic developments.

The UK has a relatively high degree of political stability, stemming at least in part from the two-party system. In principle, the 2008 Climate Change Act provides a clear and legally binding long-term strategy to reduce greenhouse gas emissions by 80 per cent in 2050. By setting-up a system of five-yearly carbon budgets, the first four until 2027 already having been set, the UK has established a clear framework in the medium-to-long term. However, significant instability is observed in policy-instrumentation, with frequent changes to policies and instruments used. On a more short-term level then, the UKs Conservative/LibDem government has frequently been criticised over policy U-turns, inconsistencies and unlawful actions. With respect to energy efficiency, the government has lowered the ECO-targets for energy providers and significantly watered down and delayed the introduction of the Zero-Carbon-Homes standard, providing little impetus for more ambitious policies, while the Green Deal aimed at stimulating energy renovations is overall considered a disappointing failure, at least in part due to frequent changes to the scheme. With respect to renewable energies, the UK is doing slightly better. Having introduced a Feed-In-Tariff in April 2010, the government suddenly slashed tariffs in October 2011 to rein in costs. Since then, however, the system has largely been stable. While the UK now has one of the biggest offshore wind-markets in Europe, onshore wind is under significant pressure in certain parts of the UK, with Conservative representatives in particular against wind-turbines in their local constituencies. The upcoming May 7 national election renders some uncertainty on the future course of the energy transition in the UK. Prior to the elections, the party leaders of the three main political parties signed a joint pledge to work together in tackling climate change and accelerating the transition to a low-carbon economy after the general election. This agreement ensures the topic is not a central issue in the election campaign running up to voting day.

8.3 Technological Regime

Although levels of domestic energy-use are remarkably similar in different European countries, significant differences are observed in the technological frameworks of each of the four countries, in particular with respect to their preferred technological pathways. This section first focuses on the parameter of 'technological preference'. Table 10 lists the main technological preferences for each country, which will subsequently be discussed below. Technological preferences cannot always be seen as separate from historical developments and existing industrial networks. The latter part of this section thus focuses on the parameter 'path dependency' and illustrates how the choices of today at least in part depend on yesterday's actions. Table 11 summarises the most important findings for this parameter.

Table 10: Technological preferences

The Netherlands	Market-based choice of technologies; Govt. focuses strongly on future technologies & innovation; natural-gas; wind-energy (onshore/offshore)
Denmark	Active stimulation of wind (onshore/offshore), biomass & biogas; strong focus on current renewable energy technologies; large number of (municipal) district heating networks
Germany	Active stimulation of wind (onshore/offshore) & solar; strong focus on current renewable energy technologies; nuclear phase-out
United Kingdom	Market-based choice of technologies; Govt. focusing strongly on future technologies & innovation; offshore-wind, nuclear & fracking

Due to the relatively large share of energy-intensive petrochemical-, iron- and steel industry in the Netherlands, the country continues to rely on fossil fuels for over 90 per cent of its energy needs. The current Dutch government does not express a preference towards any of the renewable energy technologies, relying on market-preferences and –mechanisms to determine which technologies will be utilised to achieve a successful energy transition in the Netherlands. In 2014 the share of renewable energies stood at just 4.5 per cent of total energy, thus remaining far below the 14 per cent required in 2020 and at one of the lowest levels in the EU.

In 2013, the Dutch government and over forty private-sector parties concluded the 2013 Energy Agreement on Sustainable Growth. In the Agreement, the signatories set out how they achieve the 14 per cent target by 2020, in which they focus in particular on the further development of onshore- (6000MW/54PJ) and offshore (4450MW) wind-energy and various forms of decentralised energy (40PJ), largely through the improvement of fiscal incentives for energy cooperations and private citizens, improved long-term security for investors, and the removal of organisational obstacles. Overall, however, the strategy appears to be fairly general, with actual commitments phrased rather vaguely. Adoption-levels of renewable energy technologies in households remains low and there is little to indicate the changes by the Energy Agreement are having a significant effect on consumer uptake of sustainable technologies. The reluctance by government to pick and promote a 'winner' amongst renewable energy technologies, coupled with weak financial- and regulatory incentives are thus likely to be a significant barriers in the sustainable energy transition.

In Denmark, renewable energies today account for around 29 per cent of gross final energy consumption as a result of the active stimulation of biomass, biogas, CHP and onshore- and offshore wind-energy. While the country continues to rely heavily on fossil fuels such as oil, coal and gas, the Danish government has firmly committed to phasing out fossil fuels by 2050. A large share of Danish heating requirements are met through CHP units and by 2020, over 70 per cent of electricity needs are expected to originate from renewables. The 2008 'Promotion of Renewable Energy Act' sets out a clear regulatory framework for offshore- and onshore wind-energy and contains important elements to help foster public acceptance and uptake of onshore-wind. The Act certainly contains important lessons for countries like the Netherlands, struggling to overcome strong public resistance to wind-turbines close to local communities. Decentralised solar energy does not figure strongly in Danish policies but are considered a valuable addition. Households are encouraged to choose environmentally friendly energy technologies through subsidies, information campaigns and strict building and renovation requirements. With the majority of Danish households connected to district heating systems, they will increasingly receive their energy automatically from renewable resources through their district heating company.

Since the early 1990s, the German government has actively sought to promote the expansion of renewable energy technologies in Germany, the results of which are clearly visible in the German landscape. While the country remains heavily dependent on polluting fossil fuels such as coal and gas for most of its industrial electricity needs, renewables now play an important role, particularly in domestic electricity generation. In the first phase of the *Energiewende*, the development and market-entry of renewable energy technologies was the key part of German energy policy. With this stage now finished, wind- and solar-energy came out as the clear 'winners' according to BMWi. Now entering its second phase, the systems integration of renewable energies – the winning technologies in particular – in the energy grid will be the main goal. Citizen-led initiatives form the backbone of the *Energiewende*, with government initiatives and programmes supporting energy cooperatives. The phase-out of nuclear energies, however, has played an important role in the renaissance of coal-fired power plants and Germany will have to be careful it does not miss its CO_2 reduction-target by 2020. Important discussions on electricity-market reform are currently taking place, and capacity markets are being considered to guarantee a minimum level of capacity with an increasingly fluctuating inflow of renewables into the grid.

The United Kingdom has one of the lowest levels of energy use per unit of GDP, largely as a result of its low share of energy-intensive industry. Nevertheless, the country remains reliant on fossil fuels for the lion-share of its energy needs, predominantly gas, and ageing and polluting power plants to meet its electricity production. Throughout the 1980s and 1990s, the UK government focused strongly on the liberalisation of its domestic energy market, removing energy issues from politics. In the light of a series of recent events and market failures, this position is increasingly coming under pressure. Nevertheless, like the Netherlands, the UK government largely stresses its intention to rely on market mechanisms to determine which technologies will be key to a successful energy transition. The 'Renewable Energy Roadmap' published in 2011 identifies offshore- and onshore wind-energy, marine energy, biomass heat and electricity and heat pumps as those technologies with the biggest potential, the 2013 update adding solar-PV to this list. While the country has developed a strong offshore wind-energy market, its commitment to some of the other technologies remains questionable. A strong emphasis is placed on innovation and future technologies, with carbon capture-and-storage and fracking being two controversial technologies promoted, primarily by the Conservative party. The UK is currently seeing a renewed interest in nuclear capacity, with 16 GWe of new capacity expected to be online by 2030. Finally, the UK is currently introducing important electricity market reforms, including so-called 'Contracts for Difference' to stimulate investments in low-carbon technologies by large energy providers and a 'Capacity Market', having held its first capacity-market auction in December 2014.

Table 11: Path-dependency

The Netherlands	Highly centralised energy system; strong reliance on natural gas; Overcapacity electricity-market
Denmark	Decentralised energy system; historically strong emphasis on wind & biomass; sufficient capacity electricity-market
Germany	Centralised energy system; nuclear phase-out; Ageing & polluting coal- and gas-fired power-plants; concerns capacity electricity-market sparked by nuclear phase-out
United Kingdom	Highly centralised energy system; Ageing & polluting power-plants; strong concerns over insufficient supply on electricity-market

Since the discovery of natural gas in the northern province of Groningen, Dutch energy policy has largely been determined by this single energy source. In a relatively short time-span of about five years in the 1960s, the existing gas infrastructure was deployed across homes, business and industry in the Netherlands. Today, nearly all Dutch households are connected to the natural gas grid, with about one-third of power use generated using natural gas and over 50 per cent of electricity demand. While coal accounts for over 26 per cent of electricity generated, its share has been rising due to the low market price of coal and emission permits on global markets in recent years. The electricity distribution market is highly centralised, with a few big providers delivering energy to a relatively large share of consumers. In recent years, however, the market has gradually been liberalised, opening up the gas- and electricity-market for competition. The widespread availability of relatively clean natural gas, and large government revenues associated with its extraction, in all likelihood constitute an important barrier preventing the adoption of renewable energy technologies. Environmental gains from the switch to renewables are smaller than they would otherwise be, when switching from alternatives such as oil and coal, thus making it more difficult to justify the large costs associated with such a move. The highly centralised nature of power production in the Dutch energy system may further hamper decentralisation efforts. Under the Dutch polder model, the large market parties in particular can exert their influence to protect their interests and the State will most likely have substantial difficulties to compensate for the loss in revenue.

Denmark has traditionally been much more dependent on imports for most of its energy supply. Although the country does have some oil and natural gas in the North Sea, the country is expected to become a net-importer within the foreseeable future. Following the oil crisis in the 1970s, the Danish government has focused strongly on reducing the dependence on imported fossil fuels. Wind energy and the co-firing of biomass in existing fossil fuel-fired power plants were, and still are, seen as important instruments in reducing the dependence on fossil fuels. Furthermore, Denmark has a long tradition of district heating, with one of the worlds' oldest district heating networks located in Copenhagen, first installed in the 1920s. Since the 1980s, Denmark has gradually decentralised the energy generation system and district heating systems play a crucial role in this development. Existing district heating systems are gradually being replaced or converted to operate using renewable resources such as electricity, biomass and biogas. The oil crisis, and the actions taken in its aftermath, coupled with the historical importance of district heating networks have thus provided Denmark with an advantageous starting position for the energy transition that has been taking place gradually over the past thirty years.

With over 170GW of installed capacity, Germany has the biggest power production in Europe. While opening the energy market for competition, the four big energy providers continue to hold considerable market power. RWE, EON and Vattenfall have each taken the German State to court over several issues, including the nuclear phase-out and the costs associated with the cleaning-up of nuclear waste. There is currently no indication how Courts will rule in these cases. As the existing business models of large energy companies are increasingly threatened, growing instability on the electricity market may prove a significant obstacle in the transition process, as companies may be unwilling to make the necessary investments in an insecure economic- and political environment. While decentralised production capacity is gradually increasing in importance, Germany currently continues to rely on large centralised fossil fuel-operated power stations running, with many still running on polluting coal and brown coal. Although the current wave of investment in new coal-fired plants may primarily be the result of favourable market conditions, speeding-up the nuclear phase-out has meant that there will continue to be a need for conventional energy technologies in the near future. While decentralised generating capacity is rapidly increasing, it is uncertain its expansion will be sufficiently fast to compensate for the reduction in conventional capacity, despite strong government support.

The UK continues to rely on fossil fuels for most of its energy need, predominantly natural-gas for heating and natural gas, coal and nuclear energy for its electricity supply. Following the liberalisation of the UK energy market, investments in production capacity rapidly declined. As a result, the UK is now faced with a lack of generating capacity, fuelling concerns over black-outs during moments of peak-demand. With many ageing power plants currently out of action due to maintenance, and others being retired, the UK is facing significant challenges to 'keep the lights on'. The difficult situation on the domestic energy market may at least in part explain the UKs decision to continue to operate a number of inefficient and highly polluting coal-fired power plants and its high investments in the installation of new nuclear generating capacity. Renewable energies alone are almost certainly incapable of filling this gap quickly. However, large current investments into conventional generating capacity, coupled with lengthy return-on-investment periods and the long technological lifespan of the new production capacity could well constitute a barrier preventing the UK from making the energy transition through decentralised renewables in the way that Denmark and Germany are currently pursuing.

8.4 Market Demand

Looking at the housing markets of each of the four countries, it becomes apparent that, while displaying a number of similarities, overall, the housing markets also show some significant differences. It is important to note that the discussion provided here does not focus on the underlying causes of these differences, whether these are historical, cultural, or the result of distinct policy choices. Rather, this section chooses to focus on the three parameters previously identified, these being the 'potential for large scale renovation', 'fragmentation of the housing market' and 'access to financial means' for each country. In much of the literature, the potential for large scale-renovation is divided into (a) technological potential and (b) economic potential, with the former discussed as part of the technological framework. However, as the technological regime in this particular study focuses on the more general energy market, both the technological and economic potential of the housing stock are discussed below. Tables 12 to 14 summarise the most important findings for each country. The following section in turn discusses each of these parameters.

Table 12: Potential for large-scale renovation

The Netherlands	High standard existing housing stock; large share of terraced houses & standardised housing stock; up-do-date heating systems; innovative renovation programmes
Denmark	Good standard existing housing stock; large share of old oil- and gas-fired boilers; existing potential for deep-renovations
Germany	Low energetic standard existing housing stock; High share of multiple-family homes; large share of old oil- and gas-fired boilers; low renovation rate
United Kingdom	Low energetic standard existing housing stock; large share of terraced houses & standardised housing stock; current renovation programme ineffective

Over the past thirty years, Dutch policy has focused strongly on energy savings and the energy efficiency of its housing stock, introducing strict building requirements and offering incentives to stimulate energy efficiency improvements by homeowners and homes are generally insulated to a high thermal standard.

Nevertheless, the Netherlands seek to further improve the thermal quality of the existing housing stock to reduce its energy needs. A number of positive factors can be identified which may enable large-scale renovation of the Dutch housing stock. Firstly, the building process has been highly standardised in the post-war period, with construction largely focused on volume. Secondly, the Netherlands has a large share of terraced houses, at over 60 per cent of the building stock. Thirdly, the Netherlands has a large social housing sector, in which housing corporations own a large number of homes. Together, these three factors more readily allow for the upscaling of initiatives, whereby renovation, like construction, can take place in large volumes, allowing for standardised solutions at a lower cost per household. By actively involving housing corporations in this process, a large number of homes can be renovated at once, thus eliminating the need to persuade or incentivise individual owners. In recent years, there has been a strong focus on innovation in the Dutch building sector, with new renovation programmes being developed. The current programme '*Stroomversnelling*', in which energy renovations are financed through significant reductions in the monthly energy bill, is a good example of such an innovative approach and there are signals that scheme has been picked up by the United Kingdom.

Perhaps even more than in the Netherlands, Danish energy policy has strongly focused on energy savings and energy efficiency of its residential housing stock since the oil-crisis in the 1970s. The country has gradually introduced stricter building and renovation requirements and has a long history of legislation, information campaigns and subsidies in order to make the switch to sustainable sources of energy in the residential sector. As many of the easier measures are now taken, there is some reason to argue that large-scale renovations in the Danish housing stock may be problematic. Nevertheless, a number of beneficial factors can be identified. Firstly, the country has a large social-rental sector and while this sector may be more fragmented than is the case in the Netherlands, this may still offer sufficient potential to renovate a relatively large number of homes by a single party. Secondly, past efforts have largely focused on easy-to-treat measures at low cost. A large potential remains for deep-renovations and improved insulation of dwellings. While the large share of detached houses may be an important barrier complicating the 'serialisation' of energy renovations, the Danish building industry now focuses strongly on innovation and may be able to offer some standardised solutions for these homes.

To date, the German *Energiewende* has largely focused on the market-introduction of renewable energy technologies, with energy efficiency taking a backseat during this period. Germany introduced its first Heating Act in 1978 and gradually introduced stricter building requirements for new dwellings over the years. In terms of energy renovations, however, the country is currently lagging behind its ambitions. Large-scale renovation of the German housing stock may be problematic for a number of reasons. Firstly, with the reconstruction effort after the two World Wars focusing on quickly providing affordable housing for the German population, Germany now has a high share of multiple-family homes. While this may at first glance provide an opportunity for a serialised approach to renovations, it is important to note that these buildings have often been constructed by local- or regional construction companies. Different sets of building standards, dimensions or techniques may render the upscaling of initiatives more difficult. Furthermore, with private persons owning over 84 per cent of residential buildings, it will be difficult to find parties sufficiently large to renovate a large number of homes through one agreement. While it may be relatively simple to encourage homeowners and landlords to switch from old oil- and gas-fired boilers, achieving a larger number of deep renovations in the German housing stock may prove difficult in the years to come.

The housing market in the United Kingdom resembles that of the Netherlands in some ways. The country currently has a high rate of homeownership, at over 60 per cent of the population, in both countries result of a long history of policies to encourage households to buy rather than rent their property. The country similarly has a high rate of terraced houses, representing around three-fifths of the total housing stock, typically used to house the British working-force and spread widely in the UK even before the start of the Second World War. The high share of standardised housing may be a crucially important factor enabling the large-scale renovation of the existing housing stock. A large number of homes in the UK currently have a low energetic standard so a large potential market for such solutions currently exists. The United Kingdom appears to have picked up on the Dutch *Stroomversnelling* and offers a similar scheme through its 'Green Deal'. For various reasons, however, this renovation programme is currently ineffective. An important barrier preventing the upscaling of renovation initiatives may be the small size of the social-rental sector, the government solely providing low-cost housing to those most in need, and the fragmented nature of the public sector. Recent changes introduced, banning landlords from renting out the draughtiest homes may serve to improve the renovation rate.

Table 13: Fragmentation of the housing-market

The Netherlands	High rate of homeownership (60%); large social-rental sector (31%); growing private rental sector
Denmark	Roughly equal divide homeownership (50.5%) & social rental (48.7%); small private rental sector with strict rent-control
Germany	Low rate of homeownership (40.8%); large private-rental sector (48.8%) with strict rent-control; fragmented ownership rental properties;
United Kingdom	High rate of homeownership (64.2%) under pressure; growing private-rental sector without rent control; 'buy-to-let'

Active stimulation of homeownership by the Dutch government has resulted in a relatively high share of homeownership in the Netherlands, with a 'housing career', with progression on the property ladder long considered crucial for its stability. Homeowners' willingness and motivations to undertake energy renovations vary greatly, making it extremely difficult to target them as one group. An individual approach and tailored solutions are thus required to move these households into taking steps to renovate their homes. While this may constitute a significant barrier, the Dutch government has created a number of incentives for individual homeowners and Platform31 runs a *Stroomversnelling* pilot-project targeted at homeowners. Alongside these homeowners, a large number of Dutch citizens currently occupies a home in the social rental sector, with housing corporations of various sizes owning the properties they rent out. Strict rent controls are applied in this sector and housing subsidies are available for households on low incomes. Following a series of scandals in the social housing sector, the government now wishes to liberalise the rental sector to stimulate movement on the wider housing market, with social housing corporations focusing solely on the provision of affordable housing to those who need it. While the government is currently able to exert considerable influence on social housing corporations, which are widely regarded to also have a social responsibility, it will have considerably less influence on profit-oriented private companies, which has a primary responsibility to its shareholders. In liberalising the Dutch rental market, the Dutch government may lose an important instrument with which it can influence the direction of the energy transition in its residential sector.

The fragmentation of the Danish housing market is very different from that in the Netherlands, with the division between homeowners and those renting in the social rental sector roughly fifty-fifty. When targeting homeowners, the Danish government faces similar barriers as that of the Netherlands, as homeowners' motivation and ability to finance energy renovations may vary strongly. A tailored solution is once again required to reach this group. The Danish rental sector has strict rent controls which also apply to privately-owned properties and has strong protection for tenants. Over forty per cent of rental properties are owned by non-profit entities, nearly 20 per cent is privately-owned, over 15 per cent is owned by housing societies, over 13 per cent by cooperative societies, and nearly 4 per cent by local authorities. As a result, the fragmentation in the rental market is considerable, potentially making it more difficult to conclude a sector wide agreement. Furthermore, the strong protection against rent increases enjoyed by tenants may serve to dissuade property-owners from making the necessary investments if they deem the return-on-investment to be insufficient.

Germany has a significantly lower rate of homeownership than the other three countries. In recent years, Germany introduced a range of laws and financial incentives to promote energy efficiency improvements by homeowners. The majority of German households, however, remains in the rental sector, with most of the properties now having been turned over to the private sector. Ownership of these properties is highly fragmented, with private persons owning nearly 85 per cent of residential buildings and over 58 per cent of dwellings. Due to large number of owners and their heterogeneous composition renders it next to impossible to approach this group as a whole. Furthermore, due to the strict rent-controls applied in Germany, landlords face difficulties in charging the costs of energy renovations onto the tenants. Recent changes to the existing landlord/tenant laws seek to overcome this issue by allowing landlords to add 11 per cent of the costs to the annual rent, although its effectiveness has not yet independently been determined.

Like the Netherlands, the United Kingdom currently has a high rate of homeownership, with government policies actively stimulating people to buy their own home. For aspiring homeowners, the government has introduced 'Help-to-Buy' and 'shared ownership' schemes, while on the other hand stimulating 'Buy-to-Let' in which homeowners buy a property with the specific purpose of renting it out, now a widely popular way to invest. At the same time, however, rising property values have increasingly put homeownership out of reach for many aspiring people, mainly 20-45yr olds, often referred to as 'Generation Rent'. Following liberalisation of much of the rental market, the share of private rental housing has steadily increased over time and will overtake social housing as the second-most form of housing in the UK. With no rent controls in this sector, tenants often pay relatively high rents, for homes with a poor (thermal) standard. As properties are largely seen as an investment opportunity, landlords currently have little incentive to undertake costly energy renovation, hampering the energy transition in the UK.

Table 14: Access to financial means

The Netherlands	Feed-In-Tariff (FiT) varying per energy company; Tax-incentives for energy cooperations and owners' associations; municipal subsidies for solar-energy; low interest-rate on loans for energy renovations
Denmark	FiTs for renewables fixed per technology; grants for replacement of oil-fired boilers; national subsidy solar energy; high interest rates on loans for energy renovations (6.7 to 9.6%); high levels of household debt
Germany	FiTs for renewables fixed per technology; subsidies available for energy renovations; low interest-rate on loans for energy renovations (1 to 1.61%)
United Kingdom	Quarterly degressive FiTs; no subsidies for energy renovations; high interest-rate on loans for energy renovations (7 to 9%); high living costs;

The Netherlands has a wide range of policy instruments aimed at promoting energy efficiency renovations and investments in renewable energy technologies. FiTs for consumers delivering energy into the grid are determined by the energy providers and may thus vary depending on the company. If consumers generate more energy than they use, they can deliver this back into the grid. The system may be confusing for consumers who will need to compare energy providers to see which one best suits their particular needs. While this does not generally apply to homeowners installing solar-panels on the roof of their home, it does apply to energy cooperatives and energy associations. A tax discount of 7.5ct/kWh was introduced in January 2014 for energy produced through these two groups. Overall, the scheme is often considered to be overly complicated, while return-on-investment periods are too long to persuade citizens' investments, and thus constituted an important barrier preventing increased pick-up of renewable technologies by households. With respect to energy savings, municipal subsidies for solar-energy are available in some cities. In addition, homeowners may be eligible for finance through a national 'energy-savings loan' (*Energiebespaarlening*) or regional/local 'sustainability loan' (*Duurzaamheidslening*), with interest-rates varying between 0.5 to around 3.3 per cent. Despite these low interest rates, so far pick-up of the scheme by homeowners appears limited, possibly due to limited awareness of their availability by homeowners.

FiTs have been a key element in the rapid spread of renewable energies in Denmark, particularly wind-turbines. FiTs are set individually for each renewable energy source, with rates depending on the costs of that particular technology. This system provides consumers with clear information and guaranteed access to the electricity grid. While renewable energies were initially exempt from energy-taxes this is no longer the case following the 2012 Energy Agreement, which lifted the exemption to counter decreasing tax revenues from fossil fuels. Overall, this does not seem to have impacted the pick-up of renewable energy technologies by Danish consumers. With respect to energy efficiency, the Danish government has made available grants for the replacement of oil-fired boilers in favour of more sustainable technologies, and a national subsidy-scheme for solar energy is in place. While loans are available to finance energy renovations through *Grøn Boligkontrakt*, at between 6.7 and 9.6 per cent, interest are almost certainly too high to persuade many homeowners. Another important barrier preventing energy renovations from taking place may be the already high levels of household debt, which may prevent households from requesting or receiving any more loans.

For Germany, the introduction of FiTs in the early 1990s can be considered crucial to the energy transition. By giving renewable energy preferential access to the energy grid, and paying a rate of between 65 and 90 per cent of the average tariff for final consumers, the scheme has been highly successful in creating a market for renewable energy in Germany. Since the introduction of the first Renewable Energy Act (EEG) in 2000, small-scale producers of renewable energy are guaranteed fixed feed-in-tariffs for a period of twenty years, with rates based on the cost of generation of each specific technology. While the tariffs are lowered regularly to encourage efficiency improvements, the system is sufficiently stable to provide private citizens to continue to invest in small-scale renewable energy. Through the KfW-bank, a range of subsidies and low-interest loans, with interest rates around 1 to 1.6 per cent, are available for energy renovations in the residential building stock. Although the current renovation rate remains below the level desired by the German government, access to financing appears adequate to provide homeowners and landlords with the necessary funding.

The United Kingdom, like the other countries, has a system of FiTs in place, a system first introduced in the UK in April 2010. Rates are set in the form of quarterly digressive tariffs. While sudden changes to the scheme do not inspire much confidence, the FiT-system has remained relatively stable since then and over 2,000MW of solar-capacity has been installed in about 4.5 years.

With respect to energy renovations, no grants currently appear to be available for efficiency improvements or renewable energy technologies. Finance is available to homeowners through the 'Green Deal' scheme and financing has been made available through the Green Deal Finance Company. With homeowners unable to borrow from the GDFC directly, they will have to go through an intermediary bank, further raising the already high 7 per cent interest-rate to somewhere around 9 per cent. Coupled with the high costs of living in the UK, these high financing costs are an important barrier preventing the uptake of energy renovations under the Green Deal scheme.

9. Conclusion

This thesis has explored and analysed the energy transition pathways in the residential sector of the built environment in the Netherlands, Denmark, Germany and the United Kingdom. By using a sectoral analysis framework, important differences between countries' in terms of strategies and policy preferences have been uncovered in relation to (1) actors, interactions and networks, (2) the legal framework, (3) technological regime and (4) market demand. At the hand of the different country profiles, it is possible to identify a number of factors for policy success and –failure.

9.1 Factors behind policy success and –failure

Defining "policy success" is problematic, as there are no systematic or objective criteria by which to assess success or failure. While a specific policy may be considered a success by some (e.g. political actors consider a policy a success because it meets certain targets), it can at the same time be considered a failure by others (e.g. interest groups, academics or citizens). This study has found a number of factors which may facilitate or inhibit energy transition processes in each of the respective countries.

With respect to *actors and their interactions*, the findings of this research indicate that strong ties and cooperation between ministries and/or departments are important factors facilitating policy success. Conversely, departmental fragmentation and competition pose a significant barrier in the energy transition process. Furthermore, a high degree of cross-party support and stability of the political landscape, contrary to frequent turnover of governments, can be considered important factors for success.

In terms of the *institutional framework*, policy stability is an important facilitating factor, while frequent changes to existing policies or a series of consecutive short-term policies help explain why pick-up of renewable energy technologies has lagged in some countries. Furthermore, the formulation of clear and non-voluntary targets generally appears to be a factor behind policy success, as they provide clear and measurable goals, although some voluntary agreements have also proven effective. Finally, the absence of a long-term policy framework appears to be a detrimental factor for policy success. Together, measurable and long-term targets may help focus a country's activities.

Looking at the *technological regime*, active (financial and non-financial) support for certain renewable energy technologies by governments is also a factor underlying policy success. Evidence from the case studies suggests that countries in which the choice of technologies is largely market-based, such as the Netherlands and the UK, currently lag behind countries such as Denmark and Germany, with a more interventionist government approach. So-called 'path-dependency', resulting from historical developments and existing infrastructure appears to be significant for the shape of the energy transition and can both be of a positive and negative influence on the transition to more sustainable forms of energy.

Finally, with respect to the *housing market* and households' financial situation, the existence of a large standardised terraced housing stock is a potentially important factor enabling the upscaling of innovative initiatives, more difficult to replicate in countries with a more localised building sector or large share of detached individual homes. The existence of a large and highly fragmented private rental sector is likely to be a negative factor, as landlords with one or two properties may not have the necessary funds or motivation to make the investments required. High interest rates on financing products are another important barrier to increasing a country's renovation rate. Low interest-rates alone are not sufficient however, suggesting that a lack of knowledge or awareness of available financing mechanisms for homeowners may be another factor underlying policy failure.

9.2 Connection between factors

Many of the factors identified in section 9.1 cannot be viewed as separate from one another. The persistently low share of renewable energy in the Netherlands, for example, is at least in part explained by the strong continued reliance on natural gas, not only for domestic energy needs but also as an important source of government revenue. The Government's decision to include gas as an important element in meeting the country's climate goals increases the difficulty for other low carbon technologies to penetrate the market.

In Denmark, energy policy has focused strongly on reducing dependence on imported fossil-fuels. The historical importance of decentralised district heating networks has proven hugely advantageous for Denmark's energy transition. The decentralised and small-scale nature of many district heating systems allows Danish district-heating companies to gradually replace ageing technologies with low carbon alternatives at relatively lower costs. In addition, the fact that wind energy has been fairly common in Denmark since the 1970s has in all likelihood done much to avoid large-scale resistance to the erection of onshore wind turbines experienced by other countries today.

The UK is characterised by a highly centralised production- and governance structure. With close ties between government and industry, the country has been able to develop a strong offshore wind-energy market. However, the centralised nature of energy production may also help to explain some of the strong local resistance against onshore turbines over which those affected have relatively little say. Furthermore, the UKs decision to invest heavily in new nuclear production capacity cannot be seen as separate from geo-political concerns and looming energy shortages resulting from its existing ageing and polluting production capacity.

Finally, the increased reliance on polluting coal- and oil-fired power plants in Germany cannot be seen entirely separate from the nuclear phase-out and mounting pressure to keep energy affordable for German households.

Where the factors for policy success or -failure are important for the energy transition to take place, the connections between different factors are important in that they may, in part, explain the chosen transition pathways.

9.3 Replicating good examples

While an energy transition is seen to be taking place in all four countries, the pathways favoured by each of the four governments is highly distinct. This study has found the policy instruments and technologies favoured by national governments to be highly context specific, both depending on decisions made in the past (path-dependency) and countries' visions for the future.

Nevertheless, when designing policies, ministries and departments do expand their views across national borders to learn from other countries' experiences. The German feed-in tariff system, for example, has served as a model for other countries and the UK is currently keeping an eye on the Dutch "Stroomversnelling"-approach for improvements to its own residential housing stock. While this outward look is important for countries to prevent trying to reinvent the wheel, the findings of this study indicate it is difficult to replicate good examples one-on-one. Policy-makers will have to take care to take into account the large differences in structures, sectors, technologies and markets. A "translation" of policies is thus required, adjusting successful policies to fit with country-specific contexts.

9.4 Limitations of the study

The research presented in this thesis has made a first step in overcoming the lack in theoretical framework-based approaches in energy transition analyses. Using a sectoral analysis, the study allows for a comprehensive analysis of the housing sector, rather than assessing specific elements without a consideration of their context. The primary objective was to examine what the main barriers are for a sustainable energy transition in the residential sector. Furthermore, as only a limited number of interviews were conducted, further expert-interviews with representatives from the building sector, government and regional organisations may yield new observations or provide a more nuanced perspective.

9.5 Recommendations for further study

The cases presented in this thesis have resulted in a number of interesting findings. Having focused particularly on just four countries, it is important not to draw any firm conclusions beyond their boundary as replicating the process for other countries may result in different conclusions. However, the theoretically and systematically structured case studies do allow for well-founded hypotheses to be formulated on the connection between energy transition pathways and "policy success". They are:

1. Countries with strong institutional and departmental cooperation are more likely to be successful in their energy transition than countries characterised by fragmentation;
2. The formulation of clear and binding targets is more conducive to policy success than non-binding and voluntary goals;
3. Countries with strong government support for certain renewable energy technologies have a higher share of renewable energy than countries in which the choice of technologies is largely market-based; and
4. Fragmentation of ownership in the (private) rental sector is a negative factor, limiting the number of energy renovations.

Future research can build on these hypotheses and provide further insight to policy-makers.

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Appendix I: List of organisations consulted for this report

Netherlands:

Platform31	A Dutch knowledge- and network organisation for urban and regional development. Platform31 supports professionals and organisations dealing with social, economic and spatial issues with scientific research, experiments and networks.
PBL	Netherlands Environmental Assessment Agency (*Planbureau voor de Leefomgeving*) is the national institute for strategic policy analysis in relation to the environment, nature and spatial planning. Part of the Dutch government, PBL undertakes studies, analyses and evaluations with relevance to policy-making
Urgenda	Urgenda is a Dutch foundation for sustainability and innovation, aiming to speed up the energy transition in the Netherlands together with companies, governments, societal organisations and individuals.
VEH	Vereniging Eigen Huis (VEH) is the homeowner's association in the Netherlands with over 690,000 members, representing the interests of its members, on the one hand by lobbying governments and market parties and, on the other, by offering its services and products to its members (e.g. judicial or legal advice).
Dutch Senate	For this project, a conversation took place with a member of the Dutch Senate (*Eerste Kamer*) with knowledge about the Dutch housing market

Germany:

Ecofys	Ecofys is a consultancy firm in renewable energy, energy and carbon efficiency, energy systems and markets, and energy and climate policy. With offices in the Netherlands and Germany, Ecofys has over twenty-five years' experience and regularly works together with (national) governments.
BMWi	The Federal Ministry for Economic Affairs and Energy (in German *Bundesministerium für Wirtschaft und Energie, BMWi*) is responsible, amongst other things, for energy reforms in Germany, including the energy transition, energy grid and electricity market.
Conference	Energiewende conference in Berlin, Germany November 3-4, 2014

United Kingdom:

Energy Saving Trust	The Energy Saving Trust is one of the UKs leading organisations stimulating energy savings by households, governments, businesses and organisations throughout England, Northern Ireland, Scotland and Wales. EST conducts is own research and provides advice to households, consultancy to business, and develops programmes for governments.

Appendix II: National Energy Savings- & Renewable Energy Targets in the Netherlands (Table 1&2)

Table 1: National Energy Saving Targets in the Netherlands since 1974

Source:	**Target in original formulation**	**Main Policy-Instruments residential sector**	**Other**
First White Paper on Energy – Eerste Energienota (**EZ, 1974**)	Reducing the *growth* of energy use	• Information campaign on electricity use • Energy-label for electrical appliances • Energy pricing-policy • Stricter insulation requirement for new constructions, improved insulation existing dwellings	
Second White Paper on Energy – Tweede Energienota (**EZ, 1979**)	Efficiency improvements (as compared to 1977) of over 10% in 1985, 20% in 1990) and over 30% in 2000 (40% savings compared to 1973)	• Strengthening of insulation standards • Increased efficiency standards for high-efficiency (HR) boilers • Intensification NIP • Stimulation of district heating • Introduction of energy-labels for electrical appliances	
White Paper on Energy Savings of 1990 (**EZ, 1990**)	Doubling energy-efficiency to 2% per annum	• Subsidy-scheme for insulation and energy-savings for installed technologies • Tightened energy-efficiency standards in building requirements new dwellings • Increased attention to insulation in renovations	1992: Voluntary agreement govt. & housing corporations on insulation of rental properties. Extended to 01-01-1996.
Follow-up White Paper on Energy Savings of 1993 (**EZ, 1993**)	Intensification of policy to achieve average annual savings of 1.7% in	• Introduction energy performance standard for new	Goal translates to 23% efficiency improvement in the housing sector

	the period 1989-2000	homes, minimum performance standards for electrical appliances • Removal institutional barriers • Give a central role to energy-distribution companies for existing homes. • Experiments with reward-systems and fiscal stimuli	in the period 1989-2000.
Third White Paper on Energy (**EZ, 1995**)	33% over the 1995-2020 period (1.6 per cent per annum).	• Introduction of Energy Performance Norm (EPN), parties free to determine how this norm is met. • Voluntary agreements with the installation-sector	• Supply-side of the electricity market liberalised entirely with immediate effect. Gradual liberalisation demand-side. • 1996: Introduction Regulating Energy Tax (REB), tax on the use of electricity and gas
White Paper on Energy Savings of 1998 (**EZ, 1998**); Action-Programme on Energy Savings 1999-2002 (**EZ, 1999**); Climate Policy Implementation Plan (**VROM, 1999**)	2% p.a. over the 1998-2010 period	• Energy Performance Advice • Increase REB in three annual steps, starting in 1999 • Tightening of EPN as of 01-2000 (from 1.2 to 1.0). • Energy labels made a legal requirement for dishwashers (1999) and light-bulbs (2001), minimum performance requirements for refrigerators and freezers.	• Voluntary agreement with umbrella organisation housing association
Energy Report of 2002 (**EZ, 2002**)	1.3% p.a. or as much as required to meet the Kyoto-requirements	• Improve efficiency of existing policy instruments • Stimulation of "transition" initiatives such as CHP	
'*Schoon & Zuinig*' [Clean & Efficient] (**VROM, 2007**)	Increase to 2% p.a. over the 2011-2020 period	• EPC for new dwellings to go from 0.8 to 0.6 in 2011, and 0.4 in 2015.	• 2008: ´*Meer met Minder*´ [More with Less] • Agreement with housing

		• Introduction energy label for existing buildings • Stimulating energy-efficiency of appliances	associations on improvement of energy performance rental properties
Coalition Agreement 2010	No national target, continuation and intensification of existing national policies		2011: ‘*Blok voor Blok*’ [Block by Block] – 13 projects, running until end 2014
Coalition Agreement 2012	Energy saving made “priority”, no national target	• Green Deals extended with energy-saving agreements with energy providers and housing corporations. • Removal of legislative barriers	2012: ‘*Meer met Minder*’ (2)
Energy Agreement for Sustainable Growth (**SER, 2013**)	1.5% average annual energy savings, saving 100PJ of final energy use by 2020, interim-targets of 35% by 31-12-2016 and 65% by 31-12-2018.	• Information campaign set up to inform, motivate and ‘unburden’ consumers • Thermally improve 300,000 existing dwellings each year, improving the energy-label by a minimum of 2 steps • B-label average for social rental properties and at least 80% minimally C-label for private rental properties by 2020 • New properties near-energy neutral from 2020 (conform EU requirements)	• No formulation of sector-specific goals • Large-scale roll-out of smart meters • As of January 1st, 2015, homes can only be sold or rented out with a valid energy label, €400 penalty for homes sold without. • Revolving fund for energy-saving measures established, aimed at homeowners and landlords.

Table 2: National Sustainable Energy Targets in the Netherlands since 1990

Source:	Target in original formulation	Main Policy-Instruments residential sector	Other
White Paper on Energy Savings of 1990 (**EZ, 1990**)	5% of current domestic energy use, equating to about 150PJ	• Ambition to install around 300,000 solar-boilers in new and existing dwellings by 2010	• Investment subsidies (SES) for flow-energy (e.g. solar-heating) available since the mid-1980s (**Verbong et al., 2001**). • Targets were never met
Third White Paper on Energy (**EZ, 1995**); Sustainable Energy on the Rise (**EZ, 1997**).	10% share of sustainable sources in *total* energy use in 2020, interim target of 3% in 2000, largely in electricity production	• Tax-deductibility for investments and lowering of VAT for "green" electricity, potentially solar-boilers • Demonstration projects • "adequate" feed-in tariffs for private parties	• Most important contribution from waste & biomass, followed by heat-pumps. Wind-energy in third place, solar-PV a long-term option.
Climate Policy Implementation Plan (**VROM, 1999**)	Interim-target of 5% in 2010	• Voluntary energy performance advice (EPA) for homeowners added to existing policies	
Energy Report of 2002 (**EZ, 2002**)	No new targets introduced. Share of RE 1.2% of total energy-supply (excl. imports) in 2000, thus below the target.	• Policy-agenda largely aimed at the supply-side. No further demand-side policies added. • 2003-2006: open-ended system of feed-in premiums to producers of electricity from renewable sources (MEP)	• 'Green electricity'-market liberalised from July 2001, green electricity exempted from REB. • Under Cabinet Balkenende I (2002-2002), €500 million cuts in sustainable subsidies, in particular tax-credits green electricity
Energy Report of 2005 (**EZ, 2005**)	Government expects that with current policies, 9% of electricity can be generated sustainably by 2010.	• Researching possibility of stimulating installing smart-meters in households • Policy-agenda remains	Government now unsure the 10% target for 2020 will be met, states the main goal is to learn which combination of policy instruments

		largely aimed at supply-side	delivers ‘maximum contribution to the long-term goals’
Coalition Agreement 2007; ‘*Schoon & Zuinig*’ (**VROM, 2007**)	An increase in the share of sustainable energy to 20% in 2020	• Policies remain geared towards the energy-sector • Subsidy-schemes to stimulate sustainable energy options (e.g. heat-pumps & solar-PV) • 2008-2011: MEP-system replaced by scheme for the stimulation of sustainable energy production (SDE)	• Due to large interest, the costs of MEP were considered too high. The SDE introduces the possibility of a subsidy-ceiling per technology. • Stop-and-go nature of subsidy often regarded as frustrating
Coalition Agreement 2010; Energy Report of 2011 (**EZL&I, 2011**)	European goals are leading, which means 14% sustainable energy in 2020.	• Strong policy-focus on the energy sector • ‘Green Deals’ with society to stimulate decentralised sustainable energy production with 5 categories, incl. citizens	• In 2011, the SDE is replaced by SDE+, aims at companies & (non-) profit institutions, not available to consumers. • May 2012: €200 million for the intensification of the sustainable economy
Coalition Agreement 2012;	16% sustainable energy in 2020	• Small-scale, sustainable generation of (solar-) energy fiscally stimulated through a lower tariff of energy-tax for electricity coming from, and used by, small-scale private co-operations	• October 2012: Allocation of intensification-funds turned back. • €22 million available for solar-panel subsidies in 2012 (from July 2), €30 million for 2013. Budget depleted August ’13.
Energy Agreement for Sustainable Growth (**SER, 2013**).	Increase of renewable energy to 14% in 2020, further increase of the share to 16% in 2023	• Developers of on-shore wind-energy projects commit to organising popular support by actively involving community • Removal of non-financial barriers • Tax-discount of 7,5 ct/kWh (excl. VAT) for renewable energy generated through a	• Goal of 40PJ decentralised generating capacity in 2020 • Ambition is that a minimum of 1 million households and/or SME’s meet a substantial proportion of their electricity needs through decentralised energy and use other forms of sustainable generation

		owners’ association or cooperation & used by small-scale users, provided they are in a certain post-code area	• 2014, several cities open up “Sustainability Shops” where citizens can get advice

S. ACADEM

ATIAE

RITAS