Are energy decisions about energy?

Document status and date:
Published: 01/01/2023

DOI:
10.26481/dis.20231128wb

Document Version:
Publisher's PDF, also known as Version of record

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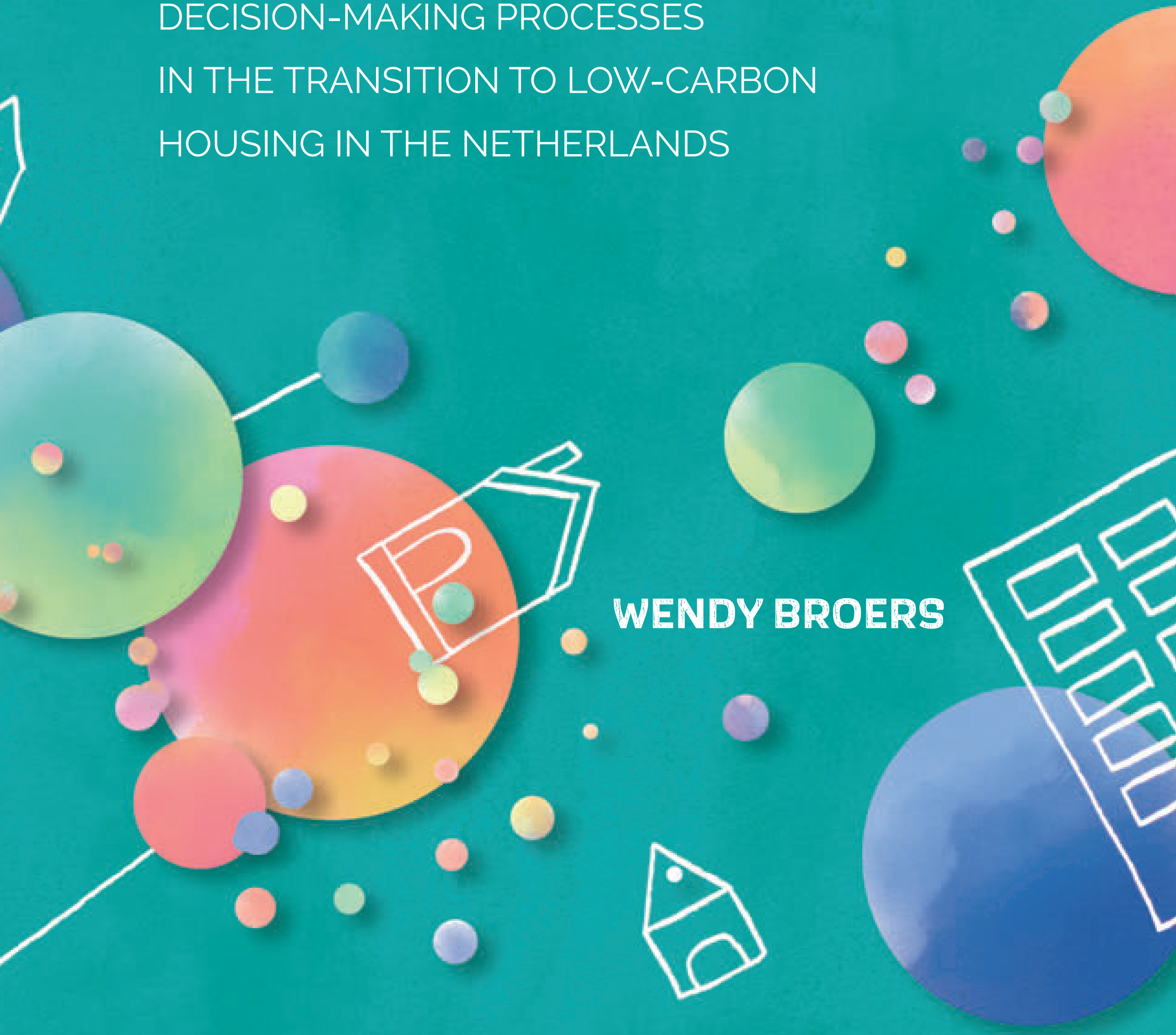
A STUDY OF HOMEOWNERS' DECISION-MAKING PROCESSES IN THE TRANSITION TO LOW-CARBON HOUSING IN THE NETHERLANDS



WENDY BROERS

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Wendy Broers

The research presented in this thesis was conducted at the Maastricht Sustainability Institute (MSI), School of Business and Economics (SBE), Maastricht University, and the lectoraat Smart Urban Redesign (SURD) of Zuyd University of Applied Sciences, Heerlen.

Cover design and layout: © evelienjagtman.com
Printed by: Ridderprint

ISBN: 978-94-6483-346-1
DOI: https://doi.org/10.26481/dis.20231128wb

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DISSERTATION

to obtain the degree of Doctor at Maastricht University,
on the authority of the Rector Magnificus, Prof. dr. Pamela Habibović
in accordance with the decision of the Board of Deans,
to be defended in public on 28 November 2023, at 13.00 hours.

by

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This research was funded by the Dutch Organization for Scientific Research (NWO, promotiebeurs voor leraren, 023.013.033); Zuyd University of Applied science (PhD funding); the Foundation Innovation Alliance (SIA, project Raakpro WoF, RAAK. PRO02.145); the European Union H2020 (project Drive 0, grant no. 841850), and Rijksdienst voor Ondernemend Nederland (RVO, project MOOI BIPV(T), MOOI32020).

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CHAPTER 1

GENERAL INTRODUCTION

1.1 Introduction

During my early career as a sustainable building consultant, the most difficult task was convincing clients to adopt low-carbon measures. As my ambitions usually exceeded theirs, it was essential to identify the factors that impacted their decision. This matter has kept me occupied throughout the years, even after I started my work as a researcher. Therefore, I decided to delve into this in more detail during my doctoral research, by using a socio-technical analysis that pays attention to the contextual circumstances of people, their needs, concerns and ways of thinking and evaluation, differences therein, justice and the role of intermediation and influences from others (professionals and non-professionals). Hence, the main title of my thesis is *'Are energy decisions about energy?'*, with the subtitle *'A study of homeowners' decision-making processes in the transition to low-carbon housing in the Netherlands'*. Throughout this thesis, I will assess the factors that can influence Dutch homeowners' energy-related choices for their homes and what interventions could encourage them to do more. The research primarily focused on the Netherlands, since there has been a long history of policy efforts to stimulate residential low-carbon measures, but diffusion has lagged behind. Furthermore, the Netherlands has a total of eight million homes, of which 57.1% are owned by private homeowners, 28.8% are owned by social housing associations, and 12.8% are owned by commercial and private landlords (Rijksoverheid, 2023). For the purpose of this thesis, the focus will be on the first two as they account for the majority of the Dutch housing stock.

This first chapter provides a general introduction to the thesis. In sections 1.2 and 1.3 the background and context of the study are discussed and the research problem is set out. In section 1.4, the research aims, objectives, and questions are presented and in 1.5 an outline of the thesis is offered.

1.2 Slow transition to low-carbon housing

Implementing low-carbon technologies is necessary for the built environment to live up to the EU's 2030 Climate Target Plan. This means cutting greenhouse gas emissions by at least 55% by 2030 and becoming climate neutral by 2050 (European Commission, 2021). Accordingly, the EU's renovation wave initiative aims at increasing the renovation rate with 3% per year which must result in renovating 35 million buildings in the EU by 2030 (European Commission, 2020c), and 1.5 million dwellings in the Netherlands (Rijksoverheid, 2019c, 2021). Despite the urgency, the housing market remains reluctant to innovate toward a low-carbon housing stock (van Oorschot, 2020). Moreover, Figure 1.1 reveals that reductions must increase more rapidly than 'business as usual' to meet the climate goals. This reduction can be realised by implementing residential low-carbon measures such as insulation, high-efficiency glazing, efficient heating and ventilation systems, and residential renewable energy production such as photovoltaics (PV). Taking on this enormous task will require the rapid diffusion of low-carbon measures in the built environment as well as policies that support this.

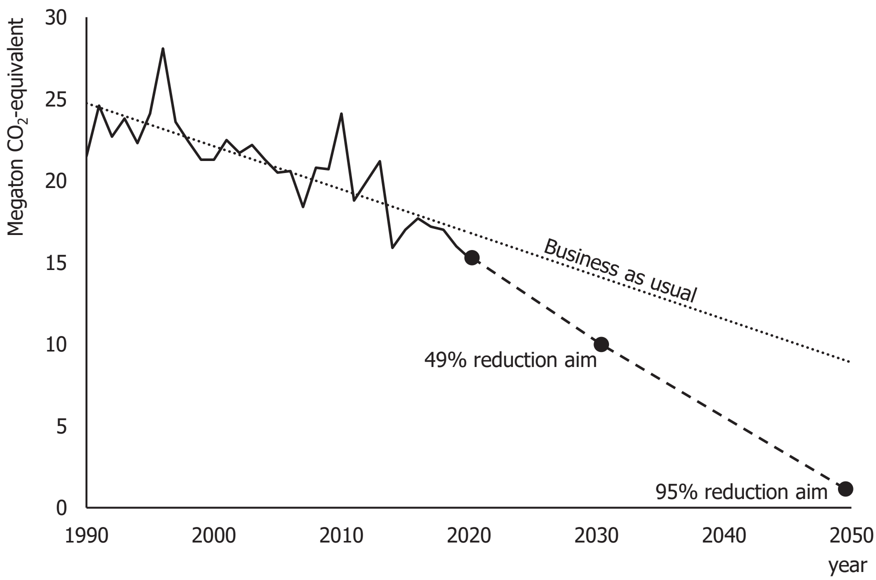

Figure 1.1. CO_2-emissions of the housing stock in the Netherlands, including the national reduction aims for 2030 and 2050 (based on CBS (2020c) & Rijksoverheid (2019c)

The current slow adoption rate of low-carbon measures in the housing stock can be attributed partly to the fact that energy policies generally disregard the diversity of concerns and motivations of homeowners, but often rely on a generic approach instead (Bartiaux et al., 2014; Crosbie & Baker, 2010; Judson & Maller, 2014; Karvonen, 2013; Kastner & Stern, 2015; Sovacool, 2014; Wilson et al., 2015). However, homeowners' choices about low-carbon measures are affected by a range of considerations, motivations, and contextual elements that require a holistic and comprehensive understanding. This deeper understanding is necessary in order to enhance the impact of energy policies, communication programs and marketing actions (Kastner & Stern, 2015; Malone et al., 2018; Wilson et al., 2018). A variety of stakeholders can make use of this knowledge at different system levels, including policymakers, employees and members of social housing and tenant associations, suppliers, consultants, energy coaches and architects. These insights will lead to better policies, products and more tailored advisory services for consultants and energy coaches to enhance the effectiveness of their work. Towards this end, this thesis seeks to identify and analyse the various factors influencing homeowners' decision-making processes regarding residential low-carbon measures, to provide a more comprehensive and holistic understanding of how these processes can be improved.

1.3 Challenges in decision-making

1.3.1 Complexity in decision-making processes

Prior studies have shown that homeowners' decisions about residential low-carbon measures are not isolated decisions, but are embedded in their daily lives and social practices. (Bartiaux et al., 2014; De Wilde, 2019; Fyhn & Baron, 2017; Gram-Hanssen, 2014a, 2014b; Judson & Maller, 2014; Karvonen, 2013; Kastner & Stern, 2015; Kerr et al., 2018; Malone et al., 2018; Shove, 2012; Vlasova & Gram-Hanssen, 2014; Wilson et al., 2013; Wilson et al., 2015; Wilson et al., 2018). In other words, low-carbon measures are a practice of home maintenance with multiple decision-making moments that homeowners engage on a regular basis. According to Rogers (2003a), the decision-making process consists of five stages, ranging from gaining an initial understanding of the innovation (1. knowledge stage), developing an attitude towards it (2. persuasion stage), determining whether to adopt it or reject it (3. decision stage), implementing it (4. implementation stage), and confirming the adoption of the innovation (5. confirmation stage). Several studies have tested this model and found it useful in the context relevant to domestic low-carbon measures (e.g. Ebrahimigharehbaghi et al., 2019; Faiers & Neame, 2006; Klöckner & Nayum, 2016; Mahapatra & Gustavsson, 2008; Wilde & Spaargaren, 2018; Wilson et al., 2018).

Homeowners are subject to a wide variety of influences during this decision-making process (Kerr et al., 2018), which can be more or less relevant at the various stages of the process (Ebrahimigharehbaghi et al., 2019; Klöckner & Nayum, 2016). Despite previous studies, the understanding of these factors influencing homeowners' decision making processes is still limited (Ebrahimigharehbaghi, 2022). Moreover, most of the studies focus only on a few factors (Kastner & Stern, 2015). In order to develop policies and communication programs that are more effective, comprehensive knowledge is required to account for the complexity and diversity of the concerns and motivations of homeowners. Therefore, this thesis will address this literature gap by studying the various factors influencing the multistage decision-making process of homeowners in all its complexity and interconnectedness through a mixed-methods analysis.

1.3.2 Heterogeneity in homeowners' characteristics

According to Rogers' decision model (Rogers, 2003a), the knowledge stage of the decision-making process is influenced by the personal characteristics of the decision-maker, such as socioeconomic characteristics, personality variables, and their communication behaviour. In the subsequent stage, the persuasion stage, the perceived characteristics of the innovation by the decision-maker are key. This means that people will evaluate the advantages and disadvantages of the innovation for their particular situation (Rogers, 2003a). These personal characteristics and the perception of the innovation influences the decision stage of the decision-making process. It is therefore crucial to gain more insights into which personal factors can influence this process.

The diffusion of residential photovoltaics (RPV) can make a major contribution in the transition to low-carbon housing. There have been several studies using Rogers' theory to develop segmentation models to identify potential adopters of innovations such as RPV (e.g. Faiers & Neame, 2006; Palm & Eriksson, 2018; Petrovich et al., 2019; Sigrin et al., 2015; Vasseur & Kemp, 2015b). Several authors have recognized that socioeconomic factors influence the decision to adopt an innovation in the context of RPV, such as age, income, and education level (e.g. Bondio et al., 2018; Busic-Sontic & Fuerst, 2018; Faiers & Neame, 2006; Palm, 2017; Vasseur & Kemp, 2015a; Wolske et al., 2017). However, personal variables such as environmental concern and type of education or profession regarding RPV adoption got less attention in the literature or give inconclusive results. This thesis explores this research gap by developing a segmentation model for the adoption of RPV, and gains a theoretical and empirical foundation for understanding the heterogeneity of potential adopters of RPV by examining the influence of these personal characteristics.

1.3.3 Limited attention to justice in the decision-making process of social housing

One of the goals of the EU's Renovation wave initiative is a socially just transition to a carbon-neutral Europe, which supports vulnerable groups and social housing retrofits by bringing together climate and social cohesion goals (European Commission, 2020b, 2020c). As energy poverty is a growing issue in the EU, affordability is considered a key principle of the EU's policy, particularly for low-income and vulnerable households (European Commission, 2020c). In 2020, about 35 million EU citizens were unable to heat their homes adequately (about 8% of the EU's population). This situation is likely to have declined an already difficult situation for many EU citizens, due to the surge in energy prices that began in 2021 and worsened with the Russian invasion of Ukraine in February 2022 combined with the impact of COVID-19 (European Commission, 2022). Accordingly, the European Commission recommends that countries focus on vulnerable households during their long-term energy renovation strategies (European Commission, 2020b).

Many vulnerable and low-income households live, largely, in social housing as this sector provides affordable housing for this target group (Leidelmeijer et al., 2018). However, to meet Europe's climate goals, social housing associations often implement low-carbon measures top-down, rather than involving tenants in their decision-making process (Hickman & Preece, 2019; Uyterlinde et al., 2019). In many cases, the renovation plans are merely technology-driven, based on the urgency of meeting climate goals (Boess, 2017; Hickman & Preece, 2019; Uyterlinde et al., 2019). As a result, energy renovations in social housing do not always have a positive outcome for their residents. Consequently, tenants may become dissatisfied with the renovations, be noncooperative, and experience increased energy poverty if the low-carbon measures fail (Sovacool et al., 2019; Straver & Mulder, 2020). Thus, the EU recommends a co-creation process with tenants to ensure that renovation costs are balanced by energy savings and do not become a burden. Hence, a fair transition to a climate-neutral housing stock touches on critical justice aspects when it comes to distributional and procedural issues. Despite this, there are only a few justice studies related to the transition to low-carbon social housing (e.g. Breukers et al., 2017; Gillard et al., 2017; Sovacool, 2015; Sovacool et al., 2019). Moreover, the few studies that exist do not encompass the entire energy renovation process in social housing. Therefore, this thesis will investigate how to make the decision-making process on low-carbon measures for social housing more just for tenants.

1.3.4 Deficient knowledge of intermediation in decision-making processes

A variety of challenges can emerge during the stages of the decision-making process for any technical innovation, such as a lack of awareness or misinformation about the innovation or difficulties in obtaining financing. Such difficulties can impede the diffusion of the innovation (Glaa & Mignon, 2020). Prior research revealed that intermediaries can play a crucial role to in dealing with such challenges (e.g. Aspeteg & Bergek, 2020; Bergek, 2020; Glaa & Mignon, 2020; Howells, 2006; Hyysalo et al., 2022; Sovacool et al., 2020). Intermediaries can positively influence innovation adoption processes by connecting different visions and interests, actors and activities, and their resources and expectations; and they can promote innovation diffusion by creating new networks and collaborations (Kivimaa, Boon, et al., 2019; Sovacool et al., 2020). However, most of the studies on intermediation have focused on intermediaries acting at the system level (Bergek, 2020). Though, several studies indicate that there is a lack of systematic knowledge about intermediaries located downstream in the supply chain between technology adopter and supplier (e.g. Aspeteg & Bergek, 2020; Mignon & Broughel, 2020).

User and diffusion intermediation are often overshadowed by more prominent supply-side intermediaries in previous studies (e.g. Aspeteg & Bergek, 2020; Bergek, 2020; Mignon & Broughel, 2020; Murto et al., 2020; Murto et al., 2019; Stewart & Hyysalo, 2008; Vihemäki et al., 2020). There are also limited studies on the role of intermediaries across the multistage decision-making process (Mignon, 2017). This can pose problems because technologies need to be developed and adopted widely to contribute to sustainable transitions (Bergek, 2020). Accordingly, this thesis will address this literature gap by studying how intermediation can affect the multistage decision-making process.

1.4 Research aim, objectives, questions, and methods

Given the lack of insight into the homeowners' decision-making processes about low-carbon measures for the transition to low-carbon housing, this thesis aims to identify and evaluate the varying factors that influence the multistage decision-making processes of homeowners about low-carbon measures. By studying this topic, a more holistic understanding will be gained of how this process can be improved. Hence, the main research question is:

> *What factors influence the decision-making processes of Dutch homeowners regarding residential low-carbon measures, and what interventions can encourage them to do more?*

To address the main research question, this study consists of four empirical studies. An overview is presented in Figure 1.2, along with the sub-research questions that are theoretically and empirically examined in this thesis, and the methods used. Policymakers, employees and members of social housing and tenant associations, suppliers, and consultants can benefit from this comprehensive understanding, enabling them to improve policies, internal procedures, and communication campaigns aimed at increasing the diffusion of residential low-carbon technologies. This thesis contributes to the body of academic literature on low-carbon housing, renewable energy, innovation adoption and diffusion, justice perspectives, and studies on intermediation in the transition to low-carbon housing. To analyse the decision-making process of homeowners, an exploratory mixed-methods approach is used, combining quantitative and qualitative data to collect and analyse data. Considering that these approaches answer different research questions, combining them can result in deeper insights (Tashakkori & Creswell, 2007). The four empirical studies are discussed in more detail below.

The aim of **Study I** is to provide a more holistic perspective concerning the decision-making process of Dutch private homeowners regarding energy renovation measures (ERM). It studies the influencing factors in the various stages of the decision-making process of Dutch private homeowners concerning ERM. Adoption and diffusion theories are used to investigate which factors influence the various stages of this process. Data are collected among private homeowners of the city region of Parkstad Limburg (NL) by using surveys and interviews. Data collection is applied in a flexible and open way, leaving room for exploring unexpected insights to gain a better understanding of how decisions are reached. The study takes this approach to provide a holistic perspective on the stages of the decision-making process, the many factors homeowners consider, and the many factors that influence the decision-making process. Specifically, this study develops a decision-making model for private homeowners regarding ERM.

Based on the findings of the first study, **Study II** pursues the development of a segmentation model to gain a theoretical and empirical foundation for understanding the heterogeneity of potential RPV adopters. It investigates how a better knowledge of the heterogeneity of potential RPV adopters via a segmentation model can be used for designing targeted communication campaigns. A survey is conducted among participants in the 'solar panel project' in the city region of Parkstad Limburg (NL). Rogers' diffusion theory (Rogers, 2003a) is used to collect and analyse the data. A particular focus in this study is on how homeowners perceive RPV's characteristics based upon their own personal characteristics. Within the study a segmentation model is developed based on homeowners' level of environmental concern and educational background or profession.

Study III focuses on the decision-making process for low-carbon measures for social housing in the Netherlands. It uses a multidimensional justice perspective to provide better insights into a just and people-centred energy renovation process. This study investigates what justice dimensions affect energy renovations in social housing, and how better knowledge of these can be used to achieve outcomes that are more just and socially fair. The topic was explored by interviewing employees and members of Dutch social housing and tenant associations in order to gather their experiences and perspectives. The study explores multiple justice dimensions and their interrelations, including distribution, recognition, participation, capability and responsibility (Davoudi & Brooks, 2014), and develops recommendations for a more just and people-centred energy renovation process in social housing.

In **Study IV**, an emerging technology is explored: building-integrated photovoltaics (BIPV). Several challenges can emerge in the decision-making process of an emerging innovative technology. Prior work has demonstrated that intermediaries can play an effective role in countering these challenges. Therefore, this study examines how intermediation can help to catalyse the various stages of the decision-making process of potential BIPV adopters. Data is collected by interviewing various actors within the Dutch BIPV system. Rather than focusing on specific intermediary actors, the Dutch BIPV system is explored, to identify which actors act or can act as intermediaries, and investigate what intermediation activities can support homeowners' decision-making process.

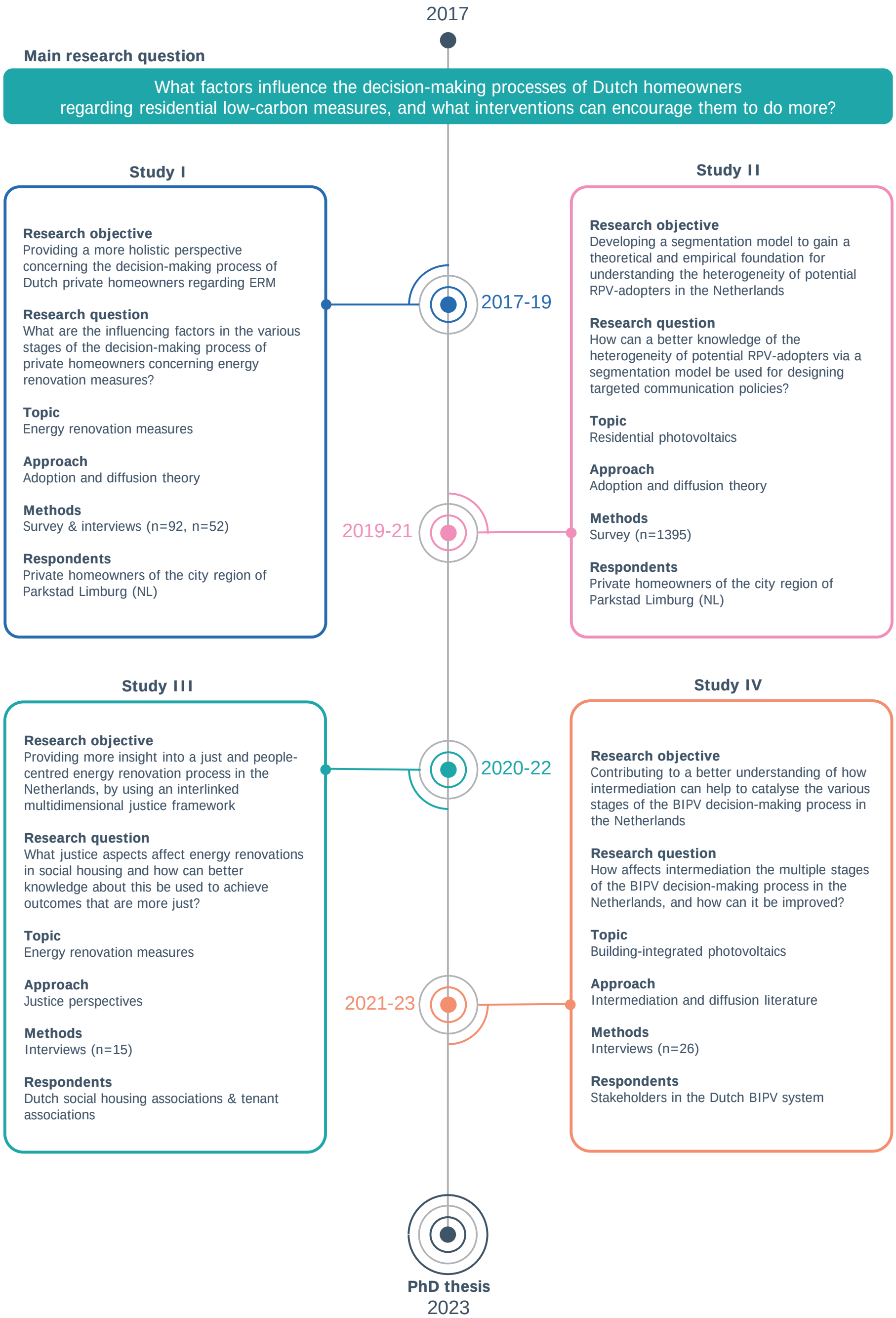

Figure 1.2. Timeline with an overview of the four empirical thesis studies, their research objectives, questions and methods

1.5 Outline of the thesis

In Chapter 1, the context of the thesis has been introduced. Research objectives, questions, and methods have been identified, and the value of such scientific research is argued. Chapter 2 introduces an integrative model for private homeowners' decision-making process concerning energy renovation measures. The model distinguishes between the various stages of the decision-making process, the multiple factors that influence these stages, and the many considerations facing homeowners as they decide to adopt or reject energy renovation measures. Chapter 3 reveals a study on the development of a segmentation model, which gives a theoretical and empirical foundation for understanding the heterogeneity of potential adopters of RPV. The five segmentation groups are based on homeowners' educational background or profession and level of environmental concern. In Chapter 4, the energy renovation process in social housing is explored by using a multidimensional justice perspective, to provide lessons and recommendations for a more people-centred process in which the needs of vulnerable households are addressed. In Chapter 5, the role of intermediation in the decision-making process of building integrated photovoltaics is investigated by identifying which actors act or can act as an intermediary, and what intermediation activities can support this process. Next, Chapter 6 presents a discussion of the key findings and contributions of this thesis and the concluding remarks on this thesis as a whole. It also indicates the limitations and recommendations are given for further research. Finally, the scientific and societal impact is presented, as are the acknowledgements and information about the author.


2

CHAPTER 2

DECIDED OR DIVIDED? AN EMPIRICAL ANALYSIS OF THE DECISION-MAKING PROCESS OF DUTCH HOMEOWNERS FOR ENERGY RENOVATION MEASURES

W. Broers, V. Vasseur, R. Kemp, N. Abujidi, Z. Vroon

Published in Energy Research & Social Science 2019; 58, 101284

Abstract

The pace at which energy renovations are made to the existing housing stock must increase if the Netherlands is to reach the energy goals outlined in the nation's climate mitigation policy. In this chapter, this challenge is addressed by introducing a novel integrative model for a private homeowner's decision-making process concerning energy renovation measures. The model distinguishes between the various stages of the process, the multiple factors that influence these stages, and the many considerations facing homeowners as they decide to adopt or reject energy renovation measures. Data were collected from interviews with and questionnaires completed by private homeowners in the city region of Parkstad Limburg (NL) who received an energy audit for their home. The findings reveal that various factors are relevant in different stages of the decision-making process. In the first stage, external developments, physical factors, socio-demographic factors, and environmental concerns can trigger an interest in energy renovation measures. In the second stage, homeowners gain knowledge about the measures, and personal background and advice from their social network or from professionals can influence this decision stage. In the third stage, during which financial-economic factors are particularly important, homeowners form an opinion about the energy renovation measures. After implementing the energy renovation measures, homeowners can also influence others in their social network and become ambassadors for further energy-saving changes. Based on the results, policy recommendations are provided to increase the adoption of energy renovation measures by private homeowners.

2

2.1 Introduction

According to the United Nations (2018), countries worldwide must triple their efforts to keep global warming below 2 degrees Celsius and must increase their efforts fivefold to stay below 1.5 degrees (UNEP, 2018) and meet the goals of the Paris climate agreements (UN, 2015). To contribute to this latter effort, 1.5 million houses in the Netherlands (20% of the housing stock) need to be renovated before 2030 to cut carbon dioxide (CO_2) emissions 49% by that time (SER, 2018). This can be realised by energy renovation measures (ERM) such as insulation, high-efficiency glazing, efficient heating and ventilation systems, and renewable energy production (e.g., PV panels) that interact with collective renewable energy solutions on a district level. Despite this technical potential and widespread policies supporting energy renovations (Wilson et al., 2015), the average rate of renovations is between 0.5% and 1.2 % per year in Europe (Šajn, 2016). As a result, the energy renovation pace is not on schedule to meet the emission targets (NRP, 2015).

This limited impact of current policy measures can be explained by: 1) instituting non-coercive policy instruments, 2) placing the responsibility for energy efficiency solely on homeowners (Murphy et al., 2012), 3) addressing homeowners in policies as rational decision-makers (Ariely, 2010; Lutzenhister, 2014; Maller & Horne, 2011; Murphy, 2014; Schelly, 2014; Taranu & Verbeeck, 2017; Wilson et al., 2015), and 4) overlooking the social aspects of renovation (Bartiaux et al., 2014; Gram-Hanssen, 2014a; Judson & Maller, 2014; Karvonen, 2013; Kastner & Stern, 2015; Malone et al., 2018; Wilson et al., 2015). As a direct result, most policies ignore the diversity of concerns and motivations in relation to ERM (Bartiaux et al., 2014; Crosbie & Baker, 2010; Judson & Maller, 2014; Karvonen, 2013; Kastner & Stern, 2015; Sovacool, 2014; Wilson et al., 2015).

To increase the impact of policies, a more holistic perspective is needed concerning the decision-making process of private homeowners regarding ERM (Kastner & Stern, 2015; Malone et al., 2018; Wilson et al., 2018). This challenge is addressed in this paper by analysing this complex and diverse decision-making process. The main research question of this study is:

> *What are the various stages in the decision-making process of private homeowners concerning energy renovation measures and what are the influencing factors in these stages?*

An interdisciplinary approach for data collection is chosen for the development of a decision-making model for of private homeowners for ERM. Data is collected from three Dutch projects in which home energy audits[1] were offered to private homeowners.

This Chapter is structured in the following way: In the next section, existing literature on the decision-making process of private homeowners is discussed; in section 2.3, the research method is explained; in section 2.4, the results of this study are presented; in section 2.5, the discussion is presented; and in section 2.6, the conclusions of the study are presented and recommendations are formulated for policy actions and further research.

1 *An energy audit is advice given by a trained professional to reduce the energy use of the house. This advice includes energy-efficiency measures and renewable energy options.*

2.2 Background: the decision-making process of private homeowners

2.2.1 Decision-making stages

In this section, relevant theory and empirical results from others are presented examining the decision-making process of private homeowners for ERM. Previous studies argue that the homeowners' decisions about ERM are not isolated decisions but are situated in daily life and embedded in social practises. This is because the decision-making process of homeowners regarding ERM can be seen as an ongoing practise of home maintenance with multiple decision-making moments (Bartiaux et al., 2014; De Wilde, 2019; Fyhn & Baron, 2017; Gram-Hanssen, 2014a, 2014b; Judson & Maller, 2014; Karvonen, 2013; Kastner & Stern, 2015; Kerr et al., 2018; Malone et al., 2018; Shove, 2012; Vlasova & Gram-Hanssen, 2014; Wilson et al., 2013; Wilson et al., 2015; Wilson et al., 2018). According to Rogers (Rogers, 2003b), there are five stages in the decision-making process, which are explained in Table 2.1.

Table 2.1. Innovation decision-making process (based on Rogers, 2003b)

Innovation decision-making process	
Prior conditions	Perceived need or problem, social norms, current practises
1. Knowledge stage	In this stage, an individual gains understanding about an innovation
2. Persuasion stage	In this stage, an individual forms a favourable or unfavourable attitude about the innovation
3. Decision stage	This stage leads to the decision to adopt or to reject an innovation
4. Implementation stage	In this stage, the innovation is implemented
5. Confirmation stage	This stage occurs when an individual seeks reinforcement of an innovation decision already made

This model has been tested and proved useful in contexts relevant to ERM (Faiers & Neame, 2006; Mahapatra & Gustavsson, 2008; Wilson et al., 2018). Furthermore, other models using different theories have been developed for the decision-making process concerning ERM (Ebrahimigharehbaghi et al., 2019; Klöckner & Nayum, 2016; Wilde & Spaargaren, 2018). Based on these previously developed decision models, we specify six decision-making stages for ERM in this study. These stages define the activities that are taking place in the decision-making process for ERM and are described in Table 2.2.

Additionally, homeowners have a multitude of considerations and are also subject to a wide variety of influences (to greater or lesser extent) when making their way through the decision-making process (Kerr et al., 2018). These influencing factors can be more or less relevant in the various stages of the process (Ebrahimigharehbaghi et al., 2019;

Klöckner & Nayum, 2016). Despite this, Kastner & Stern (Kastner & Stern, 2015) point out in their review that only a few empirical studies address the subject and focus mostly on a limited number of variables. Additionally, only a few studies have used a qualitative in-depth analysis of the decision-making process of homeowners in all its complexity and interlinked connections. Therefore, they argue for an integrative, interdisciplinary, theoretical framework explaining energy-relevant investment decisions in which the relationship between variables is also studied.

Table 2.2. Decision-making stages for ERM, conceptual framework for this study (based on Ebrahimigharehbaghi et al., 2019; Faiers & Neame, 2006; Klöckner & Nayum, 2016; Mahapatra & Gustavsson, 2008; Rogers, 2003b; Wilde & Spaargaren, 2018; Wilson et al., 2018)

Decision-making stages for ERM	
1. Getting interested	Homeowners start to think of ERM
2. Gaining knowledge	Homeowners are exposed to the existence of ERM and gain an understanding of how these measures function
3. Forming an opinion	Homeowners form a positive or negative attitude and perception towards ERM
4. Making a decision	Homeowners decide to implement or reject ERM
5. Implementing ERM	ERM are implemented in the house
6. Experiencing ERM	Homeowners experience ERM and form a positive or negative attitude towards the measures taken, based on their own experiences

Therefore, the conceptual framework for the decision-making stages for ERM will be used in this study to investigate the influence of the various factors in the several stages of the decision-making process. Nevertheless, the framework is applied in a flexible and open way, to leave room for exploring unexpected new leads to gain a better understanding about how decisions are made. This approach is chosen because the aim of the study is to provide a holistic perspective on the stages of the decision-making process of ERM, the many factors homeowners must consider, and the many factors influencing the process. This research will fill the literature gap by developing a novel integrative model of the decision-making process used by private homeowners concerning ERM.

The findings of other studies on the influencing factors in the different stages of the decision-making process are discussed in the sections below.

2.2.2 Getting interested

Firstly, external developments can create awareness among homeowners to pique their interest in ERM. On the one hand, this can be policy actions such as financial schemes (Caird et al., 2008), information campaigns, or community energy events (Darby, 2006;

Oteman et al., 2017; Scott et al., 2016). On the other hand are grass-roots initiatives and energy co-operatives in which a group of citizens themselves take action to create awareness and organise the implementation of ERM (Galvin & Sunikka-Blank, 2014; Hoppe et al., 2019; Oteman et al., 2017; Sifakis et al., 2019; Vergragt & Brown, 2012).

Secondly, the physical factors[2], such as the house itself, can also influence homeowners' decisions to implement ERM in this stage. Homeowners are more willing to consider ERM when they experience poor (thermal) comfort (Banfi et al., 2008; Karvonen, 2013; Mortensen et al., 2014; Nair et al., 2010a; RVO, 2016), when they are relatively new homeowners (Mortensen et al., 2016; Nair et al., 2010a), or when they want to change the architecture or aesthetics of the house (Karvonen, 2013; Mortensen et al., 2016).

Thirdly, socio-demographic factors can also be important influencers in this 'considering' stage (Ebrahimigharehbaghi et al., 2019; Wilson et al., 2018). Previous studies argue that there is a possible correlation between socio-demographic factors and homeowners' choices for ERM. There seems to be a positive correlation between younger homeowners and adoption of measures (Mortensen et al., 2016; Moula et al., 2013; Nair et al., 2010a; Poortinga et al., 2003), the presence of younger children (Mortensen et al., 2016), and homeowners with a higher education level or higher average income (Hrovatin & Zorić, 2018; Kastner & Stern, 2015; Mortensen et al., 2016; Nair et al., 2010a; Poortinga et al., 2003; Sardianou & Genoudi, 2013). Uncertainty about how long one will stay living in the house can be a barrier to investing in the home (Hrovatin & Zorić, 2018; Murphy, 2014; Wilson et al., 2018). However, other studies have found that socio-demographic factors such as gender, education, and occupation are rarely related to the adoption of ERM (Kastner & Stern, 2015).

Fourthly, previous studies have demonstrated that personal norms (among other factors) are important influencing factors in pro-environmental choices; this is also argued in several developed and proved theories (e.g., theory of planned behaviour, (Ajzen, 1991, 2006), norm activation model (Schwartz, 1977), and value belief norm theory (Stern, 2000)). These models have been widely tested in several areas and were confirmed on their predictive power (e.g. Bamberg & Möser, 2007; Kastner & Stern, 2015; Steg et al., 2005). Furthermore, there were also efforts to include other predictors or factors into more comprehensive frameworks (e.g. Bamberg & Möser, 2007; Huijts et al., 2012; Venkatesh et al., 2003). However, the great majority of these studies focus on curtailment behaviour and rarely on investment decisions such as ERM (Kastner &

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2 By physical factors, we mean material aspects whose influence occurs via evaluation.

Stern, 2015). Black et al. (1985) reported that major energy investment decisions have different patterns of predictors than energy curtailment behaviour (Black et al., 1985) and, therefore, their usability for these decisions is questionable for the adoption of ERM (Kastner & Stern, 2015).

Nevertheless, these theories and related research indicate that environmental concern or awareness (as a personal norm) is an important influencing factor in the decision-making process (Bamberg, 2003; Gardner & Stern, 2002; Owens & Driffill, 2008; Poortinga et al., 2004; Poortinga et al., 2003; RVO, 2016; Steg et al., 2015). With environmental concern, we mean that people feel responsible for the environment and take action themselves. Conversely, some studies argue that focus on the environment in policy can also be a hindrance, especially for more politically conservative people (Goldstein et al., 2008; Gromet et al., 2013; Schelly, 2014). So far, the role of environmental concern in the decision-making process of private homeowners concerning ERM is understudied, and more research is needed to achieve insight into this issue.

2.2.3 Gaining knowledge

When a homeowner becomes interested in ERM, the next stage is gaining knowledge about the measures being considered (Ebrahimigharehbaghi et al., 2019; Rogers, 2003b; Wilde & Spaargaren, 2018; Wilson et al., 2018). Additionally, other studies point out that knowledge about (Huijts et al., 2012), experiences with (Schuitema, 2011; Venkatesh et al., 2003), or competencies of the individual (Shove, 2012) with a certain technology can influence a homeowner's decision to implement ERM. Consequently, a lack of adequate knowledge or information can have a negative effect on a homeowner's decision to invest in ERM (Banfi et al., 2008; Löfström & Palm, 2008; Mortensen et al., 2016; Nair et al., 2010b; Schleich, 2004; Tuominen et al., 2012). A tailored face-to-face energy audit has been revealed in several studies as an effective tool to overcome this barrier (Benders et al., 2006; Delmas et al., 2013; Novikova et al., 2011; Steg, 2008; Stern, 1992). By contrast, other studies demonstrate only a weak link between energy audits and homeowners' decisions to invest in ERM (Abrahamse et al., 2005; McDougall et al., 1982; Murphy, 2014) or demonstrate a negative correlation (Frondel & Vance, 2013; Murphy, 2014). These diverse outcomes of the effect of energy audits are presumably linked to research and sampling methodologies (Abrahamse et al., 2005; Murphy, 2014) and need further investigation.

Regarding this knowledge stage, several studies point out that interpersonal communication, through face-to face exchange, is the most effective way to persuade an individual to adopt an innovation (Mahapatra & Gustavsson, 2008; Malone et al., 2018; Rogers, 2003b). Likewise, other studies identified social influence (Darby, 2003; Venkatesh et al., 2003) and social norms (Bamberg, 2003; Elmustapha et al., 2018; Huijts et al., 2012) as influencing factors. After implementing ERM, homeowners can also influence others in their social network to adopt ERM (Wilson & Dowlatabadi, 2007) and thereby increase the adoption of ERM by other homeowners. Despite this importance, the influence of advice from homeowners' social networks is an aspect that is not widely studied yet with regard to ERM in homes, and more research is needed on how and when a social network influences a homeowner's decision-making process (Bartiaux et al., 2014; McMichael & Shipworth, 2013).

Next to advice from their social network, other studies have revealed that installers of ERM[3] play an important role in informing homeowners (De Wilde, 2019; Nair et al., 2010a; Owen et al., 2014; Risholt & Berker, 2013; Wade et al., 2016; Wilde & Spaargaren, 2018) but the ERM industry is often seen by the homeowners as unreliable and non-transparent (Bartiaux et al., 2014; De Wilde, 2019; Karvonen, 2013; Risholt & Berker, 2013). Therefore, trust and reliability are important issues when homeowners deal with these energy companies (De Wilde, 2019; Weiss et al., 2012; Wilson et al., 2015). In addition, other studies point out that installers of ERM often lack knowledge about new technologies and are reluctant to install them (Risholt & Berker, 2013).

2.2.4 Forming an opinion

Financial-economic factors are often important in the 'forming an opinion-stage' of the decision-making process in which homeowners form a favourable or unfavourable attitude towards ERM (Ebrahimigharehbaghi et al., 2019; Stieß & Dunkelberg, 2013; Wilson et al., 2018). Financial motivations can be the perception of a high energy bill (Carroll et al., 2016; Nair et al., 2010a) and a positive project economy (Mahapatra & Gustavsson, 2008; Mortensen et al., 2016; Nair et al., 2010b). On the other hand, reported barriers for adoption are lack of finances (Murphy, 2014), uncertainty of the benefits (Amstalden et al., 2007; Kemp & Never, 2017; Liu et al., 2010; RVO, 2016), underestimation of the energy savings (Attari et al., 2010), and a perceived long payback period (Murphy, 2014). Furthermore, homeowners who experience a low energy bill or homeowners who evaluate their house as being in good condition will refrain from taking measures as well (Mortensen et al., 2016; Murphy, 2014; Nair et al., 2010a; RVO, 2016). Governmental grants, subsidies, and loans can be important drivers for homeowners to adopt ERM (Caird et al., 2008).

3 *Installers of ERM: e.g., building contractors, heating installers, installers of PV panels.*

2.2.5 Making a decision, implementing ERM, experiencing ERM

After homeowners have formed an opinion, they will decide whether or not to adopt ERM; this is the 'making-a-decision' stage. If they have decided to make the necessary changes, the 'implementing ERM stage' and the 'experiencing ERM stage' will follow (see Table 2.2). In these last two stages, the homeowners form a positive or negative perception about the ERM based on their own experiences. These perceptions will influence what they will tell others in their social network about ERM.

2.3 Research method

2.3.1 Energy audits for homeowners in the city region of Parkstad Limburg (NL)
The empirical data were collected from three projects in the city region of Parkstad Limburg (NL) after professional advice (an energy audit) was offered to private homeowners regarding making their homes more energy-efficient. The city region, which is located in the south of the Netherlands, comprises eight municipalities and counts 125,885 households (Stadsregio Parkstad Limburg, 2016). This region was selected as a case study because it is one of the frontrunners on energy strategies in the Netherlands (VNG, 2018) and is home to several projects targeting the existing housing stock. Historically, the city region grew rapidly during the coal mining boom from 1900 to 1960 but has experienced a decline in households since the closing of the mines in the 1970s. As a result, the current average income per household and the average property value are lower than those figures for the Netherlands as a whole, mainly because of fewer job opportunities. The region has both an urban and a rural character, which are strongly intertwined (Parkstad-Limburg, 2009). The study results can also be relevant for regions where the situation is different because regions with less-developed energy strategies can learn from these frontrunners. This study focuses on owner-occupied homes, as they form the majority of the housing stock (56% in NL (Rijksoverheid, 2016) and 70% on average across the EU (Eurostat, 2018).

The three projects (A, B, C) where data were collected have slightly different setups. Project A included all eight municipalities in the city region, Project B was implemented in the municipality of Landgraaf, and Project C targeted the municipality of Nuth. In Project A, only advice was offered; in Projects B and C, the participants also received an offer from local companies to install the energy-saving measures; and Project B also provided financing from the municipality in the form of a low-interest loan. The projects were executed by three intermediary organisations that were hired by the involved municipalities and provided the advisers for the energy audits (see Table 2.3). The homeowners received a home visit from the adviser and a written report afterwards with recommendations for ERM.

2.3.2 Data collection
In this study, data were collected with online questionnaires (n = 91) and face-to-face interviews (n = 52). The online questionnaires were used to provide preliminary input for the interviews to assist in selecting purposeful samples and to identify (new) topics for further analysis. The questions were therefore merely open-ended questions to explore the topics. The interview method was used to gain a better understanding of the cases in depth and detail, to grasp meaning in a particular (dynamic) context (Patton,

1999), and to allow the homeowners to satisfactorily describe their entire decision-making process and experiences. A quasi-inductive approach was chosen to provide room for new findings and to gain a better understanding about how decisions are made. The semi-structured interview protocol was composed of open-ended questions to guide the conversation with the homeowner about his or her decision-making process, experiences with the energy audit, and any other advice received. In addition, information was collected about the characteristics of the homeowner and the dwelling (see Appendix A of this Chapter). By interviewing the respondents in person, it was possible to correct misunderstandings in the questions and ask follow-up questions if unexpected, but relevant, themes were brought up by the respondent. Furthermore, the personal contact with the homeowner gave the researcher knowledge about the context in which the question was answered (Evers, 2015), and additional information about the physical context of the home could be collected.

Table 2.3. Overview of data sampling and project characteristics

Case-studies	**Project A**		**Project B**		**Project C**		**Total**	
Municipalities targeted	city region of Parkstad		Landgraaf		Nuth			
Intermediary organisations	DUW		GEAS		Susteen			
Energy audit	X		X		X			
Offer from companies			X		X			
Financing			X					
Costs[4]	free		€60		€45			
	#	%	#	%	#	%	#	%
Contacted people	420	58%	87	12%	222	30%	729	100%
Interested people	74	54%	20	15%	42	31%	136	19%
Respondents questionnaires	54	59%	-[5]	0%	37	41%	91	12%
Interviews	19	37%	18	35%	15	29%	52	7%

Data collection was completed between October 2017 and June 2018; private homeowners were recruited by email through the municipalities. Interested homeowners received the online questionnaire and a sample of these respondents were selected for interviewing. Due to the fact that only homeowners who responded are studied, there is a possible selection bias as this group may not represent the entire sample. The interviews were

4 *These costs refer to the amount of money homeowners had to pay for the energy audit. The actual costs were higher and were subsidised by the municipality.*

5 *No questionnaires were sent out in Project B because of the limited interest. The questions from the questionnaires were added to the interview questions instead.*

conducted in person by the researcher (first author) and a research assistant at the homeowner's house. The homeowners received a gift voucher of 20 euros for their participation. The interview data were analysed every 5 to 10 interviews and discussed by the research team (authors). The interview protocol was adjusted when found necessary after analysis of the data. Data collection was ended when data saturation was reached and no new data relevant to the research themes emerged (Guest et al., 2006). The interviews were digitally recorded, stored (with permission of the respondent), and transcribed. All interviewees were given pseudonyms from the transcript stage onwards.

The sampling led to an interview sample containing private homeowners who exhibit a high rate of adoption of ERM (78%), have an average age of 54, are predominantly highly educated (56% having a bachelor degree or beyond, in contrast to the average of 30% in the Netherlands (CBS, 2018c)), and demonstrate an average share of households with children living at home, namely 37% (33% in average in NL, (CBS, 2018b)). They also live in a single-family house[6], have a larger living area (181 m^2) than average in the Netherlands (140m^2) (CBS, 2018e), and have an average house value of €224,000, which is lower than average in the Netherlands (€230,000) (CBS, 2018f). This can be explained by the fact that the houses in this region have a lower house value than in other regions of the country (CBS, 2018f) (see Appendix A of this Chapter).

The findings are therefore fairly representative of homeowners with a medium-high socioeconomic status who live in regions (or countries) with similar energy strategies targeting private homeowners and who live in a similar climate such as the Netherlands. This sample group is relevant because current policies in the Netherlands have not yet succeeded in engaging this group of middle-class homeowners to largely implement ERM to meet the national energy and climate goals (De Wilde, 2019). Another aspect regarding this study sample is the high share of adopters of ERM (78%),[7] which indicates that this sample is not an average sample of the population but contains of a high number of 'early adopters'. Rogers (Rogers, 2003d) points out that 'early adopters' generally have a higher socioeconomic status than 'later adopters', which is in line with our sample. Moreover, the high adoption rate can also be explained by the fact that the targeted group was already interested in energy renovation measures because they applied for an energy audit. However, the insights into the decision-making process of these early adopters can also be relevant for other homeowners whose situation is different (Berry et al., 2014; Fawcett & Killip, 2014; Galvin & Sunikka-Blank, 2014).

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6 *Condominiums were excluded from the data collection because of their joint decision-making process.*

7 *There are no data about the share of adopters in the total number of contacted people.*

2.3.3 Data Analysis

The objective of our analysis is to better understand the diversity of homeowners' experiences in the decision-making process of ERM. The results from the questionnaires and the interview transcripts were used to systematically analyse the transcripts using the thick analysis method (Evers, 2016a) and using qualitative software (Atlas.t 8.1). Various coding and analysis techniques were used: 1) thematic (deductive) coding based on the theoretical framework; 2) argumentation coding and analysis, to provide insight into the reasoning of the homeowners in their decision-making process about making their homes more energy-efficient; and 3) open coding, to look inductively to other methods of data organisation that could lead to different results. These techniques were used to explore; compare; and find patterns, linkages, and differences (Evers, 2016b; Patton, 1999). The data provide a holistic perspective on the different stages of the decision-making process, the multitude of considerations facing the homeowners, and the influencing factors in the different stages of this process. Consequently, the data are used to develop an integrative model of the decision-making process of homeowners.

2.4 Results

2.4.1 The decision-making model

Based on the studied findings, a decision making model could be discerned that emphasises the various stages of the decision-making process and the multiple factors that influence the homeowners in their decision to adopt or reject ERM. Figure 2.1 illustrates the decision-making model in which, on top, the six decision stages are presented. The various influencing factors are positioned in the middle. On the left, the factors that can have a positive influence are presented, and on the right, the factors that can have a negative influence are listed. The decision-making model points out that in the 'getting interested stage', external developments, physical factors, socio-demographic factors, and environmental concern are influencing factors. In the 'gaining knowledge stage', personal background and advice from others (social network or professionals) are important, and in the 'forming an opinion stage', financial-economic factors are important. In the next stage, homeowners will make a decision to adopt or reject ERM. When they decide to adopt ERM, the homeowners will also go through the 'implementing ERM stage' and the 'experiencing ERM stage'. These last three stages are not discussed in further detail in this section because this study focuses on the stages prior to the decision-making.

Considering that the model is developed from empirical evidence in a specific region, we do not suggest that this model is comprehensive. Extending the scope of data collection can generate further elaboration of this model. Nevertheless, the decision-making model thus provides an overview of the decision-making process used by private homeowners concerning ERM. The influencing factors in the various decision stages found in this study are discussed in the next sections.

2.4.2 Getting interested

External developments

External developments can trigger homeowners to begin thinking about ERM. During the time of the interviews (September 2017 to June 2018), additional media attention was focussed on the announcement that the national government was seeking to decrease natural gas consumption in the Netherlands partly due to the problems with extraction in the north of the country and the dwindling national gas reserves. (Natural gas provides 41% of the total national energy consumption) (CBS, 2018d; SER, 2018). Some homeowners explained that it was not clear what this would mean for their personal situation. For instance, Donald wants help to disconnect his house from the natural gas network:

> *'I would consider disconnecting the house from the natural gas if the municipality would take over a bit of technical expertise, maybe offer a subsidy and take some of the risk. Then we would consider it faster'. (Male respondent, age 57, PV panels)*

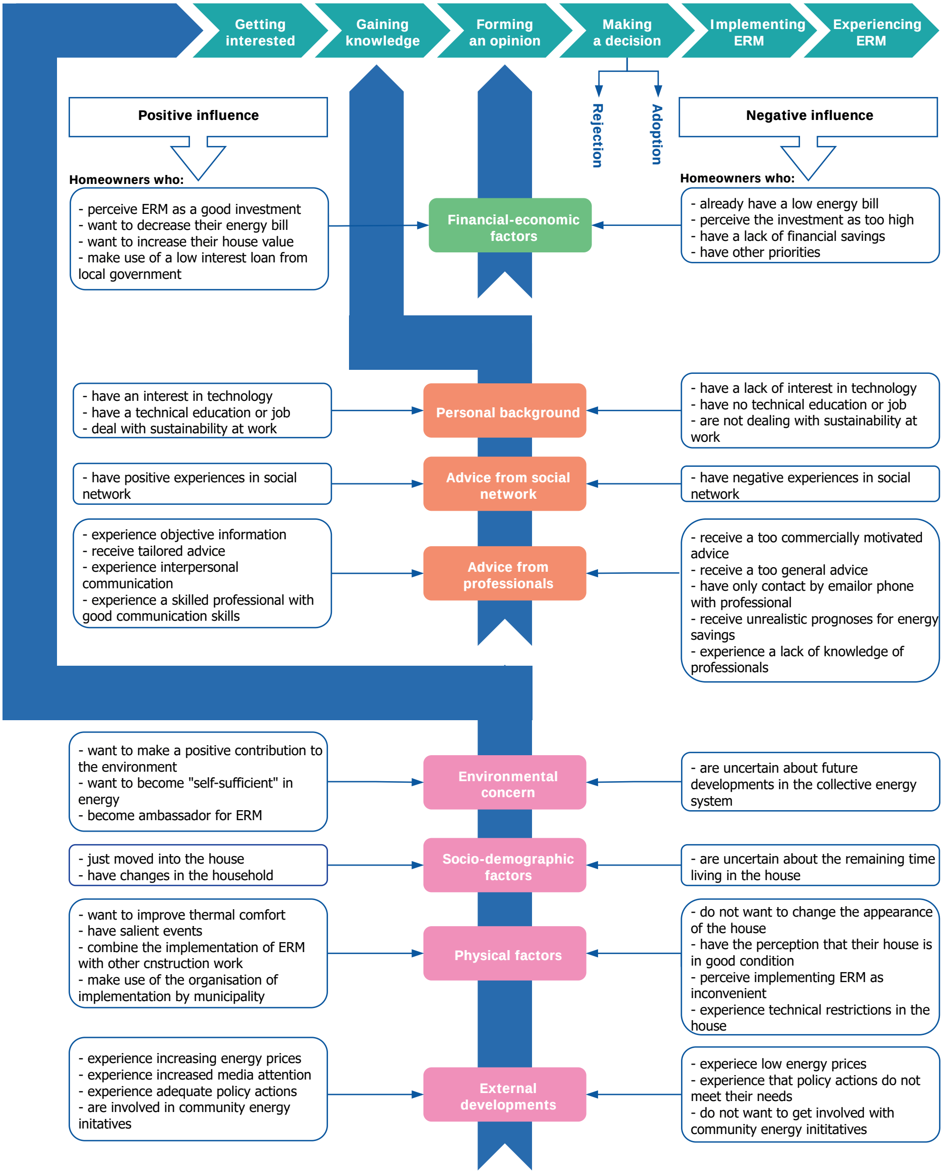

Figure 2.1. Decision making model of homeowners for energy renovation measures (based on the interview results and Ebrahimigharehbaghi et al., 2019; Faiers & Neame, 2006; Klöckner & Nayum, 2016; Mahapatra & Gustavsson, 2008; Rogers, 2003a; Wilde & Spaargaren, 2018; Wilson et al., 2013) 'have changes in the household': e.g. children born, working at home, less able to walk stairs 'salient events': e.g. boiler breaking down, broken window

Table 2.4. Key findings of interview results

		Non-adopters (n=12)*		Adopters (n=40)*	
Influencing factors		**#**	**%**	**#**	**%**
Socio-demographic	uncertainty about remaining time living in the house	3	25%	8	20%
Personal background	in contact with sustainability at work	2	17%	8	20%
	technical education or job	5	42%	17	43%
	financial-economic education or job	2	17%	9	23%
	high knowledge level of ERM	4	33%	17	43%
Environmental concern	environmental concern	7	58%	25	63%
	becoming self-sufficient	1	8%	12	30%
Physical factors	technical restrictions house	2	17%	18	45%
	aesthetics as barrier	3	25%	7	18%
	improve comfort	5	42%	23	58%
Implementation of ERM	prefers local companies	2	17%	4	10%
	appreciates service by municipality	2	17%	13	33%
	combine with other construction work	0	0	9	23%
Financial-economic factors	want to increase house value	2	17%	24	60%
	have financing of local government	0	0	15	38%
	already a low energy bill	1	8%	2	5%
	(some) ERM are too expensive	10	83%	21	53%
	have other financial priorities	4	33%	2	5%
	want to decrease energy costs	9	75%	30	75%
	ERM = good investment	2	17%	8	20%
Advice	satisfied with energy audit*	6	55%	25	74%
	influenced by social network	8	67%	31	78%
	ambassador of ERM	2	17%	24	60%
	lack of reliable and suitable information	1	8%	6	15%

Percentages have been rounded up or down to the nearest whole number. The researchers want to point out that the percentages must be treated with caution because of the limited sample sizes.
* Only 45 homeowners received an energy audit in this sample (11 non-adopters, 34 adopters), so the percentage is based on this total.

2

Table 2.5. Results questionnaires, barriers of non-adopters and motivations of adopters (respondents could select multiple options)

Barriers of non-adopters (n=20)		Motivations of adopters (n=71)	
House is already in good condition	20%	Improve comfort	31%
Already a low energy bill	5%	Environmental concern	56%
Too expensive	30%	Saving energy (costs)	72%
Other priorities	25%	Becoming self-sufficient	15%
Lack of right information	10%	Setting an example	1%
Planning to do	20%	Personal interest	1%
Other reasons	20%		

Table 2.6. Results questionnaires, type of adopted energy renovation measures (n=71)

Adopted energy renovation measures	
PV panels	55%
HE-glazing	26%
Façade insulation	23%
Roof insulation	22%
Floor insulation	18%
Heat pump	7%
Solar water heater	3%

Another possible development that could have triggered homeowners to begin thinking about ERM is the national net-metering scheme to promote small-scale renewable energy installations such as rooftop PV panels (Oteman et al., 2017). However, this scheme has been the subject of political debate for a few years, and it will be phased out starting in 2023 (Rijksoverheid, 2019e). Despite this, the city region of Parkstad launched a still-active PV panel project in 2016 to stimulate placement of residential rooftop PV panels. In this project, all details are arranged for the homeowner: installation of the photovoltaic (PV) panels, a 15-year guarantee and service, and an optional low-interest-loan from the municipality. Some of the interviewees (25%) also participated in this project, and they appreciated it greatly, for instance, Roos:

> *'Before I participated in the PV panel project, I had to do everything myself. What helped me a lot was that they guided me step for step in the decision-making process. In addition, they also organised the tax refund which was something I dreaded before because I have so much on my mind. So I was very happy with that. Everything went well; they arranged everything, from installation to all the administrative things. I did not have to do anything'. (Female respondent, age 54, participant in the Parkstad PV panel project)*

A third external development was that 21% of the interviewees made use of the low-interest loan from the municipality to finance their PV panels (see Appendix A of this Chapter). In addition, five of the interviewees made use of a low-interest loan to promote several sustainable measures for private homeowners from the province of Limburg (where Parkstad is located). In addition, at the time of the interviews, the community-network project 'Buurkracht' was active in several neighbourhoods in Parkstad (Ramakers, 2019) but only one interviewee mentioned participating in such a meeting so the impact of this project cannot be discerned from the study results. Additionally, at the time of the interviews, there were no local energy co-operatives active in the Parkstad region (Straten, 2019).

When reflecting on the results of the various approaches taken in Projects A, B, and C (see Table 2.3), the results reveal that an 'all-in-one offer' such as in Project B is the most effective. This is because three barriers are addressed in this approach: the lack of knowledge is addressed by the energy audits, the fear of 'hassle' or inconvenience is addressed by organising the implementation of the ERM, and financial barriers are addressed by offering a loan from the municipality. This is further explained in the next sections.

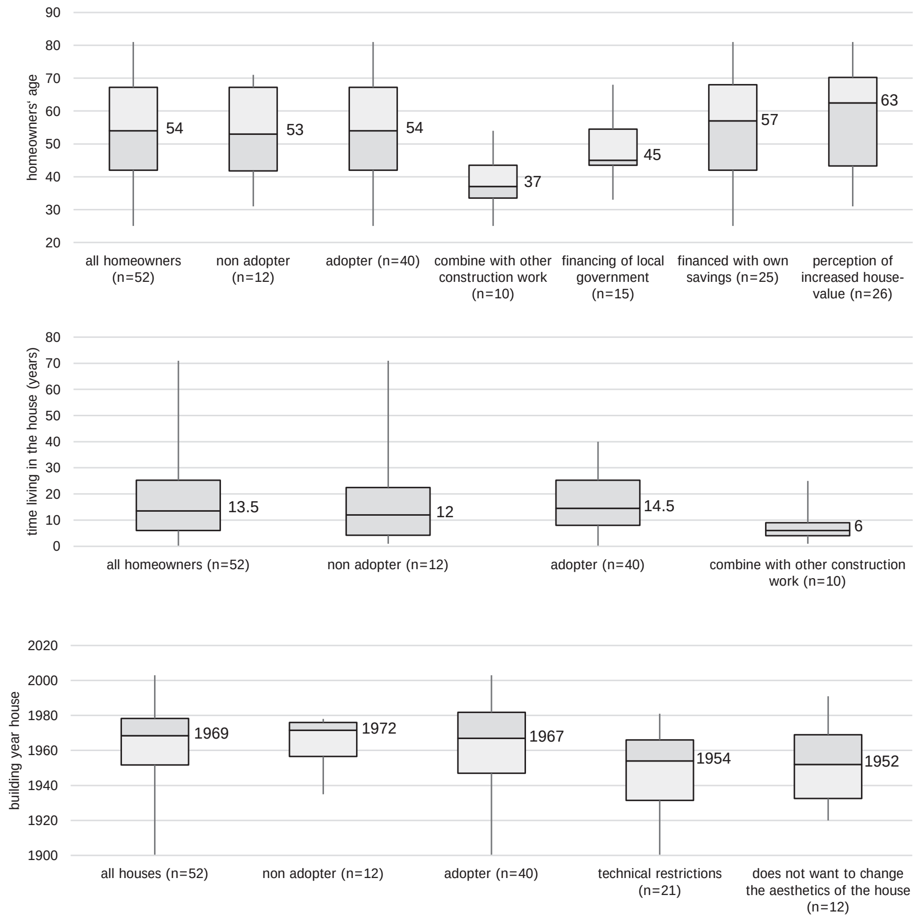

Figure 2.2. Box-plots of interview results

Top: boxplot of homeowners' age of 1. all homeowners, 2. non-adopters 3. adopters, 4. homeowners who combine the implementation of ERM* with other construction work, 5. homeowners who make use of financing of local government, 6. homeowners who have financed the ERM with their own savings, 7. homeowners who have the perception of an increased house value after implementing ERM.

Middle: boxplot of time living in the house (years) and 1. all homeowners, 2. non-adopters, 3. adopters, 4. homeowners who combine the implementation of ERM with other construction work.

Bottom: boxplot of building year house of 1. all houses, 2. houses from non-adopters, 3. houses from adopters, 4. houses with technical restrictions, 5. houses from homeowners who do not want to change the aesthetics of the house.

Physical factors

Next to external developments, physical factors can also trigger homeowners to begin considering ERM because they want to improve their living conditions. These physical factors were also mentioned in the interviews. Firstly, the perceived (thermal) comfort in the home was mentioned as an important motivator to implement ERM by 58% of the adopters in the interviews and by 31% of the respondents of the questionnaire (see Tables 2.5 and 2.6). Secondly, the age of the house could be a motivator for renovation, as older houses often need updates to improve energy efficiency according to current standards and comfort levels. However, the box plots in Figure 2.2 illustrate only a small difference between the age of the houses owned by adopters (1967) and non-adopters (1972); this can be due to sample bias. Thirdly, some homeowners (38%, see Table 2.5) face technical restrictions that make it difficult to implement energy-efficiency measures, especially in older houses. This is illustrated in Figure 2.2: The median year the house was built is 1969 for all interviewees and the median is 1954 for houses that face technical restrictions. Reasons for these technical restrictions are the absence of a cavity wall or limited space under the ground floor for insulation or the unwillingness to demolish the floor finishing. Another technical restriction mentioned was that the roof was unsuitable for PV panels because of a northerly orientation. Fourthly, another building-related barrier that influences some homeowners' decisions is the prospect of changing the aesthetics of the house (19%, see Table 2.5). This is especially the case for those living in older, more characteristic, houses. Figure 2.2 illustrates that the median year the house was built is 1963 for all interviewees and 1952 for homeowners who do not want to change the aesthetics of the house. These aesthetic-related measures include insulation on the outside of the façade (8%), high-efficiency (HE) glazing (6%), and PV panels (15%). Arnold is still hesitant to install PV panels on his red tile roof but has installed other measures:

> *'Since we insulated the roof and the walls, it has become more pleasant in winter: It stays warm longer and in summer it gets less warm, but we do not like the appearance of current PV panels, so we will wait for future developments'. (Male respondent, age 35, roof and cavity wall insulation, HE-glazing, HE-gas boiler)*

The results of the questionnaires reveal another barrier for implementing ERM: 20% of the respondents perceive their house as in a good condition (see Table 2.5) and do not think they need more ERM. Additionally, the installation of ERM is perceived as inconvenient by some homeowners; two respondents referred to the need to clean up the attic or storage room to install insulation. Other homeowners combine the implementation of ERM with other construction work (23%, see Table 2.5), such as an extension or changes in the floorplan. This is mainly done by younger homeowners who have just purchased the house or a few years after the purchase, which is demonstrated in Figure 2.2. The median age for ERM adopters is 54 years and the median age is 37 years for people who combine ERM with other construction work on the house. Furthermore, the median for time lived in the house is 14 years for adopters and 6 years for people who combine ERM with other construction work.

Socio-demographic factors and environmental concern

Socio-demographic factors can have an influence on homeowners in the 'getting interested stage'. The interview results reveal that for the adopters, 58% are younger than 60 years, 37% have children living at home, and 56% have a bachelor degree or higher, which is much higher than the average of 30% in the Netherlands (CBS, 2018c) (see Appendix A of this Chapter). Furthermore, an important personal driver for homeowners is environmental concern and the willingness to act upon this: 56% of the respondents of the questionnaire mention this as a priority along with 62% of the interviewees (see Tables 2.5 and 2.6). This includes, for example, Truus, who wants to take responsibility for the environment:

> *'You also have to take responsibility yourself. You can think 'my time will come', and it will, but I do not think that's a good idea to leave the world behind without my own contribution'. (Female respondent, age 53, PV panels, roof and cavity wall insulation, HE-glazing)*

In addition, 'becoming self-sufficient' for energy supply (15% in questionnaires, 25% in interviews, see Tables 2.5 and 2.6) can be a motivation related to environmental concern. The main drivers for this are having more control of energy costs, making a positive contribution to the environment and becoming less dependent on energy utilities. This is illustrated by Tamara:

> *'At some point I just decided to become green. In the long run, I want to become self-sufficient in energy'. (Female respondent, age 33, roof insulation, HE-glazing, PV panels)*

It can be expected that in the future, more homeowners will be motivated to become self-sufficient when the consequences of climate change become more visible and energy prices increase.

2.4.3 Gaining knowledge

The results of this study demonstrate that when homeowners begin to think of ERM, they obtain their information in various ways. On the one hand, a homeowner's background seems to be an important influencing factor: More than half of the interviewees (52%) report having a technical education or job or becoming familiar with sustainability at work (see Table 2.5). This includes Piet, who has worked as a financial controller at a pension fund:

> *'Sustainability became more and more important at work, and as a result I got 'infected' with it. I learned that investing in the environment is a good thing and that it has good revenues in the long run'. (Male respondent, age 66, PV panels, cavity wall insulation, HE-glazing)*

On the other hand, homeowners ask also others for advice on ERM. Next to the received energy audits, homeowners search the internet for information on company and semi-public websites. Additionally, they ask installers of ERM for advice. Moreover, the results indicate that homeowners' social networks are important sources for information as well. These three types of information sources—the municipality (energy audits), advice from installers of ERM, and advice from the homeowners' social network—are described below.

Energy audits from a municipality

The results reveal that homeowners experience the audits in a different way (see Table 2.5). On the one hand, the majority (69%) appreciate the objective advice. Ria, for instance, explains her reaction:

> *'I found it very convenient because now I did not have to delve into the matter myself. Otherwise I have to make comparisons between different measures, companies, technical specifications, etc., and that is really not my cup of tea. I find it hard to motivate myself for doing that, so it is also laziness. It is great that the municipality does that for you. ... It was very clear, what he told me, in just normal language, not too detailed and not too technical, otherwise I would not understand it. That gives confidence and trust when it is clear, and he also placed it in my context'. (Female respondent, age 53, PV panels and floor insulation)*

On the other hand, the less satisfied homeowners found the advice too general and containing irrelevant information. For instance, Felix offered the following advice to improve this:

> *'They should do more customisation and work more with the neighbourhood associations. They have to listen to the experiences of what people already have done and look at how they can deliver customised solutions in the right way, because the houses here are not uniform. I think that would be a big step forward'. (Male respondent, age 68, PV panels)*

Another aspect ,that some of the less satisfied homeowners mentioned, is that they missed detailed information about specific, less diffused technologies. Hans states:

> *'They told nothing new. The advice is meant for someone who has no idea what to do; if you have informed yourself, then the advice is less useful'. (Male respondent, age 35, roof and cavity wall insulation, PV panels)*

This demonstrates that the knowledge level of these homeowners was higher than addressed in the energy audit. A total of 40% of the homeowners already had quite a lot of knowledge about ERM before they received the energy audit (Table 2.5). Moreover, some homeowners perceived the energy audit as less than objective and indicated that the advice was too 'commercial' because certain companies were recommended. This includes Rob:

> *'I attended the information meeting and signed up for an energy audit. I had the impression that it was a sales pitch. I never received a thorough report. I only received a financial offer which I can apply for myself'. He suggests an energy help desk as a possible solution for this: 'That they set up an 'energy help desk' where people get objective information, no commercial information but a fair and neutral story. The municipality could be a kind of an intermediary and select good and trustworthy companies'. (Male respondent, age 45, roof and cavity wall insulation, HE-glazing, shutters and PV panels)*

Next to the content of the energy audit, the skills of the adviser seem to be an important factor as well, including reliability and effective communication skills. Karin appreciated the adviser's skills:

> *'It was a good advice and a friendly man to talk to. He saw my problems and wanted to think along, and it was also pleasant conversation'. (Female respondent, age 44, cavity wall insulation, PV panels)*

In contrast, others pointed out that the adviser lacked communication skills, such as what Arjan experienced while renovating his house and building an extension:

> *'The adviser was very technically competent, but you also need sales skills when giving an energy audit'. (Male respondent, age 43, roof and cavity wall insulation, PV panels)*

To summarise, homeowners appreciate the objective, independent advice in an energy audit provided by a municipality if this advice is customised to their specific situation and their knowledge level of ERM. Next to technical expertise, the energy auditor must have communication and organisational skills.

Advice from installers of ERM

The second type of information source is advice from installers of ERM. In the interviews, homeowners said a significant amount of information about ERM can be found on corporate websites but that they find it difficult to assess this information, especially when applying it to their specific situation. They said they cannot decide what is reliable and suitable information from the massive amount of information available on the internet. In addition, seven homeowners (see Table 2.5) mentioned that the information provided by installers is often ambiguous and that different installers say different things because they are promoting their own products, which is not always the best solution for the homeowner. As a result, homeowners express doubt about what the best choice is for them. For instance, Ellen wants to insulate her roof and install PV panels:

> *'All the companies claim to have 'the holy grail'; there is an overkill of websites, you don't know whom to believe because they all have a different approach or philosophy'. She suggests a centralised website with objective information: 'I think you can make something like an internet platform, for example, with the most frequently asked questions and checklist, organised by the government. ... I have asked several companies about an offer for one brand of PV panels, and they advised me something else regarding the different components of the system. How is that possible? That you get completely different advice about one product?' (Female respondent, age 32, floor insulation, HE-glazing)*

Homeowners often ask installers directly for advice, frequently combined with an offer request. Some interviewees point out that they prefer a local company (12%, see Table 2.5) or an installer who is known in their social networks. Another finding is that homeowners seem to be more willing to trust a certain installer if that person provides advice combined with a site visit to their homes and is focussed on the homeowner's personal circumstances and wishes. Sabina and Tanja state about this:

> *'The man who made an offer for replacing the roof came here and was very honest and open. We made good arrangements. His offer clearly showed what he was going to do and what not. We have more trust in people who give an honest advice and are enthusiastic. Therefore, we chose him'. (Female respondents, ages 34 and 38, roof and cavity wall insulation, HE-glazing, HE-gas boiler, shutters)*

In contrast, unrealistic promises about possible energy savings generate little trust in the installer, as Daan points out:

'Some companies say that you will save so much, then I say, 'That's interesting because it means that I'm going to save more than I use at the moment '. (Male respondent, age 68, non-adopter)

Another bottleneck in implementing ERM is the lack of knowledge among installers about upcoming technologies and materials. Edwin reports the following:

'I noticed that companies are not really responding to the new developments. The installers need to be trained because they lack knowledge'. (Male respondent, age 67, roof insulation, HE-glazing, PV panels)

In summary, homeowners encounter difficulty finding reliable and suitable information for their specific situations. Homeowners often prefer local installers of ERM who are known in their social network. A visit to their home with personalised advice is appreciated and leads to trust in that installer.

Advice from social network

The third source of information is the social networks of homeowners such as family, friends, neighbours, and colleagues. Most of the adopters (78%, see Table 2.5) mention that discussions with people in their social networks influenced their energy renovation choices in a positive way. This held true for Derk and Rita:

'We talked to people who already had PV panels like friends and neighbours before deciding for them ourselves'. (Male respondent, age 72, and female respondent, age 70, PV panels)

Another phenomenon addressed by the homeowners in the interviews is that 50% of the interviewees (see Table 2.5) actively advise people in their social network about ERM. They become ambassadors (or 'opinion leaders') (Rogers, 2003d)) for ERM. Rogers (Rogers, 2003c) says, 'Potential adopters look to early adopters for advice and information about an innovation. The early adopter is considered by many to be 'the individual to check with' before adopting a new idea'. This happened in the case of 'ambassador' Cor:

'I brag about my PV panels and energy savings to people I know. A man came here with pen and paper to ask about the PV panels, so yes, I advertise them'. (Male respondent, age 73, HE-glazing, PV panels)

The high share of ambassadors in this sample can perhaps be explained by the fact that this group of homeowners can be seen as early adopters (see section 3.2) and they are therefore more informed than the majority of homeowners (Rogers, 2003d).

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To summarise, a social network is a strong influencing factor in a homeowner's decision-making process. Additionally, some adopters also become influencers or 'ambassadors' in their network.

2.4.4 Forming an opinion

When homeowners have gained knowledge about ERM, they start to form an opinion about the measures in the next stage, during which financial-economic factors can have significant influence. The results from the questionnaires demonstrate that saving energy (also saving money) is the most-mentioned motivation (72%) for adoption. In the group of non-adopters, financial barriers were mentioned the most: either 'too expensive' (30%) or having 'other priorities' (25%) for their time or money (see Table 2.6). The findings of the interviews reveal that a homeowner's age is strongly connected to how the ERM are financed. Most older adopters (17 adopters are age 60 and older) financed the measures with their own savings (82%); among the younger homeowners, only 48% did so. (Twenty-three adopters are younger than 60; see Tables 2.4 and 2.5). An explanation can be that older homeowners have fewer expenses (lower mortgage, no kids living at home) than younger homeowners and have had more time to build their savings. Younger homeowners appreciate the low-interest loans offered by the local government because they often do not have enough savings or have other financial priorities. Figure 2.2 demonstrates that the median age for the adopters is 54 years, the median age for people who financed the measures with their own savings is 57, and the median age for homeowners who used financing from the local government is 45. Interviewees who invested their savings in ERM explained that their return on investment in ERM is higher than on their savings account because of the current low interest rates. This is especially the case with PV panels, where homeowners have the perception of a short payback time. For example, Mike sees ERM as a good investment and tries to convince others:

> *'I told a friend this morning, 'You are crazy not to do it when you have savings'. At the bank you get 0.5% and when you invest it in PV panels, you get a return of 8 to 15%'. (Male respondent, age 62, PV panels, a solar water boiler and a heat pump)*

Another outcome is that half of the interviewees believe the measures they took will increase the value or saleability of their home (see Table 2.5). Figure 2.2 reveals that this is especially the case for the older homeowners. The median age for all adopters is 54 years and the median age for homeowners who perceive an increased house value is 63 years. This is illustrated by a quote from Cor (age 73), who renovated his entire house after purchase:

> *'Because our home is also our piggy bank. Suppose we have to go to a nursing home then I can get a better price for a home that is up to date'. (Male respondent, age 73, PV panels, roof and façade insulation, HE-glazing, HE-gas boiler)*

2

2.5 Discussion and conclusions

2.5.1 The decision-making process and implications for policy-makers

This paper introduced a novel model for the decision-making process of private homeowners who are considering installing energy renovation measures. The model distinguishes between the various stages of the process, the multiple factors that influence these stages, and the many considerations facing homeowners as they decide to adopt or reject energy renovation measures. The results demonstrate that energy decisions are not isolated but are situated in daily life with multiple decision moments; they are influenced by many factors (De Wilde, 2019; Fyhn & Baron, 2017; Karvonen, 2013; Kerr et al., 2018; Wilson et al., 2018). Moreover, these influencing factors are important in the various stages of the decision-making process (De Wilde, 2019; Ebrahimigharehbaghi et al., 2019; Klöckner & Nayum, 2016). To improve the impact of policies, we suggest that it is vital that correct policy actions are deployed for the particular stages of the decision-making process to be successful and lead to higher adoption of ERM by homeowners (De Wilde, 2019; Klöckner & Nayum, 2016).

Getting interested

The model illustrates that the first stage (getting interested) is the most important as this is the moment that people begin to think about energy renovation measures; this was confirmed in previous research (Fyhn & Baron, 2017). Policy actions will succeed only if people who were not considering ERM at first begin thinking about it. However, at this time, policy-makers tend to focus on the decision-makers, the homeowners who are already considering ERM (Fyhn & Baron, 2017), and less on the homeowners who are not. To target the latter group as well, policy actions can be effective in increasing environmental awareness. This is necessary because the results reveal that homeowners who have an environmental concern and are willing to act on this are more likely to begin considering ERM, which confirms previous studies that demonstrate a positive relationship between environmental concern and adoption of pro-environmental measures (Ajzen, 1991; Bamberg, 2003; Gamtessa & Guliani, 2019; Hoppe et al., 2019; Huijts et al., 2012; Poortinga et al., 2003; Risholt & Berker, 2013). We suggest the following three policy actions to increase environmental awareness to influence the consideration stage in the decision-making process:

Firstly, governments are able to influence external developments in this stage by creating or stimulating external developments. This can be done by ensuring more media attention about the subject, stimulating energy communities, launching grass-roots initiatives, and supporting local energy co-operatives by raising awareness and attracting public support (Hoppe et al., 2019). By targeting neighbourhoods, information about ERM can be shared among homeowners living in similar homes and having similar socioeconomic backgrounds (Southwell & Murphy, 2014). To be successful, however, these community approaches must be tailored to the characteristics of the neighbourhood and the specific needs of the homeowners (McMichael & Shipworth, 2013; Scott et al., 2016).

Secondly, policy actions can be designed to target the homeowners' specific needs because homeowners will begin considering ERM if they want to improve their living conditions to match their changing needs (Fyhn & Baron, 2017; Malone et al., 2018; Vlasova & Gram-Hanssen, 2014), such as improving their thermal comfort (Banfi et al., 2008; Karvonen, 2013; Mortensen et al., 2014; Nair et al., 2010a; RVO, 2016) or enhancing aesthetics (Karvonen, 2013; Mortensen et al., 2016). In addition, policy actions can target specific homeowners who are planning to change the layout of their house through an extension or a remodelling because ERM are often combined with other construction work. This has also been demonstrated in other studies (Galvin & Sunikka-Blank, 2014; Judson & Maller, 2014; Mortensen et al., 2016; Nair et al., 2010a; Wilson et al., 2018). Salient events (e.g., boiler breaking down, broken window) or changes in the household (e.g., moving, retiring, having children) can also be good moments to inform homeowners about the possibilities for their homes (Stieβ & Dunkelberg, 2013).

Thirdly, policy actions can specifically target homeowners who are less likely to adopt at this moment because they are older, less educated, or have a lower income (also suggested in (Gamtessa & Guliani, 2019; Scott et al., 2016; Southwell & Murphy, 2014)). The results of this study illustrate that owners of newer homes and highly educated homeowners are more likely to adopt ERM; these results have also been exhibited in previous studies (Hrovatin & Zorić, 2018; Mortensen et al., 2016; Moula et al., 2013; Nair et al., 2010a; Poortinga et al., 2003; Sardianou & Genoudi, 2013). Additionally, other studies have indicated that income can have a positive influence on adoption of ERM (Kastner & Stern, 2015) but this is not studied in this research.

Gaining knowledge

If homeowners begin to think about ERM, they will gain more information about the measures in the knowledge stage. A lack of knowledge about ERM can negatively influence the adoption (Banfi et al., 2008; Huijts et al., 2012; Löfström & Palm, 2008; Mortensen et al., 2016; Nair et al., 2010a; Tuominen et al., 2012). Personal background—such as an interest in technology (Risholt & Berker, 2013; Schelly, 2014), a technical background, or familiarity with sustainability issues at work—can also influence the decision-making process because of the higher level of awareness about ERM**.** Specific policy actions can focus on increasing knowledge levels of private homeowners about ERM so they can make informed decisions.

Firstly, local governments can offer credible, objective advice about ERM focussed on the homeowner's specific situation, knowledge levels about ERM, personal needs, and preferences in which the non-energy benefits for ERM also are revealed. In this study, homeowners received an energy audit for their home arranged by intermediary organisations on behalf of the municipality. These intermediaries and energy auditors can play an important role in adoption of ERM by private homeowners, as indicated in previous studies (Fyhn & Baron, 2017; Kooij et al., 2018; Owen & Mitchell, 2015; Vlasova & Gram-Hanssen, 2014; Wilde & Spaargaren, 2018). The results demonstrate that individual homeowners have their own specific expectations about an energy audit. A 'one-size-fits-all' audit will be less successful than in-person advice tailored to a homeowner's specific needs. This conclusion has also been confirmed in several studies (Abrahamse et al., 2005, 2007; Benders et al., 2006; Delmas et al., 2013; Ingle et al., 2012; Kastner & Stern, 2015; Novikova et al., 2011; Steg, 2008; Stern, 1992). Additionally, the findings of this study reveal that advice must be targeted to the homeowner's specific situation, needs, and preferences (Desmedt et al., 2009; Risholt & Berker, 2013; Šćepanović et al., 2017; Scott et al., 2016); if the advice is too general, homeowners have difficulties relating to it (Ellegård & Palm, 2011). Moreover, the energy auditor or adviser needs to understand and adjust to the homeowner's wishes, interests, circumstances, and knowledge level to provide tailored energy advice in a dialogue with the homeowner (Darby, 2003; Ingle et al., 2012). Objectivity, technical knowledge, and communication skills are also important features for an energy auditor or adviser (Desmedt et al., 2009; Ingle et al., 2012).

Secondly, this study reveals that positive experiences from a homeowner's social network can aid the adoption of ERM. Additionally, social networks are a possible point of intervention for local government because potential adopters are more likely to pay for energy-efficiency changes when they receive information from someone in their social network who already did so. These outcomes confirm previous studies which reveal that the role of advice from social networks has a positive effect on the adoption rate of ERM (Bartiaux et al., 2014; De Wilde, 2019; Hoppe et al., 2019; Hrovatin & Zorić, 2018; Kastner & Stern, 2015; Malone et al., 2013; McMichael & Shipworth, 2013; Palmer et al., 2015; Risholt & Berker, 2013; Rogers, 2003b; Southwell & Murphy, 2014). In addition, grass-roots community energy initiatives and renewable energy co-operatives can raise awareness among homeowners to take action (Galvin & Sunikka-Blank, 2014; Hoppe et al., 2019; Oteman et al., 2017; Sifakis et al., 2019; Vergragt & Brown, 2012). Moreover, local governments can facilitate 'ambassadors' (Rogers, 2003d) to demonstrate their ERM in their homes so that other potential adopters can look at, feel, and listen to these measures to test their aesthetics, comfort, and noise. This is also recommended in other research (Hrovatin & Zorić, 2018; McMichael & Shipworth, 2013; Scott et al., 2016) and implemented in policies as well, but on a rather small scale (e.g., Blok voor Blok (RVO, 2014), Buurkracht (Buurkracht), and HOOM (Coöperatie Hoom) in the Netherlands). More insights are needed into how this group of ambassadors could be increased to create a larger impact on the adoption of ERM. A possibility to do so is by organising this in energy communities, grass-roots initiatives, and/or local energy co-operatives.

Thirdly, policy-makers can engage installers of ERM (companies) in the promotion of their products because they also play an important role as adviser in a homeowner's decision-making process, as demonstrated in this study and in previous literature (De Wilde, 2019; Nair et al., 2010a; Owen et al., 2014; Risholt & Berker, 2013; Wade et al., 2016). However, the ERM industry is often seen by the homeowners as unreliable and non-transparent (Bartiaux et al., 2014; De Wilde, 2019; Karvonen, 2013; Risholt & Berker, 2013); therefore, trust and reliability are important issues when homeowners deal with companies (De Wilde, 2019; Weiss et al., 2012; Wilson et al., 2015). However, the results reveal that these issues can be enhanced by a personal visit by the installer at their home who provides realistic projections of energy savings and works through the changes with the homeowner. Another barrier pointed out by the homeowners in this study is the lack of knowledge of some installers about new technologies. As a result, these companies will advise the most familiar technologies and are reluctant to suggest new technologies. Additionally, an installer may be an expert in his product but lacks knowledge about an overall approach to improving energy efficiency throughout the entire house (Risholt & Berker, 2013). Because of this fragmented market, this often results in contradictory advice (Bartiaux et al., 2014). Policy actions can facilitate educational programs for installers (Bartiaux et al., 2014) to improve their knowledge about new technologies and the necessary integrative approach for making homes more energy-efficient.

Forming an opinion

After gaining enough knowledge about ERM, homeowners form a certain attitude and perception towards ERM in this stage. Now, financial-economic factors become more important; this has also been identified in other studies (Mortensen et al., 2016; Murphy, 2014). Local government can address the financial barriers that some homeowners have by offering financing options such as low-interest loans or subsidies. Another barrier that can influence this stage in the decision-making process is the perception of inconvenience or the 'hassle factor' of making energy-efficiency improvements (Fawcett & Killip, 2014; Galvin & Sunikka-Blank, 2014; Murphy, 2014; Roy et al., 2007). Local governments can help by organising the installation of ERM by skilled and trustworthy local companies such as the PV panel project in Parkstad (see section 4.2). Moreover, governments can combine energy audits, financing options, organisation of

ERM installation, and guarantees into an all-in-one offer that has also been suggested in previous research (Mahapatra et al., 2013). Other research also suggests using project managers to guide the entire process for the homeowner (Risholt & Berker, 2013). These suggestions have been executed successfully, for instance, in the 'Blok voor Blok' project in the Netherlands. Here, intermediary organisations were subsidised by the national government to guide homeowners through the entire decision-making process. The organisations offered energy advice to homeowners and helped select and install the measures in a 'one-stop' fashion. Street ambassadors and demonstration houses have been deployed as well to raise awareness among homeowners. The project ended in 2014 and some initiatives were carried on in other projects (RVO, 2014). However, these initiatives failed to scale up to a larger population and more insights are needed into how this can be done.

Making a decision, implementing ERM, and experiencing ERM

Even though the last three stages in the decision-making process were not studied in detail in this study, some conclusions can be made. When homeowners decide to adopt ERM (in the 'making a decision stage') the next stages are 'implementing ERM' and 'experiencing ERM' (see Figure 2.1). In these last two stages, the homeowners form a positive or negative perception about ERM based on their own experiences, and this perception will influence what they will tell others in their social network about ERM.

To summarise, this study illustrates that the decision-making process of private homeowners for energy renovation measures is divided in several stages and that these stages are influenced by multiple factors that can be different for every homeowner.

2.5.2 Limitations and implications for further research

In this study, a novel integrative model for a homeowner's decision-making process concerning ERM is developed. The decision-making model is developed based on empirical evidence in a specific region with a limited sample size and with a high share of adopters. Therefore, we do not suggest that this model is comprehensive. Extending the scope of data collection can generate further elaboration of this model. Further studies could test a wider set of factors, such as cultural aspects and neighbourhood characteristics, along with testing the influencing factors in the last three stages of the decision-making process. Moreover, follow-up research could investigate further which factors are important in which stage. Additionally, further research could study whether some factors also influence other factors and are therefore interlinked. It would be useful to test the relationship of the developed model on larger samples for making generalisations to a larger population and also test it on groups such as those with less education and lower incomes in different regions and geographical areas. Validation of the model in expert groups (e.g., policy-makers) could also be a valuable addition for the further development of the decision-making model and the policy actions.

Acknowledgements and funding

The authors would like to thank the city region of Parkstad Limburg and the municipalities of Heerlen, Landgraaf and Nuth for assistance in undertaking the questionnaires and interviews. We also want to thank Elizabeth Malone (Pacific Northwest National Laboratory) for reviewing an earlier draft of this paper and the anonymous reviewers for their valuable contributions to this paper. This research was funded by the Foundation Innovation Alliance (SIA, RAAK.PRO02.145), Zuyd University (PhD funding) and the Dutch Organization for Scientific Research (NWO, 023.013.033).

2.5.3 Appendix Chapter 2

Supplementary data to Chapter 2 can be found online at:

- **Appendix A**. Table A-1. Study sample with characteristics of the 52 interviewees. https://doi.org/10.1016/j.erss.2019.101284
- **Appendix B**. Transcripts interviews. https://doi.org/10.25385/zuyd.7887095

3

CHAPTER 3

NOT ALL HOMEOWNERS ARE ALIKE: A SEGMENTATION MODEL BASED ON A QUANTITATIVE ANALYSIS OF DUTCH ADOPTERS OF RESIDENTIAL PHOTOVOLTAICS

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Published in Energy Efficiency 2021; 14 (30)

Abstract

The implementation of residential photovoltaics must increase more rapidly to combat climate change and its impacts. This challenge is addressed in this study by introducing a segmentation model in order to develop a theoretical and empirical foundation for understanding the heterogeneity of potential adopters. Data were collected by means of a survey among Dutch adopters (n = 1395) and the data is analysed with statistical descriptive analyses and nonparametric tests. The five segmentation groups are divided by the homeowners' educational background or profession (technical, financial-economic or other) and level of environmental concern. The results demonstrate that the groups are substantial in size and that there are significant differences between these groups on personal characteristics such as homeowners' level of environmental concern and the level of influence of their social network on their decision to adopt. In addition, significant differences are found between the groups on the perceived characteristics of the residential photovoltaics such as perceived complexity and aesthetics, and the amount of previous practice with other energy measures in their home. Accordingly, these insights can be used by policymakers and the public and private sectors to promote residential photovoltaics more effectively by targeting the segmentation groups more adequately. The different groups will be drawn to different aspects and therefore, a broader pallet of benefits must be presented; a mix of different communication channels must be used; objective and non-technical assistance in the decision-making must be offered; and different kind of products must be provided.

3.1 Introduction

To combat climate change, the built environment must reduce its CO_2 emissions by 50% by 2030 (UNEP, 2018). The use of residential photovoltaics (RPV) can make a significant contribution in this regard. In addition to enhancing energy security and energy affordability (Balta-Ozkan et al., 2015; Bondio et al., 2018), RPV also have economic and employment benefits (SolarPower Europe, 2018). However, RPV are far from reaching their full potential. In 2018, photovoltaics[1] accounted for only a small share of 4.5% of the total net electricity generation in the European Union (EU, Jäger-Waldau, 2018), whereas rooftop photovoltaics alone have the potential to grow to a quarter of total electricity demand (Bódis et al., 2019). To facilitate this uptake, studies have demonstrated that tailoring messages to targeted homeowners is more effective than a 'one-size-fits-all' approach (Sachs et al., 2019; Vasseur & Kemp, 2015b; Wolske et al., 2018). However, more insight into potential RPV adopters is needed to make policy actions, communication and marketing campaigns more effective by targeting specific groups (Petrovich et al., 2019).

The diffusion of innovations (DOI) theory (Rogers, 2003a) has been tested and proved useful for RPV adoption in several studies in the past (e.g. Bondio et al., 2018; Busic-Sontic & Fuerst, 2018; Faiers & Neame, 2006; Palm, 2017; Vasseur & Kemp, 2015a; Wolske et al., 2017). According to this theory, the personal characteristics of the potential adopter play an important role in the adoption process next to the perceived characteristics of the RPV by the potential adopter. This means that people will evaluate the advantages and disadvantages of RPV in relation to their personal situation (Rogers, 2003a).

In the past, DOI theory has been used to develop segmentation models in order to gain a better understanding of potential RPV adopters. For instance, Faiers and Neame (2006, (n=1000)) studied the differences between innovators, early adopters, early majority, late majority and laggards in RPV adoption in Central England. This study demonstrates differences in the perceived RPV characteristics but these findings are not representative anymore as the RPV market has evolved rapidly since then. Vasseur and Kemp (2015b, (n=817)) investigated the differences between Dutch voluntary and involuntary adopters (when people buy a house with RPV), and potential RPV adopters and rejecters. They found differences in socio-demographic factors (age, level of education, income), level of influence by their social network and level of environmental concern. However, this study does not give a further segmentation of the voluntary adopters. In addition, a study of Sigrin et al. (2015,

1 *Total of ground-mounted and rooftop photovoltaics.*

(n=1234)) discusses the differences in personal characteristics and perceived RPV characteristics between adopters and non-adopters, early and more recent adopters, and buyers and leasers in the United States. This study reveals differences between the groups on socio-demographic factors (income, level of education, house size); other expectations about expected energy prices in future; perception of house value after RPV adoption; and differences on how they received their information about RPV. Furthermore, a Swiss study of potential RPV adopters defines a premium segment, who care more about the aesthetic features of RPV (such as coloured or building integrated photovoltaics) and have a higher environmental concern, and a value segment who is more price-sensitive (Petrovich et al., 2019, (n=408)). Lastly, Palm and Eriksson (2018, (n=58)) investigated the personal characteristics of Swedish (potential) RPV adopters in more depth, and studied the differences between non-adopters, environmentally engaged adopters, a professionally skilled group and accidental adopters and found differences on how these groups found their information about RPV and their level of environmental concern.

Despite these previously developed segmentation models, there are also understudied aspects and aspects with inconclusive results. First, previous studies demonstrate inconclusive results regarding the level of environmental concern and RPV adoption. Some studies demonstrate that a high level of environmental concern will enhance RPV adoption (Palm & Eriksson, 2018; Petrovich et al., 2019; Vasseur & Kemp, 2015b), whereas a quantitative study by (Wolske et al., 2017, n=904), among potential adopters in the USA, demonstrates that pro-environmental norms only indirectly increase the interest in RPV through perceived personal benefits. Moreover, a study by (Schelly, 2014, n=48), based on qualitative interviews with RPV adopters in Wisconsin (USA), points out that environmental values alone are not sufficient and/or not always needed for RPV adoption. In view of these inconclusive previous results, more data on this topic are collected in this study by using the homeowners' level of environmental concern as one of the segmentation criteria.

Second, there are only limited studies on the influence of the type of educational background or profession in relation to RPV adoption. There are studies which have studied the level of education in relation to RPV adoption: some studies suggest that people with a higher level of education are more willing to adopt (Schelly, 2014; Sigrin et al., 2015; Vasseur & Kemp, 2015b) but other studies do not identify this correlation (White, 2019; Wolske et al., 2017) which makes them inconclusive. In addition, these studies did not investigate the nature of the educational or professional background whereas other studies suggest that an interest in technology (Schelly, 2014), affinity with energy (Leenheer et al., 2011), a technical background (Broers et al., 2019), or an energy related profession (Palm & Eriksson, 2018) can enhance the willingness to adopt RPV. However, these studies are limited in number and the majority of them are qualitative studies with a limited number of respondents. In order to contribute to this literature, we will use the homeowners' educational background and profession (technical[2] and/or financial-economic[3] or other) as one of the segmentation criteria to study the differences between the personal characteristics and perceived RPV characteristics between the groups.

Therefore, this paper aims at developing a segmentation model in order to gain a theoretical and empirical foundation for understanding the heterogeneity of potential RPV adopters. The five segmentation groups are divided by the homeowners' educational background or profession (technical, financial-economic or other) and their level of environmental concern. Data were collected by means of a statistical analysis of an online survey among participants in a Dutch regional RPV project in the metropolitan region of Parkstad Limburg in the Netherlands (n=1395) and the data is analysed with statistical descriptive analyses and nonparametric tests. In our study, we examined the (significant) differences between the segmentation groups in relation to the homeowners' personal characteristics and their perceived RPV characteristics, based on DOI theory (Rogers, 2003a). The results demonstrate significant differences between the groups and these insights can be used by policymakers and the public and private sectors to promote RPV more effectively by targeting them more adequately.

This chapter is structured as follows. Section 3.2 presents an overview of the development of the photovoltaics market in Europe and the Netherlands. Section 3.3 presents a discussion of previous research, while section 3.4 presents the research methodology and conceptual framework used in this empirical investigation. The empirical results and analysis are presented in section 3.5, while the final section examines these results and makes recommendations.

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2 *Technical education: e.g. technology, industry, engineering, ICT, mathematics, natural sciences. Technical professions: e.g. engineers and technical researchers, specialists in nature and technology, construction workers, metal workers, machine technicians, electricians and electronics technicians, production machine operators, construction and industry auxiliaries, ICT specialists CBS. (2019d, 14 August). Werkzame beroepsbevolking; beroep. 2018. CBS Statline. Retrieved 2 October from https://opendata.cbs.nl/statline/#/CBS/nl/dataset/82808NED/table?fromstatweb.*

3 *Financial-economic education: e.g. business administration, trade, financial and business services. Financial-economic professions: e.g. salespeople, purchasers, sellers, business management, commissioners, accountants, financial specialists, accountants, economists, business administration, business services ibid..*

3.2 The residential photovoltaics market

3.2.1 Europe and the Netherlands

In 2018, 19% of the EU's cumulative photovoltaics system capacity was installed on residential rooftops (SolarPower Europe, 2018). However, market conditions for RPV differ substantially in the various countries, due to different energy policies, regulations and public support programmes (Jäger-Waldau, 2018). The first wave of RPV diffusion was driven primarily by policy incentives[4] (Curtius et al., 2018); however, such incentives are being increasingly phased out in the light of retail grid parity[5] having been reached in most countries in Western Europe (Jäger-Waldau, 2019; Karneyeva & Wüstenhagen, 2017; Petrovich et al., 2019; Weiss, 2013). In the Netherlands, the dominating energy sources in the central electricity system are natural fossil gas (50.4%) and coal (24.0%, CBS, 2020a). At the end of 2018, the share of renewables was just 7.4% (CBS, 2019a) and photovoltaics account for a relatively small share of 1.9% in the Dutch net electricity generation (Jäger-Waldau, 2018), with 57.8% of these photovoltaics being installed on residential rooftops (CBS, 2019e). Since 2011, the main incentive for RPV in the Netherlands has been a net-metering scheme[6] (Jäger-Waldau, 2019), which will be phased out between 2023 and 2030 (Rijksoverheid, 2019b).

3.2.2 City region of Parkstad Limburg

In addition to national incentives for RPV, there are also regional and municipal policies aimed at enhancing the adoption of RPV, such as the Solar Panel Project Parkstad (SPPP). This project is used as a case study in this research. At the end of 2016, the city region of Parkstad Limburg in the Netherlands (244,447 inhabitants CBS, 2018a) launched the SPPP to increase the adoption of RPV among its residents. The SPPP provides an 'all-in-one' offer, including an audit to check individual circumstances and needs[7], purchasing the RPV panels, installing them and offering 15 years of guarantee and service. In addition, participants can make use of a low-interest loan (15 years, 1.5%) offered by the municipalities. Everyone can join the project (inclusivity) because there is no credit check. Participants who make use of the loan enjoy an immediate financial

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4 *Examples of these support initiatives are subsidies, tax-benefits and feed-in tariffs (FiT).*

5 *Grid parity: achieving a stage of development of PV technology at which it is competitive with conventional electricity sources Weiss, I. (2013). Definition of grid-parity for photovoltaics and development of measures to accompany PV applications to the grid parity and beyond. https://ec.europa.eu/energy/intelligent/projects/en/projects/pv-parity.*

6 *Net metering allows consumers who generate some or all of their own electricity to use that electricity at any time, instead of when it is generated.*

7 *Such as roof size, orientation, technical condition of roof and fuse box, current electricity use, shading of trees or neighbouring objects.*

benefit, because the monthly costs of repaying the loan are lower than the energy savings. The service-provider (Volta Limburg) was selected after a tender procedure, and is carrying out the SPPP on behalf of the municipalities. The service-provider coordinates the RPV installers and is the first point of contact for all participants. However, the participants sign a contract with the municipality and not with the service-provider, which gives the participant more security in the case of a service-provider going bankrupt. To reduce the burden on participants, applications for VAT refunds are also organised within the project (Parkstad Limburg, 2019).

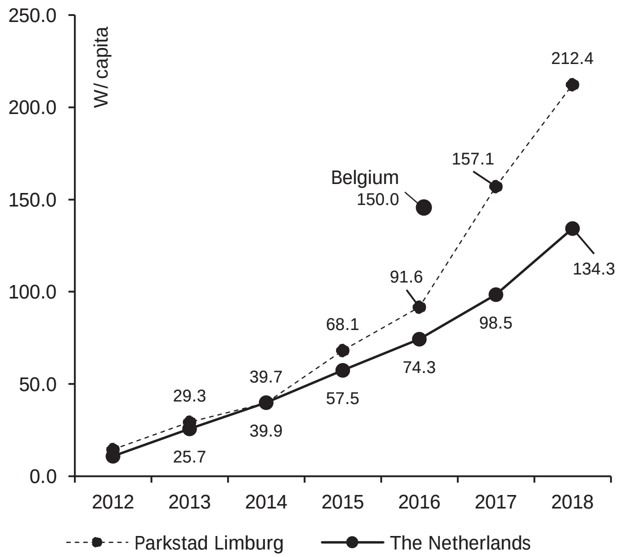

Figure 3.1. Yearly average installed RPV per capita in the city region of Parkstad Limburg in comparison to the Netherlands (CBS, 2019c, 2019e)

In 2017, approximately 82.1% of all photovoltaics in the region of Parkstad Limburg were RPV (CBS, 2019e). The remainder were placed on other buildings (such as public and commercial buildings) as there are no large ground-mounted photovoltaics park in the region. Figure 3.1 presents the installed capacity of RPV in 2018 in Parkstad (212.4 W/ capita) compared to the average in the Netherlands (134.3 W/ capita, CBS, 2019c, 2019e). By comparison, the largest RPV capacity per capita in Europe is in Belgium, with 150 W/ capita in 2016 (Wilkinson, 2018). Notwithstanding the above, the Dutch potential for RPV is much higher, namely 2,386 W/ capita (PBL, 2014).

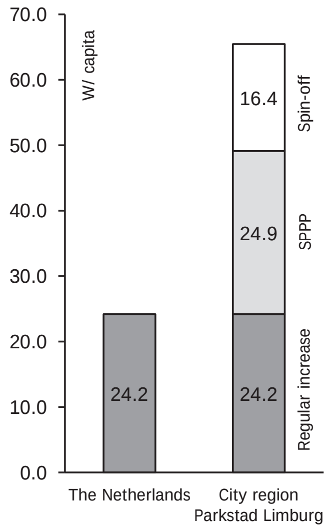

Figure 3.2. Increase in RPV in 2017 in the city region of Parkstad Limburg in comparison with the Netherlands (CBS, 2019c, 2019e; Volta Solar, 2019)

Looking at the impact of the SPPP, Figure 3.1 indicates that the amount of RPV per capita in Parkstad increased more than at the national level in 2015. This can be explained by the fact that a pilot solar project was launched in one of the municipalities of the city region (Landgraaf) in that year. A strong increase is also visible in 2017, the year in which the SPPP was launched. Figure 3.2 demonstrates that in 2017 the average national increase was +24.2 W/ capita, and in the city region +65.5 W/ capita (CBS, 2019c, 2019e). The difference can only be partly be justified by the installed capacity in the SPPP in 2017 (namely +24.9 W/ capita, CBS, 2019c; Volta Solar, 2019). The remaining 16.4 W/ capita can be explained by the assumption that the project caused a 'spin-off' resulting from the increased media attention, a possible increase in the level of discussion in social networks and the increased visibility of solar panels in the streets. Due to this spin-off effect, the impact of the project is much larger than the project itself. This project demonstrates that an all-in-one offer contributes to a more rapid increase in the adoption of RPV. Due to this success the project has been copied by various other Dutch municipalities – for example in Eijsden-Margraten, Schinnen, Stein, Beek, Heumen, Maasgouw, Oss, Roermond and eight municipalities in the southeast Brabant region[8] .

8 *From personal communication with Pim Derwort from the city region of Parkstad Limburg (Jan 2020).*

3.3 Diversity of (potential) adopters of residential photovoltaics

3.3.1 Personal characteristics

As discussed in the introduction, the homeowners' personal characteristics level of environmental concern and educational background or profession (technical, financial-economic or other) will be used in this study as segmentation criteria to study the differences between the homeowners' personal and perceived RPV characteristics. Regarding other personal characteristics, previous studies have demonstrated that there are several personal characteristics which can influence the RPV adoption. First, numerous studies have been undertaken to study the possible relation between socio-demographic factors and RPV adoption, such as age (Balcombe et al., 2013; Briguglio & Formosa, 2017; Islam, 2014), household composition (Balcombe et al., 2013; Sigrin et al., 2015) and gender (Leenheer et al., 2011; Tjørring, 2016). However, due to substantial contradictions among the results of these studies, further investigations into these socio-demographic characteristics will be investigated in this study. In addition, the communication behaviour of the homeowner can also be an important factor as previous studies point out (Rogers, 2003a). First, there is the way in which homeowners receive information about an innovation such as RPV. Previous studies have demonstrated that communication with peers who have already adopted RPV is an important communication channel in the decision to adopt RPV (Abreu et al., 2019; Baranzini et al., 2017; Bondio et al., 2018; Busic-Sontic & Fuerst, 2018; Fornara et al., 2016; Palm, 2017; Petrovich et al., 2019; Rai et al., 2016; Rai & Robinson, 2013; Scarpa & Willis, 2010; Schelly, 2014; Sigrin et al., 2015; Wolske et al., 2017; Yamamoto, 2015). Second, after adopting RPV, the adopters can also influence others in their social network by sharing their experiences and acting as an ambassador for RPV (Broers et al., 2019). Therefore, communication behaviour will be studied in more depth in this paper as this is an important influencing factor in the adoption process.

3.3.2 Perceived characteristics

In addition to personal characteristics, the adoption of RPV is also influenced by the way the RPV characteristics are perceived by the potential adopters. This means that the homeowner develops a general perception of the RPV system which will determine the decision to adopt or to reject. Rogers (2003) describes five attributes which can lead to a more favourable perception: 1. relative advantage, 2. Compatibility, 3. complexity, 4. trialability, and 5. observability (Rogers, 2003a), but also stresses that other attributes can also be important in different contexts or technologies.

First, RPV must be perceived to have a relative advantage over the status quo (Wolske et al., 2017). This can be a financial advantage, which has been studied in numerous previous studies – for example, energy cost-savings (Balcombe et al., 2013; Bondio et al., 2018; Hille et al., 2018; Islam, 2014; Korcaj et al., 2015; Sigrin et al., 2015; Wolske et al., 2018); protection against rising electricity prices (Balcombe et al., 2013, 2014; Bondio et al., 2018; Islam, 2014; Palm & Tengvard, 2011; Sigrin et al., 2015; Wittenberg & Matthies, 2016); or financial incentives (Balcombe et al., 2013; Bondio et al., 2018; De Groote et al., 2016; Dharshing, 2017; Karjalainen & Ahvenniemi, 2019; Karneyeva & Wüstenhagen, 2017; Palm, 2018; Sarzynski et al., 2012; Schaffer & Brun, 2015; Simpson & Clifton, 2017; Sun et al., 2018; Timilsina et al., 2012; Vasseur & Kemp, 2011). Moreover, the way homeowners perceive these financial-economic factors is important, and therefore some studies suggest there should be more focus on perceived affordability than on costs alone (Rai & Beck, 2015; Vasseur & Kemp, 2015a).

In addition, another perceived relative advantage can be gaining identity expression (referred to as 'social status' by Rogers (2003a)). Adopters want to express their 'green status' which is especially the case for highly visible innovations such as RPV (Korcaj et al., 2015). Associated with this is the perception of the aesthetic features of RPV, which can also be an important attribute of the RPV system in view of the high visibility aspect. Accordingly, several studies argue that improving the aesthetic features of solar panels is key to expanding the diffusion of RPV (Balcombe et al., 2013; Bao et al., 2017; Faiers & Neame, 2006; Hampton & Eckermann, 2013; Hille et al., 2018; Palm & Tengvard, 2011; Petrovich et al., 2019; Vasseur & Kemp, 2015b).

Second, RPV are more likely to be adopted if they are perceived to be compatible with the homeowners' personal situation, which will make RPV more familiar (Rogers, 2003a). Previous practice with other energy renovation measures (ERM) can contribute to this (Rogers, 2003a; Wolske et al., 2017). Nevertheless, technical issues that are encountered when installing RPV can hinder the adoption – for example, not having enough suitable roof-space, or shading from trees and neighbouring buildings.

The third perceived RPV characteristic is the perception of the complexity of the RPV technology (Karakaya & Sriwannawit, 2015; Palm, 2018; Rogers, 2003a) – for example, concerns about the quality of the RPV system or a lack of understanding of the technicalities of the RPV system (Karakaya & Sriwannawit, 2015). If the RPV system is perceived as too complex to handle or to implement, it is likely that the homeowner will reject the technology.

Trialability is the fourth RPV characteristic. With some innovations it is possible to try out the technology before adopting it (such as a cell-phone) but this is not really possible with RPV, except for certain plug-and-play systems. As a result, homeowners will want to reduce their uncertainty relating to making a decision on RPV by seeking social reinforcement and asking peers about their experiences. This can have a positive influence on the decision to adopt RPV, as numerous studies have demonstrated (Abreu et al., 2019; Baranzini et al., 2017; Bondio et al., 2018; Fornara et al., 2016; Palm, 2017; Petrovich et al., 2019; Rai et al., 2016; Rai & Robinson, 2013; Scarpa & Willis, 2010; Sigrin et al., 2015; Yamamoto, 2015).

Finally, observability can also enhance the adoption rate, which means that the technology is visible to other members of the social system – for example, the fact that RPV is visible by people in their social network and in their neighbourhood. This effect will emphasize their 'conferral of status' on potential RPV adopters (Rogers, 2003a), and therefore this characteristic is related to identity expression, as discussed earlier, but places more emphasis on 'being part of the group' than on expressing their green status. Observability can increase the probability of further RPV adoptions through interpersonal communication, raised awareness and feelings of perceived social pressure (Busic-Sontic & Fuerst, 2018). Wolske et al. (2017) state that seeing others with RPV systems indirectly influences interest by increasing the perceived relative advantage of RPV and reducing the perceived risks. This is also demonstrated in several studies focused on geographical peer effects (Balta-Ozkan et al., 2015; Bollinger & Gillingham, 2012; Busic-Sontic & Fuerst, 2018; Curtius et al., 2018; Davidson et al., 2014; Dharshing, 2017; Graziano & Gillingham, 2014; Kwan, 2012; Linder, 2013; Müller & Rode, 2013; Rai & Robinson, 2013; Richter, 2013; Schaffer & Brun, 2015).

This study undertakes an in-depth examination of the RPV characteristics perceived by the homeowner in relation to the different segmentation groups based on educational background or profession and level of environmental concern.

3.4 Research method

3.4.1 Conceptual framework

The literature review demonstrates that the personal characteristics of potential RPV adopters and the perceived characteristics of the RPV system can influence the homeowners' decision-making process when considering whether to opt for RPV. To our knowledge, no segmentation models for the adoption of RPV have been developed based on educational background or profession and level of environmental concern. We therefore contribute to closing this research gap by introducing a novel segmentation model based on these segmentation criteria. Figure 3.3 presents the conceptual framework which is based on the previously discussed literature and used to collect and analyse the data. The segmentation model will provide a deeper understanding about the diversity of the personal characteristics of potential RPV adopters and their perceived RPV characteristics.

3.4.2 Data collection and analysis

To gather data, an online survey (setup in Qualtrics) was sent by email to 2,787 participants of the SPPP[9] in May 2019, and reminders were sent one and two weeks later. The survey was first pretested on ten RPV owners. This outreach resulted in 1,395 fully completed surveys. Due to the fact that only homeowners who responded to the survey were studied, there is a possible selection bias, as this group may not represent the entire sample. The data from the online survey was analysed in IBM SPSS 25 and the significant differences between the segmentation groups were tested with descriptive analyses and nonparametric tests. Kruskal-Wallis tests were used to determine whether there were significant differences ($p < .05$) between the different segmentation groups on the independent ordinal (five-point Likert scale) and scale variables (Kruskal & Wallis, 1952). The Kruskal-Wallis test orders the scores from low to high and gives them a ranking number. The ranks were added together within a group, after which the test statistics were calculated. In this case, a high mean score means 'less' and a low score 'more', in terms of the setup of the five-point Likert scale, where 1 = very much, 2 = quite a lot, 3 = average, 4 = a little, and 5 = not at all. Subsequently, Mann-Whitney U test pairwise multiple comparisons were carried out as a post hoc procedure to determine between which groups the significant differences occur (Mann & Whitney, 1947). In addition, significance values were adjusted by the Bonferroni correction[10] for

9 *These are participants who had their RPV system installed in 2017 or 2018.*

10 *When conducting multiple analyses on the same dependent variable, the chance of committing a type I error increases, thus increasing the likelihood of arriving at a significant result by pure chance. The significance level for the p-value is therefore altered by dividing it by the number of tests (10 in this case, $p < .005$).*

multiple tests (Bonferroni, 1936). To analyse the nominal variables, chi-square tests were performed to determine the significant differences between the segmentation groups, and as a post-hoc procedure Pearson's chi-square pairwise tests were conducted, also using the Bonferroni correction for multiple tests.

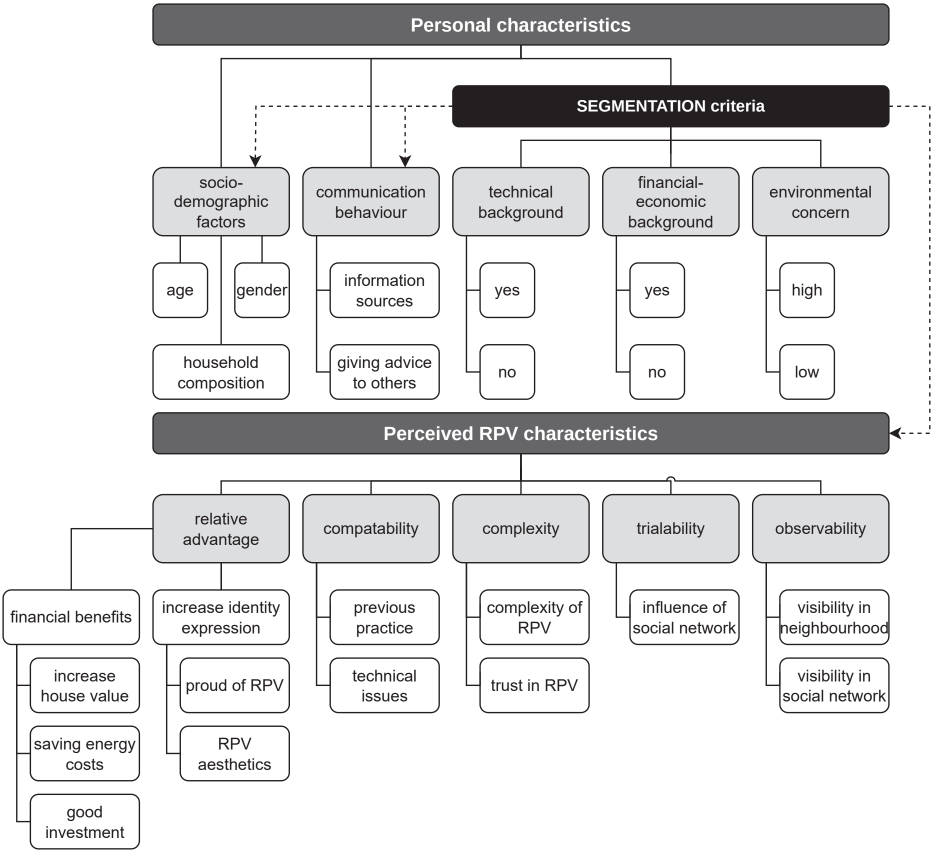

Figure 3.3. Conceptual framework for this study (based on the literature review)

3.5 Results

3.5.1 Sample profile

Table 3.1 presents the socio-demographic details of the study sample in comparison to the Dutch average. There are significant differences from the Dutch average ($p < .001$) on the socio-demographic aspects of gender, age-groups (25-64 years), household composition and housing type. First, the sample consists of a majority of men (79.6%). A possible explanation could be that men are more interested in RPV and other energy renovation measures (Leenheer et al., 2011; Tjørring, 2016), but there are also studies that do not report this difference (Wolske et al., 2017). Moreover, our sample also reveals a majority of households of couples (85.9%), and this could therefore also mean that the men were more willing to fill in the survey.

Second, the average age of the respondents was 55 years (min. 24, max. 87), which confirms previous research: Wolske et al. (2017) found a mean age of 56, Balcombe et al. (2013) reported that the group between the ages of 45 and 64 was more aware and had a more positive attitude towards installing RPV, while Vasseur and Kemp (2015b) found that voluntary adopters were located in the age category of 50–59 years. Third, the sample has fewer households with children (41.1%) than the Dutch average (44.3%), which contrasts with earlier research on RPV adoption which reports that households with children are more likely to adopt RPV (Balcombe et al., 2013; Sigrin et al., 2015). Fourth, regarding educational background and profession, the sample reveals significantly more persons with a technical education (39.3%) or profession (29.7%) than the Dutch average (respectively 16.7%, 17.4%, Min. EZK, 2019). In addition, the sample demonstrates that 22.4% of the respondents have a financial-economic education and 15.8% have a financial-economic profession. By contrast, 18.5% of Dutch working people had a financial-economic profession in 2018, which is significantly higher ($p < .01$, CBS, 2019d, numbers for education are lacking).

Another consideration to take into account is that the respondents did not necessarily make the decision to adopt RPV on their own. It is very likely that this is a joint decision, made together with their partner and/or family. Whenever that is the case, the profile of the joint decision-maker is also relevant, but these data were not collected in this study. The differences can be explained by the fact that the sample does not represent an average sample of Dutch homeowners of single-family, owner-occupied homes but is made up only of RPV adopters in a certain region. However, the insights into the characteristics of these RPV adopters and their perception of the RPV characteristics can also be relevant for other homeowners whose situation is different (Berry et al., 2014; Fawcett & Killip, 2014; Galvin & Sunikka-Blank, 2014).

Table 3.1. Socio-demographic characteristics of the study sample compared to the Dutch average (CBS, 2018a, 2019b; Detiger & Oostrom, 2019; Min. EZK, 2019; Rijksoverheid, 2019a)

	Study-sample (%)	Dutch average (%)	Chi-Square
Gender			501.2***
Female	20.4	50.4	
Male	79.6	49.6	
Age (years)[1]			
< 25	0.1	0.4	3.8 0
25 - 44	20.5	27.2	31.6***
45 - 64	52.9	46.6	22.3***
≥ 65	26.5	25.8	0.4 0
Household composition[1]			
Single person household	9.9	17.5	55.9***
Couple without child(ren)	49.0	38.2	69.3***
Household with child(ren)	41.1	44.3	37.0***
Technical background			
Education	39.3	16.7	490.9***
Profession	29.7	17.4	146.3***
Financial-economic background			
Education	22.4	-	
Profession	15.8	18.5	6.9**

** $p < .01$, *** $p < .001$

[1] Dutch average in the group single family, owner-occupied homes

3.5.2 Segmentation groups

The total sample of respondents was divided into five mutually exclusive segmentation groups, based on the segmentation criteria of the conceptual framework (Figure 3.3). Table 3.2 presents the questions concerning these segmentation criteria: first, the questions about having a technical or financial-economic education or profession; and second, two questions about the respondents' general environmental concern. The last two are measured on a five-point Likert scale and respondents were considered to have a high environmental concern when they answered 'very much' or 'quite a lot' to one of these two questions. Subsequently, Table 3.3 presents the five segmentation groups used to analyse the data and explore the possible differences between the groups.

3.5.3 Level of environmental concern and homeowners' background

Figure 3.4 presents the level of environmental concern in relation to educational background and profession (see also Tables 5 & 6 in the supplementary materials). The statistical analysis demonstrates statistically significant differences between some groups. Group E-T+F reported that it was significantly less environmentally conscious than groups E-T-F and E+T+F ($p < .05$). In addition, group E+T+F found it significantly less important to make a positive contribution to the environment than groups E-T+F and E-T-F ($p < .05$; see Tables 5 & 6 in the supplementary materials).

Table 3.2. Survey questions used as segmentation criteria

Questions	Scale
Do you have a technical education?	yes/ no
Do you have a technical profession?	yes/ no
Do you have a financial or economic education?	yes/ no
Do you have a financial or economic profession?	yes/ no
How environmentally conscious do you find yourself in comparison to others?	very much*/ quite a lot*/average/ a little/ not at all
How important is it to you to make a positive contribution to the environment?	very much*/ quite a lot*/average/ a little/ not at all
	* high environmental concern

In addition, the respondents were asked whether environmental concern was one of their reasons for adopting RPV. An overwhelming number of respondents (63.5%; see Figure 3.5) mentioned environmental concern as one of the reasons for adopting RPV. Concerning differences, the non-environmentalists mentioned environmental concern as a reason for adopt RPV significantly less frequently ($p < .001$; see Figure 3.5) than the other groups. There were no significant differences between the other groups on this aspect, which can be explained by the fact that these groups all had a higher environmental concern than the non-environmentalists.

3.5.4 Personal characteristics of the segmentation groups

First, regarding the socio-demographic differences between the groups, the results of the statistical tests reveal no statistical significant differences in age and household composition (see Table 7 in the supplementary materials). However, there are significant differences regarding gender. In group E-T-F there are significantly fewer men (61.1%) than in all the other groups ($p < .001$), and there are significantly fewer men in group E-T+F (77.2%) than in groups E+T-F (98.2%) and E+T+F (96.6%, $p < .001$). Moreover, in group N-E there are significantly fewer men than in group E+T-F (87.9%; $p < .001$; see Tables 7 & 8 in the supplementary materials). This can be explained by the fact that more men opt for a technical education or technical jobs in the Netherlands (Min. EZK, 2019).

Table 3.3. Segmentation of study sample into five mutually exclusive segmentation groups

	Segmentation groups	High environmental concern	Technical background	Financial-economic background	Number in sample	Share in sample %
E-T-F	Environmentally motivated people with no technical or financial-economic background	1	0	0	540	38.7
E+T-F	Environmentally motivated people with a technical background and no financial-economic background	1	1	0	439	31.5
E-T+F	Environmentally motivated people with a financial-economic background and no technical background	1	0	1	228	16.3
E+T+F	Environmentally motivated people with a technical and financial-economic background	1	1	1	89	6.4
N-E	People with a low environmental concern	0	0/1	0/1	99	7.1
	TOTAL				**1395**	**100.0**

1= yes; 0 = no

Second, regarding communication behaviour, the respondents reported that they were initially informed about the SPPP in different ways. Most mentioned people in their social network (37.5%), followed by the project information evening (27.5%), social media or internet (15.6%), the local newspaper (14.8%), while 4.6% mentioned other sources (see Figure 3.5). There are no statistically significant differences between the groups regarding information sources (see Table 7 in the supplementary materials). Furthermore, after adopting their RPV system, the homeowners can also influence others in their social network by sharing their experiences. Regarding the SPPP, the results reveal that an overwhelming majority of respondents (93.8%) recommended the project to others in their social network (with no significant differences between the groups (see Table 7 in the supplementary materials). Furthermore, groups E+T-F and E+T+F advised others in their social network about energy renovation measures significantly more than the other groups ($p < .001$), which is probably related to their technical background and expertise.

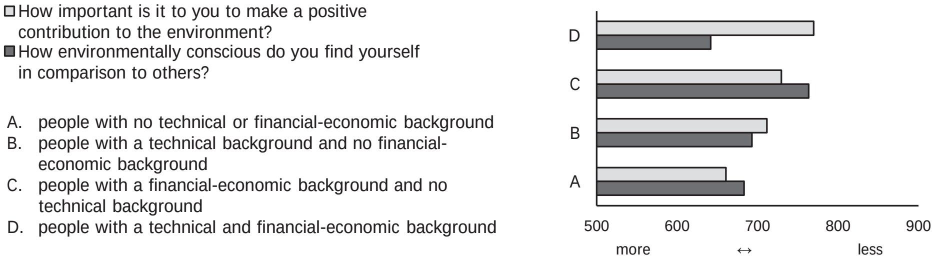

Figure 3.4. Level of environmental concern in relation to educational background and profession (mean rank per group)

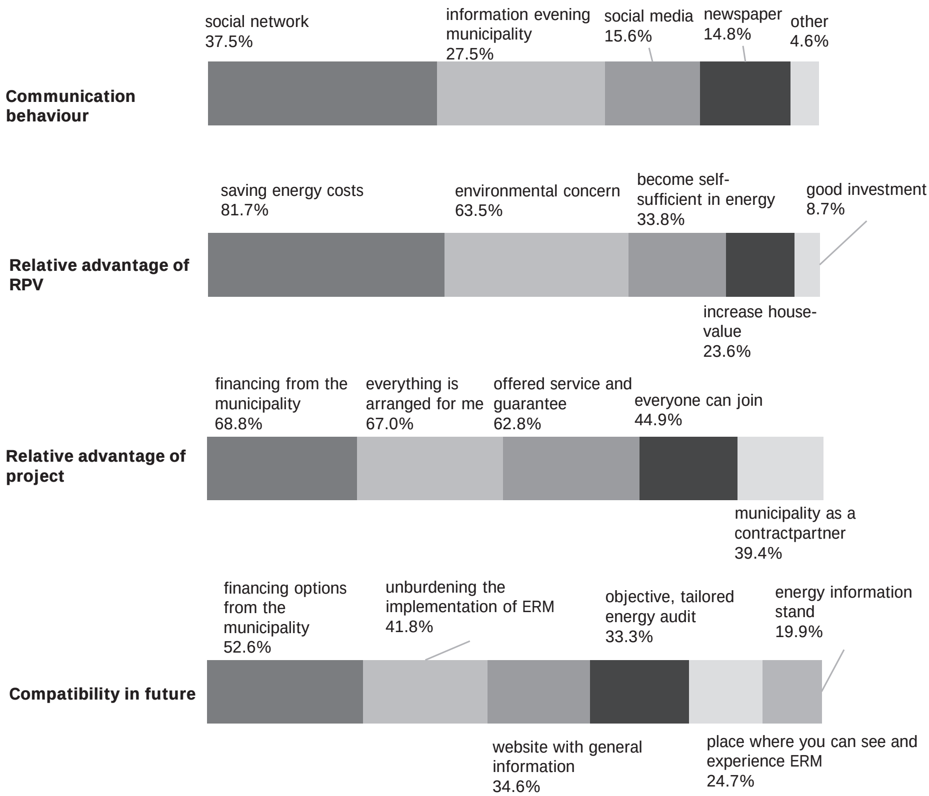

Figure 3.5. Descriptive study results of the nominal variables

Communication behaviour: respondents' initial information sources about the project

Relative advantage of RPV: reasons for adopting residential photovoltaics (multiple options possible)

Relative advantage of project: appreciated aspects in the project (multiple options possible)

Compatibility in future: future help wanted from the municipality (multiple options possible)

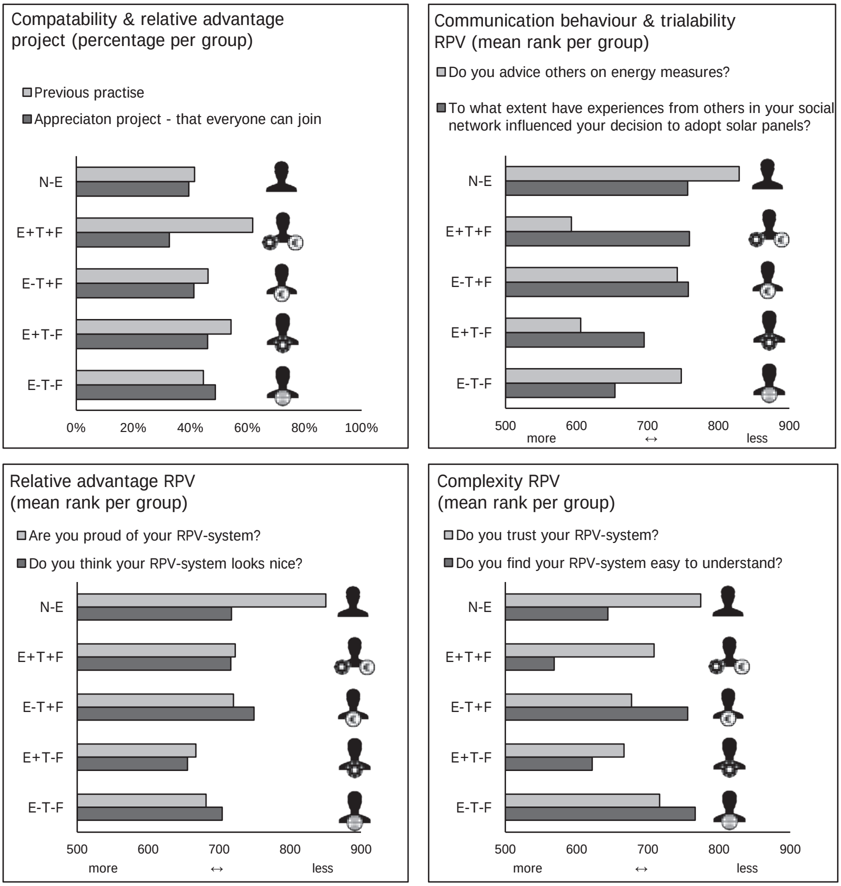

Figure 3.6. Statistical study results of nominal and ordinal variables with significant differences between the segmentation groups (p < .05)

Top left: Compatibility and relative advantage of project: percentage per segmentation group for appreciation project and previous practice.

Top right: Communication behavior and trialability: mean rank per segmentation group for communication behavior.

Bottom left: Relative advantage of RPV: mean rank per group per segmentation group for perceived aesthetics and proudness.

Bottom right: Complexity: mean rank per segmentation group for perceived complexity and trust.

E-T-F: Environmentally motivated people with no technical or financial-economic background

E+T-F: Environmentally motivated people with a technical background and no financial-economic background

E-T+F: Environmentally motivated people with a financial-economic background and no technical background

E+T+F: Environmentally motivated people with a technical and financial-economic background

N-E: People with a low environmental concern

3.5.5 Perceived characteristics

Relative advantage of the project

The SPPP was appreciated highly by the respondents; they graded the project with an average of 8.3/ 10, with no significant differences between the segmentation groups. There were also no significant differences between the groups on whether the project met their wishes and expectations (see Table 9 in the supplementary materials). Figure 3.5 demonstrates that various different aspects were appreciated in relation to the SPPP (multiple options possible): financing from municipality (68.8%), everything is arranged (67.0%), offered service and guarantee (62.8%), everyone can join (44.9%), and municipality as contract partner (39.4%). There was only one significant difference: group E-T+F found the aspect that everyone can join significantly less important than group E-T-F ($p < .001$; see Figure 3.6 and Tables 7 & 8 in the supplementary materials).

Relative advantage of residential photovoltaics

Figure 3.5 reveals that, in addition to environmental concern (mentioned by 63.5%), financial motives for adopting RPV were mentioned frequently by the respondents: saving energy-costs (81.7%), increasing house value (23.6%), and seeing it as a good investment (8.7%). There were no statistically significant differences between the groups on these aspects (see Table 7 in the supplementary materials of this Chapter). In addition, there were no significant differences on perceived advantage of the RPV system and perceived increased house value after implementing RPV (see Table 9 in the supplementary materials). In addition, the results demonstrate that the non-environmentalists were significantly ($p < .001$) less proud of their RPV system than the other groups (see Tables 9 & 10 in the supplementary materials). This could be explained by the fact that this group displayed less environmental concern and therefore found a 'green image' less important. In addition, group E-T+F liked the aesthetics of their RPV significantly less ($p < .001$) than group E+T-F (see Figure 3.6 and Tables 9 & 10 in the supplementary materials).

Compatibility

To investigate the compatibility of RPV with other energy measures, respondents were asked whether they had implemented other energy renovation measures. More than half (52.9%) of the respondents had done so in the past five years. From this group, 53.0% had installed insulation, 43.8% high-efficiency glazing, 48.8% a high-efficiency gas-boiler, 2.7% a heat-pump, and 1.9% a thermal solar collector. This demonstrates that the level of adoption of more innovative technologies was much lower for this group (except for RPV). Group E-T-F had installed significantly less ERM than groups E+T-F and E+T+F, and group E+T+F had installed more ERM than groups E-T+F and N-E ($p < .001$;

see Figure 3.6 and Tables 9 & 10 in the supplementary materials). This demonstrates that individuals with a technical background had more previous experience with installing comparable measures. In addition, the majority (84.3%) experienced no technical problems when installing their RPV system, with no significant differences between the groups (see Table 7 in the supplementary materials).

To investigate how the perceived compatibility for implementing other energy measures in future could be enhanced, the participants were asked how the municipality could help them in future. Figure 3.5 presents the following aspects: financing options (52.6%), unburdening the implementation of ERM (41.8%), website with general information (34.6%), objective, tailored energy audit (33.3%), place where you can see and experience ERM (24.7%), and an energy information stand (19.9%). However, there were no significant differences between the segmentation groups on these aspects (see Table 7 in the supplementary materials).

Complexity

Figure 3.6 indicates that group E-T-F found their RPV-system significantly more complicated than the other groups ($p < .001$), except for group E-T+F. In addition, group E-T+F found their RPV system more complex than groups E+T-F and E+T+F ($p < .001$). Furthermore, the non-environmentalists trusted their RPV system significantly less than group E+T-F ($p < .001$; see Tables 9 & 10 in the supplementary materials). This demonstrates that people with a technical background or profession find their RPV system less complicated, which could be an important influencing factor to enhance adoption (Rogers, 2003a).

Trialability and observability

As stated before, 37% of the respondents stated that they were informed about the SPPP by people in their social network (no significant differences between groups). This is in line with multiple other studies that communication with peers who have already adopted RPV can influence the decision to adopt RPV positively (Abreu et al., 2019; Baranzini et al., 2017; Bondio et al., 2018; Busic-Sontic & Fuerst, 2018; Fornara et al., 2016; Palm, 2017; Petrovich et al., 2019; Rai et al., 2016; Rai & Robinson, 2013; Scarpa & Willis, 2010; Schelly, 2014; Sigrin et al., 2015; Wolske et al., 2017; Yamamoto, 2015). The results demonstrate that group E-T-F had been significantly more influenced by others in their social network than group E-T+F ($p < .001$; see Figure 3.6). In addition, there were no statistically significant differences between the segmentation groups for the visibility of RPV in their social network and neighbourhood (see Tables 9 & 10 in the supplementary material).

Table 3.4. Overview of statistical study results
Statistically significant differences between segmentation groups are marked with an 'x' (p < .05, after Bonferroni correction)

Characteristic	Question		E+T-F	E-T+F	E+T+F	N-E
Personal characteristics						
Socio-demographic characteristics	What is your gender?	**E-T-F**	X	X	X	X
		E+T-F		X		X
		E-T+F			X	
		E+T+F				
Communication behaviour	Do you advise others on energy measures?	**E-T-F**	X		X	
		E+T-F		X		X
		E-T+F			X	
		E+T+F				X
Perceived RPV-characteristics						
Relative advantage – project	Reason for participation in project - environmental concern	**E-T-F**				X
		E+T-F				X
		E-T+F				X
		E+T+F				X
	Appreciation project - that everyone can join	**E-T-F**			X	
		E+T-F				
		E-T+F				
		E+T+F				
Relative advantage – RPV	Do you think your RPV system looks nice?	**E-T-F**				
		E+T-F		X		
		E-T+F				
		E+T+F				
	Are you proud of your RPV system?	**E-T-F**				X
		E+T-F				X
		E-T+F				X
		E+T+F				

Table 3.4. Continued

Characteristic	Question		E+T-F	E-T+F	E+T+F	N-E
Perceived RPV-characteristics (Continued)						
Complexity	Do you find your RPV system complicated?	**E-T-F**	X		X	X
		E+T-F		X		
		E-T+F			X	
		E+T+F				
	Do you trust your RPV system?	**E-T-F**				
		E+T-F				X
		E-T+F				
		E+T+F				
Compatibility	How many other ERM did you install the past five years?	**E-T-F**	X		X	
		E+T-F				
		E-T+F			X	
		E+T+F				X
Trialability	To what extent have experiences of others in your social network influenced your decision to adopt solar panels?	**E-T-F**		X		
		E+T-F				
		E-T+F				
		E+T+F				

3.6 Discussion and conclusions

The uptake of residential photovoltaics must increase more rapidly to combat climate change and its impacts. In order to address this issue, this study aimed to gain a better understanding of the heterogeneity of potential RPV adopters in order to make policy actions, communication and marketing campaigns more effective by targeting specific groups. We developed a segmentation model based on data from a survey of RPV adopters in the city region of Parkstad Limburg in the Netherlands, and identified five substantial segmentation groups based on people's type of educational background or profession (technical, financial-economic or other) and level of environmental concern. First, environmentally motivated people with no technical or financial-economic background (38.7%); second, environmentally motivated people with a technical background, but no financial-economic background (31.5%); third, environmentally motivated people with both a technical and a financial-economic background (16.3%); fourth, environmentally motivated people with a financial-economic background, but no technical background (6.4%) and fifth, people who are less environmentally motivated (7.1%). The results demonstrate that there are significant differences between these groups relating to personal characteristics and their perception of the RPV characteristics (see Table 3.4). This segmentation model makes a contribution to the literature which adds insights to the research on RPV adoption by households. Recommendations are made per segmentation group in the sections below, based on these results. This is so that they can be targeted more effectively by policies and the private sector in order to increase the uptake of RPV.

3.6.1 Relative advantage of the project

One mechanism by which local governments can increase RPV adoption is by removing relevant barriers for homeowners (White, 2019). The SPPP demonstrates that this kind of project (the all-in-one-offer) can have a significant impact on the diffusion of RPV: the project caused a significant increase in RPV adoption in the region compared to the national increase. There was also the 'spin-off' effect, which is presumably caused by increased media attention, peer effects and increased visibility in the region. Moreover, the project was highly appreciated by the participants, especially the all-in-one-offer of the municipalities, which is something that has been suggested previously for the wider scope of energy renovation measures (Mahapatra et al., 2019). In addition, other benefits of the project are reduced carbon emissions, increased energy security, decreased energy bills, local economic activity and job opportunities. Due to this success, the project has been copied by several other municipalities in the Netherlands.

The financing (low-interest loan) offered by the municipality was highly appreciated by the participants. First, this loan addresses the perceived high upfront costs that are often mentioned in other research as an important barrier (Balcombe et al., 2013, 2014; Hille et al., 2018; Islam, 2014; Karakaya & Sriwannawit, 2015; Palm, 2018; Scarpa & Willis, 2010; Wolske et al., 2018), and confirms other studies which suggest that leasing systems can help to grow the RPV market (Liu et al., 2014; Rai & Sigrin, 2013; Sigrin et al., 2015). Moreover, this loan – without the credibility check – makes RPV also available for people with a lower income and will therefore contribute to the inclusivity of RPV. Second, the majority of the respondents appreciate that everything is arranged for them in the project, from start to finish. Other studies have argued that the complexity of administrative procedures and comparing quotes from different companies can be a barrier for the uptake of RPV (Karteris & Papadopoulos, 2012; Palm, 2017; Palm, 2018; Palm & Eriksson, 2018). All these aspects are organised for the participants in this project. Third, the offered guarantee and service within the SPPP addresses concerns about increasing maintenance costs, which is mentioned in other research as an important barrier (Balcombe et al., 2013; Claudy et al., 2013; Rai et al., 2016). Fourth, the respondents mention that the fact the municipality is the contract partner and not the company as an advantage. Contractors are often seen as unreliable and non-transparent by homeowners, which can hinder the uptake of RPV (Abreu et al., 2019; Knudsen, 2002; Margolis & Zuboy, 2006; Palm & Eriksson, 2018). Difficulties in finding trustworthy, transparent and impartial information are mentioned as a significant barrier complicating the adoption of RPV (Balcombe et al., 2014). Having the municipality as a contract partner in the SPPP reduces these perceived risks for homeowners, as the former is regarded as a neutral party which provides objective and transparent information (Wolske et al., 2017).

3.6.2 Segmentation model

Compared to other developed segmentation models for RPV adoption, this model provides a segmentation of RPV adopters based on educational background or profession and level of environmental concern. The study findings reveal significant differences between the segmentation groups concerning personal characteristics and RPV characteristics perceived by the homeowners.

Environmentally motivated people with no technical or financial-economic background

The group of individuals who are environmentally motivated but with no technical or financial-economic background (E-T-F) displays similarities with the ‘environmentally engaged adopters’ group discussed in the segmentation study of Palm and Eriksson (2018) because both groups often find information about RPV too technical and complicated. To counter this, a clear explanation about the operation of the RPV system must be given, in a less technical way, to reduce the level of complexity of the system that they perceive. In addition, this group is more influenced in their decision-making process by the experiences of RPV adopters in their social network. Therefore, this group can be targeted more effectively by making use of existing social networks to promote RPV. This supports previous literature which reports that potential adopters look for assurance from trusted sources such as neighbours, family and friends (Abreu et al., 2019; Baranzini et al., 2017; Bondio et al., 2018; Busic-Sontic & Fuerst, 2018; Fornara et al., 2016; Palm, 2017; Petrovich et al., 2019; Rai et al., 2016; Rai & Robinson, 2013; Scarpa & Willis, 2010; Schelly, 2014; Sigrin et al., 2015; Wolske et al., 2017; Yamamoto, 2015).

Another significant feature of this group is this that they mention environmental concern for RPV adoption more often than those with a low environmental concern. Therefore, it can be effective to emphasize the environmental benefits in communication and marketing campaigns for this group. This is also suggested in other research, but for a broader group (Bondio et al., 2018; Leenheer et al., 2011; Palm, 2018; Schelly, 2014; Sun et al., 2018; Tjørring, 2016; Vasseur & Kemp, 2015b; Wittenberg & Matthies, 2016; Wolske et al., 2017; Wolske et al., 2018). However, framing RPV only as an environmental decision may limit the adoption by less environmentally minded people (Schelly, 2014), and communicating a broader pallet of RPV benefits is recommended to overcome this. Lastly, as this group finds it more important that everyone can join, inclusivity can be organised and highlighted clearly in communication and marketing campaigns.

Environmentally motivated people with a technical background

The second group is made up of environmentally motivated people with a technical background and no financial-economic background (E+T-F). This group bears a resemblance to the 'professionally skilled' group in the segmentation study by Palm and Eriksson (2018), because both groups demonstrate more knowledge about RPV and find their RPV system less complex than the other groups. This group can be targeted more effectively by emphasizing the technical specifications of the RPV system. The study results also demonstrate that this group has more previous practice with other energy measures, and also has more experience in advising people in their social network. Based on the above, this group can be used and facilitated by policy-makers and companies as an ambassador for energy renovation measures such as RPV. For the third group – environmentally motivated people with a technical and financial-economic background (E+T+F) – the same recommendations can be made as for the technical environmentalists.

Environmentally motivated people with a financial-economic background and no technical background

The fourth group is made up of environmentally motivated individuals with a financial-economic background and no technical background (E-T+F). The results demonstrate that these people have a lower environmental concern than others. This (cautiously) confirms studies from other fields which demonstrate that students majoring in financial-economic disciplines display lower environmental scores than students with other university majors (Hodgkinson & Innes, 2001; Lang, 2011; Sherburn & Devlin, 2004; Smith, 1995; Thapa, 2001; Tikka et al., 2000). In addition, this group finds inclusivity (everyone can join) in a project less important. Consequently, these two aspects can be highlighted less in communication and marketing to target this group more effectively.

In addition, this group reveals that they like the aesthetics of their RPV system less, which corresponds with the 'early majority' group identified by Faiers and Neame (2006), as they also find their RPV system visually less attractive. In addition, this group demonstrates similarities with the 'premium segment' identified by Petrovich et al. (2019), because the latter is more interested in colour or building integrated photovoltaics and is willing to pay more for these. Therefore, offering aesthetically more attractive photovoltaics could enhance the RPV uptake by this group. Lastly, this group finds their RPV system more complex, and therefore a clear, less technical explanation about the operation of the RPV system must be given to increase their comprehensibility of the system, as for the other groups with no technical background.

Less environmentally motivated people

Lastly, there are individuals with lower environmental concern (N-E). They can be targeted more effectively by placing less emphasis on the environmental benefits in communication and marketing campaigns and more on a broader pallet of RPV benefits. The results also demonstrate that this group is less proud about their RPV system, which suggests that they are less interested in increasing their 'identity expression' when installing RPV (expressing 'green status'). In addition, they trust their system less, which can be countered by a clear explanation of both the RPV system and the conditions of joining the project. Finally, the results demonstrate that this group has less experience in installing other measures in their home.

3.6.3 Communication strategies

The results demonstrate that the five segmentation groups have to be targeted in different ways to make policies, communication and marketing campaigns more effective. The different groups will be drawn to different aspects in a campaign and therefore a broader pallet of RPV benefits must be presented (e.g. environmental and financial benefits). The specific aspects that trigger certain people are not mutually exclusive, and attention must therefore be devoted to all those aspects so that people can select for themselves which criteria are relevant for them. The potential RPV adopters with a technical background can be specifically targeted by sharing technical information and reviews in technical magazines and by means of information stands at local hardware stores. Existing social networks can be used to promote RPV – for example, (neighbourhood, music) associations and sport and recreation clubs. The findings reveal that this is especially effective for people with no technical or financial-economic background, as they put more trust in their peers when making a decision. For example, local governments could make it possible for people with a technical background to advise others on RPV in their social networks. In addition, people without a technical background could be unburdened by offering them objective assistance in the decision-making process – for example with the comparison of offers and by giving a clear, less technical explanation about the operation of the RPV system. A local government or non-profit organisation could offer such a service. Furthermore, communication campaigns could reach out to potential adopters who already have adopted other energy measures in their home. Lastly, the uptake by people with a financial-economic background could be enhanced by offering aesthetically more attractive photovoltaics.

3.6.4 Limitations and implications for further research

Even though the presented segmentation model was developed from empirical evidence relating only to RPV adopters in a certain region and in a specific municipal project, the insights into the characteristics of these RPV adopters and their perception of the RPV characteristics could also be relevant for other homeowners whose situation is different or for other energy-saving household technologies such as energy renovation measures or the use of electric cars. Nevertheless, follow-up studies could include non-adopters, other regions, other contexts, and an investigation of other educational backgrounds and professions. Extending the scope of data collection could generate further elaboration of this model and could include other energy-saving household technologies. In addition, the sample consists of a large number of respondents with a high environmental concern, which would be different when non-adopters are included. The group of non-environmentalists and the group with another background than technical or financial-economic, could also be divided into subgroups in follow-up studies.

Acknowledgements and funding

The authors would like to thank the city region of Parkstad Limburg (NL) for the assistance in undertaking the survey. This research was funded by the Dutch Organization for Scientific Research (NWO, 023.013.033), the Foundation Innovation Alliance (SIA, RAAK.PRO02.145) and Zuyd University (PhD funding).

3.6.5 Appendix Chapter 3

Supplementary data to Chapter 3 can be found online at: https://doi.org/10.1007/s12053-021-09937-0:

- **Table 5**. Statistical tests among groups based on educational background and profession
- **Table 6.** Pairwise follow-up tests (Mann-Whitney U)
- **Table 7.** Statistical test results nominal variables
- **Table 8.** Pairwise follow-up tests nominal variables (Pearson chi-square)
- **Table 9.** Statistical test results ordinal variables
- **Table 10.** Pairwise follow-up tests nominal variables (Mann-Whitney U)

4

CHAPTER 4

JUSTICE IN SOCIAL HOUSING: TOWARDS A PEOPLE-CENTRED ENERGY RENOVATION PROCESS

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Published in Energy Research & Social Science 2022; 88, 102527

Abstract

The annual renovation rate of the existing housing stock must increase rapidly to reach climate neutrality by 2050. This transition will require major investments but will also need to be affordable for everyone. Affordability is especially relevant for vulnerable and low-income households, many of which live in social housing in the Netherlands. Previous studies show that such a transition faces justice issues but this paper argues that a more pluralistic justice approach is needed, which also studies the interrelations between the justice dimensions. A multidimensional perspective is used based on five interrelated justice dimensions: distribution, recognition, participation, capability, and responsibility. Empirical data were collected by interviewing members of tenant associations and employees from social housing associations in the Netherlands on their experiences with, and views on, justice aspects in the energy renovation process. The data analysis shows that the multidimensional justice perspective can be applied to implement a broader and more pluralistic perspective on justice principles. These insights can be a starting point for achieving a more just energy renovation process in social housing, especially for addressing the needs of vulnerable households. Moreover, the results point out that all five dimensions are important to take into account in all stages of the energy renovation process, that they are strongly interlinked, and should not be addressed separately. The developed recommendations can be used by policymakers, and tenant and social housing associations.

4.1 Transition to a climate-neutral social housing stock

To address climate change, the European Union (EU) intends to reach climate neutrality by 2050, and aims at a 55% reduction of greenhouse gas emissions by 2030 compared to 1990 levels (European Commission, 2020c). Households are responsible for almost 30% of the CO_2 emissions in Europe (Eurostat, 2020), and 20% in the Netherlands (CBS, 2020b). This is mainly due to an energy-inefficient housing stock (European Commission, 2020c). Nevertheless, 85-95% of these buildings will still be in use in 2050, which means that this inefficient housing stock needs to be renovated to reach the climate goals (European Commission, 2020c). Despite this urgency, the annual energy renovation rate is only 1% at this time in the EU (European Commission, 2020c), and the implementation rate of deep energy renovations in Europe is only 0.2% at this time (European Commission, 2020c). The latter are renovations that reduce the energy consumption by at least 60% (European Commission, 2020c) by implementing measures such as insulation, high-efficiency glazing, efficient heating and ventilation systems, and renewable energy production (Broers et al., 2019). In an effort to face this challenge, the EU has implemented a new strategy in 2020 to boost energy renovations, 'A Renovation Wave for Europe'. In this strategy, they aim to double the renovation rates by 2030, which must result in 35 million renovated buildings in Europe (European Commission, 2020c) and 1.5 million renovated dwellings in the Netherlands (Rijksoverheid, 2019c).

One of the main priorities in the EU's new renovation strategy is the necessity for a just transition towards a climate neutral Europe by 2050 (European Commission, 2020b, 2020c). The EU expresses affordability as one of the key principles for this, especially for vulnerable and low-income households (European Commission, 2020c). The reason for this is that energy poverty is a growing problem in the EU; nearly 34 million Europeans (7.6%) were unable to keep their home adequately heated in 2018 (European Commission, 2020b). Therefore, the European Commission recommends that countries specifically address vulnerable households as a priority in their national long-term energy renovation strategies (European Commission, 2020b). Energy poverty is also a growing issue in the Netherlands, particularly among low-income households. This group lives, largely, in social housing as this sector provides affordable housing for those with lower incomes (Braga & Palvarini, 2013). The Dutch housing stock has the highest share of social housing in Europe (Schilder & Scherpenisse, 2018), namely 29.6% (Rijksoverheid, 2019a) compared to an European average of 10.7% in 2018 (Eurostat, 2019). This gives them a strong position in the Dutch housing sector, compared internationally, and makes the social housing sector a crucial sector to address to realise a fair transition towards a climate neutral housing stock by 2050.

Implementing energy renovations in social housing has the potential to lower the energy costs for their tenants (European Commission, 2020b). However, some households experience a rise in their living costs after the renovation because the energy savings do not cover the rent increase after renovation (Filippidou et al., 2019; Guerra-Santin et al., 2017). This can worsen the vulnerability to energy poverty and inequality in the future (Sovacool et al., 2019; Straver & Mulder, 2020). In addition, energy renovations are not always socially accepted by tenants because they do not suit their wishes and needs concerning improving their living conditions (Breukers et al., 2017). Moreover, tenants are often hardly involved in the decision-making process of the renovation plans at this time (Hickman & Preece, 2019; Uyterlinde et al., 2019). The plans are often developed from the urgency to meet the climate goals, and are merely technology-driven and often introduced top-down (Boess, 2017; Hickman & Preece, 2019; Uyterlinde et al., 2019). As a result, energy renovations in social housing do not always have a positive outcome for their residents.

Regarding these distributional and procedural issues in the energy renovation process of social housing, a fair transition towards a climate neutral housing stock touches upon important issues of justice. This is especially relevant in the case of social housing, as a large amount of vulnerable households live there. Justice perspectives have received much interest in previous literature regarding environmental and climate issues. Early environmental justice studies focused on inequities in environmental burdens such as toxic burdens, air pollution, and landfills in the political issues in the 1950s and 1960s (Brooks & Davoudi, 2018; McCauley & Heffron, 2018; Taylor, 2000). Since then, the scope of these studies has expanded to a wider range of environmental problems (Davoudi & Brooks, 2014), such as the accessibility of green spaces in cities (Brooks & Davoudi, 2018; De Sousa Silva et al., 2018; Kronenberg et al., 2020), the global burdens and benefits of climate change (Jenkins, 2018; McCauley & Heffron, 2018), the acceptance of renewable energy (Kluskens et al., 2019; Levenda et al., 2021; Pandey & Sharma, 2021), and energy security (Sovacool & Saunders, 2014). However, there are only a few studies related to household energy renovations. For instance, Gillard et al. (2017) and Sovacool (2015) studied energy justice in the context of fuel poverty and domestic retrofits in the UK. Sovacool et al. (2019) investigated energy justice issues of household low carbon innovations in the UK, such as energy services contracting, electric vehicles, solar photovoltaics and low carbon heating. In the Netherlands, Breukers et al. (2017) performed a study on justice issues in a sustainable neighbourhood transformation, but they mainly focused on the initiative phase of the development and investigated a single case-study in Eindhoven. Overall, justice studies in the context of domestic energy renovations are rare, and do not capture justice aspects in the whole energy renovation process of social housing, which will therefore be the focus of this paper.

In the past, justice studies were mainly focused on distributional issues, but the scope of justice has widened (Moroni, 2020; Sovacool et al., 2019). For example, to include recognition of the various needs, rights, and experiences of different groups (especially socially deprived people); the degree and nature of participation of individuals in the decision-making process (Gillard et al., 2017; Jenkins et al., 2016); the responsibility for all nations to protect the natural environment (McCauley et al., 2019; Sovacool & Dworkin, 2015); and the capability of the people involved (Kimhur, 2020; Robeyns, 2017). The growing attention to issues of recognition, participation, capability, and responsibility, is especially important in the case of social housing because of the presence of a large number of vulnerable people. Those justice issues are highly interrelated: effective participation requires a capability to do so and requires recognition of such difficulties by others. Participation may be needed for circumventing negative distributional effects and for catering to demands for being heard. However, this interrelation of the different justice dimensions has not received much attention yet in literature. Therefore, we opt for a multidimensional view on justice in this study, which also examines the relations between the justice dimensions.

Comparable to Breukers et al. (2017) we use the framework of Davoudi and Brooks (2014) for studying multiple dimensions of justice. The framework is a pluralistic framework which covers five dimensions of justice, being distribution, recognition, participation, capability, and responsibility. The framework is used to gain further insight on the five justice dimensions as a framework, with special attention given to the interrelations between these dimensions for the case of energy renovations by social housing associations in the Netherlands. The findings are used to develop recommendations for a more people-centred energy renovation process for social housing. This study will contribute to the knowledge base of the use of a multidimensional justice framework in the context of the entire energy renovation process of social housing, and provides more insight into the interrelations between the different justice dimensions. As far as we know, the paper is the first attempt to study those interrelations systematically, laying the ground for further research.

This paper attempts to determine the relevance and nature of the justice dimensions and the interactions between them, for the case of energy renovations in social housing. This will be done through the following research questions:

1. *What are the experiences with, and views on, the justice dimensions and their interrelations (distribution, recognition, participation, capability, and responsibility) of members of tenant associations and employees of social housing associations in the energy renovation process of social housing in the Netherlands?*

2. *How can a multidimensional justice perspective be used for a more people-centred energy renovation process in social housing?*
3. *What lessons can be gathered, and what recommendations can be developed for a more just energy renovation process in social housing?*

To address these research questions, this chapter proceeds as follows: It first assesses the context of social housing in the Netherlands, followed by a literature review on justice perspectives in section 4.3. The research design is discussed in section 4.4. In section 4.5, the results are presented of the interviews with members of tenant associations (TAs) and employees of social housing associations (SHAs) in the Netherlands on their experiences with, and views on, justice aspects in the energy renovation process and their interrelations. In section 4.6, lessons and recommendations are presented, and in section 4.7, we offer a discussion of the framework and draw conclusions.

4.2 Social housing in the Netherlands

4.2.1 Characteristics of Dutch social housing

In the mid-1990s, Dutch SHAs became privatized but they continued to carry out their social task (Hoppe, 2012; Nieboer & Gruis, 2016). Dutch social housing is characterized by housing rented out under rent regulation and aims at affordable housing for low-income households: at least 80% needs to be assigned to households with a yearly income below € 39,055, up to 10% to households with an income between €39,055 and €43,574, and up to 10% can be allocated to other target groups. The maximum rent is €737 (reference date 2020, Rijksoverheid, 2020b). Figure 4.1 presents the composition of the Dutch housing stock in 2018 and reveals that 35.3% are rent-regulated dwellings, which are mostly owned by SHAs (Rijksoverheid, 2019a, 2019d).

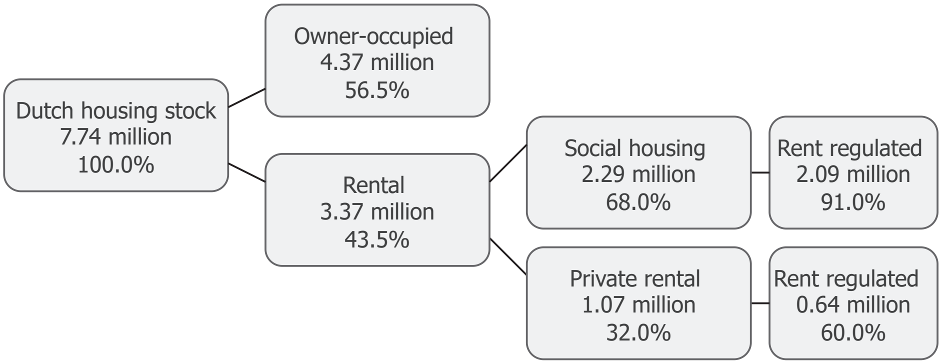

Figure 4.1. Composition of the Dutch housing stock in 2018 (based on Rijksoverheid, 2019a; Rijksoverheid, 2019d)

The energy performance of the existing housing stock in the Netherlands is being regulated through energy labels as a result of the European Energy Performance of Buildings Directive (EPBD, European Union, 2010). Dwellings with an A - energy label are the most energy efficient and dwellings with a G – energy label are the least energy efficient (see Table 4.1). In the Dutch Climate Agreement (Rijksoverheid, 2019c), it was agreed that the social housing stock will have an average B energy label in 2021, which will result in a 33% reduction of CO_2-emissions compared to 2008 levels (Rijksoverheid, 2019c). Aedes, the Dutch association of SHAs, states that this will probably be achieved (Aedes, 2019). However, there are no specific goals yet for 2030 and 2050. Figure 4.2 demonstrates the distribution of the energy labels in the Dutch housing stock in 2018, and reveals that the social housing stock has the lowest share of highly energy efficient houses (9% A - energy label). Every year, SHAs make performance agreements ('prestatieafspraken') with local municipalities and TAs on social housing policy (Rijksoverheid, 2015) such as where and when energy renovations will take place.

Table 4.1. Primary fossil energy consumption per energy label (based on Lente-Akkoord, 2020)

Energy Label	Primary fossil energy consumption in kWh/m2.yr
A++++	≤ 0.00
A+++	0.01 - 50.00
A++	50.01 - 75.00
A+	75.01 - 105.00
A	105.01 - 160.00
B	160.01 - 190.00
C	190.01 - 250.00
D	250.01 - 290.00
E	290.01 - 335.00
F	335.01 - 380.00
G	≥ 380.00

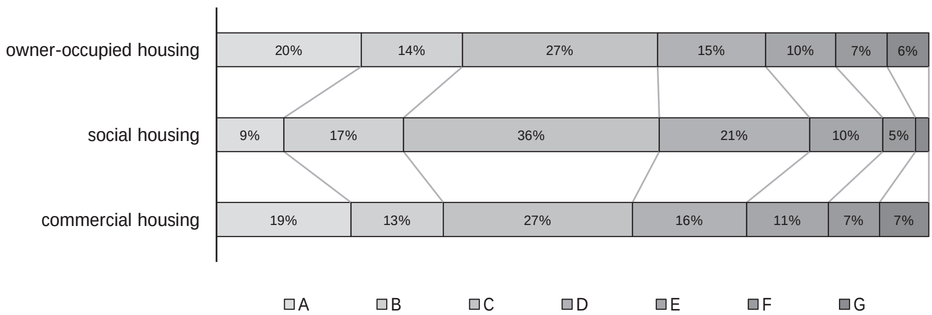

Figure 4.2. Distribution of energy labels in the Dutch housing stock in 2018 for owner-occupied, social, and commercial housing

To reach the climate goals, the SHAs will need to rapidly broaden the implementation of deep energy renovations in their dwellings and not limit themselves to more straightforward traditional energy measures with lower energy savings. However, the financial feasibility for SHAs are often an issue in the case of deep renovations, and deep renovations can often not be covered by additional rental incomes, and keep the rents affordable at the same time (Aedes, 2020 ; Hoppe, 2012). Although SHAs can receive support from national subsidy schemes in the Netherlands for deep energy renovations (Renovatieversneller, RVO, 2020), the budget is very limited. As a result, SHAs mainly invest in more straightforward traditional energy measures with lower energy savings (Filippidou et al., 2017). This creates a lock-in for the transition to a climate neutral social housing stock and makes deep renovations hard to implement for SHAs. This limited investment potential of SHAs is reinforced by an additional property tax ('verhuurdersheffing') SHAs have had to pay since 2013, which is based on the value of their dwellings. This tax was initially introduced to generate additional revenues for the state to encounter the financial crisis, but has gained a more permanent status. SHAs and municipalities deeply resented the tax because of its negative effects on the investment capacity of SHAs (Companen & Thesor, 2020). Overall, this tax has resulted in less investment potential for SHAs for the decarbonisation of their housing stock and higher rents for low-income households.

With the introduction of the new Dutch Housing Act (Woningwet 2015, Rijksoverheid, 2015), SHAs need the approval of the tenants when they want to renovate more than ten dwellings. In that case, 70% of the tenants have to agree with the renovation plans that go beyond maintenance work like painting, replacement of window frames, and repairs (Rijksoverheid, 2020a). Tenant agreement is not always easy to accomplish (Breukers et al., 2017; Sijpheer et al., 2015), but it paves the way for tenant participation. Traditionally, tenant associations are the most common structures for tenant participation (Simmons & Birchall, 2007). In the Netherlands, TAs have several legal rights: the right to receive information, to consult with the SHA, to advice the SHA, to put topics on the agenda at board meetings of the SHA, to invite experts to participate in the consultation with the SHA, and they are entitled to an expense allowance from the SHA (Rijksoverheid, 2020a). In addition, tenant representatives are the local consultation partner of the municipality and the SHA on the performance agreements of public social housing policy on a local level (Rijksoverheid, 2015). Overall, tenants have several legal rights in the participation process of energy renovations in social housing in the Netherlands.

4.3 Justice in the energy renovation process

As discussed in the introduction, the scope of inquiry of justice studies is being widened from a focus on distributional issues in the past to more pluralistic multidimensional justice frameworks (Breukers et al., 2017; Moroni, 2020; Sovacool et al., 2019). The five justice dimensions distribution, recognition, participation, capability, and responsibility are found to be relevant in previous justice studies. These dimensions are discussed in more detail in the sections below.

The dimension *distribution* is defined in this study as a fair and equal distribution of financial and non-financial costs and benefits between the SHA and the tenants. However, what is fair and just can be different for every individual, which calls for a pluralistic view. Distribution is an important issue to address in the context of energy renovations, because of the high number of vulnerable people living in social housing. Vulnerable people can experience even more inconvenience and difficulties during the renovation process due to their disabilities, and are also often less capable to participate in the energy renovation process to express their needs. In addition, energy renovations have the potential to reduce living costs but in some cases costs increase because the energy savings do not cover the rent increase after renovation (Filippidou et al., 2019; Guerra-Santin et al., 2017). This can worsen the financial situation of tenants, especially those with a low income.

As well as the distribution of costs and benefits, the dimension recognition has been highlighted as an equally important issue concerning justice (e.g. Bell & Davoudi, 2016; Jenkins et al., 2016; Schlosberg, 2009). This dimension is defined as acknowledging the various needs, rights, and experiences of different tenants in the energy renovation process, when involving them in the energy renovation process. However, it is more than acknowledging the presence of vulnerable groups, but also seeking to recognise the diversity within these groups (Gillard et al., 2017) and to avoid certain people being ignored or misrepresented (Davoudi & Brooks, 2014; Gillard et al., 2017; Schlosberg, 2009). The dimension recognition is an important issue to address because previous studies have demonstrated that SHAs have difficulties in recognising and involving tenants equally in the renovation process (Atrive & Aedes, 2015; Breukers et al., 2017; Hickman & Preece, 2019; Preece, 2019). This is especially true for vulnerable households, which are less present and potentially less recognised. In this study, vulnerable people are defined as people who have a reduced self-reliance because of financial problems (very low income or unemployed), psychiatric problems, intellectual disability, dementia, addiction problems, physical problems, and/ or have to deal with social exclusion (Leidelmeijer et al., 2018). Due to the changed Dutch healthcare system, increasingly more vulnerable people live independently instead of in an institution. As a result, the group of vulnerable households has increased in the social housing stock (Aedes, 2017) which makes this an important group to recognise in the energy renovation process. Yet, previous literature has generally avoided this discussion on the issues of vulnerability in low-carbon transitions (Sovacool, 2021).

Strongly associated with recognition is the dimension *participation, which* is strongly interlinked with procedural justice. It is about information access, decision-making, and legal rights of individuals and groups in decision-making processes (Gillard et al., 2017). An important distinction is between consultation of tenants and tenants having actual decision-making power in the participation process (Boess, 2017; Hickman & Preece, 2019; Liu et al., 2015; Suszyńska, 2015; Uyterlinde et al., 2019). Tenant participation in social housing is included in multiple studies, but at this time, tenants are often still only informed about the renovation plans after they are developed. This leads to very little room for changes or suggestions from the tenants (Hickman & Preece, 2019; Uyterlinde et al., 2019). Hence, acquiring empirical insights on the usefulness of different participation approaches to stimulate a greater diversity of participating tenants, is of great importance to adopt a more just energy renovation process.

Davoudi and Brooks (2014) broadened the justice framework by adding the dimension *capability* (Breukers et al., 2017). This dimension originates from the capability approach developed by Martha Nussbaum (Nussbaum, 2003, 2011; Nussbaum, 2009) and Amartha Sen (Sen, 1999; Sen, 2009) and has been applied and discussed in many studies since then. According to Robeyns (2017), the approach has emerged as a 'theoretical framework about wellbeing, freedom to achieve wellbeing, and all the public values in which either of these can play a role, such as development and social justice' (Robeyns, 2017, p. 23, pg 23). Kimhur (2020) applied the capability approach to housing policy and stresses that participatory housing planning may fail to stimulate capability enhancement, because of a focus on physical needs and because of structural barriers to capability enhancement. Deprived people experience less freedom to pursue life in a valuable way through self-chosen functioning, which extends to processes of participation. At present, there exists very little research on this topic in the context of housing (Kimhur, 2020) and especially on energy renovations in social housing.

The dimension *responsibility* is another dimension studied in justice studies (e.g. Breukers et al., 2017; Davoudi & Brooks, 2014; McCauley et al., 2019; Sovacool & Dworkin, 2015). This dimension is defined as taking responsibility for other humans, society, and non-human nature at individual and collective levels. In the case of energy renovations in social housing, this means that SHAs are responsible for offering well-maintained, affordable social housing for low-income households but also for facilitating a fair participation process for tenants. Climate change introduces an extra responsibility for SHAs and tenants to reduce energy (Breukers et al., 2017). However, people's capability to carry responsibility can be constrained by their vulnerabilities and capabilities (Davoudi & Brooks, 2014). This demonstrates that the dimension capability is strongly interrelated with the dimension of responsibility and is an especially a difficult issue for vulnerable households.

These reported five justice dimensions are found to be highly relevant in the context of the energy renovation process of social housing. This is because many vulnerable households live there, which makes a broader view on justice more relevant considering that the dimensions recognition, capability, and responsibility are specifically important for this group, next to the more common justice dimensions of distribution and participation. In addition, our review demonstrates that the interrelations between these dimensions are also important but this is not studied in detail in previous work. Therefore, we will use the environmental justice framework of Davoudi and Brooks (2014) with the five justice dimensions as a framework for our study (presented in Fig. 3). It offers a comprehensive and pluralistic view on justice aspects, allowing for a study of positive and negative interaction effects between the different justice dimensions, especially related to vulnerable households. The five dimensions have been demonstrated as suitable for empirical use and, as we will show, can be used to determine in what ways the justice dimensions are co-extant, interconnected, and mutually reinforcing (Gillard et al., 2017). Their relevance is demonstrated in a study by Breukers et al. (2017) on sustainable neighbourhood development in the Netherlands. Our study will continue to build on the knowledge base developed in this study, and extend it by not only focusing on one neighbourhood, but adopting a more general approach by interviewing TAs and SHAs about their experiences. In addition, our study will not only cover the initiative phase of the development but the entire energy renovation process, and also will investigate the interrelations of the five justice dimensions in more depth.

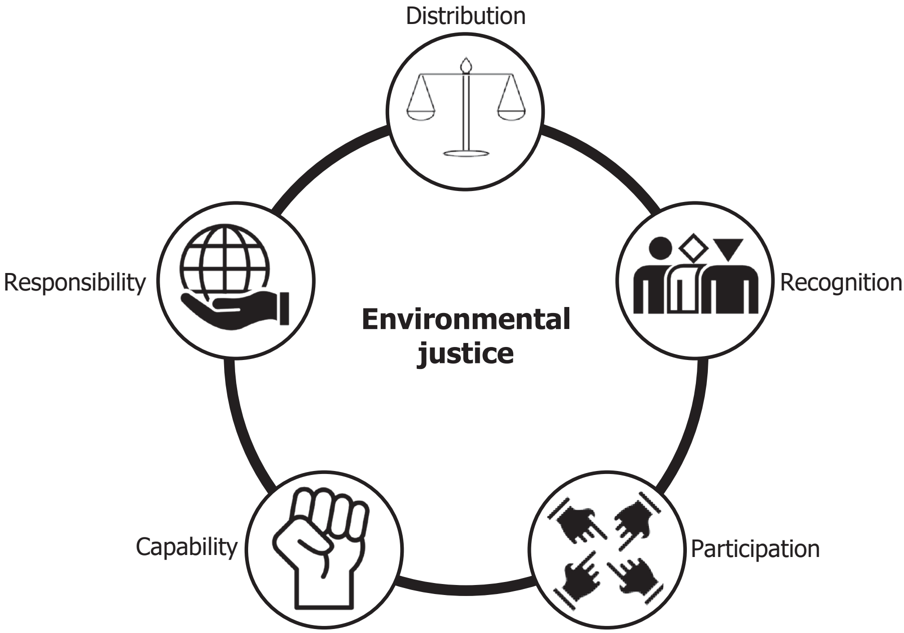

Figure 4.3. The five interrelated dimensions of environmental justice (based on Breukers et al., 2017; Brooks & Davoudi, 2018; Davoudi & Brooks, 2014; Rijksoverheid, 2019a; Schlosberg, 2009)

4.4 Research method

The aim of this paper is to gather lessons and develop recommendations for a fair, people-centred energy renovation process, in order to contribute to a more just transition towards a climate neutral social housing stock. Therefore, we studied the experiences with and views on the justice aspects of the energy renovation process in social housing by interviewing members of TAs and employees from SHAs in the Netherlands who have experiences with energy renovations in social housing. Theoretical sampling was applied for the identification of interviewees. Employees working in the social and technical-economic domain within the SHA were interviewed (see Figure 4.4) because it was expected that they would have different perspectives on the topic. Furthermore, SHAs were selected from different regions in the Netherlands to take into account possible regional differences. The interviewed SHAs are located in the Provence of Limburg, of Noord Brabant, of Noord Holland, and of Groningen. In addition, different sizes of SHAs and SHAs with different energy ambitions were included, in order to have a diverse sample (see Table 4.2). The European umbrella organisation Housing Europe (Brussels) was also interviewed, and the researchers also tried to interview the Dutch umbrella organisation of SHAs (Aedes) but unfortunately, this was unsuccessful. Data collection was completed from July - November 2020 and stopped when no new topics, relevant to the research questions, emerged from the interviews (Evers, 2016b).

The multidimensional justice perspective was used to collect and analyse the data. A semi-structured interview guide was setup using the five justice dimensions (see supplementary materials of this Chapter) and was used for comparing and maintaining data quality, which also allowed the interviewer to ask additional questions if an interesting topic emerged (Young et al., 2018). The interview guide was piloted in two interviews and the questions were refined afterwards. The interviews were conducted face-to-face and in online interviews, by using Microsoft Teams. The latter was due to the COVID-19 restrictions in 2020. The researcher (first author) conducted the interviews. The interviews were audio recorded and digitally stored for transcription and analysis, with permission of the respondents. The interviews had an average duration of 50 minutes (30 – 90 minutes) and the names of the respondents and organisations are anonymized in the analysis to let them speak freely. The transcripts of the interviews were analysed by using qualitative software (Atlas.ti 8.1) and thematic coding was used to analyse the data. Analysis of the data was carried out within the research team of the five authors of this paper.

The interview technique was used to gain a better understanding of the involvement of tenants in the decision-making process about energy renovations in social housing in more depth and detail. This method allowed the interviewees to describe their experiences and their point of view on this topic satisfactorily. However, the interview technique also has disadvantages, such as a possible bias in sampling technique, interviewer bias, and subjectivity in the coding process (Young et al., 2018). Another limitation is that the tenants' views and needs were examined indirectly via the SHAs and TAs due to the restrictions of the COVID-19 pandemic. Consequently, the views of tenants on justice could vary from the ones offered by SHAs and TAs, which can have implications for the results and recommendations. These restrictions have to be taken into account when assessing this paper.

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Table 4.2. Characteristics of the interviewed SHAs (based on the SHA's year plans of 2019 and data from the interviews)

Acronym	# rental dwellings	# employed fte's*	# rental units / fte	Average rent	Energy ambition
SHA_A	14,500	129	112.4	unknown	2022: average energy label B 2034: average energy label A
SHA_B	6,064	34.6	175.3	€ 561	2030: average energy label A
SHA_C	9,730	100	97.3	€ 544	2027: 90% of the houses have energy label A or B and 0% houses with energy label E, F or G
SHA_D	2,844	32.9	86.4	€ 503	Not defined yet
SHA_E	26,062	217.2	120.0	€ 528	2020: average energy label B, 50% houses with energy label A or B 2025: 75% of the houses have energy label A or B
SHA_F	10,362	100	103.6	unknown	2026: average energy label B
SHA_G	8,354	80.5	103.8	€ 547	Average energy label B, renovate 300-500 dwellings every year until 2023
SHA_H	13,285	141.4	94.0	€ 512	2021: average energy label B

** fte: fulltime-equivalent*

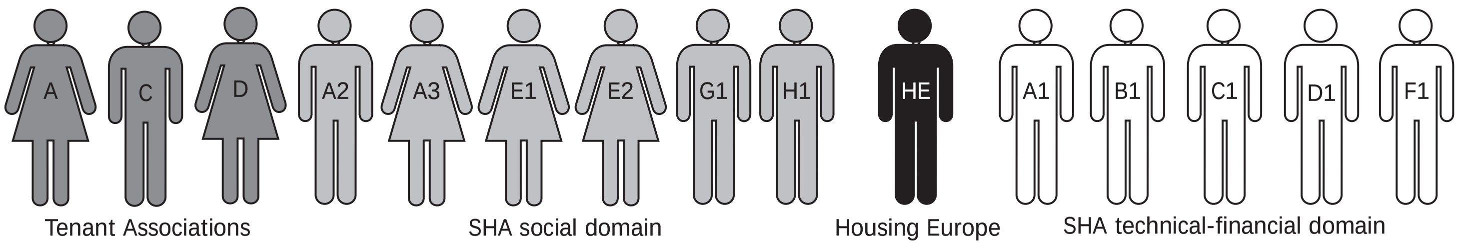

Figure 4.4. Sample composition (n = 15) of interviewees (Letters refer to the involved SHAs, see **Table 4.2**)

4.5 Experiences with and views on justice in the energy renovation process

4.5.1 Distribution

Financial distribution of costs and benefits

The analysis of the interview results demonstrated that the SHAs deal differently with the distribution of costs and benefits of energy renovations. Some SHAs implement a rent increase after the renovation (SHAs C, F, G, H), but others do not (SHAs A, B, D, E). However, as stated by TA_A, in most cases the costs are included in the general annual rent-increase for their complete housing stock. One way or another, the renovation has to be financially feasible, but respondent H1 questions whether it will be economical to continue to invest in the future because the rents have to stay affordable. Therefore, it was questioned by TA_A, if the SHA has to do everything the government wants regarding the climate goals, because it could make social housing unaffordable for low-incomes. External funding from national government could be a solution to overcome this barrier in reaching climate neutrality in future.

The interview results demonstrated another issue regarding the financial distribution, namely the uncertainty for the tenants if the energy savings will cover the rent increase after the renovation. It was pointed out by B1 and C1 that the calculated energy savings after renovation are based on average savings, which in practise can differ greatly per household. In addition, they both reported that there have been projects in the past in which the tenants used more energy than prior to the renovation:

> *'In the past we experienced far less energy savings in some dwellings as could be expected from the calculated energy label. To avoid that kind of problems, we do not have a rent-increase anymore after renovation, except for solar panels'. (B1)*

Partly due to this uncertainty about energy savings, some SHAs do not implement a rent increase anymore after an energy renovation. However, this can make deep energy renovations less financial feasible in future when deep renovations are needed to reach the climate goals. To ensure financial security for the tenants, a clear agreement on the transfer of risks about the actual energy performance and savings between the SHA and tenants can be made (Breukers et al., 2017; Uyterlinde et al., 2019). This agreement must be based on the individual energy profiles of the tenant, as they can differ greatly per household (Guerra-Santin et al., 2017).

Non-financial distribution of costs and benefits

Respondents TA_C, B1, and D1 reported that the experienced inconvenience and the disruption of the domestic life during the renovation are important bottlenecks for the tenants. Consequently, this could mean that tenants will be reluctant to agree with the renovation plans, or that tenants will be less satisfied after the renovation. Table 4.3 presents an overview of the reported potential inconveniences for tenants in the interviews. In addition, TA_C revealed that it could differ per individual to what extent it is perceived as an inconvenience. Specifically people who are home during the day experience this inconvenience more, such as elderly, households with small children, and people who work in shifts and need a quiet place to sleep during the day. Moreover, D1 mentioned that the renovation is also a great challenge for tenants that are more vulnerable. Therefore, A3 advised to map the special needs of tenants regarding the renovation process, early in the process:

> *'Map the people with special needs during the renovation process, such as people working in shifts, and disabled people, or help 'hoarders' to clean up', so we take them into account'. (A3)*

In addition, TA_C indicated that it is needed to make clear arrangements about the inconvenience the tenant can expect during the renovation, and about what the builder will do to limit this inconvenience. In the Netherlands, these agreements can be drawn up in the legally obliged Social Plan.

Table 4.3. Potential inconvenience issues for the tenants in the energy renovation process (derived from the interview results)

Potential inconvenience issues for tenants during the renovation process
• Lack of communication of the SHA and builder
• The mess builders make and leave behind
• Nuisance from scaffolding – reduced accessibility dwelling
• Too many house visits
• Noise disturbance
• Ongoing work in every living space (multiple measures)
• Occupied parking places
• Changing time-schedule
• Excessive dust

In the interviews, respondents TA_A, TA_C, A1, A3, E1, E2, G1, and H1 revealed that tenants are often more interested in non-energy related benefits of a renovation to improve their overall living conditions. In contrast, B1 and C1 expressed that they do not combine energy renovations with bathroom and kitchen renovations, because, they said it causes too much inconvenience for the tenants to do everything at once. Table 4.4 presents the reported potential non-energy related benefits on a dwelling, and neighbourhood scale. As these non-energy related benefits could differ per individual household, it can be difficult to collect and implement this diversity in wishes and needs in the renovation plan.

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Table 4.4. Potential non-energy related benefits of energy renovations (derived from the experiences of the respondents)

Dwelling	Neighbourhood
Improving thermal comfort	Improving the liveability of the neighbourhood (e.g. creating more green areas for recreation, creating meeting places, setting up playgrounds for children)
Improving indoor air quality	Strengthening social cohesion
Applying new bathrooms, kitchens, and toilets	Solving climate issues (e.g. heat-stress, lack of biodiversity, drought)
Making more living space (e.g. making the attic a living space)	Improve traffic safety
Implementing architectural upgrades (e.g. new front façades, painting)	Improving safety (e.g. more outdoor lighting, safety measures for traffic)
Improving gardens (e.g. new garden and – fences, paths to the front door)	Improving the maintenance of public spaces
Solving moist-issues	
Addressing safety issues (e.g. burglar resistance, outdoor lighting)	
Removing asbestos	

4.5.2 Recognition

Reluctance to formal participation

The analysis of the interview results pointed out that it is increasingly difficult to attract a diverse group of people in their board. The interviewed TAs mentioned that this is because of the increasing legal requirements in terms of meetings, reporting, and administration, which does not appeal to most tenants. Another reason is that the social housing matters have become too complex and members have to develop a very broad knowledge about several topics to be able to participate in the process.

Overall, these barriers make it is challenging to involve a diverse group of tenants in formal TAs, and as a result, tenants often do not feel represented by a TA, something what is also reported in previous work (e.g. Breukers et al., 2017; Hickman & Preece, 2019; Preece, 2019).

Representativeness in participation

Respondents A1, A3, B1, C1, E1, E2, and F1 revealed that is also challenging to include tenants in more informal participation methods, such as local resident groups. Respondent C1, F1 and A3 explained that in most cases, they are glad to find even a few tenants who are willing to participate:

> *'We always hope that there is a delegation of the tenants in a project, but if this delegation is representative that is often the question'. (C1)*

In addition, respondents A1, A2, C1, E2, and F1 stated that people who are willing to participate in the process, are often older people (55-75 years), mostly pensioners, people with a Dutch native background, and people with a strong connection to the neighbourhood. The latter are usually people who have lived in the neighbourhood for a long time. However, younger people, people with a different ethnic background, and vulnerable groups are much harder to involve in the participation process. This lack of diversity is also reported in other studies (Atrive & Aedes, 2015; Conway & Hachen Jr, 2005; Hickman & Preece, 2019; Preece, 2019; Simmons & Birchall, 2007; Stenberg, 2018). The under-representation is often caused by lack of time, because of a busy household and/ or work (Breukers et al., 2017; Brooks & Davoudi, 2018), or a lack of connection to their neighbourhood (Breukers et al., 2017). As a result, the recognition of the diversity in needs and wishes of the tenants are not always met in the participation process at this time.

Vulnerable households

Respondents TA_A and TA_D mention that vulnerable households are even harder to involve because they have to deal with issues that are more urgent. Respondents A2 and E1 reported that not all vulnerable households are known by the SHA prior to the renovation, which can make it more difficult to recognise them. Consequently, the needs and interests of these vulnerable households could be less recognised in the renovation process and plans, which can lead to an increase of inequality. To encounter this, A3 suggested that an individual approach is needed to collect the wishes and needs of these vulnerable households.

4.5.3 Participation

Multiple participation methods

The analysis of the interviews revealed that there are multiple participation methods used in the current energy renovation process of social housing (see Table B1 in the in the supplementary materials). Respondent G1 discusses that it is important to offer different participation methods to address individual needs:

> *'Some tenants prefer to participate in a traditional resident committee, but younger people are more eager to participate in a thematic working group with concrete goals and actions'. (G1)*

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These identified methods demonstrate different participation levels varying from informing, consulting to actually having decision power in the renovation process. In addition, also other studies recommend to implement a mix of participation methods, so that tenants can choose how they want to be involved: collective or individual, formal or informal, long-standing or short-standing (Claridge, 2004; Hickman & Preece, 2019; Mundaca et al., 2018). In addition, different participation methods are also context specific and can be appropriate in different phases of the process (Hurlbert & Gupta, 2015), and no method is superior to others and that it is not always needed to reach the highest level of involvement [71]. However, the interview results reported that the participation methods are mostly determined by the SHAs at this time, and the tenants have little influence on this method. In addition, SHAs have still little experience with contemporary participation methods such as online platforms and videos. Nevertheless, respondents A3, B1, E2, F1, and H1, pointed out that the COVID-19 pandemic has forced them to implement and experiment with digital methods, and respondents F1 and H1 stated that these contemporary digital methods were especially appreciated by the younger tenants. This group was hard to involve in the past, and therefore they want to keep using these methods in the future.

Early involvement

The interview results demonstrated that it is best to involve tenants in an early stage of the project, to build up support for the renovation measures; to create a sense of ownership among the tenants; and to manage tenants' expectations early on. This is demonstrated in the following quote:

> *'By investing more time in the early stages of the renovation process, the renovation process runs more efficiently and faster and tenants experience less inconvenience'. (H1)*

In addition, respondent G1 suggested that the needs and wishes of the tenants, but also tenants' knowledge of the dwelling and possible issues, can be incorporated into the renovation plan. This information could help to make better renovation plans, which fit better to the needs and wishes of the tenants (see also Mundaca et al. (2018)). Furthermore, respondents A1, G1, H1 and F1 reported that this would lead to more support among the tenants and a better renovation process with less complications and delays. However, respondents A2, B1, C1 reported that this was often not the situation, and involvement was often organised when most of the renovation plans were almost finished. Furthermore, respondents A3, C1, E2 revealed that tenants, in most cases, only have decision-power on peripheral phenomena, such as (the colour of) the front door, the tiles in the bathroom or the design of the outside area. Consequently, the tenants had little influence on the energy renovation plans, and as a result, the plans did not always meet their individual wishes and needs. Surprisingly, the interviewed TAs did report that they find it important that they as TA are involved in an early stage, but did not report the importance of an early involvement of (other) tenants. Thus, at this time, an early involvement of tenants is in most cases not embedded yet in the energy renovation process.

Multidisciplinary project team

Respondents A2, E2, and H1 identified that there is often a gap between the social department and the technical-economic department within a SHA. On the one hand, there are the project leaders of the renovation projects, which have to reach the energy, time and budget targets. On the other hand, there is the social department who represent the interests of the tenants. The results showed that this could sometimes cause a conflict in a renovation process:

> *'We prefer to work in a multidisciplinary team but this is often hard because the project leaders are used to develop a project within strict time and budget restrictions. Social aspects are often seen as a barrier'. (E2)*

Therefore, A2 suggested a more equal partnership between the social teams and the project leaders.. However, there were no statements of TAs or SHAs' technical/ economic employees on this matter. From this it can be concluded, that some SHAs experiment with multidisciplinary teams but that they are not mainstream yet.

To prevent this separation of interests of the social and technical-economic departments in a SHA, respondent A3 explained that they have a new project organisation with a multidisciplinary project team for renovation projects. In this team, different disciplines are represented, such as someone from communication, social workers, the project supervisor, and the project leader participation. By working in this multidisciplinary way, project team members are more used to look at the process from different perspectives and learn to listen better to the needs of the tenant. As a result, the project members have declared, to interviewee A3, that they have received less negative feedback from the tenants and experienced that this way of working is more pleasant, because they can address tenants' needs prior the renovation, instead of dealing with it -ad hoc- when renovating. In addition, the renovation process is more efficient because the needs of the tenants during the process are met, and vulnerable households are helped with their problems prior to the renovation. Overall, the results demonstrate that a multidisciplinary team can contribute to a more just and people-centred energy renovation process.

4.5.4 Capability

Illiteracy

The results of the interviews reported that the growing problem of illiteracy among tenants can be a significant issue in the participation process. There is a growing problem of illiteracy in the Netherlands, where 14.7% of the adults have difficulties with reading and writing and 25% of the unemployed are illiterate (De Greef et al., 2018). However, SHAs still work quite a lot with written documentation. Nevertheless, respondent G1 mentions that many tenants solve this problem by asking a neighbour or relative for help. To address this growing illiteracy, it was proposed by E2 and A3 to find a way to communicate with the tenants, which is understandable for everyone to adapt to the tenants needs and capabilities, for instance with visual aids.

Capacity building

Respondent A1 identified that tenants are often reluctant to participate in the process because they think that they cannot contribute, and are often afraid they will not understand certain issues. However, A1 stated that the SHAs find the input of the tenants very valuable for the renovation process, and that tenants often underestimate what they can contribute in the process. In addition, A1 explained that they want to involve unemployed tenants in their renovation projects:

> *'In future, we would like to involve unemployed tenants in the renovation process, to allow them to gain experiences in renovation skills and enhance their possibilities in the labour market'. (A1)*

Furthermore, there were no other solutions for capacity building reported for individual tenants, but A2 suggested that the information has to be presented in such a way that all tenants can understand so that individual capacity building is not needed. Overall, capacity building for individual tenants is still an underexposed issue for SHAs.

Regarding the issue of capacity building in formal TAs, the interview results revealed that TAs have several possibilities for capacity building in the Netherlands. The TAs reported in the interviews, that they often make use of an advisor of the National tenants Union (Woonbond) when necessary. Woonbond is a National Association who stands up for the interests of tenants and TAs. They can advise tenants and TAs on several topics and assist in discussions with SHAs. This advisor from Woonbond can help the TAs to understand the technical and financial reports better. In addition, the advisor can also join the TAs in discussions with the SHA. Furthermore, the interview results reported that the formal TAs have the possibility to follow courses so that they can understand the documents of the SHA. They receive a yearly fee from the SHA for this. Overall, formal TAs have several possibilities for capacity building in the Netherlands.

Vulnerable households

The interview results expressed that especially the more vulnerable households are less willing or able to participate because they often have to deal with issues, which are more urgent, such as health or financial problems. As a result, they cannot afford to spent time on additional issues such as participating in an energy renovation process. Therefore, the interviewed SHAs try to help these households as much as possible before the renovation starts:

> *'Our social team tries to tackle social problems as much as possible before the renovation starts. In most cases we know the more vulnerable households'. (D1)*

When needed, they involve social authorities to help the tenants with their problems. However, respondents A2 and E1 reported that not all vulnerable households are known by the SHA on prior to the renovation, which can make it more difficult to help them in the participation process.

4.5.5 Responsibility

Responsibility for the participation process

All interviewed SHAs reported that in most cases the communication and participation process with the tenants is outsourced to the contractor, and the SHA stay more on the background. They only intervene when the contractor asks for help or when there are vulnerable households known prior to the renovation. Respondent B1 explains that SHAs often choose this working method because they have too little capacity in time and people themselves, and/ or prefer not to take on this extra responsibility. However, the results demonstrated that this could cause problems with the tenants. Respondent H1 revealed that the SHAs have an important responsibility regarding the participation process, because they have a long-term commitment with the tenants:

'I think we outsource too much to the contractor; we have to depend on the contractor whether certain signals from the tenant are identified. However, their main focus is technology, and not on how we can let the resident live as pleasantly as possible after the renovation'. (H1)

The outsourcing of the participation process forgoes an opportunity for SHAs to get to know their tenants better and to build up a good relationship. In addition, E2 explains that contractors do not always have the capabilities to recognise vulnerable households. Furthermore, also TA_C, A3, E2 and H1 reported the lack of social and communication skills of some builders, as they are more focused on the technical aspects of the renovation. As a result, the tenants felt dissatisfied, and especially vulnerable households did not get the help they needed. According to A3 and E2, the builders need to have empathy and social skills to address the tenants' needs in the renovation process. Thus, outsourcing the participation process to third parties can cause several difficulties in the energy renovation process if social issues are not dealt with properly. Overall, outsourcing the participation process to third parties will also require more multidisciplinary skills from this party to address the social issues in a renovation process.

4

Tenants' sense of ownership

Next to the responsibilities of the SHAs, the interview results reported that tenants also have a responsibility in the energy renovation process. The responsibilities tenants have are to participate in the process to express their wishes and needs for improving their living environment, to co-operate with the contractor in the execution of the energy renovation, and to take care of their newly renovated house and its surroundings after the renovation. However, respondents TA_A, TA_D, and A3, also revealed that it is often difficult for the more vulnerable groups to take this responsibility, as they have to deal with issues that are more urgent. Therefore, E1 stated that these vulnerable households would often need help from the SHA and other social organisations to express their needs and wishes in the energy renovation process and beyond. Overall, tenants also have their responsibilities in the energy renovation process but especially the vulnerable households will need help to carry this responsibility.

Respondents A1 and A2 revealed that a sense of ownership of the tenants for their homes and neighbourhood is important, so that tenants feel responsible to take good care of their homes and surroundings:

'If you are not proud about your home, you will also not keep it tidy and neat, but if you are proud because you feel it's yours, you will also address other tenants who do not keep it tidy'. (A1)

To address this issue, respondents A1, A3, E1, and G1 explained that they often initiate neighbourhood projects, together with the municipality, to work on the social cohesion in the neighbourhood and tenants' sense of ownership. A strong social cohesion in the neighbourhood can contribute to a greater willingness to participate in the energy renovation process and it can increase the sense of responsibility tenants feel regarding taking care of their home and its surroundings (Breukers et al., 2017). This social cohesion can improve over time by working on strengthening the social ties within communities and encouraging interaction between different groups of tenants (Hickman & Preece, 2019; Uyterlinde et al., 2019). However, our study results reveal that projects, regarding strengthening social cohesion, are often project based, and within a limited time. As a result, the built up social ties often fall apart when the project finishes:

> *'The long-term commitment of the SHA and municipality is often lacking, and as a result, the group of volunteers falls apart when the project is finished'. (TA_A)*

Therefore, A1 explained that they want to invest in more long-term projects to maintain these social ties in the neighbourhood. Overall, the results revealed that a strong social cohesion and sense of ownership among the tenants could help improving their living environment. However, a long-term commitment from all stakeholders is needed to succeed.

4.5.6 Interrelations between justice dimensions

Next to bringing out the relevance of the five justice dimensions, our empirical findings show that the five dimensions of the multidimensional justice perspective are interrelated, and can reinforce each other. Figure 4.5 demonstrates the interrelatedness of these dimensions. The relations are numbered 1-10 and are referred to in the following text. We found direct interrelations between most of the justice dimensions, except between the dimension distribution and responsibility (1) and the dimension recognition and responsibility (5) , which influence each other only indirectly through the other dimensions.

Our analysis of the interview results identified that the dimension distribution can affect the capabilities of tenants (2) positively when the energy renovation improves their financial situation and negatively if it worsens it. In addition, the inconvenience during the renovation could worsen the situation for especially vulnerable households if they are not able to cope with the disruption of the renovation. Next, our findings revealed that the dimension distribution could be influenced by the dimension participation (3) when tenants' needs and wishes are incorporated in the renovation plan and process, thanks to a fair participation process early in the process. However, when there is no rent increase after the renovation, the housing association is not legally obliged to have a participation process:

> *'For years the project developers have tried to do everything without a rent increase, because with a rent increase you have to talk with the tenants and get their agreement. They have to carry out the renovation in a certain time to reach the energy targets, and consultation with tenant's makes this more complicated and time consuming. Therefore, the rent increase is avoided at this time. This is something that is still very traditional in our organization'. (A2)*

In that case, not having a rent increase appears a good distributional result but the absence of a participation process means opportunities for catering to specific needs and wishes are missed. Another finding was that the dimension distribution directly interrelates with the dimension recognition (4). When tenants are recognised in the process, their distributional needs and wishes can be better addressed in the renovation plan and process.

Next to the connection between recognition and distribution, the dimension recognition can also influence the dimension capability (6). This is because when tenants, especially vulnerable households, are recognised, they can receive the help they need, which can enhance their capabilities and the possibility to live the life they want. Furthermore, the dimension recognition influences the dimension participation (7) because when tenants are recognised, they are better able to participate in the energy renovation process. When especially vulnerable households are identified in an early stage, more can be done to help them to participate, and as a result, their individual needs can be represented better. However, vulnerable people are not always recognised as such in the process, especially not in case of non-participation. This is illustrated by the following quote:

> *'Vulnerable households will not attend plenary meetings. As a result, only the issues of the people, who are present, are addressed' (TA_D)*

This quote demonstrates that vulnerable households often do not participate in the energy renovation process, and as a result, their needs for improving their living conditions are often not met in the renovation plans.

Another finding of this study was that the dimensions participation and responsibility mutually influence each other (8). First, when tenants participate from the start, they can develop a sense of ownership, which can lead to a sense of responsibility for their home and its surroundings. In the words of one respondent:

'You can create a sense of ownership by investing in a good participation process'. (A2)

Moreover, in most cases tenants with a sense of responsibility will be more willing to participate. Tenants have the responsibility to participate in the renovation process, but this is often difficult for the more vulnerable groups. Furthermore, the SHA is responsible for facilitating the participation process, but in practise, this is often outsourced to the contractor, which can hamper a fair process. The results also demonstrate that the dimension participation and the dimension capability influence each other (9). This is illustrated by respondent TA_A who questions if vulnerable households must be 'bothered' with renovation plans because they have issues that are more pressing:

'Social housing is increasingly rented out to vulnerable households, who are concerned with their own health or financial problems. Should you bother these people with renovation plans?' (TA_A)

However, this can lead to renovation plans in which their needs to improve their living conditions are not met. In addition, through participation tenants can acquire certain capabilities, which can also be used in other aspects of their lives. Lastly, this study demonstrated an interrelation between the dimensions capability and responsibility (10). When tenants have more capabilities, they are more competent and capable to take responsibility for their home and its environment. This also means that vulnerable households, which often have fewer capabilities, can have problems to take that responsibility, and will need help to do so. Of course, capabilities cannot be enhanced so easily. Overall, our study revealed that it is important to also take the interrelations between the justice dimensions into account as they influence each other.

4.6 Lessons and recommendations

One of the goals of this study was to gather lessons and develop recommendations for a just and people-centred energy renovation process in social housing. Data was collected by interviewing members of TAs and employees of SHAs in the Netherlands on their experiences with, and views on, a fair energy renovation process. Based on the analysis of our interview results, we developed recommendations for a people-centred and just energy renovation process in social housing. Table 5 reveals the main lessons of this study and presents the main barriers and recommendations per justice dimension for a fair and people-centred energy renovation process of social housing. In addition, Table B1 (in the supplementary materials), reports the participation methods reported in this study, including the benefits and barriers for each method. These identified methods demonstrate different participation levels varying from informing, consulting, to actually deciding. Based on our results, we recommend an implementation of a mix of participation methods adapted to the needs, preferences and capabilities of the tenants, the context of the neighbourhood, and the different phases of the energy renovation process. As discussed in section 5, no participation method is superior to others and it is not always needed to reach the highest level of participation [71]. This overview can be used by SHAs and TAs to determine which methods are most useful depending on their specific situation.

A practical contribution of this study is presented in Table C1 of in the supplementary materials of this Chapter, which reveals recommendations for a more people-centred energy renovation process per renovation phase and per justice dimension. These findings demonstrate that awareness is needed for the five justice dimensions in all the renovation phases. From this it can be concluded that more attention must be given for justice aspects throughout the whole energy renovation process, and not only focus on energy renovations as a whole. These outcomes contribute to the literature by giving more insight into the five justice dimensions and their interrelations in the context of the energy renovation process of social housing. The recommendations can be used by policymakers, SHAs and TAs to implement a more just energy renovation process in social housing in the transition to climate neutrality.

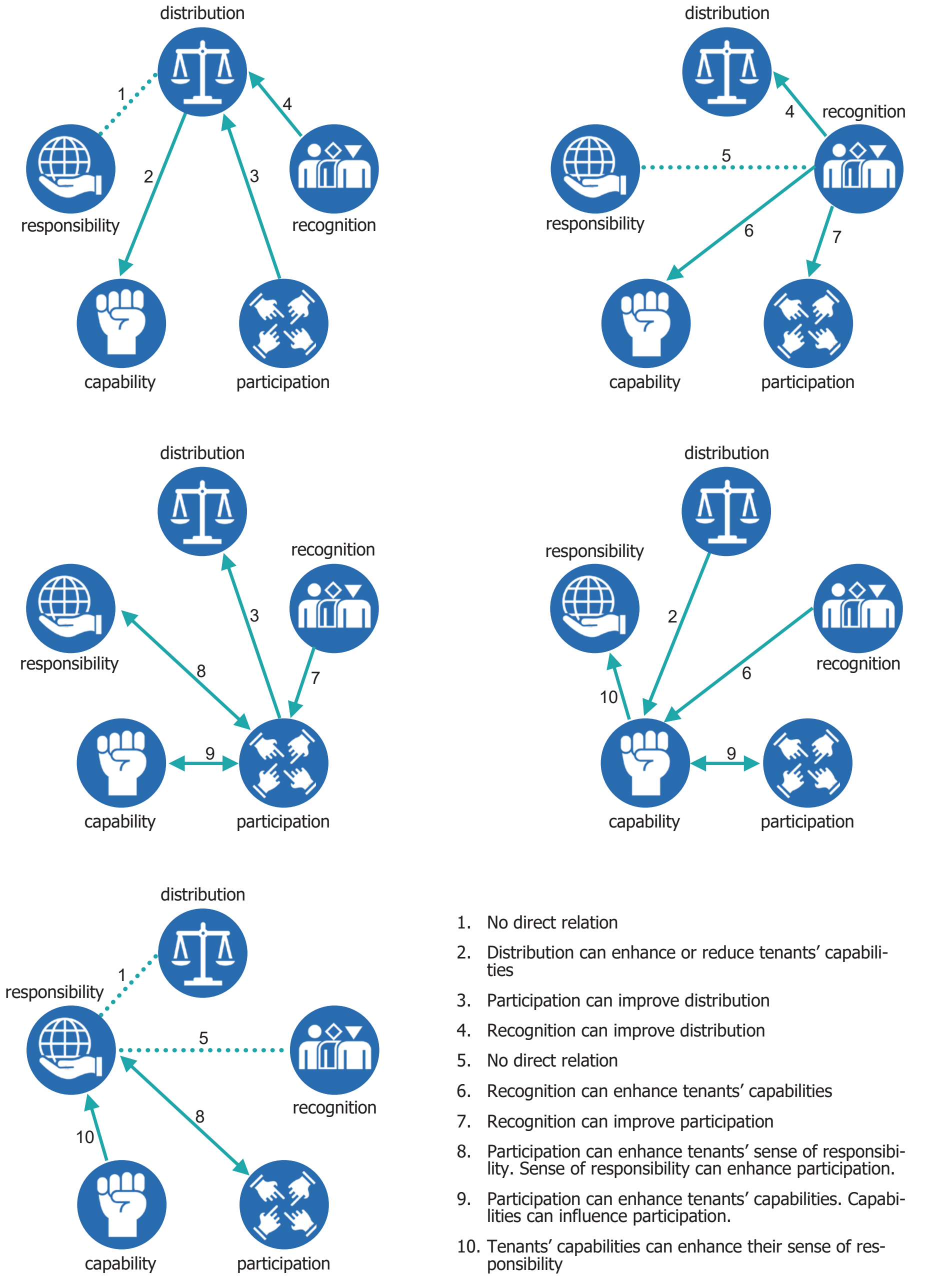

Figure 4.5. The interrelations between the five justice dimensions distribution, recognition, participation, capability and responsibility (derived from our study results)

Table 4.5. Overview of main barriers and recommendations per justice dimension for a people-centred energy renovation process in social housing

People-centred energy renovation process		
	Main Barriers	**Main recommendations**
Distribution	• The transition to a climate neutral social housing stock can worsen energy poverty when the energy savings are not realised. • The investments needed for a climate neutral social housing stock often cannot be covered by the rental revenues, and subsidies are often insufficient. • Many tenants experience major inconvenience during the renovation, especially vulnerable households. • Energy saving is not considered that important by most tenants, and if energy measures are the only ingredients of the renovation, the plan will fail to connect to most of the tenants.	• Make a clear agreement about the transfer of financial and non-financial risks and benefits between the SHA and the tenant, based on tenants' individual characteristics. • Additional funding is needed to realise the energy transition and keep rents affordable in social housing. • Limit the inconvenience of the renovation for the tenants as much as possible. • Solve problems quickly and efficient and make someone responsible for this. Include also non-energy related benefits of the renovation in order to meet the tenants' needs.
Recognition	• Tenants often do not feel represented by a formal tenant representation. • It is difficult to recognise and involve vulnerable households. • There is often no complete overview of the social profiles of the tenants early in the process, which can hinder the renovation process. • It is difficult to take diversity into account when there are many relocations of tenants.	• Acknowledge and recognise the diversity of tenants and neighbourhoods. • Adapt to the norms, values, and attitudes of the tenants and the neighbourhood and use their way of communication. • Map the social profiles of the tenants and neighbourhoods on forehand. • Take the special needs of (vulnerable) households into account during the renovation process.

Table 4.5. Continued

People-centred energy renovation process		
	Main Barriers	**Main recommendations**
Participation	• Tenants are often not involved until late in the process, leaving little room to take their needs into account. • The different departments within a SHA often do not cooperate enough to tackle the renovation-process in a multidisciplinary way. • It is difficult to involve a representative group of tenants who are willing to participate.	• Involve tenants early in the process, to better address their needs and use their knowledge about and experiences with the dwellings. • Implement an individual participation approach in order to collect the individual needs and wishes of the tenants for improving their living conditions, and to detect vulnerable households early in the process and assist them to get the help they need. • Implement a mix of participation methods to adapt to the different preferences of tenants to participate, and involve a more diverse group of tenants. • Communicate clearly the level of control tenants have in every renovation phase. • Implement a multidisciplinary team with equal partnerships between the technical and social departments within the SHA, to create joint responsibility for the participation process.
Capability	• Vulnerable households often do not have the capabilities to participate in the energy renovation process because they have to deal with more urgent issues. • Information from the SHA is often not read or not properly understood by the tenants due to illiteracy. • Tenants often feel not capable to participate in the participation process.	• Invest in capacity enhancement of (vulnerable) tenants on individual and neighbourhood level. • Make information about the renovation plans understandable for everyone. • Use visual and spoken communication as much as possible to address illiteracy. • Use informal and individual low-profile participation methods to involve (especially vulnerable) households.

Table 4.5. Continued

People-centred energy renovation process		
	Main Barriers	**Main recommendations**
Responsibility	• Vulnerable tenants often do not have the capacity to take responsibilities. • Tenants often feel less responsible for their homes when there is less social cohesion in their neighbourhood. • SHAs often do not have the capacity themselves to carry out the participation themselves. • In the event that participation is left to third parties, often less attention is paid to the social issues of the tenants, and vulnerable households are often not recognised.	• Help vulnerable households to be capable to participate, and to communicate their needs. • Make sure that the SHA is primarily responsible for the renovation process, as opposed to a third party. • Be visible and easily accessible as an SHA for tenants during the whole renovation process. • Work on building up social cohesion in the neighbourhood on the short and long-term, to increase a sense of joint responsibility among the tenants for their living environment.

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4.7 Towards a people-centred energy renovation process

Prior work has documented that implementing energy renovations in social housing could worsen vulnerability to energy poverty and inequality (Filippidou et al., 2019; Guerra-Santin et al., 2017; Sovacool et al., 2019; Straver & Mulder, 2020). Moreover, energy renovations are often technology-driven and often do not fit the wishes and needs of the tenants (Boess, 2017; Breukers et al., 2017; Hickman & Preece, 2019; Uyterlinde et al., 2019). This is reinforced by the large share of vulnerable households living in social housing (Braga & Palvarini, 2013). Hence, the transition to climate neutral social housing touches upon important issues of justice, but so far little attention has been devoted to justice aspects in the energy renovation process of social housing. First, we argue that a broader pluralistic justice approach is needed to address the needs of vulnerable households in particular. Therefore, we applied the multidimensional justice perspective of Davoudi and Brooks (2014) through an investigation of the five interrelated justice dimensions of distribution, recognition, participation, capability and responsibility.

The five justice dimensions are found to be highly relevant in the context of the energy renovation process of social housing. This is because of the presence of vulnerable households, which makes a more pluralistic view on justice more relevant, considering that the dimensions recognition, capability and responsibility are specifically important for this group, next to the more common justice dimensions of distribution and participation. Second, we argue that it is also important to study also the interrelations between these justice dimensions, something what has not been done in depth in the past. Our study demonstrates that these dimensions are strongly interlinked and should not be addressed separately. Third, we argue that more awareness is needed for the five justice dimensions in the different phases of the energy renovation process, as they can differ per phase. Overall, the results demonstrate that all five justice dimensions and their interrelations are important to address in the different phases of the energy renovation process of social housing.

From our results, we conclude that a clear agreement should be made between the SHA and the tenants on how to deal with the financial and non-financial distributional issues in the energy renovation process. An interesting finding in this study is the trade-off between distributional and procedural justice in the event that no rent-increase takes place after the renovation, and therefore a participation process is not mandatory. Consequently, also other distributional issues are not discussed an agreed upon with the tenants. Not having a rent-increase seems as a kind distributional offer from SHAs but also leaves the opportunity to engage with their tenants about their needs and wishes concerning their living conditions.

In order to have a fair participation process, it is important to recognise the diversity of tenants with their various needs, rights, and experiences in the energy renovation process. However, our results demonstrate that it is often difficult to recognise the diversity of tenants with their various needs, rights, and experiences in the energy renovation process. It is often a challenge for SHAs to involve a representative group of tenants in the participation process, and specifically to involve vulnerable households. First, it is difficult to involve vulnerable households because they have other more urgent problems to deal with, and are therefore less capable of participating. Second, it is not always easy to identify or recognise vulnerable households, and consequently they do not receive the help they need to improve their living conditions and capabilities. These barriers can hinder the recognition of the diversity of needs of vulnerable households in the energy renovation plan and process, which can have a negative effect on distribution issues. To recognise the diversity of tenants in the energy renovation process, a more individual participation approach is needed to recognise and map the different needs of the tenants prior to making the renovation plans.

Our results point out that a more multidisciplinary way of working is needed to implement a more people-centred energy renovation process in social housing. Social aspects should be put on a par with technical and financial aspects. However, this way of working is not mainstream yet within the SHAs, as the different departments within an SHA often work separately. Nevertheless, some SHAs have started working with multidisciplinary teams in which there is a more equal partnership between the project leader (technical/ financial department) and the social department. The results demonstrate that this has several advantages: vulnerable households are recognised and helped before the renovation starts; tenants are better informed, due to openness in communication and better accessibility of the project members; and justice-related problems can be recognised prior to the renovation, and do not need to be solved ad-hoc during the renovation process. This results in fewer complaints from the tenants.

The dimension recognition is an essential precondition to develop a fair and inclusive participation process. In this participation process, it should be possible for tenants to make their needs and wishes known about how to improve their living environment and how to limit their inconvenience during the renovation process. An important issue is that this participation starts prior to the development of the renovation plans. This is seldom done. A mix of participation methods can be used to acquire this diversity in needs, and to address the different preferences in how tenants want to participate. Individual methods can be used especially for vulnerable households, as they are harder to involve in participation processes. In the participation process, the financial and non-financial *distribution* issues should be discussed and agreed fairly between the SHA and the tenants.

The dimension capability is a justice dimension, which is understudied in previous research on energy renovations, principally because it is not part of the framework. However, it is an important dimension because of the large number of vulnerable households in social housing. Our study argues that vulnerable households often do not have the capabilities to participate in the energy renovation process. Also, a recent study by Stapper (2020), about participatory processes in urban developments, reports that participatory processes are likely to increase social inequality caused by differences in capabilities. This is because in many cases, high-educated people express themselves, better, and are therefore better understood by civil servants and advisors. Whereas less privileged residents, often do not have these capabilities and as a result, often see that their needs are not met in the new development (Stapper, 2020). Consequently, the participation process will be less inclusive and social inequality can increase because of this.

Capacity enhancement can help tenants to build up capacities and skills to participate in the energy renovation process but also to take on responsibilities. These capabilities can also be useful in other aspects of their lives. Accordingly, Kimhur (2020) stresses that more focus is needed on expanding capabilities in the participation process of housing policies, to also empower people in other aspects of their lives. A study by Preece (2019) demonstrates that when participating tenants can acquire certain capabilities, which also can be used in other aspects of their lives, such as gaining skills and knowledge, building confidence, and developing a sense of pride in their achievements (Lewis, 2014; Preece, 2019). In line with this, Breukers et al. (2017) in their study recommend that time and effort should be given to build up local capacities, so tenants have the capabilities and feel empowered to participate in the energy renovation process. Working on capacity building in the participation process can bring benefits to the energy renovation process and plan, but also to other aspects of tenants' lives. However, our study showed that this is not really a focus area at this time for SHAs. Capacity enhancement is a difficult and complex task because there are more structural problems at the root, which are not easy to solve and need long-term commitment from several stakeholders. Participating in the energy renovation process can act to create or enhance *responsibility* among the tenants for their home and its surroundings. However, tenants need to have certain capabilities to take this responsibility and specially targeted action may be required (which makes use of existing assets). Overall, this study demonstrates that dealing with justice is not a simple managerial issue because of the contested nature of what is just and differences in values and interests.

In conclusion, our study reveals that the multidimensional justice perspective, and the five interrelated justice dimensions, can be a starting point for achieving a more just energy renovation process in social housing. The perspective can be used to implement a broader and more pluralistic perspective on justice principles. This study contributes to existing literature by providing more insight into the five justice dimensions and their interrelations in the context of energy renovations of social housing. The multidimensional perspective is found useful for addressing different justice aspects, and especially when dealing with the needs of vulnerable households. A particular novel contribution is the identification of interaction effects, which demonstrate that the five justice dimensions are strongly interlinked and should not be addressed separately.

Limitations and further research

Since the recommendations were developed from empirical evidence in the Netherlands and a limited sample size was used, we do not suggest that these are comprehensive and hold true for all contexts. Nevertheless, municipalities, SHAs and TAs in countries with similar social housing structures can use the findings to make their renovation process more just and people-centred. In addition, the findings can be used in broader discussions regarding justice in housing but also in other related topics, such as to compare the findings with co-ownership forms of housing (e.g. condominiums). Regarding the testing of the multidimensional framework, the scope of data collection could be extended to other cases, larger sample sizes, and other regions, to generate further elaboration. Validation of the lessons and recommendations in expert and tenant groups could also be a valuable addition for further development of the people-centred energy renovation process. In particular, the views of tenants on justice could vary from the ones offered by SHAs and TAs in this study, and it could therefore be a valuable follow-up to inquire into this. The tensions and trade-offs between the different dimensions are a topic for further research because our study was not designed to study those in great detail, for instance in an in-depth case-study. How SHAs can help to enhance tenants' capabilities in the energy renovation process is an important issue that also warrants more research.

Acknowledgements and funding

The authors would like to thank the respondents for sharing their insights and experiences in the interviews. This research was funded by the Dutch organisation for Scientific Research (NWO, 023.013.033), Zuyd University of Applied Science (PhD funding), the Foundation Innovation Alliance (SIA, Raakpro 02.145), and the H2020 project Drive 0 (grant no. 841850).

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4.7.1 Appendix Chapter 4

Supplementary data to Chapter 4 can be found online at https://doi. org/10.1016/j. erss.2022.102527:

- **Table A1.** Main interview questions per justice dimension.
- **Table B1.** Overview of participation methods based on the interview results including the advantages and disadvantages derived from the interview results.
- **Table C1.** Recommendations for a people-centred energy renovation per renovation phase and justice dimension, derived from the interview results and literature review. These are additional to the recommendations made in Table 5.
- **Table D1.** Supporting quotes from respondents per justice dimension.

5

CHAPTER 5

CROSSING MULTIPLE SOLAR ENERGY GAPS: A DUTCH CASE STUDY ON INTERMEDIATION FOR BUILDING-INTEGRATED PHOTOVOLTAICS

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Published in Energy Research & Social Science 2023; 102, 103149

Abstract

Building-integrated photovoltaics are a promising technology to enhance renewable energy production in the built environment while improving the aesthetics of buildings at the same time. Several challenges hinder this technology's uptake, such as information asymmetry and limited value chain coordination. Prior work demonstrates that the support of intermediaries can play a crucial role in coping with these challenges, but this aspect has not yet been previously investigated for this technology. A comprehensive overview is lacking of how various intermediaries can support a multistage decision-making process. Rather than focusing on specific intermediary actors, we explore the Dutch system for building-integrated photovoltaics, identifying which actors act or can act as an intermediary, and what intermediation activities can support the decision-making process. This article identifies the need for intermediation at the various stages of the decision-making process and the actors best suited to providing this. Drawing from our empirical findings from 26 in-depth interviews and the literature on innovation adoption and intermediaries, the results revealed that a dynamic 'ecology of intermediaries' is necessary to perform various intermediation activities at different system levels in the multistage decision-making process. As these activities and actors are highly interrelated and interdependent, we argue that it is vital to assess intermediation in a holistic way. These findings are significant for suppliers, potential intermediaries, and governments because they can support improving the decision-making process with the help of intermediation. The present paper contributes to innovation and intermediation studies by demonstrating that intermediation is an interrelated, multilevel, and variegated phenomenon.

5.1 Introduction

The European Union aims to cut greenhouse gas emissions by at least 55% by 2030, compared to 1990 levels (European Commission, 2020c). Buildings account for 36% of these greenhouse gas emissions in 2020 (European Commission, 2020a) and are therefore an important sector to address. Reductions can be achieved via the adoption of energy efficiency measures (e.g., insulation, efficient ventilation, and heating appliances), the replacement of natural gas-based heating systems with low-carbon methods of heating, and the implementation of photovoltaics (PV). Photovoltaics (ground-mounted and rooftop) account for a 5.2% share of total net electricity generation in the European Union in 2020 (European Commission, 2020d), but rooftop PV alone has the potential to grow to a quarter of total electricity demand in Europe (Bódis et al., 2019). One reason for the non-use of solar PV panels is that people find solar panels aesthetically unattractive, and a promising technical innovation in this regard are building-integrated photovoltaics (BIPV) (Petrovich et al., 2019). Building-integrated photovoltaics differ from traditional PV in that they are integrated into the building envelope and fulfil at least one additional function besides generating electricity, such as weather protection, insulation, or shading (Heinstein et al., 2013). A key advantage of BIPV is that these products have improved aesthetic qualities compared to traditional PV. Moreover, prior research points out that these improved aesthetics can increase society's social acceptance of renewables (Broers et al., 2021; Gholami et al., 2019; Hille et al., 2018; Petrovich et al., 2019), thus facilitating the transition to a low-carbon society.

The Netherlands have an active BIPV sector but despite several governmental initiatives and pilot projects, it is still a niche market as diffusion is low (Vroon et al., 2021). The uptake of BIPV still faces challenges, such as a lack of awareness and knowledge in the construction sector and among potential adopters (Agathokleous & Kalogirou, 2020; Vroon et al., 2021), limited value chain coordination between the BIPV and construction sectors (ICARES, 2019; van Horrik et al., 2016; Vroon et al., 2021), and perceived high investment costs (Agathokleous & Kalogirou, 2020; Boesiger & Bacher, 2018; Gholami et al., 2019; Vroon et al., 2021). With a share of 1% in the global PV market (Agathokleous & Kalogirou, 2020), BIPV potentials are far from being fully exploited as BIPV continues to struggle to compete with incumbent technologies such as traditional PV (Vroon et al., 2021).

There are several recent studies on the techno-economic aspects of BIPV, such as energy performance and building integration (e.g. Agathokleous & Kalogirou, 2020; Gholami & Røstvik, 2020; Gholami et al., 2019; Vroon et al., 2021), but less is known about the factors influencing the BIPV decision-making process. As innovation-diffusion pioneer Rogers (2003a) points out, decision-makers can be individuals, groups or organisations. Rogers' model for the innovation-decision-making process includes five stages: I. the knowledge stage, II. the persuasion stage, III. the decision stage, IV. the implementation stage, and V. the confirmation stage (Rogers, 2003a). These decision-making stages have been tested and proved useful in contexts relevant to BIPV, such as traditional PV and energy renovation measures for dwellings (e.g. Broers et al., 2019; Ebrahimigharehbaghi et al., 2019; Wilson et al., 2018). In general, for any innovation, various challenges can emerge in the different stages of the decision-making process, such as a lack of awareness or disinformation about the innovation in the knowledge stage, and difficulties in financing in the persuasion stage (Glaa & Mignon, 2020; Kanda et al., 2022; Kivimaa, Boon, et al., 2019). These challenges can hamper the diffusion of the innovation (Glaa & Mignon, 2020). To cope with such challenges, previous research demonstrates that the support of intermediaries plays a crucial role in the diffusion of innovations (e.g. Aspeteg & Bergek, 2020; Bergek, 2020; Glaa & Mignon, 2020; Howells, 2006; Hyysalo et al., 2022; Sovacool et al., 2020). Intermediaries can affect innovation decision-making processes positively by connecting diverse visions and interests, actors and activities, and their resources and expectations; moreover, they can create new networks and collaborations (Kivimaa, Boon, et al., 2019; Sovacool et al., 2020) to enhance the diffusion of the innovation.

Various studies have investigated the importance of intermediation in the development and diffusion of technical innovations related to BIPV, but not to BIPV as such; for example, large-scale solar and wind power (Aspeteg & Bergek, 2020; Mignon & Broughel, 2020), small-scale renewable energy technologies (Hyysalo et al., 2018), heat pumps (Hyysalo et al., 2022; Hyysalo et al., 2018; Kivimaa, Hyysalo, et al., 2019) low-energy/net-zero housing and retrofits (Brown et al., 2019; Grandclément et al., 2015; Hyysalo et al., 2022; Kivimaa, Hyysalo, et al., 2019; Kivimaa & Martiskainen, 2018b; Kivimaa, Primmer, et al., 2020; Murto et al., 2020; Murto et al., 2019; Sovacool et al., 2020), and local energy and climate initiatives (Boyle et al., 2021; Matschoss & Heiskanen, 2017; Seyfang et al., 2014; Warbroek et al., 2018). Most of these studies have focused on intermediaries acting at the system level (Bergek, 2020), but several studies point out that there is a lack of systemized knowledge about intermediaries located downstream in the supply chain between the technology adopter and supplier (e.g. Aspeteg & Bergek, 2020; Mignon & Broughel, 2020) and that there is a need for more knowledge about user (Murto et al., 2020; Murto et al., 2019; Stewart & Hyysalo, 2008) and diffusion intermediation (Aspeteg & Bergek, 2020; Bergek, 2020; Vihemäki et al., 2020) because the more prominent supply-side intermediaries tend to overbalance the often more informal but crucial user-side intermediaries in most studies (Stewart & Hyysalo, 2008). This can cause problems because technologies need not only to be developed but also adopted at a large scale to contribute to sustainable transitions (Bergek, 2020). Investigation of the role of intermediation across all stages of the decision-making process is also rare (Mignon, 2017). An exception is a recent study by Glaa and Mignon (2020), who identified gaps and overlaps in intermediary support in the various stages of the decision-making process in the context of renewable energy technology in Sweden. However, they focused on organisations with a designated and specific intermediation role for supporting adopters, neglecting the role of not-designated intermediaries such as architects and engineers as potential intermediaries. Both architects and engineers could be essential intermediaries in the BIPV decision-making process as they advise potential adopters in the building process.

The purpose of this paper is to contribute to a better understanding of how intermediation affects the multiple stages of the BIPV decision-making process in the Netherlands, what type of intermediation is needed, who can/may act as an intermediary, between which actors intermediation is needed, and at what system level intermediation is required. The following research questions have been formulated for our empirical investigation:

1: *What kind of intermediaries and intermediary activities exist in the BIPV decision-making process in the Netherlands?*
2: *What kind of intermediation gaps and challenges slow down the diffusion of BIPV?*
3: *How can intermediation improve the multiple stages of the BIPV decision-making process in the Netherlands?*

We start by setting the scene for BIPV in section 5.2, followed by a discussion of the literature on innovation adoption and intermediaries in section 5.3. Subsequently, we report on our research method in section 5.4. The results of the analysis of the semi-structured interviews with 26 stakeholders from the BIPV system in the Netherlands are presented in section 5.5. In section 6, we offer a discussion of the results and present our main conclusions, together with recommendations for intermediation for the case of BIPV.

5.2 Building-integrated photovoltaics: key actors and challenges

There is a wide range of BIPV products, such as roof and façade products, semi-transparent and non-transparent systems, custom-made and 'off-the-shelf' products. These are presented in Figures 5.1 and 5.2. This wide variety of products and actors makes the BIPV system complex. An often-used framework to determine the network of involved actors and institutions that interact in a specific technological system is the technical innovation system (TIS). TIS is described as a set of networks of actors and institutions that interact in a specific technological field and support the development and diffusion of technologies (Kant & Kanda, 2019; Negro et al., 2012). TIS includes five components (e.g. actors) and relations (see Figure 5.3): (1) the supply side, which develops, manufactures, and supplies BIPV products; (2) the demand side, consisting of the potential adopters; (3) the governmental infrastructure; (4) the supportive infrastructure; and (5) intermediaries that function as brokers between the various parties (Alkemade et al., 2007; Negro et al., 2012; Smits & Kuhlmann, 2004; van Lente et al., 2003; Vasseur, 2014). The TIS framework was used in a recent Dutch BIPV study by Vroon et al. (2021) to compile an overview of actors in the Dutch BIPV system. We used this overview and complemented it with results from other Dutch (Hurk & Teunissen, 2015; Osseweijer et al., 2017; van Horrik et al., 2016) and European BIPV studies (Boesiger & Bacher, 2018; Curtius, 2018; ICARES, 2019; Osseweijer et al., 2018; Tabakovic et al., 2017). However, these studies did not include or study intermediaries specifically in their framework. Therefore, we address this research gap by incorporating intermediaries into the BIPV system (based on Alkemade et al., 2007; Smits & Kuhlmann, 2004; van Lente et al., 2003; Vasseur, 2014). Figure 5.3 is based on our review and presents the TIS system for the BIPV ecosystem including intermediaries and examples of actors. It demonstrates that intermediaries can connect different actors in the BIPV system, which we will further investigate in this study.

Even though there is a vibrant BIPV market in the Netherlands, it still struggles to compete with incumbent technologies such as traditional PV (Vroon et al., 2021), as do other (European) countries. Table 5.1 presents an overview of the reported challenges in BIPV systems in prior studies divided into European and Dutch BIPV studies. Main challenges are, for instance, a lack of awareness among potential adopters and in the construction sector, a lack of policy support, and a lack of large construction companies within the system. These reported challenges could influence the BIPV decision-making process which can hamper diffusion. Based on our analysis, we assorted these challenges per decision stage, which these challenges could affect directly or indirectly. Multiple studies report that intermediaries can play an essential role in overcoming challenges in the diffusion of an emerging technology (e.g. Bergek, 2020; Hyysalo et al., 2022; Kanda et al., 2022), such as BIPV. There is, as reported before, a lack of insight into what these roles and activities are and who should act as an intermediary between the various actors in the BIPV system. This paper, therefore, explores these questions further.

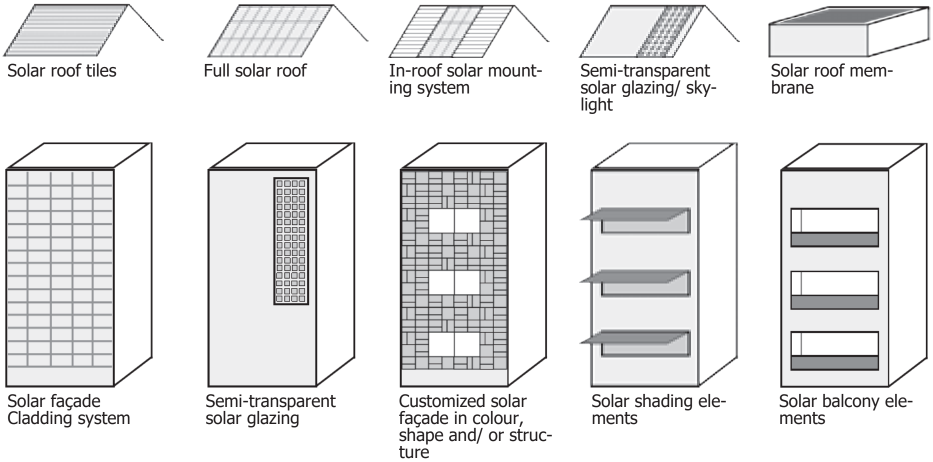

Figure 5.1. Examples of BIPV applications (authors own work based on ICARES, 2019; Pillai et al., 2022; Tabakovic et al., 2016)[1].

1 *For a comprehensive overview of BIPV products: https://www.bipv.ch/images/Report%202017_SUPSI_SEAC_BIPV.pdf*

	Product	Supplier	Supplier website	Project location
Top left	Full solar roof	Exasun	*www.exasun.nl*	Pijnacker
Middle left	Solar roof tiles	Solinso	*www.solinso.nl*	Unknown
Bottom left	Coloured custom-made solar façade	Solarix	*https://solarix-solar.com/*	Helmond
Top right	Solar façade	Zigzagsolar	*www.zigzagsolar.nl*	Sittard-Geleen
Bottom right	Solar roof membrane	Hyet Solar	*www.hyetsolar.com*	Rotterdam

Figure 5.2. Examples of realised BIPV projects in the Netherlands

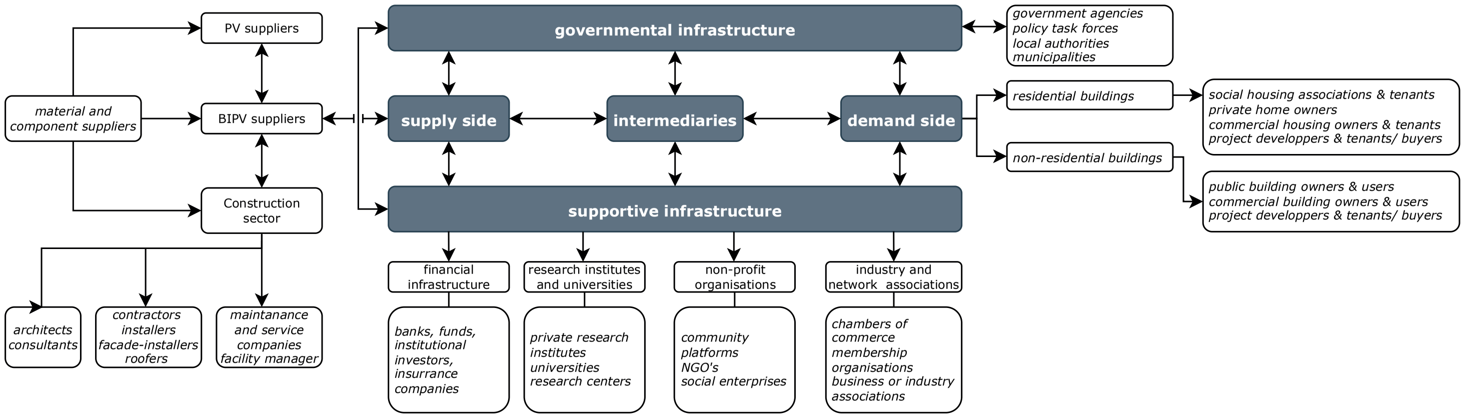

Figure 5.3. Diversity of actors in the BIPV system

The main TIS framework (grey) is based onAlkemade et al., 2007; Smits & Kuhlmann, 2004; van Lente et al., 2003; Vasseur, 2014, and the examples of actors are derived from Boesiger & Bacher, 2018; Curtius, 2018; Hurk & Teunissen, 2015; ICARES, 2019; Osseweijer et al., 2017, 2018; Tabakovic et al., 2017; van Horrik et al., 2016; Vroon et al., 2021

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Table 5.1. Reported challenges in the BIPV system assorted per decision stage

Decision stages (Rogers, 2003a)	Description
I. Knowledge stage	A potential adopter is exposed to the existence of BIPV (awareness) and gains an understanding of how it functions and can be used. Prior conditions are needed to make this happen; for example, a perceived need or problem, social norms, or current related practices
II. Persuasion stage	A potential adopter develops a general perception of BIPV for their situation and forms a favourable or unfavourable attitude towards BIPV.

Reported challenges in the BIPV system	BIPV studies	
	EU	NL
Lack of awareness among potential adopters and the construction sector (contractors, architects, engineers); Many BIPV suppliers spent a lot of time informing potential adopters	(Agathokleous & Kalogirou, 2020; ICARES, 2019)	(Vroon et al., 2021)
Many BIPV suppliers focus more on product development and less on marketing and business development		(van Horrik et al., 2016)
Limited coordination between the BIPV industry and the construction sector; the BIPV system is largely dominated by research institutes and BIPV start-ups, but the construction sector is lacking	(ICARES, 2019)	(van Horrik et al., 2016; Vroon et al., 2021)
Hard to find objective and detailed product information on BIPV for the demand side and construction sector	(Tabakovic et al., 2017)	(van Horrik et al., 2016)
BIPV is not part of current education programmes/ vocational training	(Curtius, 2018; Tabakovic et al., 2016)	(Osseweijer et al., 2017, 2018; Vroon et al., 2021)
The construction industry is risk-averse and reluctant to change	(ICARES, 2019)	(Hurk & Teunissen, 2015)
Lack of confidence among insurance companies due to an (over)estimation of risk perception	(ICARES, 2019)	
Perceived uncertainty about guarantees, as many BIPV suppliers are still start-ups or SMEs		(Hurk & Teunissen, 2015; van Horrik et al., 2016)
For small BIPV companies, it is difficult to pre-finance testing for certification and standardisation		(Hurk & Teunissen, 2015; van Horrik et al., 2016)
Perceived uncertainty about the durability of the products and maintenance procedures	(Agathokleous & Kalogirou, 2020; ICARES, 2019)	(Vroon et al., 2021)
Current procurement culture in the construction sector on the lowest price, rather than on total lifespan costs and benefits and/ or multiple value creation of BIPV; Hard to monetise the additional features of BIPV, such as aesthetics and building-related functions.	(Brown, 2018; ICARES, 2019)	(Hurk & Teunissen, 2015; van Horrik et al., 2016)

Table 5.1. Continued

Decision stages (Rogers, 2003a)	Description
III. Decision stage	A potential adopter engages in activities that lead to a decision to adopt or reject BIPV.
IV. Implementation stage	A potential adopter implements BIPV in their building(s) and puts it to use.
V. Confirmation stage	An adopter experiences BIPV and forms a positive or negative attitude towards it, based on their own experiences, and/or seeks reinforcement of the decision already made, and sometimes promotes (or discourages) BIPV to others.

	Reported challenges in the BIPV system	BIPV studies	
		EU	NL
	(Perceived) high investment costs	(Agathokleous & Kalogirou, 2020; Boesiger & Bacher, 2018; Gholami et al., 2019; ICARES, 2019; Tabakovic et al., 2017)	(Hurk & Teunissen, 2015; van Horrik et al., 2016; Vroon et al., 2021)
	Inexperience often leads to an overestimation of costs by the construction sector		(Hurk & Teunissen, 2015; van Horrik et al., 2016)
	Lack of governmental support for the implementation of BIPV for the demand side	(Agathokleous & Kalogirou, 2020)	
	Lack of governmental support for upscaling BIPV production (supply side)		(Vroon et al., 2021)
	Unreliable and complex regulatory frameworks, such as lack of codes, certifications, or guidelines combining PV and building requirements	(Agathokleous & Kalogirou, 2020; Tabakovic et al., 2017)	(Hurk & Teunissen, 2015; van Horrik et al., 2016)
	Lack of BIPV demonstration examples	(Tabakovic et al., 2016)	
	BIPV products have to be more compatible and complementary with traditional building components and suitable for renovations		(Vroon et al., 2021)
	Negative publicity regarding the installation of BIPV products on site, such as failure of fixings, rain effects, incorrect cabling and connections, and poor waterproofing makes the demand side reluctant to implement BIPV	(Agathokleous & Kalogirou, 2020)	
	Negative publicity regarding fire safety makes contractors reluctant to implement BIPV		(Bende & Dekker, 2019)

5.3 Innovation intermediaries

5.3.1 Intermediary functions and activities

Intermediation is a way to overcome challenges in the innovation decision-making process through a variety of intermediation activities (Kanda et al., 2022). There are valid theoretical reasons for assuming that intermediation can help to align different actors whose activities are needed for innovation. Many intermediary studies have investigated these activities and generally arrived at an enabling role for intermediation. Table 5.2 presents a compilation of these intermediation activities, drawn from the literature. Based on common emerging themes from the literature, we grouped the intermediation activities into five main intermediation functions: 1. knowledge development and exchange, 2. networking, 3. facilitating projects, 4. visioning, and 5. institutional change. Based on this overview it can be concluded that intermediation can cover a wide variety of activities, but it is not clear what intermediation activities are needed at which stage of the decision-making process and specifically for BIPV.

5.3.2 Intermediary actors

As described in previous literature, intermediation functions and activities can be performed by a variety of actors, such as private, public or non-profit organisations (Bergek, 2020; Gliedt et al., 2018; McCauley & Stephens, 2012). Table 5.3 presents an overview of actors identified in prior studies as intermediaries, ranging from industry associations to voluntary groups. A study by Bergek (2020) reveals that some of these intermediary actors are specifically assigned to be an intermediary, while others are not. This means that they sometimes act as an intermediary but are primarily engaged in other activities. Many intermediary studies focus on specialised intermediaries, but 'unspecialised intermediaries' make up a large share of the intermediaries, and it is therefore imperative not to exclude them in intermediation studies (Bergek, 2020). In the construction sector, in particular, intermediation is often performed by actors who are not specifically assigned to be an intermediary (Kivimaa & Martiskainen, 2018b; Vihemäki et al., 2020) such as architects and building managers. Therefore, this paper investigates all key actors in the BIPV system to identify specialised and unspecialised intermediaries in the BIPV system.

5.3.3 Intermediation and system levels

Prior intermediation studies conclude that an 'ecology of intermediaries' is needed to enhance the diffusion of innovations, especially in and between the supply and user side (Hyysalo et al., 2022; Kivimaa & Martiskainen, 2018a; Stewart & Hyysalo, 2008). This means that specific types of intermediaries are required, with different competences, activities, and roles that can also change over time. However, most studies have focused on a specific type of intermediary (Kivimaa & Martiskainen, 2018a) or specialised intermediaries (Bergek, 2020). Therefore, rather than focusing on specific types of intermediaries, we will explore a variety of intermediation activities and actors in the multistage BIPV decision-making process in the Netherlands.

In their comprehensive review of intermediaries, Kivimaa, Boon, et al. (2019) introduce a typology of intermediaries based on the multilevel perspective (MLP). Table 4 gives an overview of these five intermediary types ranging from a system to a user level. The MLP distinguishes three different system levels: the landscape level, the socio-technical regime, and the micro-level of socio-technical niches (Geels, 2002; Rip & Kemp, 1998). The landscape level is '*a set of heterogeneous factors, such as oil prices, economic growth, wars, emigration, broad political coalitions, cultural and normative values and environmental problems*' (Geels, 2002, p. 1260, pg 1260). The landscape level generally develops autonomously but directly influences the regime and niche level (Geels, 2002; Vasseur, 2014). The regime level refers to widely-used technologies, practices and institutions (Geels, 2002; Van Boxstael et al., 2020), whose presence influences the micro-level of niches for '*the generation and development of radical innovations*' (Geels, 2002, p. 1261, pg 1261). Niches are the protective space for radical and path-breaking technical alternatives that are currently too weak to compete with the current socio-technical regime (Kemp et al., 1998). The defined intermediation typologies, based on the MLP in Table 4, are not mutually exclusive as many intermediaries can be profiled as more than one type (Kivimaa, Boon, et al., 2019). As the micro-level of user intermediation can shape and influence transitions on the system level (Murto et al., 2020) and vice versa, we will not focus on specific intermediaries which act on a certain system level but investigate the ecology of intermediaries within the BIPV system.

Table 5.2. Main intermediary functions and examples of activities (based on the literature review of intermediation studies related to energy and sustainability transitions)

Main function	Examples of intermediation activities
1. Knowledge development and exchange	Supporting learning processes, exploration and dissemination, reducing information gaps
	Facilitating experimentation and pilots
	Consulting demand side about implementation
2. Networking	Building and managing networks of multiple stakeholders
	Translating and mediating between actors and interests and developing consensus
	Enabling and coordinating cooperation between actors
	Putting suppliers in contact with end-users
3. Facilitating projects	Facilitating/ supporting the adoption and implementation of innovations
	Facilitating and managing change processes or innovative projects.
	Resource mobilisation/ funding
	Configuration of the innovation
4. Visioning	Articulation of expectations, requirements and creating visions
5. Institutional change	Political advocacy & lobbying
	Policy implementation
	Legitimising institutional change
	Developing standards

Authors
(Brown et al., 2019; Kemp et al., 1998; Kivimaa, 2014; Kivimaa, Boon, et al., 2019; Kivimaa, Hyysalo, et al., 2019; Kivimaa & Martiskainen, 2018b; Klerkx & Leeuwis, 2009; Sovacool et al., 2020; Van Boxstael et al., 2020; van Lente et al., 2003; Vihemäki et al., 2020; Warbroek et al., 2018)
(Kivimaa, 2014; Kivimaa, Primmer, et al., 2020; Van Boxstael et al., 2020; Warbroek et al., 2018)
(Bergek, 2020; Kivimaa, 2014; Mignon & Kanda, 2018; Owen et al., 2014; Theodorakopoulos et al., 2014; Vihemäki et al., 2020)
(Brown et al., 2019; Kant & Kanda, 2019; Kemp et al., 1998; Kivimaa, 2014; Kivimaa, Bergek, et al., 2020; Kivimaa, Hyysalo, et al., 2019; Kivimaa & Martiskainen, 2018b; Kivimaa, Primmer, et al., 2020; Klerkx & Leeuwis, 2009; Seyfang et al., 2014; Sovacool et al., 2020; Stewart & Hyysalo, 2008; Vihemäki et al., 2020)
(Kivimaa, 2014; Kivimaa, Bergek, et al., 2020; Kivimaa, Hyysalo, et al., 2019; Kivimaa, Primmer, et al., 2020; Sovacool et al., 2020; Van Boxstael et al., 2020)
(Backhaus, 2010; Gliedt et al., 2018; Grandclément et al., 2015; Mignon & Kanda, 2018)
(Bergek, 2020; Sovacool et al., 2020)
(Aspeteg & Bergek, 2020; Bergek, 2020; Kivimaa & Martiskainen, 2018b; Mignon & Broughel, 2020; Owen et al., 2014)
(Kivimaa, 2014; Kivimaa, Boon, et al., 2019; Kivimaa, Hyysalo, et al., 2019; Kivimaa & Martiskainen, 2018b; Seyfang et al., 2014; Sovacool et al., 2020; Van Boxstael et al., 2020)
(Aspeteg & Bergek, 2020; Gliedt et al., 2018; Kant & Kanda, 2019; Kivimaa, 2014; Kivimaa & Martiskainen, 2018b; Mignon, 2017; Mignon & Kanda, 2018; Seyfang et al., 2014; Sovacool et al., 2020; Stewart & Hyysalo, 2008; Van Boxstael et al., 2020; Vihemäki et al., 2020)
(Brown et al., 2019; Hyysalo et al., 2013b; Kivimaa, Hyysalo, et al., 2019; Stewart & Hyysalo, 2008; Vihemäki et al., 2020)
(Brown et al., 2019; Hargreaves et al., 2013; Howells, 2006; Kanda et al., 2020; Kemp et al., 1998; Kivimaa, 2014; Kivimaa, Boon, et al., 2019; Kivimaa & Martiskainen, 2018b; Kivimaa, Primmer, et al., 2020; Klerkx & Leeuwis, 2009; Sovacool et al., 2020; Van Boxstael et al., 2020; van Lente et al., 2020; van Lente et al., 2003; Vihemäki et al., 2020)
(Kivimaa, 2014; Kivimaa, Hyysalo, et al., 2019; Kivimaa & Martiskainen, 2018b; Kivimaa, Primmer, et al., 2020; Mignon & Broughel, 2020; Mignon & Kanda, 2018; Sovacool et al., 2020; Vihemäki et al., 2020; Warbroek et al., 2018)
(Backhaus, 2010; Kivimaa, Primmer, et al., 2020; Sovacool et al., 2020; Vihemäki et al., 2020; Warbroek et al., 2018)
(Gliedt et al., 2018; Kivimaa, Primmer, et al., 2020; Sovacool et al., 2020; Warbroek et al., 2018)
(Rohracher, 2009; Sovacool et al., 2020)

Table 5.3. Actors that take on intermediary roles

Private	Public
Business or industry associations (Bergek, 2020; Kanda et al., 2020; Mignon & Kanda, 2018; van Lente et al., 2003)	Government agencies (Bergek, 2020; Sovacool et al., 2020)
Membership organisations (Kivimaa & Martiskainen, 2018b; Sovacool et al., 2020)	Local authorities (Kivimaa & Martiskainen, 2018b; Sovacool et al., 2020)
Business development organisations (Mignon & Kanda, 2018)	Cities and city-level organisations (Hodson et al., 2013; Kampelmann et al., 2016; Kanda et al., 2020; Kivimaa, Hyysalo, et al., 2019; Mignon & Kanda, 2018)
Architects (Kanda et al., 2020; Kivimaa, Hyysalo, et al., 2019; Kivimaa & Martiskainen, 2018b; Mignon & Kanda, 2018; Sovacool et al., 2020)	Policy task forces (Kivimaa, Bergek, et al., 2020)
Building managers (Grandclément et al., 2015; Kivimaa & Martiskainen, 2018b; Sovacool et al., 2020)	Energy agencies (Kivimaa, Bergek, et al., 2020; Kivimaa, Hyysalo, et al., 2019; Kivimaa & Martiskainen, 2018b; Sovacool et al., 2020)
Project development companies (Kivimaa, Bergek, et al., 2020; Mignon & Kanda, 2018)	Innovation funding agencies (Kivimaa, Bergek, et al., 2020; Kivimaa, Hyysalo, et al., 2019; Kivimaa & Martiskainen, 2018b; Mignon & Kanda, 2018)
Consultant companies (Bergek, 2020; Howells, 2006; Kivimaa, Bergek, et al., 2020; Kivimaa, Hyysalo, et al., 2019; Kivimaa & Martiskainen, 2018b; Klerkx & Leeuwis, 2009; Mignon & Kanda, 2018; Sovacool et al., 2020)	
Chambers of commerce (van Lente et al., 2003)	

Private/ public / public-private partnership	Non-profit
Research institutes/ centres/ organisations (Bergek, 2020; Mignon & Kanda, 2018; van Lente et al., 2003)	Environmental NGOs (Bergek, 2020; Kivimaa, Bergek, et al., 2020; Kivimaa, Hyysalo, et al., 2019)
Network organisations (Kivimaa & Martiskainen, 2018b; Sovacool et al., 2020)	Social enterprises (Kivimaa & Martiskainen, 2018b; Sovacool et al., 2020)
Incubators and acceleration centres (Bergek, 2020; Gliedt et al., 2018)	Charity organisations (Bergek, 2020; Kivimaa & Martiskainen, 2018b; Sovacool et al., 2020)
Innovation centres/platforms (Kivimaa & Martiskainen, 2018b; Sovacool et al., 2020; van Lente et al., 2003)	Voluntary groups (Bergek, 2020)
Science parks (Howells, 2006; Kivimaa, Hyysalo, et al., 2019; Kivimaa & Martiskainen, 2018b)	Local actors supporting technology use (Howells, 2006; Kivimaa, Hyysalo, et al., 2019)
Universities (Bergek, 2020; Howells, 2006; Sovacool et al., 2020)	Community energy actors (Hargreaves et al., 2013; Kivimaa, Hyysalo, et al., 2019; Martiskainen, 2017)
University technology transfer offices/agencies/ liaison offices (Howells, 2006; Kanda et al., 2020; Kivimaa, Bergek, et al., 2020; Kivimaa, Hyysalo, et al., 2019; Kivimaa & Martiskainen, 2018b; Mignon & Kanda, 2018; Sovacool et al., 2020; van Lente et al., 2003)	Religious congregations (Parag & Janda, 2014; Sovacool et al., 2020)
Knowledge-intensive business services (van Lente et al., 2003)	Internet discussion forums and platforms (Hyysalo et al., 2013a; Hyysalo et al., 2018; Kanda et al., 2020; Kivimaa, Bergek, et al., 2020; Kivimaa, Hyysalo, et al., 2019; Kwon & Mlecnik, 2021; Mignon & Kanda, 2018; Sovacool et al., 2020)

Table 5.4. Intermediary types (derived from Kivimaa, Boon, et al. (2019))

Intermediary types	**Definition**
Systematic intermediary	Intermediation at system level between multiple actors & interests and across niches and sometimes regimes. Operates on niche, regime, and landscape level. Aims for change of the whole system, promotes an explicit transition agenda.
Regime-based transition intermediary	Intermediation on system level between multiple actors, within mandate given by dominant regime actors. Interacts with a range of niches or the whole system. Has a specific goal to promote transition.
Niche intermediary	Intermediation between local projects, individual companies or across them. Can also intermediate with higher levels of aggregation. Is an insider to a specific niche. Tries to influence the prevailing regime.
Process intermediary	Intermediation within experimental projects or specific processes contributing to transitions. Intermediate day-to-day action in transition projects or processes. Facilitates a change process or a niche project.
User intermediary	Intermediation at project level between technologies and end-users of the technology. Support demand side in innovation adoption process. Can be tied to a particular niche or cover multiple niches.

Overall, this paper investigates how intermediation can improve the multiple decision-making stages of the BIPV adoption process in the Netherlands. We examine what the challenges are in the adoption process in the Dutch BIPV ecosystem, who acts or can act as an intermediary, at what system level, and between which actors; and what intermediation is needed at what stage of the decision-making process.

5.4 Research methods

5.4.1 Case study selection

Implementing low-carbon technologies is necessary for the built environment to live up to the EU's 2030 Climate Target Plan. This means cutting greenhouse gas emissions by at least 55% by 2030 and becoming climate neutral by 2050 (European Commission, 2021). These goals need to be met by the Netherlands as well. Nevertheless, the Netherlands have a high population density of 513 people per square kilometer, compared to the EU's average of 109 (Eurostat, 2023). Since there is limited space for large-scale wind and solar parks, integrating low-carbon technologies in the Dutch built environment is essential to making the transition to a low-carbon society (NP RES, 2023). Due to its improved aesthetics, BIPV can also enhance social acceptance by integrating better with the built environment (Petrovich et al., 2019). In spite of this, BIPV is still considered a niche market that only accounts for 2% of the Dutch PV market [10]. Vroon et al. (2021) studied the historical development of the Dutch BIPV system. They reveal that since the dawn of the system in 1995, it has increased, developed and accelerated till 2015 due to diverse research projects, governmental initiatives and pilot projects. However, from 2016 to 2019, the Dutch BIPV system stagnated. Therefore, the Dutch BIPV market represents a highly relevant case for the analysis of low-carbon innovations for the transition to a low-carbon built environment within Europe.

5.4.2 Data collection

The study was conducted using a qualitative case study method to investigate the BIPV decision-making process. There have been prior studies of the Dutch BIPV system but they did not include intermediaries into their studies. We address this research gap by investigating what kind of intermediaries and intermediary activities exist in the Dutch BIPV decision-making process (RQ1), what kind of intermediation gaps and challenges slow down the diffusion of BIPV (RQ2), and how intermediation can improve the multiple stages of the BIPV decision-making process in the Netherlands (RQ3). As part of the data collection process, we first reviewed relevant academic literature about intermediaries and the BIPV system; and second, we conducted semi-structured interviews with actors from the Dutch BIPV system. Sample selection was based on the literature review and actor analysis of the BIPV system (presented in Figure 5.3). Figure 5.4 reveals an overview of the interviewed respondents per actor-group in the TIS of BIPV, and Table 5.5 demonstrates the key characteristics of the respondents.

The first round of interviewees was selected based on their participation in a research project (n=9, see Table 5.5). The 'BIPVT geeft MOOI energie' runs from 2020-2024 and aims at developing an innovative, integrated renovated approach for a low-carbon built environment. One of the key actors was the Dutch Association for BIPV (BIPVNL). This association was founded in 2018 with the main goal of increasing the market and product awareness of BIPV in the Netherlands. The Dutch Association for BIPV has members from the supply side and research institutes, which pay a participation fee. As part of the second round of interviews, actors outside the project were interviewed (n=17), including actors from the construction sector, the demand side, and a national government organization, which were not well represented in the project. This study did not focus on individual end-users as this group is very diverse and their decisions are influenced by a wide range of factors that differ from person to person (Broers et al., 2019; De Wilde, 2019; Fyhn & Baron, 2017; Karvonen, 2013; Kerr et al., 2018; Wilson et al., 2018). Moreover, the demand side was addressed by focusing on actors who can support the transition from early adopters, who are typically private homeowners, to mainstream adopters (early majority). We included, therefore, social housing associations and project developers as they make decisions for a large group of end-users, which can help to accelerate BIPV diffusion.

The interviews were conducted from October 2021 to April 2022. The semi-structured interview guide (see supplementary material) was organised around the main functions presented earlier in Table 5.2. The interview method was used to gain a better understanding of intermediation in the BIPV decision-making process and the interaction between actors, but it also allowed the researcher to be responsive to unexpected relevant issues raised in the interviews (Patton, 1999). It gave the respondents the opportunity to satisfactorily describe their experiences and their views on the topic. The interviews were conducted in person by the first author, and the interview data were analysed every 5 to 10 interviews and discussed in the research team (all authors). The interviews were digitally recorded, stored (with permission of the respondents), and transcribed. Additional data were collected in 16 project meetings (see supplementary materials for an overview), and intermediate results were also discussed within the project group. These meetings were recorded in meeting notes.

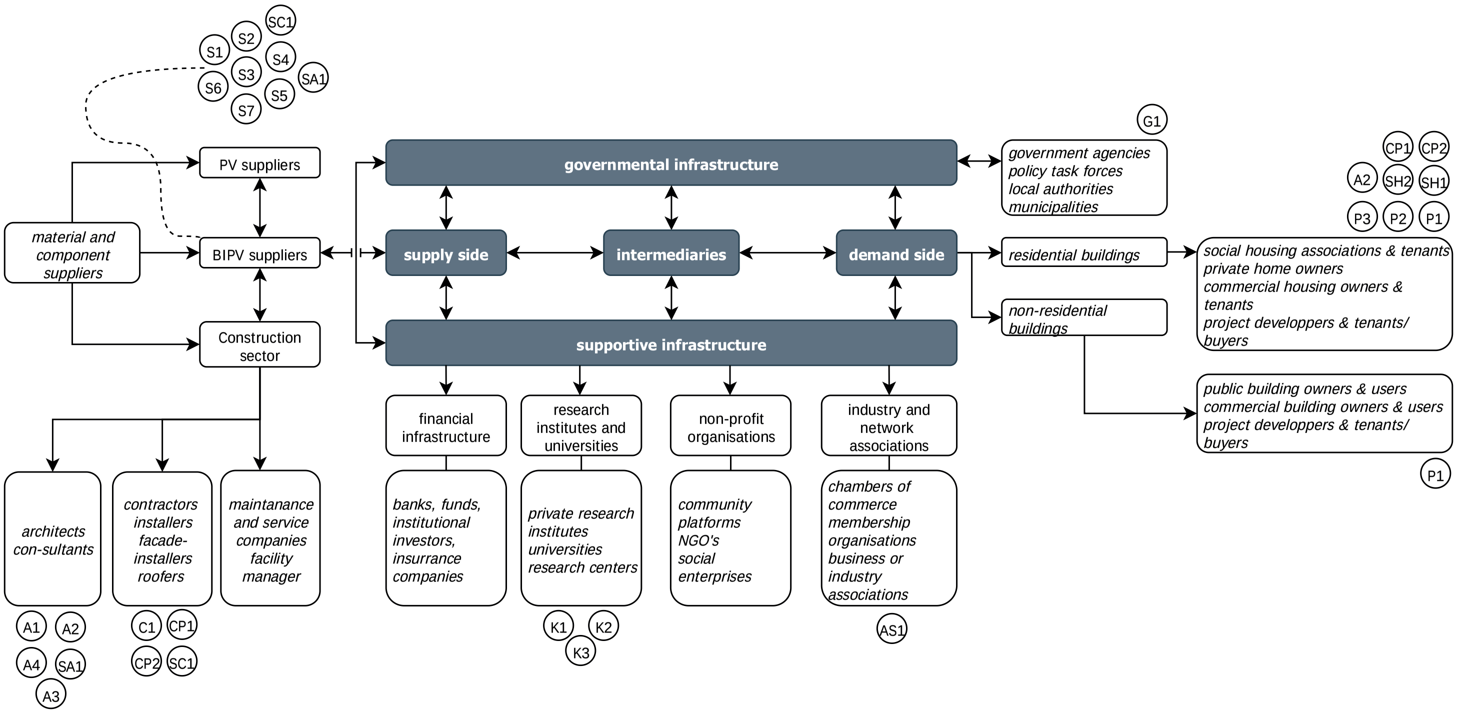

Figure 5.4. Sample selection based on the actor analysis presented in section 5.2

The respondents are presented as circles; the abbreviations are explained in Table 5.5 (some respondents belong to multiple actor groups)

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Table 5.5. Overview of interviewees

Actor group*	Code	Description stakeholder
Association (As)	AS1	BIPVNL
Construction sector (C)	A1	Architectural firm
	A2	Architectural firm & private homeowner with BIPV roof tiles
	A3	Architectural firm
	A4	Architectural firm
	C1	Façade contractor
	CP1	Building contractor & project developer
	CP2	Building contractor & project developer
Demand side (D)	P1	Real estate developer
	P2	Real estate developer
	P3	Real estate developer
	SH1	Social housing association
	SH2	Social housing association
Government (G)	G1	Governmental agency
Knowledge institutions (K)	K1	University
	K2	Private research institution
	K3	Private research institution
BIPV suppliers (S)	S1	Supplier BIPV façade elements (mainly residential multistorey housing)
	S2_a	Supplier PV-power foil (mainly commercial/ industry buildings)
	S2_b	Supplier PV-power foil (mainly commercial/ industry buildings)
	S3	Supplier integrated thermal solar roof
	S4	Supplier BIPV roof tiles (mainly single family homes)
	S5	Supplier (coloured) BIPV facades (mainly residential & non-residential multistorey buildings)
	S6	Supplier PV roof tiles & BIPV roofs (mainly residential terraced dwellings)
	S7	Supplier BIPV facades (mainly commercial buildings)
	SA1	Supplier (coloured) BIPV facades (mainly residential & non-residential multistorey buildings) & architectural firm
	SC1	Supplier BIPV facades (mainly non-residential buildings), infra integrated PV & building contractor

Project partner	Position respondent
X	Chairman
X	Architect-owner
	Architect-owner
	Building engineer
	Architect
	Lead concept designer & civil engineer
	Director region South
	Project leader
	Owner/project developer
	Director/ CEO
	Project developer
	Project developer
	Project developer
	Senior advisor energy transition
X	Professor/researcher
	Researcher/project coordinator
	Business developer
X	Owner/director
X	Research and development manager
X	Chief technology officer
X	Owner/managing director
X	Owner/director
	Owner/director
	Owner/director
	Owner/director
X	Business developer
	Owner/ CEO

5.4.3 Data analysis

The literature, interview transcripts, and meeting notes were systematically analysed with qualitative software (Atlas.ti 9) and by using the thick analysis method. This method allows a more comprehensive analysis by combining several analysis methods (Evers, 2016a). Thematic coding was used, based on the theoretical framework (intermediary actors, functions and activities, types, challenges, decision-making stages) and open coding, to adopt an inductive approach to identify other methods of data organization that could lead to different results (Evers, 2016b). Analysis reports were used to determine which intermediation activity occurred in what decision-making stage, by which stakeholder intermediary, between which stakeholders, and on what system level. The findings were used to explore how intermediation can improve the multiple stages of the BIPV decision-making process in the Netherlands.

5.5 Intermediation in the BIPV decision-making process: empirical findings

5.5.1 Knowledge stage

In the knowledge stage of the decision-making process, it is important that potential adopters become aware of BIPV and gain more knowledge about the technology and its possibilities. The findings indicated that intermediation is needed in this stage between different stakeholders of the BIPV system, which is discussed in more detail in the sections below.

Intermediation between supply and demand side: BIPV suppliers - demand side

The interviews revealed that there is an intermediation gap between the BIPV suppliers and the demand side. It was reported that potential adopters are unaware of the possibilities of BIPV, which makes them reluctant to choose this technology. As a result, the interviewed suppliers declared that they have to spend a lot of time informing potential adopters individually in order to raise awareness and share information about their products (see also Table A1 in the Appendix of this Chapter). The Dutch Association for BIPV stated that their objective was to raise awareness of BIPV by publishing in mass media, attending consumer fairs and the like, but that at this time their resources were limited to fulfil this role satisfactorily:

> *'We do not play a very active role in informing potential adopters. There is information on the website and in the handbook, but they have to contact the individual supplier if they want more information. We do not have the means to do more' (AS1).*

Furthermore, the interviewed stakeholders from the demand side reported that in the current situation it is hard to find detailed and objective information about BIPV. Project developer P3 explained as follows:

> *'There is a lack of objective, non-commercial information about BIPV but also other innovations. Maybe the government could play a role in this' (P3).*

The interviews reveal that government(s) or another impartial organisation could play an intermediary role between suppliers and the demand side. Overall, no main platform exists for raising awareness among potential adopters, and systematic intermediation between supply and demand side has to be improved in order to increase BIPV adoption. The required intermediation activities include raising awareness, knowledge exchange about BIPV products (systemic and accessible for a large audience), and networking with potential adopters such as private homeowner associations, social housing (associations), and project developers.

Intermediation within the supply side: BIPV suppliers - construction sector
Another identified challenge is that most BIPV start-ups originate from the PV sector and are less familiar with the construction sector (see also Table A1 in the Appendix). As BIPV are integrated products, collaboration is needed between these two sectors. An important stakeholder in the construction sector is the construction supply sector, which supplies building components such as roofs, facades, and windows. The interviews revealed that there is an intermediation gap between the BIPV suppliers and the construction supply sector. It became clear from the results that the construction supply sector can play an important intermediation role between demand and supply, as BIPV can be integrated into their (traditional) building components. However, the findings indicated that certain BIPV products are less compatible with traditional building components (e.g., in size and construction) and therefore more difficult to incorporate in the current building process. In addition, the construction sector in general was regarded as risk averse by the interviewees and reluctant to change, which leaves little room for innovations such as BIPV. Project developer P1 and knowledge institution K2 stated that the BIPV-products have to be more compatible with traditional building components, so that they can be more easily integrated in the traditional way of building:

> *'You cannot change the construction sector, so BIPV products have to be adapted to traditional building products, such as prefab cladding or insulation systems for large facades' (P1).*

> *'It is hard to change existing regimes such as the construction sector, so it is better to look how to work together. Being too disruptive will slow down market introduction' (K2).*

It was discussed in the interviews that when BIPV suppliers become sub-suppliers to construction suppliers, they can benefit from their large marketing and sales resources which is helpful for increasing market volume. Moreover, it was suggested that BIPV suppliers could reduce their current individual business-to-client activities which will be done by the marketing and sales department of the construction supplier. Some interviewed suppliers declared that they already have started to organise their business this way (S4, S6, SC1) and that they work together with large construction suppliers who have incorporated the BIPV product in their product range:

'To make a better connection between BIPV and the construction sector, we have a partnership with a façade builder, a glass producer, a metal worker, and a supplier of aluminium products' (SC1).

However, these collaborations are still quite recent, and other BIPV suppliers do not engage in such collaborations. Overall, there is too little connection between the BIPV and construction sectors; in addition, there is a need for intermediation between these two sectors concerning the exchange and development of knowledge, as well as networking, to improve the BIPV decision-making process.

Intermediation within the supply side: BIPV suppliers - architects & engineers

In the interviews it was revealed that architects and engineers could play an important role as intermediaries between the BIPV supply side and the demand side. Martiskainen and Kivimaa (2018) indeed contend that an architect can be a crucial intermediary with the demand side and facilitate the progress of zero-carbon building. In the knowledge stage (as well as the persuasion stage), architects and engineers can create awareness about BIPV among potential adopters by furnishing them with information about the possibilities of BIPV. Furthermore, architects were also mentioned in the interviews as important intermediaries between the supply side and contractors:

'We receive most information about innovative products via architects; they are more aware of these developments than we do as contractors' (PC2).

'We follow up with new developments, but specifying the products – that's really up to architects' (C1).

While architects and engineers do have the potential to be intermediaries between BIPV suppliers and the demand side, at present most of them do not have sufficient knowledge of BIPV products; nor are they facilitated to act as intermediaries:

'There is someone missing in the design and building process who makes sure that BIPV is integrated in the design but also implemented at the end. This needs negotiation with all the stakeholders in the process, such as the client, contractor, installer and electrician. However, we as architects are not paid to play this role' (A1).

Several interviewees (see Table A2, Appendix) have suggested in the interviews that knowledge about BIPV should be integrated in training and vocational and educational programmes for architects and engineers to raise awareness and knowledge levels. The Dutch Association for BIPV (AS1) reported that they had organised some information sessions for architects, but that these were not well structured as their means are limited. In order to organise this in a more structured manner, intermediation in the form of knowledge exchange and networking is needed between the BIPV suppliers and architects and engineers (associations). The results also suggested the development of uniform 3D-design tools for BIPV applications, which can assist architects and engineers to implement the BIPV products early in the design process and receive the required information about the product:

> *'We work with 3D modelling tools in which building products are integrated. Within the library of the model all kinds of technical specifications of the product are available. We need this also for BIPV so we can quickly integrate it into our designs. At this time, we have to send our drawings to the BIPV supplier to ask for the specifications, but this takes too much time for us and them' (A1).*

Lobbying for funding will also be needed to bring about these educational changes and the development of the 3D tools which can help to raise awareness of BIPV among architects and engineers.

Intermediation within the supply side: BIPV suppliers - energy coaches
The findings revealed that local energy coaches (volunteers or financed by local governments) could play an intermediating role in knowledge exchange between the supply and demand sides, a point that has also been made in prior studies (Broers et al., 2019). The Dutch Association for BIPV revealed in the interview that they organised this on a small scale in 'woonwijzerwinkels'[2] (home advice shop). This is a Dutch initiative of several local governments and is a physical place where several low carbon technologies are demonstrated and information is provided by energy coaches to potential adopters on making dwellings more energy efficient. Certain BIPV products are displayed at the Rotterdam location, but this could be expanded to other locations in order to raise more awareness and exchange objective knowledge about BIPV. Nevertheless, energy coaches need to have sufficient knowledge about the BIPV products so that they can advise their clients on them, as was the case for architects and engineers in the previous section. Therefore, at present there is an intermediation gap between the BIPV suppliers and energy coaches concerning knowledge exchange, development, and networking.

2 *For more information: https://www.woonwijzerwinkel.nl/*

Intermediation between supply side and government: BIPV suppliers and government
The interview results revealed that there is an intermediation gap between BIPV suppliers and the government. The results identified that under current Dutch energy regulations, it is not necessary or obligatory to implement full solar roofs and facades, and therefore traditional PV panels are most frequently installed rather than BIPV. Project developer P3 revealed the following:

> *'We will only implement more innovations when the energy regulations are amended, or if there is a large demand from buyers, for instance because of high energy prices' (P3).*

In their studies on intermediation, Kanda et al. (2020) and Hargreaves et al. (2013) point out that lobbying for institutional change of national policy is an important intermediation activity. In our interviews, BIPVNL reported that they do try to lobby but that they have very little capacity to do so (see also Table A1 in the Appendix). Moreover, there is no clear national vision on how to integrate photovoltaics into the built environment on a large scale. As a result, systematic intermediation is needed between BIPV suppliers and the government concerning visioning and institutional change.

5.5.2 Persuasion stage

In the persuasion stage, potential adopters develop a general perception of BIPV for their situation and form a favourable or unfavourable attitude towards BIPV, based on the knowledge they accumulated in the knowledge stage. They will consider the advantages and disadvantages for their specific situation.

Intermediation between supply and demand side: BIPV suppliers - demand side
The results demonstrated that in this stage there is an intermediation gap between the supply and demand side regarding knowledge exchange, networking, and facilitating. As discussed in the previous section, architects, engineers, and energy coaches are potential intermediaries between the BIPV suppliers and the demand side, and this also applies to the persuasion stage.

Intermediation within supply side: BIPV suppliers - construction sector
In general, the construction sector was regarded by the interviewees as risk averse and reluctant to change, which leaves little room for innovations such as BIPV (see also Table A1 in the Appendix). In addition, prior studies report that the diffusion of innovations in the construction sector is difficult due to a multitude of factors which make the current regime very stable and conservative (e.g. Brown, 2018; Kivimaa & Martiskainen, 2018b). Social housing association SH1 had the following to say on this:

'Within our organization it was sometimes difficult to implement BIPV; it disrupts our smooth-running building process, and that is never appreciated so much, and it also creates a bit of uncertainty' (SH1)

The findings demonstrated that this attitude of the construction sector is often caused by a feeling of insecurity about the durability of the innovative BIPV products, because the products have not been on the market that long. Product guarantees could help to reduce these risks. However, the findings from the interviews also revealed that there is often a lack of confidence in the guarantees of the BIPV products as many BIPV suppliers are start-ups or small companies, and it is uncertain whether these companies will still exist in a few years' time. This is illustrated by the following input from supplier S1:

'Insurance companies want to have a business risk profile which is based on historic data. This is difficult for a start-up if the product was developed two years ago.'

In addition to guarantees, the development of certifications and standards could also offer more security. Nevertheless, the findings pointed out that the certification procedures for BIPV are not very clear as they combine separate codes for PV and the building envelope – a point that has also been reported in other BIPV studies (e.g. Agathokleous & Kalogirou, 2020; Tabakovic et al., 2017). Supplier S4 stated the following on this subject:

'Certification for BIPV products is very complex and many start-ups do not know how to deal with this' (S4).

In addition, BIPV start-ups often have limited financial resources to finance testing for certification, which hinders the upscaling of their products. Some of the suppliers interviewed mentioned that they serve on these kind of committees, but that they are not organised in a very structured manner and are not financed. Sovacool et al. (2020) identified the development of standards in order to realise an institutional change as an important intermediation activity. In the case of BIPV, this has not been designated to any particular organisation or actor. An intermediary should negotiate with national government(s) to improve certification for BIPV products and lobby for funding for certification.

Another challenge identified in the interviews is the procurement culture in the construction sector which insists on lowest price, rather than on total lifespan costs and (non-financial) benefits such as improved aesthetics and building-related functions. This is illustrated by the following statement by project developer PC1:

> *'There are very nice BIPV products but they cost 50% more, and you have to take their measurements into account in your design. You will save on roof tiles, but there are extra costs for labour. If upscaling and industrialisation of the BIPV production process will result in a reduction in the price difference between BIPV and traditional PV from 50% to 30% or 20%, it will make it much more interesting for large construction companies to install BIPV' (PC1).*

As a result, A2 explained that at present BIPV are adopted primarily by people who can afford them and want aesthetically integrated solar, which means that it remains a niche market at this time. A lack of experience with BIPV often leads to overestimated costs by contractors and installers:

> *'Installers have too little experience, and therefore too little knowledge about BIPV costs, labour time, and how to install, and therefore they do not offer the product or ask too high a price' (A2).*

This makes it challenging for BIPV to enter the market. Intermediation could help to improve the knowledge exchange about how to communicate BIPV costs and benefits with potential adopters and should be shared with potential user-intermediaries such as architects, engineers, and energy coaches.

5.5.3 Decision stage

Based on their experiences in the first two decision stages, potential adopters will decide to adopt or reject BIPV. Innovations, such as BIPV, carry some degree of uncertainty, and potential adopters will often seek social reinforcement or the opinion of peers in this stage to reduce this uncertainty (Rogers, 2003a). Rogers (2003a) points out that the perceived uncertainty about an innovation can be reduced if the innovation can be tried out on a partial base. The trial by a peer can be a substitute in the case when this is not possible, such as with BIPV. However, as BIPV have not yet been widely diffused, it is hard for potential adopters to find peers who have adopted BIPV. Several interviewees in this study proposed that pilot projects should be facilitated (see Table A2 in the Appendix) in order for the demand side to gain more awareness and knowledge on BIPV, and reduce uncertainties. Previous research has indicated that pilot projects can be an alternative way to build up trust in the innovation and share knowledge about the experiences with the demand side and other stakeholders (Van Boxstael et al., 2020). Lobbying for additional (governmental) funding is needed to finance the additional costs of the pilot projects, as well as to share the knowledge in several stakeholder networks.

5.5.4 Implementation stage

When the adopter choses in favour for the innovation in the prior stage, they will engage in activities to purchase BIPV and will start organising the implementation stage. Glaa and Mignon (2020) point out that an incorrect implementation can lead to a suboptimal use of the innovation, which can lead to dissatisfaction on the part of the adopter in the confirmation stage. However, the results indicated that there is a lack of qualified and experienced BIPV installers (see also Table A1 in the Appendix). Some interviewed suppliers (S1, S2, and S4) mentioned that they had to invest a lot of time in instructing installers at the building site, which will no longer be feasible when demand increases. This hampers the uptake of BIPV, and therefore more qualified installers are needed. To facilitate this knowledge exchange, training for installers, electricians, and roofers should be offered more systematically. An intermediary could organise and facilitate this kind of training, but lobbying for additional government funding will also be needed; moreover, educational institutions will have to be lobbied to implement this knowledge in their training programmes.

As discussed earlier, another solution to improve the implementation stage is that BIPV products can be made more compatible with traditional building components, so that they can be more easily incorporated in the building. Integrating BIPV in large prefab building elements (roofs and facades) can also contribute to a better and faster implementation. A strong collaboration between the BIPV suppliers and the construction supply sector is needed for this. However, as discussed in a previous section, there is an intermediation gap between BIPV suppliers and the construction supply sector when it comes to facilitating this change.

5.5.5 Confirmation stage

In the confirmation stage, adopters experience BIPV and form a positive or negative attitude towards the innovation, based on their own experiences, and/ or seek reinforcement of the decision already made (Rogers, 2003a). One issue that emerged from the interview results was that negative publicity about BIPV in the past has restrained potential adopters and the construction sector from implementing BIPV (see also Table A1 in the Appendix). The results indicated that there have been certain issues regarding fire safety – issues that continue to influence adoption decisions. Two architects explained this question as follows:

> *'There have been a number of fires with integrated panels in the past, and that has had a very negative impact on the market. In hindsight, this was caused by an unprofessional performance, but still influences perception at this time' (A3).*

> *'Many contractors use this argument to convince clients not to install BIPV' (A4).*

A study by Bende and Dekker (2019) has demonstrated that these problems were caused by poor installations. Therefore, a proper installation of BIPV in the implementation stage is crucial as it directly influences the confirmation stage, as well as the perception of BIPV by the new potential adopters. However, further knowledge exchange is needed on the exact circumstances of these incidents and how to prevent them. In addition, training installers on how to implement BIPV correctly is crucial in this regard.

Another way to counter negative experiences is to exchange knowledge about positive experiences with BIPV, as potential adopters look to early adopters for advice, information, and best practice examples (Rogers, 2003a). Since BIPV is not widely diffused yet, it is difficult for potential adopters to find peers. This can be improved by publishing information about previous projects to raise awareness (see also 5.4.1), as well as by pilot projects (see 5.4.2). In addition, the literature points out that exchanging knowledge on innovations in social networks can have a positive effect on the adoption rate (e.g. Broers et al., 2019; Wilson & Dowlatabadi, 2007). Supplier S4 explained how they organise this:

> *'We have an aftersales talk with our clients and leave brochures behind. They act as our ambassadors and this leads to new customers' (S4).*

This exchange of positive experiences is currently done on a very limited scale. To address this problem, an intermediary organisation could enhance and facilitate this knowledge exchange on previous projects between adopters and potential adopters in a more structured way.

5.6 Discussion and conclusions

The objective of this study was to contribute to an improved understanding of how intermediation affects the multiple stages of the BIPV decision-making process in the Netherlands. It contributes to the existing literature by empirically ascertaining: 1) what kind of intermediaries and intermediary activities exist in the Dutch BIPV decision-making process, 2) what kind of intermediation gaps and challenges slow down the diffusion of BIPV, and 3) how intermediation can improve the multiple stages of the BIPV decision-making process. The remainder of this section discusses a number of findings arising from our specific focus on the demand for intermediary activities and actors within the BIPV decision-making process, as well as key practical and policy implications and recommendations.

5.6.1 Diversity in intermediation actors and functions

Our analysis identified a number of actors who can act as intermediaries in the BIPV decision-making process. First, private actors, such as architects, engineers, and companies in the construction supply chain. Second, public actors, such as local energy coaches. Third, public-private actors such as the BIPV Association, and fourth, non-profit actors, such as BIPV adopters who can act as intermediaries for their peers. These (potential) intermediation actors were also identified in prior studies (see Table 5.3). Our results indicated also that not only designated intermediaries (as studied by Glaa and Mignon (2020)) can perform intermediation activities, but that un-designated intermediaries play a key role in the BIPV decision-making process. It is therefore imperative to apply a holistic approach when studying intermediation.

The findings of our study demonstrated that a variety of intermediation functions and activities are required to enhance the BIPV decision-making process in the Netherlands. All five intermediation functions were found to be essential. However, the emphasis is most on knowledge exchange and networking at all stages of the decision-making process, because this is an emerging technology and more awareness is essential among potential adopters and other actors within the system. The function of facilitating is mostly needed in the persuasion and implementation stage, as adopters need assistance with configuring the BIPV technology to their specific contexts, and with integrating BIPV into their building. It was found that the functions of visioning and institutional change are more crucial between the BIPV suppliers and the government, but also between suppliers and the construction supply sector. This higher system level intermediation is needed to perpetuate and accelerate the diffusion of BIPV.

5.6.2 Maturation of the BIPV decision-making process needs a dynamic ecology of intermediaries on different system levels

The study findings highlighted that 'an ecology of intermediaries' (Hyysalo et al., 2022; Kivimaa & Martiskainen, 2018a; Stewart & Hyysalo, 2008) is crucial to perform diverse intermediation activities in the various stages of the BIPV decision-making process between different actors, but also at different system levels. Based on our analysis, we compiled an overview of the intermediation needs, functions and actors in the BIPV decision-making process assorted per decision stage. This is presented in Figure 5.5. At the top, the stages of the decision-making process are presented, and below the intermediation needs. Intermediation needs are divided into user and process intermediation needs that directly affect the BIPV decision-making process, and into niche and regime-based intermediation that indirectly affect the decision-making process. This higher system level intermediation is needed to improve user and process interaction, to facilitate and educate potential user and process intermediaries such as architects, engineers and energy coaches, but also BIPV adopters (peers). This is discussed in more detail in the following sections.

The construction supply sector can also play a pivotal role as an intermediator between BIPV suppliers on the one hand, and the potential adopters and process intermediaries (architects, engineers, and energy coaches) on the other. Further, construction supply companies can also act as intermediaries between BIPV suppliers and contractors and installers to improve the implementation process. As illustrated in Figure 5.5, regime-based intermediation by the construction supply sector can enhance the BIPV decision-making process in the stages preceding the decision, as well as post-decision. However, Stewart and Hyysalo (2008) report that in uncertain and immature markets, such as BIPV, intermediaries play an influential role. However, this position can sometimes be fragile and difficult to predict and requires nurturing and protection. It is therefore necessary to implement policies to facilitate these potential intermediaries (peers, architects, engineers, energy coaches, the construction supply sector), as well as to educate them about BIPV technologies.

The representation of the intermediation needs in Figure 5.5 could be seen as a rather static portrayal of ecologies of intermediaries as it demonstrates the intermediation needs at this time. Hyysalo et al. (2022) point out that intermediaries are part of complex ecologies of intermediation in changing ecological and societal fields. As the BIPV system evolves and technology advances, some challenges will be bridged by intermediaries but could also be overcome by other developments in the system such as expanded supplier offerings, better adjustment to the demand side, and better integration with more standard traditional building products.

Consequently, as the BIPV market evolves, also the need for intermediation will change: new intermediary actions, other actors acting as intermediaries, different intermediary support, and intermediation between other actors within the BIPV system.

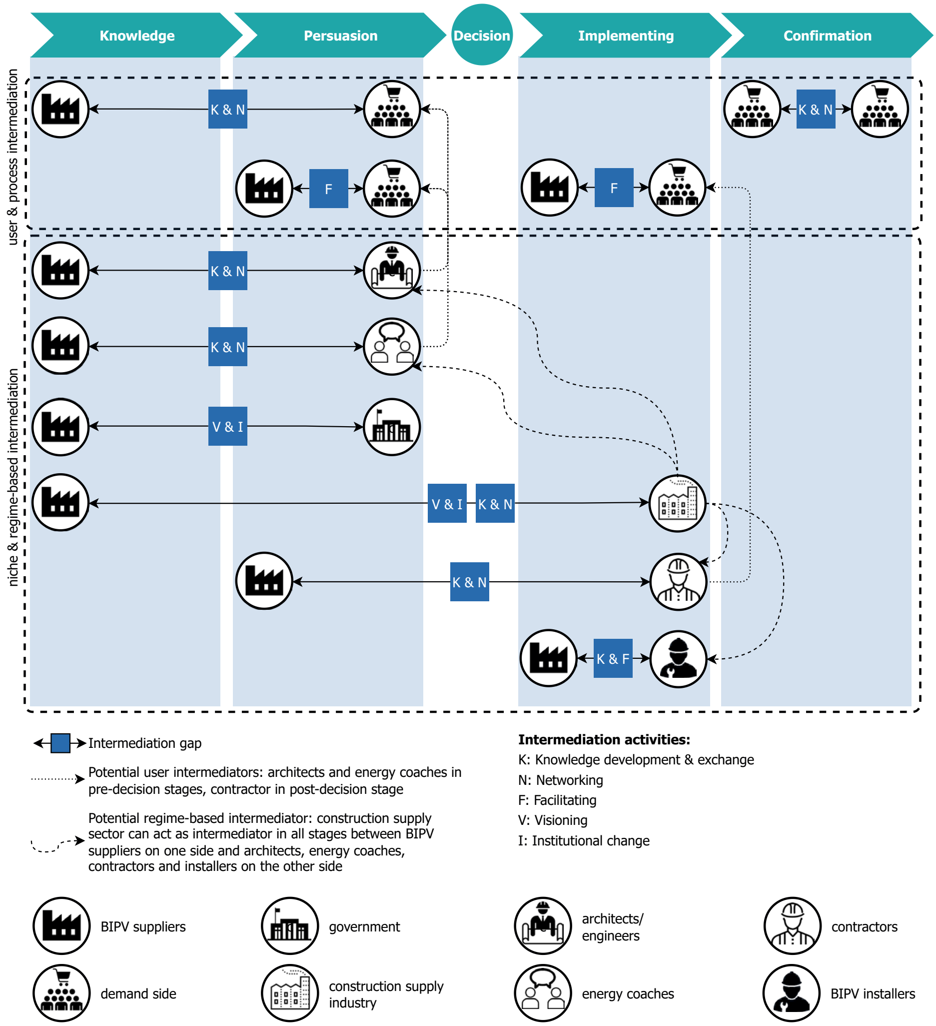

Figure 5.5. Structural intermediation needs, functions and actors in the different stages of the BIPV decision-making process in the Netherlands

5.6.3 Insufficient facilitation of intermediaries

This study reported that architects, engineers, and energy coaches are potential user and process intermediaries in the current regime. They can greatly support both projects and the demand side in the decision-making process, and can therefore play an effective intermediation role by informing and facilitating potential adopters about BIPV in the knowledge and persuasion stage of the decision-making process. Fischer and Guy (2009) also argued that architects can play a crucial role as intermediaries but that this role has not been actualised thus far. This is also the case in the context of BIPV adoption in the Netherlands. Most of these identified potential intermediaries are not facilitated as such, nor do they always have sufficient knowledge of BIPV products. This can make them reluctant to provide potential adopters with positive advice about BIPV. Therefore, intermediation has got to be facilitated within educational institutions for developing training programmes on BIPV for architects, engineers, and energy coaches. This is so that they can more effectively fulfil their role as a user and process intermediary in the knowledge and persuasion stage of the BIPV decision-making process. To facilitate the required resources and knowledge development, intermediation is needed at a regime-based policy system level.

The BIPV industry association was also identified as a key intermediary between different actors. However, our results showed that they have limited resources to structurally reach out to potential user and process intermediaries (architects, engineers, energy coaches), the demand side, the construction supply side and contractors and installers. Furthermore, they also have a lack of means to structurally lobby the national government for more specific and stricter energy legislation, clear certifications for BIPV, and funding for educational programmes and industrialisation of BIPV. This struggle for resources for intermediation has also been reported in other studies (e.g. Kivimaa, Primmer, et al. (2020). In order to address this issue, BIPVNL announced in August 2022 (after the interviews) that they will become part of Holland Solar. Holland Solar is an industry association for Dutch solar companies with 246 members. In this way, they hope to improve their operational effectiveness.

5.6.4 Peers as demand-side intermediaries

Our analysis revealed that BIPV adopters are key potential demand-side intermediaries. They can exchange knowledge, and network with potential adopters on their experiences with the technology. Previous studies reveal that this can be achieved through social networks (Broers et al., 2019; Wilson & Dowlatabadi, 2007), internet-based energy communities (Hyysalo et al., 2018), and pilot projects (Van Boxstael et al., 2020). According to Wilson and Dowlatabadi (2007), homeowners who have adopted certain energy measures can influence peers in their social network. Likewise, Hyysalo et al.

(2018) point out that adopters of energy measures can act as transition intermediaries by helping other citizens '*who demand more exposure, clearer information and less uncertainty about new technology options*' (Hyysalo et al., 2018, p. 872, pg 872). In their study on community energy in the UK, Seyfang et al. (2014) found a different source of learning: knowledge sharing between local energy projects and how this can contribute to niche development: '*projects tend to learn from each other rather than from dedicated networking organisations*' (Seyfang et al., 2014, pg 42). However, as BIPV is not widely diffused yet, it is more difficult for potential adopters to find peers. In addition, we found that this interaction between 'experienced' BIPV adopters and potential adopters has not yet been facilitated or organised in the case of BIPV in the Netherlands. This is a challenge because well-resourced intermediaries are likely to achieve more (Kivimaa, Primmer, et al., 2020). Therefore, intermediation is needed at the niche or regime-based level to facilitate this demand-side intermediation.

To act as intermediaries, BIPV adopters have to be satisfied with their installed BIPV. A good installation by contractors and installers is therefore essential. Educational training for contractors and installers can improve the implementation and confirmation stage of the decision-making process, as the BIPV will be properly installed and adopters will be more satisfied, which will assist in the diffusion of the innovation. Intermediation at a regime-based policy level is needed to facilitate this.

5.6.5 Demand-side configuration

According to our findings, BIPV needs to be better adapted to be widely used in standard building products as well as customizable to different contexts of the demand side. Rogers' diffusion theory points out that re-invention (changing and modifying) of a technology by the demand side can lead to a faster rate of adoption (Rogers, 2003a). Moreover, a study by Hyysalo et al. (2013b) demonstrates that sustainable home energy technologies, which have some level of modularity and adaptability, can speed up diffusion, as these technologies can be more easily modified to particular circumstances such as variation in demand-side buildings and needs. This demand-side-led configuration was also reported by Stewart and Hyysalo (2008) as one of the distinct actions of intermediaries, next to facilitating and brokering. Especially in the energy retrofit market, this adaptability to the context of the demand side is particularly necessary (Hyysalo et al., 2013b; Murto et al., 2019), because their current situation is relatively fixed, in contrast to newly built homes in which BIPV can be taken into account in the design. Some of the current BIPV products have these properties already, but many still need adjustment to meet the needs of the demand side. User intermediation between suppliers and the demand side could help to accumulate their wishes and needs regarding BIPV, which can be used to adapt and improve the technology in order to accelerate diffusion.

The demand-side configuration of BIPV products could be improved by better adapting them to widely-used building products in the construction supply sector (standardisation). This will allow the construction supply industry to play an intermediary role between the supply and demand side, as discussed in 6.1. The construction supply sector already performs this intermediary role for other building products, and BIPV suppliers could make use of these existing networks. However, the data demonstrated that collaboration between BIPV suppliers and the construction supply sector is still limited to only a few suppliers at present, and intermediation between BIPV suppliers and the construction supply sector is essential to enhance diffusion. The Dutch Association for BIPV could play an intermediating role as an industry association, but has meagre resources to organise and facilitate this.

5.6.6 Concluding remarks

In conclusion, this study reveals that the BIPV decision-making process requires different kinds of intermediation. Rather than focusing on specific types of intermediaries, we explored what intermediation activities can support the decision-making process. The findings demonstrate that a dynamic 'ecology of intermediaries' is needed to perform various intermediation functions and activities at different system levels, to enhance the multistage decision-making process. As these activities and actors are highly interrelated and interdependent, it is imperative to consider all these aspects and interrelations and not to address intermediation in a one-dimensional way by focusing on certain types of intermediaries or isolated activities. This paper contributes to innovation adoption and intermediation studies as it combines these two lenses, and provides insight into what type of intermediation is essential at each and every stage of the decision-making process, at what system-level, and who should act as an intermediary in the case of BIPV adoption in the Netherlands and beyond.

Limitations and further research

While this paper contributes to a better understanding of how intermediation can improve the (BIPV) decision-making process, the study also has a number of limitations. The main limitation is that we were unable to determine whether intermediation is sufficient for dealing with the identified barriers. We were only able to determine the necessity for intermediation, based on identified barriers for which intermediation is useful and relevant. This relates to the fact that intermediation needs can change over time when the system and technology evolves. Another limitation is that this study focused on one specific type of innovation in one specific country, and with a limited number of respondents. We therefore suggest that further studies should be undertaken relating to intermediation in the decision-making process for other technologies and other countries. It is likely that in other contexts the required intermediation actors, activities, and functions could differ at the various decision-making stages. Lastly, some actors were not included in this study, such as (potential) individual BIPV users, energy coaches, financial, non-profit and regional governmental organisations, and their inclusion could yield additional information about the decision-making process.

Acknowledgements and funding

The authors would like to thank the respondents for sharing their insights and experiences in the interviews. This research was funded by the Dutch Organization for Scientific Research (NWO, 023.013.033) and Rijksdienst voor Ondernemend Nederland (RVO, project MOOI BIPV(T), MOOI32020).

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

5.6.7 Appendix Chapter 5

Supplementary data to Chapter 5 can be found online at: https://doi.org/10.1016/j.erss.2023.103149:

- **Table A1**. Reported challenges in the different stages of the BIPV decision-making process, identified from the interview results.
- **Table A2**. Reported suggestions by the respondents to improve intermediation by the respondents, per decision-making stage and pe intermediary function.
- **Supplementary materials**: Interview protocol & overview project meetings

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CHAPTER 6

DISCUSSION AND CONCLUSIONS

6.1 Introduction

Homeowners can contribute to the transition to a low-carbon housing stock by choosing and implementing low-carbon measures to improve energy efficiency and produce renewable energy in their homes. The need to better understand homeowners' decision-making processes and how they can be improved has been the driving force behind this thesis. Therefore, this thesis aimed to identify and evaluate the varying factors that influence homeowners' multistage decision-making processes about low-carbon measures. The main research question of the thesis is:

> *What factors influence the decision-making processes of Dutch homeowners regarding residential low-carbon measures, and what interventions can encourage them to do more?*

This research was conducted through the analysis of a number of residential low-carbon technologies: ERM (chapters 2 and 4), RPV (chapter 3), and BIPV (chapter 5). Despite the proven technical and economic potential of these technologies, their implementation has been slower and more challenging than expected. The research primarily focused on the Netherlands, since there has been a long history of policy efforts to stimulate (most) of these technologies, but diffusion has lagged behind.

This chapter summarizes the key results of the empirical chapters of the dissertation. It answers the (sub)research questions and presents the key findings of theoretical and empirical research on low-carbon decision-making processes by private homeowners and social housing associations. Next, the concluding remarks to answer the main research question, followed by a discussion of the main limitations and recommendations for further research.

6.2 Key findings

In response to the title of this thesis, the theoretical and empirical findings reveal that homeowners' energy decisions are NOT only about energy. Instead, the socio-technical analysis in this thesis demonstrates that homeowners' multistage decision-making processes are influenced by a wide range of factors, which are shaped by homeowners' heterogeneity, embedded in social practises, affected by justice aspects, and encouraged by intermediary activities. Table 6.1 presents an overview of the research questions and key findings, which are further discussed in the remainder of this section.

Table 6.1. Summary of key-findings per (sub)research question

Study	Sub-research questions	Key findings
1	What are the influencing factors in the various stages of the decision-making process of private homeowners regarding energy renovation measures?	• An ERM decision-model is developed that distinguishes between different stages of the decision-making process, the multiple factors that influence the stages, and the factors homeowners consider when making a decision whether to adopt or reject ERM • Energy decisions aren't isolated decisions but are situated in daily life with multiple decision moments • Influencing factors differ per decision stage and may differ from homeowner to homeowner • The use of appropriate policy actions at different stages of the decision-making process is crucial to making ERM more appealing to homeowners
2	How can better knowledge about the heterogeneity of potential adopters of residential photovoltaics via a segmentation model be used for designing targeted communication strategies?	• A segmentation model is created that identifies five substantial segmentation groups based on people's type of educational background or profession (technical, financial-economic or other) and their level of environmental concern • The segmentation groups reveal significant differences relating to their perception of RPV • The five segmentation groups must be targeted differently, to make policies, communications, and marketing campaigns more effective • RPV adopters should be facilitated by municipalities to demonstrate and promote RPV to their peers • RPV diffusion requires objective advice for potential adopters

Table 6.1. Continued

Study	Sub-research questions	Key findings
3	What justice aspects affect energy renovations in social housing and how can better knowledge about this be used to achieve outcomes that are more just?	• The multidimensional justice perspective can contribute to more just energy renovation processes in social housing • A broader pluralistic justice approach is needed to meet the needs of vulnerable households • It is imperative to examine the interrelationships between the justice dimensions as they influence each other • More awareness should be given to the five justice dimensions during the various stages of the energy renovation process, as they can vary depending per stage
4	How does intermediation affect the multiple stages of the BIPV decision-making process in the Netherlands, and how can it be improved?	• The multistage adoption process requires the development of a dynamic 'ecology of intermediaries' at various system levels • There are different intermediary activities needed at the various stages of the BIPV decision-making process, between different actors and at different system levels • Intermediation needs can change over time • Undesignated and informal intermediaries play a key role in the decision-making process • It is imperative to study intermediation holistically, as the processes and actors are highly interdependent and interconnected • The use of effective policy actions are needed on different system levels and targeting different decision stages to encourage BIPV adoption

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6.2.1 Exploring the influencing factors in decision-making processes of private homeowners regarding energy renovation measures

The first study addresses the limited understanding of the influencing factors of homeowners' decision-making processes regarding low-carbon measures for their homes. It provides a holistic perspective on energy renovation decisions taken by Dutch private homeowners. The research aim was to explore what the influencing factors are at the various stages of private homeowners' decision-making regarding ERM. Data were collected among private homeowners in the city region of Parkstad Limburg (NL) using online surveys (n=91) and interviews (n=52). The study introduces a decision-making model for private homeowners. The model distinguishes between various stages of the decision-making process and the factors homeowners consider when deciding whether to adopt or reject ERM. These factors are different at every decision stage. Below, these factors are discussed in more detail by decision stage.

The first stage. 'getting interested', of the decision-making process is the most critical as people begin to consider ERM here. The findings demonstrate that this stage can be influenced positively and negatively by the following factors: level of environmental concern, socio-demographic factors, physical factors, and external developments. Policy actions can encounter these factors by (1) creating more environmental awareness and the need for ERM by increasing media attention; (2) implementing specific policy actions to target homeowners who are less likely to adopt because they are older, less educated, or have a lower income; (3) targeting specifically homeowners who have just moved into the house or have changes in the household; or (4) have plans to do construction work or replacement of building elements or heating systems; (5) unburden the homeowners by organizing the implementation of ERM by skilled and trustworthy local companies; (6) stimulating energy communities, launching grass-roots initiatives, and supporting local energy co-operatives by raising awareness and attracting public support.

The second stage of the decision-making process is the 'knowledge stage'. The results reveal that a lack of sufficient knowledge can negatively affect homeowners' ERM adoption during this stage. The three main influencing factors at this stage are: personal background, such as an interest in technology or sustainability; advice from their social network; and advice from professionals. Policy interventions to improve ERM adoption at this second decision-stage may include: (1) facilitating information exchange about ERM among homeowners living in similar homes and having similar socioeconomic backgrounds. Local governments can facilitate 'ambassadors' to demonstrate their ERM in their homes to their peers; and (2) offering credible, objective advice by local governments about ERM focused on the homeowner's specific situation, knowledge levels about ERM, personal needs, and preferences.

After gaining enough knowledge about ERM, homeowners form a certain attitude and perception towards ERM at the 'forming an opinion' stage. Financial-economic factors, such as the perception of their energy bill, ERM investment costs, and the availability of financial savings or other financial possibilities, are now more relevant. Local governments can address these financial barriers by offering financing options such as low-interest loans or subsidies.

The last three stages of the decision-making process are: 'making a decision', 'implementing ERM', and 'experiencing ERM'. Even though these final stages were not studied in detail, some conclusions can be drawn. When homeowners decide to adopt ERM, the next steps are implementing ERM and experiencing ERM. In these last two stages, homeowners form a positive or negative perception of ERM based on their own experiences. This perception will influence what they tell others in their social network about ERM and are therefore very relevant. Local governments can facilitate experienced homeowners to exchange their ERM knowledge with their peers, as also discussed in the previous section.

Contributions to science and practise

As a result of Study I, and to answer the first research question, this study developed a decision-making model for private homeowners regarding ERM that identifies a variety of influencing factors throughout the multistage decision-making process. This study contributes to adoption and diffusion literature by giving more in-depth insights into which factors affect what stages of the decision-making process in the context of ERM adoption by private homeowners. The results demonstrate that energy decisions are not isolated decisions, but are situated in daily life with multiple decision moments. It is also imperative to note that these influencing factors are crucial at different stages of the decision-making process. In order to make ERM more appealing to homeowners, it is crucial to deploy the appropriate policy actions that target different stages of the decision-making process and the variety of factors that influence them.

6.2.2 Understanding the heterogeneity of residential photovoltaics adopters via a segmentation model

In the second study of this thesis, a segmentation model was developed to gain a theoretical and empirical understanding of the heterogeneity of potential RPV adopters. It tackles inconclusive results on the influence of the level of homeowners' environmental concern and the lack of insight into homeowners' type of educational background or profession on adoption decisions in prior studies. The aim of the study was to investigate how a better knowledge about the heterogeneity of potential RPV adopters via a segmentation model can be used for designing targeted communication strategies. To investigate this, a quantitative survey (n=1395) was conducted among participants of the 'solar panel project' in the city region of Parkstad Limburg (NL). The segmentation model identifies five substantial segmentation groups based on people's type of educational background or profession (technical, financial-economic or other) and their level of environmental concern. The results reveal significant differences between the segmentation groups, relating to personal characteristics and their perception of RPV. Homeowners' perception of RPV was conceptualised by Rogers' five attributes: relative advantage, compatibility, complexity, trialability and observability (Rogers, 2003a). The main findings of this study are discussed in more detail below.

In the statistical analysis, no significant differences were found between the segmentation groups on the perceived relative advantage of RPV. According to Rogers (2003a), homeowners should consider RPV as having a relative advantage compared to their current situation before adopting them. This could be saving energy costs, increasing house value and seeing RPV as a worthwhile investment. The data demonstrate that homeowners' perceived relative advantage was positively influenced by the local solar panel project they participated in. The project included a loan to address perceived high upfront investment costs, which was also available for low-income households. In addition, the majority of respondents highly appreciated that everything was arranged for them in the project. Moreover, they valued that the municipality, not a company, provided the service and guarantee, as the municipality was considered more trustworthy. Overall, the 'all-in-one' project positively affected homeowners' perceptions of RPV's relative advantage which led to a higher adoption rate than the national average in this project.

The group of individuals who are environmentally motivated but have no technical or financial-economic background demonstrate some specific features. First, they perceive RPV, and the information about it, as too technical and complicated. This negatively influences their perceived complexity of RPV. To counter this, a clear explanation of the operation of the RPV system must be given, in a less technical way. In addition, this group is more influenced in their decision-making process by the experiences of peers who have adopted RPV. Therefore, this group can be targeted more effectively by making use of existing social networks to promote RPV.

The group of environmentally motivated people with a technical background and no financial-economic background demonstrate more knowledge of RPV and finds their RPV system less complex, than the other groups. This group can be targeted more effectively by emphasising the technical specifications and benefits of the RPV system in communication strategies. Also, this group has more prior experience with other energy measures, as well as advising people in their social network. Therefore, this group could be used and facilitated by policy-makers and companies as ambassadors for energy renovation measures such as RPV.

The group of environmentally motivated people with a technical and financial-economic background display similar results as the second group and therefore, the same recommendations apply to this group.

The group of environmentally motivated people with a financial-economic background and no technical background reveal that they liked the aesthetics of their RPV system less. Therefore, offering visually appealing photovoltaics could improve RPV acceptance by this group. Furthermore, this group perceives their RPV system to be more complex (similar to group 1). Therefore, a clear and less technical explanation of the RPV system operation must be given.

Lastly, for the group of individuals with a lower environmental concern, RPV benefits could be targeted more effectively by focusing more on a broader range of RPV benefits, and less on environmental benefits. The findings reveal that this group is also significantly less proud of their RPV system. This suggests that they are not really interested in expressing their 'green status' when installing RPV. Furthermore, they tend to trust their RPV system less, which can be countered by explaining it more clearly and giving objective information. In addition, the findings reveal that this group has a limited amount of experience installing other energy measures and could benefit from peers in their social network who have already adopted RPV.

Contributions to science and practice

In summary, this study provides an answer to the second research question by revealing that a segmentation model can be used for a better understanding of the heterogeneity of potential RPV adopters. It demonstrates that the five identified segmentation groups, based on level of environmental concern and personal background, should be targeted differently to make policies, communications, and marketing campaigns more effective. Specific aspects that trigger certain people are not mutually exclusive, so attention must be paid to all those aspects so that people can choose for themselves which are relevant to them. RPV adopters can be facilitated by municipalities to demonstrate and promote RPV to their peers in their social networks. Additionally, offering aesthetically pleasing photovoltaics, as well as providing objective, clear advice, can also help promote RPV diffusion under certain groups. This segmentation model makes a contribution to the adoption and diffusion literature and adds insights to the research on RPV adoption by households. Compared to other developed segmentation models for RPV adoption, this model provides a segmentation of RPV adopters based on educational background or profession and level of environmental concern.

6.2.3 Applying a multidimensional justice perspective for a more people-centered energy renovation process in social housing

The third study of this thesis used a multidimensional justice perspective to provide better insight into socially fair and people-centered energy renovations in social housing. This is a topic which is understudied in previous work. The aim of the study was to explore what justice aspects affect energy renovations in social housing and how better knowledge about this can be used to achieve outcomes that are more just. The topic was investigated in-depth by interviewing members of tenants' associations and employees of social housing associations in the Netherlands (n=15) to gather their experiences and perspectives. The findings of this study reveal that the multidimensional justice perspective applied to social housing renovation processes can contribute to more just and socially fair energy renovation processes. This is because it offers a more pluralistic justice perspective which is especially crucial in the context of vulnerable households.

Prior studies demonstrated that energy renovations in social housing are often technology-driven and often implemented top-down (Boess, 2017; Breukers et al., 2017; Hickman & Preece, 2019; Uyterlinde et al., 2019). Moreover, the needs and wishes of the tenants are often not taken into account, which could result in increasing vulnerability to energy poverty and inequality (Filippidou et al., 2019; Guerra-Santin et al., 2017; Sovacool et al., 2019; Straver & Mulder, 2020). The transition to climate neutral social housing touches on important justice aspects due to the high proportion of vulnerable households living in social housing (Braga & Palvarini, 2013). So far, not enough attention has been given to the justice aspects of the energy renovation process for social housing. To meet the needs of vulnerable households, this study points out that a broader pluralistic justice approach is needed. This approach comprises five interrelated justice dimensions: distribution, recognition, participation, capability and responsibility. These are discussed in more detail below.

The results indicate that the five justice dimensions are interrelated and that they can reinforce each other directly or indirectly. As many vulnerable households are present in social housing, a more pluralistic view of justice is necessary. This is because the dimensions of recognition, capability and responsibility are particularly relevant to this group, in addition to the more common justice dimensions of distribution and participation. It is therefore crucial to examine the interrelationships between each of these justice dimensions, which has not been explored sufficiently in prior research. According to the findings, the five justice dimensions and their interrelations should be given more attention throughout the energy renovation process, as they can vary from stage to stage.

As for distribution, the study points out that tenants and the SHAs should establish a clear agreement regarding how to resolve financial and non-financial distributional issues during and after the energy renovation process. In the Netherlands, tenant participation is not mandatory when there is no rent increase due to the renovation. Due to this, distribution issues are often not discussed and agreed upon with tenants, which can lead to negative outcomes for tenants.

A fair participation process requires recognizing tenants' diversity with their various needs, rights, and experiences. However, SHAs often struggle to involve a representative group of tenants, particularly vulnerable households. Vulnerable households are often less capable of participating because they have other more pressing issues to deal with. Furthermore, it is not always straightforward to identify vulnerable households as such. As a result, they aren't receiving the assistance they need to improve their living conditions and capabilities. In the energy renovation process, these barriers may hinder the recognition of diverse needs of vulnerable households. This may adversely affect distribution issues.

In order to have a fair participation process, tenants should have the opportunity to express their needs and wishes regarding improving their living environment and limiting their inconvenience during renovations. It is therefore imperative that this participation begins before the design of the renovation is developed. However, in most cases, this does not happen. A variety of participation methods can be utilised to meet individual needs and preferences, and also working in multidisciplinary project teams can help to improve this. Since vulnerable households are often difficult to involve in participation processes, individual methods can be used specifically for them. It is important for the SHA and tenants to fairly discuss and agree on the distribution of financial and non-financial distribution issues during the participation process. This is also required when there is no rent increase after the renovation because rent is only one distributional issue within the process.

Capability is a justice dimension that has been understudied in previous research on energy renovations, primarily due to its absence from the framework. However, it is a vital dimension because of the large number of vulnerable households in social housing. According to this study, vulnerable households often lack the capability to participate. As a result, participation will be less inclusive and social inequality may increase. Tenants may benefit from capability enhancement by learning new skills and abilities that are useful not only in the participation process but in other aspects of their lives too. As tenants build capabilities, they can take on more responsibilities during energy renovations and this could also result in them taking better care of their home. However, the results demonstrate that SHAs are not currently focusing on this area that much. This is because enhancing tenants' capability is a complex and difficult task because structural problems are at their root. These problems are not easily resolved and require long-term commitment from all stakeholders. Special targeted actions and long-term programmes will be necessary for this capability enhancement.

Contributions to science and practice
In order to answer the third research question, this study reveals which justice aspects affect energy renovations in social housing, and how better knowledge about this can be used to achieve outcomes that are more just and socially fair. The findings demonstrate that a more just and people-centred energy renovation process in social housing can be achieved through the application of the multidimensional justice perspective of the five justice dimensions. The study found that the multidimensional perspective is especially useful when dealing with the needs of vulnerable households. The perspective can be used to implement a broader and more pluralistic perspective on justice aspects in the energy renovation process. The study contributes to existing literature by providing a deeper understanding of the five justice dimensions and their interrelationships in the context of energy renovations of social housing. Another important contribution is the identification of interaction effects, which reveal that the five justice dimensions are closely interrelated and should not be treated separately. Yet, dealing with justice is evidently not a simple managerial issue due to the contested nature of justice and the role of various values and interests.

6.2.4 Intermediating the decision-making process for building-integrated photovoltaics

The fourth study of this thesis explored the decision-making process of an emerging technology: BIPV. Several challenges can arise during the decision-making process of an emerging innovative technology. Prior research has demonstrated the effectiveness of intermediaries in dealing with these issues. However, intermediation was not studied yet in-depth in previous BIPV-studies, and there is a also a general lack of knowledge about intermediaries located downstream in the supply chain between adopter and supplier. Therefore, the aim of the study was to investigate how intermediation affects the multistage BIPV decision-making process in the Netherlands, and how it can be improved. In order to collect data, Dutch actors involved in the BIPV system were interviewed (n=26). This study developed an overview of the structural intermediation needs, functions and actors in the multistage BIPV decision-making process in the Netherlands, which are discussed in more detail below.

The study findings highlight that an ecology of intermediaries is crucial to perform diverse intermediation activities at the various stages of the BIPV decision-making process. This is not only between different actors, but also at different system levels, and can change over time. The analysis identified that there are several actors who act as intermediaries in the BIPV decision-making process. These are often not specially assigned intermediaries, but have other main activities or are peers in the homeowners' social network. These undesignated intermediaries play a key role in the BIPV decision-making process. It is therefore imperative to apply a holistic approach when studying intermediation actors so that these intermediaries are not overlooked.

The following five main intermediation activities are identified in our comprehensive literature review: (1) knowledge development and exchange, (2) networking, (3) facilitating projects, (4) visioning, and (5) institutional change. All five intermediation functions were found to be essential to enhance the BIPV decision-making process in the Netherlands. However, it is imperative to emphasize knowledge exchange and networking throughout the entire decision-making process. BIPV is an emerging technology and more awareness is needed among potential adopters and other stakeholders in all stages. The function facilitating is most crucial at the persuasion and implementation stages, when adopters are faced with configuring BIPV technology according to their specific contexts, as well as with integrating it into their buildings. The study also reveals that the functions of visioning and institutional change are most required between BIPV suppliers and the government, as well as between suppliers and construction suppliers.

The results of the analysis demonstrate that BIPV adopters are important demand-side intermediaries since they can exchange knowledge and network with potential adopters about their experiences with the technology. However, potential adopters may have difficulty finding peers because BIPV has not been widely diffused. Further, the results demonstrate that the interaction between 'experienced' BIPV adopters and potential adopters has not yet been facilitated or organized. Thus, intermediation is needed at the niche or regime-based level to facilitate this demand-side intermediation. Furthermore, in order to act as intermediaries, BIPV adopters must be satisfied with their system. Therefore, contractors and installers must have enough knowledge and skills to install BIPV properly. This is not always the case at this time. To improve the implementation and confirmation stages of the decision making process, educational training for installers is needed. Intermediation at a regime-based policy level is needed to facilitate these educational needs.

Another key finding is that BIPV needs to be better adapted to widely-used standard building products and customizable to different demand contexts. This re-invention (Rogers, 2003a) or demand-side-led configuration (Stewart & Hyysalo, 2008) is a distinct action for intermediaries that can lead to a faster adoption rate. Some of the current BIPV products have these properties already, but many still need adjustment to meet demand needs. When standardised, construction supply companies will be able to play an intermediary role between the supply and the demand side. This is what they already do with other building materials. It is evident, however, that structural collaboration between BIPV suppliers and the construction supply sector is restricted to only a few suppliers at present. In order to enhance diffusion, regime-based intermediation between BIPV suppliers and the construction supply sector is necessary.

Contributions to science and practice

To answer the fourth research question of this thesis, this study reveals how intermediation affects the multistage BIPV decision-making process in the Netherlands and how this can be improved. Instead of focusing on specific types of intermediaries, this study examined what types of intermediaries and intermediary actions could support the BIPV decision-making process. The results demonstrate that to enhance the multistage decision-making process, a dynamic 'ecology of intermediaries' is required to perform different intermediation functions and activities at different system levels. Since these activities and actors are highly interconnected and interdependent, it is imperative to examine all of these aspects and their interrelationships. This is rather than focusing on a single type of intermediary or isolated intermediation activities. By combining both innovation adoption and intermediation perspectives, this study contributes to innovation adoption and intermediation literature by providing insight into what type of intermediation is essential at each and every stage of the decision-making process, at what system-level, and who should or could act as an intermediary. In addition, this study demonstrates that intermediation is highly interdependent and interconnected, it is crucial to assess it holistically.

6.3 Concluding remarks

This thesis investigated the factors that influence Dutch homeowners' decision-making processes regarding residential low-carbon measures, and what interventions could persuade them to take further action. The socio-technical analysis of homeowners' energy decisions demonstrates that relevant decisions are not isolated decisions but are situated in daily life with multiple decision moments and dynamic circumstances. These multistage decision-making processes are influenced by a variety of factors which affect different decision stages, and are shaped by homeowners' heterogeneity, embedded in social practises, affected by justice aspects and encouraged by both formal and informal intermediaries. There are many stakeholders that can utilise this knowledge, including policymakers, employees and members of social housing and tenant associations, suppliers, consultants, energy coaches, and architects. By understanding these insights, low-carbon policies, internal procedures, advice to homeowners, and communication campaigns can be enhanced to increase the diffusion of residential low-carbon technologies. To conclude, homeowners' decision-making processes regarding residential low-carbon measures are complex and vary per context and individual, which is why a holistic approach in research and policies is necessary to address homeowners' different preferences and needs. In conclusion, energy decisions are not only about energy but are influenced by a variety of factors and dynamic circumstances.

6.4 Limitations and recommendations

The findings of this thesis have to be seen in light of some limitations. There are some apparent limitations regarding sample collection. First, data was gathered in a specific country and in some studies in a specific region (Studies I and II). Results could be different in other geographical contexts. Follow-up studies could extend the scope of data collection to other regions and countries. Second, in studies I, III, IV, the interview method was used to gain a better understanding of the cases in depth and detail, to grasp meaning in a particular (dynamic) context (Patton, 1999), and to allow the respondents to satisfactorily describe their decision-making process and experiences. As a result, there was a limited sample size for these studies and extending the scope of data collection can generate further elaboration of the study findings. Third, in studies I and II there was a high share of adopters of ERM and/or RPV, which could influence the predictions made for non-adopters. This strategy was chosen because of the limited access to non-adopters in the chosen case studies. Follow-up research should include more non-adopters in their studies. Fourth, in studies III and IV there were no actual users included in the data collection. This is because of the limited access to this groups of people since data-collection was executed during the COVID-19-pandemic. Most interviews were therefore held online and limited to professionals in the field. Additional studies should include validation of the findings in user-groups, additional interviews or surveys. Fifth, this thesis focused mainly on private homeowners and social housing associations. Commercial landlords were not investigated in this study as they own a minor share (14%) of the Dutch housing stock and also owner associations of for example condominiums were not studied. In order to gain a deeper understanding of these groups' decision-making processes, they could be included in future research.

There were also some limitations regarding the methods used for data collection. For the Studies I, II, III and IV interviews were conducted to collect data. This qualitative data gives rich and detailed information about the experiences and visions of the respondents. However, the results could be influenced by the researcher who conducted the interviews and analysed the data. This has been overcome by employing a semi-structured interview protocol and discussion of the results in a larger research group to make interpretation and analysis more objective. In study II, a survey was conducted to collect statistical data. By using this method, a large sample size could be investigated but the results miss certain context and in-depth information about the respondents. To address these limitations, this thesis used a mixed-methods approach that combined qualitative and quantitative methods. Future research could take advantage of a wider variety of mixed-methods approaches combining quantitative and qualitative approaches.


A

ADDENDUM

Scientific and societal impact

This thesis offers a socio-technical analysis of homeowners' energy decisions, demonstrating that relevant decisions are not isolated choices but are situated in daily life with dynamic circumstances and multiple decision moments. The research uncovers that homeowners' decisions on the adoption of residential energy renovation measures, photovoltaics, and building-integrated photovoltaics are influenced by a variety of factors. Their decisions are shaped by the homeowners' heterogeneity, embedded in social practices, affected by justice aspects, and encouraged by intermediary activities. The thesis moves beyond socio-technical systems analysis by carefully considering the decision-making processes of heterogeneous actors and by highlighting justice aspects and the details of intermediation. The thesis offers insights into interventions that could encourage homeowners to do more to conserve energy. These acquired insights are essential because, although low-carbon technologies have proven technical and economic potential, their implementation has been slower and more challenging than expected. In part, this slow adoption can be attributed to the fact that low-carbon policies generally fail to take into account homeowners' diversity of concerns and motivations, often relying on generic approaches instead. This thesis offers a more holistic and comprehensive view of homeowners' decision-making processes regarding low-carbon measures to understand how they make choices based on a range of considerations, motivations, and contextual factors. This knowledge can be used by a variety of stakeholders, including policymakers, employees and members of social housing and tenant associations, suppliers, consultants, energy coaches, and architects. A better understanding of these insights can enhance the impact of low-carbon policies, internal procedures, advice to homeowners, and communication campaigns aimed at increasing the diffusion of low-carbon technologies. The remainder of this section presents the scientific and societal impact of this thesis.

Scientific impact

The scientific contribution of this thesis relates to the fields of low-carbon housing, renewable energy technologies, innovation adoption and diffusion theorie, justice perspectives, and studies on intermediation. In terms of methodology, this thesis demonstrates the use of a variety of research methods to study decision-making processes within broader theoretical frameworks. To investigate this topic, four empirical studies were conducted.

Study I addresses the limited understanding of the factors that influence homeowners' decision-making processes regarding the uptake of residential low-carbon measures. A novel integrative decision-making model regarding energy renovation measures was developed that distinguishes between different stages of the decision-making process and reveals the complex and interconnected factors that influence homeowners' energy decisions. The findings demonstrate that these factors are crucial at different stages of the decision-making process and may differ from homeowner to homeowner. These insights can be a starting point for further studies.

Study II introduces a segmentation model to allow a better understanding of homeowners' heterogeneity in the adoption of residential photovoltaics. It addresses previous inconclusive results on the influence of the level of environmental concern and the lack of insight into how educational background or profession (technical, financial-economic, or other) affects an adoption decisions. The segmentation model identifies five substantial segmentation groups and reveals significant differences relating to these personal characteristics and their influence on perceptions of RPV. These findings can be used in follow-up studies regarding the adoption of residential low-carbon technologies.

Study III demonstrates that applying a multidimensional justice perspective can contribute to more just and socially fair energy renovation processes in social housing. These insights are important because previous research provided insufficient understanding of the justice aspects of the energy renovation process in social housing. The pluralistic justice approach gives an enhanced insight into the needs of vulnerable households because it incorporates not only the usual justice dimensions such as distribution and participation but also the dimensions of recognition, capability, and responsibility. Furthermore, this study reveals that it is imperative to examine the interrelationships between each justice dimension, as they affect each other. These interrelations were hardly studied in the past. However, this study demonstrates that these relationships are crucial, especially to gain more insight into the position of vulnerable households in the energy renovation process.

Lastly, **Study IV** provides further insights into how intermediation can affect the multistage decision-making process in the adoption of building-integrated photovoltaics in the Netherlands. These insights are important because there is a lack of systematic knowledge about intermediaries in decision-making processes involving technology adopters and suppliers located downstream in the supply chain. Furthermore, intermediation in the context of the adoption of building-integrated photovoltaics has not yet been studied in depth. This study demonstrates that a multistage decision-making process requires the development of a dynamic 'ecology of intermediaries' at various levels of the BIPV system. This ecology of intermediaries is crucial to performing diverse intermediation activities between different actors, at different system levels, and at different decision stages, which can also change over time. Undesignated or informal intermediaries play a key role in the decision-making process. Therefore, a holistic study of intermediation is vital, as the processes and actors are highly interdependent and interconnected. These insights can be used in follow-up studies on intermediation in (low-carbon) innovation adoption processes.

Dissemination of these insights to the scientific community has taken place through four published journal publications, three abstract publications in conference proceedings, and presentations at seven international scientific conferences. The results were also presented multiple times to three national and international research project consortia (including research and industry partners) in which I participated during the course of my PhD research. To disseminate the knowledge gathered in this thesis into education, the findings have been incorporated into several lectures for the Bachelor of Built Environment programme at Zuyd University. Additionally, I have supervised 10 master's thesis students from the Master Sustainability Science, Policy, and Society programme at Maastricht University and 12 thesis students from Zuyd University's Bachelor Built Environment programme on topics related to this thesis. Furthermore, every year I supervise a workshop week on decision-making processes in the transition to low-carbon housing, in which several students from Zuyd University participate. This knowledge sharing with the scientific community and in education will continue after I complete my dissertation.

Societal impact

Society faces major challenges such as climate change, energy security, and affordability. The transition to a low-carbon built environment can contribute to reducing these threats. It is imperative to address homeowners' decision-making processes in policies and consulting actions, as they can enhance the adoption of residential low-carbon technologies. The outcomes of this thesis can be used by regional and national policymakers, employees and members of social housing and tenant associations, suppliers, consultants, energy coaches, and architects to enhance their actions for a low-carbon built environment.

Policymakers can use the insights of this thesis to design appropriate policy actions for the different stages of homeowners' decision-making processes and to target various influencing factors that affect these decision stages to ensure greater appeal of low-carbon measures. In addition, these policies should consider homeowners' heterogeneity to make certain that policies and communication actions are effective and adequate. Furthermore, the findings can be used to develop policies in which the needs of vulnerable households are better addressed in the transition to low-carbon housing. To encourage less-diffused low-carbon technologies, several policy actions are needed on various system levels and targeting different decision stages as well as to support formal and informal intermediaries. Moreover, local governments could help residential low-carbon technology adopters demonstrate and promote these technologies to their peers. As this thesis demonstrates, actions such as these can be highly effective. Local governments can also provide thorough advice on low-carbon housing to support diffusion.

These results can be applied by several stakeholders. First, employees and members of social housing and tenant associations can use the findings to gain further insight into their tenants' decision-making processes. This increased awareness can be used to develop effective communication and participations strategies to ensure a renovation process and plans for the tenants to ensure that the energy renovation process is socially fair and people-centred. Particularly, the multidimensional justice approach can be helpful in addressing the needs of vulnerable households. Second, suppliers of residential low-carbon technologies can take advantage of these findings to better address their potential clients' needs in their communication and marketing actions. Additionally, they can reshape their products to better fit the demand-side needs. Third, this thesis demonstrates that effective advice for homeowners can be beneficial. Therefore, the results can be used by potential intermediaries such as consultants, energy coaches, and architects to target this advice towards homeowners' needs and wishes.

Dissemination of these findings to societal partners has taken place through several meetings and presentations. The results of Study I were presented to local policymakers and aldermen of municipalities in the city region of Parkstad Limburg, which helped to gain support for the establishment of the WoonWijzerWinkel in the region. This initiative helps residents make decisions regarding residential low-carbon technologies. Study II results were presented to local aldermen and policymakers in Parkstad Limburg; the findings were used to evaluate the city region's solar panel project and resulted in a follow-up project in the region and in other municipalities. In response, Volta Limburg, the executing party, adjusted its communication strategies based on the findings. Other municipalities have taken advantage of these experiences to establish similar initiatives. Study III results were summarised in a non-scientific publication for sharing with study respondents (employees and members of social housing and tenant associations) and on social media. Furthermore, the results were implemented in the H2020 Drive 0 project to design the participation programme for the pilot project. The key findings of Study IV were presented at several consortia meetings of the MOOI BIPV(T) project. In these meetings, a diversity of stakeholders is represented, such as BIPV suppliers, contractors, and research organisations. The dissemination of this knowledge with societal partners will continue in follow-up (applied) research projects.

In conclusion, the findings of this thesis are beneficial for both scientific and societal stakeholders and can be used in follow-up research, educational programmes, and by societal stakeholders to enhance homeowners' decision-making processes regarding residential low-carbon measures.

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Appendices

Chapter 2

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- **Appendix A**. Table A-1. Study sample with characteristics of the 52 interviewees: https://doi.org/10.1016/j.erss.2019.101284
- **Appendix B**. Transcripts interviews: https://doi.org/10.25385/zuyd.7887095

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Chapter 4

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Chapter 5

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- **Table A1**. Reported challenges in the different stages of the BIPV decision-making process, identified from the interview results
- **Table A2**. Reported suggestions by the respondents to improve intermediation by the respondents, per decision-making stage and pe intermediary function
- **Supplementary materials**: Interview protocol & overview project meetings

List of abbreviations

BIPV:	Building integrated photovoltaics
DOI:	Diffusion of innovations theory
ERM:	Energy renovation measures
EU:	European Union
NL:	The Netherlands
PV:	Photovoltaics
RPV:	Residential photovoltaics
SHA:	Social housing association
SPPP:	Solar panel project Parkstad Limburg
TA:	Tenant association

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Summary

The transition to a low-carbon housing stock must increase more rapidly to meet the European climate goals: 55% reduction of greenhouse gasses in 2030 and becoming climate neutral in 2050. This transition can be realised by implementing residential low-carbon measures such as insulation, high-efficiency glazing, efficient heating and ventilation systems, and residential renewable energy production such as photovoltaics. Despite the urgency of climate change, the housing market remains reluctant to innovate toward a low-carbon housing stock. The current slow adoption rate of low-carbon measures in the housing stock can be attributed partly to the fact that energy policies generally disregard the diversity of concerns and motivations of homeowners and often rely on a generic approach instead. However, homeowners' choices about low-carbon measures are affected by a range of considerations, motivations, and contextual elements that require a holistic and comprehensive understanding. This deeper understanding is necessary to enhance the impact of energy policies and offer more tailored advisory services to consultants and energy coaches to ensure the effectiveness of their work. The Netherlands has a total of eight million homes, of which 57.1% are owned by private homeowners, 28.8% are owned by social housing associations, and 12.8% are owned by commercial and private landlords. For the purpose of this thesis, the focus will be on the first two as they account for the majority of the Dutch housing stock.

To boost the implementation of residential low-carbon measures, an in-depth understanding of homeowners' decision-making processes is needed. However, previous research has revealed limited insights into the factors influencing the various decision-making stages. Moreover, homeowners' heterogeneity in terms of their personal characteristics and how they influence their decision-making process is poorly understood or provides inconclusive results. Justice aspects of the decision-making process regarding residential low-carbon measures are also understudied. Justice aspects are related to the fairness in the way people are dealt with. These issues are of particular importance in social housing, which typically is home to many vulnerable households. Furthermore, prior studies have demonstrated that formal and informal intermediaries can play a significant role in enhancing decision-making, but only a few studies have examined intermediation between the supply and demand side. Overall, this lack of knowledge of the factors influencing homeowners' decision-making processes can hamper the uptake of residential low-carbon measures.

The research in this thesis aims to identify and evaluate the varying factors that influence the multistage decision-making processes of homeowners regarding residential low-carbon measures. The thesis focuses on the Netherlands, which has

a long history of policy efforts initiated since the late 1970s to stimulate residential low-carbon measures, but diffusion of these measures has lagged. Additionally, this thesis examines owner-occupied and social housing, as they account for the majority of the Dutch housing stock. The aim of this research is to deepen the understanding of this topic to gain a more comprehensive and holistic understanding of homeowners' decision-making processes and how they can be enhanced. Hence, the main research question is:

> *What factors influence the decision-making processes of Dutch homeowners regarding residential low-carbon measures, and what interventions can encourage them to do more?*

The socio-technical analysis highlights the contextual circumstances of people; their needs, concerns, and ways of thinking and evaluation; differences therein; justice aspects; the role of intermediation; and influences from others (professionals and non-professionals). To address the main research question, this research consists of four empirical studies. A mixed-methods approach was used, which combined quantitative and qualitative data to collect and analyse the data. The four studies and their sub-research questions are discussed in the following sections.

In the first study, the influencing factors in the various stages of the decision-making process of private homeowners concerning renovation measures were investigated using the adoption and diffusion literature. Private homeowners were chosen, as they comprise more than half of Dutch residential property owners. Data were collected through surveys and interviews with private homeowners in the city region of Parkstad Limburg (NL). As part of the study, a novel integrative model of private homeowners' decision-making processes about energy renovation measures was developed. The model differentiates between the various decision-making stages, the factors that influence these stages, and the many considerations homeowners face when deciding whether to invest in energy renovation measures. The study results reveal that a variety of factors are relevant at different stages of decision-making. At the 'getting interested' stage, external developments, physical factors of the dwelling, socio-demographic factors, and environmental concerns can trigger an interest in energy renovation measures. At the 'gaining knowledge' stage, homeowners gain knowledge about the measures, and personal background and advice from their social network or from professionals can influence the decision process. At the 'forming an opinion' stage, homeowners form an opinion about the energy renovation measures and in this stage financial-economic factors are particularly important. In the 'making a decision' stage, they decide whether to adopt the measures. After implementing the measures, homeowners can also influence others in their social network and become ambassadors for further energy-saving changes in the 'experiencing' stage. Future policy interventions should, therefore, address the specific barriers at each decision stage to increase the uptake of energy renovation measures by private homeowners.

In the second study, the outcomes of the first study were used to gain further insights into the heterogeneity of potential residential photovoltaic adopters via a segmentation mode for designing targeted communication policies. Data were collected through a survey of Dutch adopters, and the data were analysed with statistical descriptive analyses and non-parametric tests. The five segmentation groups are divided by homeowners' educational background or profession (technical, financial-economic, or other) and level of environmental concern. The results demonstrate that the groups differ significantly in the homeowners' level of environmental concern and the level of influence of their social network on their decision to adopt. Moreover, the groups differ significantly in their perceptions of the complexity and aesthetics of the photovoltaic system and their prior experience with other home energy measures. These insights can be used by policymakers and the public and private sectors to more effectively promote residential photovoltaics by adequately targeting the specific characteristics of the various segmentation groups. The groups will be drawn to different aspects, and therefore, (1) a broader range of benefits must be presented, (2) a mix of different communication channels must be used, (3) objective and non-technical assistance in decision-making must be offered, and (4) different products must be provided to target a broader audience.

The third study investigated what justice aspects affect energy renovations in social housing and how a better understanding of this can be used to achieve outcomes that are more socially fair and just for tenants. This priority is not always valued at this time. Approximately one third of the Dutch housing stock is owned by social housing associations which make them a crucial sector to address. The study examines the impact of a multidimensional justice perspective on energy renovations in social housing and how this knowledge can be applied to achieve more beneficial outcomes for tenants. Justice in the context of energy renovations in social housing is a topic that has been understudied in the past. The five dimensions of justice are distribution, recognition, participation, capability, and responsibility. The topic was, therefore, explored in this study by interviewing employees and members of Dutch social housing and tenant associations to gather their experience and perspectives. This study demonstrates that a more pluralistic justice approach is needed in the transition to a low-carbon social housing stock and that the multidimensional justice perspective can be applied to implement a broader perspective of justice principles. These insights can be a starting point for achieving a more just energy renovation process in social housing, especially by addressing the needs of vulnerable households. Moreover, the results reveal that all five dimensions are imperative to consider at all stages of this renovation process; they are strongly interlinked and should not be addressed separately.

The fourth study examined how intermediation affects the multistage decision-making process about building-integrated photovoltaics in the Netherlands and how it can be improved. Intermediation is the act of connecting or brokering between individuals or organisations. Several challenges hinder this emerging technology, such as information asymmetry and limited value chain coordination. As demonstrated in previous studies, intermediaries can play a crucial role in managing these challenges, but this aspect has not yet been examined in depth for this technology. Moreover, there is a lack of insight into intermediaries positioned between the supply and demand sides. A comprehensive overview of various intermediaries' abilities to facilitate the multistage decision-making process is lacking. Instead of focusing on specific intermediary actors, the Dutch system for building-integrated photovoltaics is investigated by identifying which actors act or can act as intermediaries and what intermediation activities can help with decision-making. The study combined both innovation and intermediation perspectives to collect and analyse the data, and the results demonstrate that intermediation is essential at every stage of the decision-making process. A dynamic 'ecology of intermediaries' is recommended to perform various intermediation activities at different system levels in the multistage decision-making process. As these activities and actors are highly interrelated and interdependent, it is argued that it is crucial to assess intermediation in a holistic way, as it demonstrates that intermediation is an interrelated, multilevel, and varied phenomenon. These findings are useful for suppliers, potential intermediaries, and governments because they can support the decision-making process with the help of intermediation.

In conclusion, this thesis offers a socio-technical analysis of homeowners' energy decisions, demonstrating that relevant decisions are not isolated choices but are situated in daily life with multiple decision moments and dynamic circumstances. The thesis reveals that homeowners' decisions on the adoption of residential photovoltaics, building-integrated photovoltaics, and other residential low-carbon measures are influenced by a variety of factors. These decisions are shaped by homeowners' heterogeneity, embedded in social practises, affected by justice aspects, and encouraged by intermediation activities. The research moves beyond socio-technical systems analysis by considering the decision-making processes of heterogeneous actors in much more detail and by highlighting justice aspects and the details of intermediation. Many actors can utilise this knowledge, including policymakers, employees and members of social housing and tenant associations, suppliers, consultants, energy coaches, and architects. By understanding these insights, low-carbon policies, internal procedures, advice to homeowners, and communication campaigns can be enhanced to increase the diffusion of low-carbon technologies. Overall, energy decisions are not only about energy but are influenced by a variety of factors and dynamic circumstances.

S

Samenvatting

De transitie naar een energiezuinige woningvoorraad moet sneller om de Europese klimaatdoelen te behalen, zijnde 55% reductie van broeikasgassen in 2030, en de transitie naar klimaatneutraal in 2050. Deze transitie kan worden gerealiseerd door energiemaatregelen in woningen toe te passen, zoals isolatie, efficiënte beglazing, verwarming- en ventilatiesystemen, en hernieuwbare energieproductie zoals zonnepanelen. Ondanks de klimaaturgentie blijven woningeigenaren terughoudend om te innoveren in de richting van een energiezuinige woningvoorraad. Dit kan deels worden toegeschreven aan het feit dat energiebeleid over het algemeen geen rekening houdt met de diversiteit aan factoren die beslissingen van woningeigenaren beïnvloeden, maar in plaats daarvan vaak vertrouwt op een generieke aanpak. De keuze van woningeigenaren voor energiemaatregelen wordt echter beïnvloed door een reeks overwegingen, motivaties en contextuele elementen die een holistisch begrip vereisen. Dit diepere inzicht is nodig om de impact van energiebeleid te maximaliseren en meer op maat gemaakte adviesdiensten door consultants en energiecoaches aan te bieden om hun werk effectiever te maken. De Nederlandse woningmarkt bestaat uit 8 miljoen woningen en is voor 57,1% in eigendom van particuliere woningeigenaren, 28,8% van woningcorporaties en 12,8% is in handen van commerciële verhuurders. De focus in deze studie is op de eerste twee sectoren omdat deze het grootste aandeel van de Nederlandse huizenmarkt vormen.

Om de acceptatie van energiemaatregelen in woningen te stimuleren, is een goed begrip van de besluitvormingsprocessen van woningeigenaren nodig. Eerder onderzoek heeft echter beperkte inzichten opgeleverd in de factoren die hierop van invloed zijn. Bovendien is er weinig inzicht in de heterogeniteit van de persoonlijke kenmerken van woningeigenaren en hoe deze hun besluitvormingsproces beïnvloeden, of de resultaten zijn niet eenduidig. Daarbij zijn rechtvaardigheidsprincipes in het besluitvormingsproces over energiemaatregelen in woningen in het verleden onvoldoende bestudeerd. Vooral bij sociale huurwoningen, waarin veel kwetsbare huishoudens wonen, is deze kwestie van belang. Bovendien hebben eerdere studies aangetoond dat formele en informele bemiddelaars een significante rol kunnen spelen bij de verbetering van de besluitvorming, maar weinig studies hebben hun rol tussen de vraagzijde en de aanbodzijde onderzocht. Dit gebrek aan inzicht in de factoren die van invloed zijn op de besluitvormingsprocessen van woningeigenaren kan de brede implementatie van energiemaatregelen in woningen belemmeren.

Het onderzoek in dit proefschrift heeft tot doel de verschillende factoren te identificeren en te evalueren die van invloed zijn op de besluitvormingsfasen van woningeigenaren bij energiemaatregelen. Het onderzoek richt zich op Nederland. Dat levert sinds eind jaren zeventig beleidsinspanningen om energiemaatregelen in woningen te stimuleren, maar grootschalige implementatie blijft uit. Het onderzoek richt zich met name op koopwoningen en sociale huurwoningen, aangezien zij het grootste deel van de Nederlandse woningvoorraad uitmaken. Een tweede doel van dit onderzoek is om een holistisch begrip te krijgen van hoe deze besluitvormingsprocessen kunnen worden verbeterd. De centrale onderzoeksvraag luidt:

> *Welke factoren beïnvloeden de besluitvormingsprocessen van Nederlandse woningeigenaren met betrekking tot energiezuinige woningen en welke interventies kunnen hen aanmoedigen om meer te doen?*

De socio-technische analyse besteedt aandacht aan de contextuele omstandigheden van woningeigenaren, hun wensen, omstandigheden en denk- en beoordelingswijzen, hun verschillen daarin, de rol van rechtvaardigheid, de rol van bemiddeling en de invloed van professionele en niet professionele anderen op hun besluitvormingsproces. Om de hoofdvraag van het onderzoek te beantwoorden, bestaat dit onderzoek uit vier empirische studies. Gekozen is voor een mixed-methods aanpak waarin kwalitatieve en kwantitatieve methoden zijn toegepast om data te verzamelen en te analyseren. De vier studies worden hieronder in meer detail beschreven.

In de eerste studie van dit proefschrift zijn de factoren onderzocht die van invloed zijn op besluitvormingsprocessen van particuliere woningeigenaren bij energiemaatregelen voor hun woning. De adoptie- en diffusie theorieën zijn gebruikt om de data te verzamelen en te analyseren. Deze doelgroep is gekozen omdat ze meer dan de helft van de Nederlandse woningvoorraad in eigendom hebben. Data zijn verzameld door middel van enquêtes en interviews met particuliere woningeigenaren in de Stadsregio Parkstad Limburg. In het onderzoek is een nieuw integraal model ontwikkeld voor het besluitvormingsproces van particuliere woningeigenaren bij energiemaatregelen. Het model maakt onderscheid tussen verschillende besluitvormingsfasen, de factoren die deze fasen beïnvloeden en de overwegingen van woningeigenaren bij de beslissing om al dan niet te investeren in energiemaatregelen.

Uit het eerste onderzoek blijkt dat een verscheidenheid aan factoren relevant is in verschillende stadia van de besluitvorming. In de eerste beslissingsfase kunnen externe ontwikkelingen, fysieke factoren, sociaal-demografische factoren en milieuoverwegingen de belangstelling voor energiemaatregelen wekken. In de tweede fase doen woningeigenaren kennis op over de maatregelen en zijn persoonlijke achtergrond en advies uit hun sociale netwerk of van professionals van invloed. In de derde fase zijn vooral financieel-economische factoren van belang. Hierin vormen woningeigenaren een oordeel over de energiemaatregelen en besluiten ze of ze wel of niet overgaan tot implementatie. Na de implementatie van energiemaatregelen kunnen woningeigenaren ook anderen in hun sociale netwerk beïnvloeden. Dit betekent dat zij ambassadeurs worden voor energiemaatregelen in hun sociaal netwerk. Toekomstige beleidsinterventies zouden daarom de specifieke belemmeringen in elke besluitvormingsfase moeten aanpakken om de acceptatie van energiemaatregelen door particuliere woningeigenaren te vergroten.

In de tweede studie zijn de resultaten van de eerste studie gebruikt om meer inzicht te krijgen in de heterogeniteit van potentiële gebruikers van zonnepanelen onder particuliere woningeigenaren. Hiervoor is een segmentatiemodel ontwikkeld dat kan worden gebruikt voor doelgerichtere communicatiebeleid. Data zijn verzameld via een enquête onder gebruikers van zonnepanelen in de Stadregio Parkstad Limburg. De gegevens zijn geanalyseerd met statistische beschrijvende analyses en niet-parametrische tests. De gebruikers zijn op basis van opleidingsachtergrond, beroep en mate van milieubewustzijn ingedeeld in vijf segmentatiegroepen. De resultaten tonen aan dat de groepen significant verschillen wat betreft de mate van milieubewustzijn en de mate van invloed van het sociale netwerk op hun beslissing om zonnepanelen te implementeren. Bovendien verschillen de groepen significant in hun perceptie van de complexiteit en esthetiek van de zonnepanelen en in hun eerdere ervaring met andere energiemaatregelen in huis. Deze inzichten kunnen beleidsmakers en de publieke en private sector gebruiken om zonnepanelen effectiever te promoten door zich beter op de verschillende segmentatiegroepen te richten. De verschillende groepen worden door verschillende aspecten aangetrokken. Daarom moet (1) een breder scala aan voordelen worden gepresenteerd, (2) een mix van verschillende communicatiekanalen worden gebruikt, (3) objectieve en niet-technische hulp bij de besluitvorming worden aangeboden en (4) verschillende typen zonnepanelen worden aangeboden om de implementatie van zonnepanelen uit te breiden.

De derde studie heeft onderzocht welke rechtvaardigheidsaspecten van invloed zijn op energierenovaties bij sociale woningen en hoe meer kennis hierover kan worden gebruikt om rechtvaardigere resultaten voor huurders te bereiken. Dit is op dit moment niet altijd het geval. Ongeveer een derde van de Nederlandse woningvoorraad zijn sociale huurwoningen. Dit maakt het een significante sector voor dit onderzoek. De studie biedt diepgaande inzichten in een meer rechtvaardig en mensgericht energie-renovatieproces met behulp van een multidimensionaal rechtvaardigheidsperspectief. Dit is in het verleden onvoldoende is bestudeerd. De studie onderzoekt de impact van vijf rechtvaardigheidsdimensies op energierenovaties bij sociale woningen en biedt inzicht in hoe deze kennis kan worden toegepast om rechtvaardigere resultaten voor huurders te bereiken in het renovatieproces. Deze vijf dimensies zijn: verdeling van kosten en baten, erkenning, participatie, bekwaamheid en verantwoordelijkheid. Het onderwerp is onderzocht door Nederlandse sociale woningcorporaties en huurdersbelangenverenigingen te interviewen en hun ervaringen en perspectieven te verzamelen en te analyseren. Deze studie laat zien dat een rechtvaardigheidsbenadering nodig is bij de transitie naar een energiezuinige sociale woningvoorraad. Deze inzichten kunnen een startpunt zijn voor het bereiken van een rechtvaardiger en mensgerichter renovatieproces bij sociale woningen, waarbij met name wordt ingespeeld op de behoeften van kwetsbare huishoudens. Bovendien wijzen de resultaten erop dat het noodzakelijk is om alle vijf de rechtvaardigheidsdimensies te integreren in alle stadia van het renovatieproces, aangezien ze sterk met elkaar verbonden zijn en elkaar beïnvloeden.

In de vierde studie is de rol van bemiddelaars onderzocht in het besluitvormingsproces voor gebouw-geïntegreerde fotovoltaïsche zonne-energie in Nederland en hoe dit proces kan worden verbeterd. Deze innovatieve technologie wordt nog niet breed toegepast vanwege informatieasymmetrie en een beperkte coördinatie van de waardeketen. Zoals in eerder werk is aangetoond, kunnen bemiddelaars een cruciale rol spelen bij het oplossen van deze knelpunten, maar dit aspect is voor deze technologie nog niet diepgaand onderzocht. Bovendien ontbreekt het aan inzicht in bemiddelaars tussen de vraagzijde en de aanbodzijde. Een alomvattend overzicht ontbreekt van de mogelijkheden van verschillende bemiddelaars om het beslissingsproces te vergemakkelijken. In andere onderzoeken is de focus gelegd op specifieke intermediaire actoren. In deze studie is het volledige Nederlandse systeem voor gebouw-geïntegreerde fotovoltaïsche zonne-energie onderzocht en zijn actoren geïdentificeerd die intermediairs zijn of kunnen zijn. De resultaten van studie tonen aan dat een ‘ecologie van bemiddelaars’ nodig is om de benodigde bemiddelingsactiviteiten van verschillende actoren uit te voeren op verschillende systeemniveaus en in verschillende besluitvormingsfasen. Deze activiteiten en actoren zijn sterk met elkaar verweven en onderling afhankelijk. Het is essentieel is om de rol van bemiddelaars op een holistische manier te analyseren, aangezien bemiddelingsactiviteiten onderling zijn gerelateerd en zich op verschillende systeemniveaus afspelen. De bevindingen kunnen worden gebruikt door productleveranciers, (potentiële) bemiddelaars en overheden, omdat zij met behulp van beleid bemiddeling voor het besluitvormingsproces kunnen ondersteunen.

Concluderend biedt dit proefschrift een socio-technische analyse van de beslissingen van woningeigenaren over energiemaatregelen. Het toont aan dat relevante beslissingen geen geïsoleerde beslissingen zijn, maar onderdeel zijn van het dagelijks leven met meerdere besluitvormingsmomenten. Het proefschrift laat zien dat het besluitvormingsproces van woningeigenaren over zonnepanelen, energiemaatregelen en gebouw-geïntegreerde zonne-energie wordt beïnvloed door een breed scala aan factoren. Deze beslissingen worden bepaald door de heterogeniteit van woningeigenaren, ingebed in sociale praktijken, beïnvloed door rechtvaardigheidsaspecten en aangemoedigd door bemiddelingsactiviteiten. Het onderzoek gaat verder dan een socio-technische systeemanalyse door gedetailleerd in te gaan op het besluitvormingsproces van heterogene actoren en door aandacht te besteden aan rechtvaardigheidsaspecten en de details van bemiddeling. Veel stakeholders kunnen de kennis uit dit proefschrift gebruiken, onder wie regionale en nationale beleidsmakers, woningcorporaties, huurdersbelangenverenigingen, toeleveringsbedrijven, adviseurs, energiecoaches en architecten. Met de inzichten kunnen beleidsmaatregelen, interne procedures, advies aan woningeigenaren en communicatiecampagnes worden verbeterd en kan de verspreiding van energiemaatregelen in woningen worden vergroot. De besluitvormingsprocessen van woningeigenaren met betrekking tot energiezuinige woningen zijn complex en variëren per context en persoon. Een holistische benadering is nodig om tegemoet te komen aan de verschillende behoeften en voorkeuren. Energiebeslissingen gaan niet alleen over energie, maar worden beïnvloed door een verscheidenheid aan factoren en dynamische omstandigheden.

Dankwoord

Met het schrijven van dit dankwoord is er een einde gekomen aan de grote onbekende reis die ik in 2017 begon. Het uitvoeren van een promotieonderzoek kun je niet alleen. Juist door samen te werken, maar ook met andere dingen bezig te zijn, kom je tot nieuwe inzichten en ontwikkel je jezelf verder. Ik heb de route van mijn reis een aantal malen moeten aanpassen, wat heeft geleid tot onverwachte, maar zeer welkome ervaringen en inzichten. Vele personen hebben dan ook bijgedragen aan de totstandkoming van dit proefschrift. Het was een mooie reis met inspirerende reisgenoten.

Allereerst dank aan mijn begeleiders René, Veronique, Nurhan en Zeger. Een team van 4 was soms geen sinecure, maar de combinatie van de verschillende disciplines, achtergronden en persoonlijkheden heeft mij veel nieuwe inzichten verschaft. Bedankt allemaal voor de feedbackmomenten en adviezen die ik van jullie heb mogen ontvangen. René, bedankt voor de mogelijkheid om bij jou te promoveren. Ik heb onze gesprekken altijd als heel constructief ervaren en met een aantal opmerkingen wist je me altijd te inspireren om het eens van een andere kant te bekijken of wat dieper uit te werken. Daarbij liet je me heel vrij om mijn eigen weg te volgen en pad te bepalen. Dat heb ik als heel prettig ervaren. Ik heb veel van je geleerd, dank daarvoor. Veronique, dankzij jou ben ik begonnen aan deze reis. Ik had nog zo mijn twijfels of ik dat wel zou kunnen met mijn praktische bouwkundige achtergrond, en alleen ervaring in toegepast onderzoek, maar door jouw positiviteit en geloof in mij heb ik de stap durven nemen. Je hebt me vaak geholpen en gemotiveerd als ik ergens vastliep, zeker in het begin. Vooral de literatuur was nieuw voor mij en daar heb je me goed wegwijs in gemaakt. Ondertussen ben je een vriendin geworden, en ik hoop dat we nog veel koffie- en lunchmomenten mogen delen in de toekomst om ons leven thuis en op het werk te bespreken. Nurhan, thank you for all the support the last years, and to give me enough room en time to combine my PhD and my other activities at Zuyd. I think we built up a good constructive relationship over the years, and I hope that we will continue in developing inspiring projects and educational programs. Zeger, hartelijk dank voor de steun die je me de afgelopen jaren hebt gegeven tijdens mijn PhD en met name ook het organiseren van de nodige financiële middelen die nodig zijn om een PhD traject te doorlopen.

De leden van de leescommissie wil ik hartelijk bedanken voor de tijd en aandacht die zij aan dit proefschrift hebben geschonken: prof. dr. Harro van Lente, prof. dr. Floor Alkemade, prof. dr. Griet Verbeeck, en dr. Ron Cörvers. Dank voor jullie tijd en aandacht voor het beoordelen van deze thesis.

Ook mijn BBE-familie mag natuurlijk niet ontbreken. De combinatie van een promotieonderzoek en daarnaast ook nog lesgeven en in onderzoeksprojecten actief zijn was soms pittig, maar ook mijn redding. Door de afwisseling van de werkzaamheden was het traject minder eenzaam, maar gaf het me ook tijd om bepaalde stukken te laten bezinken. Collega's bedankt voor het tonen van jullie interesse al die jaren en met name de gezellige werksfeer wat het schrijven een stuk leuker maakt. Jullie bevlogenheid en betrokkenheid motiveert mij als docent en onderzoeker. Speciale dank gaat uit naar mijn paranimfen Marijn en John, mijn kamergenoten bij Zuyd. Jullie hebben het grootste deel van mijn PhD gevold en mij bijgestaan bij successen, maar ook bij mijn klaagmomenten. Dank voor jullie steun en raad al die jaren. Ik hoop dat we in de toekomst nog vaak mogen samenwerken aan mooi onderzoek en onderwijs. Fijn dat jullie aan mijn zijde staan bij mijn verdediging.

Dank ook aan het MSI-team die me als parttime collega hebben verwelkomd, eerst aan de Kapoenstraat en later op Tapijn. Met speciale dank voor Annet voor het organiseren van alle stukken die nodig waren voor de afronding.

Er zijn veel huiseigenaren en collega's uit het werkveld die hebben meegewerkt aan mijn onderzoeken. Deze informatie heeft de basis gevormd van mijn proefschrift en waren daarom essentieel om mijn onderzoek te kunnen uitvoeren. Dank jullie wel voor je tijd. Specifiek dank aan de Stadregio Parkstad, Volmar & Ralph, die me hebben geholpen met het uitzetten van de eerste twee studies.

Daarnaast wil ik al mijn vrienden en familie bedanken voor de nodige afleiding en gezelligheid de afgelopen jaren. Met name dank aan mijn moeder. Mam, je bent een sterke vrouw waar ik veel van heb geleerd. Ook dank voor de zorg voor onze twee jongens de eerste jaren. Deze stabiele basis heeft voor veel rust gezorgd en waardoor er ruimte overbleef om dit traject in te gaan. Pap, je bent al heel lang niet meer bij ons, maar ik weet zeker dat als je er nog was, je zat te glimmen van trots op de eerste rij.

Als laatste dank aan mijn jongens. Harold, dankjewel voor je steun de afgelopen jaren en het nooit klagen dat ik te veel aan het werk was. Excuses ook voor de vele moppermomenten als het even niet lekker liep. Tom en Juul, toen ik begon, waren jullie nog schattige jongetjes en nu zijn jullie uitgegroeid tot bonkige maar vriendelijke pubers. Op jullie ben ik het meest trots. Ik hoop dat dit onderzoek een klein beetje bijdraagt aan een betere wereld voor jullie, maar dat het jullie ook inspireert om voor iets te gaan als je het graag wilt. Ik weet nu dat je meer kunt dan je zelf denkt.

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About the author

Wendy Broers was born on the 23rd of July in Heerlen, the Netherlands. She grew up in the country-side of Groot-Welsden in Margraten, where she still lives. She obtained her Master of Science degree in architecture, building and planning from the Technical University of Eindhoven in 2000, where she specialised in sustainable building technology and development. Since then she has worked for several organisations as a sustainable building consultant and researcher in the Netherlands and Belgium. Wendy is currently employed as a senior researcher and lecturer in sustainable built environment at Zuyd University of Applied Sciences in Heerlen. She has participated in several international research projects, such as LIFE Buildupspeed, H2020 Drive 0, H2020 STORM, IEA Annex 51 Energy efficient communities, IEE Ides-EDU, Erasmus+ EurI3A, and the Interreg Modlar project; and various national and regional funded projects such as MOOI BIPV(T), Raakpro Window of the Future, EOS LT TRANSEP-DGO , Parkstad Limburg Energy Transition (PALET), TIORC project, Samen Duurzaam, and the TKI Treco home project. Furthermore, she teaches and supervises thesis students at the Bachelor of Built Environment of Zuyd University. In 2017, she started her PhD research at Maastricht University at the Maastricht Sustainability Institute. There, she has supervised multiple thesis students at the Master Sustainability Science, Policy and Society. The results of her PhD studies have been translated into scientific and popular publications, and educational programs.

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