Are energy decisions about energy?

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.