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Energy policy instruments and technical change in the residential building sector

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Energy policy instruments and technical change in the residential building sector

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Acknowledgements

Is it possible to discover your life's interest when still a child? It never was technology itself that interested me in childhood (disregarding the Lego and other construction toys). It was more a case of technology being necessary to enable me to do what I wanted: a pre-war manual sewing machine for making clothes and a typewriter for writing stories. And in fact, I am still doing much the same these days. Technology as such still fails to interest me, but I still use it for writing stories (and for sewing). Perhaps it is for that reason that I decided to research a subject that lies on the interface of technology and society. The theme explored by this dissertation is energy policy for the residential building sector and its implications for innovation.

First of all, I would like to thank my supervisor Hugo Priemus. Although the distance between us increased with his move to the Faculty of Technology, Policy and Management, Hugo has always been a great source of inspiration to me and a meeting with Hugo always gave me renewed energy. I want to thank Linda Sheridan for making the research visit to the University of Liverpool possible and for the guidance in Liverpool and the surroundings at the time. This research was partly conducted within the framework of an EU Altener project and – though the project was finished some time ago – I still have good memories of meetings with Kirsten, Carol, Roel, Claudia and Gerelle. Sylvia Janssen helped me a lot with the statistical aspects of my thesis. Most of all, I am indebted to my brother Niels who, as an experienced scientific researcher, taught me a lot with his vision of social science. Co-writing an article was a wonderful experience and an excellent learning curve for appreciating academic work.

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Thanks to Eugene for allowing me to e-mail whenever I needed distraction, with a fully guaranteed smile in the answer. A special thanks to Frido who – as a member of the construction sector – could provide me with interesting details from his working experience. Thank you Tet, Saskia, Krista, Jolien, Marie-Jose, Katja, Emmely, Lineke, Nicole, Lonneke, Druschke and Jacqueline for always showing an interest in my PhD while never expressing concerns about its progress. Thanks to all (ex-)members of the most unique student club in Eindhoven for the many nights of Spanish music, fun, drinks, carnival and sweaty black suits. A special thanks to Laure who seemed to cope wonderfully with my - at times rather autistic - working habits in our office. Thanks to all my current and former colleagues for the many discussions at work and the pleasant and friendly atmosphere.

I want to thank my mother, Bertho and my mother-in-law for babysitting during the past four years and for their help and advice on how to combine work and family life. A special thank-you to my father-in-law who always showed a great interest in my thesis and was convinced all along that I would get a good result. During this entire PhD process I have received immeasurable moral support from Harry. Thank you for everything and for being an inexhaustible sounding board for whatever my mind creates. Kick and Ina, your worries these days revolve mainly around the size of the Christmas tree and I hope it will stay like that for a long time.

Finally, I want to thank my greatest source of inspiration, my father. This is the second thesis that is dedicated to him. I hope they provide plenty of reading time in heaven....

1 Introduction

1.1 Background

Today's world leaders increasingly acknowledge that we need to make a transition to utilising sustainable energy systems on a global scale (G8 Summit, 2007). The supply of clean energy, for example geothermal power, hydropower, and solar power, seems boundless, but it is only limitedly being converted into useful energy. At the present time, fossil fuel is the most dominant source of energy in our global economy with natural gas, oil, and coal being the primary energy carriers. The use of fossil fuels coincides with problems for the environment and security of supply. The consequences of emitting twice as much CO_2 than the atmosphere can absorb are dominating discussions about energy conservation these days. Originally, however, energy supply was the principal factor that drove the need to reconsider energy consumption. During the 1970s, the Club of Rome issued a warning that the supply of natural gas would run out in a few decades (Meadows *et al.*, 1972). Today, however, opinions regarding how long fossil fuels will last differ greatly. According to the International Energy Agency, fossil fuels will still be available in sufficient quantities until at least 2030 (OECD/IEA, 2006). The Association for the Study of Peak Oil & Gas, however, warns that world oil production will peak in the very near future, predicting an energy crisis in 2015 when China's energy demands will be booming while at the same time oil production will be in severe decline (ASPO, 2007). Today, in addition to the issue of declining resources, energy supply seems even more to be a problem of dependency on supply, since only a limited number of countries dominate the fossil fuel market. Even as early on as the oil crisis initiated by the Yom Kippur War between Israel and a coalition of Arab nations in the early 1970s, the economic aspect of energy conservation was considered as a reason to promote energy conservation and to diminish dependency on fuels supplied from a limited number of countries. The European Commission announced in it's Green Paper – *Towards a European strategy for the security of energy supply* – that the EU would depend on external energy sources for 70% of its supply by the year 2030 if no action was undertaken (European Commission, 2006a). Influential organisations such as the International Energy Agency (IEA) and the Energy Information Agency (EIA), an institute of the US Department of Energy, have come to similar conclusions in their predictions: OECD countries are expected to depend on imports for about 66% of their fossil fuel needs by the year 2030 (OECD/IEA, 2006; EIA, 2006). The IEA also foresees that energy use will increase by 60% by 2025, and that renewable energy will still only play a minor role by that time (OECD/IEA, 2006.). This means that geopolitical issues will significantly influence energy supplies to countries that do not have their own fossil fuel resources. Hoogeveen and Perlot describe several scenarios that could take place in the near future (Hoogeveen & Perlot, 2005). The extremes consist of on the one hand globalisation where energy is traded on market-based principles and where the U.S. dominates the rules of the game; while on the other it is possible that national interests will dominate fuel trade, with autocratic economies such as China, Russia and, more recently, Venezuela providing fuel based on bilateral contracts between consumer and producer countries (ibid.). The position of the EU on the fossil fuel energy market in the near future is unclear. It will be more important than ever to agree on common ground when creating a European energy policy.

More recently, arguments that focus on the effects of fossil fuel combustion dominate discussions pleading for energy conservation. During the combustion of coal, oil, and natural gas, nitrogen oxide (NO_x) and carbon dioxide (CO_2) are released. In addition, the combustion of coal and oil releases sulphur dioxide (SO_2). NO_x and SO_2 cause acidification in the environment, and CO_2 contributes to the greenhouse effect. Increasingly, climatic changes are being attributed to the greenhouse effect (IPCC, 2007). The gradually growing acceptance of views regarding climatic changes prompted the United Nations Framework Convention on Climate Change in 1992, in which 189 countries ratified an overall framework for intergovernmental efforts to tackle the challenges posed by climate change (United Nations, 1992). An addition to the treaty was made in the 1997 Kyoto Protocol which significantly strengthened the Convention by committing parties to individual, legally-binding targets to limit or reduce their greenhouse gas emissions (United Nations, 1998). The ratification of the Kyoto Protocol by Russia caused it to enter into force on 16 February 2005, meaning that, by 2008-2012, developed countries have to reduce their Green House Gas (GHG) emissions by an average of 5% below their 1990 levels. The reduction target that was imposed on the European Union, a reduction of 8% of GHG emissions, was subsequently distributed into separate reduction targets per member state under the principle of 'burden sharing' (Council of the European Union, 2002). Besides reducing GHG emissions in a country's own production, emissions reductions can also be purchased from elsewhere by means of financial exchanges – emissions trading or Joint Implementation – as well as by setting up projects that reduce emissions in developing countries (Clean Development Mechanism). At the end of 2006, 168 countries had ratified the Kyoto Protocol. However, two of the largest emitters on a per capita basis, the United States and Australia, have not ratified the agreement.

The Brussels European Council of March 2007 acknowledged the importance of energy conservation and called on EU member states to pursue actions to develop a sustainable integrated European climate and energy policy (Council of EU, 2007). In their statement, the 27 leaders committed themselves to a target of reducing EU GHG emissions by 20% by 2020, and offered to go to 30% if major nations such as the United States, Russia, China, and India followed suit. They also endorsed the EU aim of having a binding target of a 20% share of renewable energies in overall EU energy consumption by 2020. In its

Action Plan – *Energy Policy for Europe* – and in concordance with the Presidency conclusions of the European Council, the EC calls for a rapid implementation of priorities as formulated in the Commission's *Action Plan on Energy Efficiency* (European Commission, 2006b), relating to energy-efficient transport, dynamic minimum efficiency requirements for energy-using equipment, energy-efficient and energy-saving behaviour of energy consumers, energy technology and innovations, and energy savings from buildings (Council of EU, 2007).

1.2 Energy conservation in the building sector

The building sector is a major end user of energy. In the European Union, households and the non-residential sector account for about 40% of total energy demand (EC, 2003). Energy consumption in the EU in this sector grew steadily from 355 million tonnes of oil equivalent (TOE) in 1980, to 384 million TOE in 1998 (1 TOE = 42.7 GJ). In absolute terms, energy consumption has increased in recent years. This is due to the growing number of households and the resulting increase in electricity and domestic hot water consumption. In the European Union, households are the largest consumers of natural gas, accounting for one third of total gas consumption. Space heating is by far the largest energy end-use of households in Member States (57%), followed by water heating (25%) (EC, 2003). Electrical appliances and lighting make up 11% of the sector's total energy consumption (ibid.).

Since the 1970s, many national governments have recognised the building sector as an important end-user of energy, and have initiated information campaigns to make people aware of their energy use. Cost reduction was an important argument that was used to convince households of the need for energy conservation. At the same time, regulations were introduced in the building sector that imposed minimum levels of facade, floor, roof, and glazing insulation for new building. In many countries, energy regulations for the building sector gradually evolved from minimum insulation levels to more extensive types of regulations, consisting of heat loss calculations, or heat demand calculations, the latter also including efficiencies of heating, ventilation, and air-conditioning (HVAC) equipment.

Building regulations impose constraints on the physical appearance of a building, thus providing optimal conditions for energy conservation. The actual total energy consumption per household, however, is determined by household behaviour and electricity use, dominated by appliances. In The Netherlands, the use of natural gas (used for space heating and domestic hot water) decreased about 45% between 1980 and 2004, while electricity use increased by 24% between 1988 and 2004 (ECN, 2007). Electricity consumption can barely be influenced by building regulations, and instead correlates highly with affluence.

Today, the aim of energy conservation is based largely on environmental goals. The importance of government intervention seems to be greater than ever, because – with environmental quality only being a public good – no market prices exist and demand would be too low without government intervention. The European Union finds the subject of energy conservation in the building sector important and has decided on a communautary approach. In December 2002, the European Parliament decided to harmonise energy regulations for the building sector in their directive COM 2002/91/EC, also known as the Energy Performance of Buildings Directive (EPBD) (European Commission, 2003).

1.3 Problem definition

The topic of energy policy instruments for the building sector in the European Union is timely, and is currently very much influenced by EU Directive 2002/91/EC, also known as the Energy Performance of Buildings Directive (EPBD) (European Commission, 2003). When the EPBD was announced in 2003, an overview of current energy regulations for the building sector in EU member states was not available and the effort expected from the member states was unknown. Knowledge of the experience of energy performance regulations in EU member states can help in finding suitable cases for carrying out evaluation research.

Energy performance policy in the building sector – such as is described by EU Directive 2002/91/EC – has the aim of reducing energy consumption in buildings caused by heating, hot water production, lighting, cooling, and ventilation. Energy performance policy has already proven to be a successful means for realising energy conservation in The Netherlands (Joosen *et al.*, 2004). Energy conservation targets have been developed on a global level, a European level, as well as by nearly all individual nations in order to mitigate climate change. Long-term targets for energy conservation are severe, and they will require huge efforts from nations, industries, and consumers. In light of this, there is growing awareness that in order to tackle the dangers of climate change in the longer term (30 to 50 years), a transition to a sustainable energy supply system will be necessary (Shackley & Green, 2007). A transition to a sustainable energy supply will need, on the one hand, a radical change in behaviour and, on the other hand, more environmentally benign technologies that preserve the natural environment. Environmentally benign technologies in the residential building sector are, for example, technologies that use renewable energy sources such as solar thermal systems that provide heat for domestic hot water or space heating; solar photovoltaic panels that providing electricity; or heat pumps that provide low temperature heat for domestic hot water or space heating.

When energy performance regulations were introduced in The Netherlands in 1995, the Dutch government stated that this type of regulation would stimulate innovations in heating, ventilation, and air-conditioning (HVAC) technology (Ministerie van VROM, 1995). The energy performance standard in The Netherlands has been tightened three times during the last ten years. Every time a new standard has been introduced, it has been accompanied by statements claiming that innovation would be encouraged (Tweede Kamer, 2004). However, several studies in policy science have concluded that setting standards does not lead to innovation, since a standard does not encourage a performance that is better than the standard, and therefore does not promote a continuous strive to search for more efficient solutions (Driessen & Glasbergen, 2000; Vermeulen, 1992; Schot, 1990). In a number of studies, the effectiveness of different types and combinations of policy instruments in stimulating environmental innovations has been scrutinised (Kemp, 1997; Hemmelskamp, 2000). The results of these studies suggest several ways in which (combinations of) policy instruments could be more effective in stimulating environmental innovations.

Given the importance of the development of innovations in energy technology, and a transition to a sustainable energy supply system, it is necessary that policy instruments for energy conservation in the building sector stimulate the development and diffusion of 'really new' and incremental innovations, or that they at least prevent a 'lock-in' effect which makes it difficult to deviate from conventional techniques. Although several member states already make use of energy performance regulations, as far as we know – and confirmed by a European project into this matter – none of them has investigated the effect of energy performance regulations in stimulating innovations in energy technology for the residential building sector (Enper, 2004).

At the same time, the discussion of energy conservation in the building sector is moving from new building, where the topic started some time ago, to existing building, where the topic only started recently. There is consensus that more energy conservation investment benefits can be expected in the existing building than in new building, since the existing building stock exceeds the number of new building by far, and since the existing building stock was built under prevalently poor energy standards at the time of construction. The target group for addressing energy conservation policies for existing buildings is heterogeneous, consisting of individual house-owners, housing associations, and commercial real estate agents. This makes it difficult to develop and attribute policy instruments that do not cause undesirable financial pressures on low-income households. EU directive 2002/91/EC mentions, as one of its conditions, that in future all building should display an energy label, based on an energy performance type instrument (EC, 2003). This voluntary policy instrument is expected to contribute to energy conservation in the building stock, but this is still a largely unexplored topic.

The eventual aim in terms of energy reduction in the building sector is to mitigate climate change (IPCC, 2007). For this aim, innovation is needed on a large scale, going beyond the scope of energy performance policy alone. A broader view, in terms of the innovation system in the building sector, is needed in order to formulate long-term recommendations for encouraging innovation.

Finally, it is obvious that technological innovation will not solve the problem of climate change on its own. Joint acceptance of new technology is needed for success, and changes in user behaviour are required in order to tackle the negative effects of affluence. The results of this study will therefore have to be related to the broader issue of a transition to an economy based on sustainable energy. In addition, the benefit of energy performance policy will have to be discussed in relation to other possible solutions and the level of government through which energy policy is introduced.

1.4 Objective and research questions

The objective of this study is threefold. First, it aims to contribute to knowledge about the content of energy performance policy, and the way in which this policy is designed to encourage innovations. Descriptive comparative analysis of energy policies in European member states can identify possible directions in which energy performance policy can be shaped, and the impact that different directions can have. It acknowledges that national policies develop in line with national systems and national institutions, and that they differ to a large extent according to the degree of development of a nation. In terms of energy policy, it is of course important to consider national, and even regional, climates which directly influence the necessity for, and content of, energy policy. For that reason, it is interesting to see whether efforts for energy policy in a number of nations with similar levels of development and somewhat similar climates show divergent or convergent developments, and whether it is possible – to some extent – for an overall theory to be applied. A comparative analysis of experiences with energy policy also helps in finding suitable cases for submitting evaluation research. Within the context of studying the content and possibilities of energy performance policy, the feasibility of policy instruments for the existing residential building sector has also been explored.

Secondly, the study aims to provide insight into the effect of energy performance policy in encouraging innovation, in order to find out whether or not the general expectation that energy performance policy promotes innovation is true. Policy evaluation research is therefore carried out, starting with mapping energy performance policy process and its variables, defining the concept of innovation, and then refining this collective term into categories of innovation. The effect of environmental policies on innovation has been studied on a small scale from an innovation system perspective (see Hemmelskamp *et al.*, 2000; Vollebergh *et al.*, 2004; Kemp, 1995; 2000). For this research, the approach has focused on the innovation system theory from the perspective of the sectoral innovation system. Since the innovation system approach is broad and fragmented, we introduce theoretical knowledge in this field in Chapter 2. In our research, the innovation system of the Dutch building industry has been explored; both quantitative as well as qualitative research form the basis for conclusions about the relation between energy performance policy and innovation in energy technology. This part of the study contributes to knowledge about the expected side-effects of energy performance policy in encouraging the use or development of innovations for energy technology in buildings. The study contributes to innovation system literature in the exploration of the effectiveness of policies in encouraging innovations. The study especially focuses on the effects of environmental policies in an innovation system that is dominated by project-based firms.

Thirdly, the study contributes to the discussion about the impact of government policy – and possibilities and/or impossibilities – for energy conservation in the building sector, in the context of climate change policy. In this part of the study, recommendations for effective and efficient energy policy are formulated. Recommendations for the use of energy performance policy can be useful for all European member states, since these will have to (re)develop energy performance policy for buildings as a consequence of the EU Directive 2002/91/EC.

Following the aims of this study, the research questions can be divided into three groups (see Figure 1.1). The first part of the research consists of a descriptive analysis concentrating on the content of energy performance policy, and covers the following research questions:

1 *What lessons can be learned from comparing experiences in energy policies for residential buildings in European member states?*

1.1 What energy policy designs for new residential building are available in northern European member states, and what are the implementation demands of EU Directive 2002/91/EC? (Chapter 3)

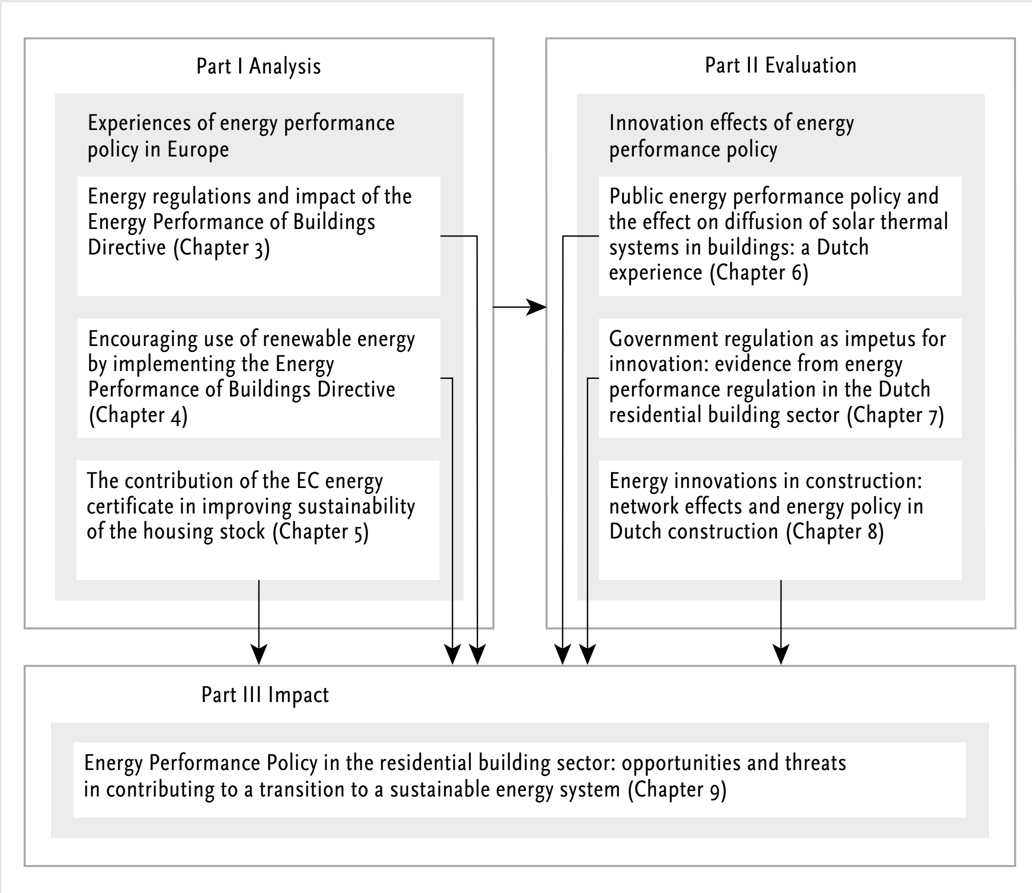
1.2 What possibilities exist for encouraging renewable energy technologies by means of energy performance policy? (Chapter 4)

1.3 What energy conservation effects can be expected from introducing energy performance labels for existing residential building? (Chapter 5)

The second part of the book focuses on evaluating the innovation effects of energy performance policy, and covers the following research questions:

2 *What is the relation between energy performance policy and innovation in energy technology, and what influence can be observed from the sectoral innovation sys-*

Figure 1.1 Research structure



tem of the construction industry?

2.1 What is the effect of energy performance policy for new residential buildings in the diffusion of solar thermal systems? (Chapter 6)

2.2 What are the innovation effects in heating technology of energy performance regulations for new residential buildings in The Netherlands? (Chapter 7)

2.3 What is the effect of the interplay between projects and firms in the sectoral innovation system of the construction sector in relation to energy performance policy and the diffusion of innovation in heating technology? (Chapter 8)

The third part of the book consists of the final chapter, which brings the research of Chapters 2 to 8 together in explaining the impact and possibilities of government policy for energy conservation in the building sector. It covers the following final research question:

3 *What is the benefit of energy performance policy in relation to other possible solutions, what is its relation to mitigating climate change, and to what extent might*

more intensive government intervention be justified in reducing greenhouse gas emissions in the residential building sector? (Chapter 9)

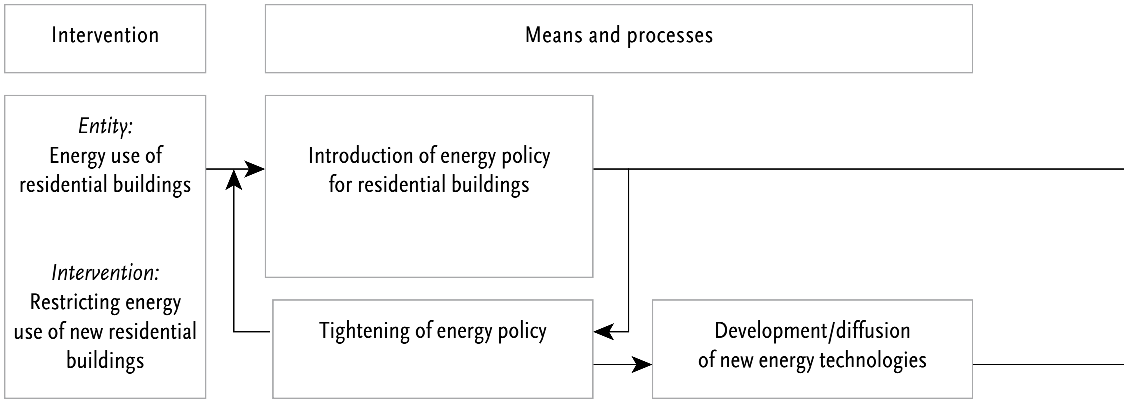
1.5 Research approach

The research questions of this study have been approached using a variety of research methods. The study into experiences with energy performance policy in the EU is a descriptive comparative analysis on the basis of desk research and additional interviews. Comparative analysis of national systems of policies, or national institutional structures, has a long research tradition. Comparing national systems allows for the placing of experiences in a broader context, and for the confrontation of the national naturalness of policies or institutions with possible 'unnaturalness' when juxtaposed on an international level. Comparisons between nations can also indicate whether overall theories apply on a global scale, or whether either convergent or divergent developments can be found. On a national level, it can be fruitful to mirror national experiences with foreign practices (Boelhouwer & Van der Heijden, 1992).

The core of this study consists of policy evaluation research. Evaluation research can be defined as "the systematic application of social research procedures for assessing the conceptualisation, design, implementation and utility of social intervention programmes" (Rossi & Freeman, 1993). It implies that social research methodologies are used in order to judge and improve policies, and in order to assess the effectiveness and efficiency of such policies. Doing so, at first the policy process has to be mapped. The policy process starts from the policy target and continues in a causal cycle to the policy intervention, the means and processes used to implement the intervention, the products or services that result from the intervention, and finally, to the results of the intervention. We mapped the process of energy performance policy for the residential building sector according to the general model for evaluation research introduced by Mayer & Greenwood (Vall, 1987). Figure 1.2 shows the basic outline of energy performance policy process.

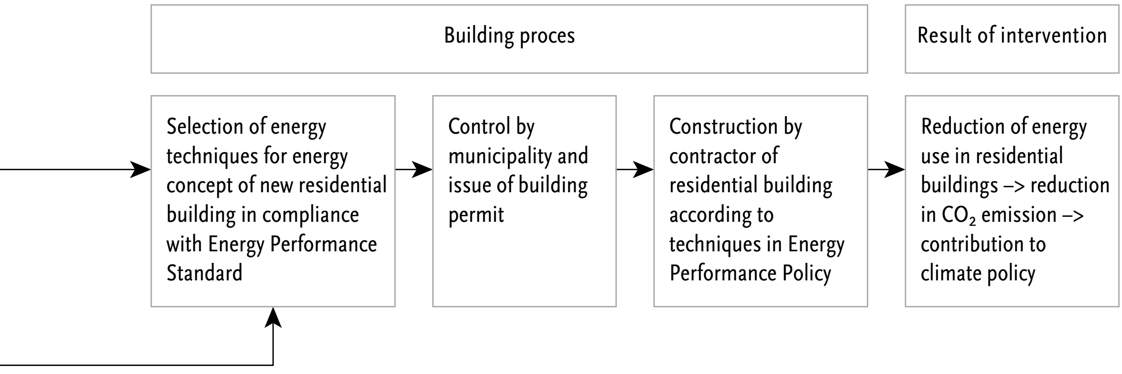
The illustration of the policy process helps to identify the causal relationships between the independent and dependent variables, which are the subjects of the evaluation research. In our research, we will identify the causal relationship that exists between intervention by means of imposing energy performance standards – *the independent variable*; and the development and diffusion of new energy technologies – *the dependent variable*. Figure 1.2 shows how the innovation effects of introducing an energy performance policy are primarily a side-effect of the actual policy goal of reducing CO_2 in the building sector, since the main goal of energy performance policy is the reduction

Figure 1.2 Energy policy process for residential building



of energy use in residential buildings as a contribution to climate policy. This evaluation study can be defined as an impact assessment that estimates the extent to which the policy caused changes in the desired direction. Since the subject of the evaluation is an expected side-effect of the policy, measurable policy goals are lacking and the desired direction is formulated in general terms as 'more innovation'. We have therefore paid attention to defining innovation and identifying advancing factors (adjuncts) and restricting factors (constraints) outside the system that also encourage or prevent the development and diffusion of new energy technologies (see Chapter 7). Many types of impact assessments are possible, but since we aim to scrutinise the long-term effect of the programme over a number of years, we have chosen to use both quantitative (Chapters 6 and 7) as well as qualitative research methods (Chapter 8). The combination of both quantitative as well as qualitative research is often advocated as a useful combination in policy evaluation research where qualitative data can help to explain the quantitative numbers (Bressers & Hoogerwerf, 1995). By means of a time series approach for which data has been collected during the period from 1996 – the introduction of energy performance policy in the Netherlands – until 2003, it is possible to indicate the diffusion of HVAC techniques in new residential building, and to use statistical techniques in order to assess the relative influence of energy performance policy. By means of interview-studies, explanations and opinions about the functioning of energy performance policy in the Netherlands have been elucidated.

A crucial topic of this research is to explore energy regulations in the European Union. This study has been based on desk research, in combination with expert interviews. Part of this study was completed at the University of Liverpool, School of Architecture, in order to complement the view of British energy regulations.



The exploration of energy performance regulations continued by focusing on the relation between energy performance policy and the use of renewable energy techniques in the residential building sector. This study was performed in the European Build-On-RES research project, which was partly funded by the Fifth Framework Programme (FP5) of the European Commission, and initiated and coordinated by the author on behalf of the OTB Research Institute for Housing, Urban and Mobility Studies.

The expected effect of energy performance policy for the existing building sector is studied by means of case-study research, and comparison of the compulsory energy labelling scheme in Denmark with the voluntary energy labelling scheme in the Netherlands.

Innovation effects of energy performance policy in the Netherlands have been studied by means of quantitative research on the basis of energy performance calculations that were collected from one municipality and from two consultancies, because energy performance calculations are not monitored in the Netherlands. In total, 352 energy performance calculations for residential buildings were collected from various sources covering the period from 1996 to 2003. The calculations were randomly selected from municipal archives, and represent each year equally. The database of energy performance calculations allows us to identify the effect of energy performance policy for solar thermal systems in the Netherlands, and allows us to identify the innovation effect of energy performance policy for the residential building sector in the Netherlands.

Factors determining choices for innovation in the supply sector of the Dutch residential building industry have been explored qualitatively, by means of interview-studies with stakeholders in this industry.

The impact of energy performance policy and its possible contribution to a transition to a sustainable energy system brings together the work of Chapters 2 to 8 and places the results in the broader perspective of climate change, and the policy needed to bring about a transition to a sustainable energy system. This research is founded on desk-based study of the efforts needed to mitigate climate change, and research into the possibilities of transition management, combined with the results of the analysis and evaluation of energy performance policy.

1.6 Added value and context of the PhD-thesis

This research was conducted at the OTB Research Institute for Housing, Urban and Mobility Studies, an interfaculty research institute within Delft University of Technology, involving the faculties of Architecture, Civil Engineering and Geosciences, and Technology, Policy and Management. The research first started as a European Project, partially funded by the European Commission through the Altener Fifth Framework Programme, and by the OTB Research Institute for Housing, Urban and Mobility Studies. In 2002, part of the research described in Chapter 3 was conducted at the University of Liverpool, School of Architecture, facilitated by a grant from the British Council. The research continued with funding provided by BSIK funds (*Innovative Land-Use* programme), as part of the Delft Research Centre Sustainable Urban Areas research programme. It is related to the programme's four other dissertations on sustainable housing: Sustainable solutions for Dutch housing, reducing the environmental impacts of new and existing houses (Klunder, 2005); Cost-effectiveness of sustainable housing investments (De Jonge, 2005); Policies for improving energy efficiency in the European housing stock (Sunikka, 2006); and the forthcoming doctoral thesis by Inge Blom (Environmental assessment of building use).

The second part of the research was conducted in the framework of the Habiforum programme *Innovative Land Use* (BSIK), an expert network promoting innovations in spatial planning with government funding, and Corpovenista (Housing Associations Renewing the City, a project running in 2004-2007), a joint venture of Aedes (branch organisation of Dutch housing associations), a number of Dutch housing associations, the Dutch government, and SBR (Stichting Bouwresearch). These stakeholders took part in the steering committee of the project and commented on the results during the project.

This research focuses on the energy consumption that is restricted by energy performance policy for buildings and which can be attributed to the physical features of a building. This amounts to energy use related to space heating, heating of domestic hot water, energy lost as a result of ventilation, and – to some extent – lighting. Energy performance policy calculates energy use of a building for these features for a standardised occupancy pattern, such as a household of 2.3 people heating its living accommodation to a temperature of 20˚C. Differences in occupancy behaviour can result in rather different energy consumption than that calculated by an energy performance calculation. Energy performance policy does not review electricity use by household appliances, such as washing machines, refrigerators, and computers. Therefore, it is possible that a building with very good energy performance can conversely have high levels energy consumption because of intensive use of, and/or having a large number of, household appliances. This research recognises that it is focusing on technical measures that only form a part of the actual energy consumption of households.

The subject of energy performance policy is timely, since the EU Directive known as the EPBD is being implemented right now, with an ultimate deadline of 1 January 2009. Since all EU member states are required to introduce energy performance policies for buildings, it is remarkable that, to date, very little scientific research has been carried out into the benefits that such policies can offer in comparison to other solutions. The study of policies as a research subject, however, has the problem of being faced with continuous change and development. As this research was conducted from 2001 to 2007, some of the work may seem outdated, especially the first part of the study. However, the first part of this study provides a clear view as to which member states offer suitable situations for performing evaluation research. It also presents a clear picture of the differences experienced by member states when dealing with energy policies, and the resulting efforts needed in order to implement the EPBD. It is therefore not strange to notice that although the European Commission asked member states to implement Directive 2002/91/EC by 1 January 2006, many member states – including the Netherlands – ultimately took the opportunity to postpone its introduction until 1 January 2009.

This research has been published in five articles – a sixth article is currently under review – which are included as chapters in this book. Since every article needs to be introduced so that a reader can obtain a clear picture of the research framework, some repetition in the introduction of the articles may appear. The reader should note that the articles have been published over a period of time, starting in 2002, and may therefore be subject to changes that have not been incorporated.

The study focuses on residential buildings and has used the experience of The Netherlands to evaluate innovation effects. In the residential building sector, twice as much energy is consumed as compared to the non-residential building sector. The residential building sector has a different approach to developing energy systems compared to the non-residential sector, a significant difference being, for example, the complexity of installations, and the differences in need for cooling, or for domestic hot water. The Netherlands is known for having extensive experience of energy regulations, and more specifically of energy performance regulations (see Chapter 3). The Netherlands therefore provides a suitable case for evaluating the effects of energy performance policy for residential buildings.

Energy performance policy on its own is not expected to drive the transition to a sustainable energy system. It is, however, important that the use of energy performance policy is not counterproductive to such a policy goal. The problems of climate change are currently acknowledged on a worldwide scale, and it is these problems that have provoked the unique situation of development of worldwide policies. The side-effects and benefits of energy performance policies will therefore be related to such policy goals on national, European, and international levels.

1.7 Organisation of the PhD-thesis

This PhD thesis comprises one chapter containing a literature overview (Chapter 2), two chapters based on two books and previously published international academic articles (Chapters 3 and 4), three chapters based on previously published international academic articles (Chapters 5, 6 and 7) and one chapter based on an article that was recently submitted to an academic journal (Chapter 8).

Research question 1, dealing with the analysis of energy performance policy, is answered in Chapters 3, 4 and 5.

Research question 1.1 "*What energy policy designs for new residential building are available in northern European member states, and what are the implementation demands of EU Directive 2002/91/EC?*" is addressed in Chapter 3, which is based on the study: *Energy regulations for new building – in search of harmonisation in the European Union* (Beerepoot, 2002), and the article: *Energy regulations and impact EC Directive "Energy Performance of Buildings"* (Beerepoot, 2003), published in *Open House International 28* (1): 53-59.

Research question 1.2 "*What possibilities exist for encouraging renewable energy technologies by means of energy performance policy?*" is answered in Chapter 4, covering the article: *Encouraging use of renewable energy by implementing the Energy Performance of Buildings Directive* (Beerepoot, 2006), published in *European Environment 16* (3): pp. 167-177. This article is based on the study: *Renewable energy in energy performance regulations* (Beerepoot, 2004).

Research question 1.3 "*What energy conservation effects can be expected from introducing energy performance labels for existing residential building?*" is addressed in Chapter 5, and is based on the article: *The contribution of the EC energy certificate in improving sustainability of the housing stock* (Beerepoot & Sunikka, 2005), published in: *Environment & Planning B,* Vol. 32, pp. 21-31.

Research question 2, dealing with the evaluation of innovation effects of energy performance policy, is addressed in Chapters 6, 7 and 8.

Research question 2.1 "*What is the effect of energy performance policy for new residential buildings in the diffusion of solar thermal systems?*" is dealt with in Chapter 6 and contains the article: *Public energy performance policy and the effect* *on diffusion of solar thermal systems in buildings: a Dutch experience* (Beerepoot, 2007), published in: *Renewable Energy*, Vol. 32, pp. 1882-1897.

Research question 2.2 "*What are the innovation effects in heating technology of energy performance regulations for new residential buildings in The Netherlands?*" is answered in Chapter 7, which consists of the article: *Government regulation as impetus for innovation: evidence from energy performance regulation in the Dutch residential building sector* (Beerepoot & Beerepoot, 2007), published in: *Energy Policy,* Vol. 35, pp. 4812-4825.

Research question 2.3 "*What is the effect of the interplay between projects and firms in the sectoral innovation system of the construction sector in relation to energy performance policy and the diffusion of innovation in heating technology?*" is answered in Chapter 8, which contains the article: *Energy innovations in construction: network effects and energy policy in Dutch construction* (Beerepoot, submitted).

Research question 3, dealing with the impact of energy performance policy and its possible contribution to a transition to a sustainable energy system, is answered in Chapter 9.

The central theme of this book is energy performance policy for the residential building sector, its capacity for encouraging use of renewable energy sources and diffusion, and its effect in the diffusion and development of innovation in order to mitigate climate change. Moreover, all chapters of this book can be read as separate essays. Each chapter starts with an introduction and an explanation of the research approach, and ends by formulating conclusions.

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2 Theoretical perspectives

2.1 Introduction

To focus on concepts such as energy performance regulations, innovations and policy instruments, this chapter clarifies these ideas and discusses the existing literature and research. As stated in the previous chapter, we focus specifically on energy performance policy. Alongside many other possible strategies to encourage energy conservation in buildings, energy performance policy is one way of trying to counteract energy use for space heating, domestic hot water and ventilation. We will therefore explain the concept of energy performance policy and discuss research that has been carried out on this subject.

Another concept introduced in Chapter 1 is the innovation system. This scientific notion has evolved from a wide range of research approaches, mainly originating from the field of economics. We will provide an overview of the development of the concept of innovation systems and survey the literature on sectoral innovation systems.

2.2 Energy performance approach

Regulatory control of buildings is a factor in many domains and intended to guarantee aspects such as construction safety, indoor climate and comfort. Many countries have moved away from the approach of prescribing detailed product demands in favour of prescribing performance objectives (Meacham *et al.*, 2005). The difference between the two is that the first prescribes an acceptable solution, while the second prescribes the required performance. In other words, the performance approach is centred on the concept of working in terms of ends instead of means (CIB, 1982). In the practice of building codes, prescriptions have been experienced as restricting innovation, preventing cost-optimisation and hindering the international trade in building components (Foliente, 2000). The key driver for the trend towards performance-based building regulations is the idea that performance-based regulations provide more freedom in product choice and product development (ibid.). Although most Western European countries consider their building codes to be performance-based, the actual approach can differ substantially per country (Visscher *et al.*, 2005a). A comparison of building regulations in eight European countries shows that, although the general trend is towards performance-based requirements, the concept of performance requirements is interpreted differently, and in most situations, technical regulations include specifications (Visscher *et al.*, 2005b). So far, there has been no impetus for the harmonisation of building codes, since the construction industry operates mainly on a regional scale. In that respect, the European Directive on the Energy Performance of Buildings is a unique initiative in harmonising building regulations in Europe.

Energy performance regulations would appear to be derived from the same idea as performance-based building regulations. In January 2003, the European Commission published EU Directive 2002/91/EC on the energy performance of buildings in the residential and tertiary sector (European Commission, 2003). The basic objective underlying the EU directive is to promote cost-effective improvement of energy performance in buildings within the EU. The directive introduces the term "integrated energy performance of buildings", which is defined as "... the total energy efficiency of a building, reflected in one or more numeric indicators which have been calculated, taking into account insulation, installation characteristics, design and positioning, own energy generation and other factors that influence the net energy demand". The energy performance of a building is calculated by estimating the energy use associated with standardised use of the building caused by spatial heating, hot water heating, cooling, ventilation and lighting. The EU directive asks, first and foremost, that all member states develop a common methodology for calculating the energy performance of a building, taking local climatic conditions into account. It also imposes the obligation on the member states to formulate minimum standards for energy performance for both new buildings and major refurbishments of existing large buildings. Another element of the directive is the obligatory introduction of a system of building certification that will make energy consumption levels much more apparent to owners, tenants and users of buildings. Finally, the directive intends for member states to introduce an inspection scheme for boilers and air conditioning systems above minimum sizes, which must be inspected on a regular basis to verify their energy efficiency and greenhouse gas emissions.

Energy performance regulations were introduced in The Netherlands in 1996 (see Box 2.1). Since that time, all new dwellings in The Netherlands must satisfy an 'Energy Performance Coefficient'. The Dutch standard (NEN 5128) defines the 'Energy Performance Coefficient' as follows: "The Energy Performance Coefficient is the measure – at a certain user behaviour pattern – for the energy properties of a building or part of a building, including its installations".

In view of the definition of 'energy performance regulations', the aspects of energy consumption by household appliances and the subject of consumer behaviour goes beyond the scope of this study. Energy regulations are assumed to influence aspects inherent to building construction and building installations, but cannot influence the energy consumption of residents in their use of appliances. Another effect that sometimes can be noted is that people tend to behave less energy-efficiently when they have energy efficient technology available; this is also referred to as the 'rebound effect'. These are prominent examples illustrating the difference between theoretical and practical effects, and can increase the difficulty of projecting the reduction in greenhouse emissions from an improvement in energy efficiency.

Box 2.1 Dutch Energy Performance Regulations

In the Netherlands, two separate energy performance calculation methods have been developed: one for residential buildings and one for non-residential buildings. The methods are described in the Dutch standards NEN 5128 (residential) and NEN 2916 (non-residential). The output of an energy performance calculation is an energy performance coefficient (EPC), a non-dimensional figure that expresses the energy efficiency of a building. The estimated level of energy use is set against a permitted level that is based on the size and shape of the building. This geometrical correction makes allowances for large buildings, so that all buildings, regardless of size, have the same energy performance coefficient when similar energy features are applied. The estimated characteristic primary energy use in MJ of a residential building can be calculated from the EPC as follows:
Q [MJ] = EPC *(330 * usable surface of dwelling [m²]) * (65* loss surface [m²]) * 1.12
The geometrical correction means that estimated energy consumption, as represented by the EPC, can vary considerably for different housing types. The expected energy consumption corresponding to an EPC of 1.0 (which has been the obligatory standard for residential buildings since January 2000) represents about 43 GJ of primary energy use for an average terraced dwelling (123 m² floor surface). At the same time, an EPC of 1.0 is expected to result in an energy consumption of 89 GJ for a detached dwelling (floor surface 220 m²) and 26 GJ for an apartment (floor surface 75 m²). These figures only reflect consumption for space heating and domestic hot water. The Dutch building regulation, the Building Decree, specifies an EPC figure that may not be exceeded for either residential or non-residential buildings. At the introduction of the EPC in 1996, this standard was set at 1.4 for residential buildings, which represented almost the usual building practice at that time and therefore was not considered difficult to realise. In 1998, the standard was tightened to 1.2 for residential buildings, and tightened further to 1.0 in 2000. Recently, in January 2006, it was tightened to 0.8.

Source: Beerepoot, 2006

2.3 Studies on the effects of energy performance regulations

On a European scale, a huge effort is being devoted to studies (partly financed by the European Commission in their Research Frameworks) that mainly examine the technical specification of the five elements of the Energy Performance of Buildings Directive, such as energy performance calculations, the design of energy certificates, the design of boiler inspections or the training and certification of experts (see e.g. www.buildingsplatform.org). However, given the importance attributed to the idea of energy performance regulations by the European Union, it is remarkable that very little research has been conducted into the effects of energy performance regulations. The European project ENPER-TEBUC (partially financed under the Fifth framework

SAVE programme) not only devoted attention to technical aspects of energy performance regulations but also dedicated time to the expected impact on the market, legal aspects and the expected effects of innovation (see www.enper.org). This study did not, however, actually constitute evaluation research, but reported on existing research (or lack thereof) and developed recommendations for future action on the basis of expert meetings. One of its presentations concluded that there is virtually nothing available by way of evaluation studies of the side-effects of energy performance policy, particularly in reference to effects in innovation (see www.enper.org).

A number of studies that are available have looked to the actual energy savings of the introduction of energy performance regulations in The Netherlands. An evaluation of Dutch Climate Policy for the built-up environment described the effect of the energy performance regulations for the period of 1995 to 2002 (Joosen *et al.*, 2004). The study concluded that energy performance policy became a well-known policy instrument to participants in the building sector rather readily. Compliance with energy performance standards is considered to have been fairly high in the period 1995-2003, due in part to the fact that the standard represented building practice at the time of introduction of energy performance policy in 1996 and was tightened according to a schedule published at the same time. The study describes municipal building control of energy performance calculations as apparently failing. As a result, this was made the subject of an improvement effort in 2003. Overall, the study concludes that the introduction of energy performance regulations resulted in a reduction of 10% of building-related energy use in new residential buildings in the period 19952003. Another study looked into the relation between estimated energy use according to the energy performance calculation and actual energy use (PRC Bouwcentrum, 2004). This study collected addresses of recently built dwellings with known energy performance standards and approached the residents with a questionnaire about their energy use and user behaviour. The collected data on energy use were combined with the estimated energy use according to the energy performance calculation. The study showed that on average, the energy performance calculation presented a fairly good estimate of the actual energy use for space heating, hot water heating and ventilation. There were, however, clear deviations from the estimated energy use, both upwards and downwards, depending on factors such as household makeup and user behaviour.

A study by the Energy Research Centre of The Netherlands demonstrated the relative influence of user behaviour versus technical solutions on the actual energy use in residential buildings (Jeeninga *et al.*, 2001). One of the conclusions of this study was that technical solutions have a much higher effect on energy savings than influencing user behaviour. A minor improvement of the insulation level of a dwelling could quickly save as much as 38% on energy demand, while influencing user behaviour (such as setting the thermostat

1°C lower or reducing the frequency of showering/bathing) resulted in a 9% reduction of energy demand. This study also found that the estimated energy use of the energy performance calculation represents the actual energy use for space heating, hot water and ventilation fairly accurately.

In The Netherlands, a few evaluation studies into the secondary effects of the country's energy performance policy (since 1996) are available. Two elaborate studies into the question of whether the energy performance standard set in 2000 could be tightened further without causing economic harm to the building industry, and without resulting in health problems for the inhabitants, were conducted. Research into the 'self–reported health' in relation to the level of compliance with the level of the Dutch energy performance standard concluded that tightening energy standards did not have an effect in the self-reported health of subjects in The Netherlands (Dongen & Vos, 2003), although it was reported that the factors of age and education of the inhabitants and time spent in the home was relevant to the self-reported health. It was shown that homes with tight energy standards were disproportionately inhabited by younger people with a higher level of education who spend a lot of time outside the home. Residential buildings with poorer energy standards were often shown to be social housing, occupied by older persons with lower incomes. Regarding the use of balanced ventilation systems, research showed that it was not possible to relate health problems to a specific type of ventilation system (Pernot *et al.*, 2003). It was, however, noted that when inhabitants do experience health problems, they often relate to indoor air and climate problems thought to be linked to balanced ventilation systems.

Another study conducted in light of the possible tightening of the energy performance standard set in 2000 focused primarily on the economic effects (Vierveijzer & Wichers Hoeth, 2003). This study's main question was whether additional costs of a tightened energy performance standard would be counterbalanced by the savings in energy costs for the inhabitant. Additionally, this study looked at effects for the construction sector and the inhabitants, environmental effects and effects for building control administration. In regard to the construction sector, the study concluded that tightened energy performance standards most likely necessitated more attention to design and construction. In the area of social housing, the expectation was that housing associations would probably be burdened with extra costs since energy savings would benefit the inhabitant. According to the study, project developers were expected to pass on extra costs to the housing owner and possibly use the extra energy savings as a selling point. The consultancy business was expected to gain most from tightened energy performance standards, in the expectation that consultants would see increased business in contracts for producing detailed energy performance calculations. Environmental effects had been calculated using a tool based on Life-Cycle Assessment (LCA) analysis. The calculations showed that tightened energy performance standards lead to an overall improvement in environmental effect. In regard to the effects on building control administration, the study concluded that the tightened standard would probably not have substantial effects. Remarkably, in this context the study stated that new, improved techniques such as ventilation with higher heat recovery efficiencies need an additional 'quality declaration' to evidence these performances. The study considered that these additional 'quality declaration' would be an extra burden on building control administration, consequently concluding that any such declarations should be abandoned. The most important conclusion of this study, however, was that at that time (2003) tightening the energy performance standard was not considered cost-effective.

This study provoked a number of responses, such as a study performed at the commission of the Dutch WWF (Global Environmental Conservation Organisation) (Van der Waart *et al.*, 2003), which concluded that the Vierveijzer and Wichers Hoeth study was highly susceptible to assumptions of costs and energy prices, and that the actual construction practices on the ground showed that construction according to tightened energy performance standards was already being done in the field voluntarily at numerous locations.

The energy performance standard was tightened in 2006, and a second-opinion study in response to Vierveijzer and Wichers Hoeth 2003 followed. The second-opinion research took a new look at the cost-effectiveness of tightening of the energy performance standard, in view of new insights available at the time (KPMG, 2006). In a letter to the president of the Dutch Lower House, the minister of Housing, Neighbourhoods and Integration concluded that the more expensive housing types (e.g. detached and semi-detached) in particular could not yet be built cost-effectively under the new tightened energy performance standard, but that this situation was only temporary. The expectation is that the tightened energy performance standard will provoke new innovative techniques, which will improve and become cost-effective in about three years (Ministerie van VROM, 2007).

Two studies looked into the side effects of the introduction of energy performance regulations. The Energy Research Centre of The Netherlands (ECN) assessed the quality and size of the employment impact of the introduction of energy performance regulations on the basis of interviews (Dougle & Oosterheert, 1999). The authors conclude that the amount of new jobs created through the introduction of energy performance regulations in 1996 was in the order of 100 by the year 1999, most being in the installation and maintenance of high efficiency boilers, that is, jobs for skilled and semi-skilled blue collar workers. According to the study, the number of jobs in the design of houses with a low enough energy performance and the calculations required for this purpose are likely to increase in the future, since sharpening of the energy performance standard will lead to more complex solutions requiring new employees that can handle these matters, such as recently graduated professional managers (university or higher vocational training). The study concludes that employment can be expected in the consultancy sector, in research and development of more advanced systems and in the production, installation and maintenance of these systems, such as solar heating boilers and heat recovery for heating systems.

One study specifically analysing secondary effects of energy performance regulations (Essers & Mooij, 2001) is known. On the basis of a survey among contractors, municipalities, architects, suppliers, installers and consultants, a qualitative analysis has been made of effects in terms of developments in technologies used, constraints in control of calculations, costs, indoor climate and design freedom. Almost all respondents felt that the energy performance regulations had caused a change in the technologies used. About a quarter of the subjects (50% of architects interviewed) thought the energy performance regulations hindered design freedom. The study also asked respondents about the effect of the energy performance regulations on indoor climate. Remarkably, respondents answered this question in two opposite directions: 23% had the opinion that the indoor climate had improved as a consequence of more low-temperature heating systems, heat recovery and less draught, while 25% said that indoor climate had deteriorated as a result of higher indoor temperatures (linked to improved insulation) and worsened air quality because of balanced ventilation systems. At that time (2003), 66% of respondents had the opinion that possible higher costs resulting from energy performance regulations were acceptable in consideration of the expected environmental gains.

As far as we know, there is little to no scientific research into the effects of energy performance policy. One study by Utrecht University looked into the success factors for energy innovations in the non-residential building sector commissioned by the Dutch Agency for Energy and Environment (Vermeulen *et al.*, 2004). One of the factors considered in this research is the extent to which energy performance regulations influence the diffusion of innovations. This study is based on a survey among stakeholders in the construction industry. Their research develops and tests a model for predicting the diffusion of E-innovations in office buildings. Using this model, several variables representing the nature of decision-making, company characteristics, technology characteristics, economic characteristics, government policy, and influences from market and society have been tested for their influence in adopting energy innovations in office building construction. One of the conclusions is that the decision to adopt 'mature' innovations as opposed to 'young' innovations is based more on routine procedures than project-specific considerations. Although the study of Vermeulen *et al.* is based on a picture on a given moment in time and considers non-residential buildings, we have been able to use elements of the model developed in this study for our research. This is discussed in Chapter 7.

Another study covers the subject of institutional barriers to sustainable construction in The Netherlands (Bueren & Priemus, 2002). In this study, institutions are seen as ground rules that strongly influence players' perceptions of their role, tasks and responsibilities in the process of construction and management. Bueren & Priemus conclude that the institutional structure of the construction industry is fragmented into various phases, and as a result decision-making is decentralised and strongly influenced by professional codes and cost-efficiency goals. This puts heavy demands on the decision-making regarding sustainable measures. Bueren & Priemus present two possible solutions, one involving integrating decision-making towards one player instead of many. Design and build procedures could be a practical approach to this solution. The second approach relates to institutional changes, and calls for a further 'greening' of the tax system and improvement of information channels. We discuss this subject in more depth in Chapter 8.

2.4 Innovation research: from a linear to an evolutionary approach

The scientific literature devotes a minor degree of attention to the extent in which environmental policy instruments can contribute or have contributed to the development and spread of innovations (see, among others, Hemmelskamp *et al.* (2000), Vollebergh *et al.* (2004), Kemp (1997) and Kemp (2000)). The literature in this area has its roots in theories surrounding innovation development. The science of innovation has its origins in economic theory, but in recent decades has grown into a multidisciplinary research area with its own (not always clearly defined) theoretical framework. The approach used to answer the research questions in this thesis is applying theoretical insights from the science of innovation, with particular attention to the concept of the 'sectoral innovation system', to the practice of implementing energy-saving innovations in new residential construction. The approach of the innovation system, which follows from the conception that innovation is not a linear process, focuses on the interaction, cooperation and knowledge exchange between the various actors in the innovation system. The insights concerning the theory of the 'sectoral innovation system' are still changing at a very fast pace.

While historically, theories on the rise of innovations were primarily studied from the perspective of economic theory and initially interpreted in a very linear fashion (technology-push or demand-pull), over time innovation studies took on a multidisciplinary character, and the innovation sciences developed into a knowledge area with a number of different schools. We first outline a picture of the developments in the science of innovation, and then define the approach to our research question.

Since the dawn of economic theory, there has been an interest in the relationship between technical innovations and economic development. Nineteenth-century economists did not, however, venture into studying the technology itself, but considered the technology as an exogenous factor in economic theories. In the early years of the twentieth century, it was Kondratieff (1926; 1935) who, in his theory of long-term cycles in the world economy, explicitly highlighted economic development and technological change. Schumpeter (1942), building on Kondratieff's work, shifted the focus towards technology development as an endogenous factor in economic development. He noted that in times of economic crisis, companies are open to taking the risks that give rise to innovation. These innovations/innovation clusters then, in turn, cause a long cycle of economic upturn. In this light, Schumpeter saw technology development as a linear development. It was also Schumpeter who made the distinction between different phases of technology development, which was later translated into a phased development of invention to innovation to, finally, diffusion. In the nineteen-sixties, innovation research still had a primarily economic perspective, and technology development was studied as a linear process driven by either technology push or demand pull. One defender of the latter position, who assumed that the innovation process was driven by existing market needs, was Schmookler (1966), who studied the relationship between the investments in capital-demanding industries and patent applications of capital-producing industries, concluding that a relationship could be drawn that confirmed the hypothesis that the demand is the driver of the supply, and not vice versa[1]. In recent decades, innovation research has created more and more consensus on the idea that technology development is not a linear process, but that both technology push and demand pull exert influence on technology development, in combination with a range of other factors. Research into technology development has been given a historical and sociological focus alongside its economic focus. The work of Nelson & Winter (1977; 1982) and Dosi (1982; 1988) created a scientific breakthrough by establishing the basis for the evolutionary school within the science of innovation. The evolutionary approach is founded on the idea that the processes of technology development are analogous to the processes of evolutionary biology: on the basis of variation and selection, creating a strong interaction between a wide range of factors such as socio-cultural and institutional factors. Nelson and Winter thereby introduced the concept of the technological regime referring to the learning and knowledge environment in which firms operate (Nelson & Winter, 1982). Dosi introduced a similar concept: the technological paradigm (Dosi, 1982). This concept attempts to capture both the nature of the technological knowledge upon which innovative

1 Schmookler's study has come under fire over the years from various corners, with Kleinknecht & Verspagen (1990) being just one example.

activities draw and the organisational procedures for the search for and exploitation of innovations.

Branching off of the evolutionary school, the 'quasi-evolutionary approach' is identified, which builds on the evolutionary approach but with more of a focus on sociological processes (Van de Belt & Rip, 1987). While the evolutionary approach opts for the central premise of economic processes and the effects of technological change on companies and sectors, the quasi-evolutionary approach takes the technology itself as the central premise and then looks at the interaction between technology and environment. The quasi-evolutionary approach also moves away from the idea that all technology development happens as it were at random, according to variation and selection, instead adhering to the concept that the process of technological change can, to some degree, be influenced, for example by creating a protected environment or 'strategic niche' at the early stage of development (Kemp *et al.*, 1998).

2.5 Network approach and system approach

The sociological perspective highlights the 'network approach' (Callon, 1986). In the network approach, technical, socio-scientific, economic and political arguments are used in concert to explain technological development. In a 'network', elements of varying natures are described as equivalent components: artefacts alongside social groups, institutions, materials, etc. Callon's famous example describes the efforts by Electricité de France (EDF) to develop an electric vehicle, in which EDF set up a network to develop products (fuel cells and the body of the vehicle) and to sell social groups (consumers) on the concept. Callon claims that a network can be maintained as long as the individual elements in the network accept their roles in it. But the Renault company did not accept its role as 'just a car body manufacturer', and developed its own alternative: the relatively fuel-efficient Renault 5. EDF's electric car was crowded out by the Renault 5, and ultimately failed.

Taking a historical perspective, Hughes developed the 'system approach' (Hughes, 1987). The system approach focuses on the analysis of technological systems. In this approach, technology is not considered an artefact but an element of a larger gestalt of components, which may be technical or social. A change in one of the components automatically leads to adaptation of the other components: a change in the average power (watts) of equipment connected to an electricity distribution system automatically leads to changes in transformers and generators. The network approach makes it possible to explain developments in technologies. As one example, Hughes introduced the term 'reverse salient', which refers to the potential for technological development to stagnate if a given component fails to keep up with the rest. Because the components of a system are strongly connected, a technical problem with one component may keep the entire system from developing further. Another term derived from the system approach is 'technological momentum'. This refers to the fact that a technological development, once initiated, has a certain direction and speed determined by interests arising within organisations to complete the development in question.

The system approach and network approach have certain commonalities, and have both been 'radicalised' by social constructivists who analyze technological developments on the basis of the individual significance that different relevant social groups ascribe to new products. This approach is sometimes referred to as the SCOT approach (Bijker *et al.*, 1987). The SCOT approach is explained in Bijker (1987) by the historical example of the bicycle, in which different groups of actors – housewives and sporting types – ascribed an entirely different significance to the bicycle: on the one hand, a safe means of transport, and on the other, a piece of athletic equipment to be used to achieve breakneck speeds. As soon as one interpretation gets the upper hand, the technology is reduced to that interpretation. This is referred to as a 'technological frame'. Once the technological frame is established, then the parties directly involved will primarily seek technological change in the improvement of the technology, or the 'incremental innovations'. Actors not directly involved in the technological frame can move away from it and arrive at what is referred to as the 'really new innovations'.

2.6 Innovation system theory

Both the evolutionary approach, the system approach, the actor-network approach and the social-constructivist approach exhibit striking correspondences, in the sense that they all emphasise that technology can never develop in and of itself, but its development depends in part on the context, consisting of social, political, cultural and economic factors. The evolutionary approach and its derivatives are all based on the analysis of processes that explain the technology development. Following this, at the end of the nineteen-eighties, the concept of the 'national innovation system' appeared (Freeman, 1987; Lundvall, 1988; Nelson, 1993). The central idea behind the national innovation system is that the success of technological development is related to the degree to which different organisations and institutions are aware of each other's activities in a certain field, and coordinate their activities accordingly. While the evolutionary approach begins with using the analysis of processes to explain the rise of new innovation systems, the system approach begins with the analysis of the institutions, organisations, industries and other actors to explain the appearance of socio-technical innovation from the perspective of their mutual connection. Initially, the analysis of the innovation system is introduced from a national perspective: R&D activities of universities, research institutes, governmental institutions and government policy are studied as components of a national innovation system, and the connections between all these is the subject of study. The nineteen-nineties saw attention to the examination of sectoral innovation systems (Breschi & Malerba, 1997). The study of the sectoral innovation system is advanced by the idea that different sectors or industries operate under different technological systems, which are characterised by specific combinations of circumstances such as the presence of technical knowledge and properties of the specific required knowledge.

For our research, it is important to obtain insight into the energy-saving technologies for residential construction and their context. Consequently, our intention is to follow the concept of the 'sectoral innovation system', and we will apply this practically in the use of energy-saving technologies in new residential construction.

2.7 Sectoral innovation system approach

In the vision of the founders of the concept of 'sectoral innovation systems', the analysis of the sectoral innovation system combines the concepts and ideas of both the evolutionary approach and the system approach (Malerba, 2002). We define a sectoral innovation system as follows: a sectoral innovation system consists of new and existing products for a specific use and the array of companies and institutions that undertake market activities and related activities for the development, production and sale of these products (Malerba, 2002). Terms from the evolutionary approach, such as 'learning', 'knowledge', 'competencies' and the attention to the dynamic nature of technology development are used to describe the sectoral innovation system. The system approach sees attention to networks and relationships as important elements for technology development. Malerba claims that the components from which the description of a sectoral innovation system should be built are 'the products', 'companies and institutions', 'knowledge and learning processes', 'the technology around the products' (e.g. the supply-side industry), 'interaction mechanisms within and between companies', 'competition and selection processes', and 'institutional preconditions' (Malerba, 2002). Following on from Malerba's ideas, Geels (2004) adds that the study of sectoral innovation systems calls for more attention to the demand side. While attention to sectoral innovation systems has so far been primarily directed towards the study of the development of knowledge, this attention should also go to the diffusion and application of technology and its impact on society (Geels, 2004). For this reason, Geels argues for the study of socio-technical systems instead of sectoral innovation systems, in order to emphasise the co-evolution of technology and society. A contribution by Carlsson (2002) to the discussion of the study of innovation systems examines the level studied, the definition of the population and the method in which the presentation of a system is measured. In terms of the level at which a system is studied, a technology, product or market (or combinations thereof) can be identified with a series of mutually related products (Carlsson, 2002). A technology can be applied in a variety of products, so that the study of a technology can relate to various product types (each with a corresponding consumer market). By the same token, a product can, in turn, make use of multiple technologies, so that the study of a product can relate to multiple technologies. When studying an entire market, a series of technologies and products (with corresponding consumer markets) may be the subject of analysis. The distinction in levels of analysis is relevant to the delineation of the description of a sectoral innovation system, or any innovation system. Depending on the level of analysis, the actors, networks and institutional preconditions to be described may differ.

2.8 Conclusions

Since the release of the EU directive 2002/91/EC, attention to energy performance policy has increased sharply. Many subjects concentrating on the technical specification of the five elements of the directive, such as energy performance calculations, the design of energy certificates, the design of boiler inspections or the training and certification of experts are currently under investigation, but to a lesser degree attention is also being given to the effects of energy performance regulations in terms of both energy conservation and side effects of the introduction of energy performance policy, such as the effect on innovation. Some examples of the study of the side-effects of energy performance regulations are known in The Netherlands, these being mainly based on surveys of stakeholders in the construction industry. No results of quantitative scientific research into the innovation effect of energy performance policy for residential buildings are available as yet.

The potential influence of policy in establishing innovation is being examined in innovation system research. Innovation research has made great strides over the years. While initially, innovation was seen as a black box in economic development, this attitude gradually gave way to the monumental importance now attributed to technological innovation for the survival of economies. Linear approaches, based on the view that technological innovation is either a consequence or a precursor of demand, have developed into evolutionary approaches emphasising the importance of many elements interacting with each other. Of the several approaches examining the development of innovation, the innovation system approach, introduced in the late 1980s, has emerged as the most dominant. This approach focuses on the idea that the interaction between organisations and institutions within an innovation system is crucial in order to achieve successful innovations. While the innovation system approach started with exploring systems on a national level, the more recently developed sectoral innovation system approach examines the interaction between organisations and institutions with regard to specific products or product groups.

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3 Energy regulations and impact of the Energy Performance of Buildings Directive

Based on:
Beerepoot, M. (2002). Energy regulations for new building; in search of harmonisation in the European Union. Delft, Delft University Press, ISBN 90-407-2325-7.
Beerepoot, M. (2003). Energy regulations and impact EU Directive "Energy Performance of Buildings". Open House International 28 (1), pp. 53-59.

To ensure that the case of The Netherlands provides a solid basis for evaluation of the effects of energy performance policy, this chapter presents a state-of the art overview of energy policies in the following eleven European member states: Belgium, Germany, France, The Netherlands, Denmark, England and Wales, Austria, Finland, Sweden, Luxembourg and Ireland. It addresses the research question: What energy policy designs for new residential building are available in northern European member states, and what are the implementation demands of EU Directive 2002/91/EC? The information was analysed in 2002 and – as a consequence of developments resulting from EU directive 2002/91/EC – is a product of its time, and consequently, to some extent outdated by the time of publication of this thesis. The study resulted in the conclusion that The Netherlands has the most comprehensive experience with energy performance regulations, and showed the differences in efforts required on the part of member states to meet the requirements of EU directive 2002/91/EC. Consequently, in finalising this thesis the author decided not to update the information, but to only increase the level of detail.

Abstract
Energy regulations for new buildings have existed in many countries since the oil crisis in the 1970s showed the problems of dependency on fossil fuels, while at the same time the Club of Rome warned that the supply of natural gas would run out in the near future. In most cases, energy regulations initially prescribed insulation levels for building elements. During the last three decades, these types of building regulations have often exhibited gradual shifts towards more integrated approaches, though all countries have developed their own systems. The research for this thesis attempted to provide an overview of approaches in energy regulations for new buildings in eleven European member states at the time that EU Directive 2002/91/EC had been developed by the European Commission but had not yet been approved by the European Parliament. At the time, in 2002, the EU consisted of 15 member states. Consequently, this study does not consider the countries of the 'eastern enlargement' in 2004. The study tried to find experiences with energy performance regulations and see what countries might provide suitable conditions for evaluating effects of energy performance policy over a number of years. The research was part of a European Project, partially funded by the European Commission in the Altener Fifth Framework programme and partially funded by OTB Research Institute for Housing, Urban and Mobility Studies. In 2002, part of this research was conducted at the University of Liverpool School of Architecture, supported by a grant by the British Council.

Keywords
Energy policy, building regulations, energy saving

3.1 Introduction and research question

The issue of energy regulations for new building is one of current relevance, certainly since April 2001, when the European Commission proposed the draft directive COM (2001) 226 on improving the energy performance of buildings, including the development of a common framework throughout Europe for the design of energy regulations. The directive was accepted in December 2002 by the European Parliament and entered into force on January 4th 2003 as directive 2002/91/EC (EC, 2003). Through this directive, the European Union is moving towards a Europe-wide introduction of energy performance regulations, since one of its main purposes is to develop a common methodology of energy regulations for buildings within Europe. The methodology has to be based on the concept of calculating the estimated energy consumption of buildings and is commonly known as the 'energy performance method'.

In recent years a small number of studies have explored energy regulations for buildings in European countries (Eichhammer *et al.*, 1998; Schaefer *et al.*, 2000; Bioarchitettura, 2001; Beerepoot, 2000). A SAVE project launched in March 2001 is the ENPER-TEBUC project, studying energy performance regulations and the potential for a European model building code. These examples of existing studies on energy regulations in European member states either cover a large number of member states without going into detail, or address only a limited number of member states but do so in detail. All studies were performed before the ideas of the European Commission in harmonising energy regulations were launched.

The idea of harmonisation of energy regulations in Europe according to the 'energy performance' approach can have considerable impact on several member states, depending on the nature of their current energy regulations. This chapter describes the comparison of energy regulations in eleven European member states that were part of the EU15 in 2002. Descriptive comparative analysis of energy policies can identify possible directions in which energy performance policy can be shaped and whether divergent or convergent developments have taken place. A comparative analysis of experiences with energy policy also helps to identify suitable cases for evaluation research. This chapter answers the research question: "What designs of energy policy for new residential building are available in northern European member states, and what efforts are required for implementation of the EU directive 2002/91/EC?"

3.2 Research approach

This study covers the analysis of energy policy for residential buildings in 11 European member states. The member states were selected on the basis of their climate: the analysis includes all ten northern EU member states (of the fifteen European nations that were a members of the European Union in 2002). Austria was added to the study, although this member state's climate is influenced by three climatic systems: it has a sea climate in the west transitioning to a continental climate in the eastern part and a typical alpine climate in the Austrian Alpine provinces. The four remaining member states, Portugal, Spain, Italy and Greece, were left out of this study since their Mediterranean climates may call for a different approach in energy policy.

To analyse and compare energy regulations, first a framework is developed that allows identification and categorisation of different types of energy regulations. This framework development was based on existing literature in the field. Next, energy regulations in eleven EU member states are described on the basis of their regulations as of April 2002. An overview of energy regulations was illustrated by classification in the framework. Differences and similarities with the foreseen developments of EU draft directive COM (2001)226 were indicated. From the overall comparison of regulations, it was possible to describe differences and similarities in current energy regulations among the member states, the efforts needed for harmonising energy regulations and a discussion of what can be learned from the analysis and comparison of energy regulations for future developments of harmonised energy regulations in Europe.

3.3 Framework for categorising energy regulations

Three existing studies on energy regulations, the EPISODE project, the MURE project and a national study in The Netherlands by Beerepoot, classify regulations into different categories, showing a degree of integration of the building as a system (Eichhammer *et al.*, 1998; C. Schaefer *et al.*, 2000; Beerepoot, 2000). In two of the literature sources, the EPISODE and the MURE study, the categorisation of energy regulations is described according to the distinction into four contiguous groups (Eichhammer *et al.*, 1998; C. Schaefer *et al.*, 2000). Beerepoot distinguishes three types of energy calculations in the national study of The Netherlands (Beerepoot, 2000), showing that the organisation of categories in the two groups of studies is, to a large extent, comparable. The combination of both the MURE categorisation and the categorisation expressed in Beerepoot (2000) seems to result in the most complete framework with the most compact and clear descriptions for categorising energy regulations. This combination results in the framework illustrated in Figure 3.1. This framework is used for categorising energy regulations in the eleven European member states included in this study.

Figure 3.1 Framework for categorising energy regulations

1 Unit approach	U-value component 1 U-value component 2 U-value component 3 U-value component 4		
2 Heat loss calculation	Insulation floor, roof and facade		
3 Heat demand calculation	Insulation floor, roof and facade	Ventilation, internal heat production and passive solar energy	
4 Energy use calculation	Insulation floor, roof and facade	Ventilation, internal heat production and passive solar energy	Efficiency of hot water, heating and ventilation systems

The first category of regulations, the 'unit approach', features the simplest method, consisting of requirements regarding insulation levels for construction elements. The second category, the 'heat loss calculation', is based on calculating the average insulation level of a building or its transmission loss. The third category, the 'heat demand calculation', requires a calculation based on identifying heat loss by considering transmission and ventilation losses, and heat gain, by means of passive solar energy and internal gains, resulting in the heat demand of a building. The fourth category, the 'energy use calculation', requires the most comprehensive calculation, based on calculating heat demand and combining this with energy supply efficiencies, resulting in an estimate of the actual energy use of a building for space heating, hot water, cooling, ventilation and lighting.

3.4 Country studies

3.4.1 Belgium

As of 2002, energy regulations in Brussels, Flanders and Wallonia consist of requirements regarding the approximate insulation level for buildings, called the 'k-level' (BBRI, 2000a). Because the k-level only takes heat loss by transmission into account, this type of energy regulation can be categorised as a 'transmission loss calculation'. The Flemish government introduced energy regulations for residential buildings in 1992 by establishing a maximum 'k-level' for the approximate insulation of buildings. In 1993, a more stringent k-level was introduced. The k-level in Flanders in the year 2002 dates back to 1993. The k-level of a building depends on its compactness and insulation level. The compactness of a building is expressed by the ratio of its heat loss surface (A_T in m^2) and its volume (V in m^3). The ratio V/A_T (in m) expresses the compactness of a building. A building's insulation level is expressed as k_s (in W/m^2K) and is calculated by the ratio of transmission losses per construction element (in W/K, including thermal bridges) and the heat loss surface (in m^2). In addition to the required maximum k-level, there are maximum U-values for construction elements. These maximum U-values function as a baseline level; the k-level usually requires higher U-values.

At the time of this study (2002), energy regulations in Flanders were expected to change in 2004 through the implementation of energy performance regulations (BBRI, 2000-b). Ultimately, new energy performance regulations were implemented in 2006. The new Flemish energy performance regulations are much more elaborate than the k-level calculation; they also include the calculation of the energy demand and energy use in buildings. In light of this development, we can expect the region's energy regulations to include all of the elements in the EU directive. So far, however, Flanders has not introduced energy regulations for the non-domestic sector. Consequently, it faces an enormous transition in its non-domestic building sector when it introduces energy performance regulations: from no regulations to the most comprehensive type of regulation, the energy performance method.

According to a study conducted by BBRI in 1999, most buildings in Flanders do not meet energy requirements in practice (BBRI, 1999). The introduction of energy performance regulations in Flanders is, therefore, likely to be used as an opportunity to change the moment of compliance monitoring in the building control system. Monitoring of building control after construction is rare in Europe, as we will see in the following chapters.

3.4.2 Germany

The German *Energieeinsparverordnung (EnEV)* was introduced in 2002 and uses a methodology for calculating the primary energy use of a building (Bundesministerium für Wirtschaft, 2001). The calculation considers the primary energy use as a derivative of transmission losses, ventilation losses, internal and solar gains, heat use for domestic hot water, and the losses of the heating, hot water preparation and ventilation systems. Furthermore, the primary energy use covers production, transformation and transport of the energy itself. The EnEV regulations offer both the possibility of a rather simple calculation as well as the option of a comprehensive detailed energy performance calculation. Maximum values for the annual primary energy use and the transmission heat losses are related to the heat loss surface in relation to the heated volume of the building, i.e. the A/Ve-ratio, which represents the compactness of the building shape, and requirements differ for residential and non-residential buildings.

The EnEV energy performance regulations require, above all, a standard for annual primary energy uses. A secondary requirement relates to transmission losses: the transmission loss must be calculated using the energy performance calculation. The integration of the requirement for transmission loss within the energy performance calculation is an interesting feature of the German energy performance method, because energy performance method requirements in other member states focus exclusively on the final output of the energy performance calculation. In those countries, transmission loss requirements mainly consist of restrictions on U-values for construction elements. Along with the requirements of the energy performance regulations, a number of separate regulations have been formulated, for example in regard to air-tightness of the building, ventilation, and summer comfort if more than 30% of the façade consists of glazing.

The new German energy regulations (EnEV) meet most of the criteria in the EU directive on Energy Performance of Buildings and have progressed further than other energy performance regulations in their integration of a separate requirement for transmission losses. Nonetheless, the German energy use calculation does not include elements of cooling and lighting, at least not yet.

3.4.3 France

France introduced energy performance regulations as early as 1988. As far as we know, this makes it the first country to have introduced this type of energy regulation. Prior to 2001, French energy performance regulations offered one of three possible methods for compliance. Until that year, other options for complying with energy regulations included simpler methods such as transmission loss calculations or heat demand calculations.

A new scheme for energy regulations has been in force since 2001, when the energy performance became the basis for French Energy Regulations (CSTB, 2000a; CSTB, 2000b). Energy regulations require an energy performance standard for buildings and a standard for thermal comfort in summer. The standard for thermal comfort in summer is a unique feature of French energy regulations, as virtually no other member state imposes requirements for comfort in summer weather. In order to comply with energy regulations, the energy performance of a building must meet the energy performance of a reference building. This implies that French energy regulations do not impose absolute requirements in terms of primary energy use related to the compactness of a building. Another option for complying with regulations involves a simplified method consisting of technical solutions. Certain minimum performance standards must be guaranteed (e.g. maximum U-values for construction elements).

French energy performance regulations as introduced in 2001 comply with all elements cited in the EU directive concerning harmonised energy performance regulations in Europe. So far, the aspect 'cooling' was considered primarily by means of prescriptive rules, but in 2003, this aspect was included in the energy performance calculation. The aspect of 'lighting' has already been included in the energy performance calculation. The implementation of aspects, such as 'cooling' and 'lighting' is interesting because European CEN standards on energy performance calculation do not yet cover these subjects. A question remains regarding the second option for complying with French energy regulations (the simplified procedure with technical solutions), since it is uncertain whether this method fulfils the requirements in the EU directive. Admittedly, the French technical solutions do take many of the elements required by the EU directive into account; be that as it may, they do not offer an integrated method, an item stressed by the EU directive as a specific feature of the energy performance method required by the EU.

The French approach to monitoring compliance with construction and energy regulations differs to some extent from those of other European countries. Compliance with building and energy regulations is primarily the responsibility of contractors themselves, who are not required to demonstrate compliance to building authorities. Thus, submission of energy performance calculations to public authorities is not mandatory. Regarding building air density, the French energy performance regulations allow for two options: choosing a rather poor default value that will not be checked during or after the building process, or opting for a better air density in the knowledge that this air density may be verified after construction.

In addition to the energy performance regulations, France has introduced an energy label scheme consisting of two energy labels. One of these, the 'high energy performance label', will be issued for buildings the performance of which is 8% better than the current energy performance standard. The second, the 'very high energy performance label', will be issued where performance is 15% better than the current energy performance standard. This scheme is intended to prepare the French construction industry for more stringent energy standards in the future. The energy labels are issued by certification boards that carry out inspections based on their own certification rules (Visier, 2002).

3.4.4 The Netherlands

The Netherlands first introduced energy regulations by means of using the energy performance method in 1996. The calculation of the energy performance coefficient of a building is outlined in two national standards for non-domestic buildings and residential buildings (NNI, 1998a; NNI, 1998b). Since that time, the energy performance calculation is the only option for complying with energy regulations; no simplified method exists. Dutch energy performance regulations meet all criteria of the EU directive on energy performance of buildings. The Dutch energy performance method covers more aspects than those mentioned in the EU directive. ‘Cooling’ and ‘lighting’ are also included in calculations: an extensive method is used for non-domestic buildings, while a simplified calculation is part of the energy performance calculation for residential buildings. A special feature in the Dutch energy performance method is that it makes provisions for electricity produced by photovoltaic (PV) energy systems; it allows this ‘green electricity’ to be extracted from the ‘grey’ electricity calculated in the energy performance calculation. This approach seeks to encourage the use of photovoltaic (PV) energy systems. European CEN standards do not yet cover these aspects.

The Energy Performance Coefficient is calculated by comparing the characteristic energy use of a building to the standardised energy use. The standardised energy use depends on the size and shape of the building, thus ensuring similar energy performance for buildings with comparable energy characteristics but different shapes and sizes.

Dutch procedures for building permit applications and monitoring buildings impose strict control on energy performance calculations. These calculations are checked by officers of the Building Inspection Department, who are specially trained to interpret them. Municipal control during construction is also part of the extensive process of monitoring energy performance in buildings.

An interesting development in The Netherlands is the introduction of the energy performance method for entire building sites. This method can address many more options for reducing CO_2 emission because it can take energy supply systems, such as Combined Heat and Power installations (CHP), and renewable energy sources like biomass or wind energy into account. At the national policy-making level, some have advocated replacing the energy performance method for individual buildings with the method for entire building sites in the near future.

3.4.5 Denmark

As of 2002, Denmark has two sets of building regulations: BR-S 98, which applies to small buildings, and BR 95, which applies to all buildings not covered by the first category (Boligministeriet, 1998; Boligministeriet 1995). Danish energy regulations offer three separate optional methods for complying with regulations. The three methods cover the first three categories of energy regulations in the framework outlined in Section 3.2. The most integrated method is the heating demand calculation. The heating demand calculation in Denmark is referred to as the ‘Energy Frame’.

Remarkably, the formula for the standard of the Energy Frame for residential buildings contains no area-dependent term. This is because Denmark has a policy of promoting compact designs for housing. All other member states provide for compensation for heat loss area in order to enable all types of buildings to be assessed in a comparable manner. Danish energy regulations for non-domestic buildings do not seek to promote compact designs.

The Energy Frame method appears to be the most common option for compliance with Danish energy regulations (Engelund Thomsen, 2002). This method consists of a heating demand calculation, which covers many aspects mentioned in the EU directive on energy performance of buildings. However, heating and hot water installations, as well as installations for lighting and cooling, are not covered by the Danish 2002 energy regulations. Discrepancies between Danish practices and the requirements in the EU directive will depend on the experience that professionals have with each of the three options for complying with energy regulations. If most professionals are already familiar with the Energy Frame method, then installations for hot water, heating, lighting and cooling will be the only new elements that they have to deal with as required by the EU directive.

Under Danish regulations, building permit applicants must submit detailed information about energy features to municipal authorities. Inspections by the municipality during construction also comprise part of the full procedure for ensuring compliance with energy regulations.

3.4.6 England and Wales[1]

As of 2002, English energy regulations lay down a generally formulated functional requirement stating that "Reasonable provision shall be made for the conservation of fuel and power". In other words, England allows numerous options for compliance. However, for every prescription in English building regulations, there are Approved Documents that present practical solutions for complying with the regulations. Approved Document L contains common solutions for compliance. In April 2002, Approved Document L1 for residential buildings and Approved Document L2 for non-domestic buildings entered into effect (DTLR, 2001a; DTLR, 2001b). However, the solutions given in the Approved Documents are optional, and alternative means such as innovative methods may be used if they can be demonstrated to achieve similar performance. In practice, Approved Document L will be used for compliance with requirements for conservation of fuel and power in the vast majority of cases. Since 1998, an energy performance-based method has become one of the options for compliance with regulations in England and Wales. This method was formerly known as the Energy Rating Method, but since the introduction of Approved Document Part L1 and Approved Document Part L2, the method has

1 Though energy regulations are largely similar in the three parts of the United Kingdom (Scotland, England and Wales and Northern Ireland), we have concentrated on England and Wales.

been adapted into the Carbon Index Method. The Carbon Index Method requires an SAP (Standard Assessment Procedure) calculation. Where the output of the Energy Rating Method was based on energy costs, the output of the Carbon Index Method is based on CO_2 emissions (BRECSU, 2001), reflecting the increasing importance of energy use as a factor causing climate change by means of CO_2 emissions.

The other two options are the Elemental Method, a unit approach method, and the Target U-value method, a transmission loss calculation. Remarkably, extra requirements are added to these methods by means of boiler efficiencies that may not be exceeded. A boiler efficiency database is available online and is updated at the beginning of every month. The Target U-value method allows for some trade-off between boiler efficiencies and insulation levels.

The Carbon Index Methods include many of the elements required by the EU directive on energy performance in buildings. There are, however, two other, simpler methods containing only two or three elements of the EU directive. The difference between current energy regulations in England and Wales and the approach envisioned by the EU depends on the building sector's familiarity with all three options. The building sector's familiarity with the SAP calculation will determine, more than anything else, the effort required if the kind of scheme proposed in the EU directive is actually introduced.

3.4.7 Austria

Austria's ten *Bundesländer* are responsible for building regulations, the *Wohnbauförderungen* (WBF). In 1995, the central Austrian government set up an agreement, Art. 15a B-VG Vereinbarung, with the *Bundesländer* on the promotion of a variety of energy conservation activities. Art. 15a regulates the requirements regarding heat transmission coefficients for construction elements, establishing maximum insulation values in a unit approach (Schuler *et al.*, 1998). The *Bundesländer* were allowed a period of three years to adopt these requirements in their building regulations.

As of 2002, almost all *Bundesländer* have adapted their regulations regarding requirements for insulation values established by Art. 15a. There are, however, differences in requirements between the *Bundesländer*. Moreover, a number of *Bundesländer* have decided to make the requirements more stringent than the national agreements, although where the national requirements in Art. 15a are more stringent than local requirements, those in Art. 15a must be satisfied.

Art. 15a has also introduced the heat demand calculation for space heating based on the Austrian standard ÖNORM B 8110-1 and the European standard CEN EN 832. Instead of the minimum requirements for heat transmission coefficients, it is possible to comply with energy regulations by demonstrating that heat loss by transmission and heat demand for space heating will not exceed the state of compliance with regulations by virtue of the minimum requirements for heat transmission coefficients. In 2002, almost all *Bundesländer* allow compliance by means of a heat demand calculation as an alternative for the insulation requirements (E.V.A., 2001). However, the results of the heat demand calculation must be comparable to the minimum requirements for insulation levels.

The Austrian Institute for Building Construction (OIB) has developed a standard (ÖNORM B 8110-1) in an attempt to create a uniform method for calculating heating demand for space heating in buildings in the *Bundesländer* (OIB, 2001). The method makes use of the LEK-value of a building, expressing the compactness of a building by means of a ratio of heat loss surface and volume of the building. The output of this calculation method can be translated into an energy label, or *Energieausweis*. This energy label distinguishes seven classes, A to G, and is similar to the energy label used for domestic household appliances.

The difference between Austrian energy regulations and the EU directive on energy performance of buildings depends on the extent to which the two options for compliance are used in building practice. If the first method, which is based on transmission losses, proves to be the most common, the EU directive's impact could be severe. If the Austrian construction industry is already fairly familiar with the heating demand calculation and the energy label, then the consequences of the EU draft directive would be limited to the introduction of efficient heating, hot water installations, lighting and cooling installations in energy regulations.

3.4.8 Finland

Finnish building regulations are laid down in the Building Act and the Building Decree. The practical implications of provisions regarding energy conservation are explained in the National Building Code issued by the Ministry of Environment. The National Building Code consists of a number of chapters, of which thermal insulation is covered in Part C3 Thermal insulation regulations and Part C4 Thermal insulation guidelines (Ministry of the Environment, 1985; Ministry of the Environment, 1978). As of 2002, Finland provides two options for complying with energy regulations:

1. Unit approach: prescription of maximum U-values for construction elements.
2. Average U-value calculation: compensation for U-values different from standards of method 1, the unit approach. This is elaborated by allowing a certain maximum average U-value for the building shell that cannot be exceeded.

   Energy regulations will be revised and are expected to enter into effect in 2003. The revised energy regulations will introduce a third option for complying with regulations:

3. Energy use calculation: compensation for non-compliance with the requirements in method 1 or method 2. This is effected by calculating the building's energy consumption.

An interesting feature of the different options for compliance is that they are intended to be used in order. Method 1 is the first choice. In cases where its application proves impossible, methods 2 and 3 are the next available options for compliance. Method 3 came into effect in 2003. The introduction of the energy use calculation in 2003 adds another interesting aspect to Finnish regulations: Since this calculation is applicable only when compliance by methods 1 and 2 proves impossible, it must demonstrate how much extra energy consumption the building design would entail. The extra energy consumed must be multiplied by a factor of 1.3 and come from renewable energy sources.

As of 2002, Finnish energy regulations only covered one element (transmission losses) of the scheme proposed by the EU directive on energy performance of buildings, but the new energy regulations of 2003 also allow for the energy use calculation, though only as an alternative in cases where compliance by methods 1 and 2 proves impossible.

3.4.9 Sweden

Sweden's building regulations are laid down in two sets of regulations, both of which date from 1994: (1) the Building Regulations (BBR 94) and (2) the Design Regulations (BKR 94). The Building Regulations were updated in 1998 (Bengtsson, 1999). Two chapters discuss aspects of energy conservation and indoor climate. Chapter 6 covers Hygiene, health and the environment', focusing in on ventilation, lighting and indoor thermal comfort. Chapter 9 of the Swedish Building Regulations covers Energy economy and heat retention'. The energy regulations prescribe complementary requirements regarding the following subjects:

1. Limitation of heat losses
a. Requirements for a maximum U-value of the building
b. Requirements for air-tightness in buildings
c. Requirements regarding ventilation: thermal insulation, air-tightness and control systems
d. Requirements regarding production and distribution of heat: boiler efficiency, water heating systems, control systems
2. Requirements for efficient heat use
3. Requirements for efficient use of electricity.

In special cases, compliance with regulations is possible by means of a trade-off calculation (heat and domestic hot water demand calculation). A trade-off calculation can show that, even if the specific requirements regarding limiting heat loss and efficient heat use are not fulfilled, the energy demand for space heating, domestic hot water and heat recovery does not exceed the energy which would be needed if the above-mentioned requirements were met.

Swedish energy regulations differ to some extent from the scheme proposed by the EU directive on energy performance of buildings. Although Swedish regulations cover many of the energy aspects proposed by the EU directive, they impose separate requirements for each of these aspects. By contrast, the EU directive seeks to establish an integrated approach by means of an energy use calculation, also known as energy performance calculation.

3.4.10 Luxembourg

As of 2002, energy regulations in Luxembourg are laid down in the *Wärmeschutzverordnung Luxemburgs* and mainly focus on preventing transmission loss by means of imposing requirements regarding the approximate insulation levels of buildings (Kippenberg & Schallehn, 1997). This approximate insulation level is referred to as the building's 'k-level'. A simplified procedure is allowed for small buildings ('energy use surface' < 200 m^2), which consists of maximum insulation levels for construction elements. The average k-level for a building may not exceed a certain maximum. A building's maximum k-level will depend on its insulation level, compactness and average inside temperature. A distinction is made between buildings with normal inside temperatures (≥ 19°C) and those with low inside temperatures (≥ 12°C; ≤ 19°C). The average insulation level for buildings (k_m in W/m^2K) is calculated by the ratio of transmission losses per construction element (in W/K, including thermal bridges) and the heat loss surface (in m^2).

Only one of the several aspects mentioned in the EU directive on energy performance of buildings are covered by Luxembourg's energy regulations, which concentrate primarily on transmission losses. If the scheme as proposed by the EU directive is implemented, it could have a considerable impact on Luxembourg's construction industry, since it will introduce several new concepts, such as energy efficiency for heating, hot water, lighting and cooling installations.

3.4.11 Ireland

Irish energy regulations consist of a generally formulated functional requirement stating that 'A building shall be designed and constructed as to secure, insofar as is reasonably practicable, the conservation of fuel and energy'. The general building regulations are accompanied by documents by which methods for complying with building regulations are illustrated. The *Technical Guidance Document L: Conservation of Fuel and Energy* (Department of the Environment and Local Government, 1997) has been developed for compliance with energy regulations. *The Technical Guidance Document L* dating from 1997 is under revision and the revised *Technical Guidance Document L* came into effect in July 2002 (Department of the Environment and Local Government, 2001). Under the *Amended Technical Guidance Document L*, three methods are presented for complying with energy requirements:

1. The 'Elemental heat loss' method (unit approach).
2. The 'Overall heat loss' method (heat loss by transmission).
3. The 'Heat Energy-Rating' method.

The first method consists of insulation requirements for construction elements and is therefore categorised as the unit approach. The 'Overall heat loss' method calculates a general U-level of a building, expressing possible heat losses by transmission. This method is categorised as transmission loss calculation. The Heat Energy Rating Method is an energy performance calculation, taking into account heat demand and energy use by heating, hot water and ventilation systems.

The Heat Energy Rating Method includes many of the elements required by the EU directive on energy performance of buildings. However, the other two methods are simpler methods, which only contain one element of the proposed EU directive: transmission losses. The difference between current energy regulations in Ireland and the approach envisioned by the EU depends on the extent of the building sector's familiarity with all three options. More than anything else, the extent of the Irish building sector's familiarity with the Heat Energy Rating calculation will determine the effort required if the scheme proposed in the EU directive is actually introduced.

3.5 Comparison of energy regulations

Table 3.1 presents an overview of the content of energy regulations in 11 European member states, showing the state of affairs of energy regulations as of April 2002 (Beerepoot, 2002). It shows that the 'unit approach', imposing maximum U-values to construction elements, is a method of compliance with building regulations in six member states, namely Denmark, England and Wales, Austria, Finland, Luxembourg and Ireland. In Austria, Finland and Luxembourg (only for buildings < 200 m^2) this is the main method of compliance with energy regulations. In England/Wales and Ireland, although there are two other possible methods of compliance, in practice the unit approach seems to be the most frequently chosen (Sheridan, 2002). In England and Wales, with a recent update of energy regulations in 2002, the unit approach is supplemented with standards for minimum efficiencies of hot water and heating installation systems. In Denmark, where there are two other possi-

Table 3.1 Energy regulations in 11 European member states

	Unit approach	Heat loss calculation	Heat demand calculation	Energy use calculation
Belgium		Flanders (1993): 'K-level': dwellings only Wallonia (1996): Option 1: 'K-level': dwellings and non-domestic buildings Brussels (2000): 'K-level': dwellings and non-domestic buildings	Wallonia (1996): Option 2: heat demand calculation	(Flanders: Energy Performance Regulations, introduced 2006)
	(Wallonia (1996): Requirements for ventilation rates)			
Germany		EnEV (1 Feb 2002), condition 1: max. transmission losses	(Space Heating Demand + requirements for boilers: until 1 Feb 2002)	EnEV (1 Feb 2002), condition 2: max. yearly primary energy use
France		(Heat loss calculation GV: until 2001)	(Heat demand calculation BV: until 2001)	Option 1: Energy Performance Regulations + Thermal comfort in summer (Reglementation Thermique 2000) (2001)
	Option 2: Simplified procedure with 'technical solutions'			
The Netherlands		(Until 1996)		Energy performance regulations (1996, current standard for housing: 2006)
Denmark	Option 1: Max. U-values (BR '95/BR-S 98)	Option 2: Heat loss calculation (BR '95/BR-S 98)	Option 3: Energy frame/Heat demand calculation (BR '95/BR-S 98)	
England and Wales	(Ap. Doc. L 2002) Option 1: Elemental method (+ min. SEDBUK efficiencies)	(Ap. Doc. L 2002) Option 2: Target U-value (+ possible correction factor for boiler efficiencies)		(Ap. Doc. L 2002) Option 3: Carbon Index Method: SAP calculations

ble methods of compliance, this method is used the least, because the other methods are considered to allow more design freedom (Engelund Thomsen, 2002). This means that in five member states – Austria, Finland, Luxembourg, England/Wales and Ireland – the unit approach is either the only or the most commonly applied method for compliance with energy regulations. In England and Wales, there are extra requirements for boiler efficiencies.

Table 3.1 shows that the 'heat loss calculation', imposing a standard for the average insulation level of a building, is an option for compliance with energy regulations in seven member states, namely Belgium, Denmark, England, Finland, Sweden, Luxembourg and Ireland. In Germany, a requirement for the average insulation level of a building is one of the conditions for compliance

Table 3.1 Continued

	Unit approach	Heat loss calculation	Heat demand calculation	Energy use calculation
Austria	All *Bundesländer* (1995): Maximum U-values for construction elements		Almost all *Bundesländer* (1995): Alternative to unit-approach: a heat demand calculation, comparing the situation with the unit-approach requirements	
Finland	(1985-1997) Method 1: Unit Approach	(1985-1997) Method 2: Average U-value of the building		(2003: Method 3: Energy use calculation)
Sweden		(1994-1998) Average U-value of a building	(1994-1998) As an extra option, it is possible to show compliance by means of a trade-off calculation	
	(1994-1998) Additionally, prescriptive requirements concerning limitation of heat losses, efficient use of heat and efficient use of electricity are covered			
Luxembourg	*Wärmeschutz-verordnung* 1996 buildings < 200 m^2: Maximum U-values	*Wärmeschutz-verordnung* 1996 buildings > 200 m^2: k-level of a building		
Ireland	Option 1: Elemental heat loss method (TGD L 2002)	Option 2: Overall heat loss method (TGD L 2002)		Option 3: Heat Energy Rating (dwellings only) (TGD L 2002)

with regulations, but it is not itself an independent route to compliance. In Belgium, Luxembourg (only for buildings > 200 m^2) and Sweden, the heat loss method is the primary method for compliance with energy regulations, although in Sweden, the requirement by means of a heat loss level is accompanied by several additional requirements, such as for hot water and heating installation systems. In Finland, the heat loss method is used if one cannot show compliance with method 1, the unit approach method. The heat loss method allows a trade-off between insulation levels of different construction elements, as long as the requirement for the average insulation level of the complete building is not exceeded. In England and Wales, the heat loss method is supplemented with minimum efficiencies of hot water and heating installation systems. This method is not the method of choice in Denmark, where the third possible method for compliance is considered to offer the most design freedom (Engelund Thomsen, 2002). This means that in three countries, the heat loss method is the main method used for compliance with energy regulations; those three countries are Belgium, Sweden (although several additional requirements exist there) and Luxembourg (only for buildings > 200 m^2).

Table 3.1 indicates that the 'heat demand calculation', is one of the possible methods for demonstrating compliance in four member states, namely in Wallonia (Belgium), Denmark, Austria and Sweden. It has been observed that this method is little-used in Wallonia because it is considered to be too complex (De Coninck, 2002). In Sweden this method is classified as an extra option, to demonstrate compliance if compliance cannot be demonstrated with the most common method, the average U-value of a building (heat loss calculation). In Austria this method is being introduced as an alternative to the most commonly used method, the unit approach. Only in Denmark this method is the most commonly used method for complying with energy regulations.

It can be derived from Table 3.1 that the 'energy use calculation' or 'energy performance method' is available as a method for compliance with energy regulations in five member states, namely Germany, France, The Netherlands, England/Wales and Ireland. In Germany and France, this method has recently been introduced as the only method for demonstrating compliance (in France in 2001, in Germany in February 2002). In Germany, the requirement for energy use is accompanied by a requirement for transmission loss. In The Netherlands, too, after being introduced in 1996, the energy use calculation is now the only method for demonstrating compliance with energy regulations. In England/Wales and Ireland, the energy use calculation is one of the three methods possible for demonstrating compliance with regulations. In Finland and Flanders (Belgium), energy use calculations as a method for compliance with energy regulations have been developed recently. In Finland this method was introduced in 2003 as an additional option for demonstrating compliance, where compliance cannot be demonstrated by one of the other two possible methods provided. In Flanders, energy performance policy was introduced in 2006 as the only method allowed for demonstrating compliance.

3.6 Conclusions and recommendations

This research leads to an overview of energy regulations in eleven European countries in 2002, analysing their identities in terms of degree of integrating aspects determining energy use of a building. The European Commission is heading towards harmonisation of energy regulations by means of the most comprehensive level of integration of energy related aspects, known as the energy use calculation or 'energy performance method'. Currently, five member states make use of such energy regulations (The Netherlands, England and Wales, Ireland, France and Germany), with only three of those (The Netherlands, France and Germany) using them as the only method for complying with energy regulations. This implies that eight out of eleven member states will have to redraft their present energy regulations. Since this study dates from 2002, we did not take into account the member states of the first and second waves of enlargement of the European Union, which has led to a total of 27 member states in 2007. The new European member states are assumed to have a lower rate of economic development and therefore probably will not be experienced with energy performance policy, although there may be some experience with the earlier stages of energy policy, such as heat loss calculation or heat demand calculation. The results of this study have made it clear that the experiences with energy performance regulations in The Netherlands offer the best case for evaluation research, since it is the only EU member state that introduced the energy performance approach as early as 1996 as the only acceptable method for showing compliance with regulations.

Energy performance regulations in five member states exhibit considerable differences in structure. Some notable elements of energy performance regulations in those countries can be worth considering for future development of energy performance regulations. In France, specific attention is paid to summer comfort by means of an additional requirement for compliance to energy regulations, alongside the energy performance requirement. The French energy performance method is also known for its creative solution for the problem of air density of a building. This building feature, which can be of great impact on the energy performance, is primarily determined during construction. In most situations, however, compliance with the energy performance regulations will have to be demonstrated prior to construction. In France, the builder must choose between a default value or using a better air density. If the latter is chosen, the builder will have to consent to the possibility that the air density will be verified after construction. The German energy performance method has two requirements: one for the heat loss of a building and one for the energy performance of a building. This setup prevents a builder from focusing solely on the efficiency of installations while neglecting the insulation level of a building. In Austria, the output of heating demand calculations is expressed in energy labels varying from A to G, comparable to the energy labels on many household appliances.

This study showed that, since there is no European energy performance standard available, the energy use calculation, also referred to as energy performance calculation, can be performed in several ways, varying from fairly simple (as used in Germany) to rather complex (as used in France). The question as to which level of complexity is preferable is a difficult one, since both options have their advantages and disadvantages. Since the energy performance calculation only provides an estimate of energy use consumption and its main purpose is to compare buildings and to provide a general insight to real estate owners, one could ask whether it might be better to keep the energy performance calculation as simple as possible. The kind of energy performance calculation used in Germany seems to be suitable for use by architects and developers (at least for overview purposes). The argument against a more complex calculation is that the more complicated the energy performance calculation, the fewer people who will be capable of understanding it; as such, architects and developers could lose interest in energy aspects of buildings. On the other hand, it is assumed that the most realistic possible method for calculating the efficiency of installations will give installation manufacturers an incentive to improve the efficiency of their installations. It is for this reason that The Netherlands, for instance, recently replaced its energy performance method with a more elaborate method for determining the calculation of hot water use. The promotion of product development or product innovation can be a very important aspect of introducing energy performance regulations. In conclusion, a balance is needed between insight into energy issues for architects and developers and a realistic calculation aimed at promoting product development. Complex issues in energy performance calculations that do not relate to product development, such as detailed calculations of shading of windows, should, therefore, be reconsidered.

Some feel that more attention should be devoted to building insulation levels, since these features are hard to improve after construction. Installations for hot water and heating, on the other hand, have fairly short life spans of some 15 years. Even so, few countries currently impose regulations regarding minimum standards for boiler efficiencies at the time of replacement. Another argument used to stress the importance of sufficient insulation is that several innovative heating techniques, such as the heat pump, make use of low temperature heating and require a good insulation level in the building. Such techniques may not yet be feasible, but will be in future. When heat pumps replace the boiler systems currently in use, insulation levels will need to be subject to high requirements. Given this discussion, the idea of a standard for transmission loss within the energy performance calculation (such as that of the German energy performance calculation) could be worth considering. Another option would be to introduce a standard for heating demand in addition to the standard for energy performance, since the heating demand calculation takes all energy features except for installations into account, while the energy performance method includes installation efficiencies.

Promoting exceeding the energy performance standards required in building regulations is an interesting aspect, and one that merits further exploration. The options for providing a financial bonus when performance surpasses the required standards could be experimented with. France has developed another solution for promoting energy performance in excess of the standard:

two energy labels, the HPE ('high energy performance') label, issued where the performance is at least 8% better than the current standard, and the THPE ('very high energy performance') label, where the performance is at least 15% better than the current standard. These labels were also introduced with a view to preparing the construction industry for more stringent standards in future energy regulations.

One of the major reasons for introducing energy performance regulations is to introduce a tool for meeting the Kyoto CO_2 reduction targets. It could be interesting, therefore, to use the actual CO_2 emissions as a basis for the output of an energy performance calculation. In England, the new energy regulations introduced in April 2002 make use of an energy performance calculation the output of which is based on CO_2 emissions and expressed in a 'Carbon Index'. The EU directive on energy performance of buildings mentions, as a specific aim for introducing energy performance regulations, the promotion of the use of renewable energy sources. In this context, it explicitly cites active solar systems as an example. Most of the eleven member states in this study do not appear to devote specific attention to renewable energy in the energy performance method. The issue of promoting renewable energy sources requires more attention and could be addressed by exercises exploring the options for using more renewable energy technologies.

Finally, building control is an important aspect to consider in introducing energy performance regulations. Energy performance calculations can be complicated, thus making it difficult for building control authorities to check compliance. Exercises that explore options for private control bodies could be helpful in resolving these problems.

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4 Encouraging use of renewable energy by implementing the Energy Performance of Buildings Directive

Based on:
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Beerepoot, M. (2006). Policy Profile: Encouraging use of renewable energy by implementing the Energy Performance of Buildings Directive. European Environment 16 (3), pp. 167-177.

One of many promising directions that shape innovations in energy technology is technology that makes use of renewable energy sources (RES). Since the introduction of the EU directive 2002/91/EC all EU member states will have to introduce energy performance policy for buildings. The introduction of such policy can be a point of departure for encouraging the use of renewable energy sources in the built environment. In this study the following research question is addressed: What possibilities exist for encouraging renewable energy technologies by means of energy performance policy? The information was analysed in the framework of the European Vth framework Altener project Build-On-RES that run in the period 2002 to 2004. Although the benchmark information might be partly dated, the findings for encouraging RES by means of energy performance policy are still topical. It was therefore decided not to update the information during finalising the thesis.

Abstract
The introduction of the EU Energy Performance of Buildings Directive (EPBD) paves the way for, amongst others, extra incentives for renewable energy, such as a 'renewable energy' accreditation to accompany the energy certificate; or an explicit indication of the share of renewable energy in the output of the energy performance calculation. This article seeks to appraise the possibilities for encouragement of the use of renewable energy sources (RES) by benchmarking experiences in this field in five member states. On the basis of these experiences opportunities for the incorporation of renewable energy incentives in energy performance regulations are presented and recommendations for creating synergy between renewable energy and energy performance regulations are formulated.

Keywords
EPBD, energy performance policy, renewable energy sources

4.1 Introduction

The EU Directive on the Energy Performance of Buildings (EPBD, Directive 2002/91/EC) requires member states to develop and introduce energy performance regulations ultimately in the year 2009. According to Article 3 of the EPBD, the energy performance methods developed should (in accordance with Annex I.2.a) "take into account the positive influence of active solar systems and other heating and electricity systems based on renewable energy sources". The EPBD can thus be used to create synergy in realizing national policy aims in encouraging the use of renewable energy sources (RES) and the implementation of the Energy Performance of Building Directive.

This chapter explores the possibilities for combining the implementation of the Energy Performance of Buildings Directive with encouragement for the use of renewable energy sources on the basis of benchmarking existing experiences. Benchmarking experiences in member states can be helpful in finding creative solutions for implementing European Community law. In terms of the Energy Performance of Buildings Directive (EPBD), a small number of member states are already experienced with energy performance regulations for buildings. For this research we choose to make an inventory of energy regulations in five member states that have experience with energy performance regulations in one way or another: The Netherlands, England and Wales, Denmark, Belgium and France (Beerepoot *et al.*, 2002a). The research presented in this chapter is based on the outcome of the European Vth framework Altener project Build-On-RES[1]

4.2 Benchmarking energy regulations for buildings

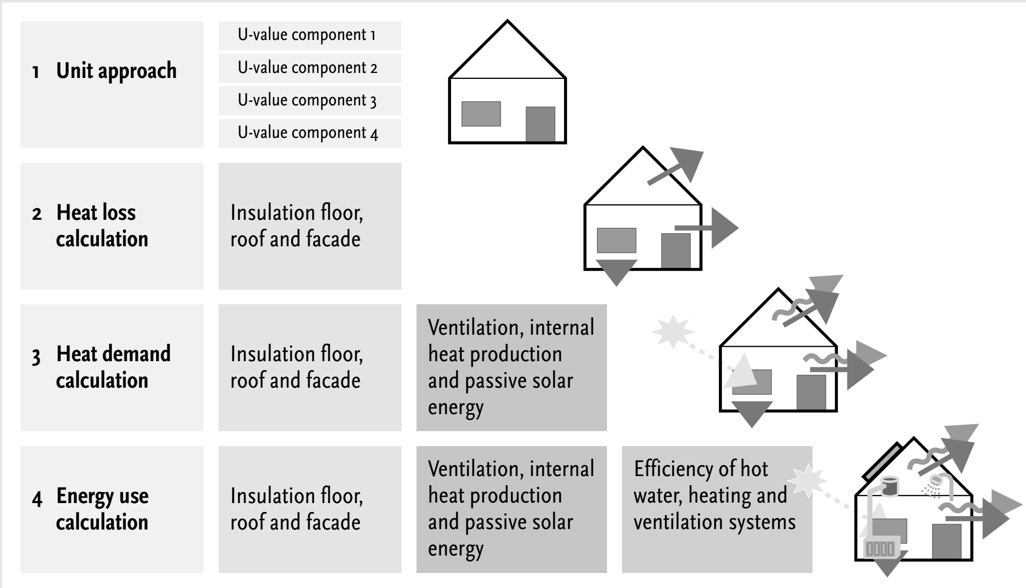
In describing energy regulations in member states we distinguish four main types of energy regulations according to (Beerepoot, 2002b): the unit approach, the transmission loss calculation, the heat demand calculation and the energy use calculation. This categorization is presented in Figure 4.1. The energy use calculation is also known as 'the energy performance' approach.

Table 4.1 shows that energy performance regulations are in place in The Netherlands, France and England and Wales[2]. France introduced energy performance regulations in 2001. The French system differs fundamentally

1 The Build-on-RES project was initiated by OTB research institute for housing urban and mobility studies and was executed with five partners from five EU member states. For more info see www.buildonres.org.

2 Though energy regulations are largely similar in the three parts of the United Kingdom (Scotland, England and Wales and Northern Ireland), we have concentrated on England and Wales.

Figure 4.1 Four approaches to developing energy regulations for buildings



Source: Beerepoot *et al.*, 2004

from the Dutch system: in France adherence to energy performance requirements falls under the principle of 'good workmanship' and is not governed by a system in which calculations are approved or checks are performed to confirm that these requirements have been met (CSTB, 2000a; CSTB, 2000b). In England and Wales, energy performance regulations – commonly referred to as SAP (Standard Assessment Procedure) – have been around since 1992 (BRECSU, 2001). However, SAP exists alongside two other systems for showing compliance with energy standards in building regulations. Up to now, SAP is seldom used in practice because it is regarded as relatively complex compared with the other two systems, one based on insulation requirements for building components and one on a heat loss calculation. A broader European study revealed that The Netherlands is unique in Europe, as the only country which has experience with energy performance regulations as the sole means of regulating energy since 1995 (Beerepoot, 2002a). Table 4.1 also shows considerable differences in the type of energy regulations in each country. Until 2006, in Flanders (Belgium) the energy performance requirements for new buildings have been based on heat loss calculations; hence, only the insulation of the shell of a building is considered, and there are no requirements for ventilation or heating (BBRI, 2000).

Our research revealed that some initial steps have recently been taken to formulate energy performance requirements for existing housing (Beerepoot *et al.*, 2004). England and Wales and Germany have started imposing minimum levels of insulation when building components are renewed. Germany has gone farther by setting a maximum U-value of 1.5 W/m^{2}K for replacement glass and a minimum Rc-value of 3.5 m^{2}K/W when constructional alterations

Table 4.1 Energy regulations for new housing in five EU member states

	Unit approach	Transmission loss calculation	Heat demand calculation	Energy use/ performance calculation
Belgium		Flanders (1993): 'K-level': dwellings only Wallonia (1996): Option 1: 'K-level': dwellings and non-domestic buildings Brussels (2000): 'K-level': dwellings and non-domestic buildings	Wallonia (1996): Option 2: heat demand calculation	(Flanders: Energy Performance Regulations, introduced 2006)
France		(Transmission loss calculation GV: until 2001)	(Heat demand calculation BV: until 2001)	Option 1: Energy Performance Regulations + Thermal comfort in summer (Reglementation Thermique 2000; 2001)
	Option 2: Simplified procedure with 'technical solutions' (Reglementation Thermique 2000; 2001)			
The Netherlands		(Until 1996)		Energy performance regulations (1996, current standard for housing: 2006)
Denmark	Option 1: Max. U-values (BR '95/BR-S 98)	Option 2: Transmission loss calculation (BR '95/BR-S 98)	Option 3: Energy frame / Heat demand calculation (BR '95/BR-S 98)	
England and Wales	Option 1: Elemental method (+ minimum SEDBUK efficiencies) (Ap. Doc. L 2002)	Option 2: Target U-value (+ possible correction factor for boiler efficiencies and passive solar gain) (Ap. Doc. L 2002)		Option 3: Carbon Index Method: SAP calculations (Ap. Doc. L 2002)

Source: Beerepoot *et al.*, 2004

are made to a roof. The German regulations also state that heating systems dating from before 1978 must be replaced by December 2006 and that heated space adjacent to an unheated attic must be fitted with roof insulation by the same date. In England and Wales insulation requirements have been formulated for replacement windows and doors and standards have been set for the yield from replacement heating systems. England and Wales monitors these requirements by awarding certificates to the firms that fit the components and systems. The certification system is managed by trade organisations, such as FENSA for glass and doors, and CORGI for heating systems. Denmark is also turning its attention to existing buildings, but has not imposed any energy performance requirements. However, it has applied an obligatory system of energy labelling since 1997: every building, when sold or leased, must have an energy label indicating its average expected energy consumption compared with an energy performance calculation. The Danish system of energy labels is largely similar to the energy certification system for existing buildings in the EPBD.

4.3 Drawing attention for renewable energy in energy performance regulations

The energy performance calculation takes account of the yields from installations that deliver heating, hot tap water and ventilation. It does not automatically cover all types of installations. The inventory of openings for including renewable energy in current energy (performance) calculations revealed wide differences in the importance that each country attaches to renewable energy applications (Buscarlet *et al*., 2004) (Cruchten, van *et al*., 2004). Until 2006 regulations in Belgium accorded no importance whatsoever to renewable energy while the Danish regulations rated only the utilization of passive solar energy. In England and Wales so far three methods for fulfilling the energy regulations exist. The third method, SAP, consists of an energy performance calculation. The first and second methods make allowances for exceptional cases, if a heat pump is used or a form of biomass. These were designed with the specific aim of promoting the use of these technologies. SAP covers the utilization of passive solar energy, solar thermal systems for hot tap water, and heat pumps. Solar thermal systems that help to heat space are not rated in SAP, nor are photovoltaic systems. The French method was introduced in 2001, but it was not until 2004 that it could be used for calculating the input of solar thermal systems (for tap water and heating). This procedure is not, however, incorporated in the general energy performance calculation but is based on the 'f chart' principle, which is fairly complex compared with e.g. the Dutch approach (Beckman *et al*., 1977). The Dutch energy performance method is the only one that addresses photovoltaic systems besides other applications like passive solar energy, solar thermal systems and heat pumps. The Dutch system therefore offers the most possibilities for rating renewable energy applications. The French energy performance system is also expected to rate the application of photovoltaic systems within soon.

The characteristics of methods for calculating energy performance were also inventoried and analysed in the research. Significant differences came to light. The English method, SAP, asks the user only for the number of square metres of collector surface in the case of, say, a solar thermal system. Other conceivable factors – such as angles, orientations, yields – remain constant. The French method, on the other hand, asks the user for a whole range of information, including heat storage characteristics such as the volume and the heat loss coefficient of the reservoir. It can also incorporate specific features of the collector – the heat loss coefficient and the solar gain factor – though these are also covered by default values. The Dutch method for calculating the energy performance of housing is positioned midway between the English and French method (NNI, 1998). The factors influencing solar thermal systems are limited to collector surface, orientation and angle, shadow and yield resulting from the heating needs of a building. The general basis for calculating the contribution of solar thermal systems is the 'solar load ratio' in The Netherlands, Belgium and England and Wales, and the 'f chart' in France.

4.4 Incorporating incentives for renewable energy in energy performance calculation

The implementation of the EPBD will demand a response from all the member states, including those which have already enacted parts of the directive (e.g. The Netherlands). The renewed focus on energy regulations in all the EU member states should create scope for synergy in the promotion of renewable energy. A first condition for encouraging the use of RES when implementing the Energy Performance of Buildings Directive is that it must be possible to calculate the contribution of RES equipment. When this condition is fulfilled it is possible to look for encouragement of RES in relation to the calculation of the energy performance of a building. Our research in the framework of the Build-On-RES project strove to identify synergy opportunities, concentrating particularly on ways in which current or future energy policy can be used, combined or adjusted without too much effort in order to boost the use of renewable energy. We found two examples of instruments that can be combined with energy performance calculation relating to renewable sources: one in Finland and one in Germany. Finland introduced energy performance regulations in 2003 (Ministry of the Environment, 2003). One of the conditions is that energy that is consumed over and above the set level must be generated from renewable sources. The German system, which dates from 2001, includes a rule which says that if the input from renewable sources exceeds 70% of the total energy consumption, there is no need to meet the energy performance requirements (Bundesministerium für Wirtschaft, 2001). The original intention behind this rule was to provide a means for rating renewable energy applications when the system was still in its infancy and there were no definitive arrangements in this area. Now, it could also be regarded as an incentive for innovative applications of renewable energy. Though, strictly speaking, a wind turbine in a building does not figure in the energy performance calculations, it can still be rated under this rule. A more developed form of regulatory policy which has not yet been applied is to give preferential treatment to renewable energy sources in the calculation core of the energy performance. It has occasionally been said that the Dutch energy performance calculation delivers inordinately good results for heat supply and that this is partly due to political choices. Something like this could also apply to renewable energy applications.

4.5 Energy performance-related policies

Before we discussed the possibilities for encouraging RES related to the energy performance calculation. However, many obstacles can hinder the use of RES in residential buildings, even when this first condition is fulfilled. Governmental intervention is often considered necessary to tackle the constraints that hinder the pace at which the use of RES equipment is spreading. This section therefore examines policy instruments that can be used over and above – as well as in relation to – energy performance regulations in order to encourage the use of RES. We distinguish three categories of policy instruments: regulatory (legislation), financial and communicative. Searches were performed to uncover already existing policy instruments in Europe and to spot new windows of opportunity. Once the importance of greater penetration of RES gains more recognition than it currently has, regulations can become an effective means of achieving that goal. In general, however, regulations are not a popular instrument in politics. In fact, they are often only considered when a problem is considered to pose a great potential threat to society and no other solution is available. Since climate change could pose such a threat, it is not inconceivable that efforts to promote a more widespread use of RES will gain even greater priority on the political agenda in a number of years. With the above in mind, Table 4.2 presents a number of options for regulations that could be combined with the introduction of an energy performance policy, and that could accelerate the penetration of RES in residential buildings. Generally speaking, the introduction of regulatory policy is often slow and sluggish. Target groups are difficult to win over and the policy needs a support base in order to be effective. But an example from Barcelona tells a different story. In 2000 Barcelona introduced the *Barcelona Solar Ordinance* under which all new buildings had to be fitted with solar thermal systems capable of meeting at least 60% of the hot tap water needs (Barcelona City Council, 1999). Close attention was paid to building a support base among the city's citizens and building partners. In 18 months the collector surface in the city rose from 1.650 m^2 to 14.027 m^2 and continued to grow afterwards at the same pace.

Some time ago, a proposal was made in Denmark to require social housing associations to install solar collectors on the roofs of their housing stock. Danish social housing associations own a large percentage of the country's housing stock and have a strong position on the housing market. Since that time, however, the government has changed and the idea has been rejected and abandoned.

Another approach, which originated in Italy but is still to be implemented, is to allow the purchase of an air-conditioning system only if a photovoltaic system is purchased at the same time. This rule would apply to climates

Table 4.2 Options for RES regulations in an EP policy

Policy instrument	Pros	Cons	Examples
RES obligation when exceeding energy performance standard	No change in design freedom, while adding extra options for RES	Violation of standards is tolerated (contradictorily signal)?	Finnish energy performance regulations (2003)
Obligation for percentage of RES in EP calculation	Guaranteed increase in percentage of RES used in buildings.	Less design freedom.	Barcelona Ordinance on the Application of Solar Thermal Energy Systems in Buildings (2000)
Obligation for application of RES techniques in specific situations: Combine PV with cooling system Obligatory solar thermal systems for social housing	Electricity demand & supply come together Guaranteed cumulative production possibilities for innovative RES techniques	Additional administrative control? In some MS, social housing is under strong governmental control; this is an example of a governmental monopoly (highest amount of pressure possible)	Preliminary idea Italy. Intention in Denmark in 2001, prevented by new government in 2002
Energy performance standards building site	More RES options will be available when considering the scale of a building site More design freedom when considering the scale of a building site, although minimum insulation levels must be set for building parts in order to prevent bad designs	Administration costs will increase as authorities exercise more complicated design control Tolerance of non-compliance can increase since building control will be more complicated	Energy Performance of a building site (EPL) (the Netherlands, voluntary information policy)
Exemption from the obligation to meet energy performance standard (primary energy) if the percentage of RES is greater than a certain percentage of the total energy consumption (e.g. 70%, as in German EnEv)	Useful in the case of new RES equipment for which calculation algorithms do not yet exist Saves time/money because EP calculation is not required (although some calculations must still be performed to check the energy concept)	Insufficient benefits for applicant. This can be interpreted as a wrong message: "when using RES, energy efficiency is no longer needed"	Energieeinsparverordnung (EnEv), November 2001 Germany

Source: Beerepoot *et al.*, 2004

with high cooling needs in the summer and ensure that the peak cooling consumption would more or less coincide with the peak yield of photovoltaic systems and thus spread the burden in power plants in the summer.

In The Netherlands another example was found, once mooted by the former State Secretary for Housing Remkes (Stromen, 2000). He took the view that the energy regulations for buildings were too limited in the long term and advocated the introduction of energy performance requirements for entire building sites. This would create more openings for the deployment of efficient generation technology, such as biomass plants or wind turbines.

Financial incentives are used quite frequently by governments to encourage energy saving or the use of RES. Financial incentives fall into two basic categories. The first consists of levies or taxes to prevent undesired behaviour, or to compensate for environmental costs. The second category consists of subsidies or tax exemptions aimed at encouraging desired behaviour. Ideally, these two types of financial incentives should be in balance with each other: the costs of RES subsidies should be covered by revenues from RES taxes, or levies. Financial incentives are often part of schemes that function separately from energy regulations. Administrative procedures can be complex and can discourage the use of subsidies. It would be interesting, therefore, to see what financial RES incentives may be proposed in combination with the energy performance regulations required under the EPBD. We present a number of existing examples and new ideas in Table 4.3. Since the objective is to encourage the use of RES, we focus primarily on positive financial incentives, such as subsidies or tax exemptions.

It is often said that energy performance regulations will – in themselves – prompt efforts to develop innovative techniques, provided that the energy performance standards are tightened regularly. However, decisions to tighten energy performance standards are political and are not, therefore, guaranteed to be made on a regular basis. In The Netherlands, energy performance standards for dwellings have not been tightened for a period of six years (2000-2006). The Netherlands' experience with tightening energy performance standards by taking one small step at a time indicates that this approach possibly results primarily in product improvements, rather than product innovations. One solution to this would be to introduce a financial incentive that rewards energy performance that exceeds the standard. If that financial impetus were large enough, it could encourage the development of innovations or the use of RES equipment. This idea was introduced for a one-year period in The Netherlands (in 2002). The energy performance standard at the time was 1.0. Performances ranging between 0.9 and 0.8 were rewarded with €450 and those that fell under 0.8 were rewarded with €1100. A subsidy scheme that provides subsidies for dwellings that use RES equipment to meet a certain percentage of the heat demand could prove feasible. In that case, it should be possible to calculate this percentage of RES, using the energy performance calculation. At present, no such subsidy schemes exist. In The Netherlands, mortgages with lower interest rates are available for homeowners, provided their dwelling meets a number of conditions regarding sustainability. The conditions are quite stringent, requiring a long list of sustainable measures. However, the costs of these measures can be covered by the money saved with a lower mortgage. The Netherlands' mortgage scheme is paid for by means of a system of 'green investments', which allows parties to invest in 'green funds' that exempt from investment taxation. These 'green funds' are, among other things, 'green investments', used for providing cheaper mortgages for

Table 4.3 Options for financial RES incentives in EP policy

Policy instrument	Pros	Cons	Examples
Subsidy for performance that exceeds the standard			
1. Subsidy for better EP performance	1. Encourage more energy saving than regulated while offering same amount of design freedom (with the expectation of increasing use of RES)	1. Subsidy expenditure needs to be covered by tax (preferably from taxation regarding the same issue?) (Regulating Energy Tax?)	EPR-2002 (the Netherlands) (non-existent since 2004)
2. Subsidy for better RES performance	2. Encourage use of RES while offering same amount of design freedom	2. Subsidy expenditure needs to be covered, by tax (preferably from taxation regarding the same issue?) (Regulating Energy Tax?)	
Subsidy for RES equipment automatically connected to submitting an Energy Performance calculation to Building Control	Administrative procedures can become more efficient Subsidy application process will become easier, thus encouraging use of RES	Subsidy expenditure needs to be covered, preferably from taxation regarding the same issue (Regulating Energy Tax?)	No examples available
Cheaper (mortgage) loan for consumers who use more:			
1. Sustainable options	1. A relationship with building mortgage can be a strong financial incentive (new buildings)	1. If not directly related to EP calculation, more effort will be needed from architect/developer, which will prevent use of RES	Green Mortgage (the Netherlands)
2. RES (related to EP in that it requires EP performance that exceeds the standard)	2. A relation with building mortgage can be strong financial incentive (new buildings)		
Land price policies: e.g. imposing (RES) conditions when selling land for housing development	Land possession is one of the few means of power that (municipal) governmental institutions can use to fulfil (municipal) 'green' goals	Power of (municipal) governmental institutions to impose more stringent regulations that those in place under national law may be limited for legal reasons	Some private initiatives in Belgium

Source: Beerepoot *et al.*, 2004

sustainable buildings. This makes the system a closed circuit with hardly any governmental interference, since green funds and mortgages are managed by private banks. A similar scheme, specially designed to promote RES, could also prove feasible. Land is often owned by governmental institutions and sold to private parties to start new land developments. This puts governmental institutions in a position to set conditions on the land they sell to private developers. However, for legal reasons, it has proven difficult for municipalities to impose conditions that are more stringent than those laid down by national law. In Belgium, housing developments are often initiated by private parties

Table 4.4 Options for RES information policies related to EP policy

Policy instrument	Pros	Cons	Examples
Explicit RES contribution in Energy Performance rating	Makes RES more visible as part of the energy performance of a dwelling.	Without any obligations.	
RES label	A RES label can be a marketing instrument/ selling point.	In a 'seller's' housing market, a RES label could be a relatively unimportant selling point.	'Solar dwelling label' (the Netherlands, 2003).
RES potential analysis	A RES analysis can provide insight into possible RES options and pay-back times, thereby seeking to promote RES.	Providing RES options and pay-back times can be too weak an instrument to change behaviour.	No example available in housing. (In NL, however, examples are available for municipalities and industries).
Establish RES agreement for new building site among all partners involved (municipality, architects)	Agreements make an intention more official.	Agreements are generally voluntary, making it easy to renege.	Danish municipality in Glostrup.

Source: Beerepoot *et al.*, 2004

who own land. Belgium has one known example of a private landowner (in Bassevelde, commune of Assenede in eastern Flanders), who set sustainability requirements in a land deal.

Information policies use fairly limited means of force. Rather, they aim to convince parties entirely by means of information about the benefits of certain behaviour. Information policies are often considered supplementary tools to other policy instruments, such as regulations or financial incentives. However, in situations where the parties involved are generally willing to change their behaviour but don't know how best to go about it, information policies can be effective. We present a number of existing examples and new ideas in Table 4.4. Labelling is an example of an informative policy where additional information is used to convince parties of the benefits. One option to consider is that of introducing a RES label for dwellings that indicates the amount of RES used. The amount of RES could be expressed by means of the percentage of heat demand met by RES equipment. It is quite easy to develop ranges of RES percentages and divided them into categories (e.g., A, B, up to G), similar to the energy labels for household appliances. In The Netherlands, a 'solar dwelling label' exists. Although the name gives the impression that this is a RES label, the label covers a much wider range of aspects, such as the use of wood from forests under proper management ('FSC' wood). The EPBD requires a feasibility analysis for alternative energy systems in new buildings that measure over 1000 m^2. The interpretation of what this 'feasibility study' should look like is very divergent per member state. In order to encourage the use of RES, the feasibility study should be more than a checklist or a statement saying that the use of alternative energy systems has been checked. This feasibility study can, of course, be extended to include smaller buildings.

Another option is to explicitly stress the share of renewable energy in dwellings, as calculated in the energy performance calculation. In The Netherlands, RES potential analysis instruments do exist for some sectors, such as industry, municipalities and horticulture.

4.6 Conclusions and recommendations

The introduction of energy performance regulations as required by the European Directive on the Energy Performance of Buildings (EPBD) offers a perfect opportunity to consider and introduce specific provisions to promote the use of renewable energy sources (RES). Since all member states have specific RES policies aimed at increasing use of renewables in the future, it is possible to create synergy when new energy policies for buildings are introduced. In comparing energy regulations in five member states – The Netherlands, Denmark, France, United Kingdom and Belgium – in the EU Vth framework Altener project Build-On-RES, supplemented by information from Beerepoot *et al.* (2002a), we found that experience with energy performance regulations – in the strict sense of making energy use calculations for buildings – is rather limited. Besides this, we found that to date, RES has not always been an obvious element in energy performance calculations but rewards for using RES equipment in the energy performance method differ per member state.

The design of energy performance calculation procedures is important. Renewable energy sources are a crucial consideration. To date, however, RES has not always been an obvious element in energy performance calculations. The Build-On-RES project found that the rewards for using RES equipment in the energy performance method differ per member state. While the SAP method in England and Wales only provides rewards for solar thermal systems for hot water production, the Dutch NEN 5128 provides rewards for all solar thermal techniques as well as solar electrical systems. None of the current energy performance regulations provide rewards for biomass or wind energy plants at the building level. Based on our findings in the Build-On-RES project, we would advocate an integrated calculation, where RES equipment is an option among many possible installations. Mandatory calculation of the contribution of RES equipment by means of separate (complicated) calculations would probably create additional obstacles to the use of RES. Moreover, the calculation procedures for taking RES equipment into account should not be more complicated as compared to those for any other installation. After all, complex calculation methods could also prevent use of RES equipment. In the near future, efforts to develop energy performance calculation methods could focus on devising additional arithmetical solutions to promote the use of RES. Regulations in some member states favour CHP (combined heat and power) installations above regular installations due to political reasons. Similar solutions could feasibly be introduced for RES.

In exploring options for combining energy performance regulations with regulatory, financial or information policies that promote RES, we have encountered a number of interesting ideas. The option of establishing regulations to increase the use of RES raises contradictory considerations. Politically speaking, the introduction of regulations is often unattractive, as regulations are felt to hinder competition and impose barriers. On the other hand, such regulations can be remarkably successful if sufficient attention is paid to public support for the scheme. Regulations will probably only be considered when a problem is felt to pose a serious potential threat to society and other solutions are not sufficiently effective. Since climate change could pose such a threat, it is not inconceivable that efforts to promote more widespread use of RES will gain even greater priority on the political agenda in a number of years.

Financial incentives have been widely used to encourage RES, often with subsidies specifically issued for RES equipment, such as solar systems. The combination of financial incentives and energy performance regulations could take the following forms: a subsidy for improvements over basic levels of energy performance rating or a subsidy for a specific RES contribution to the energy performance rating. Subsidies for RES equipment could be automatically linked to the submission of energy performance calculations to building control authorities, or of the energy performance certificate to the relevant administrative body. This would reduce the administrative burden for developers, or building owners. Subsidies appear to be a very attractive policy instrument, but may not be an effective channel for allocating government budget funds. For instance, subsidies that are awarded for well-established techniques pose the risk of the 'free-rider effect': the subsidies may end up benefiting parties who would have used those techniques anyway.

It would be relatively easy to introduce guidance or labelling to promote RES in combination with energy performance regulations. However, the effectiveness of such measures is difficult to determine and may prove to be fairly limited. A RES label combined with the energy performance rating or certificate can provide easily understandable information about RES. Ideally, a RES label that shows the amount of RES used in a dwelling would be a marketing tool. However, it would have limited success in countries where energy prices are low.

The Build-On-RES research project has resulted in recommendations for policy-makers who are working on the implementation of the EPBD (Beerepoot *et al.*, 2004). Some of these recommendations relate to concrete, technical aspects of the energy performance regulations; others concern additional policy measures, mostly combined with the energy performance calculation or the energy performance certificate. The calculations for renewable energy applications should be incorporated in the general energy performance calculations to ensure that equal attention is paid to renewable and conventional energy systems.

One of the first conditions for promoting RES is that the energy performance calculation must include a provision for calculating the contribution of RES. Renewable energy sources are a crucial consideration. To date, however, RES has not always been an obvious element in energy performance calculations. Energy performance calculations should provide rewards for all available solar thermal techniques and solar electrical systems, and elementary calculation principles should enable the calculation of contributions of new RES equipment, such as biomass or wind energy plants at the building level. Based on our findings in the Build-On-RES project, we would advocate an integrated calculation, where RES equipment is an option among many possible installations. The calculation procedures for taking RES equipment into account should not be more complicated as compared to those for any other installation. After all, complex calculation methods could also prevent the use of RES equipment.

A rather simple step in promoting the use of RES is to provide explicit information in the output of an energy performance calculation about the contribution of RES to an energy performance rating. (Example: a statement that RES contributes X W/m^2, which represents X% of the total estimated energy use).

Another way to promote RES is to introduce an RES label, automatically connected to the output of an energy performance calculation, or the energy certificate. This RES label could be issued for buildings that fulfil a certain energy consumption requirement (e.g., when RES contribute X% of the total estimated energy consumption). The RES label can be used as marketing instrument and serve as a selling point.

In introducing RES subsidies, efforts should focus on avoiding complicated administrative procedures. Subsidy procedures for building-specific RES equipment could be combined with the administrative procedures for building permit applications. Subsidies could also be introduced on an integrative level, (e.g., subsidizing the percentage of RES in the total estimated energy consumption).

Tax measures introduced to promote the use of RES should preferably consist of progressive measures in order to avoid situations of social inequality. Tax measures can consist of a reduced energy tax for the consumption of 'home-produced' energy, or progressive taxation on the consumption of non-renewable energy.

Mandatory measures could prove extremely effective in ensuring the success of efforts to promote RES. Examples of such include the introduction of a mandatory percentage of energy supplied by RES in the total estimated energy consumption, or the mandatory use of PV systems with cooling systems. Another promising option is that of favouring the use of RES in the energy performance calculation above the use of other energy sources. This could be done, for instance, by introducing correction factors or higher efficiency figures that favour the use of RES.

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5 The contribution of the EC energy certificate in improving sustainability of the housing stock

Beerepoot, M. & M. Sunikka (2005). The contribution of the EC energy certificate in improving sustainability of the housing stock. Environment & Planning B 32, pp. 21-31.

The interest in approaching the building stock for realising energy conservation aims is dictated by the relatively poor energy conditions of the building stock and the rather cost-effective potential to implement energy savings measures. Besides, the building stock respresents a large share of energy use of the total building sector. This article discusses the potential effects of energy certificates for the housing stock on the basis of experiences in Denmark and The Netherlands and addresses the following research question: What energy conservation effects can be expected from introducing energy performance labels for existing residential building?

Abstract

In 2003 the European Commission introduced the EC Directive on the energy performance of buildings in recognition of the importance of energy savings in the urban housing stock. The Directive gives the member states freedom to design the different elements in practice. The energy certificate for existing buildings, demanded by the EC Directive, can be used as a communicative instrument or combined with economic or regulatory principles. This article discusses the anticipated efficiency and effectiveness of different policy approaches in the application of the EC energy certificate for the urban housing stock. We argue that, although energy certificates as a communication instrument for household appliances have appeared to be relatively successful, the different nature of the building sector can mean that their effectiveness here will be rather limited. The combination of energy certificates with tax schemes seems promising but will have to be covered in general income taxes or in housing related taxes in order to prevent regressive social effects. Combining the energy certificate with subsidies should be rather limited due to the 'free-rider effect' and subsidies should only cover innovative products at the beginning of their 'learning curve'. Effective results can probably be expected from introducing regulations combined with energy certificate standards, but it requires a rather drastic approach and needs time to receive sufficient commitment, like for new buildings where there has already been a gradual development of energy regulations over the last 30 years. However, an introduction of energy standards for the existing urban housing stock through the EC energy certificate offers great potential in realizing CO_2 reductions. Introducing an energy standard by means of the energy certificate in combination with progressive taxes or other economic measures for rewarding better and punishing worse energy performance levels, seems an interesting approach that needs further research.

Keywords

Energy certificate, EPBD, energy conservation building stock

5.1 Introduction

In the Kyoto Protocol, governments of the industrialised countries agreed to reduce the total 1990 level of CO_2 emissions by 5.2% between 2008 and 2012 thus increasing pressure on governments to establish CO_2-reducing strategies. The European Union is preparing to implement the commitment as a community, as it is studied as an entity regarding emissions and restrictions. In absolute terms, the largest energy end users are households and the tertiary sector (EC, 2001). Dwellings yet to be built will constitute 15% of the total housing stock in 2020 and 5-10% of the total housing stock in the Kyoto period 2008-2012 (NOVEM, 2002). Consequently, the existing housing stock is an important sector in reducing green house gas emissions according to the Kyoto agreements.

The European Union also recognizes the importance of reducing of CO_2 emissions in the building sector and in early 2003 the European Parliament accepted Directive 2002/91/EC on the Energy Performance of Buildings (EC, 2003). One of the four key elements described in the Directive is the introduction of energy certificates for the existing building stock. The Directive requires that, by January 2006, an energy performance certificate, not more than 10 years old must be shown to prospective purchasers or tenants when a new or existing building is sold or let. In addition to detailing the current energy efficiency level of the building, the certificate must also include recommendations for cost-effective improvements in energy performance. The Directive demands that energy certificates are issued for the existing building stock, but it leaves it open for each member state to decide whether certain minimum energy criteria should be met and whether to combine the energy certificate with economic policy instruments or to use it only for communication purposes. The energy certificate, as demanded by the Directive, can, therefore, be seen as a tool that can be used in combination with different types of policy instruments. In the description of energy regulations in 11 EU Member States, Beerepoot (2002a) concludes that energy regulations for existing buildings hardly exist. European research studies show that voluntary energy certificate schemes for buildings already exist in a number of European member states (Blaustein, 2000; Van Cruchten, 2003). A combination of an energy certificate and a subsidy scheme exists in The Netherlands, whereas a compulsory energy certificate, without subsidies, is used in Denmark (Van Cruchten, 2003). In the inventory of economic instruments in sustainable housing policies in Europe, Sunikka (2003a) concludes that none of the fiscal instruments are self-policing, so the instruments need to be enforced by legal means. No study, however, describes the anticipated effects of energy certificates for buildings as a voluntary instrument or when combined with regulations, subsidies or taxes.

The efficiency and effectiveness of the use of the energy certificate for buildings in different policy options is an important question since the Kyoto aims are severe and governments want to realise the highest possible results with the least government means. Although evaluation studies of the existing certificate schemes can illuminate some elements of the efficiency and effectiveness of different ways that certificate schemes can be implemented, the result is rather fragmented (Van Cruchten, 2003). On the other hand, policy analysis literature has extensively described the effectiveness and efficiency of different policy instruments, but this approach has never been applied to building energy certificates (Ekelenkamp *et al.*, 2000; Murakami *et al.*, 2002; Kemp, 2000). This chapter will, therefore, describe both practical examples of current energy certificate schemes and theoretical notions of policy literature in effectiveness and efficiency of several types of policy instruments. This chapter examines how the EC energy certificate can improve the energy efficiency of the existing urban housing stock and how the certificate should be used in combination with regulatory and economic policy instruments to reach effective results. This chapter aims to answer the research question: How can the new EC energy certificate and other policy instruments be used to improve sustainability in the urban housing stock? Using examples of existing energy certification schemes and different policy instruments, the aim is to present to the member states ideas they can make use of when they begin to apply the new Directive in their national context.

First, the research approach and definitions are introduced in Section 5.2. In Section 5.3, descriptions of regulatory and economic instruments are linked with examples found in the authors' empirical research. The pros and cons of regulatory and economic instruments are examined in terms of four principal criteria: environmental effectiveness, economic efficiency, dynamic technological incentives (innovation) and administrative feasibility (Murakami *et al.*, 2002). In Section 5.4, the energy certificate schemes in The Netherlands and Denmark are discussed in detail. In Section 5.5, the expected effectiveness of inclusion of the EC energy certificate in different policy instruments is discussed. Finally, conclusions are drawn in Section 5.6.

5.2 Research approach

This chapter uses information collected by the authors for earlier studies on regulatory and economic policy instruments and elaborates these ideas further. Beerepoot (2002a) analysed energy regulations for building in eleven EU Member States based on a collection of documents describing energy regulations, such as legal documents and manuals. In a European research project co-ordinated by OTB Research Institute for Housing, Urban and Mobility Studies, energy policy instruments for building and their evaluations were collected in five EU member states (Beerepoot, 2002b). The inventory of fiscal instruments in sustainable housing policies in Europe of Sunikka (2003a) was based on the national progress reports addressing the existing policy context and policy instruments of the 3rd European Ministers conference on sustainable housing that was held in Genvalle, Belgium, in 2002 (NOVEM, 2002). Sunikka (2002) also described policies and policy instruments for sustainable building in five EU Member States on the basis of an extensive literature review (Sunikka, 2003b). In addition to the empirical data about practical policies on energy saving in buildings, scientific literature on effectiveness and efficiency of policy instruments in general is used in order to examine the possibility of combining energy certificates with different policy instruments. This chapter focuses on housing, because it is the largest sector of the building stock (Sunikka, 2003a).

In this chapter, energy certificates for buildings are defined as a tool to be used for assessing the energy quality of a building, either existing or new, residential or non-residential. Energy certificates can be embedded in different types of policy instruments. Policy instruments can be defined as a myriad of techniques available to a government to implement their policy objectives (Howlett & Ramesh, 1993; Schneider & Ingram, 1990). Different approaches in structuring environmental policy instruments are possible. This chapter is based on the most often used typology following the three concepts: direct regulation, economic instruments and communicative instruments (Kemp, 2000; Murakami *et al.*, 2002). Direct regulation includes policy instruments that by means of orders, or imposing standards in law, try to impose environmentally benign behaviour. Economic instruments influence the economic attractiveness of environmentally benign behaviour and, since the environment can be considered a public good for which insufficient market demand exists, try to restore market imperfections. Communicative instruments are policy instruments based on communication that try to persuade people to perform environmentally benign behaviour by providing information about the environment or by trying to change opinions and attitudes (Jordan *et al.*, 2000; Ekelenkamp *et al.*, 2000). Energy certification can be used as a communicative instrument, as in, for example, the energy certificates for household appliances. Communication instruments can be useful policy tools for addressing information problems but they are generally considered to be additional policy instruments and not substitutes for economic or regulatory policy tools (Kemp, 2000; Ekelenkamp *et al.*, 2000). This chapter, therefore, focuses on regulatory and economic instruments.

5.3 Regulatory and economic policy instruments

Direct regulation can be especially useful when dealing with hazardous materials that are dangerous in small concentrations (Ekelenkamp *et al.*, 2000).

Disadvantages of direct regulation are high administrative costs, possible tolerance of non-compliance by local governments, not addressing firms' responsibilities in environmental issues and in terms of economic efficiency, no perfect allocation of efforts taken by different target groups. Innovations will be limited since there are no incentives for performing better than is regulated. Direct regulation can operate by means of standards for singular measures, like minimum insulation levels for building components, or by means of standards for a general goal, like the energy performance approach. The historical development of energy regulations for buildings shows that minimum insulation levels were in many cases the first type of energy regulations introduced in the 1970s while these gradually transformed towards more integrative approaches calculating the energy demand or energy use of buildings, the so-called 'energy performance' approach (Beerepoot, 2002a). Direct regulation by means of formulating general goals, such as the energy performance standard, can overcome some of the disadvantages of direct regulation by means of singular measures. Economic efficiency can improve since it is possible to choose the most economically efficient combination of measures in order to meet the energy performance goal. Regulations by means of general goals can stimulate innovations in that it encourages firms to find cost-reductions in meeting the goals e.g. by developing new, more cost-effective, energy-saving measures. However, this type of regulation still does not realise a continuous aspiration for innovations since performing better than the standard is not encouraged. This disadvantage can be partially abolished by regularly tightening the standard. However, if no long-term ambitions are formulated when introducing the energy performance standard, the danger exists that this will be hindered for political reasons and by pressure from lobby organisations, like has happened in The Netherlands (Tweede Kamer der Staten Generaal, 2002).

No examples are known of countries with energy certificates for existing buildings that are used in direct regulations in terms of imposing standards (Beerepoot, 2002-a). Direct regulation of energy use in existing buildings has only been initiated very recently in some EU member states by means of standards for singular measures (Gilijamse & Jablonska, 2002). In Germany, since 2002, the replacement of certain building components in existing buildings is subject to minimum insulation levels (Bundesministerium für Wirtschaft, 2001). In England and Wales, revised energy regulations introduced in 2002 impose minimum insulation levels for replacement of windows and doors in existing buildings and central heating boilers being replaced will have to fulfil the same efficiency standards as for new building (DTLR, 2001).

Decentralised incentive systems are an alternative to command-and-control policy instruments. Taxes are presumed to achieve the solution involving least cost and to provide continuous incentives to search for more cost-effective technologies to improve environmental quality (Siebert, 1995; Hasegawa, 2002). However, energy taxes are unpopular with the electorate in general and with industry in particular. In order to create more sustainable practice, the price incentive needs to be relatively high, but the total environmental costs for the industry, including both abatement costs and tax payments, are also likely to be high, which may induce the government to set the tax at an insufficiently low level. The aggregate amount of pollution cannot be predicted, but depends on the forces of supply and demand. The innovation effects of environmental taxes have hardly been analysed, but since taxes are usually set at a low level, the innovation effects can be expected to be low (Kemp, 2000). The Environmental Tax Reform that aims at shifting taxes from labour onto the environment has been implemented in several European countries (Andersen, 1994; NOVEM, 2002). However, current environmental tax measures are only indirectly related to buildings in terms of energy and CO_2 costs and only a number of EU member states have introduced housing-related energy tax measures (Sunikka, 2003a). The Regulatory Energy Tax (REB), for example, applied to Dutch households in 2001, increased energy bills by a third. Research shows, however, that only half the population is aware of the Regulatory Energy Tax and only 2% take it into account in their electricity use (Van der Waals, 2001).

A subsidy is a transfer of purchasing power from society to the industrialist or individual conditional on it being spent on the investment. As a politically attractive instrument, most European countries have introduced subsidies for energy efficiency in buildings (NOVEM, 2002; Sunikka 2003a). Subsidy programmes can encourage energy efficiency investment both for new and existing buildings, but it is unlikely that such programmes would have a large-scale impact because they require tax revenue expenditures (Hasegawa, 2002). In The Netherlands, several research studies have examined the effectiveness of investment subsidies on investment decisions, showing the free-rider problem, where environmental subsidies can benefit parties that would have applied the option anyway. In 1978, the Dutch government established a large investment subsidy programme for improving energy efficiency in the existing housing stock, the National Insulation Programme (NIP). Research by Kemp (1995) showed that only a weak positive relationship existed between the subsidy for thermal home improvement and the diffusion of thermal insulation technologies. The programme mainly provided receivers with a 'windfall gain', a situation comparable to having the wind behind them, helping them in the direction they were already planning to take. The result was confirmed by Beumer *et al.* (1993). This also seems to be common with other environmental subsidies (Vermeulen, 1992; Tweede Kamer, 1987). It is unclear to what extent subsidies encourage innovation, but given that the subsidies hardly influenced adopter decisions, the innovation effects are likely to be small (Kemp, 2000). Vermeulen (1992) suggests that environmental subsidies can perform a useful supporting function, but only if they are applied as part of a combination of instruments, financed by direct or indirect environmental taxes that are paid by the same group of polluters and not used as compensation for environmental costs.

5.4 Energy certificate schemes in The Netherlands and Denmark

In 2000 The Netherlands introduced the Energy Performance Advice tool (EPA) to stimulate housing owners, both private and professional, to improve the energy performance of their dwellings. It is a voluntary system and costs about €150-200 per dwelling, although this charge is almost entirely subsidized. An EPA consists of a collection of input data from a survey of the location, which as well as building characteristics includes the heating, hot water and electricity consumption of pumps and fans, an assessment of the Energy Index and energy saving measures, advice and a digital EPA-report and monitoring data. The Regulating Energy Tax (*Regulerende Energiebelasting*, REB) on energy use should have a positive influence on the calculation of the pay-back times of the energy-saving measures proposed in the EPA. The development of the EPA tool was commissioned by the Ministry of Housing, Spatial Planning and the Environment and carried out by the administrative agency NOVEM and aims to be the most important tool in realising CO_2 reduction goals for the existing building stock in The Netherlands. Evaluation of the functioning of the EPA tool so far has indicated that the realisation of the Kyoto goals by means of EPA are dependent on quite a number of uncertain factors. Uncertainty exists in the number of EPAs that will be issued and the amount of energy savings that will be realised by them, since the tool is voluntary (Jeeninga *et al*., 2001). A promotion campaign is currently trying to increase the general public's awareness and knowledge of the tool. The subsidy paid to the home-owner for having an EPA performed has been raised to €200. There is also uncertainty about the number of consultants needed for performing the EPAs. The target of 60,000 EPAs a year requires about 100 man-years to carry out the work involved (Jeeninga *et al*., 2001). The energy savings that are realised through the measures taken by means of the EPA are also uncertain. The basic idea of the EPA is that it should result in additional energy saving efforts, compared to the autonomous development in home improvements that would be realised anyhow, such as replacement of a central heating boiler at the end of its lifespan. It is, however, very difficult to say what are the additional energy saving measures, or what energy saving measures would not have been taken without the EPA. A contradiction exists in that the approach aims to perform EPAs at 'natural moments', e.g. when a dwelling is being renovated or a central heating boiler is being replaced (Jeeninga *et al*., 2001). The EPA tool is, in fact, an economic instrument, particularly based on subsidies for energy saving measures. The Energy Performance Advice is voluntary, but can help in obtaining extra subsidies for energy saving measures (although subsidy is also available without the EPA). The question can therefore be posed as to what extent the free-rider effect, as explained in the section on economic instruments, is present in the EPA subsidy scheme (see Section 5.3). The fact that the EPA approach aims to perform EPAs at 'natural moments' suggests that the subsidy is, in many situations, used for investments that would have been taken anyway. Subsidy schemes for energy saving measures in housing in the past have proved rather inefficient, as we have seen from the discussion of economic instruments, because of the free-rider effect (see Section 5.3). We therefore argue that the EPA subsidy scheme probably also suffers from a large amount of free-riders benefiting from the subsidies and as a consequence results in a rather inefficient allocation of government finance.

In Denmark, a mandatory energy certification scheme for all existing buildings (*Energie Maerkningsordningen*) is defined in the Act on the promotion of Energy and Water Conservation in Buildings and has been applied since 1997. The main energy audit scheme consists of the annual energy certification of large buildings or energy management (ELO), energy certification in small buildings that applies only when they are sold, and the CO_2 scheme for industry. Our research has focussed on the energy certification scheme for small buildings, including single-family houses and owner-occupied flats, since the new EC energy certificate resembles that the most. Energy certification in small buildings consists of a standardised energy rating, including information about energy and water consumption and CO_2 emissions in comparison to a similar reference building. The energy plan presents proposals for further energy and water savings, estimation of the investment costs, annual savings and the expected economic lifetime of the saving measures. When the building is sold, energy certification is carried out by an appointed and trained energy consultant. The energy consumption is calculated using a standardised method, standardised conditions and consumer habits. The charged evaluation costs are paid by the seller and amount to €300-500 for a single family home (Vekemans, 2003). The Danish Energy Authority and the energy consultants are responsible for communicating the certification scheme and the Registration Committee for Energy Rating is responsible for administrating the scheme. The evaluation of the Danish energy certification scheme shows that the energy certification scheme increases energy savings to a small extent, but it has not been possible to make an exact calculation of the energy saving effect of the scheme, the realised costs of the CO_2 reduction and shadow prices (COWI consult, 2001). This is due to the fact that the saving measures implemented in practice are not recorded in the certification scheme database, making it impossible to define the exact saving resulting from the scheme. The Act focuses on the recording of energy consumption and energy saving measures and only indirectly whether the measures are actually implemented. The Act on energy savings sets a combined goal for the Energy Management Scheme and Energy Rating scheme. The targets for 2005 are: heat savings of 4-6 PJ, electricity savings of 300-600 GWh, water savings of 5-10 million m^3 and CO_2 savings of 0.6-0.8 Mton. Up to now the recorded heat saving potential for 66,000 housing units is 315 GWh or 1.1 PJ. This corresponds to 745 GWh or 2.6 PJ for all 156,628 housing units in the scheme (COWI consult, 2001). According to the 2001 evaluation, despite the fact that the energy certificate scheme is made mandatory by the Act, only 50-60% of buildings are covered by the scheme and there are great regional differences (COWI consult, 2001). Despite the legal status of the programme, sanctions have not been issued. Furthermore, over 40% of the labelled buildings show improvements in the first year, but a large energy saving potential remains unused (Laustsen, 2001). According to the evaluation, many building owners are not aware of the certification requirements that tend to get buried in the other paperwork involved when a building is sold, whereas sellers and real estate agents may see the certification as just another obligation without clear benefits (Laustsen, 2001). Home-owners show a very poor knowledge of the scheme, which is due more to the lack of promotion of the scheme than to the quality of the information material (COWI consult, 2001). The buyer should get the information on the energy condition before the purchase, but in practice, the competition between potential buyers makes this difficult. It is, therefore, necessary that the certification is mandatory. The Danish Energy Agency plans further information dissemination to buildings not currently participating in the scheme to increase adoption of the certificate and to begin follow-up initiatives to ensure that more improvements are realised.

5.5 Discussion

This chapter started with a commonly-used typology of three types of policy instruments; regulatory, economic and communication instruments. The EC Directive 2002/91/EC proposes mandatory energy certificates for buildings when selling a building but it does not impose energy standards. This implies that the energy certificate will be mainly a communication instrument since the idea is to try to persuade people to voluntarily adopt environmentally benign behaviour. Policy literature states that communication instruments can be useful policy tools for addressing information problems but they are generally considered to be additional policy instruments and not substitutes for economic or regulatory policy tools (Kemp, 2000; Ekelenkamp *et al.*, 2000).

Energy labelling schemes for household appliances, which appear to be effective, directly address information problems in purchasing decisions. Energy efficiency can be one criterion for choosing a certain product and by means of the energy label this aspect can be taken into consideration in the purchasing decision. Manufacturers of household appliances use the energy label as a marketing instrument. The market of household appliances and the building market, however, differ greatly and building markets show big differences from country to country. In The Netherlands, the building market seems to have a structural market failure in terms of supply and demand, where for a long time, the demand for housing has exceeded the supply. At the same time, there is often considerable governmental influence on the housing market, and building production can be very complex and involve a number of different skills, such as an architect, a building firm and a municipality. In case of existing housing, no manufacturer is known at all. In the building market, lack of information is therefore only one of several market failures. Therefore an energy label is not likely to influence purchasing decisions in housing since the buyer does not have a variety of choice, neither is it likely to be used as a marketing instrument since there are no obvious manufacturers.

The energy certificate for buildings includes energy advice as part of the certificate. It is therefore assumed that by providing information, the buyer will be encouraged to actually carry out energy saving measures. It is not clear, however, whether providing information alone will sufficiently encourage people to carry out work that they otherwise would not have done. The pay-back times of energy saving measures are high with the current relatively low energy prices. The energy certificate scheme as proposed in the Directive 2002/91/EC seems an exact copy of the Danish energy certificate scheme. Our discussion of this scheme shows that it is not possible to give an unambiguous answer about the size of savings obtained by the labelled buildings since saving measures implemented in practice are not recorded in the energy certificate database (COWI consult, 2001). The evaluation study did suggest, however, that a large energy saving potential remained unused (Laustsen, 2001). On the basis of these considerations we think it is worthwhile exploring the possibilities of combining energy certificates for building with regulations or economic incentives.

The question remains open as to whether energy certificates can be combined with minimum energy standards. We discussed two approaches in energy regulations: regulations formulated as singular measures and regulations formulated in global standards such as performance standards. The second approach is in general preferred as it offers most design freedom and, if the standards are tightened on a regular basis, it can provide incentives for realising innovations. Up to now, hardly any experience exists with imposing energy standards for existing buildings. Direct regulation of energy use in existing buildings has only been initiated very recently in, for example, Germany and England and Wales by means of standards for singular measures (Gilijamse & Jablonska, 2002). The question of control is a very important issue in this matter since house owners do not currently have to ask building permission to carry out such activities. In England and Wales, energy regulations for existing buildings are controlled by means of self-certification schemes. The issue of control for existing buildings is partly already evoked by Directive 2002/91/EC, which demands that imposing the energy certificate is mandatory and will therefore need a legal basis. In most member states home-owners do not have to cope with building regulations and building control when selling their house, so a more logical legal basis might be in the notary transactions involved when selling a house. A notary having to approve an energy certificate as part of the documents necessary for selling a house seems only a small step away from a notary having to record a certain energy standard derived from the energy certificate.

It is possible to assume, however, that a radical step in improving the energy efficiency of existing housing by means of imposing energy performance standards is currently one step to far. As we can see from the development of energy regulations for new buildings, it took about 30 years before singular energy regulations were transformed into global standards. It is possible that a similar gradual development will have to occur to establish general acceptance of energy performance standards for existing dwellings. This would imply that a first step could be to impose certain 'obvious' standards in regulations by means of singular measures like insulation levels or boiler efficiencies, such as happens right now in England and Wales and Germany. After this stage, the approach could transform towards regulations by means of general goals, such as a mandatory 'B'-level in an energy label. Tightening the criteria of such a 'B'-level on a regular basis would then be necessary to guarantee sufficient incentives for innovations (Kemp, 2000). Control is a very important issue in this matter and could be guaranteed by means of privately organised self-certification schemes or by means of control by notary procedures.

The question of how to make energy savings financially attractive for households remains a pre-condition for real action towards energy saving measures. The Regulatory Energy Tax (REB), introduced in The Netherlands in 2001, has had limited success in reducing household's energy consumption, but it does shorten the payback-time of energy investments. Therefore, combining an energy tax with the energy certificate could support the implementation of investment plans to fulfil the potential energy improvements included in the EC certificate. On the other hand, it can be argued that the EC energy certificate, which we have concluded is a communicative tool, can reinforce the effectiveness of other policy instruments that remain unknown to consumers, such as the Energy Tax in The Netherlands. Policy instrument literature and empirical data for this research show that higher taxes on electricity seem as effective in reducing a household's energy consumption, although due to low rates it is unlikely to have a large scale impact. The question remains, however, as to how the taxation on energy can be increased without hitting low-income households that account for a minor share of total household demand with higher energy prices. These households have less financial resources to invest in energy saving measures. As the prices increase, low-income households save energy whereas high-income households living in large dwellings seem not to react. It has been argued, therefore, that, if it causes greater inequality between rich and poor households, heavy taxation of end-user energy, which can be regarded as a necessity, is neither an advisable nor a politically viable option (Anker-Nilssen, 2003). To make the financial pressure more equal regarding low-incomes, the energy tax should be based on the value of the dwelling, or income of the household, i.e. it should be progressive. In this way the energy certificate can be used as one factor in determining the value of the housing. Energy consumption could also be taken into account in an advisory capacity on the allowed rents, a system that exists for example in The Netherlands.

Kemp (2000) states that a combination of standards with economic instruments is particularly useful as it combines effectiveness with efficiency. He takes as an example the US corporate automobile fuel economy standards which set progressive fuel economy targets for automobile manufacturers in 1979-85 under penalty of a fine of USD 50 per car for each mile per gallon of shortfall. This system of combining an economic incentive for an excellent energy performance with an economic sanction for failing to perform at a standard level could, in principle, be adapted to the energy certificate.

When studying existing energy certificate schemes and possible combinations of policy instruments, we also found that the combination of energy certificate and a subsidy scheme exists in The Netherlands. In this scheme, the costs involved in the procedure of having an energy certificate and a number of energy saving measures are almost entirely subsidized. We found that in general the effectiveness and efficiency of subsidy schemes are often disputed. In a number of evaluation studies of subsidy schemes for energy saving measures in housing that existed in the past, it was concluded that in only a very limited number of cases was the subsidy the reason for carrying out the energy saving measures, such as insulation, high efficiency condensing boilers or high-efficiency double glazing, all products that are not new on the market and should be sold without subsidies. In the case of innovative new products where unit costs are still high but are expected to decline with cumulative production, subsidies can help tackle market failure. The Dutch energy certificate scheme continues to subsidise measures such as insulation, and simultaneously enforces the disadvantages of subsidies by aiming to perform the energy certificate at so-called ‘natural moments’, like replacement of boilers or renovation of a house. Often in these situations people are already planning to take measures and will profit from a ‘windfall gain’ by the subsidy scheme. It is therefore expected that combining energy certificates with a subsidy scheme for energy saving measures can only be efficient and effective for innovative products in order to increase demand and production and bring costs down.

5.6 Conclusions

Renovation of the existing housing stock can reduce energy costs and demand, forestall an increase in demand for new housing and improve the indoor air quality. Current policies and policy instruments for sustainable building, however, are slowly re-orientating from new construction to using the environmental potential of the existing housing stock. Using practical examples of current energy certificate schemes and theoretical notions of policy literature, this chapter has examined how the introduction of the EC energy certificate in combination with regulatory and economic policy instruments can be used to improve the energy efficiency of the existing urban housing stock. The energy certification of household appliances has been successful and has increased the sales of energy efficient products. This chapter has discussed the expected efficiency and effectiveness of energy certificates for buildings.

We argue that the use of the energy certificate as a communication instrument addressing information problems, as it is suggested now in the EC Directive, will not likely to be very effective since information problems are only one of many market failures in the complex building market. The combination of energy certificates with tax schemes seems promising but will have to be covered in general income taxes or in housing related taxes in order to prevent regressive social effects. Combining the energy certificate with subsidies should be rather limited due to the 'free-rider effect' and subsidies should only cover innovative products at the beginning of their 'learning curve'. Effective results can probably be expected from introducing regulations combined with energy certificate standards, but it requires a rather drastic approach and needs time to receive sufficient commitment, like for new buildings where there has already been a gradual development of energy regulations over the last 30 years. Since communication tools are more likely to be effective when combined with regulatory or economic instruments we think introducing an energy performance standard by means of the energy certificate in combination with progressive taxes for punishing worse energy performance levels and subsidies for rewarding better performances can be a promising approach that needs further research.

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6 Public energy performance policy and the effect on diffusion of solar thermal systems in buildings:

a Dutch experience

Beerepoot, M. (2007). Public energy performance policy and the effect on diffusion of solar thermal systems in buildings: a Dutch experience. In: Renewable Energy 32, pp. 1882-1897.

The introduction of energy performance policy in The Netherlands has been accompanied by the announcement that it would result in diffusion of innovative energy techniques. One of the expectations is that the use of solar thermal systems in housing will be encouraged by energy performance policy. This chapter describes the analysis of the effect of energy performance policy on diffusion of solar thermal systems in The Netherlands. It addresses the research question: What is the effect of energy performance policy for new residential buildings in the diffusion of solar thermal systems?

Abstract
Energy performance policy is an important element in the European Energy Performance of Buildings Directive (Directive 2002/91/EC – in short: EPBD, published 4 January 2003), which the European Commission is now urging all European member states to introduce for the building sector by 2006. One of the expected benefits of energy performance policy is that it can help to introduce innovations such as solar thermal systems. However, few studies have analysed this so far. This chapter describes the extent to which the penetration of solar thermal systems in the residential building sector is directly related to energy performance policy in The Netherlands. The concept of energy performance policy is explained and the effects of using energy performance policy for several years in The Netherlands are described, through the results of an empirical study. Statistical analysis appears to show no association between Dutch energy performance policy and the application of solar thermal systems in the domestic sector.

Keywords
Energy performance policy, EPBD, solar thermal systems

6.1 Introduction

The issue of energy policies for buildings is timely; the Kyoto protocol calls for efforts to be carried out largely within the residential and non-residential building sectors. The subject is also currently relevant in the European Union, because of the introduction of the EC Energy Performance of Buildings Directive (EPBD), which was developed to improve the energy performance of buildings and which stresses the development of a common framework for designing energy regulations throughout Europe (European Commission, 2003).
Energy performance regulations in the building sector aim to limit energy consumption from heating, hot water production, lighting, cooling and ventilation by calculating an estimate of the energy consumption under those headings according to a standardised pattern of occupant behaviour. The energy performance standard limits this energy consumption to a certain maximum level. The energy performance calculation allows the user to choose a set of energy features and to trade off between these features (e.g. a higher insulation level against poorer heating installation efficiency, or the other way around), as long as the energy performance standard is still met.

A common goal of energy performance regulations is to stimulate innovation. When energy performance regulations were introduced in The Netherlands in 1996, the Dutch government stated that this type of regulation would stimulate innovation in energy techniques (Ministerie VROM, 1995a). For example, in its *Energy Report* of 1993, the Energy Research Centre of The Netherlands stated that the introduction of the energy performance policy would positively influence the penetration of solar thermal systems (ECN, 1993). This message was repeated each time the energy performance standard was tightened, including with the latest announcement that the energy performance standard has once again been tightened in 2006 (Tweede Kamer, 2004). Innovations in the energy sector, especially those that considerably reduce CO_2 levels (for example, by using renewable energy sources), are becoming an indispensable factor in the implementation of the Kyoto protocol and other long-term CO_2 reduction goals.

Many typologies are being used when classifying degrees of innovation. Since Schumpeter started theorising about innovation processes, a first level of typology has been the distinction between radical and incremental innovations (Schumpeter, 1942). The dichotomous distinction here is often felt to be too restrictive. One suggestion is to add a third category called 'really new' (Garcia & Calantone, 2002).

Incremental innovations do not require a significant departure from existing business practices. In regard to defining innovations related to energy performance policy and energy techniques for the building sector, the reference level is the business practice that existed before the Dutch energy performance policy was introduced in 1996. For that reason, the improved energy efficiency of glazing is considered an incremental innovation, since the installation of double glazing was already part of building practice before the introduction of an energy performance policy, and the main improvement is to the energy efficiency of the glazing itself. Similarly, the improved efficiency of gas-condensing boilers and that of heat recovery in mechanical ventilation systems are considered incremental innovations.

'Really new' innovation is considered to occupy a position between radical and incremental innovation (Garcia & Calantone, 2002). Really new innovation can consist of a technology that already exists but is new to a certain market. Therefore solar thermal systems are considered a really new innovation for the Dutch building sector. The installation of solar thermal systems was not part of Dutch building practice before the introduction of the energy performance policy in 1996, and requires an element to be constructed on the roof of a building, taking into consideration issues such as the element's orientation and tilt. For The Netherlands, a further new departure is that a solar thermal system requires a storage vessel, thus needing more space within the building. In the same way, the installation of heat pumps was not part of building practice before the energy performance policy was introduced. Heat pumps used for hot water production need a storage vessel, again requiring more space within the building; and building processes need to take account of additional devices required to reach the source from which heat is extracted. Techniques such as solar thermal systems and heat pumps are therefore considered really new innovations for the Dutch building sector.

Radical innovations are defined as innovations embodying a new technology that results in a new market infrastructure. Radical innovations cause discontinuity at a world, industry or market level and comprise developments such as the steam engine and the World Wide Web. Within the context of this study, radical innovation is beyond our scope, and this category is not considered in the ensuing discussion.

Although several member states already have energy performance regulations, no literature is available that investigates the effect of these in stimulating innovation in energy techniques for the building sector. Few studies to date have investigated the influence of environmental regulations on innovations in general (Hemmelskamp *et al.*, 2000). The most common response to the regulations seems to be incremental innovations in processes and products and in the diffusion of existing technology. Those studies also show that radical technological responses require rather stringent regulations, such as product bans. The Dutch energy performance policy is a good step forward in the reduction of energy consumption in buildings, but is not very stringent. It began with a small step beyond routine practice in 1996 and since then has gradually tightened standards as cost-effective solutions have become available on the market. The hypothesis for the present study is that the Dutch energy performance policy does not lead to the diffusion of really new innovations but rather to the application of incremental innovation: in other words, to product improvements.

This study specifically considers the application of solar thermal systems in residential buildings. Because this study considers solar thermal systems to be a really new innovation for the Dutch residential building industry, its hypothesis is that no significant increase in the application of solar thermal systems in Dutch residential buildings is likely to happen as a consequence of the energy performance policy that was introduced in 1996 and tightened in 1998 and 2000.

This chapter examines the effect of energy performance policy on the application of energy techniques in residential buildings, with specific attention to the installation of solar thermal systems. It uses the experience with energy performance policy in The Netherlands as an illustration. The primary research question is: what are the effects of energy performance policy on the application of energy techniques in residential buildings, and to what extent has the Dutch energy performance policy influenced the application of solar thermal systems? This research is therefore concerned with the extent to which an expected side effect of introducing the energy performance policy has occurred. It does not address the extent to which the policy has resulted in energy savings and CO_2 reduction, as this issue has already been investigated in other studies (Joosen *et al.*, 2004). The relationship between energy performance regulations and the diffusion of solar thermal systems would ideally be demonstrated by showing a correlation between the tightening of energy performance standards and developments in the energy-saving techniques that are applied. Technological development, however, can be spurred by factors other than regulation, including autonomous technological development, financial stimuli or the promotion of techniques in the media and other forms of communication. Therefore, other possible factors influencing the installation of solar thermal systems in new residential buildings in The Netherlands are also discussed, such as subsidy schemes, development in gas prices and promotion campaigns.

Section 6.2 explains the concept of an energy performance policy and discusses the extent to which European energy performance policies pay attention to renewable energy. This discussion provides a useful background for understanding the specific case of The Netherlands, studied later in this chapter. Section 6.3 describes the research approach for making an empirical analysis in The Netherlands. Section 6.4 describes possible influences – other than energy performance regulations – on the diffusion of solar thermal systems in The Netherlands. Section 6.5 uses the Dutch experience to describe the effects of Dutch energy performance policies on the diffusion of energy techniques for buildings, based on the results of an empirical study covering the period 1996–2003. Section 6.6 presents the results of a statistical analysis of the relationship between Dutch energy performance policy and the penetration of solar thermal systems. Section 6.7 draws conclusions.

6.2 The position of energy performance policy and attention to solar energy

In the European Union, all member states apply energy regulations to buildings, although originally there was a considerable variety of approach. Few studies have explored energy regulations for buildings in European countries (Eichhammer & Schlomann, 1998; Schaefer *et al.*, 2000; Instituto Bioarchitettura, 2001; Beerepoot, 2002; ENPER, 2004; Beerepoot; 2004). One study of energy regulations for residential buildings in eleven European member states distinguished four main approaches (Beerepoot, 2002). The *unit* approach focuses exclusively on the transmission of heat through the individual components of the building shell. The second approach, *heat loss calculation*, calculates a single value for heat transmission, using the building shell instead of separate building components. The third approach involves *calculating heat demand*. This takes into account ventilation losses, heat gain due to solar heat recovery, and heat gain due to internal heat sources within the building, in addition to components of heat transmission throughout all components of the building. The fourth approach involves *calculating energy use* or *performance*. This approach takes both energy demand and energy supply into account by considering installations for heating and hot water production and their efficiencies, resulting in the calculation of an estimate of the actual consumption of energy required to heat a building, ventilate it and provide it with hot water according to a standardised occupant pattern. The energy performance calculation can be based on calculating energy consumption in megajoules (MJ) – as, for instance, in the Dutch energy performance method – or it can be based on a calculation of CO_2 emissions – as is done in the Carbon Index Method in the United Kingdom. The European Commission seeks to introduce the energy performance approach in all European member states by 2006.

The inventory of energy regulations used in eleven European member states showed that, although all member states use some sort of energy regulation for buildings, only a few apply the energy performance approach (Beerepoot, 2002). The European member states having several years of experience with that approach are The Netherlands, Germany and France, along with the United Kingdom. Of these, The Netherlands has used the energy performance approach the longest, as it has been the only way in which to comply with that country's energy regulations for buildings since 1996.

Research from the European Altener Vth framework project Build-On-RES showed that few countries have experience with energy performance regulations that reward the use of solar techniques (Beerepoot, 2004). The Netherlands is the only member state whose experience with energy performance calculation goes back to 1996, as it was the only method available for complying with energy regulations in that country. The Dutch energy performance method also appears to be the only method to reward all available solar techniques, both thermal and electrical, in the energy performance output calculations for buildings. The Dutch situation is therefore a suitable case study for exploring the influence of energy performance regulations on the application of solar techniques.

In The Netherlands, two separate energy performance calculation methods have been developed: one for residential buildings and one for non-residential buildings. The methods are described in the Dutch standards NEN 5128 (residential) and NEN 2916 (non-residential). The output of an energy performance calculation is an energy performance coefficient (EPC), a non-dimensional figure that expresses the energy efficiency of a building. The estimated level of energy use is set against a permitted level that is based on the size and shape of the building. This geometrical correction makes allowances for large buildings, so that all buildings, regardless of size, have the same energy performance coefficient when similar energy features are applied. The estimated characteristic primary energy use in MJ of a residential building can be calculated from the EPC as follows:

$$Q\ [MJ] = EPC * (330 * \text{usable surface of dwelling } [m^2]) * (65 * \text{loss surface } [m^2]) * 1.12$$

The geometrical correction means that estimated energy consumption, as represented by the EPC, can vary considerably for different housing types. The expected energy consumption corresponding to an EPC of 1.0 (which has been the obligatory standard for residential buildings since January 2000) represents about 43 GJ of primary energy use for an average terraced dwelling (123 m^2 floor surface). At the same time, an EPC of 1.0 is expected to result in an energy consumption of 89 GJ for a detached dwelling (floor surface 220 m^2) and 26 GJ for an apartment (floor surface 75 m^2). These figures only reflect consumption for space heating and domestic hot water.

The Dutch building regulation, the Building Decree, specifies an EPC figure that may not be exceeded for either residential or non-residential buildings. At the introduction of the EPC in 1996, this standard was set at 1.4 for residential buildings, which represented almost the usual building practice at that time and therefore was not considered difficult to realise. In 1998, the standard was tightened to 1.2 for residential buildings, and tightened further to 1.0 in 2000. Recently, in January 2006, it was tightened to 0.8. Compliance with Dutch energy regulations must be proven by submitting an energy performance calculation to the municipal building control administrators. Approval of the calculation is required in order to receive a building permit. This means that every new building in The Netherlands since the year 1996 has been the subject of an energy performance calculation. This calculation shows the exact levels of insulation that were applied for each element of the building, the types of installation (and their efficiencies) and the ventilation systems that were introduced. These energy performance calculations are registered and stored in municipal archives.

6.3 Research approach for empirical analysis in The Netherlands

To analyse the effects of energy performance regulations in the diffusion of solar thermal systems, energy performance calculations that were submitted to municipal building control departments between 1996 and 2003 were collected. The research was restricted to residential buildings. In total, 352 energy performance calculations for residential buildings were collected from various sources. The calculations were randomly selected from municipal archives, and represent each year equally. The approximately 45 energy performance calculations from each year are expected to represent at least 350 residential units, as many residential building projects in The Netherlands consist of housing that is developed as a series of identical structures (detached housing), for which only one or two energy performance calculations must be submitted. Apartment buildings are also required to be subject to only one performance calculation, even though they represent many housing units. On the basis of the data available in the municipal archives, it was not always possible to see how many dwellings were represented by one energy performance calculation; therefore it is only possible to give a rough estimate of the number of dwellings represented by the database.

The database of 352 energy performance calculations is used to describe the general trend in development of energy features from 1996 through 2003 for Dutch residential buildings. Next to this, the database allows to perform statistical analyses of associations between the energy performance policy and energy techniques applied. Since factors from outside the policy system can influence the diffusion of solar thermal systems, first the subsidies and promotional campaigns available for solar thermal systems in The Netherlands from 1996 to 2003 are analysed. The possible influence of the change in energy prices in The Netherlands is also scrutinised, as this could have a positive or a negative influence on the development of energy techniques in general.

6.4 Influences on diffusion of solar thermal systems in The Netherlands

Subsidy schemes for solar thermal systems have existed for a long time in The Netherlands. In fact, the first subsidy schemes were already in place in 1988. Until 1996, the BSET programme (Decision on Subsidies for Energy Saving Techniques) subsidised solar thermal systems as well as other techniques. Before 1995, subsidies totalling 3.2 million euros annually were allocated and depended on solar-collector surface; after 1995, subsidies were based on the system's yield. Though the original plan was to stop using the governmental

Table 6.1 Overview of subsidies for solar thermal systems in the Netherlands

Period	Subsidy (%)	Subsidy (€)
1992	40	1,000
1997	11	280
2000 - 2003	30	700
2003 - present	No subsidies	

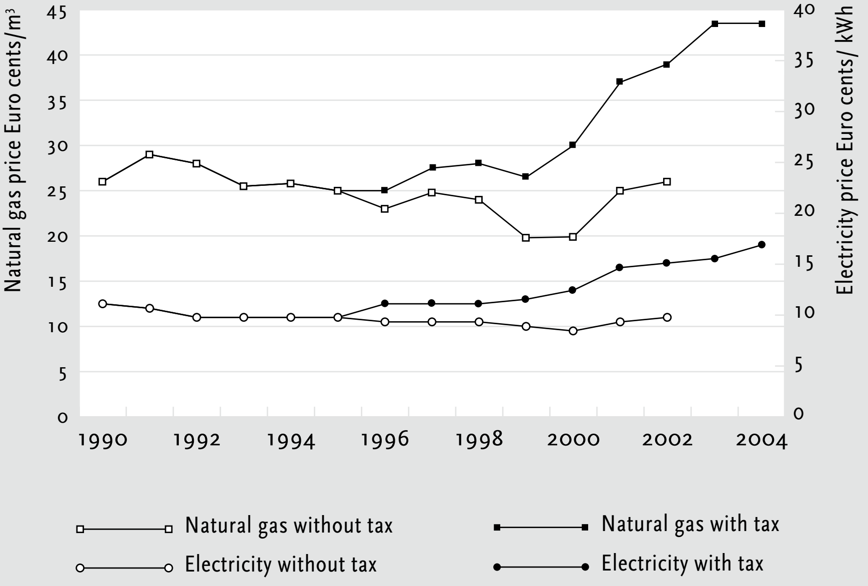
BSET programme for solar thermal systems in 1996, it was decided in 1997 to prolong the scheme until 2000 with an annual budget of 3.6 million euros, to be used for subsidising solar thermal systems. From 1994 on, energy distribution companies have received extra financing from a surcharge on energy costs that is used for energy-saving programmes. This budget – about 115 million euros a year – has been used primarily for promotional campaigns and subsidies (e.g., for individual households). This budget includes subsidies for solar thermal systems that could be obtained from regional energy distribution companies.

The amount of subsidy for a solar thermal system changed from 40% of the investment in 1992 to 10% in 1997 (Beer *et al.*, 2000). Beginning in 2000, the structure for financing solar thermal systems changed to a scheme that focused in particular on individual households and that subsidised a broad range of items, varying from household appliances with energy label A, to solar thermal systems. The peculiar situation arose that, although the level of subsidies increased considerably, it was not possible for professional project developers to make use of the subsidy. Only individual households were allowed to apply for this financial contribution. Subsidies for solar thermal systems rose to about 30% and ranged from 455 euros for a system with a yield of 2–3 GJ to 700 euros for a system with a yield of more than 3 GJ (comparable to 170–250 euros per m^2). An overview of subsidy percentages is presented in Table 6.1.

As far as new residential property development was concerned, the influence of the higher subsidy was probably reduced because only individual households could apply for it. The scheme operated from 2000 to 2003. The year 2000 saw the ending of the programme that was led by the energy distribution companies based on a budget coming from a surcharge on energy costs. Since 2003, no subsidies for solar thermal systems have been available in The Netherlands.

Promotional campaigns focusing on solar thermal systems in The Netherlands have developed continuously in a manner similar to that for subsidies. Promotional campaigns already existed in the early 1990s, partly as a result of an agreement made in 1994 (see above). In 1995, the central government launched an Action Plan for Sustainable Building (Ministerie VROM, 1995b). Between 1995 and 2000, considerable attention was given to the subject of sustainable building, which consisted of a broad range of aspects varying from material use to energy savings and biodiversity. The attention given to sustainable building also led to its promotion by a large number of municipalities, some of which organised specific campaigns to promote solar boilers and issued municipal subsidies for them. However, local or regional promotion campaigns mainly focused on existing residential building and so are not covered by the current research. A second Action Plan for Sustainable Building

Figure 6.1 Development of prices for natural gas and electricity in the Netherlands from 1990 to 2004



Source: Joosen *et al.*, 2004

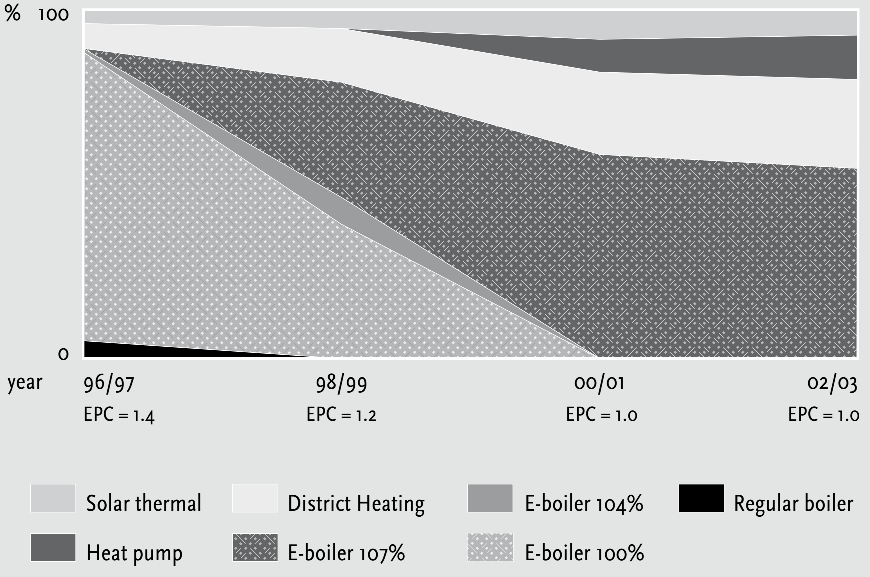
was launched in 1997 (Ministerie VROM, 1997). In 2002, the Ministry of Housing decided that it was no longer necessary to launch specific action plans, as sustainable building should have become normal practice by that time.

Based on the above analysis of subsidies and promotion campaigns for solar thermal systems since the early 1990s, it can be seen that two subsidy regimes existed in the period we are analysing. From 1996 to 2000, an 11% subsidy was available for solar thermal systems, while from 2000 to 2003 a subsidy of 30% existed. The fact that this 30% subsidy could only be applied for by individual households and not by professional developers is expected to reduce the effect of the higher subsidy.

Promotions remained stable in the period 1996–2003, except when promotional campaigns and subsidy schemes both stopped in 2003. Because this analysis investigates the period from 1996 to 2003, it can be concluded that irregularities in the diffusion of solar thermal systems owing to a radical change in subsidy schemes or promotion campaigns are unlikely to be expected.

Change in energy prices can also have a positive or a negative influence on the development of energy-saving techniques in general. Higher energy prices are expected to advance the development and diffusion of energy-saving techniques, while lower prices could retard them. In The Netherlands, a tax on electricity and natural gas (other fuels are hardly used in The Netherlands) was introduced in 1996 as a means to encourage energy savings and reduce CO_2 emissions. However, market prices for electricity and natural gas decreased from 1996 to 2001, thus resulting in only a minor change in net en-

Figure 6.2 Water-heating systems applied in new residential buildings in the Netherlands from 1996 to 2003



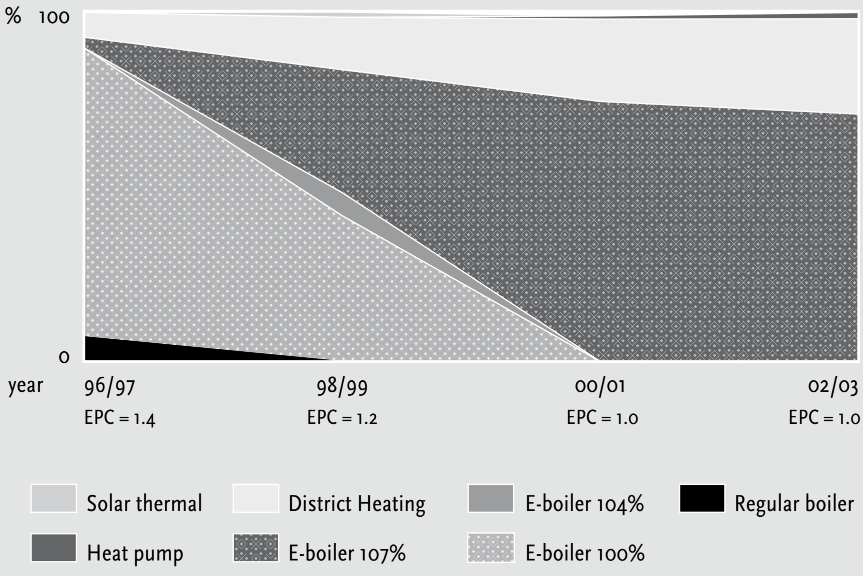
ergy prices. From 2001, both the market prices for natural gas and electricity and the energy tax were raised, resulting in substantial higher prices. Figure 6.1 represents the development of prices for natural gas in The Netherlands from 1990 to 2004.

Research into the effect of the energy tax shows that absolute energy costs increased only from 2001, since the effect of the tax was offset by the decrease in market prices (Joosen *et al.*, 2004). From 2001, a considerable increase in energy prices occurred, but energy costs as a percentage of total household consumption decreased. The price elasticity of increasing energy prices (the change in behaviour due to a price increase) seems to be relatively low, and the effects of increased energy prices are considered to be relatively small (Joosen *et al.*, 2004). We therefore conclude that for the period that is considered in this study, 1996-2003, the influence of changing energy prices is unlikely to have caused a large change in the diffusion of energy-saving techniques.

6.5 Energy techniques in residential building in The Netherlands, 1996–2003

From the database of 352 energy performance calculations from 1996 through 2003, we can identify many different types of energy feature, such as insulation and various types of heating and hot water and ventilation systems, that have been applied in new residential buildings. Figure 6.2 lists the water-heating systems that were applied in The Netherlands from 1996 to 2003 in new residential buildings.

Figure 6.3 Space heating systems applied in new residential buildings in the Netherlands from 1996 to 2003

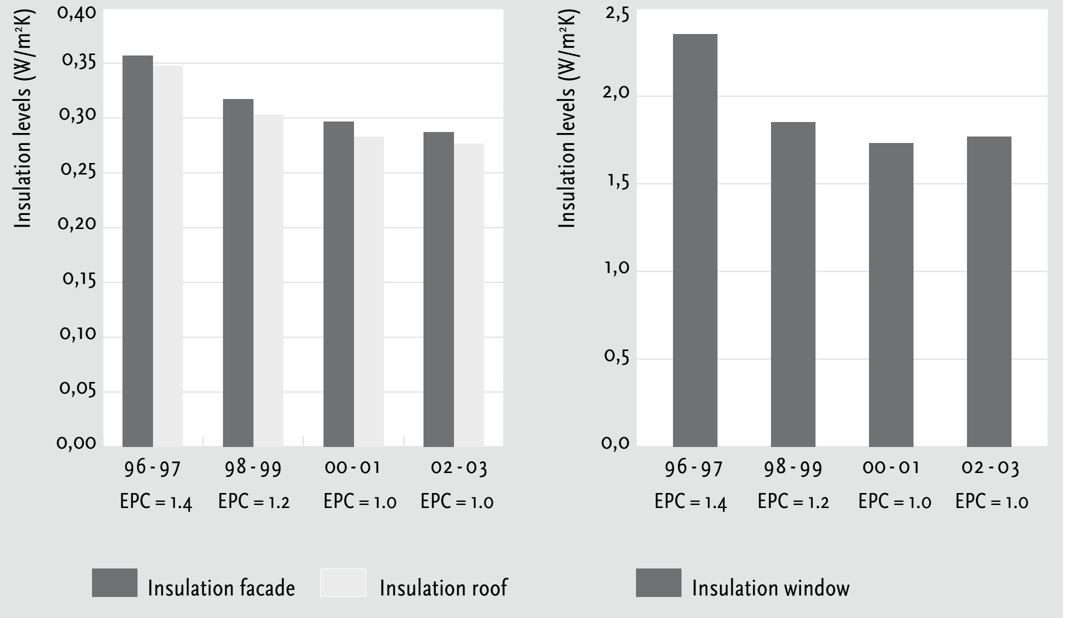


As shown in Figure 6.2, a remarkable shift occurred between 1996 and 2003 in the types of water-heating system that were applied. While it was still possible to use regular gas-condensing boilers (efficiency 80% on higher heating value – HHV[1] in 1996 and 1997, that type of boiler disappeared after the first tightening of standards in 1998, and efficient (E-boiler100: efficiency 90% on HHV, 100% on LHV[2] and highly efficient (E-boiler107: efficiency 95% on HHV, 107% on LHV) gas-condensing boilers became more common. Though it has not been possible to find data about the penetration of efficient gas-condensing boilers in new residential buildings before 1995 (because penetration data in existing studies always appear to be aggregated for both new and existing buildings), it was found that the efficient gas-condensing boiler has for a long time suffered from its problematic market introduction (Brezet, 1994). While the efficient gas-condensing boiler had already been developed by 1981, only after 1995 did it become the reference system for new buildings (Jeeninga *et al.*, 2002). After the energy performance standard was tightened in 2000, the high-efficiency gas-condensing boiler (E-boiler107) became the most common installation for domestic hot water. The use of district heating for hot water also shows an increase. From 1998, the heat pump was also used to some extent to produce hot water. Figure 6.2 shows that there was hardly any change in the use of solar thermal systems for domestic hot water during the years under study. Changes in the application of

1 The Higher Heating Value (HHV) – or gross caloric value – shows the efficiency of combustion, including the condensation energy of water vapour.

2 European standards for gas-condensing boilers often make use of the Lower Heating Value (LHV), which excludes the condensation energy of the water and thus leads to efficiencies above 100% for condensing boilers.

Figure 6.4 Insulation levels in new residential buildings in the Netherlands from 1996 to 2003: facade and roof (left) and windows (right)



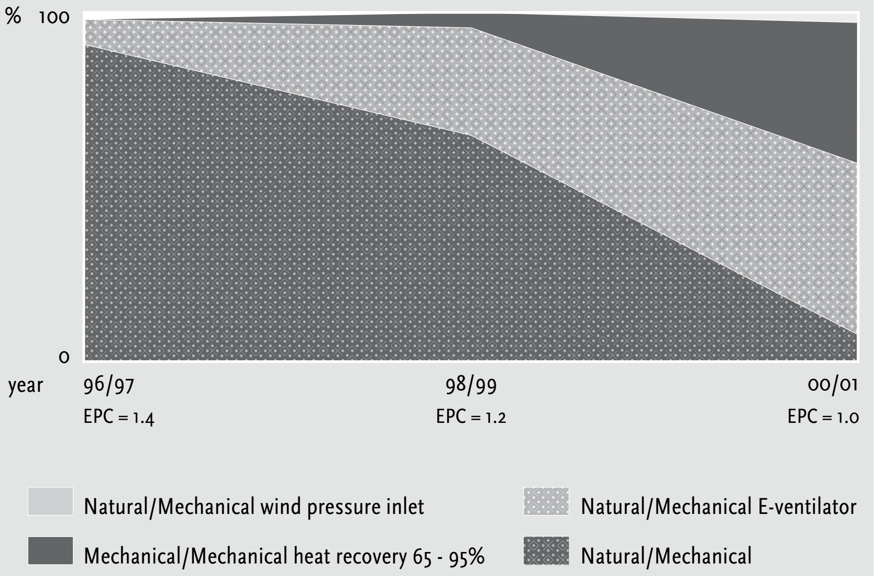
efficient gas-condensing boilers towards highly efficient gas-condensing boilers, and techniques such as district heating and heat pumps, are much more prominent, while the growth in solar thermal systems applied is not striking.

Figure 6.3 shows that the development of installations for space heating is rather similar, except that heat pumps and solar thermal systems were hardly used for space heating between 1996 and 2003.

Figure 6.4 illustrates insulation levels in new residential buildings from 1996 to 2003. Insulation levels of windows have gradually improved, through the use of higher-efficiency double glazing. Furthermore, insulation levels of façades and roofs improved to a certain extent. For example, the average insulation level of façades was 0.36 W/m^2K in 1996–97; it had decreased to 0.32 W/m^2K in 1998–99, and reached an average of 0.29 W/m^2K in 2002–03.

Figure 6.5 shows the changes in ventilation systems installed in new residential buildings in The Netherlands between 1996 and 2001 (data are not available for 2002–2003). At first, the most common ventilation system consisted of a natural inlet and a mechanical outlet, but that set-up was gradually replaced by systems that made use of energy-saving ventilators (direct current) or reduced powers, and systems that combined heat recovery with the use of mechanical inlets and mechanical outlets. Figure 6.5 shows that the amount of heat recovery by mechanical ventilation systems developed gradually from 65% for a regular system in 1996 to 95% after 2000. Figure 6.5 also shows that, while almost all ventilation systems applied in 1996-1997 used a natural inlet and a mechanical outlet, approximately 40% of all new residential buildings in 2000-2001 were equipped with ventilation systems having mechanical inlets and mechanical outlets.

Figure 6.5 Ventilation systems applied in new residential buildings in the Netherlands, from 1996 to 2001



6.6 Influence of energy performance policy on applied energy techniques

From Figures 6.2-6.5, one can see the general development in applied techniques in new residential buildings in The Netherlands during 1996-2003. All figures appear to show a strong change in techniques applied during 1996-2000, while changes after 2000 seem to happen at a much slower pace. Interestingly, the energy performance policy – after being introduced in 1996 – was tightened in the first four years, once in 1998 and once in 2000, but the energy performance standard remained constant during 2000-2003. The descriptive data give the impression that the techniques applied changed along with the energy performance policy. By means of statistical analysis, it is possible to see whether statistically significant associations can indeed be found.

Because all the data from the 352 energy performance calculations have been entered in a SPSS database, we can seek statistical associations between such variables as the energy performance policy and the techniques applied. Therefore a chi-square analysis was performed between, on the one hand, the variable 'EPC regime', representing the three periods of time with constant energy performance standard, and, on the other hand, the variables 'Solar Thermal System', 'E-boiler107', 'District Heating' and 'Heat Pump', each representing whether or not such a technique was applied. The result is shown in Table 6.2.

First, the chi-square test for solar thermal systems and the EPC regime

Table 6.2 Chi-square tests for EPC regime and selected parameters

	Value	df	Asymptotic significance (2-sided)
Solar thermal system	1,823 [1]	2	0,402
E-boiler107	88,447 [2]	2	0,000
District heating	12,980 [3]	2	0,002
Heat pump	[4]		
E-boiler100	135,662 [5]	2	0,000
E-boiler104	[6]		
Regular boiler	[7]		

1. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 5.70.
2. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 31.63.
3. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 15.56.
4. 2 cells (33.3%) have expected count less than 5.
5. 0 cells (0.0%) have expected count less than 5. The minimum expected count is 34.74.
6. 3 cells (50%) have expected count less than 5.
7. 3 cells (50%) have expected count less than 5.

showed a non-significant result, although statistical conditions were met[3]; this means that no statistical association was found between the EPC regime and the number of solar thermal systems applied. A significant result was derived from the chi-square test for E-boiler107 and EPC regime, meaning that there is a statistical association between the EPC regime and the application of the E-boiler107. There was also a significant statistical association between the EPC regime and the use of district heating, as well as between the EPC regime and the use of the E-boiler100. In the cases of heat pumps, the E-boiler104 and the regular boiler, it was unfortunately not possible to use the chi-square test, as the necessary statistical conditions could not be met.

We can conclude that a statistically significant relationship exists between the EPC regime and the application of the E-boiler107, district heating and the E-boiler100. The strength of the relationship can be determined by means of a correlation analysis. A perfect correlation between two variables is represented by a correlation coefficient of 1, a correlation of 0 means that no relationship is present. Kendall's tau correlation coefficient has been chosen, because the data are non-parametric and a large number of tied ranks can be found. The correlation coefficient squared (R^2) is a measure of the amount of variability in one variable that is explained by the other. The results of the correlation analysis are presented in Table 6.3.

3 According to Siegel and Castellan when performing a chi-square test the expected frequencies should be greater than 5. Although it is acceptable in larger contingency tables to have up to 20% of expected frequencies below 5, the result is a loss of statistical power (Siegel & Castellan, 1988). In this case, no cell has an expected count less than 5.

Table 6.3 Association (Kendall's Tau) between EPC regime and selected parameters

	Kendall's Tau correlation coefficient	Correlation coefficient squared (R^2)	Significance (2-tailed)
Solar thermal system	0.068	0.005	0.179
E-boiler107	0.470 *	0.221	0.000
District heating	0.182 *	0.033	0.000
Heat pump [1]	0.215 *	0.046	0.000
E-boiler100	-0.578 *	0.334	0.000
E-boiler104 [1]	-0.066	0.004	0.193
Regular boiler [1]	-0.152 *	0.023	0.003

1. Note that the statistical conditions of the Chi-square test for these variables could not be met (Table 6.2).
* Correlation is significant at the 0,001 level (2-tailed).

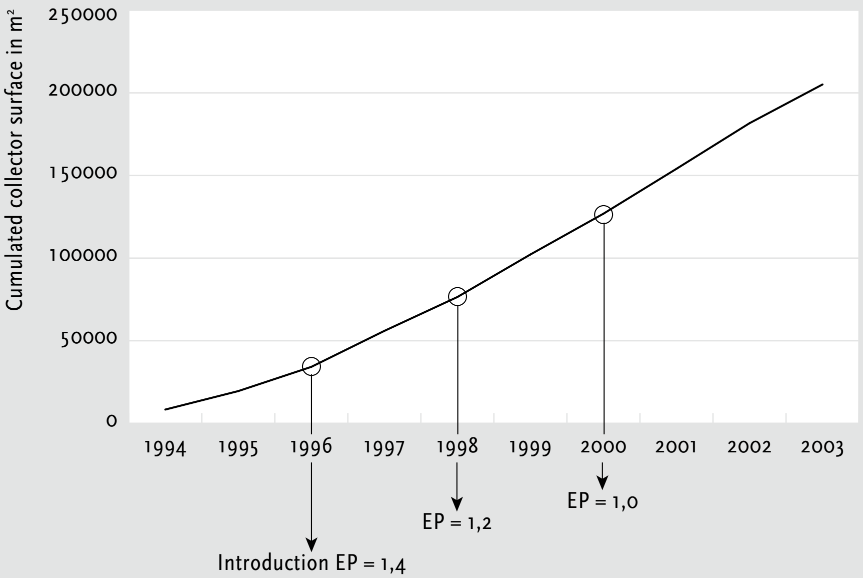
In the case of the E-boiler107, Table 6.3 shows a rather high correlation of 0.47 between the E-boiler107 and the EPC regime, indicating that the EPC regime accounts for 22% of the variability in applying the E-boiler107. This leaves 78% of the variability still to be accounted for by other variables. Similarly, the EPC regime accounts for 33% of the variability in applying the E-boiler100. Regarding district heating, the heat pump and the regular boiler, the EPC regime accounts for a negligible share (smaller than 5%) of the variability. In the cases of solar thermal systems and the E-boiler104, no significant results were found.

From the above analysis it can be concluded that, as far as domestic hot water production in new residential buildings in The Netherlands is concerned, the energy performance policy introduced in 1996 has significantly influenced the application of E-boilers, such as the E-boiler100 and the E-boiler107. For other techniques such as heat pumps and district heating, the energy performance policy seemed to have had only a very small influence.

No statistically significant relationship was observed between the energy performance policy and the application of solar thermal systems. This appears to be confirmed by Figure 6.6, showing the development of solar thermal systems installed in 1994-2003. No significant increase in the rate of increase in collector surface area was observed after the energy performance policy was introduced in 1996, and no change was evident after the energy performance standard was tightened in 1998 and 2000. Although Figure 6.6 includes all solar collector surfaces applied to both new and existing (residential and non-residential) buildings, it confirms the hypothesis that the energy performance policy had no direct influence on the diffusion of solar thermal systems.

An analysis in 2003 of the Dutch market development of solar thermal systems compared with developments in Germany showed that market growth in both countries was similar before 2000, while from then on the market in The Netherlands stabilised although German growth peaked further by 45%

Figure 6.6 Increases in solar thermal collector surface in the Netherlands 1994-2003, applied on both new and existing, residential and non-residential buildings



Based on data website Holland Solar: www.hollandsolar.nl

(Zegers, 2003). The German market, however, fell back in 2002. Conclusions from this study are that the penetration of solar thermal systems in The Netherlands depended on the facts that Dutch subsidy schemes were not stable over a long period and that government support for campaigns was abolished in 2000. Furthermore, the promotional role of the utilities changed in the liberalised energy market, and, because of new subsidy schemes introduced in 2001, photovoltaic (PV) became more profitable than solar thermal systems.

The analysis of Zegers (2003) contains an interesting remark about the influence of energy performance policy. It says that the incentive from energy performance standards in The Netherlands appeared to be too low to stimulate the use of solar thermal systems, and that energy performance standards need to be more severe in order to stimulate such use. This is confirmed by the statistical analysis of the relationship between the EPC regime and solar thermal systems.

6.7 Discussion

The energy performance approach will be an important development in energy regulation in years to come, as the European Directive on Energy Performance of Buildings (Directive 2002/91/EC, in short: EPBD) is urging all European member states to implement such regulations by 2006. The energy performance approach is often said to encourage energy-saving innovations (e.g., solar techniques) for buildings. This chapter analysed the influence of energy performance policy on the diffusion of solar thermal systems for new residential buildings by means of statistical analysis of 352 energy performance calculations submitted from 1996 to 2003 to municipal building control in The Netherlands.

The analysis shows that a remarkable shift in the types of water-heating system applied in new residential buildings occurred between 1996 and 2003. While it was still possible to use regular gas-condensing boilers in 1996, that type of heating system disappeared completely in new residential buildings following the tightening of the energy performance standard in 1998. High-efficiency gas-condensing boilers have now become the standard; heat pumps and district heating have also become more common. The application of solar thermal systems apparently increased slightly during those years. Statistical analysis of the correlation between the EPC regime and the installation of solar thermal systems does not show a statistically significant relationship. Statistical analysis of the correlation between the EPC regime and the installation of heat pumps and district heating shows a significant correlation but here the EPC regime accounts for a negligible share (smaller than 5%) of the variability. The relationship between the EPC regime and the high-efficiency gas-condensing boilers (E-boiler100 and E-boiler107) did show a significant correlation of substantial size, indicating that the EPC regime accounts for 22% and 33% respectively of the variability in applying the E-boiler107 and the E-boiler100.

It seems that, rather than encouraging the diffusion of really new innovations, such as solar thermal systems or heat pumps, the Dutch energy performance policy primarily leads to incremental innovations – in other words, to product improvements – such as increases in the efficiency of hot-water and heating installations and reductions in the energy used by ventilators. This confirms our hypothesis that the energy performance policy thus far has not led to a diffusion of really new innovation, but to incremental innovation. Because the energy policy began with a small step beyond routine practice in 1996 and since then has gradually tightened standards as cost-effective solutions have become available on the market, increases in existing systems efficiencies have appeared to be enough to meet new standards. An analysis elsewhere of the market development of solar thermal systems in The Netherlands confirmed that probably there is a relationship between the penetration of solar thermal systems and subsidy schemes, promotion campaigns and energy policy. But as long as subsidy schemes and promotion campaigns are not stable and energy performance policy is not severe, the number of solar thermal systems will not increase substantially. Our study also confirms earlier research on the innovation effects of environmental policies, which concluded that the most common response to *moderate* environmental regulations appears to be incremental innovations in processes and products and in the diffusion of existing technology. Really new technological responses require stringent regulations, such as product bans. This means that really new technological responses to an energy performance policy are not likely as long as the energy performance standards are not (regularly) tightened towards more severe levels and do not encourage a performance that exceeds the standard. In order to improve the effect of the energy performance policy, it will need to impose more severe standards and become a more flexible instrument rewarding performance that is better than the standard, in order to stimulate a continual search for improvements in energy techniques.

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7 Government regulation as an impetus for innovation:

evidence from energy performance regulation in the Dutch residential building sector

Beerepoot, M. & N. Beerepoot (2007). Government regulation as an impetus for innovation: evidence from energy performance regulation in the Dutch residential building sector. Energy Policy 35, pp. 4812-4825.

The performance approach of energy policy for buildings is expected to provide more freedom in choosing solutions thus creating competition between technologies and encouraging innovation. The project-based identity of the building sector and the complexity of the construction process can however negatively influence the theoretical potential of performance policy. This chapter describes the innovation effects of energy performance policy in The Netherlands and searches for explanations in the analysis of the innovation system of the construction sector. The study addresses the research question: What are the innovation effects in heating technology of energy performance regulations for new residential buildings in The Netherlands?

Abstract

The recent implementation of energy performance policy as a way to tackle energy consumption in the building sector in Europe draws attention to the effect it has on the development and diffusion of energy-saving innovations. According to innovation systems literature, government regulation through norms and standards is one of the factors stimulating innovation. This chapter concentrates on the role of stricter government regulation as an incentive to innovation in the Dutch residential building sector. Innovation in this sector is predominantly a process of applying incremental modifications to comply with new and stricter government regulations and standards. Energy performance policy in its current shape will therefore not contribute to the diffusion of really new innovation in energy techniques for residential buildings in The Netherlands. If diffusion of really new innovation is an explicit aim of energy performance policy then the European wide introduction of this scheme needs reconsideration.

Keywords

Sectoral innovation systems, energy performance policy, residential building sector, The Netherlands

7.1 Introduction

The passing by the European Parliament of the Energy Performance of Buildings Directive (EPBD) in 2003 obliged all European member states to implement energy regulations based on the concept of energy performance (European Commission, 2003). The aim of energy performance regulations in the building sector is to reduce energy consumption in buildings caused by heating, hot water production, lighting, cooling and ventilation. The energy performance standard limits the energy consumption of a building to a certain maximum level. The energy performance calculation allows the user to choose a set of energy features and to trade off between these features (e.g. higher insulation level for poorer heating system efficiency, or vice versa), as long as the energy performance standard is still met. Energy performance regulations have already proven successful in achieving energy conservation in The Netherlands (Joosen *et al.*, 2004). The energy performance-based approach is also expected to encourage innovation. At times that standards of the Dutch energy performance policy were either introduced or tightened, an explicit expectation of the take-off of innovative energy techniques such as solar boilers was proclaimed (Ministerie van VROM, 1995; Staatsblad, 1995; Tweede Kamer, 2004). This study aims to scrutinize the effect of energy performance policy on innovation in energy conservation technology by using data from a database of 350 energy performance calculations submitted to several Dutch municipalities from 1996 to 2003 in connection with applications for a building permit. The extent to which energy performance regulations contribute to innovation has up to now been discussed on a small scale (Gann, 1998; Vermeulen & Hovens, 2006), but these papers do not use empirical data on the energy appliances actually used in residential buildings, neither do they position the issue in the larger context of the debate on the influence of government regulations on the development and diffusion of innovations. Knowledge about the effect of energy performance policy can help to shape energy policy, both to improve its effectiveness and get realistic expectations of its innovative power.

The question this chapter addresses is what innovation effect can be expected from introducing and regularly resetting energy performance standards for the residential building sector in The Netherlands. We use the innovation systems approach to explain our findings from empirical research on the effects of Dutch energy performance policy in the development and diffusion of energy conservation technologies in the project based sector of the Dutch residential building industry. Energy performance regulations are based on setting a standard for the energy performance of a building. Some authors argue that regular resetting of the standard will encourage innovation in order to comply with the stricter requirements (see Weber & Dicke, 2001). Various scholars have looked at the contribution environmental policy instruments can make to the diffusion of innovation from an innovation systems perspective (see Hemmelskamp *et al.*, 2000; Vollebergh *et al.*, 2004; Kemp 1995; 2000). The innovation systems literature emphasizes that in most cases innovations are not developed by individual companies but through interaction and exchange with various stakeholders operating in the same field. The characteristics of the sector then decide to a large extent what scope there is for innovation and how effective policy interventions (e.g. setting norms and standards) will be there. The literature emphasizes that norms and standards can create a platform upon which new products and technologies can be developed (see Edquist *et al.*, 2004). Various authors, however, conclude that merely setting a standard will not lead to innovation, since it does not encourage performance any better than the standard (see Schot, 1989; Vermeulen, 1992; Driessen & Glasbergen, 2000). Others draw attention to a combination of factors such as stringency, flexibility, cost sensitivity and time allowed to achieve mandated emission reductions being highly influential to environmental technology innovation (Porter, 1990; Taylor *et al.*, 2003).

In terms of innovation in energy techniques a recent worldwide notion has arisen that we will need a drastic reduction of carbon-dioxide emissions in order to restrict climate change (IPCC, 2007). According to Shackley and Green a transition to a low-carbon set of inter-related technologies is needed in order to reach a large-scale reduction in carbon dioxide emissions (Shackley & Green, 2007). A *laissez-faire* approach will result in incremental technical improvements in the context of existing technologies. However, incremental innovation does not reduce overall energy use due to an increase in affluence and will therefore be unlikely to achieve large-scale decarbonisation (ibid.).

The Netherlands provides a good case for studying the innovation effects of energy performance policy. The Energy Performance approach was introduced there in 1996, thus enabling us to assess innovation effects in the residential building sector over a fairly long period. We start in Section 7.2 with a brief clarification of the innovation systems concept and explain the concept of sectoral innovation systems, then going on to discuss the various types of innovation and the innovation effect attributed to government regulation. Section 7.3 uses these theoretical notions to analyse innovation in the construction sector and its systematic features in the Dutch residential building sector. This provides us the platform and the constraints under which the policy intervention is operating as the residential building sector is the level targeted for the introduction of energy-saving techniques. Section 7.4 presents the results of an empirical study, for which about 350 Dutch energy performance permits for new residential buildings, dating from 1996 to 2003, were collected. These provide us with data on the energy conservation technologies used, since the introduction of energy performance policy in 1996 and after the standard was tightened up in 1998 and 2000. Section 7.5 sets out the conclusions.

7.2 Innovation systems

Terms such as 'innovation' and 'national', 'regional' or 'sectoral' 'innovation systems' are used in multiple ways in the literature, and the difference between them is often left vague (for an overview see e.g. Cooke *et al.*, 2004; Malerba, 2004; Lundvall, 2005; Sharif, 2006). Since the original interest in innovation and its systematic features, various strands of literature have evolved around this concept. In academic and policy spheres the innovation systems concept can take on several forms based on distinct classification criteria, spatial, technological, and industrial or sectoral (Sharif, 2006). This chapter starts with a brief clarification. The concept of innovation refers to the transformation of an idea into a marketable product or service, a new or improved manufacturing or distribution process, or a new method or social service (Heidenreich, 2004). Moving away from the original Schumpeterian equation of innovation with invention, the concept is now extended to cover continuous improvement in product design and quality, changes in organisation and management routines, creativity in marketing, and modifications to production processes that bring cost down, increase efficiency and ensure environmental sustainability (see Mytelka, 2000).

The process of innovation is incremental, cumulative, and assimilative. In other words, new ideas that actually get to market are usually incremental improvements on existing technology. The increment can be large, but it builds upon what has gone before, hence the process is cumulative (Fri, 2003). Innovation is also an interactive process in which enterprises, in interaction with one another and supported by institutions and organisations – e.g. industry associations, R&D, innovation and productivity centres, standard-setting bodies, universities and vocational training centres, information-gathering and analysis services, and banking and other funding mechanisms – play a key role in bringing new products, new processes and new forms of organisation into economic use (Mytelka, 2000). The emphasis on embedding innovation in networks of actors has led to the conceptualisation of innovation systems in order to capture the systematic characteristics of the innovation process. An innovation system can be seen as a network of organisations, people and institutions within which the creation, diffusion and commercial exploitation of new technologies and other types of knowledge takes place (Malmberg & Power, 2005). The national systems of innovation (NSI) literature made enormous strides in defining innovation and correcting perceived wisdom about innovation processes by showing them to be not linear but interactive and introducing the important concept of 'institutional learning' into this more systematic analysis of innovation (Cooke, 2004). The concept was intended to help develop an alternative analytical framework to standard economics and to criticize the way it neglects dynamic processes related to innovation and learning when analysing economic growth and economic development

(Lundvall, 2005). Over the last decade various authors have focused on other levels of innovation (e.g. sectoral, regional), thereby extending the original NSI concept. A sectoral system of innovation is a collection of economic activities organised around a common technological or knowledge base in which individual enterprises are likely to be either actual or potential competitors with one another (Edquist *et al.*, 2004). For this study (i.e. a focus on one particular sector) the sectoral system is the most convenient framework. A sectoral system of innovation (and production) is composed of a set of agents carrying out market and non-market interactions for the creation, production and sale of sectoral products (Malerba, 2004). Sectoral systems have a knowledge base, technologies, inputs and – potential or existing – demands (ibid.). They each have a particular type of innovation process, depending on the characteristics of the sector. Boundaries within a sectoral system are not static; they must be expected to evolve as the underlying problems of innovation evolve (Edquist *et al.*, 2004). The sectoral system provides a good starting point for understanding what stakeholders are involved and how effective public policies are, as innovation policy should be sensitive to sectoral distinctions. Sectoral systems can be classified in terms of sectors predominantly organised around (a) functionally organised firms and (b) project-based firms. The innovation systems literature still focuses mainly on functionally organised firms, which are presented as bounded entities of consistent divisions and units. Project-based firms consist of project teams that work off-site in teams with many other firms, having limited contact with senior management (Gann & Salter, 2000). Project-based sectors (such as the construction sector in our case) are characterized by design and production processes that are organised around projects, the production of one-off – or at least highly customized – products and services, and the fact that they operate in diffuse coalitions of companies along the supplier-customer chain. Innovation activities in project-based firms are performed within, or closely related to, business projects, instead of in separate R&D departments (Blindenbach-Driessen & Van den Ende, 2006). Innovation in project-based firms will be considered when we elaborate on the sectoral system of innovation in the construction sector in Section 7.3.

7.2.1 Types of innovation

Innovation should be regarded as a container term that covers a variety of processes. Lundvall (2005) characterizes it as a continuous cumulative process involving not only radical and incremental innovation but also the diffusion, absorption and use of innovation. Although the link between innovation and technology is not a necessary one, in practice, in current conceptions of both process and product innovations, the empirical literature most often takes ‘innovation’ to mean some form of technological change, either in a product or in the production of a good or service (Blake & Hanson, 2005). The basic distinction among innovations is between product and process innovations, and incremental and radical innovations (see Feldman, 2000). Innovations vary along a continuum from incremental to radical. The term 'radical' has been associated with revolutionary innovations, whereas 'incremental' is associated with innovations within a paradigm (Johannessen *et al.*, 2001). Dahlin & Behrens (2005) emphasize that an innovation should fulfil two characteristics to be considered radical: it should be dissimilar from prior and current innovations and it should influence future innovations. Very few innovations, however, represent substantial, and disruptive, milestones; the majority of innovations are continuous, incremental improvements to products. Incremental innovations include minimal changes in the technological basis of a product which are matched by only a minimal improvement in benefits to customers (Herrmann *et al.*, 2006). A key difficulty in the innovation systems literature is the categorisation of innovations in between this basic differentiation of incremental versus radical innovation. Various authors have looked for a more refined way of differentiating between innovation processes but provide limited harmony (see e.g. Garcia & Calantone, 2002; Dahlin & Behrens, 2005; Smith, 2005). Garcia & Calantone (2002) make a distinction between radical, incremental, really new, discontinuous and imitative innovations, and between architectural, modular improving, and evolutionary innovations. Inevitably, overlap between types of innovation exists within such a refined categorisation. Of importance for this study is to stress that many innovations are not radical or incremental but may be new in their application within a certain sector and therefore can be considered as 'really new' (see Section 7.4). Compared to incremental innovations, 'really new' innovations not just carry with them higher social and environmental benefits but also the premium of becoming technological leader in a certain field.

The diffusion and adoption of innovations is complex and depending on various factors. Rogers (2003) stressed that the potential adopter's perception of the compatibility, complexity, divisibility, and communicability affect the rate of adoption of an innovation. Adopters should have an incentive to change their traditional habits and practices. The adoption of alternative technological systems is often inhibited by the dominance of the present technological growth trajectory (Hall & Kerr, 2003). A long history exists of technologically superior solutions in particular fields that were not picked up by the market (see also Shackley & Green, 2007).

7.2.2 Government regulation and innovation

The innovative systems approach is not entirely based on a belief in the blessings or basically advantageous functioning of the market economy. Firms are not the only important actors in the approach, and local synergy could and should in some circumstances be enhanced through the creation of a *local* *agent d'animation* or cross-firm organizer (Maskell & Kebir, 2006). Many studies emphasize that the government (or policy-making bodies) should play this role in innovation systems and that government regulation should provide an incentive for innovation. The most common reason for government intervention is market failure in achieving socially desirable objectives, which can range from international competitiveness to environmental transformation. Innovation policy has a role in bringing about industrial dialogue, particularly between producers and users aimed at mitigating the cost of coordination (Edquist *et al.*, 2004). The options for policy makers to fundamentally change the course of industrial development are rather limited, however, given the many regions that want to become new Silicon Valleys but have failed to do so. Because of the very nature of the innovation process – its variability and its technological, financial and marketing uncertainties – and the actors involved, there are inherent limitations on what public policies can achieve (Rothwell & Zegveld, 1988).

The role of the government in an innovation system is to facilitate innovation through either support measures (e.g. funding public research institutes, R&D subsidies) or government regulation (i.e. norms and standards). The first role is directly interventionist or facilitating, whereas the second is to stimulate innovation indirectly, as it should encourage or force companies (e.g. by means of product bans) to make transformations. Traditional innovation policies have been designed to provide public resources for R&D and increase the incentives for firms to innovate, typical examples being tax breaks for R&D, innovation subsidies and patents (Edquist *et al.*, 2004). These policies were basically legitimized by the concept of market failure, whereas modern innovation policies also have to deal with system imperfections (Smits & Kuhlmann, 2004). Normative R&D policy rationales (market failure, public goods) do not generally rule the de facto behaviour of decision-making actors in innovation policy arenas (ibid.). Policymaking means compromising by reframing stakeholders' perspectives and achieving a consensus. Public policy is very much a matter of formulating 'rules of the game' that facilitate the formation of operational innovation systems (Edquist *et al.*, 2004).

Porter (1990) puts forward the criticism that most of the policies that would make a real difference are either too slow and require too much patience for politicians or, even worse, carry with them the sting of short-term pain. His emphasis on radical innovation through the implementation of public policy was a new way of looking at providing incentives for innovation. He advocated the enforcement of strict product safety and environmental standards long before such ideas became fashionable, and even longer before social responsibility became part of managerial rhetoric and practice (Maskell & Kebir, 2006). Taxes, subsidies, standards and covenants are not concerned directly with innovation but should encourage the development of new technologies. The most common responses to regulation are incremental innovation in processes and products and the diffusion of existing technology (Kemp, 2000). The stringency of regulation is an important determinant of the degree of innovation: stringent regulations such as product bans are necessary for radical technology responses (ibid.). Non-stringent regulations do not encourage companies to make radical changes that could provide cost or performance benefits. Companies will then just make sufficient product modifications or improvements to existing technology to comply with new regulations. Incremental innovation is the path of least resistance for industry and policy makers who are constrained by industrial dynamics and economic pressures (Hall & Kerr, 2003). Transitions cannot be steered by a central actor; to do so implies that such an actor has knowledge of specific objectives and knows, in advance, which of the new technologies will be the 'winner' (Shackley & Green, 2007). It is obvious that public authorities often lack expertise on the various technological opportunities in the market. Geels (2004) stressed that rules and regulations are a game that is played out by actors like firms, public authorities, users, scientists and suppliers, acting and interacting in response to one another. Their resources (e.g. money, knowledge and tools) and opportunities to achieve their purposes, serve their interests and influence social rules are unequal. Public authorities need to be in constant negotiation with the other main stakeholders in the sectoral system to accomplish their goals.

7.3 The innovation system in the Dutch residential building sector

The construction industry is notorious for its complex context, caused by characteristics inherent to construction work such as inter-organisational collaboration, an approach based on constructing unique projects every time, and power that is distributed amongst collaborating organisations (Harty, 2005). Dubois & Gadde refer to the project-based nature of the construction process as a system of 'tight and loose couplings' (Dubois & Gadde, 2002). In individual projects the couplings are tight, whereas those in the permanent network are loose. Inter-firm adaptation beyond the scope of individual projects is rare, and firms tend to rely on short-term market-based exchange (ibid.). In the complex inter-organisational collaboration involved in a particular project the contractor is a mediator and plays a key role in the construction value chain when it comes to adopting innovations. Since it is the contractor who has the contacts with both the institutions developing new products (materials and components suppliers, developers of energy appliances, specialist consultants) and the ones that need to adopt these innovations (clients, regulators and professional institutions) he has to be convinced of the benefits of innovation in order to apply them (Miozzo & Dewick, 2002). Because innovations in construction are not implemented in a firm itself but as part of the projects in which firms are engaged, most innovations also have to be negotiated with one or more parties in the project coalition (ibid.). Since every construction job is unique there are hardly any economies of scale, hence there is little reason for contractors to invest in innovation (Pries & Janszen, 1995). The financial organisation of the construction sector also has direct influence on innovation capability. The industry is dominated by intense price competition (Pries & Janszen, 1995). The practice of awarding contracts based on the lowest cost tender is likely to act as a constraint on innovation, since it gives contractors very little scope to change design specifications and introduce innovations (Miozzo & Dewick, 2002). Also, it is quite common for contractors to have relatively little fixed capital, since they do not own any significant assets other than their own office, buildings under construction and, in some cases, land.

7.3.1 Characteristics of the Dutch building sector

The residential building industry is highly dependent on geographical factors such as availability of materials and building sites. Building sites are scarce in The Netherlands, as it has one of the highest population densities in the world, and land use is government-regulated (De Wildt *et al.*, 2005). The Dutch building sector is also tied down by technical regulations on safety, health, functionality, sustainability and energy consumption. In many cases it is municipal authorities that commission construction work, which often means working on sizeable developments at the same time. The Dutch building sector is known for a large share of small enterprises. The portion of construction enterprises employing more than 100 man-years is only 1.6% of the total number of registered construction companies (EIB, 2002). Overhead in small companies is limited, resulting in relatively little means for R&D expenditure. The computerization level of the construction sector is - compared to other industries – still underdeveloped. Most small and medium construction enterprises operate on a local level. International activity is only found at few large companies.

Competition in the building sector is usually imperfect due to the long life span and the place-bound character of buildings (Priemus, 2004). Furthermore, private commissioning is rare in The Netherlands, with only 15% of residential buildings being commissioned directly by clients, compared to neighbouring countries such as Belgium, where 70% of new residential building is commissioned by private clients. Innovation led by client demand is therefore hard to achieve in the Dutch residential building industry. A recent study showed that the primary motive for innovation in the Dutch construction industry is to improve productivity (75%) while only 25% of innovation appeared to be in response to specific market demands (Pries & Doree, 2005). Although the market motive seems to be growing recently, the construction industry continues to be inward-looking, rarely recognizing customer needs (ibid.).

Due to the characteristics of the Dutch construction industry as described above, it is being criticized since time immemorial for having a conservative nature thus causing restraints rather than encouragement for innovation (Jacobs *et al.*, 1992). The sector is subject to a strong path-dependent development trajectory whereby old routines are too pervasive to make substantial changes in techniques applied.

7.3.2 Energy innovation and performance regulation

There are a number of obstacles to the introduction of innovations in the residential building sector. Investment in energy-saving technology, moreover, creates an advantage for users rather than builders. Low-energy buildings could be designed so as to create a market niche for construction firms. Since the sector competes mainly on price rather than quality, however, this argument does not create sufficient incentive to apply energy innovations. The demand side in the sector is weak, thus aggravating the situation that innovation is not used for competitive positioning. Even where clients could exert an influence, households' relatively low expenditure on energy (4.5% of their total expenditure, only half of which goes on heating) causes a lack of user demand for more energy-efficient housing (Gann, 1998). As energy prices increase consumers are likely to pay more attention to the issue of energy-efficient housing, but the low price elasticity of energy will limit the response (Haas & Schipper, 1998; Jeeninga & Boots, 2001). Another barrier to consumers evaluating the life cycle costs of a building is the lack of transparency when it comes to energy efficiency, which places a damper on the demand for low-energy housing (Sprei & Nassen, 2005). Research by Sprei & Nassen (2005) demonstrates that firms regard investing in the energy performance of buildings as an economic risk. This market failure justifies government intervention to achieve energy conservation in the building sector.

The energy consumption of new buildings in The Netherlands has been regulated since 1975 in the wake of the oil crisis in 1973-1974. The recent maturation of prescriptive standards into energy performance standards is supposed to allow firms to decide for themselves how to meet the standard. Flexible options for meeting the energy performance standard create competition between different technologies, e.g. insulation versus heating technology (Weber & Dicke, 2001). According to these authors, energy performance regulations can speed up both innovation and market penetration in the building sector if requirement levels are tightened up stepwise and specific mechanisms for dealing with innovations such as flexibility, reliability and cost-effectiveness are included. Given the complexity of the construction process, however, it is disputable whether design teams take sufficient advantage of the flexibility they have to choose energy technologies: research indicates that they will first try to meet the energy performance standard by using conventional technologies, e.g. efficient boilers and increased insulation (Essers & Mooij, 2001). Although the regulations offer flexible ways of meeting the standard, the standard itself still sets a required level; it does not provide any incentive to innovate beyond that level. Interviews in Sweden show that the energy performance standard is perceived as a guideline and it is uncommon for people even to consider the profitability of additional investments in energy efficiency (Sprei & Nassen, 2005). Gann *et al.* (1998) noted that when the energy regulations in Great Britain were revised, this was taken up by manufacturers of construction components as an incentive to improve their products, but problems were often experienced in achieving market entry for these products, owing to regulatory conformance mechanisms and the structure of the construction value chain (ibid.). The same thing happened in The Netherlands with the introduction of efficient gas condensing boilers: although this technology was brought onto the market in 1981, its diffusion was very slow (Brezet, 1994). It was only when the energy performance regulations were introduced in 1996 that the efficient gas condensing boiler had become the standard for new residential building in The Netherlands.

Energy performance regulations in the building sector mainly address construction, which needs to meet certain requirements as regards e.g. minimum insulation levels or maximum permitted energy use. It is the manufacturers of materials (insulation etc.) and appliances that need to respond to the building regulations and produce innovative solutions to meet these requirements. The government does not impose product quality requirements directly on upstream materials and components manufacturers. The challenge for regulators is to encourage upstream innovation in materials and components through downstream whole-building regulations.

There have been government schemes in The Netherlands to encourage energy conservation in building since the early 1990s. The Dutch government's energy conservation plans are implemented using a combination of information, financial and regulatory policies. Experimental low-energy building projects have been built under a national programme to demonstrate sustainable and low-energy building (SEV, 1999). The Netherlands has provided financial incentives for energy saving in building since 1988. Until 2000 the BSET scheme (Energy-Saving Technologies (Subsidies) Decree) subsidised the development of several innovative energy technologies. In addition, from 1994 onwards energy distribution companies received special funding from a surcharge on energy costs that was used for energy-saving schemes (mainly promotional campaigns and grants to individual households). Starting in 2000, the energy technology funding system changed to a scheme that focused particularly on individual households. All subsidy schemes were discontinued in 2003, however, owing to changing political priorities. As regards regulatory policies, energy is covered in the building regulations. Dutch building regu-

Table 7.1 Expected energy consumption for space heating and domestic hot water corresponding to an EPC of 1.0

Dwelling type	Floor surface	Expected energy consumption for EPC 1,0
Terraced dwelling	123 m²	43 GJ
Detached dwelling	220 m²	89 GJ
Apartment	75 m²	26 GJ

Source: W/E consultants sustainable building

lations cover five areas, energy being one of them. Until 1996 energy regulations involved calculating transmission losses based on the average insulation value of the building shell, which had to be below certain limits. The energy regulations were revised in 1996: the new energy performance regulations lay down an energy performance standard. Compliance with a maximum figure without dimension must be demonstrated by means of a calculation which is submitted to the municipal building authorities when applying for a building permit.

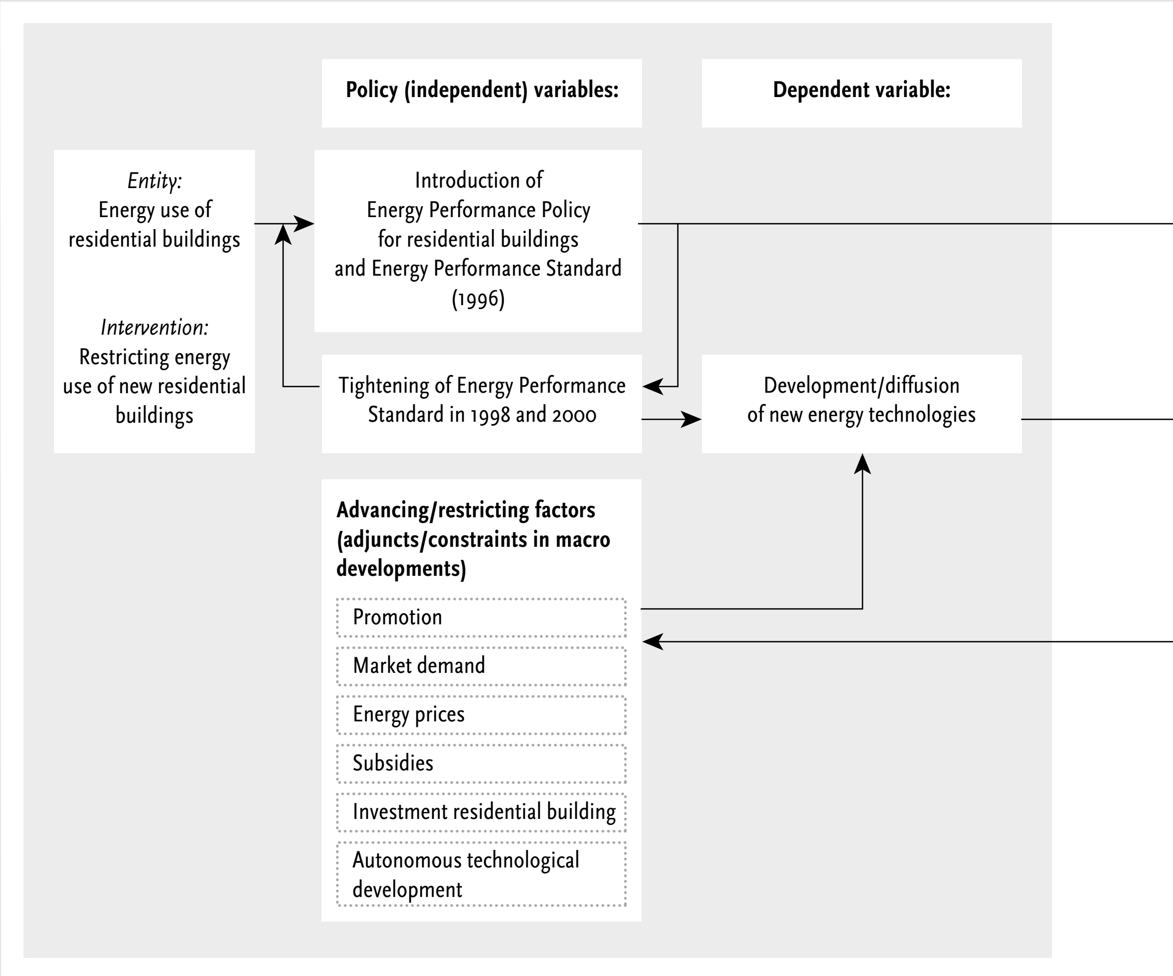
The output of an energy performance calculation is an energy performance coefficient (EPC), a non-dimensional figure that expresses the energy efficiency of a building. The calculation contains a geometrical correction, so that all buildings, regardless of size, have the same energy performance coefficient when similar energy features are applied. The geometrical correction means that estimated energy consumption, as represented by the EPC, can vary considerably for different housing types. Table 7.1 presents the estimated energy use for a number of housing types corresponding to the energy performance regime of 2000 to 2006. When the Energy Performance Regulations were introduced in 1996 the EPC for residential buildings was set at 1.4: this more or less represented standard building practice at that time and was therefore not considered difficult to achieve. In 1998 the limit was tightened up to 1.2, and still further to 1.0 in 2000.

7.4 Empirical data on the diffusion of energy-saving innovations in the Dutch residential building sector

The analysis of the innovation system of the Dutch construction sector demonstrated that the conditions for innovation in energy-saving techniques are not very favourable. A strong path dependency is indicated, implying an important constraint in discussing innovation in the building sector.

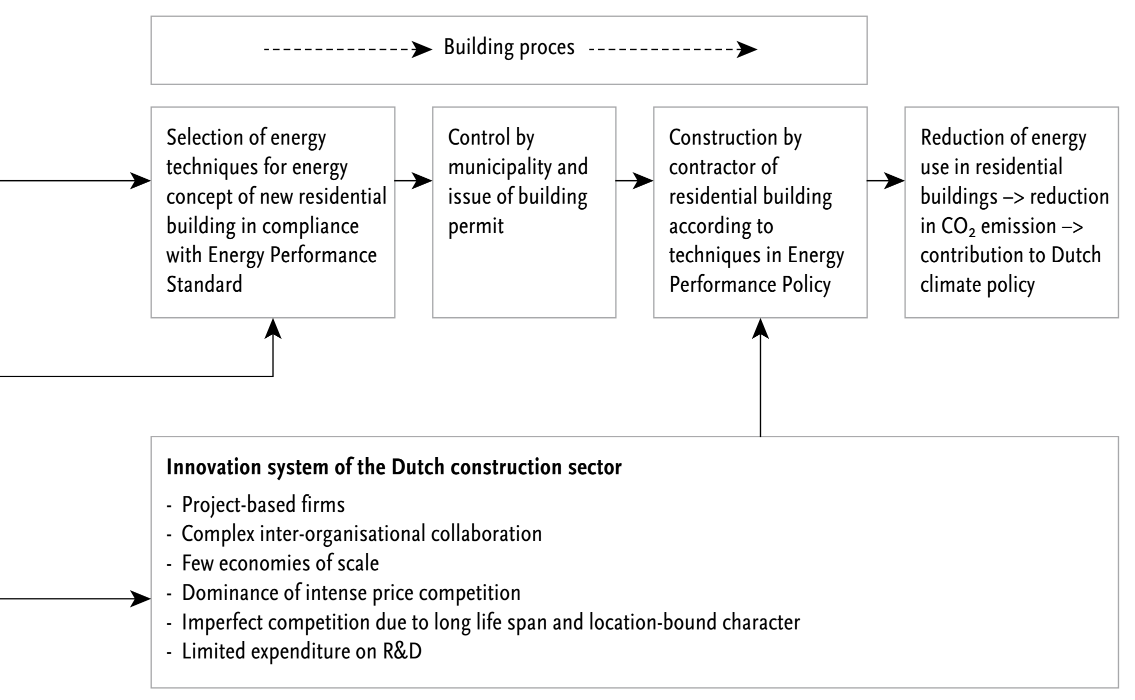
We constructed an explanatory model in order to ascertain the relative influence of the EPC regime in relation to other factors that influence technological development in the residential building sector, using which – after adding variables to the database – we were able to perform regression analyses. We combined a general model for evaluation research introduced by Mayer & Greenwood (Vall, 1987) with the framework for explaining the diffusion of innovations in new office buildings as developed by Vermeulen & Hovens (2006). Vermeulen & Hovens' framework focuses on decision-making but also puts forward explanatory variables for the macro-context, consisting of the 'macroeconomic situation', 'market demand in terms of environmental awareness

Figure 7.1 Research model



in society' and 'energy price developments'. They did not take the 'macro-context' factor into account, however, since their research focuses on one moment in time. Our research covers a period of eight years (1996-2003) and therefore specifically analyses the 'macro-context'. The combination of these two approaches is shown in the explanatory model in Figure 7.1.

Mayer & Greenwood's general conceptual model for policy evaluation describes the policy process from start to finish, based on a series of causal relations. In this case, the independent variable is the actual practical intervention designed to result in the policy goals (the dependent variable) being achieved. Figure 7.1 shows how the innovation effects of introducing energy performance policy are primarily a side effect of the actual policy goal of reducing CO_2 in the building sector. Our research focuses on the grey-shaded area of the policy process, which shows the correlation between introducing and tightening up the Energy Performance Standard (in 1996, 1998 and 2000)



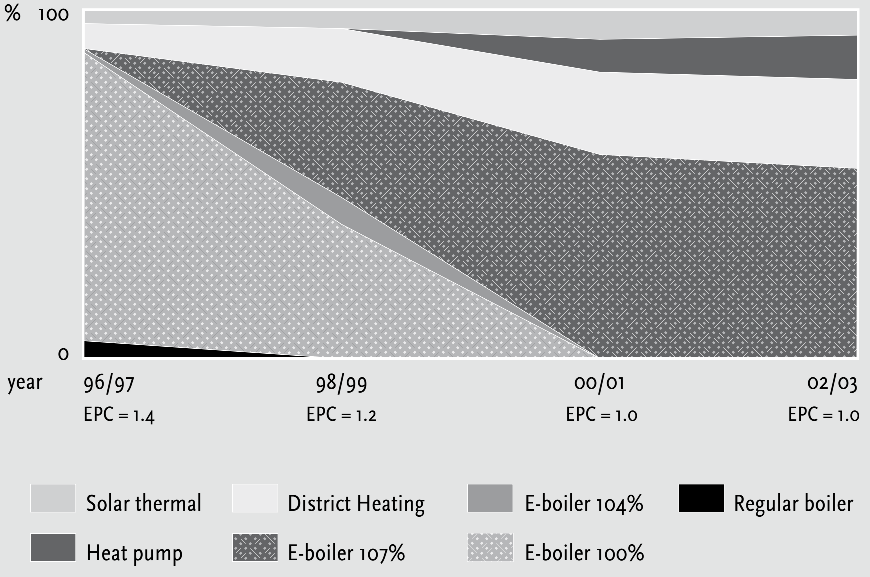
and the use of improved and new technologies in energy concepts for residential buildings. Factors outside the system can also encourage or prevent the development and diffusion of new energy technologies: these are referred to as advancing factors (adjuncts) and restricting factors (constraints). We used the adjuncts and constraints as described by Vermeulen & Hovens (2006) for the macro-context, adding the factors ‘subsidies’, ‘promotional campaigns’ and ‘autonomous technological development’ to their variables ‘macro-economic situation’, ‘market demand’ and ‘energy prices’. The innovation system of the construction sector, shapes the environment for policy intervention.

To analyse the innovation effects of energy performance policy on residential building in The Netherlands we collected energy performance calculations, used when applying for building permits, in the files of one municipality and two consultancy companies. The collection of 352 calculations is equally distributed over the years 1996 to 2003 and represents all the possible types of residential building. A single energy performance calculation can cover an apartment building or a block of similar linked housing. It was not possible to find the number of dwellings the calculations represented: we estimate that the 352 calculations represent about 2000 housing units. It is not possible to provide details of the precise percentages of technologies used in The Netherlands, but the database is thought to reflect the general trend. The data in the energy performance calculations enable us to extract the technologies used for insulation, space heating, hot water production and ventilation in the buildings.

The next step was to include the advancing and restricting variables for the macro-context in our database. We included Dutch national gas prices per year for domestic use derived from Statistics Netherlands (CBS, 2006). Dutch national gas prices showed a steady rise during the years 1996 to 2003. The rise of yearly gas prices reflects the basis on which decision making for energy techniques has taken place. National yearly gas prices are preferred to future energy prices since the latter are highly speculative and imply the use of scenario studies. In addition, we included in the database the investment in residential building during the 1996-2003 period. Our analysis of the innovation system in the Dutch residential building sector leads to the conclusion that market demand is a negligible factor in The Netherlands. Subsidies have been provided for solar thermal boilers and heat pumps. Research into the influence of energy performance policy on the use of solar thermal boilers indicates that subsidies until 2003 can be regarded as a stable factor over the years (Beerepoot, 2007). Financial incentives for heat pumps, which consisted of fiscal incentives until 2000 and a subsidy scheme from 2000 until 2003 can be considered stable during the period of our analysis. Promotional campaigns for both solar boilers and heat pumps have been going on for a long time and remained constant during the 1996-2003 period. Autonomous technological development is not included in the database as there are no data available on the subject. Section 7.2 showed that innovation varies along a continuum from incremental to radical, and many innovations are not radical or incremental but may be new in their application within a certain sector. The last category is what Garcia & Calantone (2002) call 'really new' innovation. In our database we categorised all the technologies used in three categories:

1. Technologies that represent the 'state of the art' in 1996, when energy performance regulations were introduced in The Netherlands.
2. Technologies that show an improvement on the 1996 'state of the art': incremental innovations.
3. Technologies that are new to the Dutch residential construction sector compared to the 1996 'state of the art': really new innovations.

Figure 7.2 Water heating systems applied in new residential buildings in the Netherlands from 1996 to 2003



As we explained in Section 7.2, radical innovations are rare, since only very few innovations represent substantial milestones. It was not possible to identify any radical innovations in the construction sector so we left this category out of our analysis. In an earlier study we described the development of techniques for hot water production, heating, insulation and ventilation (see Beerepoot, 2007). Techniques for space heating appeared to be rather similar to techniques used for hot water production, though less diversified since solar boilers and heat pumps are less commonly used for space heating. Development in insulation could be demonstrated in terms of increasing insulation levels but cannot be categorised in terms of 'innovativeness'. Our database of ventilation techniques (covering the period 1996-2001) only showed incremental innovations. We therefore focused on the technologies used for hot water production, since this is where there is the greatest variation in available technologies. Figure 7.2 shows the water heating systems used from 1996 to 2003 in The Netherlands in the new residential buildings in our database.

As Figure 7.2 shows, in the 1996-2003 period we found seven technologies used, ranging from regular gas condensing boilers, efficient gas condensing boilers and high-efficiency gas condensing boilers (two versions) to solar boilers, heat delivery systems (mostly district heating) and heat pumps. We categorised each of the seven technologies in one of the three innovation categories according to their rate of adoption in 1996, at the time of introduction of the energy performance policy in The Netherlands. In The Netherlands energy supply is being dominated by natural gas since the discovery of huge natural gas fields in the northern part of the country. In 1988 96% of Dutch households were connected to natural gas distribution (Brezet, 1994). In 1992 73% of the Dutch households used gas condensing boilers, while at the same time 11% of households were being connected to district heating and 16% of households made use of local heating (ibid.). Efficiencies of gas condensing boilers have been improved continuously, mainly driven by rising energy prices such as caused by the energy crisis in the 1970s. The first efficient gas condensing boilers with an efficiency of 90% on Higher Heating Value[1] and 100% on Lower Heating Value) was already introduced in 1981 (Brezet, 1994). A long and slow diffusion path has made the efficient gas condensing boiler the most common technique for domestic hot water for new residential building in the second half of the 1990s. Following the energy crisis of the 1970s one of the options for energy savings was expected to be district heating, which resulted in a systematic governmental support for district heating from 1977 to 1984 (Vermeer, 2002). Regular gas condensing boilers, efficient gas condensing boilers and heat delivery by means of district heating are taken as the state of the art techniques in 1996 and categorised as such in our analysis. High-efficiency gas condensing boilers (with efficiencies of 95% on Higher Heating Value, 104% and 107% on Lower Heating Value[1]) are considered to be incremental innovations, since they show improvements on the 1996 state-of-the-art efficient gas condensing boiler. Although the first heat pumps were introduced in the Dutch market by the 1980s, a combination of factors caused that this technique was still considered to be experimental by the year 1996 (Vermeer, 2002). At the time the energy performance regulations were introduced about 2500 heat pumps had been installed in dwellings (existing and new) in all The Netherlands (ibid.). Solar boilers were developed and introduced in the 1970s as a consequence of the energy crises. Decreasing energy prices in the 1980s diminished interest in solar boilers, but in the 1990s as a result of increased attention for the environment, numbers of applied solar boilers rose (Zegers, 2003). In the year 1996 about 3500 solar thermal systems were installed in a total of about 80.000 new residential buildings that were built that year (Holland Solar, 2007; Zegers, 2003).

Decisions on whether to apply new techniques depend on the costs related to the effect they have in reducing the energy performance coefficient and on the level of energy performance that needs to be realised. However, both costs and effect on the energy performance coefficient are very project specific. Costs depend on features such as numbers of dwellings to be built while energy performance effect can vary considerably, depending on shape and size of the dwellings influencing the calculation. Really new techniques such as heat pump boiler or solar system naturally have higher costs but also result in a considerable improvement of the energy performance coefficient.

1 Higher Heating Value (HHV) – or gross calorific value – represents the efficiency of combustion, including the condensation energy of water vapour. European standards for gas condensing boilers are often based on Lower Heating Value (LHV), which excludes the condensation energy of the water, resulting in efficiencies of over 100% for condensing boilers.

Table 7.2 Indication of costs of most relevant energy technologies for hot water production (2000) and effect in Energy Performance Coefficient (EPC) related to reference: E-boiler 107%

	Indication of costs (2000)	Effect in Δ EPC
E-boiler 107% (combi-boiler, producing for hot water and space heating)	€ 1.500	(reference)
Heat pump boiler (extracting heat from ventilation air, additional boiler for space heating is required)	€ 1.800 (€ 1.300)	-0,07
Solar thermal system (2,8 m², producing for hot water only, additional boiler is required)	€ 2.000 (€ 1.500)	-0,10
Solar thermal system (5,6 m², including boiler, also producing for space heating, combined with low temperature heating)	€ 3.900	-0,20

Source: Scheepers & de Raad, 2000

Table 7.3 Levels of the Dutch Energy Performance Standard during the years 1996 to 2003

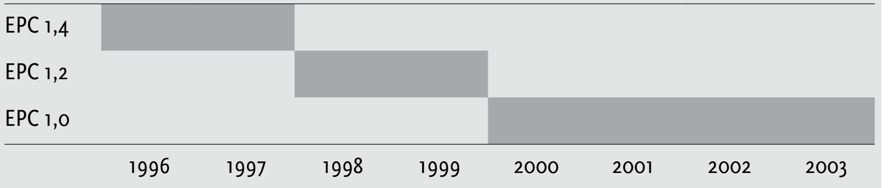


Table 7.2 gives an indication of costs of most relevant energy techniques for hot water production in the year 2000 and the effect in reducing the energy performance standard (Scheepers & De Raad, 2000).

Solar boilers and heat pumps are categorised as 'really new' to the construction industry compared to the state of the art in 1996. By attaching these labels to the variables for 'hot water production technologies used' we developed a new variable expressing the innovativeness of the technologies used, based on the three categories mentioned above. This variable was used to create two dichotomous variables, one indicating whether or not a technology represents an incremental innovation and one expressing whether it represents a really new innovation. These variables enable us to analyse the correlation between the introduction and tightening-up of energy performance regulations in The Netherlands and incremental or really new innovation in hot water production technologies. We also had a variable 'EPC regime' representing the three periods during which the Energy Performance Standard limits remained constant. Table 7.3 shows the exact levels of the Energy Performance Standard during the years 1996 to 2003.

Table 7.4 Association (Kendall's tau) between EPC regime and selected parameters

	Kendall's tau correlation coefficient	Correlation coefficient squared (R^2)	Significance (2-tailed)
Incremental innovation	0.443 *	0.196	0.000
Really new innovation	0.200 *	0.040	0.000

* Correlation is significant at the 0.01 level (2-tailed)

The introduction of a new and tighter standard has each time well in advance been prepared in consultation with the building industry. The adjustment of standards has each time been announced between 6 to 12 months before introduction. Adjustments have always taken place the 1st of January meaning that documents for building permits handed in the 1st of January had to meet the new requirements. We therefore do not expect lags between new standards and applied energy techniques to be an issue affecting the analysis. We first performed a chi-square analysis between (a) the variable 'EPC regime' and (b) the dichotomous variables 'incremental innovation' and 'really new innovation'. Both tests produced significant results, i.e. there is a statistical association between the EPC regime and both incremental innovation and really new innovation. The strength of the correlation can be determined by means of a correlation analysis. A perfect correlation between two variables is represented by a correlation coefficient of 1; a coefficient of 0 means that there is no correlation. Kendall's tau correlation coefficient was chosen, since the data is non-parametric and there are a large number of tied ranks. The correlation coefficient squared (R^2) is a measure of the amount of variability in one variable that is explained by the other. Table 7.4 shows the results of the correlation analysis.

Table 7.4 shows a correlation of 0.443 between the EPC regime and the application of incremental innovation, indicating that the EPC regime accounts for 19.6% of the variability in applying incremental innovations. This leaves about 80% of the variability still to be accounted for by other variables. The EPC regime shows a correlation of 0.2 with the application of really new innovation, which means that it accounts for a negligible share (not more than 4%) of the variability in applying really new innovation[2]. In order to ascertain the relative effect of the EPC regime on the diffusion of either incremental or really new innovation we used the independent variables 'EPC regime', 'InvestmentResidentialBuilding' and 'GasPriceDevelopment' in a regression analysis. We used the two dichotomous variables representing whether an 'IncrementalInnovation' or 'ReallyNewInnovation' had been applied. Using the dichotomous

2 The interpretation of whether the value of R^2 is acceptable is difficult to answer because it depends on the scientific field from which the data are taken. Whereas in physical sciences quite accurate predictions are possible in social sciences, of which our research is an example, prediction is much more difficult (Stevens, 1996). Our opinion is that in this research a R^2 of below 10% is not acceptable. We also think that an R^2 of 20% is a rather low level, but that it is allowed in this case to make statements about the relation between innovation and energy performance policy.

Table 7.5 Innovation explained by policy, gas prices and investment in residential buildings

Model: Cox & Snell R square	Incremental Innovation 0.238		Really New Innovation 0.059	
	Sig.	Exp (β)	Sig.	Exp (β)
InvestmentResidentialBuilding	0.019	1.137	0.045	0.867
GasPriceDevelopment	0.155	1.044	0.077	0.929
EnergyPerformancePolicy	0.000	4.485	0.002	3.070

dependent variable we can employ logistic regression analysis to investigate the relative influence of the independent variables. We first tested for multicollinearity (the strength of the correlation between two or more predictors) by means of the collinearity diagnostics of the linear regression analysis that produced the Variance Inflation Factor (VIF)[3]. In both the multicollinearity tests for (a) incremental innovations and (b) really new innovations VIF factors vary between 2 and 3. Though there is some multicollinearity they do not exceed 10, so we accepted this for our further analysis.

Table 7.5 shows the results of the logistic regression analysis. Logistic regression does not have an equivalent to the R-squared found in linear regression, but the Cox & Snell R Square is a pseudo-R-square statistic[4]. The Cox & Snell pseudo R-square statistics from our logistic regression analyses are very similar to the adjusted R-square from the linear regression analyses. The logistic regression analysis, similarly to the linear regression analysis, suggests that the model explains a considerable amount of the variance in incremental innovation applied, but it only explains a negligible share of the variance in really new innovation applied. In both cases it is mainly the EPC regime that influences the variance in either incremental or really new innovation (expressed as Exp (B)). The significance levels of the variables 'InvestmentResidentialBuilding' and 'GasPriceDevelopment' are sometimes fairly high, indicating that they have low impact on the dependent variables 'Incremental innovation' and 'Really new innovation'. The finding that mainly energy performance regulations have influenced the developments in energy techniques while developments in gas prices and investment in residential building had a negligible effect, confirms some general notions in earlier studies. Increase of gas prices is having a very low price elasticity and the effects of increased energy prices are therefore considered to be relatively small (Joosen, S. *et al.*, 2004). The investment in residential building did not influence innovation in energy techniques, which coincides with the general market imperfections of the Dutch housing market.

3 Since multicollinearity can not be tested by means of logistic regression analysis, we used the collinearity diagnostics of the linear regression analysis to produce the Variance Inflation Factor (VIF). VIF factors higher than 10 are considered to be a concern, although some say that if the average VIF is greater than 1, multicollinearity may already be biasing the regression model (Field, 2000).

4 As the Cox & Snell statistic does not indicate what R-squared means in linear regression (the proportion of variance explained by the predictors), this statistic has to be interpreted with great caution.

7.5 Discussion and conclusions

The objective of this chapter was to identify whether energy performance regulations encourage innovation in energy-saving technologies in the Dutch residential building sector. The conclusions of the literature on innovation systems as to whether resetting environmental standards encourages innovation are mixed. Critics say this mainly encourages firms to make incremental modifications to existing products in order to comply with stricter norms and standards. The sectoral innovation systems literature emphasizes how the characteristics of a sector determine the scope for innovation within that sector. This study used data from energy performance permits for residential buildings dating from 1996 to 2003 in order to assess the innovation effect of resetting energy performance standards during this period.

The empirical analysis in this chapter shows a significant correlation between the EPC regime and both 'incremental' and 'really new' energy-saving innovations in hot water technologies in the Dutch residential building sector during the 1996-2003 period. Whereas the correlation between the EPC regime and incremental innovation is relatively strong (R^2 = 19.6%), that between the EPC regime and really new innovation (R^2 = 4%) is negligible, however. The logistic regression analyses confirm these findings, showing at the same time that related factors, such as changes in the gas price or in the amount of housing investment, had hardly any influence on incremental or really new energy-saving innovation in the Dutch residential building sector. This study demonstrates that energy performance policy in The Netherlands did not contribute to the diffusion or development of really new innovation in hot water production technologies during the 1996-2003 period. It partly contributed to the improved efficiency of conventional hot water production technologies but it did not result in solar hot water boilers or heat pumps taking off to any significant extent. The improvements in the efficiency of conventional technologies were sufficient to meet the tighter Energy Performance Standard. Further tightening of the Energy Performance Standard in 2006 is expected to sustain this situation. New standards will continue to be achieved using conventional technologies such as gas condensing boilers, whereas new technologies such as heat pumps will only be used if they enjoy additional government support for instance in the form of grants.

The chapter has identified how the project-based nature of the construction industry is the main obstacle to 'learning-rich' collaboration between the various stakeholders, preventing tight couplings from existing in the permanent network, since tight couplings with many other firms exist only for the duration of the project. The project phase is dominated by negotiation and heavy interdependence between the partners involved in the chain, from designer or developer to supplier and constructor. At the same time the sector is dominated by price competition and the risk of market failure owing to the long lifespan and the location-bound nature of buildings. Every construction job is unique, hence there are hardly any economies of scale. As a result of the complex nature and defensive character of the building process, builders are generally unable to be flexible in using different technologies so as to comply with the energy performance standard.

Our case study provides an example of a situation where innovation is supposed to take place in a project-based environment, which has loose couplings in the permanent network, undifferentiated user demand and limited willingness on the part of those who are expected to introduce the scheme. Such market failures and sectoral weaknesses do not favour innovation in energy-saving technologies. Government regulation through norms and standards is supposed to take the place of absent user demand. In our case study, however, such regulations have not been forceful in initiating 'radical' or even just 'really new' innovations. It confirms research indicating that non-stringent government regulation primarily results in the diffusion of incremental innovations.

The study of the innovation system of the construction sector and the empirical study on innovativeness of energy performance policy in this sector provide us with two issues that need further research. First, it appears that energy performance standards, seen from our perspective, have not been stringent enough during the period 1996 to 2003. Dutch energy performance policy started out with a standard representing normal building practice and was tightened up in such a way that it was always possible to comply with the new standard by improving conventional technologies. Hence the only technology development that has taken place is improvements in the efficiency of conventional technologies; no really new innovation has taken off.

Second, it is questionable whether energy regulations target the right level of the value chain in the construction sector. The project-based nature of this sector does not provide a favourable environment for the effectiveness of energy performance policy, based on trading off technologies resulting in most economic efficient solutions. Since our empirical data indicate that incremental innovation is only to some extent related to energy performance policy, it still leaves us with 80% of variability to be accounted for by other factors. Contractors are supposed to introduce energy-saving innovations which do not generate direct returns to them or strengthen their competitive advantage. It would be more effective to target manufacturers of energy technologies directly and encourage them to innovate.

The need for a drastic reduction in CO_2 reduction – being a socially desirable objective that is difficult to realise only on a market basis – justifies the use of energy policies. In order to reach a new set of low-carbon technologies, incremental innovation alone will not suffice. Energy performance policy in its current shape will result in incremental innovation and relatively reduced energy consumption by paying attention to the energy consumption in buildings caused by heating, hot water production, lighting, cooling and ventilation. It can be questioned however, whether this will result in an overall CO_2 reduction since affluence, e.g. by using more appliances or lower occupancy rates per dwelling, can nullify the effect. Policy makers have to be aware that the effect of energy performance policy is limited and will not result in the take-off of really new innovation if the standards are not really stringent.

This study illustrates that more research is needed into the level of sectoral systems that should be targeted for policy measures to be effective. It is also questionable whether government regulation in a sector that suffers from both market failures and innovation system failures can be stimulated to produce innovation. Government policies could just aim at influencing the 'rules of the game', bringing together different interests and tackling the obstacles in sectoral innovation systems in a project-based environment. More research is needed into innovation systems in project-based sectors and how the networks in these sectors can be strengthened. Most countries, for example, have a huge project-based residential building sector, but it has seldom been the subject of research into innovation systems.

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8 Energy innovations in construction:

network effects and energy policy in Dutch construction

Beerepoot, M. (submitted) Energy innovations in construction: network effects and energy policy in Dutch construction.

The diffusion of heating technology in the construction sector involves confrontation between two differently organised sectors: the project based construction sector and the functionally organised suppliers of heating technology. The nature of ties between industries influences competitive performance and affects innovation On the basis of interviews, this study describes the interplay and cooperation between the construction sector and suppliers of heating technology in The Netherlands. It focuses on the research question: What is the effect of the interplay between projects and firms in the sectoral innovation system of the construction sector in relation to energy performance policy and the diffusion of innovation in heating technology?

Abstract

Interplay between projects and firms is intrinsic to the innovation system of the construction industry. Differences between these organisation forms may influence the development and diffusion of innovations in this sector. In this chapter, we investigate the network relations of the construction sector, as a typical project-organised industry, in its cooperation with the supply industry of heating systems, known as a typical function-organised sector. The supply industry is expected to innovate in order to encourage CO_2 reductions, while the construction industry is urged to purchase new technology in line with the energy policies that are imposed on new construction. Whereas construction organisations are the recipients of innovations from the supply industry, government energy policy is addressed at contractors. This chapter concentrates on the network relations between project based construction firms and functionally organised suppliers in The Netherlands, in relation to energy conservation policies that target innovation in the energy techniques applied. On the basis of discussion and interviews with various stakeholders in the field, this complex innovation system and its effect on the development and diffusion of energy innovations is explored. This research will demonstrate that communication between decision makers in the design process and heating technology suppliers is rare, and that multiple layers of communication exist in the building process. Notwithstanding the effect that energy performance policy has in reducing energy consumption for heating, cooling, and ventilation in building, it cannot be regarded as having encouraged communication between contractors and heating technology suppliers, or as having promoted innovative behaviour between these two parties.

Keywords

Sectoral innovation systems, energy policy, innovation, EPBD, The Netherlands

8.1 Introduction

The construction sector is usually seen as a non-innovative sector due to circumstances such as short-term perspective, lowest-price competition, complexity in coordinating numerous actors working together within a project, and lack of interorganisational cooperation outside the scope of the project (Koskela & Vrijhoef, 2001; Gann, 2000; Dubois & Gadde, 2000). Today, there is a clear need for searching innovations to reduce energy consumption in buildings, now that the Intergovernmental Panel on Climate Change has announced – in its fourth assessment report – that worldwide climate change is most likely to be a result of human activities (IPCC, 2007). Next to the need for behavioural change from energy consumers, CO_2 reduction can be realised by improved and new energy techniques. One of the expected effects of the implementation of energy regulations for the building sector – as enforced by the EU Energy Performance of Buildings Directive (EPBD) – is the use of new energy techniques for buildings (EC, 2003). Research, however, has demonstrated that innovation in energy techniques is hardly ever found in new residential building as a result of energy performance regulations in The Netherlands (Beerepoot & Beerepoot, 2007; Beerepoot, 2007). In this respect, the construction industry and the industry supplying energy techniques are mutually dependent, although fundamentally different in organisation type. While the expected innovators are the supply industries that produce heating installations, ventilation installations, and insulating techniques, the adopters are construction companies. At the same time, policies designed to promote energy reduction and innovation are addressed at adopters, rather than suppliers. The construction industry is known to be a typical 'project-based' industry, while the suppliers mainly consist of 'functionally organised firms'. Limited research has been carried out into how the extent of the interaction between the 'projects' and 'firms' functioning within one innovation system influences the development and diffusion of innovations. The aim of this study is twofold. First, we explore the differences and complementarities of the project based construction industry and the functionally organised supplier industry, and the consequences for innovation. Second, we aim to investigate the role of energy policy in this complex network. The interaction between the project-based construction industry and the functionally organised heating system producers is studied from the perspective of innovation in heating techniques resulting in energy conservation in The Netherlands. More specifically, we look at the effect of energy policy on this complex innovation system. The Dutch construction sector is well suited for the examination of interaction between contractors and suppliers, and the relative effect of policies, since it has already experienced ten years of energy performance regulations, and numerous subsidy and promotional campaigns aimed at encouraging new energy techniques. We base our findings on semi-structured interviews with a number of stakeholders in the construction industry, and the suppliers of heating systems in The Netherlands.

We make use of innovation system theory in order to obtain an understanding of the elements that influence innovation in a sector of industry. We specifically focus on the difference between the 'projects' and 'firms' that are part of one sectoral innovation system, and we pay attention to the role of institutions in such an innovation system. On the basis of discussions and semi-structured interviews with stakeholders in this sector, we contrast the theoretical notions expressed in literature – of the differences and complementarities between 'projects' and 'firms' – to the practical situation of the Dutch construction sector. Based on the literature and the qualitative empirical findings, we formulate conclusions.

Section 8.2 explains the concept of 'projects' and 'firms' and reviews literature that has studied the differences and complementarities between these types of organisations. Section 8.3 explores the construction industry and its suppliers. Section 8.4 describes the interaction between the construction industry and heating technology suppliers in The Netherlands, and the impact that this interaction has on innovation. Section 8.5 pays attention to the impact of energy policies in encouraging new energy techniques in this complex sectoral innovation system. Findings from literature and qualitative empirical study allow us to deduce the opportunities and obstacles that impact on energy technology innovation in the building sector, and the role that can be attributed to energy policy. Section 8.6 discusses the findings and presents conclusions.

8.2 Innovation systems and functionally organised versus project-based firms

Innovation systems' literature has gradually evolved from the exploration of national innovation systems as described by Freeman (1987), Lundvall (1988), and Nelson (1993), into a variety of concepts, such as regional and sectoral innovation systems. For this study (i.e. a focus on one particular sector), the sectoral system is the most suitable framework. The study of the sectoral innovation system finds its origin in the idea that industries function under different technological regimes, and that innovation and technological change are highly affected by the sector in which they take place (Malerba, 2004).

A sectoral system of innovation is one in which a collection of economic activities is organised around a common technological or knowledge base, and where individual enterprises are likely to be either actual or potential competitors with one another (Edquist *et al.*, 2004). Next to the knowledge and technical domain, and the actors and networks, institutions are thought to be an important aspect of a sectoral innovation system (Malerba, 2005). Institutions include, for example, norms, routines, and law. Institutions can be either national or sectoral, such as energy performance policy. The sectoral system provides a good starting point for understanding which stakeholders are involved, and how effective public policies are, as policies should be sensitive to sectoral distinctions.

Sectoral systems can be classified in terms of sectors that are predominantly organised around (a) functionally organised companies, and (b) project-based companies, respectively known as ‘firms’ and ‘projects’. Differences consist of projects having a temporary status, while firms are thought to be long-term entities involved in the organisation of a working process (Ibert, 2004). For a firm, a cyclical conception of time applies, dealing with constantly recurring tasks, while the project cycle is linear, dealing with a one-off objective at the end of the project (ibid.). The construction industry is known as a typical project-based sector. In construction work, project teams work off-site with many other firms, having limited contact with senior management (Gann & Salter, 2000). In a project-based industry, innovation occurs within projects, whereas in functionally organised firms, R&D departments exist. Dubois & Gadde (2002) refer to the project-based nature of the construction process as a system of ‘tight and loose couplings’. In individual projects, partnerships are tight, whereas those in the permanent network are loose. Therefore, trusting and long-term relationships between actors – generally accepted as necessary preconditions for learning and, as a consequence, innovation in firms – are hard to realise in project-based industries (Ibert, 2004). The supply industry mainly consists of functionally organised firms. Although the construction industry mostly operates on a regional or national level, the heating technology industry generally operates on a European, or even worldwide, level. In this industry, R&D is essential for maintaining a competitive position, and rather large R&D departments are common.

Blindenbach-Driessen and Van den Ende (2006) studied differences in innovation management for project-based and functionally organised firms. A large number of the success factors for innovation that have been identified in the past for functionally organised firms, have been confronted with practices of project-based firms. Some factors are more important to project based organisations: for example, planning approaches in project-based environments are typically linear, thus missing the importance of overlapping phases and iteration. The availability of relevant expertise is thought to be crucial for the success of innovation projects, but project-based companies appear to select their employees on the basis of availability, instead of expertise. Business cases, and testing and launching a new service, appeared to be lacking in the case-studies and were therefore considered points of particular interest for project based industries (ibid.).

Ibert (2004) has discussed the differences between projects and firms, and their respective innovation capacities, from the point of view of organisational learning. The organisational learning of a company is considered crucial in explaining the existence and performance of organisations. The capacity to store knowledge is a strength of the functionally organised firm, but it prevents flexibility in adapting necessary new knowledge as well. With regard to project-based organisations, it is thought that projects are by nature "problem-solving", and that innovation and learning behaviour are therefore already part of the organisation. In a case-study on the software ecology of Munich, Ibert demonstrated that the interplay between projects and firms can, in an ideal situation, complement each other in their strengths and weaknesses with regard to organisational learning. However, in practice, tensions between the two occurred, for example as a result of conflicting interests caused by the difference in the linear timing of the firm and the cyclical timing of the project. In the software ecology of Munich, senior managers wanted to have knowledge stored for the long-term benefit of the firm, while project team members were aiming to complete the project within the set budget and time schedule, and therefore could not afford to spend time storing knowledge. It appeared that firms are stronger in accumulative learning efforts, for example storing new knowledge in databases so that they can be used again in the future, while projects are better in reflective kinds of learning, for example challenging existing standards and replacing them by new ones.

The above experience, also demonstrates that projects have to be observed in their environment. Engwall (2002) emphasises the importance of the historical and organisational context when studying projects. A study aimed at identifying success factors for innovations in sustainable transport projects, concluded that it is predominantly the political, process-related, socio-cultural, and psychological factors that determine whether a project succeeds or fails (Van den Bergh *et al.*, 2007). When it comes to the successfulness of unbounded innovations, such as the introduction of 3D CAD technology, the social and organisational context need to be considered as well (Harty, 2005). The specific environment of the sectoral innovation system – consisting of project-based organisations in confrontation with functionally organised suppliers – can therefore significantly affect the success or failure of development and diffusion of innovations.

8.3 Firms and projects in the construction industry

The nature of ties between industries influences competitive performance and affects innovation (Porter, 1990). An analysis of network effects in the construction sector indicated that the construction sector seems to depend heavily on arms-length customer-supplier relationships, rather than partnerships (Dubois & Gadde, 2000). The generally chosen strategy of tendering to the lowest price supplier causes predominantly standardised solutions to be used. Although it is felt that this strategy results in delivering the lowest costs, Dubois and Gadde question this since in many markets only a few suppliers are available (ibid.). Furthermore, the tendering procedure itself involves high costs, spent on calculations that for a large part will not be used. Lack of interorganisational cooperation and price competition causes suppliers to focus on producing mainly standardised components, while the fact that only standardised components are available necessitates huge efforts to be made at site level to adapt these components to site-specific conditions. The heavy reliance on standardised products clearly limits efforts in innovation. Thus, the potential innovative power of the functionally organised supplier industry may be hampered by the business strategy chosen by the construction industry.

Whereas many scholars blame the construction industry for the lack of interorganisational cooperation causing in underperformance in construction innovation, somewhat contrary to this, Dubois and Gadde suggest that the construction industry suffers from typical construction problems stemming from site-specificity (Dubois & Gadde, 2002). In their view, localised decision-making and the need for local adjustments result in necessary tight partnerships in individual projects, and as a consequence loose partnerships in the permanent network, providing necessary slack (ibid.). Unlike functionally organised industries, where mass production is dependent on standardised tasks, construction work is based on using standardised components that require significant effort to be assembled for site specific products. Construction work therefore needs control of a diverse range of tasks, necessitating direct supervision by a line manager controlling a large number of specialised and differentiated tasks at the site-level (Shirazi *et al.*, 1996).

Product innovation in construction is mainly located upstream at building component producers and service suppliers, while the construction industry itself principally innovates in the organisation of the building process (Meijaard, 2001; Bougrain, 2003). For small project-based construction firms, which in many countries constitute the majority of construction firms, sensitivity to the cyclical movements of stages – such as survival, stability, and development – also largely determines the motivation to innovate (Barret & Sexton, 2006). Barriers to environmental innovation in construction can also be found in the interaction processes that occur between the numerous participants involved in a construction project. In studying the institutional barriers in terms of formal barriers, such as regulations, as well as informal barriers, such as interaction patterns between players in the decision making process, a number of barriers to environmental innovation can be distinguished (Bueren & Priemus, 2002). The fragmentation of the institutional construction process structure, where each phase is characterised by its own participants and rules, causes decision-making to be linked to, and dependent on, earlier decisions. This causes barriers to decisions that depend on early observations, such as those related to location development.

In their search for the influence of interorganisational relations in the construction industry and their economic performance, Miozzo and Dewick suggest that the strength of interorganisational cooperation may be responsible for the enhanced performance of the construction industry in some countries (Miozzo & Dewick, 2004). In their study, they showed that collaboration between contractors on the one hand, and subcontractors, suppliers, government, universities, architects, and clients on the other, differs significantly among countries. By means of case-study research, Miozzo and Dewick demonstrated that Denmark and Sweden have numerous strong relationships, while Germany, France, and the United Kingdom, in general, show weak collaboration activities. At the same time, Denmark and Sweden have much higher productivity levels than other European countries. Although not part of the case-study research, The Netherlands is mentioned as having a construction industry with weak interorganisational networks and average productivity level (Miozzo & Dewick, 2004). Holmen *et al.* studied two cases where interfirm cooperation on innovation was specifically intended (Holmen *et al.*, 2005). Their conclusion, however, is that a lack of trial and error – such as is available in functionally organised firms – causes difficulties in learning in projects, where coalitions shift with every project. They noticed that even while interfirm cooperation was intended in their cases, the relationships were loose, not expecting to benefit further in later projects (ibid.). Communication can be seen as a precursor for interorganisational cooperation, and as such is an important element in the process of innovation development as an exchange process of requirements from the user (contractor) and available technology from the supplier. In a study into the way Swedish component manufacturers handle innovation processes, and related areas of information and knowledge acquisition, it was stated that innovative companies have better information processes and have knowledge of what customers need (Larsson *et al.*, 2006).

The fact that the construction industry is mainly dominated by small firms that are not especially interested in building process innovation, and at the same time suffer from many institutional barriers to innovation, might lead one to think that in this sector cooperation on R&D is laborious. Kleinknecht and Reijnen (1992), however, demonstrated that R&D cooperation is a widespread phenomenon, and that firm size, market structure, R&D intensity, and high shares of product related R&D, have little impact on R&D cooperation between firms. In this respect, the notion of Welling and Kamann regarding vertical cooperation in the construction industry is interesting (Welling & Kamann, 2001). Based on game theory, it was stated that larger construction firms suffer from less opportunities to build up stable relations with subcontractors than smaller firms, because the chance to meet the same individuals as subcontractors over time reduces with the size of the firm.

Examples of interorganisational cooperation between contractors and suppliers are few, although they do exist, especially in countries that already have relatively significant amounts of relational exchange in general. In Denmark, for example, the first and second largest contractors, NCC Danemark and Skanska DK, have undertaken vertical integration with suppliers and specialist subcontractors, resulting in 40% of work being completed by in-house tradespeople (Miozzo & Dewick, 2004). Similarly, the fourth largest contractor in Sweden, JM, has signed a three-year contract with Kune, a Finnish supplier of elevators, establishing a fixed price for elevators (ibid.). In The Netherlands, a contractor working with a modular building system, De Meeuw, has integrated the work of its technical services provider in its work process (Harkink *et al.*, 2006). In this respect, an extensive long-term relational exchange has been organised that – according to the producers – reduces installation costs by 20% (ibid.). Interestingly, in contrast to the normal routines of the construction industry, this contractor assembles about 85% of its buildings in-house, and only 15% on site.

Prescriptive building regulations are thought to serve as a barrier to innovation in that improved or cheaper products may be developed, but they may not be able to be used in case they do not meet the exact prescriptive codes (Foliente, 2000). The power of energy performance regulations in encouraging innovation, however, assumes that the construction sector has an intrinsic motivation to innovate. In their discussion about performance based building and innovation, Sexton and Barret state that if relevant actors do not have the capacity, capability, and motivation to innovate, then actors will engage the performance based building approach in a passive and minimalist fashion (Sexton & Barret, 2005). Related to energy performance policy, a generally acknowledged problem is that the benefits of using innovative energy saving technologies are for the user of the building, rather than the contractor, thus limiting motivation in terms of energy technology innovation. Sexton and Barret also warn that obstacles arise from the existence and interpretation of performance-based building codes, since any new technology will need [government] approval, and considerable effort will be required to justify it as an innovative solution (ibid.).

Based on the literature, we can conclude that the construction industry suffers from a lack of interorganisational cooperation outside the scope of projects. Cooperation between construction firms and the supply chain is rare, although small firms potentially have better opportunities to meet the same individuals as subcontractors over time, thus encouraging cooperation on R&D. The fact that the project based construction industry has to deal with the functionally organised supply industry could, potentially, cause conflict, although, in theory, complementarity could allow both industries to help each other by sharing their strengths to obviate their weaknesses. Whereas energy performance regulations are thought to encourage innovation, obstacles exist in that new technology needs considerable effort to receive government approval, and regulations often assume an automatic motivation to innovate. Since communication can be seen as a precursor of cooperation, energy performance policy could play a part in encouraging communication between the construction industry and the supply industry, thus being a first step towards encouraging innovation in, for example, heating technology. In the next section, we will explain the extent to which these notions can be confirmed by interviews with stakeholders in the construction industry, and with manufacturers of heating technology.

8.4 Collaboration between contractors and suppliers in The Netherlands

For this study, we used a number of sources of qualitative empirical research. First, we used interviews with a wide range of actors in the Dutch construction industry, in order to get a broad view of the interaction between contractors and suppliers. We interviewed nine players, consisting of both single actors such as an architect, a construction company, a manufacturer of concrete products (including a heat pump integrated in pile foundations), a manufacturer of boilers, a manufacturer of a variety of heating systems, and a manufacturer of a solar heating system, as well as representatives of umbrella organisations such as Bouwend Nederland (the Dutch organisation of building contractors), Booosting (the network organisation that aims to encourage innovation in the construction sector), and Holland Solar (a network that aims to encourage the use of solar energy in the building sector). For heating technology manufacturers, the head of the product development department was interviewed. In construction companies, project leaders were interviewed. Since we focused on innovation in heating technology, suppliers were asked about the drivers for innovation. All interviewees were asked about the impact of energy policies, and the interaction between construction companies and supplying firms. In addition, we used the results from interviews with eight engineering consultants that were carried out for a study into energy performance advice in the framework of the EPBD. Finally, we were allowed to use the results of two discussion sessions, with contractors and policy makers in construction, about the functioning of energy performance regulations in The Netherlands, and the possibilities of reshaping this policy instrument[1]. The information collated from these sources provided us with a broad view of how

1 This study was commissioned by the umbrella organisation for Dutch contractors, Bouwend Nederland, in June 2007, carried out by W/E consultants sustainable building. The discussion sessions were attended by 17 companies of varying size and profile, such as contractors, installers, and engineering consultants.

the Dutch heating technology market for contractors and suppliers functions in general, and how the energy performance policy functions in particular.

Heating technology suppliers emphasised the importance of R&D, and consequently large R&D departments, in order to survive in the energy technology market. Product ranges can be completely renewed in a decade. Innovation largely consists of product refinements and efficiency improvements. Innovation is based on expected market demand, and one interviewee mentioned that (revisions to) energy performance policy form an important part of market expectations. Recently launched products include, for example, micro combined heat and power installations. In many cases, heat pumps have been added to product ranges in the last ten years, but it was acknowledged that this was not particularly innovative, as the technology has existed for a number of decades.

Partnerships in the heating technology manufacturing sector mainly consist of alliances with suppliers of non-competing techniques. One example of such an alliance is an inter-firm cooperation between a manufacturer of ventilation systems and a manufacturer of heating systems in creating a heat pump combined with a ventilation system. In another case, a Dutch manufacturer of heating systems and a foreign expert in cogeneration technology decided to work together on a micro combined heat and power (CHP) appliance. Relations with competing manufacturers exist – as one boiler manufacturer mentioned – when delivery to, as well as purchase from, competing manufacturers occurs frequently. None of the interviewees had any alliances with the construction sector. Communication with contractors is uncommon. In complex construction projects, heating systems are most commonly purchased by the engineering consultant hired by the project team to design the heating, ventilation, and air-conditioning (HVAC) system of the building. The engineering consultant, for his part, commissions the heating equipment installer. The installer contacts the heating technology supplier to arrange the purchase and delivery of the heating system. The installer does not usually have any incentive to use new technology. Moreover, the reliance on price competition in construction means that contractors select installers that offer the lowest prices. As a result, installers choose safe, low risk options and in turn ask manufacturers to supply equipment for the lowest possible price. In more simple projects, the installer decides which heating technology to use. In small projects, it is usually the architect or the contractor who decides on the heating technology to be used, mainly opting for solutions that have complied with energy regulations in previous projects. Communication therefore mainly exists between the manufacturer of heating systems and the engineering consultant, or the installer of HVAC equipment.

Manufacturers of heating technology mainly aim their communications at engineering consultants or equipment installers. Continuing education has to prepare installers for new products, and to make them aware of developments in heating technology. Brezet (1994) concluded, in his study on the diffusion of high efficiency boilers in The Netherlands, that installers often resist new technology since it effects work routines and introduces maintenance risks. Therefore, it is essential that manufacturers offer to educate installers, emphasising that they can use new technology in order to distinguish themselves as innovative firms. However, the dependency of manufacturers on installers in diffusing technology in the construction chain can be considered as a weak link. When a design team makes use of an engineering consultant, once more an extra layer in communication is introduced, since the engineering consultant then instructs the installer. The engineering consultant, however, usually has more knowledge about new technology and is not hindered by concerns about maintenance risks. As one of the interviewees pointed out, communication with contractors and architects is limited to the trade fairs where manufacturers present their technology. This situation differs from the supply of building materials, which are mainly purchased direct by contractors. One interviewee, a manufacturer of concrete products, mentioned that communication with contractors had changed significantly since the Dutch contracting fraud was scrutinised by the Parliamentary Enquiry Committee on the Building Industry (Parlementaire Enquetecommissie Bouwnijverheid, or PEB), and which published its final report in December 2002. The manufacturer mentioned that cooperation agreements were common before the contracting fraud scrutiny, but these days a certain fear has arisen which hinders the making of agreements. However, the manufacturer still has certain alliances with some contractors and is a 'preferred supplier' in some situations. The manufacturer has also created two firms dealing with concepts that involve contractors. A concept using heat pumps integrated into concrete foundation piles has been organised as a 'gentlemen's agreement' with a manufacturer of heat pump systems.

One of the interviewed construction companies is focusing on public private partnership (PPP) projects in order to tackle conventional construction business problems. In PPP projects, a government organisation is client of a new building, for example a school building or an office, and contracts a consortium to build and maintain the building for a long-term period, such as 30 years. By doing so, the consortium has greater incentives to build a high quality building, since the costs of construction can be recouped against the building's lower maintenance expenses. The interviewee explained that part of the strategy in winning PPP projects was to expand their construction business with related businesses, such as engineering consultants, in order to ease the creation of a consortium. In fact, this can be seen as being interorganisational cooperation, or even as a redesign of a dispersed construction business into a more integrated design and construct enterprise. Interestingly, the interviewee mentioned that, in PPP projects, energy performance policy was not taken into account since it was beneficial to invest in buildings that were more energy efficient than required by the energy policy, in order to reduce service costs for the 30-year maintenance period. In PPP projects, it is possible that a supplier occasionally takes part in a consortium, but contacts are usually limited to one specific partner in the consortium. In the case of heating technology, it is mainly the engineering consultant who contacts the heating technology supplier.

8.5 Impact of energy policies in encouraging new energy techniques

When asked, most interviewees regard Dutch energy policy as encouraging innovation, with high efficiency gas condensing boilers and high efficiency double-glazing being cited as examples of innovation. However, high efficiency gas condensing boiler technology (with efficiencies of 95% on Higher Heating Value (HHV), and 104% and 107% on Lower Heating Value (LHV[2]) was already available when energy performance policy was introduced in The Netherlands in 1996. One of the manufacturers mentions that "the high efficiency gas condensing boiler with a LHV of 107% would also have been here today without energy performance policy, since this was an ongoing development since the first high efficiency boiler was introduced in 1981". This is in line with findings of earlier research where the correlation between the tightening of energy performance policy and the use of high efficiency gas condensing boilers was studied: see Chapter 7 (Beerepoot & Beerepoot, 2007). Here, a correlation of approximately 20% was found between energy performance standards during 1996 to 2003 and the use of high efficiency gas condensing boilers in new residential building. This suggests that energy performance policy has contributed, to some extent, to the diffusion of this technique, but that other factors, apart from energy performance policy, explain about 80% of the diffusion. Since the study by Beerepoot & Beerepoot excluded the influence of gas price development, economic development, and subsidies, one of the remaining factors might be the autonomous technological development highlighted by the heating technology manufacturer.

Energy performance policy hardly resulted in increased communication between contractors and heating technology suppliers. Communication between these two parties is uncommon, since the contractor hires an engineering consultant or installer who communicates with the heating technology

2 Higher Heating Value (HHV) - or gross calorific value - represents the efficiency of combustion, including the condensation energy of water vapour. European standards for gas condensing boilers are often based on Lower Heating Value (LHV), which excludes the condensation energy of the water, resulting in efficiencies of over 100% for condensing boilers.

supplier. Energy performance policy possibly created more communication between engineering consultants or installers and heating technology manufacturers, but these parties already have an automatic connection with each other. In the discussion sessions with construction industry stakeholders, it was mentioned that energy performance policy has become increasingly complicated over the years, and that architects have insufficient knowledge about current methodology. The energy performance indicator was considered as being too abstract, and a wish was expressed to have an indicator that correlates CO_2 emissions with the floor space of a building, so that larger buildings are penalised for generating more CO_2 emissions. Contractors were united in wishing to maintain the current situation whereby energy performance standards follow product developments from the heating technology industry, instead of provoking such developments.

Heating technology manufacturers differed in their opinions about the ease with which new technology can be approved for use in energy performance methodology. It was acknowledged that some system of guarantees is necessary, but some manufacturers thought the current system is not 'foolproof'. Municipal building authorities' lack of knowledge and the ease of demonstrating energy performance methodology compliance, present few barriers to those parties who are prepared to trifle with the rules. At the same time, it was thought that energy performance methodology acts as a barrier to innovative techniques that do not fit with the principles of the energy performance calculation method. The contractors expressed their aversion to the large number of declarations of conformity. In their opinion, these declarations can be realised too easily, resulting in promises that are not realised in practice.

Interviewees differed in their opinions about the functioning and effectiveness of energy performance policy in The Netherlands. As one manufacturer of heating technology puts it, "energy performance calculation is increasingly detailed, while the basic idea of energy conservation in building is rather simple". Another manufacturer, however, saw benefit in energy performance policy in marketing their products, and in thinking about the cost-effectiveness of products in relation to energy savings. The architect representative of the innovation network did not see a significant difference in the energy performance approach when compared to prescriptive solutions. As well as prescriptive solutions, the energy performance approach is used as a fixed concept of solutions for the average building project. When the standard was tightened in 2000, the solution consisted of high efficiency boilers, balanced ventilation systems, and average insulation levels. Trade-off in technologies is hardly used in the architect's practice. The representative of the solar energy network had positive expectations for the effect of energy performance policy, and was of the opinion that energy policy directly influences product development.

The majority of the interviewees criticised the Dutch subsidy system for innovations in energy technology, such as solar thermal systems, and photovoltaic systems. Subsidies have existed since the early 1990s, and they have increased during this decade with some measure of escalation in the early years of the new millennium. At that time, photovoltaics were subsidised to such an extent that their price did not reflect the actual cost price to any degree. In 2003, subsidies were suddenly cut to zero. This unstable subsidy policy is seen by many interviewees as being disruptive to heating technology product development. However, in the case of the solar thermal system, one manufacturer was critical about the effect of subsidies. The Dutch government started to promote the use of solar thermal systems in the early 1990s by showing predictions on the use of solar thermal systems in steep growing curves. However, more than fifteen years later, solar thermal systems have still not reached such large scale diffusion. According to the critical manufacturer, solar thermal technology is simply too expensive and offers only minimal energy savings.

8.6 Discussion and conclusions

Although the nature of project-based industries appears to contain elements of 'problem-solving', thus potentially encouraging innovative behaviour, in the construction industry many obstacles prevent this potential from being realised. The prevalent strategy of tendering to the lowest price supplier engenders a situation in which only standardised solutions are used. The project-based nature of construction implies that project teams, consisting of many participants, operate closely together during projects, while partnerships disintegrate when projects have ended. Even when inter-firm cooperation on innovation was specifically intended, it failed to make a difference from ordinary contracting relationships, and they still ended the same way as before. With regard to the supply sector, the construction sector seems to depend heavily on arms-length customer-supplier relationships, rather than partnerships. Therefore, the function of energy performance policy could be important in creating necessary communication between participants in the building process, especially where the nature of organisations differ as much as the project-based contractor and the functionally organised heating technology supplier.

The construction industry and heating technology suppliers differ fundamentally in nature, but in theory they could complement each other in their strengths and weaknesses with regard to organisational learning, which is considered crucial in explaining the existence and performance of organisations. However, conflicting interests – namely the differences in the linear timing of firms and the cyclical timing of projects – may create tensions in practice. In the construction industry, another problem arises even before conflicting interests can spoil possible synergy. This study demonstrated that communication between decision makers in the design process and heating technology suppliers is rare, and that multiple layers of communication exist in the building process. In the case where an engineering consultant is hired, the consultant instructs the installer, and the installer buys the heating equipment. In more simple projects, it is the installer who decides on the heating installation. Installers, however, have little incentive to choose innovative techniques, since they usually also maintain the installation. The accusation that is often put to installers of them being too conservative is a consequence of the strategy of tendering to the lowest priced sub-contractor. As a result, installers choose the safest options with the lowest levels of risk, and, in turn, ask manufacturers to offer equipment for the lowest possible price. There is a lack of cooperation between contractors and heating technology manufacturers, and consequently there is little incentive to innovate. Energy performance policy has hardly resulted in any increased communication between contractors and heating technology suppliers, but possibly created more communication between engineering consultants or installers and heating technology manufacturers. At the same time, the effect of energy performance policy on the implementation of recent innovations, such as high efficiency gas condensing boilers, is being criticised by the manufacturers of such equipment. It was stated that increases in efficiency were attributable to the continuous development of the high efficiency boiler since its introduction in 1981, and that these increases would probably have occurred irrespective of whether an energy performance policy had been enacted or not.

Notwithstanding the effect that energy performance policy has in reducing energy consumption for heating, cooling, and ventilation in building, it cannot be regarded as having encouraged communication between contractors and heating technology suppliers, or as having promoted innovative behaviour between these two parties. Where energy performance policy is addressed at the contractor, it is expected to influence innovation in heating technology. This effect, however, appears to be rather small, if not negligible. Heating technology manufacturers operate in a highly competitive market and on a European scale. Energy performance policy on a national level will therefore only influence product development to a limited extent, although manufacturers will use the policy as a marketing tool in the national market. In the case where energy performance policy 'follows' product developments – instead of inspiring product developments through the setting of exacting standards – manufacturers will hardly initiate product innovations as a result of energy performance policy. Energy performance policy can even hinder product development since products have to adhere to energy performance calculation principles. This can create a 'lock-in' effect, as it promotes traditional domestic energy technology.

The distance between decision makers in design teams and heating technology suppliers, as well as suppliers of other HVAC equipment, could potentially be reduced by opting for the vertical integration of sub-contractors, such as engineering consultants or installers. A few examples of such integration have been found with PPP projects and with some large contractors who have undertaken vertical integration with suppliers and specialist subcontractors, resulting in about 40% of work being executed by in-house tradespeople. Whether vertical integration in construction businesses improves communication between contractors and suppliers, and thereby increases innovation from suppliers, is yet another research topic worthy of exploration in the future.

The effect of energy performance policy as an incentive for heating technology innovation has proven to be limited. Energy performance policy could possibly lead to more innovation if further dynamics were added to the policy, for example by encouraging performances that go beyond the standard, or by enlarging the scope of the standard not only to the building itself, but also to the generation of, for instance, electricity or other energy carriers. By doing so, the contribution of energy performance policy could exceed the level of energy savings in the building, and prove to be a useful element of the policy toolkit that will be needed in order to reduce climate change. There is a need for more discussion on the effects of energy performance policy, and the opportunities to 'stretch' the boundaries of such a policy, instead of making promises that cannot be fulfilled whenever an energy performance policy is introduced or tightened.

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9 Conclusions

9.1 Introduction

The introduction to this study provided an understanding of the importance of energy savings in the building sector in relation to the problems of climate change. It was argued that in the European Union the building sector accounts for about 40% of total energy demand, and that, in absolute terms, energy consumption in this sector is steadily growing. Building regulations are a general means of tackling building related energy consumption, such as for space heating, hot water, and ventilation. A common development in energy regulations in many countries is the adjustment towards a performance approach, simultaneously integrating aspects of energy equipment efficiency with insulation levels. The performance approach is considered to provide for more freedom in choosing solutions, thereby encouraging innovation. The European Union decided on a communautary approach for energy regulations by means of directive COM/2002/91/EC, also known as the Energy Performance of Buildings Directive (EPBD). This directive is expected to contribute to the energy conservation targets that have been developed on a European level, as well as in nearly all nations, in order to mitigate climate change. Today, understanding is growing that severe energy conservation is needed, and that ultimately a transition towards a sustainable energy supply system is required. A transition towards a sustainable energy supply system can be realised by new environmentally benign technologies that, for example, make use of renewable energy sources such as solar energy, wind energy, or geothermal energy.

The energy performance approach can contribute to a transition towards a sustainable energy supply system if it proves that it is able to encourage innovation, and promotes the search for new environmentally benign technologies. This research therefore aimed to study the content of energy performance policy, and its effects in encouraging the use of innovative techniques, and ultimately discusses the contribution of energy performance policy in mitigating climate change.

Following the aims of this study, the research questions can be divided into three groups (see Figure 9.1). The first part of the research consists of a descriptive analysis concentrating on the content of energy performance policy, and covers the following research questions:

1 *What lessons can be learned from comparing experiences in energy policies for residential buildings in European member states?*

1.1 What energy policy designs for new residential building are available in northern European member states, and what are the implementation demands of EU Directive 2002/91/EC?(Chapter 3)

1.2 What possibilities exist for encouraging renewable energy technologies by means of energy performance policy? (Chapter 4)

1.3 What energy conservation effects can be expected from introducing energy performance labels for existing residential building? (Chapter 5)

The second part of the book focused on evaluating the innovation effects of energy performance policy, and covered the following research questions:

2 *What is the relation between energy performance policy and innovation in energy technology, and what influence can be observed from the sectoral innovation system of the construction industry?*

2.1 What is the effect of energy performance policy for new residential buildings in the diffusion of solar thermal systems? (Chapter 6)

2.2 What are the innovation effects in heating technology of energy performance regulations for new residential buildings in The Netherlands? (Chapter 7)

2.3 What is the effect of the interplay between projects and firms in the sectoral innovation system of the construction sector in relation to energy performance policy and the diffusion of innovation in heating technology? (Chapter 8)

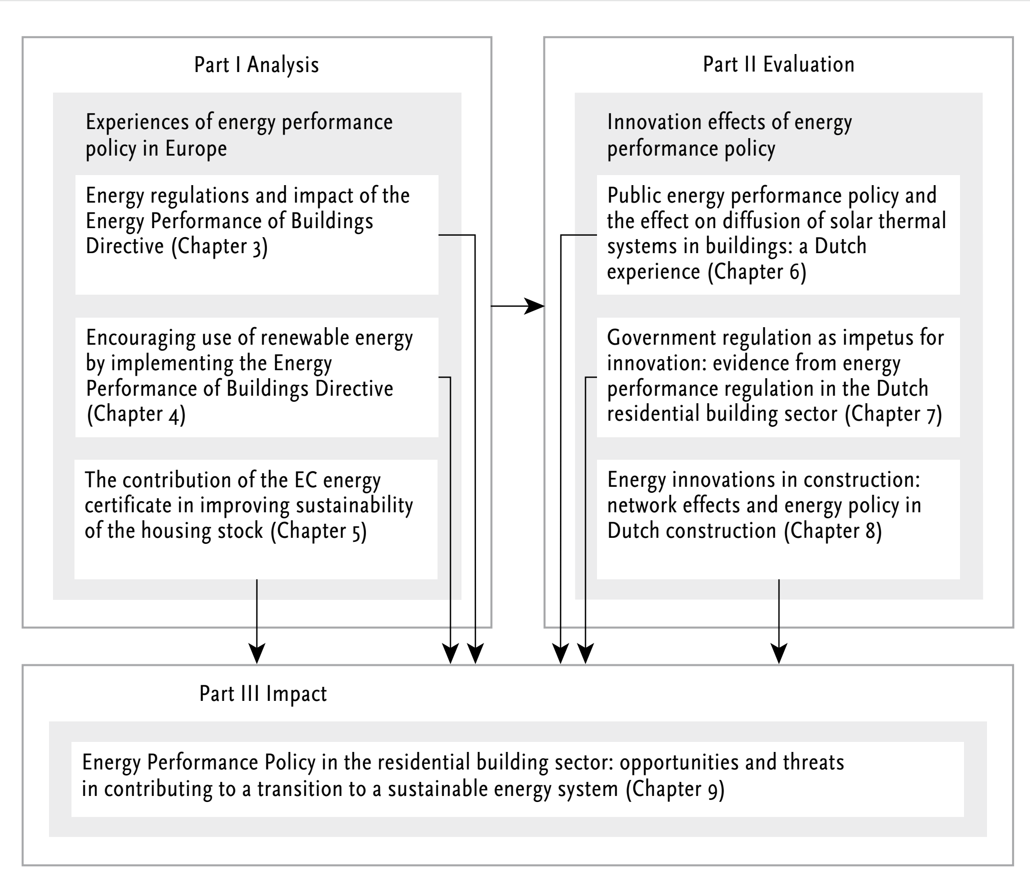
The third part of the book consists of the final chapter, which brings the research of Chapters 2 to 8 together in explaining the impact and possibilities of government policy for energy conservation in the building sector. It covers the following final research question:

3 *What is the benefit of energy performance policy in relation to other possible solutions, what is its relation to mitigating climate change, and to what extent might more intensive government intervention be justified in reducing greenhouse gas emissions in the residential building sector?* (Chapter 9)

This concluding chapter summarises the main findings that this research has generated. First, the findings of parts I and II of this study are discussed. Based on the findings of parts I and II, the benefits of energy performance policy in relation to other possible solutions, and its relation to climate change policy, are discussed in what is defined as part III of this book. This will lead to recommendations for energy policy contributing to future sustainable energy systems. We based our research on The Netherlands, as The Netherlands is known for having had years of experience of energy regulations, and, more specifically, with energy performance regulations (see Chapter 3). The Netherlands therefore provides a suitable case for evaluating the effects of energy performance policy for residential buildings.

This study has focused on the effect of energy performance policy for residential buildings, since it faces different challenges compared to the non-residential building sector. Non-residential building is mostly commissioned by the owner of the building, thereby warranting incentives to use energy efficient technologies. Investments in innovative technologies can be recouped

Figure 9.1 Research structure



during the lifetime of the building. Residential building in The Netherlands is only directly commissioned by clients on a small scale. In most cases, the investor is different from the person who profits from the building's energy saving features, and the client is hardly involved in the decision making process at all. Another difference between residential and non-residential building follows from the higher occupancy rates of non-residential building, which – in combination with the extensive usage of computers, printers, and other such appliances – results in a considerable internal heat load. Energy demand of non-residential buildings – also in a northern European climate – therefore consists, to a large extent, of a need for cooling. The fact that there is a more direct relationship between commission and ownership in the pattern of energy demand for non-residential building, means that innovations, such as heat pumps taking care of both heating in winter and cooling in summer, seem to have been primarily focused in non-residential, rather than residential building. As a result, the diffusion of energy technology innovations in residential building faces more constraints than in non-residential building, and is therefore worthy of exploration.

In this study, we concentrate on building regulations. Building regulations impose constraints on the physical appearance of the building, thereby providing optimal conditions for energy conservation with regard to energy use for space heating, domestic hot water, and ventilation. The actual total energy consumption per household, however, is determined by the size of the household, the household's behaviour, and electricity usage as dominated by appliances. In The Netherlands, the use of natural gas (used for space heating and domestic hot water) decreased by about 45% between 1980 and 2004, while electricity usage increased by 24% between 1988 and 2004 (ECN, 2007). Electricity consumption can hardly be influenced by building regulations and correlates highly with affluence. Changing consumer behaviour can be an important factor in realising energy conservation targets, but it also faces significant challenges. High price elasticities, for example for gasoline and airline tickets, cause huge difficulties in trying to disconnect increasing worldwide prosperity from the subsequent increase in energy consumption that such prosperity brings. We did not aim to solve these unprecedented and highly complicated matters in our research, although we have tried to place our results in the broader perspective of mitigating climate change.

9.2 Analysis of energy performance regulations

Question 1: *What lessons can be learned from comparing experiences in energy policies for residential buildings in European member states?*

9.2.1 Energy regulations in Europe

Question 1.1 *What energy policy designs for new residential building are available in northern European member states, and what are the implementation demands of EU Directive 2002/91/EC?* (Chapter 3)

The comparison of energy regulations in eleven EU member states shows us that experience with energy performance policy is available to some extent, although only a few member states use the energy performance approach as a singular method for demonstrating compliance with building regulations. Before the introduction of the EU Energy Performance of Buildings Directive (EPBD) in 2003, only five member states made use of an energy performance approach, while in not more than three member states no other options were provided in building regulations. The Netherlands is the only member state that introduced the energy performance approach before the new millennium, as the only method for proving compliance with regulations. The comparative analysis also demonstrated consistency in the development of energy regulations for buildings during the last three decades, in the member states that formed part of the analysis. Many member states introduced energy regulations in the wake of the oil crisis in 1973-1974. The first thing to be regulated was insulation levels in separate building parts, such as roofs, windows, façades, and floors. This prescriptive method provided no other choice than meeting the requirement for each building part. As regulations developed, the next step was towards a requirement for the overall insulation level of a building, expressed by means of a heat loss calculation. This provided the opportunity for reciprocity between insulation levels in the separate building parts. Afterwards, regulations shaped as a requirement for the heat demand of a building came into use, considering – besides the overall insulation level – heat supply by means of internal heat production, and solar gains as well. The final step in the development of energy regulations, for the moment, appears to be the energy performance approach which takes into consideration the heat demand of a building, as well as the efficiencies of the equipment that provides for space heating, domestic hot water, and ventilation. This four-step development in energy regulations is complementary, and each of the stages of this development can be found in the eleven member states that formed the comparative analysis (see Figures 3.1 and 3.2). This development, during the last three decades, in energy regulations for buildings cannot really be considered a convergent or divergent maturation since it appears to be a similar – rather linear – pathway. The differences in the extent to which each of the four steps have been completed in the member states seems to be a matter of differences between laggards and trendsetters. More uniformity in energy regulations for buildings will ultimately arise as a consequence of the Energy Performance of Buildings Directive that requires all 27 EU member states to introduce energy performance regulations by the year 2009.

Advanced experience, however, does not always imply a lead in implementing European directives. The dialectics of progress can hinder a member state that has already designed regulations when it comes to adjusting them to meet the demands of European legislation. It is suggested that The Netherlands has had problems with implementing European environmental legislation because it has been a forerunner in national environmental policies (Rood *et al.*, 2005). Another argument is that since The Netherlands has demonstrated itself to be a forerunner in environmental policies – especially during the 1990s – Dutch representatives in Brussels seem to be over ambitious during negotiations, neglecting the fact that political reality might not be able to support high environmental ambitions. This also seems to have happened with the implementation of the EPBD in The Netherlands. While the directive is partly designed in accordance with Dutch examples, The Netherlands did not meet the implementation requirement on 4 January 2006, and seems to need postponement until January 2009. On 25 August 2005, political reality caused the Dutch Council of Ministers to reconsider the decision to implement the EPBD, resulting in a reprimand from the European Commission. Advanced experience in using energy performance regulations does not necessarily go together with a higher rate of energy efficiency, since, in this respect, experience is related to using a method, and not to the standards that are imposed on the construction sector. A study that was conducted in 2000, demonstrated that insulation levels in The Netherlands were average at that time when compared with Denmark, Germany, and the United Kingdom (Beerepoot, 2001).

The argument about the 'dialectics of progress' is also used to explain the ease by which new European member states appear to be able to adjust to European environmental legislation. New European member states come from a lower state of economic development and therefore have limited energy performance policy experience; although such experience might extend to an early stage energy policy dealing with issues such as heat loss calculation, or heat demand calculation. Following on from the discussion above, this does not necessarily erect a barrier to the implementation of the EPBD, but moreover could even facilitate the implementation of this directive.

What we have also learned from the comparative analysis is that the energy performance method in itself offers several options in terms of the design of the regulations. One option of specific interest, which may be subject to political choice, is the option to compensate for the size of a building. Most member states have decided to enable similar assessments for all types of buildings, thus not discriminating against large residential buildings over small ones, so long as they use the same energy related features. However, Denmark decided to promote compact designs – thereby doing more justice to actual energy consumption by having a direct relation to the size of a building – and did not use an area-dependent term in their Energy Frame method. In The Netherlands, the compensation for the heat loss surface of a dwelling is currently being discussed. Some state that the abolition of compensation for heat loss surface and the introduction of an energy performance requirement per m^2 will result in an improved relation to actual energy use and will encourage more investment in energy equipment in (large) dwellings where these investments can be afforded. The measurement of the output of the energy performance calculation – whether in MJ/m^2 or in CO_2/m^2 – is also under discussion in The Netherlands.

Another political choice can consist of the extent to which a trade-off between insulation and heating, and air-conditioning and ventilation (HVAC) technology is allowed. Some feel that more attention should be devoted to building insulation levels, since these features are hard to improve after construction. Installations for hot water and heating, on the other hand, have fairly short life spans of some 15 years. Even so, few countries currently impose regulations regarding minimum standards for boiler efficiency at the time of replacement. Another argument that is used to stress the importance of sufficient insulation is that several innovative heating techniques, such as the heat pump, make use of low temperature heating and require good insulation levels in the building. Such techniques may not be feasible as yet, but they will be in future. When heat pumps replace the boiler systems that are currently in use, insulation levels will need to be subject to high insulation requirements. Given this discussion, the idea of a separate standard for transmission loss within the energy performance calculation (such as that used in Germany) could be worth considering.

The question as to which level of complexity of energy performance calculation is preferable is a difficult one, since both options have their advantages and disadvantages. The argument against a more complex calculation is that the more complicated the energy performance calculation is, the fewer people who will be capable of understanding it; as such, architects and developers could lose interest in energy aspects of buildings. It should be kept in mind that the energy performance calculation is input for a policy instrument that aims for comparing buildings in their energy efficiency. On the other hand, it is assumed that the most realistic possible method for calculating the efficiency of installations will give installation manufacturers an incentive to improve the efficiency of their installations. In conclusion, a balance is needed between insight into energy issues for architects and developers and a realistic calculation aimed at promoting product development. Moreover, a direct relation exists between the complexity of the energy performance calculation and the capability of building control to check compliance. Complex issues in energy performance calculations that do not relate to product development, such as detailed calculations of shading of windows, should, therefore, be reconsidered.

9.2.2 Using energy performance policy for encouragement of renewable energy

Question 1.2 *What possibilities exist for encouraging renewable energy technologies by means of energy performance policy?* (Chapter 4)

As we found in the comparative analysis of eleven European member states that the content of energy performance regulations is subject to a variety of possible options which can be designed in accordance with political choices, this also provides for opportunities in realising a design that encourages the use of renewable energy sources (RES) in buildings. Even before we can speak of specifically encouraging the use of RES by means of energy performance policy, a primary condition that needs to be fulfilled is that the policy needs to provide for the possibility to use RES, but not at the expense of the extra effort needed in relation to traditional solutions. RES equipment will have to be an option for many possible installations and cannot be discriminated against by means of extra-complicated procedures that have to be followed in order to complete the energy performance calculation.

A political choice for encouraging RES by means of energy performance policy can, for example, consist of favouring the use of RES equipment in the energy performance result. This may be criticised by building physicists who want such a calculation to be an exact estimate of energy use in a building. On the other hand, the energy performance calculation cannot be considered a building physics instrument, but has to be accepted as being a policy instrument. Even so, in The Netherlands the efficiency of district heating was underrated at first for political reasons, and was overrated later on for the same reason (Ligthart & Zijdeveld, 1995). In 2004, however, the Ministry of Housing decided that efficiencies of technology were no longer a responsibility for the ministry (Stoelinga *et al.*, 2004).

Related to the energy performance calculation, a number of options for combining energy performance regulations with regulatory, financial or information policies that promote RES have been identified. A rather simple step in promoting the use of RES is to provide explicit information in the output of an energy performance calculation about the contribution of RES to an energy performance rating. (Example: a statement that RES contributes X W/m^2, which represents X% of the total estimated energy use). This could be combined with the introduction of a RES label that could be issued for buildings that fulfil a certain energy consumption requirement (e.g., when RES contribute X% of the total estimated energy consumption). The RES label can be used as marketing instrument and serve as a selling point. The combination of financial incentives and energy performance regulations could take the form of subsidies or tax measures. Subsidy can be introduced for improvements over basic levels of energy performance rating or a subsidy for a specific RES contribution to the energy performance rating.

An ultimate option in encouraging the use of RES is the introduction of an obligatory share of RES in the energy performance outcome. Politically speaking, the introduction of regulations is often unattractive, as regulations are believed to hinder competition and impose barriers. On the other hand, such regulations can be remarkably successful if sufficient attention is paid to garnering public support for the scheme. A scheme that is often quoted today as being a successful example of imposing an obligation is the *Barcelona Solar Ordinance*, under which all new buildings have to be fitted with solar thermal systems capable of meeting at least 60% of the hot tap water needs (Barcelona City Council, 1999; Weijer, 2007). Regulations will probably only be considered when a problem is felt to pose a serious potential threat to society, and when other solutions are not considered to be sufficiently effective. Since climate change could pose such a threat, it is not inconceivable that efforts to promote more widespread use of RES will gain even greater priority on the political agenda in a number of years.

One of the main obstacles in encouraging the use of RES by means of energy performance policy is that many RES options consist of non-building related techniques, for instance wind power plants, biomass plants, or central heat pumps using heat from sources such as sea or river water. Energy performance policy – up to now – has been at building level only, and has principally rewarded RES techniques such as local heat pumps, roof-related photovoltaics, and solar thermal systems. The extension of the energy performance calculation towards site level can counterbalance this obstacle.

9.2.3 Energy performance approach for the housing stock

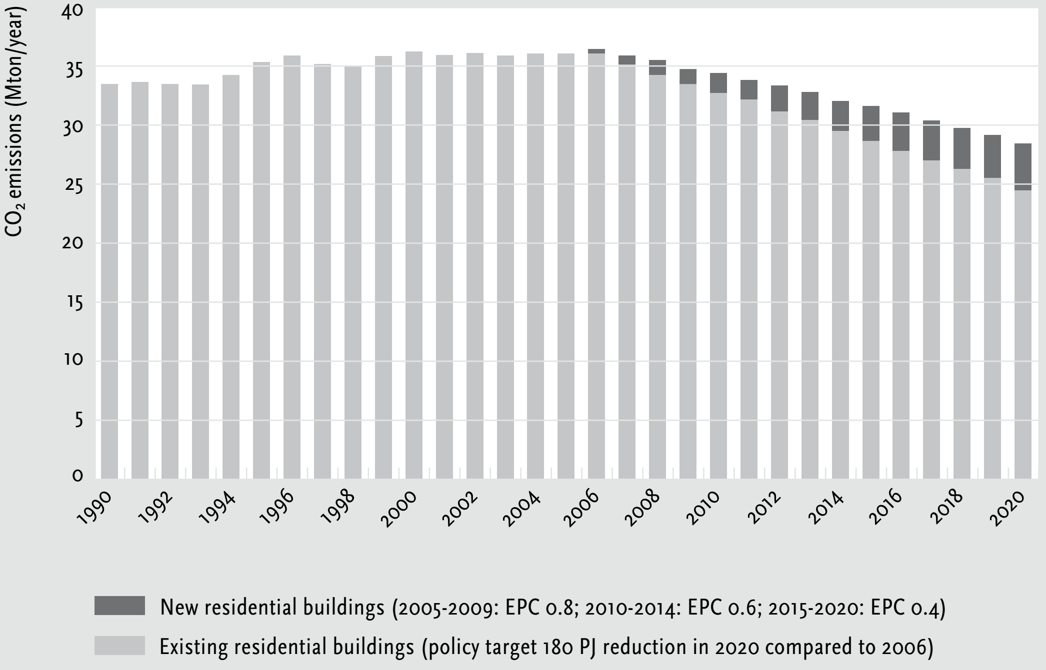
Question 1.3 *What energy conservation effects can be expected from introducing energy performance labels for existing residential building?* (Chapter 5)

One of the efforts asked from member states by the European Directive on Energy Performance of Buildings (EPBD) is the introduction of energy certificates – or energy performance labels – for new as well as existing building whenever these are sold or rented out (European Commission, 2003). The directive requires that an energy performance certificate, not more than ten years old, must be shown to prospective purchasers or tenants. The interest in approaching the building stock for realising energy conservation aims is dictated by the relatively poor energy condition of the building stock, and the cost-effective potential of implementing energy savings measures. Besides, the building stock represents a large share of energy use of the total building sector. Figure 9.2 demonstrates the share of energy use in the building stock compared to the energy use in the new residential sector in The Netherlands.

In the comparative analysis of eleven EU member states, it became clear that energy regulations for the housing stock hardly existed. At the time, a combination of an energy certificate and a subsidy scheme existed in The Netherlands, whereas a compulsory energy certificate, without subsidies, was used in Denmark. Based on experiences with these schemes, it can be concluded that it is very hard to estimate the actual savings that have resulted from the schemes. This is partly due to a lack of monitoring, but it also has to do with the fact that certificates are aimed at taking energy conservation measures at so-called 'natural moments', for example after a dwelling has been renovated, or a heating boiler has been replaced. Therefore, it is hard to indicate which measures are a result of the energy certificate, and which measures would have been taken anyway. Research in the past has demonstrated that subsidy schemes for energy conservation measures consequently suffer from a high share of 'windfall gain', meaning that many measures would also have been taken without the subsidy (Vermeulen, 1992; Beumer, 1993; Kemp, 1995; Jeeninga *et al.*, 2001).

The EPBD proposes mandatory energy certificates for buildings when selling or renting out a building, but it does not impose energy standards. This implies that the energy certificate will mainly function as a communication instrument, since the idea is to try to persuade people to voluntarily adopt

Figure 9.2 Energy use of the residential building stock with saving potential in building stock from 2006 to 2020 illustrated, and share of energy use in new residential building (built from 2006)*



* Figure drafted on the basis of energy models used for predicting energy use in the building sector (W/E consultants sustainable building, 2007).

environmentally benign behaviour. Communication instruments can be useful policy tools for addressing information problems, but they are generally considered to be additional policy instruments, and not substitutes for economic or regulatory policy tools (Kemp, 2000; Ekelenkamp *et al*., 2000). From the discussion of the innovation system in the construction sector, we found that the construction sector in general is characterised by market imperfections caused, for example, by the long life span and the location-bound character of a building. In The Netherlands, market imperfections in the construction sector have contributed to housing shortage ever since the Second World War. Exemplary of this market imperfection is the economic boom of the late 1990s, during which house prices in The Netherlands increased enormously, while at the same time production decreased (De Wildt *et al*., 2005). Whenever a shortage in the housing market exists, the energy consumption of a building will not be a decision criterion for a client. In these situations, the energy certificate will be unlikely to affect purchasing decisions, or encourage consumers to upgrade their houses' energy efficiency features in order to make them a selling point. In these situations, the information problem that is solved by the energy certificate is only one of many – far more important – problems.

It seems – right now – to be a step too far to impose energy performance limits for the housing stock. However, it is nothing more than a logical next step to look for such incentives in the future, for example by asking professional organisations such as housing associations, to make an effort. An advantage of the energy certificate is that it makes use of a scale ranging from 'bad' to 'good', thus providing incentives for benchmarking among professional organisations, and a means to formulate an organisational policy. The energy certificate is therefore a first-step development tool that can be used to effectuate energy conservation in the housing stock. However, this will probably only come into effect in the longer term when additional policies are attached to the scheme.

9.3 Evaluation of energy performance regulations: innovation effects

Question 2 *What is the relation between energy performance policy and innovation in energy technology, and what influence can be observed from the sectoral innovation system of the construction industry?*

9.3.1 Effect of energy performance policy for solar thermal systems

Question 2.1 *What is the effect of energy performance policy for new residential buildings in the diffusion of solar thermal systems?* (Chapter 6)

A database of 352 energy performance calculations – representing approximately 2800 dwellings – submitted to municipal building control for new residential buildings in the period from 1996 to 2003, and collected from various sources, provided the opportunity to analyse the effect of energy performance policy in The Netherlands. Since the database consists of calculations from 1996 to 2003, it covers three periods of the EPC regime: from January 1996 to December 1997 when the energy performance standard was set at 1.4; from January 1998 to December 1999 when the energy performance standard was tightened to 1.2; and from January 2000 to December 2003 when the standard was 1.0. The analysis of techniques related to the energy use of new residential buildings demonstrated developments in nearly all possible techniques related to energy use. Insulation levels improved for façades, floors, and roofs, as well as for windows. Ventilation techniques improved from systems based on natural inlet and mechanical exhaust, towards systems based on the same principal but using energy efficient fans for the exhaust. Gradually, a ventilation system based on mechanical inlet and mechanical outlet, combined with high efficiency heat recovery from exhaust air, emerged. With regard to heating installations, considerable progress was made in the efficiencies of gas condensing boilers. While it was still possible to use regular gas condensing boilers (efficiency 80% on higher heating value – HHV[1] in 1996 and 1997, that type of boiler disappeared after the first tightening of standards in 1998, and high efficiency (E-boiler107: efficiency 95% on HHV, 107% on LHV) gas condensing boilers became common after 2000. Heat pumps and district heating have also become more common over the years, although heat pumps have a relatively modest share.

The application of solar thermal systems increased slightly during these years. Statistical analysis of the correlation between the EPC regime and the installation of solar thermal systems does not, however, show a significant relationship between the two. The analysis did show a significant relationship between the EPC regime and the installation of heat pumps and district heating, as well as the use of high efficiency gas condensing boilers. Whereas the correlation between the EPC regime and heat pumps as well as district heating is marginal, the correlation with high efficiency gas condensing boilers is substantial, with 22% of the variance in applying the E-boiler107 accounted for by the EPC regime.

The above analysis seems to provide proof for the statement that energy performance policy mainly resulted in incremental innovation rather than in the diffusion of really new products, although the analysis only looked for correlation factors. Other factors that might possibly influence innovation were not part of the analysis. The increase in the application of solar thermal systems seems to be due to explanations other than energy performance policy and its twice-tightened standards. Since subsidy schemes and promotion campaigns appeared to be rather stable during the period from 1996 to 2003, the observed development could possibly be explained as an autonomous technological development, given that the penetration of solar thermal systems has steadily grown every year since their introduction in the early 1980s.

9.3.2 Innovation effects of energy performance policy

Question 2.2 *What are the innovation effects in heating technology of energy performance regulations for new residential buildings in The Netherlands?* (Chapter 7)

Since the initial analysis of the effect of energy performance policy in The Netherlands showed that it did not seemingly result in a higher diffusion rate of solar thermal systems, it summons for examinating the relative impact of the numerous factors influencing the penetration of energy technology by means of regression analysis. The empirical analysis showed a significant

1 The Higher Heating Value (HHV) – or gross caloric value – shows the efficiency of combustion, including the condensation energy of water vapour.

correlation between the EPC regime and both 'incremental' and 'really new' energy-saving innovations in hot water technologies in the Dutch residential building sector during the 1996-2003 period. Whereas the correlation between the EPC regime and incremental innovation was relatively strong (R^2 = 19.6%), that between the EPC regime and really new innovation (R^2 = 4%) was negligible, however. The logistic regression analyses confirmed these findings, showing at the same time that related factors, such as changes in domestic gas prices or in the amount of housing investment, had hardly influenced either incremental or really new energy-saving innovation in the Dutch residential building sector. The improvements in the efficiency of conventional technologies appeared to be sufficient to meet the tighter energy performance standard. The study thereby confirmed research indicating that non-stringent government regulation primarily results in the diffusion of incremental innovations. Further tightening of the energy performance standard in 2006 is expected to sustain this situation. New standards will continue to be achieved using conventional technologies such as gas condensing boilers, whereas new technologies such as heat pumps will only be used if they enjoy additional government support, for instance in the form of grants.

The analysis of the innovation system of the construction sector demonstrated that reasons for the underperformance of energy performance policy in the diffusion of innovations should not only be searched for in the moderate levels of the energy performance standard, or the lack of rewards for a performance that exceeds the standard. It is also the innovation system of the construction sector that causes obstacles to 'learning-rich' collaboration between various stakeholders, preventing tight partnerships from existing in permanent networks, since tight partnerships with other firms only exist for the duration of each project. The project phase is dominated by negotiation and heavy interdependence between the partners involved in the chain. Next, the sector is dominated by price competition and the risk of market failure owing to the long lifespan and the location-bound nature of buildings. Every construction job is unique, hence there are hardly any economies of scale. As a result of the complex nature and defensive character of the building process, builders are generally unable to be flexible in using different technologies in order to comply with the energy performance standard. It appears that the project-based nature of this sector does not provide a favourable environment for energy performance policy to be effective, given that technologies are sacrificed in favour of the most economically efficient solutions. This seems to be confirmed by the development where the building sector initiates projects looking for standardised solutions, in order to meet the energy performance standard that has become prevalent today (Hameetman, 2006).

9.3.3 Network effects of the Dutch construction sector in advancing innovation

Question 2.3 *What is the effect of the interplay between projects and firms in the sectoral innovation system of the construction sector in relation to energy performance policy and the diffusion of innovation in heating technology?* (Chapter 8)

Since we at first described the innovation system of the construction sector in general, we now focus on the elements of this innovation system that influence the penetration of heating technology. It appears, in this respect, that confrontation arises between the project based contractors that commission construction work and the functionally organised heating technology suppliers. The nature of ties between industries influences competitive performance and affects innovation. The construction industry and heating technology suppliers differ fundamentally in nature, but in theory could complement each other in their strengths and weaknesses with regard to organisational learning, which is considered crucial in explaining the existence and performance of organisations. However, conflicting interests, for example, caused by the difference in the linear timing of firms and the cyclical timing of projects, can impair the potential synergy. On the basis of interviews with stakeholders in the industry, it was demonstrated that communication between decision makers in the design process and heating technology suppliers is rare, and that multiple layers of communication exist in the building process. It is not even conflicting interests that impair potential synergy, but moreover the lack of common interests caused by the dispersed nature of the building process, and the subdivided responsibilities involved in the process, that prevent communication and hinder cooperation. This is especially true in regard to the implementation of heating technology, since these suppliers – in contrast with most suppliers of building materials – face multi-layered communication problems caused by the separate discipline of engineering consultancy in the building process.

Where energy performance policy is addressed at contractors, it is expected to influence innovation by heating technology suppliers. The effect, however, appears to be rather small, if not negligible. This seems to be confirmed by the sector itself stating that the high efficiency gas condensing boiler, with an LHV of 107%, was an ongoing development of the high efficiency boiler that was first introduced in 1981. Energy performance policy did not result in increased communication between contractors and heating technology suppliers, since these actors are not in direct contact with each other because of the organisational structure of the building process. Consequently, relationships between contractors and heating technology suppliers – which are often seen as a necessary precondition for innovation – are not encouraged by means of energy performance policy. Notwithstanding the effect that energy performance policy has in reducing energy consumption for heating, cooling, and ventilation in building, it cannot be regarded as having encouraged communication between contractors and heating technology suppliers, or as having promoted innovative behaviour between these two parties.

9.4 Impact of energy performance policy: contribution to mitigating climate change

Question 3 *What is the benefit of energy performance policy in relation to other possible solutions, what is its relation to mitigating climate change, and to what extent might more intensive government intervention be justified in reducing greenhouse gas emissions in the housing sector?* (Chapter 9)

9.4.1 Energy performance policy as a tool in climate change policy

The topic of reducing energy consumption in building is timely, and numerous policy plans have been developed introducing schemes and ideas that elaborate on this theme. This is stressed by the fact that the IPCC's recent fourth assessment reports have been taken more seriously than before (IPCC, 2007). Recent initiatives, such as the European proposal for an Integrated Energy Policy containing aims for the period to 2020, as well as further proposals for the period to 2050, indicate that the Kyoto Protocol to the United Nations Framework Convention on Climate Change is being accepted as an initial step towards the far more intensive efforts that will be needed in the future. Although it is still hard to say to what extent the Kyoto Protocol will indeed reduce carbon emissions by the end of the protocol period in 2012, it has already brought about some remarkable initiatives, such as a diverse range of emissions trading schemes. Emissions trading schemes exist, for example, in the United States, Australia, and the European Union, with the scheme of the EU being the largest multi-national scheme in the world. Although the scheme of the EU scheme started in the first phase (2005-2007) with an oversupply and free distribution of allowances, thus resulting in a collapse of the emissions market in April 2006, the European Commission is currently being tough on Member States' National Allocation Plans for Phase II (2008-2012), having, in June 2007, adopted the 22nd National Allocation Plan (DG Environment, 2007). An ultimate aim in combating climate change is the introduction of a global emissions trading scheme, although this is still a long way from being a reality since it will require a global level body – equivalent to the European Commission – to be founded in order to steer such a scheme. Other flexible mechanisms that have been introduced as a consequence of the Kyoto Protocol are the Clean Development Mechanism (CDM) and Joint Implementation (JI) scheme. The Clean Development Mechanism attributes credits to countries that realise emissions reductions in the so-called non-Annex I countries: developing countries that do not have Green House Gas (GHG) emissions reduction obligations. The Joint Implementation scheme allows industrialised countries with a GHG reduction commitment to invest in emission reducing projects in another industrialised country as an alternative to emissions reductions in their own countries, as the costs of emissions reductions are significantly lower in some countries.

The European Union is determined to play a leading role in the global efforts that are needed to mitigate climate change. In its meeting of March 2007, the European Council agreed on a European energy policy action plan and adopted ambitious goals to underline Europe's pioneering role in the field of global climate protection (Council of the European Union, 2007). Under the heading of 'Strengthening innovation, research and education', the European Council invites the European Commission to present proposals for achieving an integrated strategy for the promotion of eco-innovation early in 2008. Eco-innovations are expected to contribute to economic progress and to the mitigation of climate change, and are defined as sustainable and safe low carbon technologies, renewable energies, and energy and resource efficiency. The EU Prime ministers also agreed on an integrated Energy Policy for Europe (for EU-27), including commitments to increase renewable energy to 20% of primary energy supply by 2020 for the 27 EU-countries combined, increase energy efficiency by 20% by 2020, and increase biofuel in transport fuels in sustainable ways to 10% by 2020. They also agreed on a 30% reduction of greenhouse gas (GHG) emissions between 1990 and 2020, on condition that other countries also commit to reductions, with a view to reducing GHG emissions by 60-80% by 2050. If an international agreement is not possible, they agreed that the EU countries should reduce GHG emissions at least 20% for the period 1990-2020. With this message, the European Council wants to underline the leading role of the EU in international climate protection, and to express its serious commitment for a strong post-2012 agreement, for which negotiations will start at the end of 2007 at the UN international climate conference.

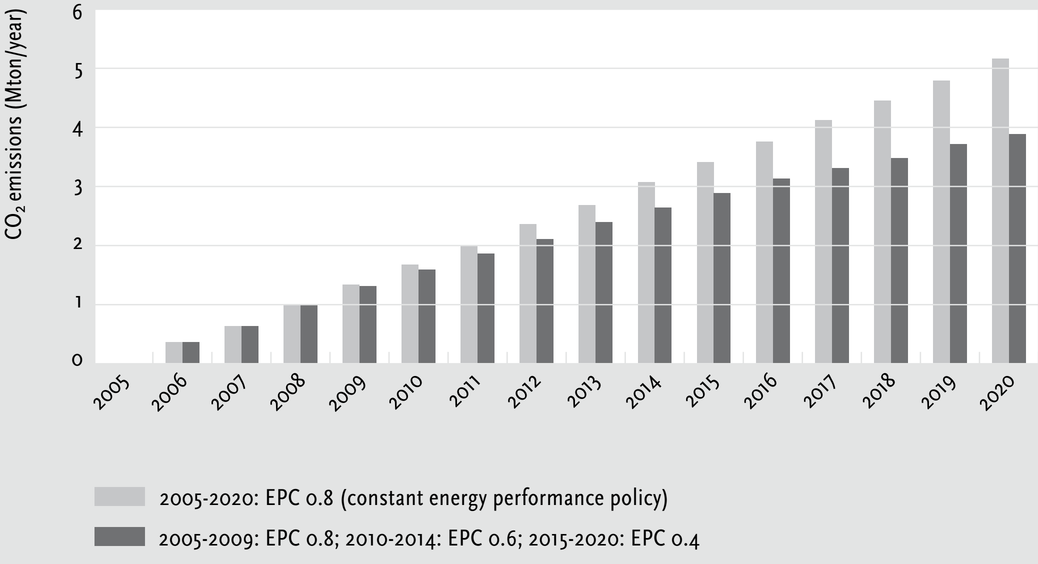
In The Netherlands, the recent national government plans, announced by the Dutch cabinet for 2007-2011, contain many elements similar to those presented by the European Council (Dutch government, 2007). Following the lead of the EU council, the Dutch government wants to achieve a 20% RES share of primary energy supply by 2020, a 30% reduction of greenhouse gas (GHG) emissions between 1990 and 2020, and yearly energy savings of 2%.

How do these global, European, and national developments relate to energy performance policy? In The Netherlands, energy performance policy is regarded as one of the tools that can be used to realise ambitious climate policy goals. The recent national government plans were accompanied by an announcement by the Minister of the Environment that a scheme for the further advancement of the energy performance standard will be introduced which will tighten the standard, in two stages, towards the figure of 0.4 by the year 2015. In quantitative terms, the effect of the energy performance policy has been calculated for the period 1995-2002, with efficiency improvements in new residential buildings estimated at about 17% (Joosen *et al.*, 2003). In absolute terms, the savings were estimated to contribute reductions of 0.2 Mton CO_2 during the period from 1995 to 2003 (ibid.). Other instruments also brought about reductions, such as the subsidy scheme for energy savings measures which contributed reductions of 0.3 Mton CO_2, while the largest savings – reductions of 3.5 Mton CO_2 – were ascribed to the energy tax scheme. In terms of the cost efficiency of these schemes, energy performance policy was estimated to cost the government about €9/ton CO_2, compared to €300/ton CO_2 for the subsidy scheme; the large difference being due to the fact that no financial transfers are required for energy performance policy. The subsidy scheme though was meant to recycle tax money to the community. The Dutch Kyoto commitment involves saving 50 Mton CO_2, of which 25 Mton CO_2 is to be realised on a national level (Ministerie van VROM, 1999). In this respect, the savings resulting from energy performance policy in residential building provide only a modest contribution to climate policy goals. However, the efficiency improvement of about 17% in eight years can be considered as being very positive, although part of this efficiency improvement[2] is attributable to autonomous technological development.

Energy efficiency improvements, by energy performance policy, seem to have come from the overall optimisation of all energy related features of the residential buildings. Insulation levels improved, although not spectacularly. Efficiencies of heating technology improved, although this seems partly to be a result of the ongoing development that started in the 1980s. The efficiency of fans used for ventilation improved, as did the efficiency of all sorts of auxiliary devices needed in heating technology, as well as the efficiency of heat recovery in balanced ventilation systems. Although energy performance policy seems to have contributed to the optimisation of all energy related features of buildings, it did not cause a breakthrough of innovative technology. Heat pumps are popular in demonstration projects, but are applied only marginally in the average building project. The same situation applies to solar thermal systems. Photovoltaics were handed out nearly for free during a period of about two years at the start of the new millennium, but as soon as the Dutch government stopped the scheme, photovoltaics were seldomly used in residential buildings. Looking at the data that have been collected in this study, we can say that it is unrealistic to claim that energy performance policy has created incentives for 'really new' technological innovation.

2 Autonomous technological development is often thought to consist of about 1% energy efficiency improvement a year (Hall & Kerr, 2003).

Figure 9.3 Comparison over 2005 to 2020 of energy use in new residential building in the Netherlands when tightening the energy performance standards in 2010 and 2015 compared to adhering to current standards*



* Figure drafted on the basis of energy models used for predicting energy use in the building sector (W/E consultants sustainable building, 2007).

Moreover, what will result from the recent plans of the Dutch government to tighten the standard on two more occasions in 2011 and 2015? Energy use for space heating, domestic hot water, and ventilation is predicted to decrease by 1.2 Mton CO_2 per year by the year 2020, when compared to what would have happened if the standard had not been tightened (Hoiting, 2007). Figure 9.3 compares the effects in energy use in the Dutch residential building sector of tightening the standards in 2010 and 2015, compared to the situation of maintaining the current standards.

The most recent tightening of the energy performance standard in 2006 will not result in a shift in the technologies applied. It is still possible to meet the standard by using conventional techniques, such as high efficiency boilers in combination with balanced ventilation systems. It is anticipated that high efficiency boilers will remain the most common heating technology used, even in 2020, while heat pumps are expected to take a share of only 10% in new residential building by 2020 (Boerakker *et al.*, 2005).

The proposal to tighten the standard in 2011 and 2015, as drafted by the Energy Research Centre of The Netherlands (ECN), is accompanied by a warning not to focus too strongly on installation driven solutions (Daniëls *et al.*, 2006). The recommendation is to demand an improved building design by imposing additional regulations for insulation levels and south-oriented designs, while preventing overheating and designing air-tight buildings (ibid.). This approach tackles one of the objections mentioned earlier on regarding energy performance policy, in that it does not take account of the fairly short life spans of installations in comparison to insulation levels and that – in accordance with the Trias Energetica – a reduction of energy demand is needed before the most efficient technology is adopted. This commendable approach, as foreseen by the Energy Research Centre of The Netherlands, will have, as a side-effect, the probability that, even when standards are tightened, it will still initially be possible to use conventional heating technology and reduced energy demand before adopting efficient technology. So even though the tightened energy performance policy will result in energy conservation – by following the recommendations of the Energy Research Centre – it will probably still have limited power to create incentives for technological innovation.

As we have seen in this study, it is not only the limitations of the energy performance scheme – which does not provide incentives for better than standard performance, and which elects to follow product development in making small schematic adjustments – that prevents the scheme from functioning as intended, but also the innovation system of the construction sector. Since the construction sector is trying to transform the energy performance scheme into a prescriptive scheme by developing standard concepts, it is questionable as to what extent the original intention of the energy performance approach – being considered a class above the traditional prescriptive approach – has been realised in practice. It provokes questions about what would have happened in current building practice if a prescriptive approach had not been chosen in the past, and if the efforts and costs of designing and redesigning energy performance methodology and numerous evaluation studies had not been needed.

9.4.2 Energy performance policy and the transition into a sustainable energy system

Energy regulations for buildings mainly aim to improve the energy efficiency of buildings. For a long time, the general perception has been that improving energy efficiency in our existing societal structures would be sufficient for solving climate change problems. However, today, increasing awareness exists that a more fundamental change is required and that our current production and consumption patterns, based on using fossil fuels, will need system innovation. In the Dutch National Environmental Policy Plan, transition pathways are seen as offering solutions for combating environmental problems in the long-term (Ministerie van VROM, 2000). In Rotmans *et al.* (2000), a transition is defined as "a non-linear process of social change in which the structure of a societal system – energy sector, water management, agriculture, mobility – transforms". Transitions in the past have, for example, occurred in the early 19th century when the shipping trade shifted from using sails to using steam engines. Similarly, in the early 20th century, a shift occurred in all industrial sectors from using steam engines to using electrical power. In terms of domestic energy use, in The Netherlands a transition can be marked in the

1960s when the use of coal for heating was replaced by central heating using natural gas (Correljé & Verbong, 2004). The principles behind transition management largely focus on providing a range of possibilities but without prescribing a specific solution (Rotmans *et al.*, 2000). Governments should set clear energy targets and goals, taking care to ensure that 'lock-in effects' or 'path dependencies' of a specific early-stage technology choice do not prevent other promising technologies from being developed and used. In Rotmans *et al.* (2000), it was therefore emphasised that current policies should be evaluated for their feasibility in encouraging new technology and offering opportunities to all possible solutions.

In reviewing energy performance policy from the point of view of transition management, there is cause for concern. Energy performance policy focuses on traditional calculation methodology, where new technology has to fit in for it to be able to receive acceptance – through a so-called 'declaration of equality' – by the energy performance standard. The energy performance standard can cause a 'lock-in' effect by encouraging techniques that fit in with the principles used by the energy performance policy, and penalising techniques that break with convention. Moreover, energy performance policy considers technology on a building level only, whereas promising techniques using renewable energy, such as wind power plants or biomass plants, operate on the neighbourhood or urban level. Solutions that provide for much more freedom are already available. In The Netherlands, a site level energy performance approach exists in the shape of a voluntary scheme that can be used for new urban developments (SenterNovem, 2007). From the point of view of supporting, instead of obstructing transition management, the reshaping of energy performance policy from building level towards an approach on site level is very much advocated, since this would create more openings for the deployment of efficient generation technology, and technology that uses renewable energy sources, such as biomass plants or wind turbines.

9.5 Recommendations

The need for drastic CO_2 reduction – being an objective that is difficult to realise only on a market basis – justifies the use of energy policies. Energy performance policy in its current shape will result in incremental innovation at the most, and reduced energy consumption of 0.2 Mton CO_2 over the period 1995 to 2003 as determined by Joosen *et al.* (2004), and 1.2 Mton CO_2 over the period 2006 to 2020 as predicted by Hoiting (2007[3]). In order to produce a new

3 Drafted on the basis of energy models used for predicting energy use in the building sector. Utrecht, W/E adviseurs duurzaam bouwen.

set of low-carbon technologies, incremental innovation alone will not suffice. Policy makers have to be aware that the effect of energy performance policy is limited, and that 'really new' innovations will not emerge unless policy standards are extremely stringent. While many recommendations regarding the content of energy performance policy and its opportunities to encourage innovation have already been mentioned in answering the research questions of this study, a few more are highlighted here.

The redrafting of energy performance policy for new housing can be realised in a number of ways. The simplest solution is to adjust the current scheme of fixed energy performance standards by adding incentives for improved performance. The easiest way to achieve this would be by introducing labels that indicate improved performance. Examples of such labels are the 'passive house' label, and the French 'HPE' and 'THPE' ('(très) haute performance énergétique/(very) high energy performance') labels. Combination with the energy certificate scheme, which is to be introduced as a requirement of the EPBD, is highly recommendable. Labels indicating improved energy performance can be labelled as 'A+' and 'A++'. Such labels can be offered as an extra option to clients and thereby introduce more client influence in a market that suffers from a weak demand side. Recognition by a national government body is required in order to ensure the acceptance of such a labelling scheme. The introduction of a labelling scheme could also help in preparing the market for tightened energy performance standards in 2011 and 2015. The extent to which labels are used could even indicate whether the market is ready for a tightening of the standards or not. Another approach for rewarding improved energy performance could be the offering of financial incentives. A simple subsidy scheme for improved energy performance existed in The Netherlands for a one-year period in 2002, but – as far as we know – it has not yet been evaluated.

In order to prevent the danger of lock-in effects and path dependency caused by the need to follow energy performance methodology, an 'escape route' can be introduced by extending the building level approach. The site level energy performance calculation could be used as an alternative to the building level energy performance calculation whenever options to use technology on the urban development level occur. In The Netherlands, such a method is already available and it can be used by a number of specialised offices that provide regular energy performance calculations. Schemes such as the one in Germany, which removes the obligation to submit energy performance calculations whenever it can be demonstrated that the share of renewable energy in the plan is more than 70%, can be useful in this respect. Ultimately, energy performance calculations – whether calculated on a building level or a site level – could function as equivalent options, the choice of usage being determined by the size of the building plan.

Furthermore, the recommendation of the Energy Research Centre of The

Netherlands to demand improved building design by imposing additional regulations for insulation levels and south-oriented designs, while preventing overheating and designing air-tight buildings is commendable. This approach tackles one of the objections mentioned earlier on regarding energy performance policy, in that it does not take account of the fairly short life spans of installations in comparison to insulation levels, and that high insulation levels are needed in order to allow for future low-temperature technologies to be fitted easily in the existing stock.

More far reaching ideas for improving energy efficiency in the building sector, while at the same time encouraging innovation, can also include dynamic systems such as emissions trading schemes. It could be worthwhile exploring the creation of an emissions trading market in the building sector, where project developers are given overall energy saving aims similar to the current ideas that already exist in the energy utility sector. This would provide the freedom to realise energy savings where they will be most cost-effective and beneficial, notwithstanding the requirement for a basic energy efficiency level set, primarily, through the means of insulation standards. It could allow developers to invest in a wind power plant on one site, while using more fundamental solutions on another. It could even possibly allow for energy savings to be bought from individual homeowners, thus encouraging energy savings in the housing stock as well.

The construction sector innovation system presents obstacles to 'learning-rich' collaboration between various stakeholders, preventing tight partnerships from existing in permanent networks, since tight partnerships with other firms usually only exist for the duration of each project. Besides, heating technology suppliers – in contrast with most suppliers of building materials – face multi-layered communication problems caused by the separate discipline of engineering consultancy in the building process. In residential building, contractors and installers do not usually have any incentive to apply new energy technology since the reliance on price competition in construction means that installers choose safe, low risk options and in turn ask manufacturers to supply equipment for the lowest possible price. Incentives are therefore needed to encourage contractors, as well as installers, to choose energy efficient technologies. The introduction of energy certificates, and, moreover, energy labels that go beyond legally binding targets, could encourage such development if the labels and certificates are presented in such way that they are communicable, allowing client demand for energy efficiency to come to the surface. Increased energy technology investment profitability for the contractor could be realised by the setting up of a building site energy management company, thereby gaining control over the energy used in the buildings on the site. This would resemble the public private partnership (PPP) projects where a government organisation is the client of a new building, for example a school building or office, and contracts a consortium to build and maintain the building for a long-term period, such as thirty years. By doing so, the consortium has greater incentives to build a high quality building, since the costs of construction can be recouped against the building's lower maintenance expenses. It could be worthwhile exploring similar schemes for residential buildings. Schemes that include responsibilities beyond the completion date of the project could also encourage vertical cooperation – between contractor and supplier – which would be seen as an incentive for innovation. Whether vertical integration in construction businesses improves communication between contractors and suppliers, and thereby increases innovation from suppliers, is a research topic that is worthy of exploration in the future. Finally, impediments to the diffusion of innovation resulting from the innovation system of the construction sector should be taken into account when drafting policies for this sector. Government policies could aim at influencing the 'rules of the game', bringing together different interests, and tackling the obstacles in sectoral innovation systems in project-based environments.

As well as incentives for the construction sector, it is also possible to think of incentives for the heating technology supply sector. Whereas energy policy is directed towards contractors, heating technology manufacturers are expected to innovate. As we have seen though, there is an enormous distance between contractors and heating technology suppliers. Soft approaches for heating technology suppliers can consist of labelling schemes such as the SEDBUK scheme in England and Wales.

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Summary

Introduction
In order to mitigate climate change, long-term targets for energy conservation will need to be severe and they will call on nations, industries, and consumers to make huge efforts. From this perspective, there is a growing awareness that in order to tackle the dangers of climate change in the longer term (30 to 50 years), a transition to a sustainable energy supply system will be necessary (Shackley & Green, 2007). A transition to a sustainable energy supply will need, on the one hand, a radical change in behaviour, and on the other, more environmentally benign technologies that preserve the natural environment. When energy performance regulations were introduced in The Netherlands in 1995, the Dutch government stated that this type of regulation would stimulate innovations in heating, ventilation, and air-conditioning (HVAC) technology (Ministerie van VROM, 1995). Given the importance of the development of innovations in energy technology and a transition to a sustainable energy supply system, it is necessary that policy instruments for energy conservation in the building sector stimulate the development and diffusion of really new and incremental innovations, or, at very least, prevent a 'lock-in' effect that makes it is difficult to deviate from using conventional techniques. Since a Europe wide energy performance policy for buildings is foreseen for the near future by EU Directive 2002/91/EC, known as the Energy Performance of Buildings Directive (EPBD), the innovation effects of such policy should be explored (European Commission, 2003).

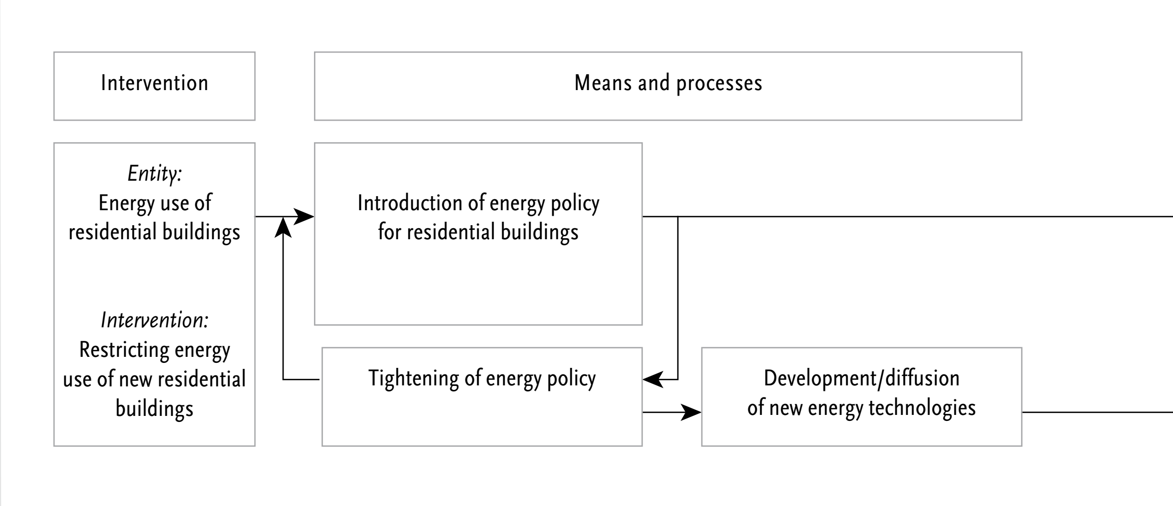
Consensus exists about the fact that more energy conservation investment benefits can be expected from the existing building stock than from new building. This is because the existing building stock exceeds the new building stock by far, and because the existing building stock was built under the relatively poor energy standards that prevailed at the time of construction. The EU directive 2002/91/EC mentions, as an additional requirement, that in the future all buildings should display energy labels, based on an energy performance type instrument (European Commission, 2003). This voluntary policy instrument is expected to contribute to energy conservation in the building stock.

The ultimate aim in terms of energy reduction in the building sector is to mitigate climate change (IPCC, 2007). To achieve this aim, innovation is needed on a large scale, going far beyond the scope of energy performance policy alone. A broader view, in terms of the building sector innovation system, is needed in order to make realistic long-term recommendations for encouraging innovation.

The research questions of this study can be divided into three groups. The first part of the research consists of a descriptive analysis concentrating on the content of energy performance policy, and covers the following research questions:

1 *What lessons can be learned from comparing experiences in energy policies for residential buildings in European member states?*

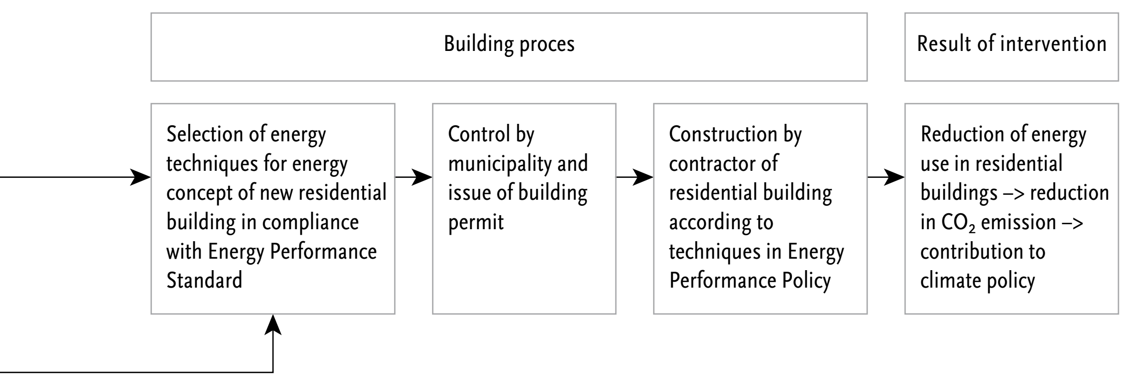
Figure 1 Energy policy process for residential building



1.1 What energy policy designs for new residential building are available in northern European member states, and what are the implementation demands of EU Directive 2002/91/EC? (Chapter 3)
1.2 What possibilities exist for encouraging renewable energy technologies by means of energy performance policy? (Chapter 4)
1.3 What energy conservation effects can be expected from introducing energy performance labels for existing residential building? (Chapter 5)

The second part of the book focuses on evaluating the innovation effects of energy performance policy and covers the following research questions:
2 *What is the relation between energy performance policy and innovation in energy technology, and what influence can be observed from the sectoral innovation system of the construction industry?*
2.1 What is the effect of energy performance policy for new residential buildings in the diffusion of solar thermal systems? (Chapter 6)
2.2 What are the innovation effects in heating technology of energy performance regulations for new residential buildings in The Netherlands? (Chapter 7)
2.3 What is the effect of the interplay between projects and firms in the sectoral innovation system of the construction sector in relation to energy performance policy and the diffusion of innovation in heating technology? (Chapter 8)

The third part of the book consists of the final chapter, which brings the research of Chapters 2 to 8 together in explaining the impact and possibilities of government policy for energy conservation in the building sector. It covers the following final research question:
3 *What is the benefit of energy performance policy in relation to other possible solutions, what is its relation to mitigating climate change, and to what extent might*



more intensive government intervention be justified in reducing greenhouse gas emissions in the housing sector? (Chapter 9)

Research approach
The research questions of this study have been approached using a variety of research methods. The study into experiences with energy performance policy in the EU is a descriptive comparative analysis on the basis of desk research and additional interviews. The core of this study consists of policy evaluation research. Here social research methodologies are used in order to judge and improve policies, and in order to assess the effectiveness and efficiency of such policies. Doing so, at first the policy process has to be mapped. We mapped the process of energy performance policy for the residential building sector according to the general model for evaluation research introduced by Mayer & Greenwood (Vall, 1987) (see Figure 1).

The illustration of the policy process helps to identify the causal relationships between the independent and dependent variables, which are the subjects of the evaluation research. In our research, we will identify the causal relationship that exists between the intervention, by means of imposing energy performance standards – the independent variable, and the development and diffusion of new energy technologies – the dependent variable. The Figure shows shows how the innovation effects of introducing an energy performance policy are primarily a side-effect of the actual policy goal of reducing CO_2 in the building sector, since the main goal of energy performance policy is the reduction of energy use in residential buildings as a contribution to climate policy. Many types of impact assessments are possible, but since we aim at scrutinising the long-term effect of the programme over a number of years, we have chosen to use both quantitative (Chapters 6 and 7) as well as qualitative research methods (Chapter 8). By means of a time series approach for which data have been collected during the period from 1996 – the introduc-

Table 1 Energy regulations in 11 European member states

	Unit approach	Heat loss calculation	Heat demand calculation	Energy use calculation
Belgium		Flanders (1993): 'K-level': dwellings only Wallonia (1996): Option 1: 'K-level': dwellings and non-domestic buildings Brussels (2000): 'K-level': dwellings and non-domestic buildings	Wallonia (1996): Option 2: heat demand calculation	(Flanders: Energy Performance Regulations, introduced 2006)
	(Wallonia (1996): Requirements for ventilation rates)			
Germany		EnEV (1 Feb 2002), condition 1: max. transmission losses	(Space Heating Demand + requirements for boilers: until 1 Feb 2002)	EnEV (1 Feb 2002), condition 2: max. yearly primary energy use
France		(Heat loss calculation GV: until 2001)	(Heat demand calculation BV: until 2001)	Option 1: Energy Performance Regulations + Thermal comfort in summer (Reglementation Thermique 2000) (2001)
	Option 2: Simplified procedure with 'technical solutions'			
The Netherlands		(Until 1996)		Energy performance regulations (1996, current standard for housing: 2006)
Denmark	Option 1: Max. U-values (BR '95/BR-S 98)	Option 2: Heat loss calculation (BR '95/BR-S 98)	Option 3: Energy frame/Heat demand calculation (BR '95/BR-S 98)	
England and Wales	(Ap. Doc. L 2002) Option 1: Elemental method (+ min. SEDBUK efficiencies)	(Ap. Doc. L 2002) Option 2: Target U-value (+ possible correction factor for boiler efficiencies)		(Ap. Doc. L 2002) Option 3: Carbon Index Method: SAP calculations

tion of energy performance policy in The Netherlands – until 2003, it is possible to indicate the diffusion of HVAC techniques in new residential building and use statistical techniques in order to assess the relative influence of energy performance policy. By means of interview-studies, explanations and opinions about the functioning of energy performance policy in The Netherlands have been elucidated.

Energy regulations and impact of the EU Directive: "Energy performance of buildings"

This research stems from an overview of energy regulations in eleven European countries in 2002, analysing their identities in terms of determin-

Table 1 Continued

	Unit approach	Heat loss calculation	Heat demand calculation	Energy use calculation
Austria	All *Bundesländer* (1995): Maximum U-values for construction elements		Almost all *Bundesländer* (1995): Alternative to unit-approach: a heat demand calculation, comparing the situation with the unit-approach requirements	
Finland	(1985-1997) Method 1: Unit Approach	(1985-1997) Method 2: Average U-value of the building		(2003: Method 3: Energy use calculation)
Sweden		(1994-1998) Average U-value of a building	(1994-1998) As an extra option, it is possible to show compliance by means of a trade-off calculation	
	(1994-1998) Additionally, prescriptive requirements concerning limitation of heat losses, efficient use of heat and efficient use of electricity are covered			
Luxembourg	*Wärmeschutz-verordnung* 1996 buildings < 200 m^2: Maximum U-values	*Wärmeschutz-verordnung* 1996 buildings > 200 m^2: k-level of a building		
Ireland	Option 1: Elemental heat loss method (TGD L 2002)	Option 2: Overall heat loss method (TGD L 2002)		Option 3: Heat Energy Rating (dwellings only) (TGD L 2002)

ing building energy use. (see Table 1). The European Commission is seeking to harmonise energy regulations by means of the most comprehensive level of integration of energy related aspects, known as the energy use calculation or 'energy performance method'. Currently, five member states make use of such energy regulations (The Netherlands, England and Wales, Ireland, France, and Germany), with only three states (The Netherlands, France, and Germany) using them as the sole method for complying with energy regulations. This implies that eight out of eleven member states will have to redraft their present energy regulations. Since the study dates from 2002, we did not take into account the member states which joined the European Union in the first and second waves of enlargement which led to the EU having a total of

27 member states in 2007. The new European member states are assumed to have a lower rate of economic development and therefore have limited energy performance policy experience; although such experience might extend to an early stage energy policy dealing with issues such as heat loss calculation, or heat demand calculation. The results of this study have made it clear that Dutch experiences of energy performance regulations offer the best case for evaluation research, since The Netherlands is the only EU member state to have introduced the energy performance approach – back in 1996 – as the only possible method for showing compliance with regulations.

Encouraging use of renewable energy by implementing the Energy Performance of Buildings Directive

As we found in the comparative analysis of eleven European member states that the content of energy performance regulations is subject to a variety of possible options which can be designed in accordance with political choices, this also provides for opportunities in realising a design that encourages the use of renewable energy sources (RES) in buildings. Even before we can speak of specifically encouraging the use of RES by means of energy performance policy, a first condition that needs to be fulfilled is that the policy needs to provide for the possibility to use RES, but not at the expense of more effort needed in relation to traditional solutions. RES equipment will have to be an option for many possible installations and cannot be discriminated by means of extra-complicated procedures that have to be followed in order to proceed with the energy performance calculation.

A political choice for encouraging of RES by means of energy performance policy can, for example, consist of favouring the use of RES equipment in the energy performance result. An ultimate option in encouraging the use of RES is the introduction of an obligatory share of RES in the energy performance outcome. Regulations will probably only be considered when a problem is felt to pose a serious potential threat to society, and when other solutions are not considered to be sufficiently effective. Since climate change could pose such a threat, it is not inconceivable that efforts to promote more widespread use of RES will gain even greater priority on the political agenda in a number of years. One of the main obstacles in encouraging the use of RES by means of energy performance policy is that many RES options consist of non-building related techniques, for instance wind power plants, biomass plants, or central heat pumps using heat from sources such as sea or river water. Energy performance policy – up to now – has been at building level only, and has principally rewarded RES techniques such as local heat pumps, roof-related photovoltaics, and solar thermal systems.

The contribution of the EC energy certificate in improving the sustainability of the housing stock

Renovation of the existing housing stock can reduce energy costs and demand, forestall an increase in demand for new housing, and improve indoor air quality. Current policies and policy instruments for sustainable building, however, are slowly re-orientating away from new construction to using the environmental potential of the housing stock. The introduction of the EC energy certificate in combination with regulatory and economic policy instruments can be used to improve the energy efficiency of the urban housing stock. We argue that – in contrast to the situation for new housing – the use of the energy certificate as a communication instrument to address information problems, as is currently suggested in the EC Directive, will be unlikely to affect purchasing decisions, or encourage consumers to upgrade their houses' energy efficiency features in order to make them a selling point, since information problems are only one of the many issues that affect the complex building market.

The idea of combining energy certificates with tax schemes seems promising, but will have to be covered by general income taxes, housing related taxes or other taxes in order to prevent regressive social effects. Combining the energy certificate with subsidies should be rather limited due to the 'free-rider effect', and subsidies should only cover innovative products at the beginning of their 'learning curve'. Positive results can probably be expected from introducing regulations that are combined with energy certificate standards, but this will require a rather drastic approach and will need time to receive sufficient commitment as, for example, with new buildings where there has already been a gradual development of energy regulations over the last thirty years. Since communication tools are more likely to be effective when combined with regulatory or economic instruments, introducing an energy performance standard certificate – in combination with taxes which penalise poor energy performance levels but which offer subsidies to reward good energy performance – could be an effective approach.

Public energy performance policy and the effect on the diffusion of solar thermal systems in residential buildings: a Dutch experience

The energy performance approach is often said to encourage energy-saving innovations (e.g., solar techniques) in buildings. The influence of energy performance policy on the diffusion of solar thermal systems for new residential buildings was analysed by means of a statistical analysis of 352 energy performance calculations submitted from 1996 to 2003 to municipal building control in The Netherlands. The analysis shows a remarkable shift in the types of water-heating system used in new residential buildings between 1996 and 2003. While it was still possible to use regular gas condensing boilers in 1996, such boilers disappeared completely from new residential buildings following the tightening of the energy performance standard in 1998. High efficiency gas condensing boilers have now become standard, and heat pumps and district heating have also become more common. The application of solar thermal systems apparently increased slightly during the same period. Statistical analysis of the correlation between the EPC regime and the installation of solar thermal systems does not show a statistically significant relationship. Statistical analysis of the correlation between the EPC regime and the installation of heat pumps and district heating shows a significant relationship, but here the EPC regime accounts for a negligible share (smaller than 5%) of the variance. The relationship between the EPC regime and high efficiency gas condensing boilers ('E-boiler100' and 'E-boiler107') did show a significant correlation, indicating that the EPC regime accounts for 22% and 33% respectively of the variance in applying the E-boiler107 and the E-boiler100.

It seems that, rather than encouraging the diffusion of really new innovations, such as solar thermal systems or heat pumps, the Dutch energy performance policy primarily leads to incremental innovations – in other words, to product improvements – such as increases in the efficiency of hot-water and heating installations, and reductions in the amount of energy used by ventilators. Because the energy policy began with a small step beyond routine practice in 1996 – and since then has gradually tightened standards as cost-effective solutions have become available on the market – increases in the efficiencies of existing systems have appeared to be sufficient to meet the new standards. In order to stimulate a continual search for improvements in energy techniques and to improve overall effectiveness, energy performance policy will need to impose more severe standards and, at the same time, become a more flexible instrument by rewarding performance that is better than the standard.

Government regulation as an impetus for innovation: evidence from energy performance regulation in the Dutch residential building sector

Empirical analysis on the basis of a data set of 352 energy performance permits for residential buildings dating from 1996 to 2003, shows a significant correlation between the EPC regime and both 'incremental' and 'really new' energy-saving innovations in hot water technologies in the Dutch residential building sector. Whereas the correlation between the EPC regime and incremental innovation is relatively strong (R^2 = 19.6%), that between the EPC regime and really new innovation (R^2 = 4%) is negligible, however. The logistic regression analyses confirm these findings, showing that, at the same time, related factors, such as changes in gas prices or in the amount of housing investment, had hardly any influence on incremental or really new energy-saving innovation in the Dutch residential building sector. This study demonstrates that energy performance policy in The Netherlands did not contribute to the diffusion or development of really new innovation in hot water production technologies during the 1996-2003 period. It partly contributed to the improved efficiency of conventional hot water production technologies, but it did not result in solar hot water boilers or heat pumps being adopted to any significant extent. Improvements in the efficiency of conventional technologies were sufficient to meet the tighter Energy Performance Standard. The further tightening of the Energy Performance Standard in 2006 is expected to sustain this situation. New standards will continue to be achieved using conventional technologies, such as gas condensing boilers, whereas new technologies, such as heat pumps, will only be used if they enjoy additional government support in the form of grants.

The project-based nature of the construction industry is the main obstacle to 'learning-rich' collaboration between various stakeholders, preventing tight partnerships from existing in the permanent network, since tight partnerships with other firms only exist for the duration of each project. The project phase is dominated by negotiation and heavy interdependence between the partners involved in the chain, from designer or developer, to supplier and constructor. At the same time, the sector is dominated by price competition and the risk of market failure owing to the long lifespan and the location-bound nature of buildings. Every construction job is unique, hence there are hardly any economies of scale. As a result of the complex nature and defensive character of the building process, builders are generally unable to be flexible in using different technologies in order to comply with the energy performance standard.

It is questionable whether energy regulations target the right level of the value chain in the construction sector. The project-based nature of this sector does not provide a favourable environment for energy performance policy to be effective, given that technologies are sacrificed in favour of the most economically efficient solutions. Since the empirical data indicate that incremental innovation is only to some extent related to energy performance policy, it still leaves us with about 80% of variance to be accounted for by other factors. Contractors are expected to introduce energy-saving innovations that neither generate direct returns for them, nor strengthen their competitive advantage. It would be more effective to directly target manufacturers of energy technologies in order to encourage them to innovate.

Energy innovations in construction: network effects and energy policy in Dutch construction

Although the nature of project-based industries appears to contain elements of 'problem-solving', thus potentially encouraging innovative behaviour, in the construction industry many obstacles prevent this potential from being realised. With regard to the supply sector, the construction sector seems to depend heavily on arms-length customer-supplier relationships rather than partnerships. Therefore, the function of energy performance policy could be important in creating necessary communication between participants in the building process, especially where the nature of organisations differ as much as the project-based contractor and the functionally organised heating technology supplier.

It was demonstrated that communication between decision makers in the design process and heating technology suppliers is rare, and that multiple layers of communication exist in the building process. In the case where an engineering consultant is hired, the consultant instructs the installer, and the installer buys the heating equipment. In more simple projects, it is the installer who decides on the heating installation. Installers, however, have little incentive to choose innovative techniques, since they usually also maintain the installation. Cooperation between contractors and heating technology manufacturers is absent, and encouragement for innovation from this point of view does not exist. At the same time, the effect of energy performance policy on the implementation of recent innovations, such as high efficiency gas condensing boilers, is criticised by manufacturers of such equipment. It was stated that the increase in efficiencies was part of a continuous development that started with the introduction of the high efficiency boiler in 1981, and which would probably have happened in a similar manner even without energy performance policy.

Notwithstanding the effect that energy performance policy has in reducing energy consumption for heating, cooling, and ventilation in building, it cannot be regarded as having encouraged communication between contractors and heating technology suppliers, or as having promoted innovative behaviour between these two parties. Where energy performance policy is addressed at the contractor, it is expected to influence innovation in heating technology. This effect however appears to be rather small, if not negligible. Heating technology manufacturers operate in a highly competitive market and on a European scale.

Energy performance policy on a national level will therefore only influence product development to a limited extent, although manufacturers will use the policy as a marketing tool in the national market. In the case where energy performance policy 'follows' product developments – instead of inspiring product developments through the setting of exacting standards – manufacturers will hardly initiate product innovations as a result of energy performance policy. Energy performance policy can even hinder product development since products have to adhere to energy performance calculation principles. This can create a 'lock-in' effect, as it promotes traditional domestic energy technology.

Energy performance policy in relation to mitigating climate change

Energy efficiency improvements, by energy performance policy, seem to have come from the overall optimisation of all the energy related features of residential buildings. Insulation levels improved, although not spectacularly. Efficiencies of heating technology improved, although this seems partly to be as a result of the ongoing development that started in the 1980s. The efficiency of fans used for ventilation improved, as did the efficiency of all sorts of auxiliary devices needed in heating technology, as well as the efficiency of heat recovery in balanced ventilation systems. Although energy performance policy seems to have contributed to the optimisation of all energy related features of residential buildings, it did not cause a breakthrough of innovative technology. Looking at the data that have been collected in this study, we can say that it is unrealistic to assert that energy performance policy has any power to create incentives for technological innovation.

The proposal to tighten the standard in 2011 and 2015, as drafted by the Energy Research Centre of The Netherlands (ECN), is accompanied by a warning not to focus too strongly on installation driven solutions (Daniëls *et al.*, 2006). The recommendation is to demand improved building design by imposing additional regulations for insulation levels and south-oriented designs, while preventing overheating and designing air-tight buildings (ibid.). This commendable approach, as foreseen by the Energy Research Centre of The Netherlands, will have, as a side-effect, the probability that, even when standards are tightened, it will still initially be possible to use conventional heating technology and reduced energy demand before adopting efficient technology.

In reviewing energy performance policy from the point of view of transition management, there is cause for concern. Energy performance policy focuses on traditional calculation methodology, whereas new technology has to fit in for it to be able to receive acceptance – through a so-called 'declaration of equality' – by the energy performance standard. The energy performance standard can cause a 'lock-in' effect by encouraging techniques that fit in with the principles used by the energy performance policy, and penalising techniques that break with convention. Moreover, energy performance policy considers technology on a building level only, whereas promising techniques using renewable energy, such as wind power plants or biomass plants, operate on the neighbourhood or urban level. Solutions that provide for much more freedom are already available. In The Netherlands, a site level energy performance approach exists in the shape of a voluntary scheme that can be used for new urban developments (SenterNovem, 2007). From the point of view of supporting, instead of obstructing, transition management, the reshaping of energy performance policy from building level towards an approach on site level is very much advocated, since this would create more openings for the deployment of efficient generation technology, and technology that uses renewable energy sources, such as biomass plants or wind turbines.

Samenvatting

Het tegengaan van klimaatverandering vraagt vergaande energiebesparingsdoelstellingen voor de lange termijn en grote inspanningen van landen, industrieën en consumenten. Met dit vooruitzicht ontstaat er in toenemende mate bewustzijn dat op de lange termijn (30 tot 50 jaar) een transitie naar een duurzame energievoorziening nodig is (Shackley & Green, 2007). Een transitie naar een duurzame energievoorziening vraagt aan de ene kant om een radicale gedragsverandering ten opzichte van onze huidige consumptiepatronen en aan de andere kant om innovaties in duurzame technologie. Bij de introductie van het Nederlandse energieprestatiebeleid in 1995, werd door de Nederlandse centrale overheid de verwachting uitgesproken dat het vernieuwde beleid zou leiden tot innovaties in verwarmings-, ventilatie- en koeltechnieken (Ministerie van VROM, 1995). De Europese Unie heeft gekozen voor eenzelfde methode in een communautaire aanpak van het energiebesparingsbeleid voor de gebouwde omgeving door middel van de EU-richtlijn 2002/91/EC, bekend geworden als de richtlijn betreffende de Energieprestatie van Gebouwen (EPBD) (Europese Commissie, 2003). De afgelopen jaren is veel Europees onderzoek opgestart waarbij wordt ingegaan op de methodologie van de energieprestatiemethode. Het effect van energieprestatiebeleid op de ontwikkeling en diffusie van innovatie bij woningbouw is echter nog niet onderzocht.

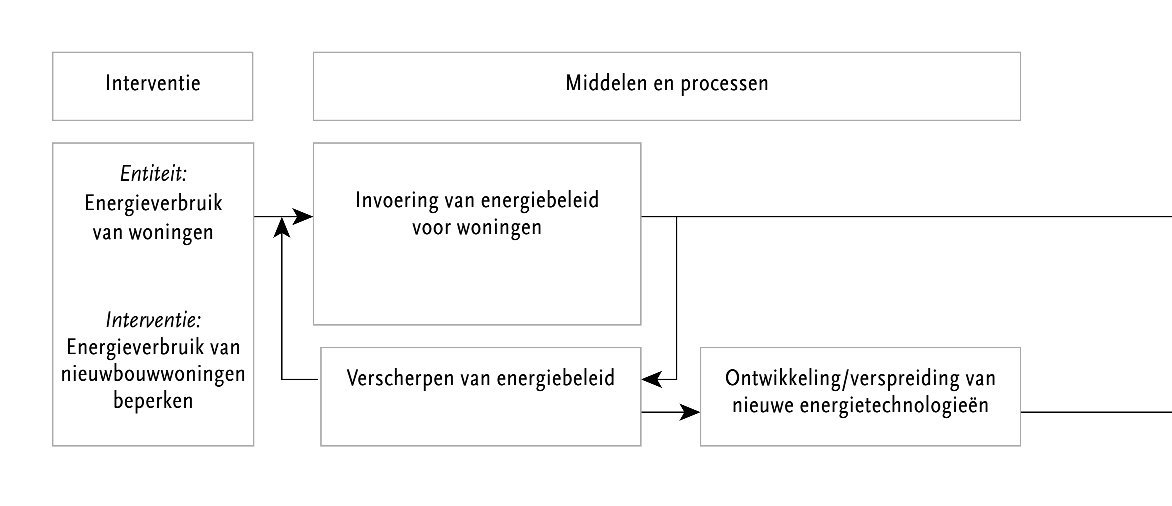
Gezien het belang van de transitie naar een duurzame energievoorziening en de ontwikkeling van innovatieve duurzame technologie is een randvoorwaarde voor beleidsinstrumentarium ten behoeve van energiebesparing in de gebouwde omgeving dat deze de ontwikkeling en diffusie van innovaties bevordert en in ieder geval een 'lock-in' effect voorkomt.

Daarnaast bestaat er consensus over het feit dat in de bestaande bouw meer voordelen van investering in energiebesparing kan worden verwacht dan in de nieuwbouw, aangezien de bouwvoorraad in aantallen veruit die van de nieuwbouw overschrijdt en aangezien de bouwvoorraad destijds onder slechte energienormen werd gebouwd. De EU-richtlijn 2002/91/EC vermeldt als extra vereiste dat binnenkort alle gebouwen over een energielabel moeten beschikken, gebaseerd op de energieprestatieberekening van het gebouw (Europese Commissie, 2003). Dit vrijwillige beleidsmiddel moet bijdragen aan energiebesparing in de bouwvoorraad.

Het uiteindelijke doel van energiebesparing is het tegengaan van klimaatverandering (IPCC, 2007). Voor dit doel is op grote schaal innovatie nodig, die verder gaat dan het werkingsgebied van het energieprestatiebeleid. Een ruime beschouwing van de bouwsector, in termen van het innovatiesysteem van de bouwsector, is nodig om aan aanbevelingen te formuleren voor het bevorderen van energiebesparende innovaties in de bouw op lange termijn.

De onderzoeksvragen van deze studie zijn in drie groepen verdeeld. Het eerste deel van het onderzoek bestaat uit een beschrijvende analyse die ingaat

Figuur 1 Proces van energiebeleid voor woningbouw



op de inhoud van het energieprestatiebeleid en behandelt de volgende onderzoeksvragen:

1 *Welke lessen kunnen geleerd worden van het vergelijken van ervaringen in energiebeleid voor woningbouw in Europese lidstaten?*

1.1 Welk energiebesparingsbeleid is aanwezig in de noordelijke Europese lidstaten en welke inspanning wordt gevraagd bij de implementatie van de EU-richtlijn 2002/91/EC? (Hoofdstuk 3)

1.2 Welke mogelijkheden biedt energieprestatiebeleid voor het bevorderen van toepassing van duurzame energietechnologie? (Hoofdstuk 4)

1.3 Welk energiebesparingseffect kan verwacht worden van de introductie van energielabels voor de bestaande woningbouw? (Hoofdstuk 5)

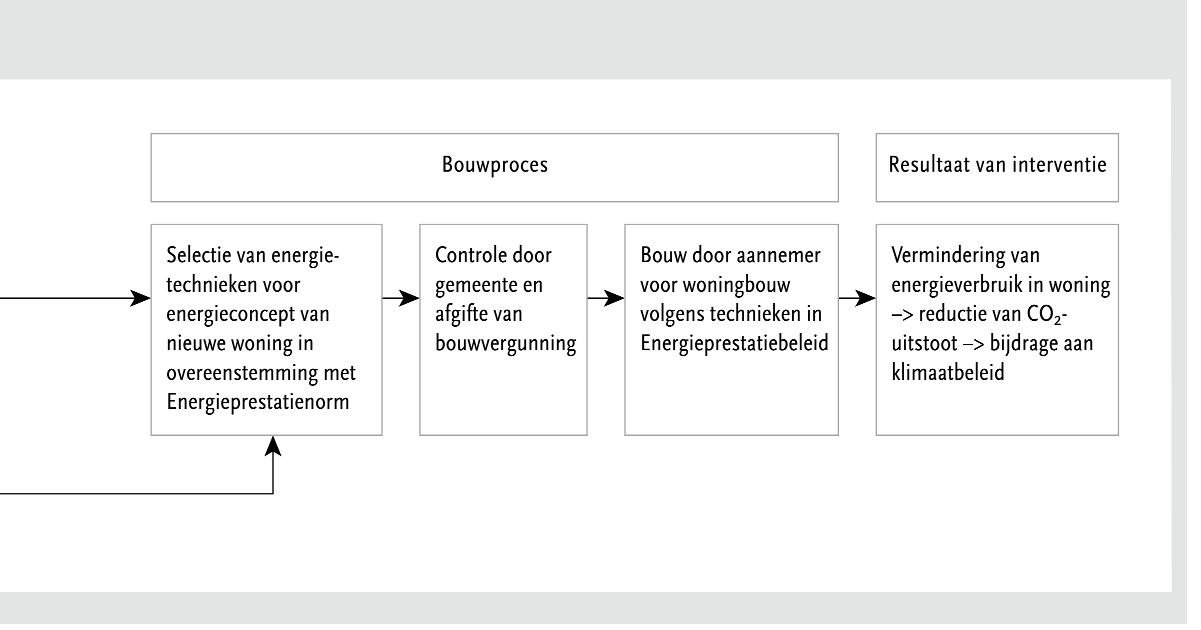
Het tweede deel van het boek concentreert zich op innovatie-effecten van energieprestatiebeleid voor woningbouw en behandelt de volgende onderzoeksvragen:

2 *In welke mate kan in Nederland een relatie aangetoond worden tussen energieprestatiebeleid en innovatie in verwarmingstechnieken voor de woningbouw en welke invloed heeft het sectorale innovatiesysteem van de bouwsector daarbij?*

2.1 Wat is het effect van het energieprestatiebeleid voor nieuwbouwwoningen op de diffusie van zonthermische systemen? (Hoofdstuk 6)

2.2 Welke innovatie-effecten heeft het energieprestatiebeleid voor nieuwbouwwoningen in Nederland teweeg gebracht op het gebied van verwarmingstechnieken? (Hoofdstuk 7)

2.3 Wat is het effect van het samenspel tussen de project-georganiseerde bouwbranche en de functioneel georganiseerde toeleverende industrie in het sectorale innovatiesysteem van de bouwsector met betrekking tot energieprestatiebeleid en innovatie in verwarmingstechnologie? (Hoofdstuk 8)



Het derde deel van het boek bestaat uit het definitieve hoofdstuk en brengt het onderzoek van hoofdstuk 2 tot 8 samen in het verklaren van het effect en de mogelijkheden van overheidsbeleid voor energiebesparing in de bouwsector. Het behandelt de volgende onderzoeksvraag:

3 *Wat is de toegevoegde waarde van het energieprestatiebeleid in relatie tot andere mogelijke oplossingen, wat is de relatie met het tegengaan van klimaatverandering en in welke mate is intensivering van overheidsbeleid in het verminderen van broeikasgasemissies in de woningbouw gerechtvaardigd?* (Hoofdstuk 9)

Onderzoeksaanpak

De onderzoeksvragen van deze studie zijn benaderd met behulp van verschillende onderzoeksmethoden. De studie naar de ervaringen met energieprestatiebeleid in de EU is een beschrijvende vergelijkende analyse op basis van bureauonderzoek en aanvullende interviews. De kern van het voorliggende onderzoek bestaat uit beleidsevaluatie. Er zijn methodologieën uit sociaal-wetenschappelijk onderzoek gebruikt om het beleid te beoordelen en verbeteren en om de effectiviteit en efficiëntie van dit beleid te evalueren. Hiervoor moet eerst het beleidsproces in kaart worden gebracht. We hebben het proces van energieprestatiebeleid voor de woningbouwsector in kaart gebracht volgens het algemene model voor evaluatieonderzoek dat is geïntroduceerd door Mayer & Greenwood (Vall, 1987) (zie Fig. 1).

De illustratie van het beleidsproces helpt de causale verbanden te zien tussen de onafhankelijke en afhankelijke variabelen, die de onderwerpen van het evaluatieonderzoek vormen. In ons onderzoek zullen we het causale verband aan het licht brengen dat bestaat tussen de interventie, door middel van het opleggen van energieprestatienormen – de onafhankelijke variabele, en de ontwikkeling en verspreiding van nieuwe energietechnologieën – de afhankelijke variabele. In Fig. 1 zien we dat de innovatieve effecten van de invoering van energieprestatiebeleid hoofdzakelijk een neveneffect zijn van

Tabel 1 Energieregelgeving in 11 Europese lidstaten

	Elementenmethode	Berekening warmteverlies	Berekening warmtevraag	Berekening energieverbruik
België		Vlaanderen (1993): 'K-niveau': alleen woningen Wallonië (1996): Optie 1: 'K-niveau': woningen en andere gebouwen Brussel (2000): 'K-niveau': woningen en andere gebouwen	Wallonië (1996): Optie 2: berekening warmtevraag	(Vlaanderen: Energieprestatieregels, ingevoerd 2006)
		(Wallonië (1996): Vereisten voor mate van ventilatie)		
Duitsland		EnEV (1 feb. 2002), voorwaarde 1: max. transmissieverliezen	(ruimteverwarmingsvraag + vereisten voor ketels: tot 1 feb. 2002)	EnEV (1 feb. 2002), voorwaarde 2: max. jaarlijks primair energieverbruik
Frankrijk		(Berekening warmteverlies GV: tot 2001)	(Berekening warmtevraag BV: tot 2001)	Optie 1: Energieprestatieregels + Warmtecomfort in zomer. (Reglementation Thermique 2000) (2001)
		Optie 2: vereenvoudigde procedure met 'technische oplossingen'		
Nederland		(tot 1996)		Energieprestatieregels (1996, huidige norm: 2006)
Denemarken	Optie 1: max. U-waarden (BR '95/BR-S 98)	Optie 2: Berekening warmteverlies (BR '95/BR-S 98)	Optie 3: Energiekader/Berekening warmtevraag (BR '95/BR-S 98)	
Engeland en Wales	(Ap. Doc. L 2002) Optie 1: Elementenmethode (+ min. SEDBUK efficiëntie)	(Ap. Doc. L 2002) Optie 2: Doel U-waarde (+ mogelijke correctiefactor voor efficiëntie ketel)		(Ap. Doc. L 2002) Optie 3: Carbon Index Method: SAP-berekeningen

het daadwerkelijke doel van het beleid, namelijk het verminderen van de CO_2-uitstoot in de bouwsector, aangezien het hoofddoel van het energieprestatiebeleid de verlaging van het energieverbruik in woningen is, als bijdrage aan het klimaatbeleid. Er zijn veel soorten effectbeoordelingen mogelijk, maar omdat wij ons willen richten op het onderzoeken van het langetermijneffect van het programma in de loop van een aantal jaar, hebben we ervoor gekozen zowel kwantitatieve (hoofdstuk 6 en 7) als kwalitatieve onderzoeksmethoden (hoofdstuk 8) te gebruiken. Door middel van een tijdreeksbenadering waarvoor gegevens zijn verzameld in de periode vanaf 1996 – het moment waarop het energieprestatiebeleid in Nederland werd ingevoerd – tot 2003, is het mogelijk de verspreiding van energietechnieken in de bouw van nieuwe

Tabel 1 Vervolg

	Elementenmethode	Berekening warmteverlies	Berekening warmtevraag	Berekening energieverbruik
Oostenrijk	Alle *Bundesländer* (1995): Maximale U-waarden voor bouwelementen		Bijna alle *Bundesländer* (1995): Alternatief voor max. U-waarden bouwdelen: een berekening van de warmtevraag, waarbij de situatie wordt vergeleken met de vereisten van de elementenmethode	
Finland	(1985-1997) Methode 1: Max. U-waarden bouwdelen	(1985-1997) Methode 2: gemiddelde U-waarde van het gebouw		(2003: Methode 3: berekening energieverbruik)
Zweden		(1994-1998) Gemiddelde U-waarde van een gebouw	(1994-1998) Als extra optie is het mogelijk naleving aan te tonen door middel van compensatieberekeningen.	
	(1994-1998) Daarnaast bestaan er voorschriften voor de beperking van warmteverlies, voor efficiënt gebruik van warmte en voor efficiënt gebruik van elektriciteit			
Luxemburg	*Wärmeschutz-verordnung 1996* gebouwen < 200 m^2: Maximale U-waarden	*Wärmeschutz-verordnung 1996:* gebouwen > 200 m^2: k-niveau van een gebouw		
Ierland	Optie 1: methode warmteverlies gebouwdelen (TGD L 2002)	Optie 2: methode algeheel warmteverlies (TGD L 2002)		Optie 3: Energieprestatiemethode (alleen woningen) (TGD L 2002)

woningen aan te geven en statistische technieken te gebruiken om de relatieve invloed van het energieprestatiebeleid te beoordelen. Met behulp van interviewstudies zijn verklaringen en meningen over het functioneren van het energieprestatiebeleid in Nederland nader belicht.

Energieregelgeving en impact van de EU richtlijn 'Energieprestaties van gebouwen'

Dit onderzoek is gebaseerd op een overzicht van energieregelgeving in elf Europese landen in 2002 en analyseert het gevoerde beleid in die landen met betrekking tot het bepalen van het energiegebruik in gebouwen. (zie Tabel 1).

De Europese Commissie wil de regelgeving op het gebied van energiegebruik van gebouwen harmoniseren door middel van invoering van een methode met een vergaande integratie van aan energie gerelateerde aspecten, bekend als de 'energieprestatiemethode'. Op het moment van deze studie maken vijf lidstaten gebruik van dergelijke energieregels (Nederland, Engeland en Wales, Ierland, Frankrijk en Duitsland), waarvan slechts drie staten (Nederland, Frankrijk en Duitsland) ze gebruiken als de enige methode om te voldoen aan de energieregelgeving. Dit houdt in dat acht van de elf lidstaten hun huidige energieregels opnieuw zullen moeten opstellen. Omdat de studie dateert van 2002, hebben we geen rekening gehouden met de lidstaten die na die tijd lid zijn geworden van de Europese Unie tijdens de eerste en tweede uitbreidingsgolf. Aangenomen wordt dat de nieuwe Europese lidstaten een lager niveau van economische ontwikkeling hebben en daardoor weinig ervaring hebben op het gebied van energieprestatiebeleid, hoewel ze mogelijk wel ervaring hebben met een vroege fase van energiebeleid die zich bezighoudt met kwesties als de berekening van warmteverlies of de berekening van de warmtevraag. De resultaten van deze studie hebben aangetoond dat de Nederlandse ervaringen met energieprestatieregels de beste basis vormen voor een evaluerend onderzoek, aangezien Nederland de enige EU-lidstaat is die de energieprestatieaanpak – in 1996 – heeft ingevoerd als de enige mogelijke methode om aan te tonen dat aan de regelgeving wordt voldaan.

Gebruik van duurzame energie stimuleren door invoering van de EU richtlijn 'Energieprestaties van gebouwen'

De vergelijkende analyse van energieregelgeving in elf Europese lidstaten heeft laten zien dat de inhoud van energieprestatieregelgeving afhankelijk is van een aantal opties die op basis van politieke keuzes kunnen worden ingevuld, en dat biedt ook mogelijkheden voor het realiseren van een ontwerp dat het gebruik van duurzame energie in gebouwen stimuleert. Voordat we zelfs maar kunnen spreken over het specifiek aanmoedigen van het gebruik van duurzame energie door middel van het energieprestatiebeleid, moet eerst voldaan worden aan de voorwaarde dat het energieprestatiebeleid de mogelijkheid moet bieden om duurzame energie technieken toe te passen, zonder dat dit meer inspanningen vereist dan de traditionele oplossingen. De toepassing van duurzame energie moet een optie zijn voor zoveel mogelijk installaties en mag niet worden belemmerd door middel van extra ingewikkelde procedures die moeten worden doorlopen om de energieprestatieberekeningen te kunnen uitvoeren.

Een politieke keuze voor het aanmoedigen van duurzame energie door middel van het energieprestatiebeleid kan bijvoorbeeld bestaan uit het gunstig beoordelen van het gebruik van duurzame energie-technieken in het resultaat van de energieprestatieberekening. De ultieme mogelijkheid voor het stimuleren van het gebruik van duurzame energie is de invoering van een verplicht aandeel duurzame energie in de totale energieprestatie. Regelgeving zal waarschijnlijk alleen worden overwogen als men van mening is dat een probleem een potentieel ernstige bedreiging vormt voor de maatschappij en als andere oplossingen niet als voldoende effectief worden gezien. Aangezien klimaatverandering een dergelijke bedreiging zou kunnen vormen, is het niet ondenkbaar dat pogingen om een bredere toepassing van duurzame energie te stimuleren over een aantal jaar een nog grotere prioriteit zullen krijgen op de politieke agenda. Een van de grootste obstakels voor het stimuleren van het gebruik van duurzame energie door middel van het energieprestatiebeleid is dat veel duurzame energie-opties bestaan uit technieken die geen verband houden met het gebouw, maar zich bevinden op hogere schaalniveaus zoals bijvoorbeeld windenergiecentrales, biomassacentrales of centrale-verwarmingspompen die gebruikmaken van warmtebronnen als zee- en rivierwater. Het energieprestatiebeleid heeft zich – tot nu toe – uitsluitend gericht op het schaalniveau van het gebouw en heeft hoofdzakelijk duurzame energietechnieken zoals gebouwgebonden warmtepompen, photovoltaïsche systemen en zonthermische systemen beloond.

De bijdrage van het Europese energielabel aan de verbetering van de duurzaamheid van de woningvoorraad

Renovatie van de bestaande woningvoorraad kan de kosten van en vraag naar energie verminderen, een toename van de vraag naar nieuwe woningen afremmen en de luchtkwaliteit binnenshuis verbeteren. Het beleid en de beleidsinstrumenten voor duurzaam bouwen richten zich echter langzamerhand minder op nieuwbouw en meer op het benutten van het milieupotentieel van de bestaande woningvoorraad. De invoering van het Europese energielabel kan in combinatie met regulerende en economische beleidsinstrumenten worden gebruikt om de energie-efficiëntie van de bestaande woningvoorraad in de steden te verbeteren. Wij zijn van mening dat het gebruik van het energiecertificaat als een communicatie-instrument om informatieproblemen aan te pakken, zoals momenteel wordt gesuggereerd in de EG-richtlijn, zal echter waarschijnlijk geen invloed hebben op aankoopbeslissingen en zal consumenten evenmin aansporen de energie-efficiëntie van hun huis te verbeteren om het huis zo beter te kunnen verkopen, want informatieproblemen zijn slechts een van de vele knelpunten die van invloed zijn op de complexe bouwmarkt.

Het idee om energielabels te combineren met belastingmaatregels klinkt veelbelovend, maar zal moeten worden gedragen door algemene inkomstenbelastingen of andere belastingen die betrekking hebben op huisvesting om negatieve maatschappelijke effecten te voorkomen. Het combineren van het energielabel met subsidies kan beter worden beperkt in verband met het 'free-rider effect' en subsidies zouden alleen moeten gelden voor innovatieve producten aan het begin van hun 'leercurve'. Positieve resultaten zijn waarschijnlijk te verwachten van de invoering van regelgeving die gecombineerd wordt met voorwaarden voor een minimaal niveau van het energielabel, maar hiervoor is een vrij drastische aanpak nodig. Tevens vraagt dit tijd om voldoende draagvlak te vinden, net als bijvoorbeeld bij nieuwbouw waarvoor gedurende de afgelopen dertig jaar al een geleidelijke ontwikkeling van energieregelgeving gaande is. Aangezien communicatie-instrumenten een grotere kans hebben om effectief te zijn als ze worden gecombineerd met regelgevende of economische instrumenten, zou de invoering van een minimaal niveau van het energielabel – in combinatie met progressieve belastingen die lage energieprestaties afstraffen, maar ook subsidies bieden om hoge energieprestaties te belonen – een effectieve benadering kunnen zijn.

Centraal energieprestatiebeleid en het effect op de verspreiding van zonthermische systemen in gebouwen: een Nederlandse ervaring

Vaak wordt verkondigd dat energieprestatiebeleid in de gebouwde omgeving heeft geleid tot energiebesparende innovaties in gebouwen. De invloed van energieprestatiebeleid op de verspreiding van zonthermische systemen in nieuwbouw woningen is geanalyseerd door middel van een statistische analyse van 352 energieprestatieberekeningen die tussen 1996 en 2003 zijn ingediend bij gemeentelijke afdelingen voor bouw- en woningtoezicht in Nederland. De analyse wijst uit dat er een opmerkelijke verschuiving heeft plaatsgevonden in de typen warm tapwatersystemen die tussen 1996 en 2003 zijn gebruikt in nieuwbouw woningen. In 1996 was het nog mogelijk om verbeterd rendement (VR) ketels te gebruiken, maar in 1998 verdwenen dergelijke ketels geheel uit nieuwbouw woningen. Hoogrendementsketels (HR-ketels) zijn vanaf dat moment de norm en warmtepompen en warmtedistributiesystemen worden eveneens gebruikelijker. De toepassing van zonthermische systemen lijkt in dezelfde periode licht te zijn toegenomen. Statistische analyse van de correlatie tussen de Energie Prestatie Norm en de toepassing van zonthermische systemen wijst echter niet op een statistisch significant verband. Statistische analyse van de correlatie tussen de Energie Prestatie Norm en de toepassing van warmtepompen en warmtedistributie toont wel een significant verband aan, maar de Energie Prestatie Norm blijkt een verwaarloosbaar aandeel te leveren (minder dan 5%) in de variabiliteit. Het verband tussen de Energie Prestatie Norm en hoogrendementsketels ('HR-100 ketel' en 'HR-107 ketel') vertoonde wel een significante correlatie: het bleek dat de Energie Prestatie Norm verantwoordelijk was voor respectievelijk 22% en 33% van de variabiliteit in het toepassen van de HR-107 ketel en de HR-100 ketel.

Het lijkt erop dat het Nederlandse energieprestatiebeleid niet zo zeer de verspreiding van nieuwe innovaties zoals zonthermische systemen of warmtepompen stimuleert, maar voornamelijk leidt tot incrementele innovaties – met andere woorden, tot productverbeteringen – zoals verhoging van het rendement van warm tapwater- en verwarmingsinstallaties en vermindering van de hoeveelheid energie die wordt verbruikt door ventilatoren. Omdat het energieprestatiebeleid in Nederland in 1996 begon met een kleine stap vanaf de bestaande gewoonten – en sindsdien de normen geleidelijk aan heeft aangescherpt naarmate er meer kosteneffectieve oplossingen op de markt kwamen – bleken de verbeteringen van de efficiëntie van bestaande systemen steeds voldoende te zijn om aan de nieuwe normen te blijven voldoen. Om een voortdurende zoektocht naar verbeteringen in energietechnieken te stimuleren en de algehele effectiviteit te verbeteren, zal het energieprestatiebeleid strengere normen moeten opleggen en tegelijkertijd een flexibeler instrument moeten worden waarmee prestaties die beter zijn dan de norm kunnen worden beloond.

Overheidsregulering als prikkel voor innovatie: case-study rond energieprestatieregelgeving in de Nederlandse woningbouwsector

Empirische analyse op basis van een dataset van 352 energieprestatieberekeningen voor nieuwbouwwoningen uit de periode 1996 tot 2003 laat een significante correlatie zien tussen de Energie Prestatie Norm en zowel 'incrementele' als 'nieuwe' energiebesparende innovaties op het gebied van warm tapwatertechnieken in de Nederlandse woningbouwsector. Terwijl de correlatie tussen de Energie Prestatie Norm en incrementele innovatie relatief sterk is (R^2 = 19,6%), is die tussen de Energie Prestatie Norm en productvernieuwing echter verwaarloosbaar (R^2 = 4%). De logistische regressieanalyses bevestigen deze bevindingen en geven aan dat tegelijkertijd gerelateerde factoren, zoals veranderingen in de gasprijs of in de hoogte van de investeringen in woningbouw, nauwelijks enige invloed hadden op de 'incrementele' of 'nieuwe' energiebesparende innovaties in de Nederlandse woningbouwsector. Deze studie toont aan dat het energieprestatiebeleid in Nederland geen bijdrage heeft geleverd aan de verspreiding of ontwikkeling van nieuwe innovaties in warmwatertechnologieën in de periode 1996-2003. Het heeft een bijdrage geleverd aan de verbetering van het rendement van conventionele warm tapwatertechnieken, maar het heeft er niet toe geleid dat zonneboilers of warmtepompen in significante mate vaker zijn toegepast. De verbeteringen in de efficiëntie van conventionele technologieën waren voldoende om te voldoen aan de strengere Energie Prestatie Normen. De verdere aanscherping van de Energieprestatienorm in 2006 zal deze situatie naar verwachting niet veranderen. Nieuwe normen zullen gehaald blijven worden met behulp van conventionele technologieën, zoals HR-ketels, terwijl nieuwe technologieën, zoals warmtepompen, alleen toegepast zullen worden als ze extra worden gesteund door de overheid.

Het projectgebaseerde karakter van de bouwsector is het grootste obstakel voor 'leerrijke' samenwerking tussen diverse belanghebbenden, want het voorkomt hechte partnerschappen in het permanente netwerk, aangezien hechte partnerschappen met andere bedrijven slechts bestaan voor de duur van elk project. De projectfase wordt gedomineerd door onderhandeling en sterke onderlinge afhankelijkheid tussen de partners die betrokken zijn bij de projectketen, van ontwerper of ontwikkelaar tot leverancier en aannemer. Tegelijkertijd wordt de sector gedomineerd door prijsconcurrentie en het risico van marktfalen als gevolg van de lange levensduur en het locatiegebonden karakter van gebouwen. Elke bouwopdracht is uniek en daardoor zijn er nauwelijks schaalvoordelen te behalen. Als gevolg van de gecompliceerde aard en het defensieve karakter van het bouwproces kunnen bouwers meestal niet flexibel zijn in het gebruik van verschillende technologieën om te voldoen aan de Energie Prestatie Norm.

Het is de vraag of de energieregelgeving op het juiste niveau van de waardeketen in de bouwsector gericht is. Het projectgebaseerde karakter van deze sector vormt geen gunstige omgeving voor een effectief energieprestatiebeleid, aangezien technologieën worden opgeofferd ten gunste van de oplossingen die financieel gezien het meest efficiënt zijn. De empirische gegevens wijzen uit dat zelfs incrementele innovatie slechts ten dele verband houdt met het energieprestatiebeleid, dus er blijft nog 80% van de variabiliteit over die door andere factoren moet worden verklaard. Aannemers worden geacht energiebesparende innovaties te introduceren die henzelf geen directe winst opleveren en evenmin hun concurrentiepositie versterken. Het zou effectiever kunnen zijn om het beleid rechtstreeks te richten op de fabrikanten van energietechnologieën om hen aan te moedigen te innoveren.

Energie-innovaties in de bouw: netwerkeffecten en energiebeleid in de Nederlandse bouwsector

Hoewel de aard van projectgebaseerde bedrijfstakken elementen van 'probleemoplossing' lijkt te bevatten en dus mogelijkerwijs innovatief gedrag zou kunnen stimuleren, bestaan in de bouwsector veel obstakels die het realiseren van dit potentieel in de weg staan. Als het gaat om de toeleverende industrie, lijkt de bouwsector sterk afhankelijk te zijn van vrijblijvende relaties tussen bouwer en toeleverancier in plaats van partnerschappen. De functie van een energieprestatiebeleid zou dus belangrijk kunnen zijn voor het creëren van de noodzakelijke communicatie tussen deelnemers aan het bouwproces, vooral als de aard van de organisaties zo verschillend is als bij de projectgebaseerde aannemer en de functioneel georganiseerde toeleverancier van verwarmingstechnologie.

We hebben gezien dat er weinig communicatie plaatsvindt tussen de besluitvormers in het ontwerpproces en de toeleveranciers van verwarmingstechnologie en dat er meerdere lagen van communicatie bestaan in het bouwproces. In het geval dat er een installatieadviseur wordt ingehuurd, geeft de adviseur instructies aan de installateur en koopt de installateur vervolgens de verwarmingsapparatuur. In eenvoudigere projecten is het de installateur die bepaalt welke verwarmingsinstallatie wordt gekozen. Installateurs worden echter nauwelijks gestimuleerd om innovatieve technieken te kiezen, want in veel gevallen onderhouden zij ook de installatie. Samenwerking tussen aannemers en fabrikanten van verwarmingstechnologie ontbreekt en vanuit dit perspectief is er geen enkele aanmoediging voor innovatie. Tegelijkertijd wordt het effect van energieprestatiebeleid op de toepassing van recente innovaties, zoals hoogrendementsketels, bestreden door de fabrikanten van dergelijke apparatuur. Men stelt dat de verbetering van het rendement deel uitmaakte van een doorlopende ontwikkeling die is begonnen met de introductie van de rendementsketel in 1981 en waarschijnlijk op dezelfde manier zou hebben plaatsgevonden als het energieprestatiebeleid niet was ingevoerd.

Ongeacht het effect dat energieprestatiebeleid heeft op het verminderen van het energieverbruik voor verwarming, koeling en ventilatie in gebouwen, kan men niet beweren dat het de communicatie tussen bouwende partijen en toeleveranciers van verwarmingstechnologie heeft gestimuleerd en evenmin dat het innovatief gedrag tussen deze twee partijen heeft aangemoedigd. Waar het energieprestatiebeleid zich richt op de bouwende partij, wordt verwacht dat het invloed heeft op de innovatie in de verwarmingstechnologie. Dit effect lijkt echter nogal klein of zelfs verwaarloosbaar te zijn. Fabrikanten van verwarmingstechnologie zijn actief in een zeer concurrerende markt en op een Europese schaal. Energieprestatiebeleid op nationaal niveau zal daardoor slechts een beperkte invloed hebben op de productontwikkeling, hoewel de fabrikanten het beleid op de nationale markt zullen gebruiken als een marketinghulpmiddel. In gevallen waarin het energieprestatiebeleid de productontwikkelingen 'volgt' – in plaats van dat het de productontwikkelingen inspireert door het instellen van veeleisende normen – zullen fabrikanten nauwelijks productinnovaties op de markt brengen als gevolg van het energieprestatiebeleid. Energieprestatiebeleid kan de ontwikkeling van producten zelfs in de weg staan doordat de producten moeten voldoen aan de beginselen van energieprestatieberekening. Dat kan een 'lock-in' effect teweegbrengen, want het stimuleert traditionele energietechnologie.

Energieprestatiebeleid in relatie tot het tegengaan van klimaatverandering

De verbeteringen van de energie-efficiëntie van gebouwen als gevolg van het energieprestatiebeleid in Nederland lijken voortgekomen te zijn uit de algehele optimalisatie van alle aan energie gerelateerde aspecten van de bouw. De isolatiegraad van gebouwen is verbeterd, hoewel niet spectaculair. Het rendement van de verwarmingstechnologie nam toe, hoewel dit deels het gevolg lijkt te zijn van de autonome technologische ontwikkeling die in de jaren tachtig is begonnen. De efficiëntie van de ventilatoren die worden gebruikt voor de ventilatie is verbeterd, evenals de efficiëntie van allerlei soorten aanvullende apparaten die nodig zijn voor de verwarmingstechnologie en die van warmteterugwinning in evenwichtige ventilatiesystemen. Hoewel het energieprestatiebeleid lijkt te hebben bijgedragen aan de optimalisatie van alle aan energie gerelateerde aspecten van de bouw, heeft het geen doorbraak opgeleverd op het gebied van innovatieve technologie. Als we naar de gegevens kijken die we in deze studie hebben verzameld, kunnen we zeggen dat het niet realistisch is om te beweren dat energieprestatiebeleid de kracht heeft om technologische innovatie te stimuleren.

Het voorstel om de norm aan te scherpen in 2011 en 2015, zoals het is geformuleerd door het Energieonderzoek Centrum Nederland (ECN), gaat vergezeld van een waarschuwing om niet te veel nadruk te leggen op installatiegerichte oplossingen (Daniëls *et al.*, 2006). De aanbeveling is om een verbeterd bouwontwerp te eisen door extra regels in te voeren voor de mate van isolatie en ontwerpen met een ligging op het zuiden en overmatig verwarmen en het ontwerpen van luchtdichte gebouwen te voorkomen (ibid.). Deze aanbevelenswaardige aanpak zal, zoals voorzien door het Energieonderzoek Centrum Nederland, een neveneffect hebben, namelijk de waarschijnlijkheid dat het, zelfs als de normen worden aangescherpt, aanvankelijk nog steeds mogelijk zal zijn om conventionele verwarmingstechnologie en vermindering van de energiebehoefte toe te passen voordat efficiënte technologie wordt ingezet.

Als we het energieprestatiebeleid beoordelen vanuit het perspectief van de transitie naar een duurzame energiehuishouding, is er reden tot bezorgdheid. Het energieprestatiebeleid richt zich op traditionele rekenmethoden en nieuwe technologie moet daarbinnen passen om geaccepteerd te kunnen worden – door middel van een zogeheten ‘gelijkwaardigheidsverklaring’ – in de energieprestatieberekeningsmethode. De energieprestatienorm kan een ‘lock-in’ effect veroorzaken door technieken te stimuleren die binnen de door het energieprestatiebeleid gehanteerde beginselen passen en technieken die met de conventie breken af te straffen. Bovendien bekijkt het energieprestatiebeleid de technologie uitsluitend op gebouwniveau, terwijl veelbelovende technieken die gebruikmaken van duurzame energie, zoals windenergiecentrales en biomassacentrales, op wijk- of stadsniveau werken. Oplossingen die veel meer vrijheid bieden, zijn al beschikbaar. In Nederland bestaat een energieprestatieaanpak op locatieniveau in de vorm van een vrijwillige methode dat kan worden gebruikt voor nieuwe stedelijke ontwikkelingen (SenterNovem, 2007). Als wordt uitgegaan van het ondersteunen in plaats van het hinderen van de transitie naar een duurzame energiehuishouding, is het sterk aan te raden het energieprestatiebeleid om te vormen van een aanpak op gebouwniveau tot een aanpak op locatieniveau, aangezien dat meer mogelijkheden zou scheppen voor de inzet van efficiënte warmteopwekkingstechnologie en technologie die gebruikmaakt van duurzame energiebronnen, zoals biomassacentrales en windturbines.

Curriculum vitae

Milou Beerepoot was born on November 7th, 1971 in Westwoud, a small village in the north of The Netherlands. Growing up in Voorschoten and Zoeterwoude she completed her secondary education at the Stedelijk Gymnasium in Leiden. In 1990 she started her studies in Industrial Design at Delft University of Technology. After completing the first year she switched to Eindhoven University of Technology where she studied Technology and Society. During her studies, she worked as an intern at the University of Amsterdam (IVAM), the European Commission (Directorate General Environment) and the consultancy firm W/E consultants sustainable building and she paid a research visit to the Escuela Superior de Arquitectura, part of Universidad Politécnica in Madrid. She received her Master's Degree in Technology and Society in 1996. After graduation she has worked for five years as a consultant for W/E consultants sustainable building and Damen consultants. During that time she developed her interest for policy research on the interface of technology and society. It was for that reason that she decided to start working at OTB Research Institute for Housing, Urban and Mobility Studies of Delft University of Technology as a researcher specialising in energy policy for residential buildings. She started in 2001 by writing a research proposal for the EC Vth framework Altener program that was accepted later that year. From 2002 to 2004 she was coordinator of this European project – named Build-On-RES – in which six partners from five EU countries participated and which contributed to the first part of the PhD research. In 2002 she paid a research visit of three months to the University of Liverpool, School of Architecture. From 2004 she continued her PhD research in the framework of the Habiforum programme 'Innovative Land Use' (BSIK) and Corpovenista (Housing Associations Renewing the City, a project running in 2004-2007).

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Energy performance policy in the building sector - such as is described by EU Directive known as EPBD - has the aim of reducing energy consumption in buildings. Given the importance of the development of innovations in energy technology, and a transition to a sustainable energy supply system, it is necessary that policy instruments for energy conservation in the building sector stimulate the development and diffusion of innovations.
This thesis contributes to knowledge about the content of energy performance policy and concludes that the effect of energy performance policy in encouraging innovation is limited. The study of the innovation system of the Dutch construction industry identifies how the project-based nature of the construction industry is an obstacle to 'learning-rich' collaboration between the various stakeholders. The study contributes to the discussion about the impact of government policy for energy conservation in the building sector, in the context of climate change policy.

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