The Renovation Wave:
An opportunity to tackle energy poverty?

A Case Study-Mixed Methods (CS-MM) approach to including justice in renovation policies considering the socio-spatial vulnerability to energy poverty

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Preface

As the energy prices are increasing significantly, many households are exposed to energy poverty. A few months ago, energy poverty was an unknown phenomenon for me but also in my surroundings. In September, when I was a Teacher Assistant, and we had to read and discuss a paper on energy poverty, I first learned about the multidimensionality of energy poverty and its significance in Europe. Reflecting on the discussion we had then, it is remarkable how many students thought that energy poverty only occurs in third-world countries and is not a significant issue in The Netherlands.

My understanding of energy poverty and how the renovation of buildings is one of the levers used to address climate change, and energy poverty was further enhanced during my time at the Energie Lab Zuidoost. It was also the first time I got to hear and see what poverty and injustices are and how poor living conditions within the residential building look within the context of The Netherlands. After finishing my thesis, I can conclude that energy poverty is truly a multidimensional phenomenon. From my point of view, tackling energy poverty and having just renovation policies requires an interdisciplinary approach.

Additionally, I would like to thank my supervisors, Trivik and Juliana, for their continuous guidance and support throughout this project. To Thomas, I would like to thank him for sharing his knowledge and counselling me in qualitative research throughout this project. I also thank Neelke for her excellent feedback on my work. I want to thank Annoesjka for her bi-weekly input, all her effort to receive data despite all the difficulties we faced, and her support throughout the long wait of 1.5 months for data. Throughout my study, I have spoken to various experts whom I would like to thank for their time, dedication, and counselling.

Last but not least, I would like to thank my family for their continuous support throughout my educational journey and without them, I would not have come to finishing my Master's degree. I am also thankful for my friends who have supported me throughout this journey.

Mobeen Nawaz
The Hague, August 2022

Executive Summary

With nearly 34 million people in the European Union (EU) unable to keep their homes adequately warm, energy poverty is a massive issue across member states. The expectations are that with the rising energy prices and COVID-19 regulations, the number of energy-poor households will increase throughout Europe. Given the wide range of socio-economic factors, such as income, gender, and age, and factors related to the performance of buildings, such as the energy efficiency and indoor living quality, that make specific households more vulnerable to energy poverty than others, energy poverty requires a multi-faceted approach.

To tackle energy poverty by its roots and protect vulnerable groups, the European Commission introduced the so-called Renovation Wave, aiming to renovate 35 million inefficient buildings by 2050. This strategy aims to reduce energy bills by renovating buildings while creating additional green jobs in the construction sector and improving residents' quality of life, health, and well-being.

Nonetheless, recent research has shown that current renovation policies have failed to address energy poverty as they lack an intersectoral integration of climate and social policies. Consequently, these policies do not target the energy poor. On the other hand, recent studies have shown that although renovation policies aim to realise higher insulation levels and improve energy systems, residents may reject or under-utilize opportunities to renovate their homes. The increased market value of renovated buildings also raises the risk of social inequity and gentrification. As a response, scholars have called for an explicit consideration of justice in the European renovation.

The present study picked up this call and explored how justice can be included in renovation policies, whereby justice was composed of recognitional (identifying and recognising vulnerable groups), procedural (including and representing vulnerable groups in decision-making), and distributional (distributing the benefits and burdens of renovation) justice. To include justice in renovation policies, it is important to identify vulnerable groups and acknowledge the socio-spatial vulnerability to energy poverty as an individual's vulnerability to it is socially and spatially variable. Current vulnerability frameworks have failed to identify vulnerable groups in great need of renovation as they are solely built on socio-economic and energy indicators. Consequently, scholars have called to include renovation indicators in vulnerability frameworks. Thus, both calls were picked up and addressed by the following main research question:

Using a Case-Study Mixed Methods (CS-MM) approach, how can justice be included in renovation policies considering the socio-spatial vulnerability to energy poverty?

A Case Study-Mixed Methods (CS-MM) approach was selected to answer the main research question, whereby a mixed-methods approach was embedded in an overarching study. In the present study, Amsterdam Zuidoost was chosen as a case study. The research consisted of three main phases: system analysis, socio-spatial analysis, and the identification of policy strategies. In the first phase, a system analysis was performed to gain insights into how justice can be included in renovation policies. In doing so, the research problem was defined, and relevant stakeholders were mapped. In the second phase, the socio-spatial vulnerability to energy poverty was defined and explored by: (1) extending current vulnerability frameworks with renovation and institutional indicators based on insight obtained from desk research and semi-structured interviews, (2) defining an index of socio-spatial vulnerability to energy poverty based on desk research, semi-structured interviews and available data at the neighbourhood level and (3) conducting a socio-spatial analysis to identify vulnerable groups and gain insights

into their spatial distribution. Next, based on the system and socio-spatial analysis results, an expert session was organised to identify tailored policy strategies that can be implemented to include justice in renovation policies and address energy poverty.

The results of the present study showed how a CS-MM approach could be deployed to explore how justice can be included in renovation policies.

The results of the system analysis showed the mismatch between residents and actors who are planning and implementing renovation policies as there are various issues related to the socio-economic status (e.g., lack of trust and language barrier), technical issues (mismatch between renovation technologies and the energy practices of residents living in underprivileged neighbourhoods), willingness to invest, and institutional issues (focus on achieving short-term results on energy savings) that cause low renovation rates in underprivileged neighbourhoods such as Zuidoost. The results also highlighted how the City of Amsterdam currently fails to identify vulnerable groups while neglecting the loss of well-being associated with energy poverty. Moreover, the system analysis highlighted the multi-stakeholder environment required to include justice in renovation policies.

The results of the socio-spatial analysis revealed seven different vulnerable groups whose vulnerability to energy poverty is related to a wide range of factors. For instance, the results revealed how large-sized households with a migration background and a low educational background have an increased vulnerability to energy poverty. Spatially, six out of the seven identified vulnerable groups were prevalent in Bijlmer-Oost.

The results of the expert session revealed that various policy strategies could be identified for each vulnerable group tailored to the needs and characteristics of the vulnerable groups. Moreover, from the expert session, it could be concluded that the seven identified vulnerable groups could be clustered into three main groups: the ‘lacking the capacity to act, ‘burdens,’ and ‘building related’ groups. Specifically, this means that the policy strategies identified for each subgroup can also be implemented for the other subgroups. For example, for the ‘lacking the capacity to act’ group, the main identified policy strategies included: improving the communication and connection with the local community, deploying FIXbrigade to provide help with small renovation measures (e.g., insulation and replacing bulbs) and the deep renovation of buildings whenever a household is moving out.

By identifying vulnerable groups based on a locally developed index of the socio-spatial vulnerability to energy poverty and acknowledging their vulnerability, recognitional justice can be included in renovation policies. Besides, identifying tailored policy strategies in a multi-stakeholder environment that, on the one hand, focus on the distribution of renovation resources based on the needs and characteristics of the identified vulnerable groups and, on the other hand, on how the vulnerable groups can be included in the decision-making, distributional and procedural justice can be included in renovation policies. Thus, it can be concluded that by deploying the current CS-MM approach, justice can be included.

The outcomes of the present study are twofold. Firstly, from a scientific perspective, the present study contributes to the current body of scientific knowledge on: (1) how vulnerable groups in need of renovation can be identified, (2) how justice can be included in renovation policies to address energy poverty and (3) how a CS-MM approach can be deployed to research how justice can be included in renovation policies considering the socio-spatial vulnerability to energy poverty. Secondly, from a societal perspective, this study provides insights to improve policy strategies that enable local decision-makers to identify vulnerable groups and include justice in renovation, considering the socio-spatial vulnerability to energy poverty.

Recommendations for future research include: (1) exploring how ethnographic research can be incorporated in the CS-MM approach to include a lived-experience perspective, (2) exploring how participatory trajectories for key stakeholders can be incorporated and designed in the CS-MM approach to create a shared vision and jointly identify policy strategies to avoid

a mismatch between residents/organisations and actors who are planning and implementing renovation policies, (3) researching how energy poverty can be measured and monitored considering the socio-spatial vulnerability to energy poverty as current results only provide insights into which groups have an enhanced vulnerability but do not allow to measure whether that household is energy-poor, (4) exploring the impact of using household level data on identifying vulnerable groups instead of data at the aggregated neighbourhood level to assess which new insights can be created and (5) assessing the applicability of the developed methodological approach to other cities.

Recommendations for policymakers include: (1) stepping away from using expenditure-based indicators solely to identify vulnerable groups and acknowledging the socio-spatial vulnerability to energy poverty and a loss of well-being, (2) deploying a CS-MM approach to identify tailored policy strategies to prevent the implementation of ineffective policy strategies and (3) establishing a multi-stakeholder environment and collaborating with key stakeholders to join forces to include justice in renovation policies and address energy poverty.

Keywords: Renovation Wave, renovation policies, energy justice, energy poverty, socio-spatial vulnerability, Case-Study Mixed Methods

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1. Introduction

In this chapter, the research topic is introduced. Subsequently, literature is reviewed to enhance the understanding of the topic, which leads to the identification of the knowledge gap and the research question that is addressed in the present study. Moreover, the research objective, approach, and relevance for the EPA Master program are discussed, and the structure of this report is presented.

1.1 Background

We all depend on energy in our daily lives and require an adequate level of heating, cooling, and lighting in our homes to have a decent standard of living and help guarantee our health. Affording such a minimum energy level may not be an issue to many people in the Western world; however, it does not apply to all individuals. With nearly 34 million people in the European Union (EU) unable to keep their homes adequately warm, energy poverty is a massive issue across member states (European Commission, n.d.). Energy poverty, also called fuel poverty, refers to the condition in which a household cannot access sufficient domestic energy services to participate meaningfully in society.

Research has shown that living in energy poverty is often associated with a range of adverse consequences among severe health issues and excess winter deaths in most European countries (Thomson et al., 2017; Meyer et al., 2018). The expectations are that with the rising energy prices and COVID-19 regulations, the number of energy-poor households will increase throughout Europe (European Parliament, 2021). Given the wide range of socio-economic factors, such as income, gender, and age, and factors related to the performance of buildings, such as the energy efficiency and indoor living quality, that make specific households more vulnerable to energy poverty than others, energy poverty requires a multi-faceted approach (European Commission, n.d.).

To tackle energy poverty by its roots and protect vulnerable households, the European Commission is keen to use building renovation, also referred to as retrofitting, as a lever to address climate change, energy poverty, and access to healthy houses. The goal is to renovate 35 million inefficient buildings by 2030 with the so-called Renovation Wave (European Commission, 2020). This strategy aims to reduce energy bills by renovating buildings while creating additional green jobs in the construction sector and improving residents' quality of life, health, and well-being (European Commission, 2020).

Nonetheless, recent research has shown that renovation programs have failed to address energy poverty as climate and social policy suffer from fragmented jurisdictions lacking an intersectoral integration between renovation and social policies while also neglecting vulnerable groups such as low-income households and disabled persons at the city level (Gillard et al., 2017; Willand & Home, 2018; Seebauer et al., 2019). Consequently, these policies do not target the energy poor. The increased market value of renovated buildings also raises the risk of social inequity and gentrification (Mangold et al., 2016). As a response, scholars have called for an explicit consideration of justice in the European renovation policy (Mangold et al., 2016; Lithmaa et al., 2018; Seebauer et al., 2019).

Thus, this research partially aims to support policymakers in elaborating just renovation policies by exploring how justice can be included in renovation policies and adequately identifying vulnerable groups who are in great need of renovation to address their vulnerability to energy poverty and improve their well-being.

1.2 Literature Review

To understand how policymakers can include justice in renovation policies and identify vulnerable groups, the concepts of energy poverty, households' vulnerability to energy poverty, energy justice, and renovation policies must be investigated. Thus, the current literature was reviewed based on a search plan. In doing so, firstly, an analysis of the research topic was conducted by identifying key concepts. Secondly, each key concept's alternative search terms were determined and mapped in a search table, shown in Appendix A. Next, the search table was used to identify search queries which eventually reduced the amount of relevant literature.

1.2.1 Defining and Measuring Energy Poverty

Although energy poverty has been researched for years, there is a lack of consensus on how energy poverty should be conceptualised and measured (Thomson et al.,2017). Buzar (2007) refers to energy poverty as the condition in which a household is unable to access sufficient domestic energy services, e.g., heating and lighting, to ensure their well-being and allow them to participate meaningfully in society. As the number of identified energy-poor households primarily depends upon the definition of an energy poverty line, it is essential to analyse and understand the different indicators and to what extent they can correctly distinguish various vulnerable groups.

There are three common expenditure-based indicators to monitor energy poverty. The first is based on the expenditure approach, which explores the household income ratio to energy expenditure. The 10% indicator is one of the most used and well-documented indicators. Using the 10% indicator, a household member is considered energy poor if they spend more than 10% of their income on maintaining an adequate standard of warmth. This indicator has often been criticised as it does not respond to income variations or energy efficiency improvements (Boardman, 2012).

Consequently, this may lead to exaggerating the impact of the rising energy prices in recent years by identifying relatively well-off households in inefficient households as energy-poor while also changing the number of energy-poor households rapidly (Middlemass & Gillard, 2014; Moore, 2021). The second indicator is the Low-Income High-Cost indicator, which identifies household energy poor if energy costs are above average and their income is below 60% of the weighted nation median. However, this indicator was criticized as well as it excludes low-income and single-person households (Middlemiss & Gillard, 2014; Walker et al., 2014). Moore et al. (2021) argue that this indicator also neglects energy efficiency. The third indicator is the Low-Income Low Efficiency. This indicator considers a household energy poor if they have an efficiency rating of D or below and fall below the national poverty line to meet energy costs. The poverty line is defined as the minimum income deemed adequate in a particular country; if an individuals income is below the poverty line, that person is considered 'poor' (Robinson, 2020).

Despite these three variations, several researchers have criticized the expenditure-based approach as it tends to prioritize specific geographies and demographics. This often leads to situations in which some vulnerable groups are not identified, and as a result, they are excluded from policy interventions (Walker & Day, 2012; Robinson et al., 2017).

1.2.2 Socio-Spatial Vulnerability to Energy Poverty

Vulnerability is an established concept when trying to understand the likelihood of negative consequences arising from global environmental change (Adger, 2006). In the present study, vulnerability is defined as the degree of "susceptibility to various stresses, which is not sufficiently counterbalanced by capacities to resist negative impacts in the medium to long term and to maintain levels of overall well-being" (Allen, 2003). Specifically, the susceptibility

is related to a lack of social necessitated energy services which vary socially and spatially (Cutter, Boruff, and Shirley, 2003; Cutter and Finch, 2008; Lindley et al., 2011).

When identifying vulnerable groups, it is important to consider socio-spatial vulnerability, as a household's vulnerability to energy poverty is socially and spatially variable. The socio-spatial vulnerability that gives rise to energy poverty has become a research focus in recent years, drawing attention to the multifaceted nature and its geographical component (Hall et al., 2013; Bouzarovski & Thomson, 2018; Robinson et al., 2019). In combination with concepts of justice, capabilities, and precarity, vulnerability framings have opened up relatively narrow debates ongoing in policymaking to reveal different household types and geographies within which energy poverty is likely to manifest (Bouzarovski and Petrova, 2015; Middlemiss and Gillard, 2015). Acknowledgement of the importance of place is also apparent in research concerned with the distribution of vulnerability to other types of global environmental change (Cutter, Boruff, and Shirley, 2003; Cutter and Finch, 2008). Here, a vulnerability index has frequently been derived from understanding the socio-spatial distribution of vulnerability at a regional or neighbourhood scale.

Scholars have identified various pathways via which a household becomes energy poor in theorising vulnerability to energy poverty. These studies have helped highlight place's importance, pinpointing the spatially varying range of vulnerability indicators. Eventually, this has led to the recognition of vulnerability to energy poverty as a highly socio-spatial phenomenon (Bouzarovski et al., 2017). Building on vulnerability debates, the concept of precarity explores the structural causes of energy poverty, drawing attention to the wider socio-economic, political, institutional, and cultural processes that shape those factors that contribute to an individual's vulnerability and impoverishment (Petrova, 2017). Examples of structural drivers include insecurities in labour and housing markets and the cultural and institutional making of new energy needs. Structural precarities are also highly locally specific, manifesting to differing extents in areas with a wide variety of socio-spatial characteristics.

To differentiate between the relative vulnerability of households and places to energy poverty, a variety of socio-economic, sociotechnical, personal, and institutional factors are documented, including high energy prices, energy efficiency related to the built environment, low incomes, above-average energy needs, lack of social networks, precarity and unhealthy energy-related practices that affect how efficiently energy is consumed and its impact on the well-being of individuals (Bouzarovski and Petrova, 2015; Middlemiss and Gillard, 2015). In England and increasingly in Europe, New Zealand, and the United States, several vulnerability factors are well understood. The psychological vulnerability related to sufficient warmth among the elderly, young children, disabled and ill; the role of high energy prices and low incomes; and the ability to invest in renovation have recently been recognised within national strategies among many countries such as England (DECC, 2015). However, there are also less understood vulnerability indicators that recent studies have drawn attention to, including a more complex understanding of energy-related needs among disabled individuals, those with poor physical and mental health, or unpaid care providers (Snell, Bevan, and Thomson, 2015). Changes within housing provision over the last three decades have led to the manifestation of vulnerability among people experiencing housing-related precarity, particularly those reliant on the private and social rental sector (Ambrose, 2015; TNO, 2021). Additionally, austerity and public service cuts have increased low wages and unstable employment (Bennett, 2014). These precarities have disproportionately affected certain households, including households with a member with a disability or illness, families with young children, and lone-parent families hit by rising living costs and benefit freezes (Millar & Ridge, 2018). They are also more likely to affect young people (Butler & Sherriff, 2017; Petrova, 2017) and transient households, including ethnic minorities (Bouzarovski, 2014).

Robinson et al. (2019) have synthesised these debates into a common framework outlining vulnerability factors derived from existing qualitative research on vulnerability to energy poverty. Figure 1.1 shows the vulnerability framework in which factors internal and external to the home are identified to highlight the socio-spatial component of vulnerability to energy poverty.

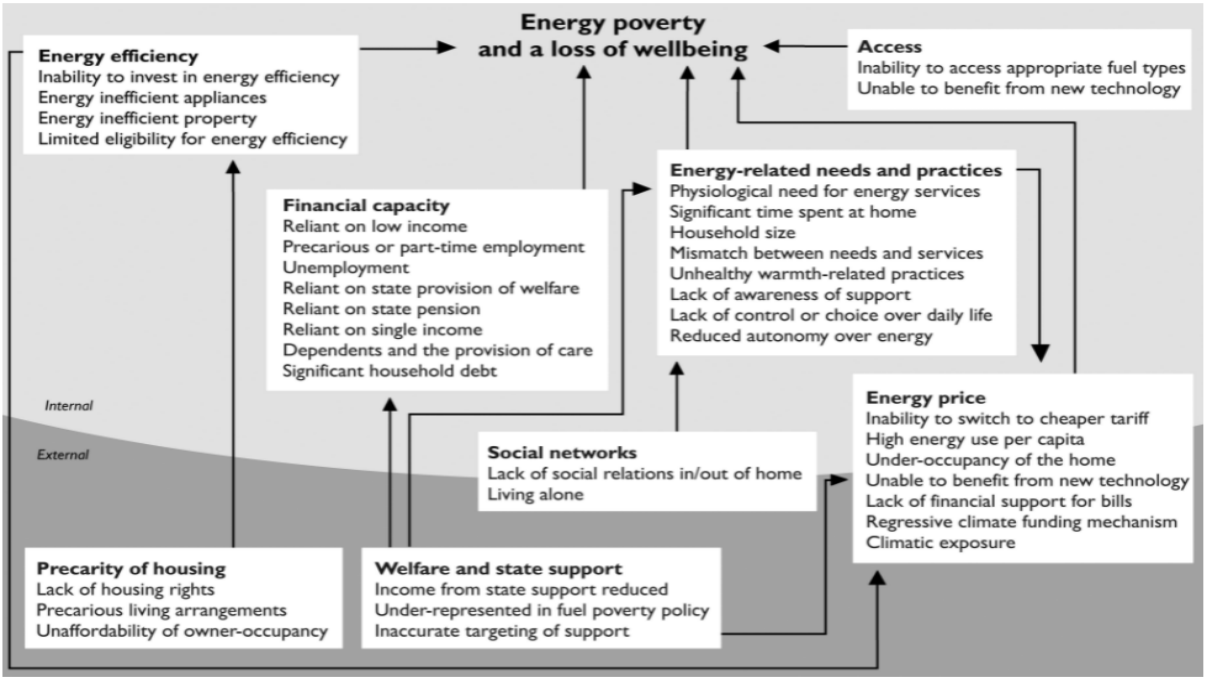


Figure 1.1. Vulnerability Framework Energy Poverty (Robinson et al., 2019)

1.2.3 Existing Analysis of the Spatial Distribution of Energy Poverty

Various researchers have advocated for a multidimensional approach to measuring and mapping the spatial distribution of energy poverty to reflect the local realities of energy poverty in different geographies. Among EU member states, policymakers tend to use expenditure-based indicators at a subregional scale to estimate the number of energy-poor households. The 10%- and Low-Income High Costs indicators are most commonly used. In England, these indicators are intended to inform the allocation and evaluation of energy poverty policies. However, analysis of the neighbourhood scale showed that these indicators tend to prioritise specific geographies and demographics (Walker & Day, 2012; Robinson et al., 2017).

Several studies have identified neighbourhoods that are urgently in need of area-based targeting of energy poverty resources, often in combination with existing indicators (Fahmy & Gordon, 2007; Fahmy et al., 2011; R. Walker et al., 2012; Reames, 2016). In addition to being restricted by the framing of existing indicators, these approaches are not spatial per se, as the importance of the drivers that enhance energy poverty in each area is determined at a national level rather than varying to reflect localised challenges (Fahmy et al., 2011). Fahmy et al. (2011) recognised that the social and spatial distribution of energy poverty varies depending upon the specific definition and measurement approach. These considerations also significantly impact the understanding of the geography of energy poverty. This implies that different measurement approaches can conceal or reveal different geographies and injustices related to energy poverty (Boardman, 2012; Robinson et al., 2017; Robinson et al., 2019).

1.2.4 Renovation Policies and Energy Poverty

Although the Renovation Wave is a public response to energy poverty, studies have shown that renovation policies have failed to address energy poverty. Research conducted by

Seebauer et al. (2019) showed that climate and social policy lack an intersectoral integration between renovation and social policies in Austria. Consequently, these policies do not target the energy poor as they often have a technical focus on, for instance, energy savings instead of considering who is benefiting from the policies; is it a rich household with a large house where significant energy savings can be made or a household who lives in a smaller house in which the energy savings will be lower but their vulnerability to energy poverty will be tackled. Moreover, the structural investments and the provision of affordable, adequate housing conflict due to the tenant and landlord dilemma, whereby a landlord and a tenant have difficulties agreeing upon a strategy for renovating the building (Astmarsson, 2013; Seebauer et al., 2019). Similarly, Siksenelyte-Butkiene (2021) argues that recently developed energy poverty indicators still fail to combine economic, environmental, and social indicators to address energy poverty. Similar patterns are found in the United Kingdom and Australia, where renovation policies have failed to address energy poverty by neglecting vulnerable groups such as disabled persons and low-income families (Gillard et al., 2017; Willand & Home, 2018). The studies highlight how different vulnerable groups have been neglected in current renovation policies across multiple countries. On the other hand, recent studies have shown that although renovation policies aim to realise higher insulation levels and improve energy systems, residents may reject or under-utilize opportunities to renovate their homes. Low renovation rates especially appear among households with lower incomes and unemployment (Brom et al., 2019).

1.2.5 Energy Justice

When identifying vulnerable groups to energy poverty, it is important to consider the concepts of energy justice to explore how justice can be included in renovation policies. Energy justice has emerged as a social science agenda that seeks to apply justice principles within energy policies and climate change. Energy justice is defined as “a global energy system that fairly distributes both the benefits and burdens of energy services and one that contributes to more representative and inclusive energy decision making” (Sovacool et al., 2017). Jenkins et al. (2016) laid the foundation of an energy justice framework that evaluates (i) where injustices emerge, (ii) which part of the society is ignored, and (iii) investigates which processes exist to include the ignored to reveal and reduce such injustices (Jenkins et al., 2016). These evaluations are respectively related to distributional, recognitional, and procedural justice.

1.2.5.1 Distributional Justice

Distributional justice focuses on the distribution of energy benefits and ills. It assesses where questions about the desirability of technologies become entangled with issues related to specific localities and represents a call for the even distribution of benefits and ills on all members of society regardless of factors such as income and race (Jenkins et al., 2016). Given the acknowledgement that some resources are inescapably unevenly distributed (for example, the location of wind resources), distributional justice requires that the evidence of inequality is combined with a notion of fair treatment. The redistribution of benefits can enforce a sense of justice, evidencing the energy justice’s normative contribution. Regarding energy poverty, energy justice concerns both the physical access to heating and questions the extent to which an individual has the freedom to make a choice over their life (Jenkins et al., 2016).

1.2.5.2 Recognitional Justice

Recognitional justice asserts that individuals must be fairly represented, be free from physical threats, and be offered complete and equal political rights. It also includes a call to acknowledge the divergent perspectives rooted in social, ethnic, racial, and gender differences. A lack of recognition can manifest itself not only as a failure to recognise but also as a misrecognition. Concerning energy poverty, studies have shown that governments across countries have failed to recognise specific groups such as the elderly in policies that not only creates injustices but may also lead to the loss of potential beneficial knowledge, values, and stories, as insights from marginalised social groups may get lost as a result. Besides non-recognition, cultural domination and disruption are defined as the main categories of misrecognition, whereby specific cultures dominate and may disrespect marginalised groups (Jenkins et al., 2016).

1.2.5.3 Procedural Justice

Procedural justice concerns access to decision-making processes that govern the distribution of resources and manifests a call for equitable procedures that engage all stakeholders in a non-discriminatory way (Walker, 2009; Jenkins et al., 2016). It inspires researchers to explore how decision-makers have sought to engage with different communities. Mobilising local knowledge, avoiding disclosing information by governments and industries to ensure meaningful participation and full information disclosure, and having gender and ethnic minorities represented in institutions are deemed part of procedural justice (Jenkins et al., 2016).

1.2.5.4 Limitations of Energy Justice Framework

As energy systems tend to be large complex systems, it is challenging to successfully address multiple forms of injustice (Jenkins et al., 2016). Sovacool et al. (2017) highlight the Western theoretical focus of energy justice and the emphasis on anthropocentric concepts in the field, whereby the field of energy justice has overwhelmingly been defined by concerns with ethics and morality among and between humans. Another weakness of energy justice has been the lack of geography in the discussion. Bouzarovski & Simcok (2017) introduce the concept of spatial justice and inequality to energy justice to provide an explicit spatial focus to research as it may help researchers to uncover and evaluate energy-related injustices. Mitigation strategies for these limitations include engaging with locals, setting up truth and reconciliation processes whenever appropriate, and moving beyond conventional strategies of using simple demographics to identify diverse needs and identities across communities (Williams & Doyon, 2019).

1.3 Knowledge Gap

From the literature review, it can be understood that although the Renovation Wave was aimed as a lever to tackle energy poverty and improve the living conditions of the individuals living or using the residential building, renovation policies have failed to address energy poverty as they lack an intersectoral integration of climate and social policies and often have a technical focus on optimising energy savings for instance while neglecting the question of who is saving energy and neglect vulnerable groups such as low-income households and disabled persons at the city level (Gillard et al. 2017; Willand & Home, 2018; Seebauer et al., 2019). Consequently, these policies do not target the energy poor. On the other hand, recent studies have shown that although renovation policies aim to realise higher insulation levels and improve energy systems, residents may reject or under-utilise opportunities to renovate their homes. Low renovation rates especially appear among households with lower incomes and unemployment (Brom et al., 2019). The increased market value of renovated buildings also raises the risk of social inequity and gentrification (Mangold et al., 2016). As a response, scholars have called for an explicit consideration of justice in the European renovation (Mangold et al., 2016; Lithmaa et al., 2018; Seebauer et al., 2019).

The present study takes up this call and explores how justice can be included in renovation policies using the energy justice framework developed by Jenkins et al. (2016) to ensure that renovation policies also target energy-poor households. Specifically, this means that the concepts of recognitional, procedural, and distributional justice will be considered in the exploration of including justice in renovation policies.

To include justice in renovation policies, it is important to identify vulnerable groups and targeted policy strategies. From the literature review, it can be understood that the scientific understanding of vulnerability to energy poverty is still in its infancy. Various scholars, such as Robinson et al. (2019), have tried to identify and synthesise vulnerability indicators that give rise to energy poverty while acknowledging the social and spatial vulnerability to energy poverty; however, these have only focused on identifying socio-economic and energy indicators. Scholars such as Lithmaa et al. (2018) have called to include renovation indicators, such as the age of the building, into vulnerability frameworks.

Given the objective of exploring how justice can be included in renovation policies and the thereby resulting need to identify vulnerable groups, the present study also picks up the call to include renovation indicators into vulnerability frameworks, as current vulnerability frameworks are solely built on socio-economic, energy indicators and lack renovation indicators due to which they cannot address renovation policies and adequately identify vulnerable groups who are in great need of renovation to address energy poverty and improve their well-being as their vulnerability is also related to the energy performance of the building and indoor living quality.

1.4 Research Approach

To explore how justice can be included in renovation policies considering the socio-spatial vulnerability to energy poverty, this research proposes to use a Case Study-Mixed Methods (CS-MM) approach, whereby a mixed-methods approach is embedded in overarching research (Guetterman & Fetters, 2018). By considering the socio-spatial vulnerability to energy poverty, the limitation of the energy justice framework related to the lack of geography can be addressed as the socio-spatial vulnerability to energy poverty also considers the spatial component of energy poverty.

For a CS-MM, it is crucial that the mixed methods design is drafted for meaningful integration of the qualitative and quantitative strands and rigorously deployed within the context of a case study. In the present study, Amsterdam Zuidoost (Zuidoost) is selected as a case study. Collaboration has been established with the City of Amsterdam and Energielab Zuidoost to research how policymakers can include justice in renovation policies. Given that energy poverty is a large issue in Zuidoost, the City of Amsterdam is keen to use renovation as a lever to address climate change and energy poverty in the future. Therefore, Zuidoost is deemed suitable as a case study (Gemeente Amsterdam, 2021). As the vulnerability to energy poverty is socially and spatially varying, an advantage of a case study is that it enables conducting analysis and developing an in-depth understanding of a phenomenon within a real-world context (Guetterman & Fetters, 2018). This aligns with the aim of this research to explore how justice can be included in renovation policies and how vulnerable groups to energy poverty who need renovation can be identified to address energy poverty and improve their well-being. Moreover, where current studies on the socio-spatial vulnerability of energy poverty have stopped at identifying vulnerable groups, the present study aims to go a step further by not just exploring how vulnerable groups can be identified but also considering how tailored policy strategies can be identified based on the identified vulnerable groups by using a CS-MM approach.

A Mixed-Method approach is selected as it allows an in-depth and broad understanding of the area under study by having at least one quantitative and one qualitative research strand (Creswell & Clark, 2010; Maggetti, 2018). For the quantitative strand, vulnerability indicators consisting of socio-economic, renovation, and energy indicators will be analysed from a socio-spatial perspective to identify vulnerable groups and gain insights into where these vulnerable groups are spatially located. The qualitative strand will use these insights to organise an expert session to identify tailored policy strategies that will contribute to including justice in renovation policies. Moreover, interviews and desk research are used throughout the present study to understand current policies, identify where injustices currently emerge, and identify relevant renovation indicators. Expert validation is also used to validate the results of the quantitative and qualitative strands. A limitation of the Mixed-Methods approach is that it is highly time-consuming as the interviews and an expert session needs to be planned, executed and analysed (Malina et al., 2011). However, given the schedule of this research, there was sufficient time to apply the Mixed-Method approach. Figure 1.2 visualises the research approach. The research phases and research methods are discussed in detail in chapter 2.

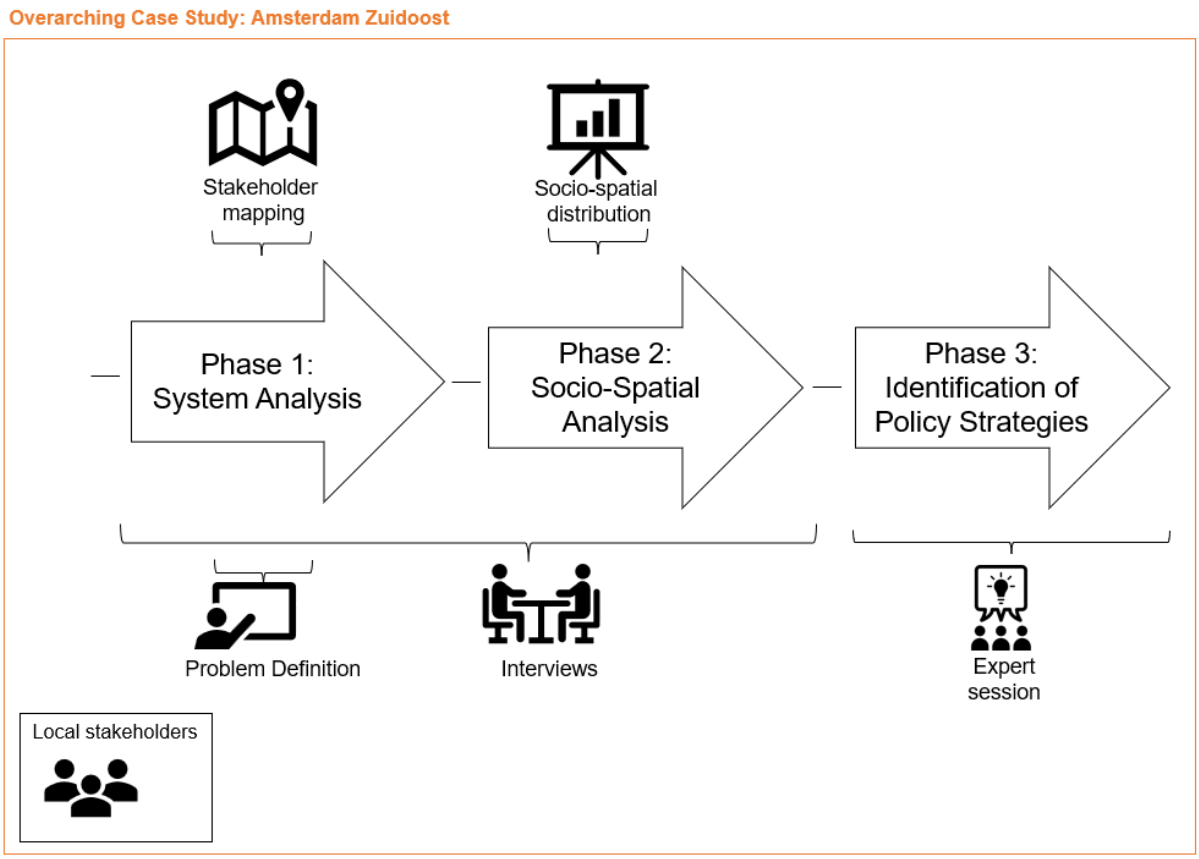


Figure 1.2. Overview of Research Approach

1.5 Research Objective

Based on the identified knowledge gap and research approach, the research aims of the present study are threefold: (1) to investigate how justice can be included in renovation policies, (2) to explore how vulnerable groups who are in great need of renovation can be identified considering their socio-spatial vulnerability to energy poverty and (3) to demonstrate how a Case Study-Mixed Methods approach can be deployed to explore how justice can be included in renovation policies. The outcomes of this research are twofold. Firstly, from a scientific perspective, the present study contributes to the current body of scientific knowledge on: (1) how vulnerable groups in need of renovation can be identified, (2) how justice can be included in renovation policies to address energy poverty and (3) how a Case-Study Mixed Methods approach can be deployed to research how justice can be included in renovation policies considering the socio-spatial vulnerability to energy poverty. Secondly, from a societal perspective, this study provides insights to improve policy strategies that enable local decision-makers to identify vulnerable groups and include justice in renovation, considering the socio-spatial vulnerability to energy poverty.

1.6 Research Questions

Based on the identified knowledge gap and research objective, the following main research question is formulated:

Using a Case-Study Mixed Methods (CS-MM) approach, how can justice be included in renovation policies considering the socio-spatial vulnerability to energy poverty?

To guide the research process, the following sub-questions are formulated focusing on the case study in Zuidoost:

1. What is the current system of tackling energy poverty by renovating residential buildings in Zuidoost? What are current policies, which issues can be identified, and which stakeholders are involved in the decision-making?
2. How to define the socio-spatial vulnerability to energy poverty in the context of Amsterdam?
3. Based on the defined socio-spatial vulnerability to energy poverty, which groups are identified as vulnerable to energy poverty in Amsterdam, and where are these groups spatially located?
4. Based on the system - and socio-spatial analysis results, which policy strategies do stakeholders identify in an expert session for including justice in renovation policies in Zuidoost?

As one of the objectives of the present study is to use a CS-MM approach to explore how justice can be included in renovation policies considering the socio-spatial vulnerability to energy poverty, quantitative and qualitative strands are used throughout the research. Sub-question 1 analyses the system by reviewing current renovation and energy poverty policies to gain insights into existing policies and the current issues surrounding the renovation of residential buildings and addressing energy poverty. Moreover, stakeholders are identified who are involved in the decision-making process and thereby influence renovation policies. Next, sub-question 2 investigates how the socio-spatial vulnerability to energy poverty can be defined in the context of Amsterdam by examining which indicators are relevant to assessing a household's need for renovation and explores how the identified indicators can be synthesised into an extended vulnerability framework that builds upon the vulnerability framework developed by Robinson et al. (2019). The defined socio-spatial vulnerability will then be applied in sub-question 3 to identify vulnerable groups to energy poverty and gain insights into their spatial distribution across Amsterdam by performing a socio-spatial analysis. Lastly, sub-question 4 explores which policy strategies stakeholders identify during an expert

session for including justice in renovation policies based on the results of the system and socio-spatial analysis.

1.7 Structure of the Thesis

In the present study, the application of a CS-MM approach to explore how justice can be included in renovation policies considering the socio-spatial vulnerability to energy poverty is described to answer the main research question. In doing so, Chapter 2 introduces the research design and describes the different research methods combined in this research to explore how justice can be included using the CS-MM approach. Chapter 3 presents the system analysis results to gain insights into current policies, issues and involved stakeholders. Based on these insights and existing literature, the socio-spatial vulnerability to energy poverty is defined within the context of Zuidoost in Chapter 4. Building upon the defined socio-spatial vulnerability, a socio-spatial analysis is performed to identify vulnerable groups and gain insights into their spatial distribution across the neighbourhoods of Amsterdam. In Chapter 5, these results are discussed. Based on the results of the system – and socio-spatial analysis, an expert session is organised to identify policy strategies that are tailored to the needs and characteristics of vulnerable groups to include justice in renovation policies. In Chapter 6, the results of the expert session are discussed, and the implications of identifying policy strategies based on the results of the system – and socio-spatial analysis are discussed to highlight the importance of policy strategies that are identified based on a quantitative and qualitative understanding of the socio-spatial vulnerability to energy poverty. Finally, the present study concludes, its limitations and relevance are discussed, and ideas for future research are posed in Chapter 7.

2. Research Design and Methods

This chapter outlines the research design, methodology and quality of the research design. In section 2.1, the research design and research flow are described. Section 2.2 describes the methodology for each research phase by discussing the method, data collection, and data analysis for each research phase. Section 2.3 discusses the quality of the research design.

2.1 Research Design

To answer the main research question, the present study was divided into three phases. In the first phase, a system analysis was performed to gain insights into how justice can be included in renovation policies. In doing so, the research problem was defined, and relevant stakeholders were mapped. In the second phase, the socio-spatial vulnerability to energy poverty was defined and explored by: (1) extending current vulnerability frameworks with renovation and institutional indicators based on insight obtained from desk research and semi-structured interviews, (2) defining an index of socio-spatial vulnerability to energy poverty based on desk research, semi-structured interviews and available data at the neighbourhood level and (3) conducting a socio-spatial analysis to identify vulnerable groups and gain insights into their spatial distribution. Next, based on the system and socio-spatial analysis results, an expert session was organised to identify tailored policy strategies that can be implemented to include justice in renovation policies and address energy poverty. To enhance the understanding of the research flow and how the different research phases are connected, a research flow diagram was made. Figure 2.1 provides an overview of the research flow. Table *C.1* provides an overview of the research flow, required data, and how the data is analysed.

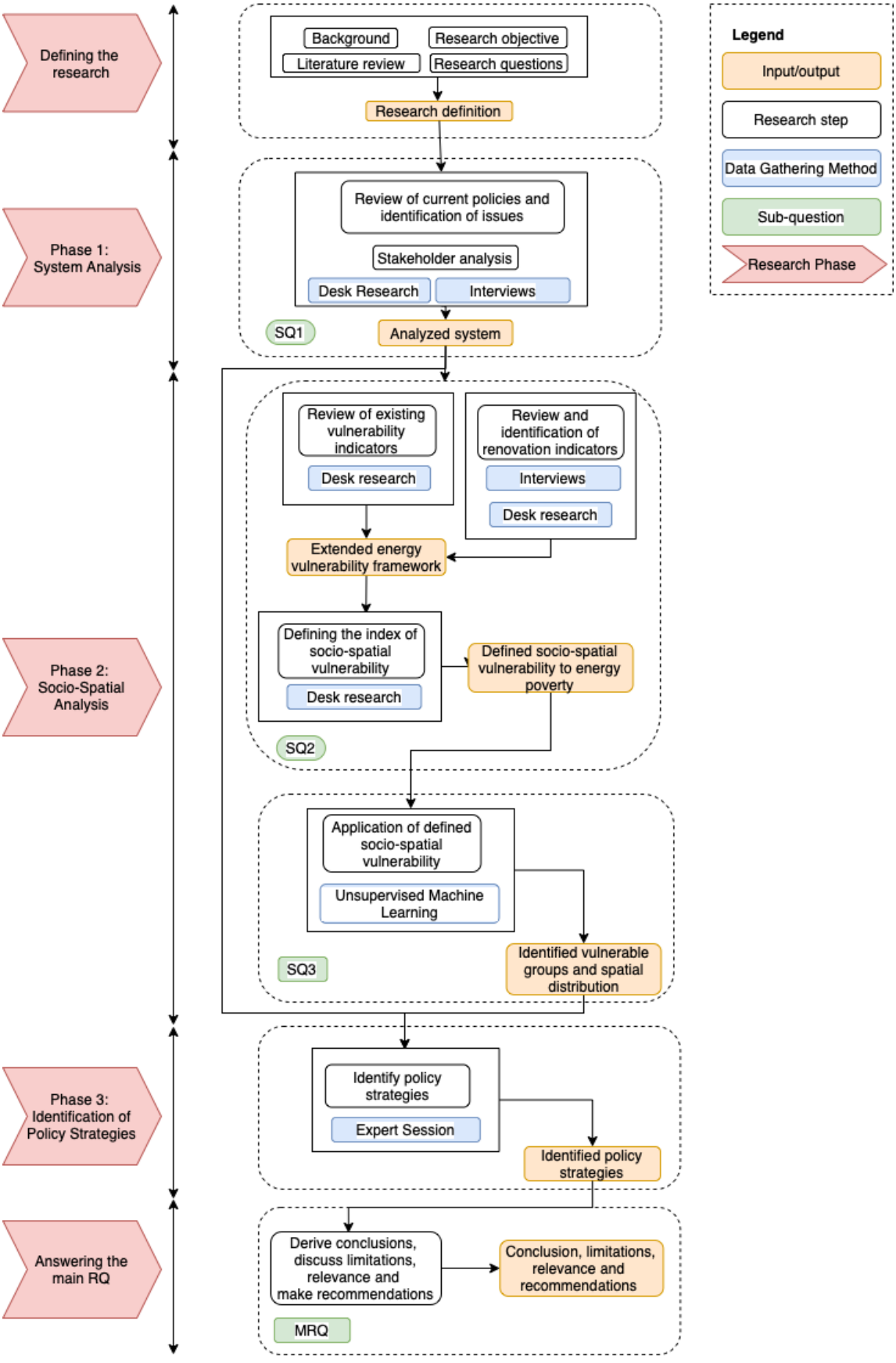


Figure 2.1 Research Flow Diagram

2.2 Research Methods

In this section, the research methods are described. Section 2.2.1 describes the research methods for the system analysis. In section 2.2.2, the research methods for the socio-spatial analysis are described. Section 2.2.3 describes the research methods for the identification of policy strategies. Appendix B provides an overview of the research methods and required data.

2.2.1 System Analysis

In the first phase, a system analysis was performed to gain insights into how justice can be included in renovation policies. In doing so, the research problem was defined, and relevant stakeholders were mapped. Desk research, semi-structured interviews, and stakeholder analysis were used as a methodology for the system analysis.

2.2.1.1 Desk Research on Renovation and Energy Poverty

At first, current renovation and energy poverty policies were reviewed based on desk research to understand the current issues in tackling energy poverty by renovating buildings. The desk research included the consultation of peer-reviewed literature and grey literature. Desk research is often used in qualitative research approaches, whereby researchers use existing data from various sources to collect, combine and compare existing knowledge. Peer-reviewed literature will form the foundation of the research. Peer-reviewed literature ensures the research's quality standards (Rowland, 2002). Hence, it was assumed that the consulted literature meets academic standards and provides reliable information. The peer-reviewed literature was gathered from scientific databases, publishers, and snowballing. Grey literature was used to complement the selection of peer-reviewed literature. The assumption was that, as the distribution of renovation resources is a policy problem, relevant contextual information about current policies and strategies of policymakers will be available in non-peer-reviewed literature, such as reports published by public entities and organisations (Adams et al., 2016). This way, new knowledge could be created as the resources are widely available, and researcher bias was reduced. To ensure data validity, the recency of grey literature was tracked. In contrast, the citation score and strongly related work of peer-reviewed literature were tracked to ensure that the data is not outdated. Moreover, contacted policymakers and experts pointed out valuable non-peer-reviewed information sources. Gathering grey literature is usually limited by time as, just like peer-reviewed literature, it is impossible to read all available documents. Therefore, the literature was carefully selected based on data saturation.

The peer-reviewed literature used was primarily drawn from the following databases: Scopus and ScienceDirect. These databases were selected as they provide a broad overview of the literature on energy poverty and an interface that makes the selection of literature easy to execute (Sarja et al., 2021). The grey literature was primarily drawn from the Openresearch database, a platform the City of Amsterdam uses to gather and share research, knowledge, and innovation about Amsterdam and its Metropolitan area (Openresearch Amsterdam, n.d.). The grey literature was complemented by reviewing various publications by TNO as they are responsible for creating and sharing knowledge on energy poverty and renovation from a national perspective (TNO, 2021).

2.2.1.2 Semi-Structured Interviews

In the present study, semi-structured interviews were conducted to complement the desk research on current policies and injustices within the case study context. To guide the interview, interview topics were defined based on the themes of energy poverty, renovation, policies, and injustices (Mason, 2011). These topics were in line with the topics covered in the present study. During the interview, there was room for a more natural conversation, indicating that the researcher could touch upon other topics and ask additional questions (Mason, 2011). The advantage of a semi-structured interview is that it allows one to delve deep into issues related to renovation and energy poverty (DiCicco-Bloom & Crabtee, 2006).

Four interviews were conducted to ensure that interviewees from multiple fields and different projects were reached to get a broad understanding of the current system. The interviews were conducted, depending on the interviewee's preferences, either through Microsoft Teams or at the office of the corresponding interviewee. To transcribe and analyse the interviews, the interviews were audio-recorded using Apple's Dictaphone application and transcribed in Microsoft Word. Each interview took a maximum of 60 minutes. Table 2.1 provides an overview of the interviewees and their corresponding organisations.

Table 2.1 Overview Interviewees

Respondent:	Organisation:
1	City of Amsterdam
2	Stichting !WOON
3	TNO
4	Energie Lab Zuidoost/ Universiteit van Amsterdam

Note. The table provides an overview of the interviewees and their organisational background

Figure *2.2* shows the generic interview structure deployed in the interviewing process and the accompanying interview topics. The interviews were also a way to assess the applicability of the vulnerability framework and proposed results of the study in the work field of the respondents to create a mutual benefit for the interviewer and interviewees.

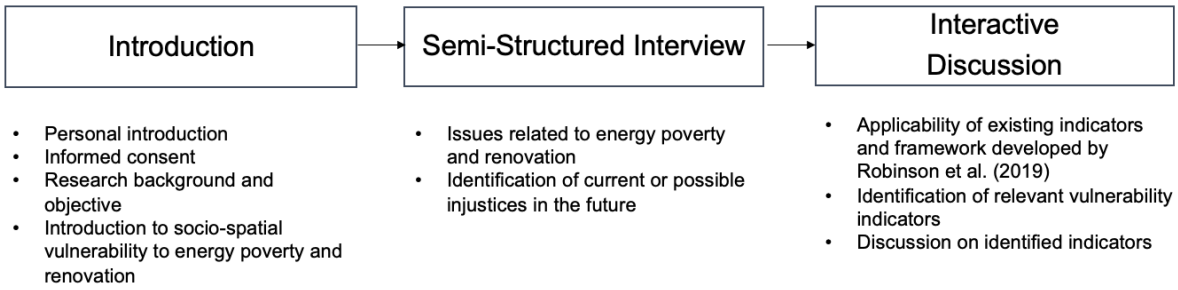


Figure 2.2 Generic Interview Structure for the Conducted Interviews

Note. The figure shows the generic structure and interview topics that were addressed during the semi-structured interviews. This diagram is created using Draw.io.

To analyse the interviews, qualitative data treatment and analysis were taken as an approach whereby various codes were generated to analyse the data. These codes were based on the research questions, desk research on energy poverty and renovation, and the vulnerability framework to ensure that relevant insights can be extracted from the data. Moreover, there was also room to generate new codes based on the data. In the present study, a computer-assisted qualitative data analysis software (CAQDAS), ATLAS.ti, was used to analyse the data. After manually codifying the initial set of codes, contradicting or overlapping codes were reviewed and adjusted accordingly if required. To enhance the understanding of the codes, various linkages were made between the codes to identify patterns that emerged from the data. After analysing the data, the results of the interviews and desk research were combined

to analyse the system and define the problem. To analyse the interviews, qualitative data treatment and analysis were taken as an approach whereby various codes were generated to analyse the data. These codes were based on the research questions, desk research on energy poverty and renovation, and the vulnerability framework to ensure that relevant insights can be extracted from the data. Moreover, there was also room to generate new codes based on the data. In the present study, a computer-assisted qualitative data analysis software (CAQDAS), ATLAS.ti[1], was used to analyse the data. After manually codifying the initial set of codes, contradicting or overlapping codes were reviewed and adjusted accordingly if required. To enhance the understanding of the codes, various linkages were made between the codes to identify patterns that emerged from the data. After analysing the data, the results of the interviews and desk research were combined to analyse the system and define the problem.

2.2.1.3 Stakeholder Analysis

A stakeholder analysis was performed to gain insights into which key stakeholders are currently involved in the decision-making surrounding renovation and energy poverty. The stakeholder analysis also allowed us to identify key stakeholders' interests, problem perception, and power in the decision-making process. Based on these results, relevant stakeholders were invited to the expert session. The results from the stakeholder analysis also allowed us to identify currently neglected key stakeholders who deal with or are affected by renovation and energy poverty policies but are now not represented in the decision-making process. The stakeholder analysis consisted of five steps: problem formulation, identification of stakeholders, determining the interests, objectives, and problem perceptions, mapping interdependencies, and determining the consequences of the stakeholder analysis (Enserink et al., 2010). Each step is discussed in detail in Appendix D. To ensure the validity of the system analysis results; the outcomes were discussed and validated with the external supervisor of the City of Amsterdam, the second supervisor and a local employee of the City of Amsterdam.

2.2.2 Socio-Spatial Analysis

In the second phase, the socio-spatial vulnerability to energy poverty was analysed.

2.2.2.1 Methodology for Defining the Socio-Spatial Vulnerability to Energy Poverty

At first, renovation indicators were identified based on desk research, interviews, and a working session with a professor in Housing Quality at the Technical University of Delft and validate the renovation indicators that were identified using desk research and interviews. Desk research is often used in qualitative research approaches, whereby researchers use existing data from various sources to collect, combine and compare existing knowledge. Peer-reviewed literature will form the foundation of the research. Using peer-reviewed literature ensures the research's quality standards (Rowland, 2002). Hence, it can be assumed that the consulted literature meets academic standards and provides reliable information. The peer-reviewed literature was gathered from scientific databases, publishers, and snowballing. Given that one of the objectives of this research was to define the socio-spatial vulnerability to energy poverty by building upon the vulnerability framework that Robinson et al. (2019) developed, their research served as a building block and was mainly consulted throughout the research phase. Grey literature was also used to complement the selection of peer-reviewed literature. The assumption is that as the vulnerability to energy poverty is a policy problem related to the socio-economic, energy, and renovation status of households, relevant contextual information about current factors that enhance the vulnerability will be available in non-peer-reviewed literature, such as reports published by public entities and organisations (Adams et al., 2016). This way, new knowledge could be created as the resources are widely available, reducing researcher bias. To ensure data validity, the recency of grey literature was tracked. In contrast, the citation score and strongly related work of peer-reviewed literature were tracked to ensure

that the data is not outdated. Gathering grey literature is usually limited by time as, just like peer-reviewed literature, it is impossible to read all available documents. Therefore, the literature was carefully selected based on data saturation.

The peer-reviewed literature used was primarily drawn from the following databases: Scopus and ScienceDirect. These databases were selected as they provide a broad overview of the literature on energy poverty and an interface that makes the selection of literature easy to execute (Sarja et al., 2021). The grey literature is primarily drawn from the Openresearch database, a platform the City of Amsterdam uses to gather and share research, knowledge, and innovation about Amsterdam and its Metropolitan area (Openresearch Amsterdam, n.d.). The grey literature was complemented by reviewing various publications by TNO as they are responsible for creating and sharing knowledge on energy poverty and renovation from a national perspective (TNO, 2021). Moreover, the results from phase 1 were combined with the peer-reviewed and grey literature to ensure synergy and a multi-informed understanding of socio-spatial vulnerability to energy poverty.

Next, the identified renovation and institutional indicators were synthesized into an extended vulnerability framework by building upon the vulnerability indicators identified by Robinson et al. (2019). This framework allowed us to adequately identify the pathways via which a household becomes vulnerable to energy poverty and a loss of well-being. To validate the framework, the extended framework was, on the one hand, compared with the identified vulnerability factors during the interviews and, on the other hand, by discussing the extended vulnerability framework extensively with experts in energy poverty, justice, and renovation to ensure that the framework identifies various pathways via which a household becomes vulnerable to energy poverty and its applicability within the context of Amsterdam.

Moreover, an index of the socio-spatial vulnerability to energy poverty was developed by aggregating multiple vulnerability indicators to investigate the relative importance of the vulnerability indicators, identify vulnerable groups, and their spatial distribution. To further enhance the understanding of the defined socio-spatial vulnerability to energy poverty, a visualization was made which allows to create an understanding of the multidimensionality of energy poverty.

2.2.2.2 Methodology for the Socio-Spatial Analysis

A socio-spatial analysis was conducted to gain insights into which groups are vulnerable to energy poverty and how they are geographically distributed across Amsterdam. As shown in Figure 2.3, the socio-spatial analysis consisted of five main steps: data, pre-processing, data exploration, principal component analysis, and spatial analysis.

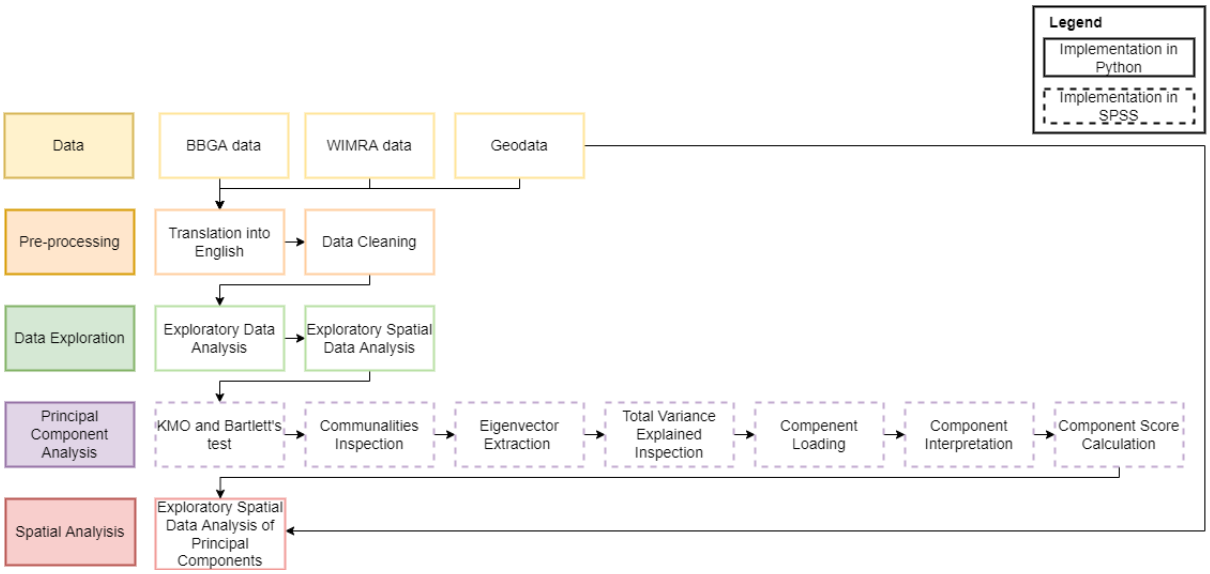


Figure 2.3 Methodology for Socio-Spatial Analysis

The main method selected to identify vulnerable groups and gain insights into the spatial distribution was the principal component analysis in combination with the spatial analysis. To assess to what extent the used methodologies are successful in identifying vulnerable groups and providing insights into their geographical distribution, the results (identified vulnerable groups and their spatial distribution) were validated during the expert session. Each step is discussed in detail in the next sections.

2.2.2.2.1 Step 1: Data Retrieval

Given the objective of the socio-spatial analysis and the research objective of gaining insights into which vulnerability indicators enhance energy poverty and a loss of well-being across the neighbourhoods of Amsterdam, the data was largely retrieved on the neighbourhood (‘wijk’) level of Amsterdam. This means that 99 neighbourhoods or so-called wijks were considered a primary analysis unit. The identified vulnerability indicators were mainly retrieved from the open-source dataset ‘Dataset Basisbestand Gebieden Amsterdam’ (BBGA) of the City of Amsterdam, which contains key numbers on various scale levels of Amsterdam. A small part of the data is received from the Department of Onderzoek, Informatie en Statistiek (OIS). The data retrieved from the OIS is based upon the responses from the ‘Wonen in de Metropoolregio Amsterdam (WiMRA)’ survey, which is conducted every two years and available on an aggregated neighbourhood level. A large part of the selected vulnerability indicators was available at the neighbourhood (‘wijk’) level of Amsterdam, representing the 99 neighbourhoods of Amsterdam. However, in the WiMRA dataset and BBGA dataset, there was no information available on the identified institutional indicators related to the participation and communication of the City of Amsterdam. Given the importance of vulnerabilities related to issues in policy-making, it was decided to find proxy data for the corresponding variables. As this information is available on a higher aggregation level, namely the ‘gebieden’ aggregation level, which represents 22 areas of Amsterdam, it was decided to assume that each neighbourhood within a certain ‘gebied’ has the same value as its aggregated ‘gebied ’ level. As the objective is this research was to gain insights into the socio-spatial distribution of vulnerable groups to energy poverty and a loss of well-being across Amsterdam, an open-source shapefile was retrieved from the Databank of the City of Amsterdam, containing geographical information on the neighbourhood level which was used for conducting spatial analysis. These three data files were combined into one data file to be able to merge all the geographical information and vulnerability indicators.

2.2.2.2.2 Step 2: Pre-Processing

In this section, all the pre-processing steps in preparion for the socio-spatial analysis are described. At first, the data was explored to gain insights into what data we have, and the variable names were translated into English. Next, irrelevant columns were removed as the objective of the data pre-processing was to have a 'clean' data frame that only contained relevant information. Moreover, the geographical data contained geographical data on neighbourhoods of Weesp, which were excluded in the analysis as the data used in this research was only available for the neighbourhoods of Amsterdam and not for the City of Weesp, which has recently become part of the City of Amsterdam (Gemeente Amsterdam, 2022). The data frame also contained missing values; based on the distribution of the missing value indicator; an accompanying strategy was selected to deal with the missing values. After dealing with the missing values, the index was set to the neighbourhood to ensure that each row represents one neighbourhood.

2.2.2.2.3 Step 3A: Exploratory Data Analysis (EDA)

EDA was carried out to understand the properties of the data and maximise insights into the dataset, visualise potential relations between indicators, and detect outliers. At first general descriptives were inspected, such as the mean, minimum, and maximum, to gain insights into the distribution and type of indicators in the data frame; from this analysis, it became apparent that the data frame contained 'objects' for the geographical information and all the vulnerability indicators were numerical variables (floats or integers). As MIT Critical Data (2016) recommended, boxplots were made to gain insights into the distribution of the vulnerability indicators and detect outliers. Moreover, the correlations between vulnerability indicators were inspected to assess the suitability of the dataset for performing PCA.

2.2.2.2.4 Step 3B: Exploratory Spatial Data Analysis (ESDA)

To gain insights into how the various indicators were geographically distributed across Amsterdam, ESDA was carried out. ESDA tools provide functions to describe and visualise spatial distributions, enhancing the discovery of spatial patterns and spatial outliers (Steiniger & Hunter, 2013). ESDA was performed using the Pysal[2] package. In this research, the spatial distribution of all vulnerability indicators was explored. As plotting the spatial data requires defining the number of clusters that you want the data to split into, Sklearn's K-means package[3] was used as it tries to minimise the distance between the points in a similar cluster.

2.2.2.2.5 Step 4: Principal Component Analysis

A socio-spatial analysis was conducted to gain insights into which characteristics enhance the vulnerability to energy poverty and a loss of well-being and where these vulnerable groups are located geographically. Methodologically, vulnerability indexes have used principal component analysis (PCA) to assess the relative vulnerability between areas (Jolliffe, 1986). PCA is a statistical analysis that allows the reduction of a large multivariate set of vulnerability indicators into principal components while retaining key statistical information and spatial patterns (Jollife, 1986). These components have loading values that are associated with each of the vulnerability indicators in the data set. The loadings portray the type (positive or negative) and strength of the relationship between a principal component and an indicator and thus provide information about the patterns of vulnerability within the data that each component is likely to represent. PCA is often referred to as a global data reduction technique whereby it produces one set of components for the whole data set, representing the whole of Amsterdam in this research. To understand the spatial distribution of the vulnerability that each principal component and locales in which the vulnerability is likely to enhance can be mapped by the component loadings. However, these loadings are spatially stationary and thus cannot account for spatial effects (Openshaw, 1984; Lloyd, 2010; Harris et al., 2011; Demšar et al., 2013). The PCA was carried out in IBM's SPSS[4] program.

KMO and Bartlett's test

The built-in Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO) and Bartlett's test was conducted to assess the suitability of the vulnerability indicators for PCA. KMO represents the proportion of variance in all variables that underlying factors might cause. Values between 0.5-1 indicate that the results of the PCA will be useful. Bartlett's sphericity test assesses whether all variables in your dataset are unrelated and, therefore, not useful for feature reduction. Values smaller than 0.5 indicate that the data might be suitable (IBM, 2021).

Communalities

Next, the communalities were inspected to assess the proportion of variance accounted for by the variable in the component solution. Small values (<0.25) indicate that the variables do not fit well with the component solution, whereby these variables should be dropped.

Eigenvalues extraction and total variance explained (TVE)

The eigenvalues were extracted in the next two steps to determine how many components the solution should retain. In the present study, only components with an eigenvalue higher than one were restored as they represent more variance than the variable itself can represent.

Component Loading

The component loadings were inspected to assess how much each variable loads onto each of the seven components. To ease the interpretation, the loadings were rotated orthogonally, sorted by size, and coefficients below 0.3 were suppressed.

Component Interpretation

The name for each component was determined based on the rotated component matrix. Variables that load the strongest on a component are used to determine the name.

Component Score Calculation

Finally, the component score for each neighbourhood on each component was calculated to gain insights into the geographical distribution of vulnerabilities related to the identified components. These scores were determined by first calculating the standardised values for each indicator and multiplying the loadings of each component by the accompanying standardised value to determine scores for each component per neighbourhood, which complies with linear regression SPSS automatically calculates this.

2.2.2.2.6 Step 5: ESDA Component Score

To gain insights into how the various components are geographically distributed across Amsterdam, ESDA was carried out. ESDA tools provide functions to describe and visualise spatial distributions, enhancing the discovery of spatial patterns and spatial outliers (Steiniger & Hunter, 2013). ESDA was performed using the Pysal package. As plotting the spatial data requires defining the number of clusters that you want the data to split into, Sklearn's K-means package was used as it tries to minimise the distance between the points in a similar cluster. To enhance the understanding of the number of clusters (=k) used in the analysis, the Elbow method was used, whereby the number of clusters used in the analysis depends on the point where there is the sharpest drop and increasing the number of clusters does not impact the distortion score (Scikit, n.d.).

2.2.3 Identification of Policy Strategies

In this research, an expert session was organised to identify policy strategies based on the results from the system and socio-spatial analysis. Expert sessions provide the opportunity to aid researchers, in an academic setting, in identifying and exploring relevant factors in a given field by providing means for understanding complex work and knowledge processes supported by technology (Ørngreen & Levinsen, 2017).

As an academic research methodology, workshops or sessions are often intended to serve participants' interests and produce valid and reliable data about the specific session topic (Ørngreen & Levinsen, 2017). An advantage of organising sessions is that they are specifically designed to engage participants and empower them to be actively involved in the corresponding topic in contrast to interviews or observations (Ahmed & Asraf, 2018). The role between the facilitating researcher and participant also becomes an interesting relationship, as a researcher needs to position himself on the one hand as an objectifying session participant for research purposes to ensure academic distance and, on the other hand, needs to become actively involved and engaged with the participant to generate trust between the facilitator and participants to enhance the likelihood of sharing backstage knowledge (Ørngreen & Levinsen, 2017). The expert sessions are also a way to assess the applicability of the present study's results in the respondents' work field to create a mutual benefit for the interviewer and interviewees.

In the present study, the expert session was selected as a method to identify policy strategies and evaluate and interpret the findings from the system and socio-spatial analyses. The results from phases 1 and 2 also served as input for the expert session. Additionally, to this research objective, the session enhanced the understanding of the various pathways via which households became vulnerable to energy poverty and a loss of well-being and allowed us to discuss how the vulnerability framework and the insights obtained from the socio-spatial analysis could be used in the daily work of the stakeholders. Thus, a mutual benefit was created between the participants and facilitator.

Various local stakeholders were invited to the expert session based on the identified vulnerable groups and stakeholder analysis. As the goal of the expert session was to have an in-depth discussion, it was decided to limit the number of participants to six while maintaining a diverse background as three different civil servants from the City were invited who have in-depth knowledge and are responsible for policymaking, a member of Stichting !WOON, whose daily work includes interaction with local vulnerable groups in Zuidoost, A local citizen and member of Stichting Co-Force, who is keen to help the local residents with tackling energy poverty and a member of the Energielab Zuidoost/ social scientist at the Hogeschool van Amsterdam who is also a project leader in a new research project related to just renovation policies in Zuidoost. Table *2.2* provides an overview of the participants.

Table 2.2 Overview of Participants of the Expert Session

Participant	Organisation:
1	City of Amsterdam
2	Stichting !WOON
3	City of Amsterdam
4	Energie Lab Zuidoost/ Hogeschool van Amsterdam
5	City of Amsterdam
6	Local citizen and member of Stichting Co-Force

Note. The table provides an overview of the participants and their organisational background

The corona guidelines were considered to ensure that participants felt COVID-19 safe during the session. The session was conducted at the office of the City of Amsterdam in Zuidoost. The experts were invited through the personal network of the researcher to ensure that experts working in the energy poverty and renovation field were invited. The session was conducted in Dutch as the native language of all participants was Dutch. It was assumed that by organising the session in Dutch, the participants would not have difficulty expressing their point of view as they would not have to translate it into English. Since their daily work is also in Dutch, conducting the session in Dutch was considered reasonable. Given time constraints, the expert session was limited to 90 minutes, whereby the results from phases 1 and 2 were shared first to ensure that all experts had a shared vision and the same starting point before identifying policy strategies. After creating a shared vision, the interactive session started.

During the first part of the interactive session, the participants identified policy strategies which the City could implement to include justice in renovation policies based on the needs and characteristics of the vulnerable groups. Each participant received a booklet which presented the identified vulnerable groups and their socio-spatial distribution across Amsterdam to ensure that each strategy was identified based on the characteristics of the vulnerable groups. Post-it notes and various pens were also provided to the participants on which they could write down the policy strategy and stick them on the corresponding flip-over sheet. Moreover, to ensure that the policy strategies are realistic and executable within the sphere of the City or key stakeholders, conditions for identifying policy strategies were also presented. During the second part of the interactive session, ideas were shared on which stakeholders should improve their collaboration and what measures the housing associations can take despite not having a high urgency to renovate relatively ‘well-performing residential buildings.’ Well-performing buildings were defined as buildings with a higher energy label than E, which complies with the national strategy. Given the results of the socio-spatial analysis, which showed that Zuidoost has a large share of buildings that perform well on the energy label, which means that housing associations do not have an urgency to renovate, it was discussed what role the housing associations could take to address energy poverty and improve the living conditions of the residents despite living in a well-performing building. Moreover, thoughts on the roles of Stichting !WOON and Stichting Co-Force in including justice in renovation policies were discussed based on the interviews and stakeholder analysis findings. Appendix G shows and discusses the prepared booklet and presentation used to create a shared vision and facilitate the session.

2.3 Quality of Research Design

The quality of the research design was assessed based on the research quality framework developed by Prochner & Godin (2022), in which five categories of research quality are discussed: traceability, interconnectivity, applicability, impartiality, and reasonableness.

To ensure the research's traceability, the study's replicability was taken into account by thoroughly explaining the research methodology and results and documenting how the results led to the research conclusion. Moreover, the recoverability and transparency were considered by explaining in the above sections how the research was conducted and describing the need for the study in Chapter 1.

The interconnectivity relates to the internal validity (cause-and-effect relations between research elements), the credibility (validation of results), and contextualisation (context in which the research is done and the consequences of doing the research in this context). For internal validity, the results were inspected, and the representativeness of the context was inspected in terms of whether the results, e.g. the vulnerability indicators, really measure what they aim to measure. The credibility of the research was assessed by validating the results of each research phase with experts; for example, the identified issues, stakeholder analysis, renovation indicators, extended vulnerability framework, identified vulnerable groups, and policies were verified by various local experts. Moreover, the selected case and context-specific vulnerability indicators were documented extensively to ensure that the implications of the results and the context in which the research was done are clear.

The applicability of the knowledge created in the present study was assessed by assessing the external validity (theories that are applicable in other contexts), transferability (knowledge to inform other studies) and impact (knowledge that will change things for the better. For external validity, the theories related to the socio-spatial vulnerability to energy poverty and the extended vulnerability framework are also applicable in other contexts, as synergies have been identified in the drivers of energy poverty globally (Bouzarovski & Petrova, 2015). Given that the EU is planning to boost renovation rates in the upcoming years and the currently increasing gas and electricity prices, the results of the present studies will inform other studies on how a CS-MM approach can be applied to include justice in renovation policies considering the socio-spatial vulnerability to energy poverty and thereby the transferability is guaranteed. Specifically, it will inform other studies on how vulnerable groups can be identified (recognitional justice) and how tailored policy strategies can be identified that, on the one hand, focus on the distribution of the benefits and burdens of renovation (distributional justice) and, on the other hand, on how vulnerable groups can be included in the decision-making (procedural justice) (Feenstra et al., 2021; Kurmayer, 2022). Zooming in on Amsterdam, the results of the study will also inform other researchers who are planning to research how just renovation of residential buildings can be achieved in underprivileged neighbourhoods, such as Zuidoost, in the so-called JUST-Prepare proposal and provide them with insights into which factors enhance vulnerability to energy poverty and how to identify vulnerable groups to be able to include recognitional justice in renovation policies (Gemeente Amsterdam, 2022). Close cooperation has been established with the project leaders of this research to ensure that the results obtained in this research will be used in their research project. Moreover, to further enhance the impact of the present study, close cooperation was established with local policymakers to ensure that the insights obtained from the socio-spatial analysis will serve as a basis to identify vulnerable groups which are currently not on the radar of the City and these insights will be used to tailor renovation and energy poverty policies based on their needs and characteristics. The results of the expert session will serve as a starting base for a structural collaboration between the key stakeholders. Through this collaboration, the stakeholders will organise multiple sessions in which the implementation of the identified policy strategies will be discussed further.

To ensure the impartiality of the research in terms of researcher bias, all research steps were documented extensively, discussed, and verified by local experts. Lastly, the reasonableness of the choices made during the research process was ensured by validating the options with the supervisors and aligning them with the accepted norms within general research design norms.

3. Results of the System Analysis

A system analysis was performed to understand what the current system of renovation and tackling energy poverty is to gain insights into current policies, issues and involved stakeholders. In Section 3.1, current energy poverty and renovation policies are discussed to understand what policies are currently implemented. In Section 3.2, the results of the stakeholder analysis are presented to provide an overview of the key stakeholders and opportunities for collaboration. Section 3.1.3 draws conclusions from the system analysis.

3.1 Energy Poverty and Renovation Policies in the context of Amsterdam

As global warming is becoming increasingly critical, many cities are trying to combat climate change. Amsterdam is one of the cities keen to combat climate change by aiming to reduce its greenhouse gas emissions by 95% in 2050 compared to 1999. However, a large part of the supplied energy is still fossil-based and stems from city surroundings. The goal is to transition to a more sustainable and local solution. To achieve this objective, the City of Amsterdam works towards a gas-free, emission-free, and energy-neutral city.

Amsterdam Zuidoost aims to go a step further by aiming to become energy neutral by 2040. The development of Amsterdam Southeast offers opportunities to combine sustainability with poverty alleviation and social improvement. Therefore, the City of Amsterdam aims to realise a social energy transition. A social energy transition is achieved by, for instance, renovating houses to improve living conditions and create local employment through large-scale renovation. Realising this requires cooperation from many different parties, including the government, residents, companies, and researchers (Gemeente Amsterdam, 2021).

3.1.1 Energy Poverty in Amsterdam

Energy poverty is a huge issue in Amsterdam, as Amsterdam is the second largest city in the Netherlands with the highest number of energy-poor households (TNO, 2021). A recent study by the City of Amsterdam (2021) showed that nearly 11% of the households in Amsterdam are considered energy poor. Moreover, the expectations are that this percentage is higher as multiple households suffer from hidden energy poverty; people who consciously consume less energy than they would like to do due to financial issues. With the rising energy prices, the expectations are that more and more households will become energy poor.

A survey conducted by the City of Amsterdam (2021) showed that energy poverty mainly affects low-income households; 90% of the energy-poor households in Amsterdam have an income below the poverty line which is significant among single-parent and single-person households. According to the City (2021), the occurrence of energy poverty among these households can be explained by the fact that these households only have one income, due to which the total net amount of household income is lower compared to larger households. Moreover, the results showed that the relative energy costs are the highest in the districts Zuidoost, Noord, and Nieuw-West; 19% of the households in Zuidoost are energy poor, and 17% in Noord and 14% in Nieuw-West. In these districts, energy costs are relatively high when considering their income. Figure *3.1* shows the spatial distribution of energy poverty across the neighbourhoods of Amsterdam.

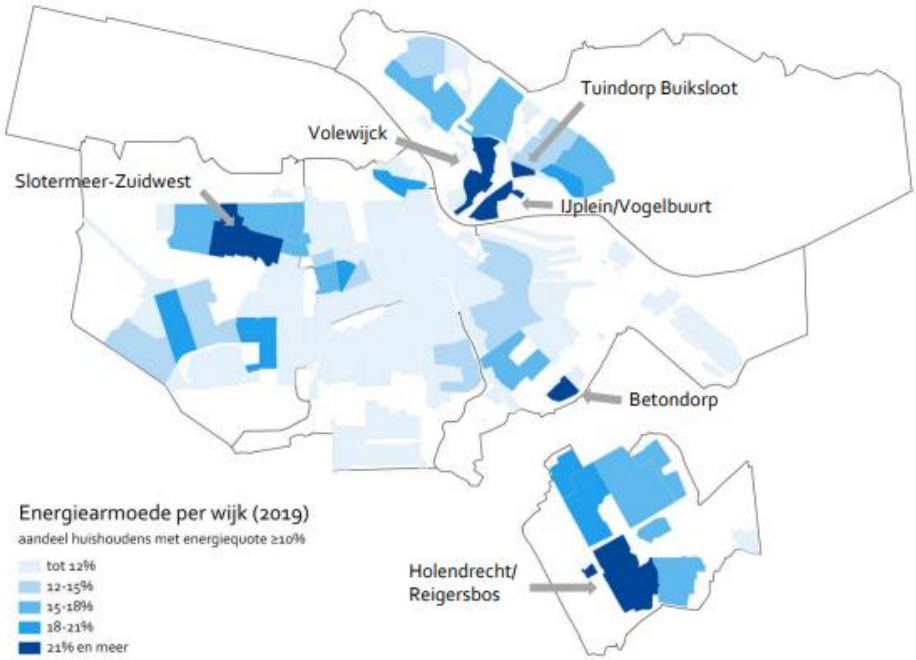


Figure 3.1 Spatial Distribution of Energy Poverty across Amsterdam (Gemeente Amsterdam, 2021)

Despite the criticism of the 10% indicator (as explained in section 2.2) and its inability to adequately identify energy-poor households, the City of Amsterdam uses the 10% indicator to identify energy-poor households. Moreover, the usage of the 10% indicator neglects the impact of energy poverty on the well-being of people living in and using the building and thereby fails to consider the multidimensionality of energy poverty. Thus, it could be argued that the City currently fails to map and identify energy vulnerable groups adequately. A statement that highlights the danger of using the 10% indicator solely to map energy poverty:

> *"I think the danger of using the 10% indicator solely is that you will not be able to identify all the vulnerable groups, and it also neglects the fact that energy poverty is not only related to poverty but is also an issue related to the well-being of individuals. We know that in poorly insulated buildings, the children often have asthmatic problems as there is a lot of humidity and mould. Living in the cold is also not beneficial for the residents, so I would say that it is important to look beyond income and energy bill "(respondent 3)*

3.1.2 Renovation Policies

With its ambition to become energy neutral by 2040 and the EU's Renovation Wave, the City of Amsterdam is taking various measures to combat energy poverty. One of the measures includes providing loans through the 'Duurzaamheidsfonds/ Sustainability Fund', by which individuals, tenants, housing condominium associations, and small private landlords (maximum of eight privately owned houses in Amsterdam) can take a loan to renovate their houses (Amsterdam, 2022). Although this policy aimed to allow everyone to renovate their homes, in practice, these loans are often used by households with high incomes, which raises the risk of gentrification and injustice.

On the other hand, the City wants to promote building renovation by providing subsidies to housing associations to renovate their buildings. Although this measure was aimed to encourage the renovation of buildings, in practice, housing associations are not actively making use of this measure due to which the living conditions for vulnerable households do not improve, and energy vulnerable households are increasingly exposed to energy poverty (Amsterdam, 2022). The renovation policies relate to the thermal insulation of existing buildings, electricity or heat generation, and improved energy efficiency and savings (Gemeente Amsterdam, 2022).

3.1.3 Current Issues and Plans to Include Justice in Renovation Policies

Although the renovation of buildings is an important measure to tackle energy poverty, improve living conditions and create local employment, residents may reject or under-utilize energy technologies. This is especially the case in underprivileged neighbourhoods, such as Zuidoost, in which households often have low incomes and high rates of unemployment; combined with the general lack of trust in the government, housing associations, and other institutions, the residents tend to resist renovation measures and are not willing to make use of the subsidies or loans to renovate (Sociaal en Cultureel Planbureau, 2021). From the interviews, it becomes apparent that the low renovation measures are caused by multiple issues varying from the lack of knowledge and language barrier to failing decision-making. Figure 3.2 provides an overview of the identified issues related to the low effectiveness rates of renovation measures.

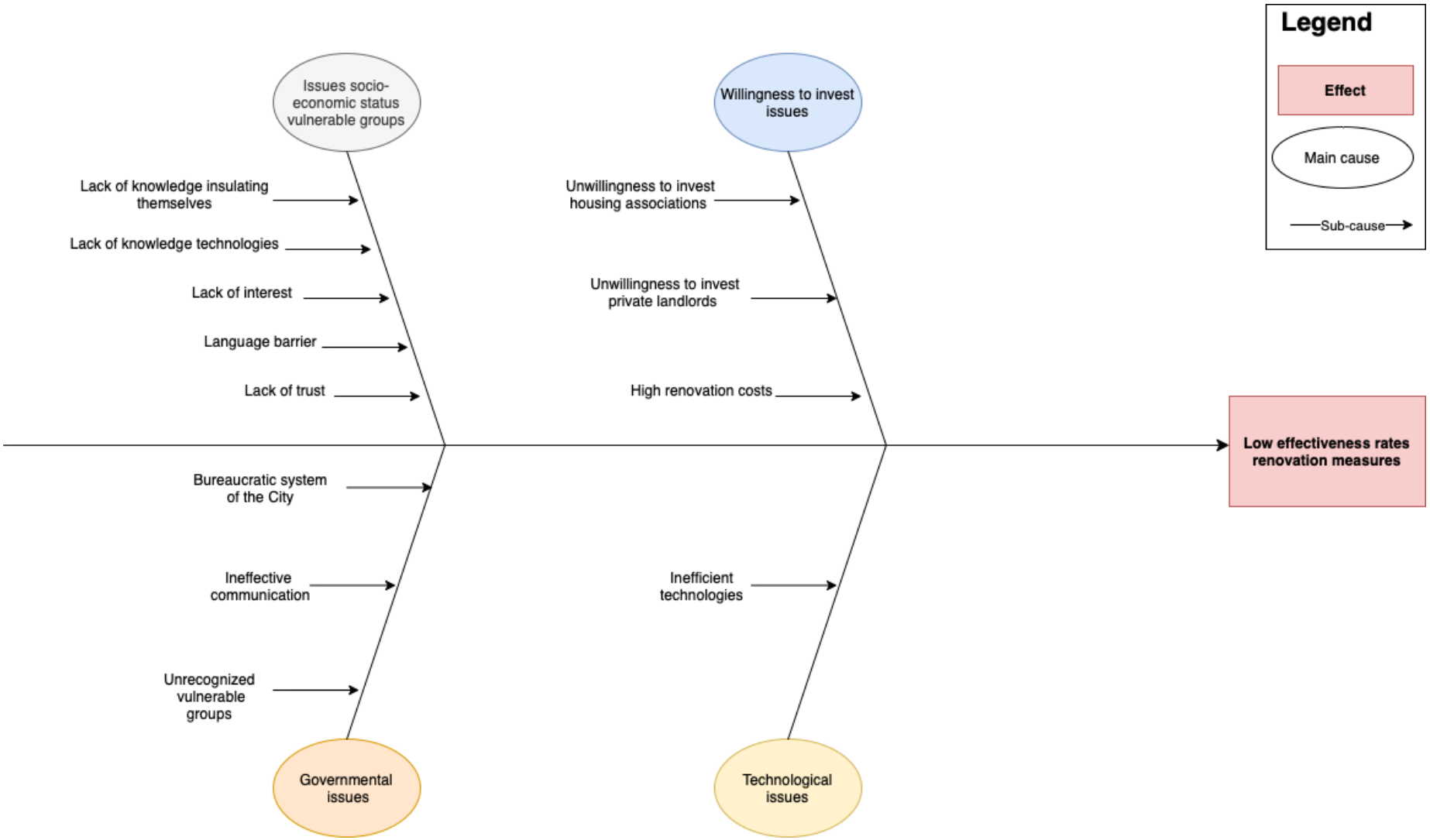


Figure 3.2 Overview of Identified Issues that Cause a Low Effectiveness of Renovation Measures

Note. This diagram has been created with Draw.io. The issues have been identified based on the quantitatively coded interview outputs.

The lack of trust in institutions is seen as an important barrier. Currently, residents often think that even speaking to someone who belongs to an institution will cost them money, making it difficult to generate interest or help those residents tackle energy poverty (Respondents 1 & 2). The language barrier is also important as Zuidoost is a multicultural neighbourhood; not everyone is proficient in Dutch or English, making it more difficult to communicate and generate interest in renovation. Often there is a lack of knowledge on technologies and how to insulate themselves making it difficult to tackle energy poverty as the residents do not understand how the technologies could help them to tackle energy poverty and improve their living conditions. This also affects the effectiveness of small measures such as providing small insulation materials and shower heads for free as residents do not tend to open the door. If they open the door and accept the free materials, they often do not know how to install it and therefore do not benefit from those measures. In Zuidoost large share of the residents have low incomes and are in debt; these residents are often difficult to reach as they tend to exclude themselves from reality by isolating themselves and accepting high risks by, for instance, terminating insurances and thereby exposing themselves to high risks just to stay under the radar of institutions as they are afraid that they will lose power over themselves. This also reinforces the amount of unrecognised vulnerable groups as they manage to stay under the radar while living in poverty and experience a loss of well-being (Respondents 1,2, and 4).

Studies have shown that there are often mismatches between renovation technologies and residents' energy practices as the technologies are typically designed for average residents in well-maintained buildings, which differ significantly from residential buildings in underprivileged neighbourhoods that have a great variety of ethnic backgrounds, general low socioeconomic status and therefore reject renovation solutions. The interviews also highlight the mismatch between renovation technologies and residents' energy practices. Moreover, there is a mismatch between actors planning and implementing the solutions (Respondent 4).

While the City of Amsterdam, housing associations, and other actors are actively trying to involve residents in the energy transition and welcome bottom-up initiatives, solutions are often still shaped among the major stakeholders who are fuelled by the Klimaatakkoord's/ National Climate Agreement's pressure to achieve short-term results a (Dignum et al., 2021; Respondent 1:4). The Klimaatakkoord's pressure also highlights how local municipalities are impacted by energy and renovation policies developed on a national level. Given the lack of trust in governments and the lacking knowledge on how renovation solutions can be incorporated into the daily practices of residents,' there is a huge risk that renovation policies in underprivileged neighbourhoods will get stuck as in public housing, at least 70% of the residents need to agree to major renovation and residents will reject or underutilise the technology. The high costs of renovation are also seen as an important barrier. It may lead to private landlords being unwilling to invest in renovation as they still receive rent for their houses without investing in a renovation.

The interviews also reveal various issues related to the decision-making surrounding renovation and energy poverty policies. Within the City of Amsterdam, there are organisational issues whereby different departments of the municipality have different agendas and objectives, which influence the effectiveness of various measures taken by the other departments. Examples include the conflicting objectives between realising the City's ambition of achieving the Klimaatakkoords goals as soon as possible without considering who is using the measures versus having justice in the energy transition and actively trying to include vulnerable groups. Close collaboration and coordination are also required between the different departments to align the ambitions and decide which districts are targeted while considering justice principles. However, these ambitions are also dependent on policies determined on the national level, which influence the range of interventions the City can take and the speed of implementation to ensure that goals set on the national level are achieved. Besides the national level, the City also needs to take the policies and plans determined at provincial, metropolitan (Metropool Regio van Amsterdam), and district levels into

consideration when dealing with renovation and energy poverty policies, indicating that there is limited room to step away from the City's agenda and slow down its ambitions to ensure that all vulnerable groups are targeted.

Moreover, housing associations also play a key role in tackling energy poverty and including justice in renovation policies. A large share of the vulnerable groups are living in social housing and are also seen as the starters of the Dutch Renovation Wave as they own a large percentage of the buildings. However, housing associations also have their agenda in which they plan all the renovations they want to conduct, and they are hesitant to change their planning for 500 euros, for example. For Zuidoost, this means that a large part of the buildings will not be renovated in the upcoming years as they have been renovated, indicating the hopelessness of the vulnerable groups living in those buildings. To ensure that those vulnerable groups are targeted, the City must collaborate with housing associations to explore opportunities by which these vulnerable groups can be helped to address energy poverty and improve their well-being by renovating.

Another issue related to renovating is that renovation stays behind in the private sector as often the households who have the financial means already took measures, and the households who do not have the financial means or the households that are not interested do not take the measures. The latter two groups are around 75%, highlighting the opportunities in the private sector. Mapping the interests and co-operating with local residents is important to tackle these issues as this may be the only opportunity to push them into renovation and create so-called 'koppelkansen' (joint opportunities) at the start of a project by researching how various initiatives can be combined.

There are also issues related to the renovation process, one of the largest issues is that the renovation process is extremely fragmented, meaning that different companies are hired for various measures, which eventually ends up in a situation where every company is unsatisfied with the work of the previous company, that they need to fix it first and then start their job. Total packages are missing by which a single company is responsible for the whole process, which would reduce the costs structurally by more than 30%. These examples also highlight the mismatch between actors planning and implementing the renovation measures. Another issue is that currently, subsidies are only available for purchasing materials and cannot be used, for instance, to hire workers to renovate, so households with a limited financial capacity will not use these measures. This also raises the issue of whether the current renovation policies target vulnerable groups in great need of renovation resources.

The bureaucratic system of the City of Amsterdam also creates issues surrounding tackling energy poverty by renovation. The low renovation effectiveness in underprivileged neighbourhoods such as Zuidoost resident's associations such as Stichting Co-Force plays an important role in mediating between residents, housing associations and the City. However, as Stichting Co-Force is a non-profit organisation, they depend on the financial aid provided by the City to operate. Currently, they are not receiving financial assistance and rely on volunteers, influencing the extent to which they can exert power to mediate. The same holds for Stichting !WOON which receives financial aid, but whenever one of its experts encounters a vulnerable household requiring immediate financial assistance, the long bureaucratic process of receiving financial help reduces the speed and opportunities to help the vulnerable groups, which is seen as a huge barrier by the aid providers.

Another issue related to addressing energy poverty and renovation is related to the current process of determining the energy label of a building. Respondent 2 raised the point that currently, the assessment is based on solely meeting the minimum requirements to achieve a certain energy label whereby each installation/measure is assessed separately, neglecting the energy performance of the installations/measures when operating jointly, which may perform worse than the current energy consumption meaning that households may receive higher

energy bills than they were used to which enhances their vulnerability to energy poverty. All in all, it can be concluded that the various identified issues cause low effectiveness rates of renovation measures in underprivileged neighbourhoods such as Zuidoost, thereby enforcing unjust renovation practices.

Moreover, current renovation measures in underprivileged neighbourhoods may reinforce already existing inequalities and energy poverty, as social housing tenants and house owners with low income generally have fewer opportunities to choose or execute renovation measures and may lead to distressing neighbourhoods as renovation costs are generically high (Mulder et al., 2021). Therefore, a vicious cycle can be observed in underprivileged neighbourhoods where actors are not trusted; impacts reinforce existing inequalities, which may affect the use of technologies, foster distrust, and further increase inequalities. Thus, it can be argued that ineffective and unjust impacts reinforce each other.

Given that Zuidoost is an underprivileged neighbourhood with low renovation effectiveness and high energy poverty rates, this research scope is limited to Zuidoost. Stadsdeel Zuidoost and the Energie Lab Zuidoost want to tackle the ineffectiveness and injustices by exploring how a just energy transition in terms of renovation can be realised in its neighbourhoods. At this moment, justice is composed of distributive (distribution of benefits and burdens), procedural (who has access to the decision-making in underprivileged neighbourhoods), and recognitional (identifying vulnerable groups and ensuring that they are recognised and respected by the involved stakeholders) (respondent 4). Figure 3.3 visualises the concept of justice in the context of Zuidoost.

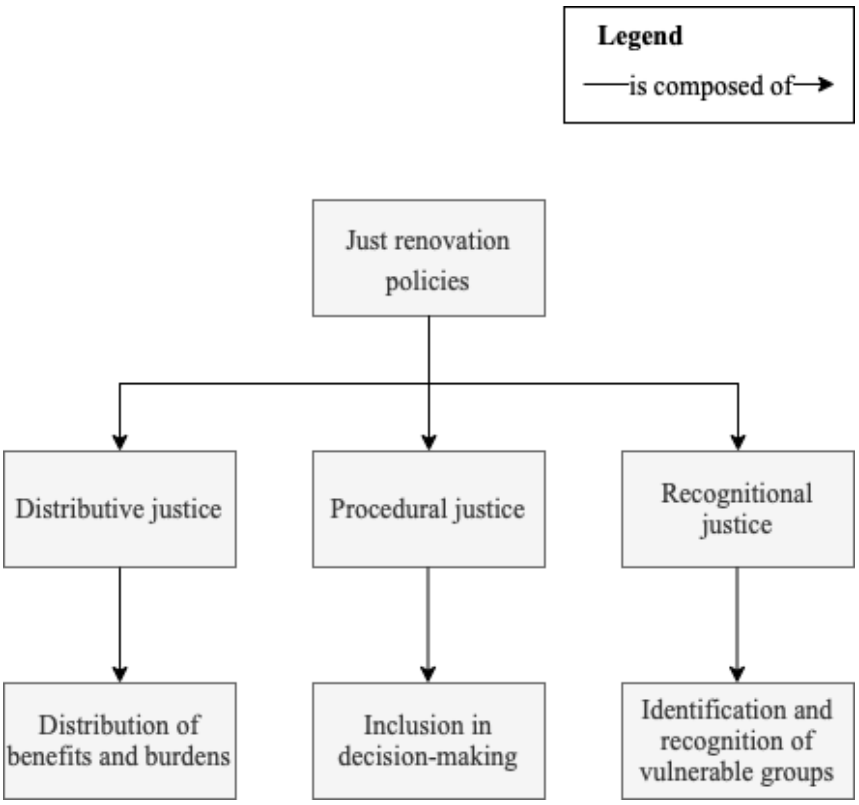


Figure 3.3 Defining Justice in Renovation Policies Within the Context of Zuidoost

Note. The figure has been created in Draw.io based on the quantitatively coded interview outputs.

To realize a just energy transition, it is important first to gain insights into which households or groups are vulnerable to energy poverty and require renovation to tackle energy poverty and improve their living conditions. This also justifies the selection of Zuidoost as a Case Study.

3.2 Stakeholder Analysis

From section 3.1, it becomes apparent that there are various issues related to the decision-making and interest in renovation that impact the success of just renovation policies. Thus, a stakeholder analysis was performed to gain insight into which stakeholders are involved or have an interest in tackling energy poverty and the renovation of residential buildings in Zuidoost. The results provided the City with insights into the key stakeholders, their interests, problem perception and resources. Based on these results, insights were gained into which stakeholders are important and whom the City must collaborate with to include justice in renovation policies. As a starting problem formulation, the insights from section 3.1 were taken as a starting point.

3.2.1 Key Stakeholders in Renovation and Tackling Energy Poverty

To include justice in renovation policies and tackle energy poverty, the Department of City Development needs to take the interests of stakeholders who can influence the success of the renovation and energy poverty policies into consideration. Therefore, it is important to map relevant stakeholders, which is the second step in conducting the stakeholder analysis.

To identify relevant stakeholders in the renovation in Zuidoost, various techniques were combined: the positional, imperative, and reputational approaches. The positional approach was used to identify stakeholders with a formal position in policy-making; these stakeholders are identified based on a review of existing policy procedures and documents. The imperative approach identifies stakeholders who feel strongly about the current renovation policies and energy poverty issue to act on their feelings. Questions such as: “Who is interested in renovation and tackling energy poverty or who will feel the consequences around including justice in renovation policies?” Lastly, the reputational approach was used as a validation method by asking the external supervisor A. Nienhuis to identify relevant stakeholders and discuss the identified stakeholders (Enserink et al., 2010). *Table 3.1* and*Table* 3.2 provide an overview of the identified stakeholders based on their role in the governance and interest in the issue. Their role and interest are determined based on the results of Table D.1 and Table D.2. The list of stakeholders was validated by discussing the identified stakeholders with A. Nienhuis and T. Hoppe and a local employee of the City of Amsterdam to ensure that all relevant stakeholders were identified.

Table 3.1 Stakeholders Classified based on their Role in the Governance

Stakeholders role in governance	
Supranational government	European Commission
National government	Ministry of Economic Affairs and Climate Policy
Local government	City of Amsterdam, Department of City Development
	City of Amsterdam, Department of Planning and Sustainability
	City of Amsterdam, Department of Housing
Companies	Energy company (Vattenfall)
	Service providers (Klimaatmissie)
	Financial institutions (Rabobank/ ABN AMRO)
Research Institutions	AMS Institute, Energie Lab Zuidoost (TU Delft, HvA, UvA)
Non-governmental Organisations	Stichting !WOON
	Stichting Co-Force
Housing Associations	Stadtgenoot
	Eigen Haard
	Rochdale
Resident Associations	Tenants
	Homeowners

From *Table 3.1*, it becomes apparent that the European Commission and the Ministry of Economic Affairs and Climate are interested in renovation and tackling energy poverty. The European Commission has formal authority to influence renovation and energy poverty measures as the Commission has developed an EU-wide strategy to tackle energy poverty by the so-called Renovation Wave and has the authority to provide subsidies to various cities based on a set of conditions to which local cities must comply to get the funds. The Ministry of Economic Affairs and Climate has the formal authority on a national level and can make policies that influence the means of the Department of City Development. For instance, they can block plans to include justice in renovation policies. On the local level, the Department of Housing has formal authority to influence local housing policies, whereas the Department of Planning and Sustainability has the power to influence policies to include justice as they are primarily concerned with achieving the Klimaatakkoords goals and thus may prioritize energy savings above including justice in renovation and energy poverty policies.

Companies are also interested in renovation as it provides them opportunities to increase their market share and profits. Financial institutions are interested in renovation as it gives them the opportunity to provide loans to local citizens and thus increase their profit. Moreover, it benefits their reputation as they will support sustainable measures. Energy service companies are interested in renovation as they are primarily concerned with energy and need to adjust their market in line with the energy transition. Service providers are interested in renovation as it allows them to increase their profits. The higher the rate of renovation, the higher the number of services they need to provide for renovation. The companies are less interested in tackling energy poverty as they are primarily concerned with increasing the rates of renovation; the question of who is using the measures does not matter as long as they can improve their market share and profits.

The Energie Lab Zuidoost is interested in renovation and tackling energy poverty as they are interested in researching and creating knowledge on how a social energy transition can be realized. Non-governmental institutions such as Stichting !WOON and Stichting Co-Force are interested in tackling energy poverty and renovation as they represent the voices of the local communities and are concerned with the high rates of energy poverty in Zuidoost and the current injustices in renovation and energy policies. Housing associations are not primarily concerned with renovation and tackling energy poverty, as the preparation and execution times and convincing the local residents are time- and money-consuming. Even though the living conditions are poor in their buildings, they still get their rent and can sell the houses to private landlords who pay huge amounts of money. Resident associations are primarily interested in tackling energy poverty and improving the living conditions in homes. However, they are often less interested in renovation and the energy transition, thus not actively using renovation measures and often rejecting them. *Table 3.2* classifies the stakeholders based on their interests. Table D.1 and Table D.2 provide an in-depth overview of the interests and objectives of the identified stakeholders.

Table 3.2 Stakeholders Classified based on their Interests

Stakeholders roles of interest	
Environment and well-being inhabitants	European Commission
	Ministry of Economic Affairs and Climate
	City of Amsterdam, Department of City Development
	City of Amsterdam, Department of Planning and Sustainability
	City of Amsterdam, Department of Housing
Economic benefits	Banks (Rabobank/ ABN Amro)
	Energy company (Vattenfall)
	Service providers (Klimaatmissie)
	Stadgenoot
	Eigen Haard
	Rochdale
Knowledge Creation	AMS Institute, Energie Lab Zuidoost (TU Delft, HvA, UvA)
Representing local communities	Stichting !WOON
	Stichting Co-Force
Energy savings and improved living conditions	Resident associations (tenants, houseowners and VVE's)

3.2.2 Possible Collaborations and Opponents for Including Justice in Renovation Policies

As mentioned earlier, the Department of City Development is keen to investigate how justice can be included in renovation policies to tackle energy poverty. However, to achieve its objective, the Department relies on the resources and collaboration of other stakeholders. Thus, it is important that the Department makes coalitions with stakeholders who have shared problem perceptions and that it is aware of which stakeholders are currently opposing the plans. The importance of stakeholders is determined by mapping the interdependencies between stakeholders by gaining insights into the objectives, interests, and resources of stakeholders. Table D.3, Table D.4 and Table D.5 provide an overview of these relations.

The Department of Housing can be an ally as both parties are concerned with tackling energy poverty and improving the living conditions of local residents. However, they are less interested specifically in renovation policies as they want to improve the overall living conditions across Amsterdam and have a clear focus on the housing stock. Renovation policies are just part of one of the measures the Department of Housing is taking or concerned with.

The financial institutions, Klimaatmissie Nederland and Vattenfall, can be allies as well as these parties are interested in renovation policies and want to collaborate with the Department of City Development. Klimaatmissie Nederland and Vattenfall have low power as their resources are replaceable by other companies. Thus, this means that both parties can exert lower influence. However, close collaboration between the parties could make it more attractive for local residents to renovate as the planning and execution will be given out of hand to Klimaatmissie Nederland, while Vattenfall as an energy company could stimulate renovation among its clients. Financial institutions have higher power as their cooperation is required to encourage renovation by providing loans to residents who want to renovate their houses; without these loans, it will be difficult for these people to renovate as the costs of renovation can be significantly high. For financial institutions, seeking a collaboration is beneficial. The higher the number of loans taken by residents, the more profit they can make. Active participation in sustainability projects in the local neighbourhood also benefits their reputation.

Besides allies, some stakeholders can resist or block interventions that include justice in renovation policies and thereby act as opponents. These stakeholders are the Department of Planning and Sustainability, housing associations, and resident associations. The Department of Planning and Sustainability is primarily concerned with achieving its ambition of making Zuidoost energy neutral by 2040 and thus prioritizes energy savings and is less concerned with including justice; this means that the measures taken by the Department of Planning and Sustainability might increase the current injustices. To prevent this, the Department must collaborate with the Department of Planning and Sustainability as the ambition of the City of Amsterdam is to realize a social energy transition, indicating that the energy transition must also improve the living conditions of residents in Zuidoost; thus, it could be argued that there is a common goal between the two parties however they must research how they can work together to achieve its goal of becoming energy neutral and its ambition to include justice in renovation policies.

The low renovation rates in Zuidoost are also primarily caused by the fact that housing associations and local residents are currently not making active use of the subsidies to renovate their buildings as the processes are time and money-consuming, and local residents tend to resist renovation measures, making it difficult to have at least 70% of the residents agreeing with the renovation plans. To include justice in renovation policies, it is essential that especially housing associations, which tend to have a lot of vulnerable groups as tenants and local residents, become interested in renovation measures as these measures are meant to improve their living conditions and tackle energy poverty. Therefore, the Department of City Development must get insights into the current issues and the local residents' objectives to make them an ally instead of opponents. Stichting !WOON and Stichting Co-Force can be

important stakeholders in this process as both organisations are close to the local housing associations and local residents, indicating that they could act as mediators in the process of including justice in renovation policies.

As the Ministry of Economic Affairs and Climate Policy and the European Commission have formal authority to block plans of the Department of City Development but are currently not actively involved and interested, these stakeholders must be kept 'satisfied' to prevent them from taking measures that may form an obstacle. Therefore, the Department must act in line with the expectations and ambitions of both parties by contributing to the energy transition by renovation and tackling energy poverty by including justice in renovation policies. Figure *3.4* provides an overview of the power and interest of the involved stakeholders. The minuses and plusses indicate whether a stakeholder has shared objectives (+) or conflicting objectives (-).

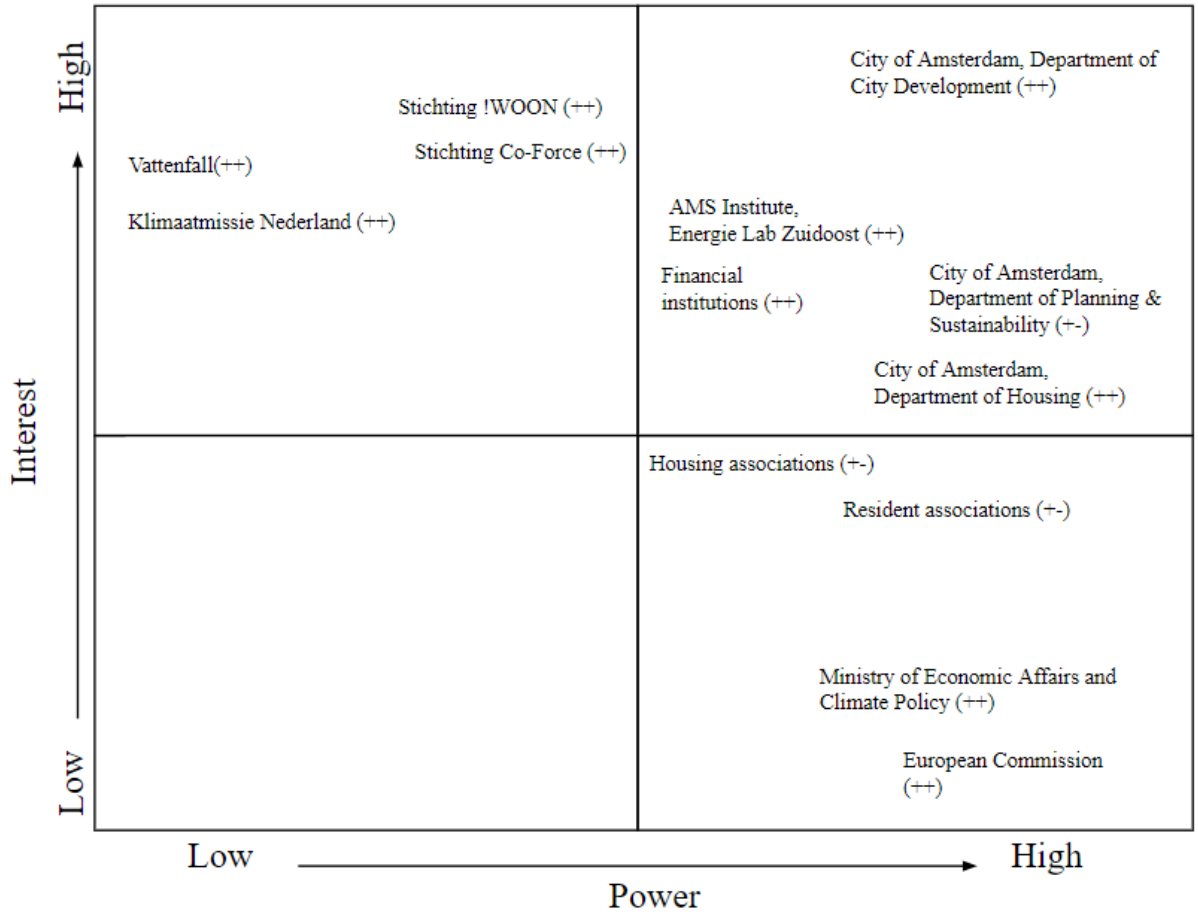


Figure 3.4 Classification of Stakeholders based on their Power and Interest

Note. The stakeholders have been classified based on the insights in Appendix D. A plus (+) sign indicates shared objectives with the Department of City Development, whereas a minus (–) sign indicates conflicting objectives.

3.3 Conclusion of the System Analysis

From the system analysis, it can be concluded that energy poverty is a huge issue in Zuidoost; however, current policies are failing to address energy poverty as current renovation policies do not consider vulnerable groups and are primarily focused on achieving short-term results instead of considering who is benefitting from the various policies. Moreover, the conflicting agendas of various departments within the City also enhance the risk of social injustices and gentrification. The effectiveness of various renovation measures is also low in Zuidoost as typically, there are various issues related to the socio-economic status (e.g., lack of trust and language barrier), technical issues (mismatch between renovation technologies and the energy practices of residents living in underprivileged neighbourhoods), willingness to invest, and institutional issues that cause low renovation rates in Zuidoost. Given that, for instance, housing associations and private landlords are not actively making use of the various renovation policies, and the renovation of buildings stays behind in underprivileged neighbourhoods such as Zuidoost, it could be concluded that there is a mismatch between the residents and actors who are planning and implementing the various proposed policies.

Moreover, renovation measures in underdeveloped neighbourhoods may reinforce already existing inequalities and energy poverty, as social housing and private sector tenants and homeowners with low incomes have, for instance, fewer opportunities to choose or execute measures. Hence, it could be concluded that technologies are ineffective, actors are not trusted, and impacts reinforce already existing inequalities which may foster the use of technologies, distrust, and further increase inequalities. Thus, unjust practices reinforce each other. Moreover, as the City uses the 10% indicator to measure energy poverty and thereby fails to identify all vulnerable groups while also neglecting the loss of well-being, it could be argued that the City fails to recognize vulnerable groups to energy poverty and thereby leaves them out of policy measures which reinforces unjust practices. Given these unjust practices and the ambition of the Department of City Development to address energy poverty by renovating buildings, justice must be included in renovation measures.

To be able to include justice in renovation measures, the City must collaborate with housing associations and resident associations to prevent the renovation measures that are resisted or not picked up. Both associations must become allies instead of opponents. Given the various issues related to the willingness to invest and the socio-economic status of residents, it is believed that the City must collaborate with Stichting !WOON and Stichting Co-Force, who can act as mediators between the City and the housing and resident associations to ensure that the associations get interested in renovating. However, given the bureaucratic system of the City and the conflicting objectives between different departments of the City, the different departments must collaborate and act together to ensure that various measures do not conflict with the objectives of the various departments and prevent implementing measures that reinforce already existing inequalities. Therefore, the departments must act as allies and prevent situations in which the departments become opponents. Given that the renovation of buildings also involves financial institutions, energy companies, and service providers, it is recommended that the City also establishes a collaboration with these parties to simplify the renovation process and thereby increase the attractiveness of taking renovation measures. From a business perspective, financial institutions are seen as important stakeholders as they are the ones who can provide financial aid to individuals or corporations who are opting to renovate their houses. Close cooperation with energy and service providers could make it more attractive for residents to renovate as the planning and execution will be given out of hand to, for instance Klimaatmissie Nederland while Vattenfall as an energy company could stimulate renovation among its clients. Given the low interest and high power of the Ministry of Economic Affairs and Climate and the European Commission, it can be concluded that the department of City Development must comply with the ambition of both parties to address energy poverty and renovate buildings to keep them satisfied. However, no close collaboration is required with both parties.

4. Defining the Socio-Spatial Vulnerability to Energy Poverty

This chapter presents the defined socio-spatial vulnerability to energy poverty within the context of Zuidoost. In Section 4.1, the current vulnerability framework developed by Robinson et al. (2019) is extended based on the insights obtained from the literature review and system analysis. Based on the extended vulnerability framework, an index of socio-spatial vulnerability to energy poverty is defined in Section 4.2 to measure socio-spatial vulnerability. Section 4.3 visualises the multi-dimensional suite of vulnerability indicators identified in Section 4.2 to enhance understanding of the multidimensionality of energy poverty. Section 4.4 draws conclusions on the defined socio-spatial vulnerability to energy poverty.

4.1 Extending the Current Vulnerability Framework

Chapter 1 showed that several studies have often identified neighbourhoods in great need of energy poverty resources. These neighbourhoods have often been identified by using existing expenditure-based indicators. Along with being restricted by the narrow framing of existing indicators, these approaches are not per se spatial as the importance of the drivers that enhance the vulnerability to energy poverty in each area is determined at a national level instead of a varying level to reflect localised challenges. To address these issues, Robinson et al. (2019) developed the vulnerability framework, shown in Figure 1.1. Vulnerability Framework Energy Poverty (Robinson et al., 2019), to draw attention to the diverse vulnerability factors likely to be of greatest importance in enhancing the vulnerability to energy poverty in different neighbourhoods. However, this framework was developed in the context of England and did not include renovation and institutional indicators, which enhance the vulnerability to energy poverty, as explained in Sections 1.3 and 3.1.3.

As the Renovation Wave aims to alleviate energy poverty by renovating buildings and improving the living conditions of people living and using the buildings in combination with recent studies that have shown that renovation policies fail to address energy poverty, this research aimed to identify various pathways via which a household becomes vulnerable to energy poverty and a loss of well-being by identifying renovation and institutional indicators. These indicators were identified based on desk research, the interviews conducted in phase 1, and collaborating with an expert in housing quality and innovation at the Technical University of Delft. The vulnerability framework has been extended with renovation indicators represented by the ‘building performance’ box and institutional indicators defined by the ‘participation’ and ‘willingness’ boxes. Figure *4.1* shows the extended vulnerability framework. The white boxes show vulnerability factors that are internal to the home, whereas the green boxes show factors that are external to the house.

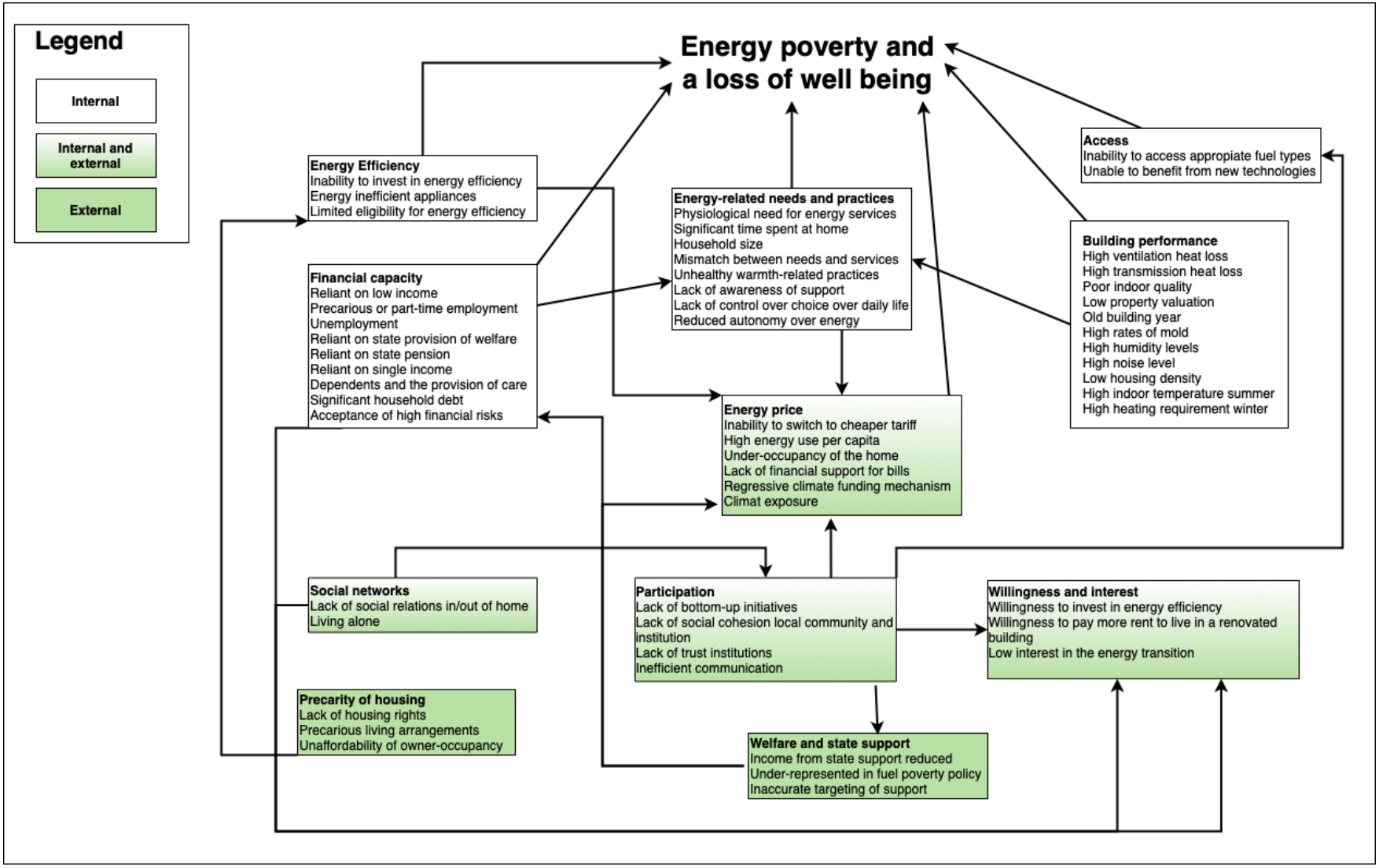


Figure 4.1 Extended Vulnerability Framework

Note. The framework developed by Robinson et al. (2019) has been extended with vulnerability factors related to the building performance, participation, willingness, and the acceptance of high financial risks.

Renovation factors that enhance the vulnerability to energy poverty and a loss of well-being are well understood. The building vulnerability related to high rates of ventilation and transmission heat loss, poor indoor quality, mould, humidity, poor indoor quality (e.g., high rates of CO2 emission) and high noise levels is all recognised within the national determinant for the energy label (Rijksoverheid, n.d.). Moreover, high heating requirements in the winter and a high indoor temperature in the summer are associated with an increased risk of energy poverty and a loss of well-being. As the EU has energy requirements for newly built buildings, it is believed that old buildings are energy inefficient. Thus, they may enhance one's vulnerability to energy poverty and tend to have a lower property valuation (Mangold et al., 2016; European Commission, 2020; Respondent 3).

From the system analysis, it became apparent that in underprivileged neighbourhoods, the lack of bottom-up initiatives, the general lack of trust in institutions, and the lack of social cohesion between the local community and institutions are important barriers to renovation and thus also enhance the vulnerability of being energy poor and a loss of well-being. Moreover, the indirect and inefficient communication between the City and private landlords/ social housing tenants/ homeowners enhances vulnerability as the addressed households often throw away flyers immediately. Thus, they are not informed about the various renovation opportunities and benefits. Moreover, as renovating is cost-intensive, the willingness to invest or pay more rent to improve energy efficiency is an important factor as households with low incomes often do not have the money to invest or pay more rent for renovation, and thus they might not be willing to invest in energy efficiency and hence their vulnerability to energy poverty is also enhanced as they are unable to invest themselves in energy efficiency while they are facing energy poverty and often live in buildings that are poorly insulated. It is also believed that the generally low interest in the energy transition is an important barrier to renovating as this is often caused by the lack of trust, survival mode of vulnerable groups, and the lacking knowledge of technologies which eventually enhances the vulnerability to energy poverty as these households are not interested in renovation and there continue to live in energy poverty.

To evaluate and validate the extended vulnerability framework, the framework was compared with the identified vulnerability factors during the interviews. Figure *4.2* shows the various vulnerability factors identified during the semi-structured interviews. From these interviews, it became apparent that common vulnerability factors are related to socio-economic factors, e.g., income and gender, renovation-related factors such as the building year and energy label, energy factors such as unhealthy warmth-related practices and institutional factors such as the underrepresentation of vulnerable groups in energy poverty policies. Moreover, the extended vulnerability framework was also discussed with experts in energy poverty, justice, and renovation to ensure that the framework identifies various pathways via which a household becomes vulnerable to energy poverty and its applicability within the context of Amsterdam.

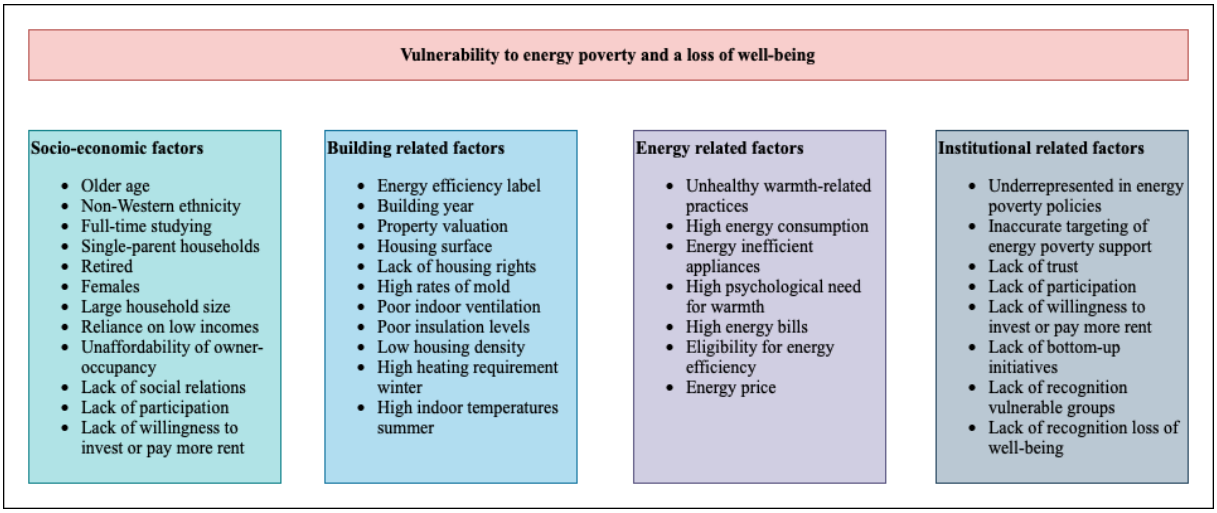


Figure 4.2 Identified Vulnerability Factors during the Semi-Structured Interviews

Note. The figure has been created in Draw.io based on the quantitatively coded interview outputs.

4.2 Index of the Socio-Spatial Vulnerability to Energy Poverty

Evidence of the multiple factors that make a household more vulnerable to energy poverty direct us to use a multidimensional suite of indicators (Fahmy et al., 2011; Liddell et al., 2012; Walker et al., 2012; Dubois, 2012; Bouzarovski & Petrova, 2015; Middlemiss & Gillard, 2015; Robinson et al., 2019). Within the global environmental change research, an index of social vulnerability is a well-established approach for dealing with multidimensionality by aggregating multiple indicators to investigate the relative importance of indicators and the spatial distribution of vulnerability (Cutter et al., 2003). Vulnerability is often conceptualised with indexes as a combination of social and spatial inequalities to overcome the assumption that individuals are equally vulnerable while aiding the understanding of the socio-spatial distribution of vulnerability. This approach often concerns mapping the theoretical determinants of vulnerability to exemplify the spatial distribution of vulnerabilities. This approach also allows us to pose social and spatial questions such as, “Where are vulnerable people located, and who in these places is vulnerable?” (Cutter et al., 2013; Robinson et al., 2019). Robinson et al. (2019) drew inspiration from these methodologies. They derived an index of vulnerability to energy poverty focusing on a case study in England which can be applied meaningfully in other national contexts as synergies have been recognised in the drivers of energy poverty across the globe (Bouzarovski & Petrova, 2015).

This approach is also used in the present study, focusing on the case study in Amsterdam. In the present study, 29 vulnerability indicators, shown in Table 4.1 , have been identified that are associated with multiple vulnerability factors represented in the extended vulnerability framework, shown in Figure *4.1*. These vulnerability indicators have been identified by combining insights from desk research, interviews and examining the available data at the neighbourhood level. Table E.1 presents the developed index of the socio-spatial vulnerability to energy poverty in detail. The index is, on the one hand, made up of the socio-spatial vulnerability factors to represent characteristics that enhance or reduce vulnerability to energy poverty and a loss of well-being, and on the other hand, indicator datasets that represent each vulnerability factor and provide measurable information. For each vulnerability indicator, the associated vulnerability factors are shown in the second column of Table E.1. These associations have been identified based on desk research and the conducted interviews; the corresponding references are shown in the third column. The last column represents the data set indicator, which has been used to measure each vulnerability indicator. For instance, the first row of the table shows how the vulnerability indicator of ‘older old’ represents individuals who are older than 75 and live alone. Moreover, based on literature and the interview results, it becomes clear that these individuals are often dependent on the provision of care, are less able to benefit from new technologies, and are underrepresented in energy poverty policy. Thus, it could be argued that these individuals have an enhanced vulnerability to energy poverty.

Proxy datasets represent the vulnerability factors for which no indirect indicator datasets exist, and more than one indicator data set can be associated with a vulnerability factor. For instance, the energy label of a building has been used to assess the building's performance. However, as pointed out by respondent 2 in the interviews, an energy label might not reflect the loss of well-being or poor living conditions in a residential building as technologies are assessed separately when determining the energy label, and the building construction also impacts the building performance. To enhance the understanding of each vulnerability indicator, Table F.1 provides an overview of each vulnerability indicator, the associated data set indicator, a description of what each vulnerability indicator represents, a description of the data set indicator, and the selected year for which the data has been extracted.

Table 4.1 Identified Vulnerability Indicators as an Index of Socio-Spatial Vulnerability to Energy Poverty

Vulnerability indicator
Older old
Young children
Disability or limiting illness
Mental health issues
Lone parent
Retired
Provision of unpaid care
Precarious
No income
Unemployment
Proficiency in Dutch
Ethnicity
Full-time student
Underoccupancy
Shared property
Large household size
Private renting
Social housing renting
Old heating system
No solar panels
Energy inefficient property
Energy consumption
Educational level
Debt assistance
Loneliness
Participation
Communication satisfaction score
Gender
Unwillingness to pay more rent or invest in renovation

It is important to be aware that not all the households represented by the indicator datasets will be vulnerable in real life; rather, these characteristics of households are likely to enhance their vulnerability to energy poverty and a loss of well-being when combined with other factors. Various researchers, such as Mould and Baker (2017), showed how multiple factors could be instrumental in amplifying a household's vulnerability, such as retired individuals who often live alone or have an illness or disability. Robinson et al. (2019) also argue that there are aspects of a vulnerability that indicator datasets cannot represent, such as vulnerabilities associated with gender. Within the context of Zuidoost, some aspects of the vulnerabilities are reflected

implicitly in the index due to its interrelation with other vulnerability factors. However, they are poorly understood regarding energy poverty and lack representative data set on a neighbourhood scale, such as the lack of trust in institutions and the extent to which local residents are satisfied with the communication between the institutions and themselves. Although the index presented in Table 4.1 is purposively applicable to different national and domestic contexts and scales, it is assumed that not all identified vulnerability factors will be relevant to every geographical context, particularly vulnerability indicators related to specific renovation and energy poverty mechanisms, such as participation, and welfare provision.

It is also worth noting that in the present study, the index of socio-spatial vulnerability was developed in the context of Amsterdam and heavenly depended on the available data at the neighbourhood scale. Various researchers have demonstrated how part-time employment, indoor quality, and looking after home/family (e.g., being a housewife) enhance the vulnerability to energy poverty and a loss of well-being; however, due to lacking data on the neighbourhood level, it was not possible to represent these vulnerabilities explicitly (Snell et al. (2015), Petrova (2017), Robinson et al. (2019), Respondents 1-3 (2022)). Moreover, climate exposure is also an important vulnerability indicator as it is related to households' energy need/consumption during winter while also relating to high indoor temperature during summer, which is associated with a loss of well-being. Given that Amsterdam is the unit of analysis, it was assumed that the difference in temperatures would be negligible within the city; thus, no index was developed for this vulnerability. For larger units of analysis, it is recommended to consider climate exposure into account as this may vary across space (Liddell & Morris (2010), Rudge (2012), Santamouris & Kolokotsa (2015), Respondents 1-3 (2022).

4.3 Visualizing the Multi-Dimensional Suite of Vulnerability Indicators

To further enhance the understanding of the multi-dimensional suite of indicators that have been identified as an index, the relation between each vulnerability indicator and the associated vulnerability factors represented in the various boxes of the extended vulnerability framework was visualized in Figure 4.3. The grey circles display the identified vulnerability indicators, whereas the other circles each indicate a different vulnerability box (represented with different colours). The size of each vulnerability box represents the relative importance of the box based on the ‘in-degree’ of each vulnerability box. The in-degree determines the importance based on how many vulnerability indicators are related to the specific vulnerability box. This diagram has been created with Kumu, which is an open-source tool for creating visualisations.

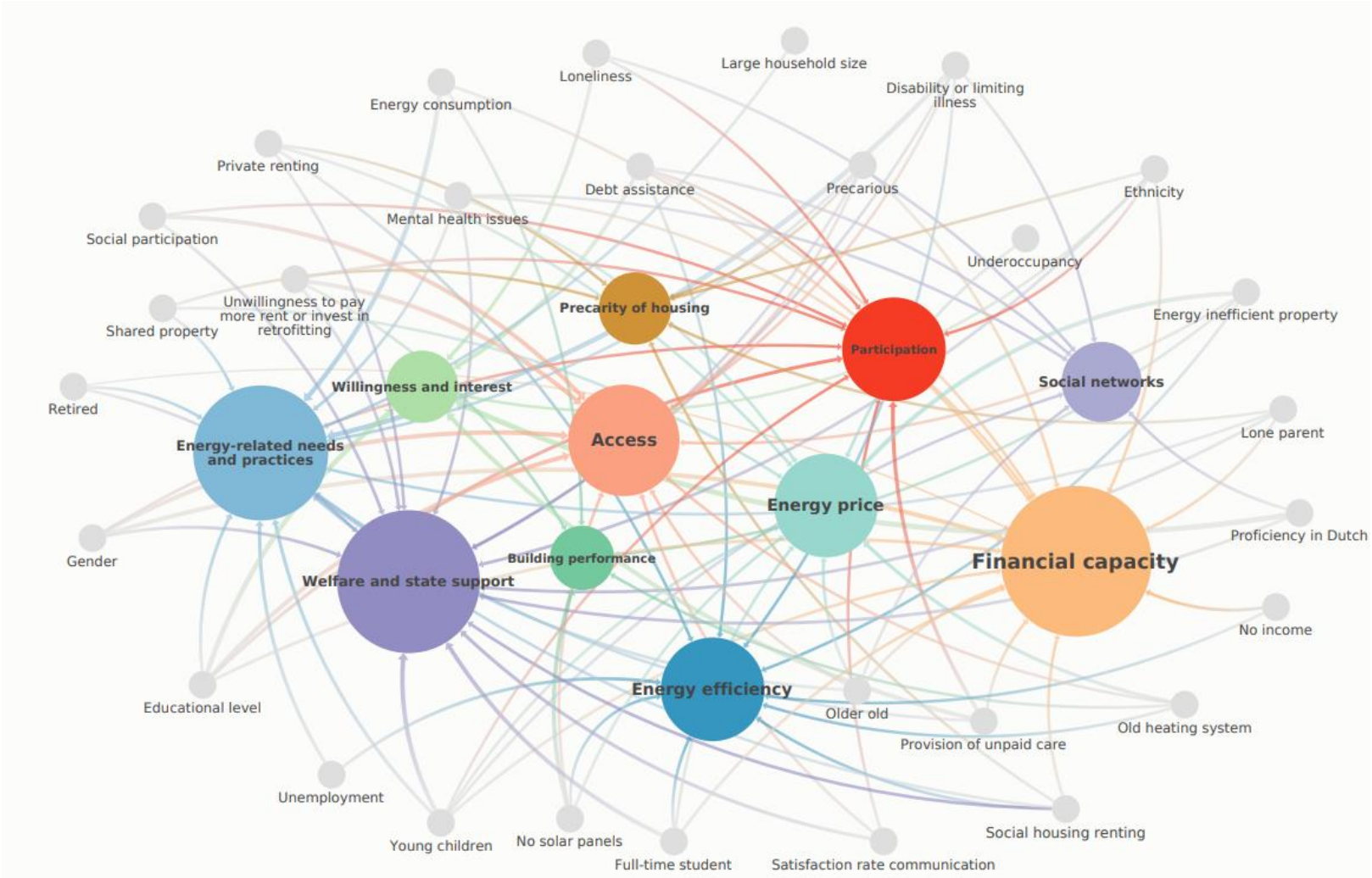


Figure 4.3 Relations between Vulnerability Indicators and the Vulnerability Boxes of the Extended Vulnerability Framework

Note. This diagram has been created with Kumu[4], which is an open-source tool for creating visualizations. The grey circles represent the vulnerability indicators, whereas the coloured circles represent the different vulnerability boxes presented in Figure 4.1. The size of the coloured circles represents how many vulnerability indicators are connected to the vulnerability box (indegree). A larger circle indicates a higher indegree.

To further enhance the understanding of the multidimensionality of energy poverty, the tool also allows to assess the multidimensionality of each vulnerability indicator individually. As an example, the associated vulnerability boxes related to the 'young children' vulnerability indicator was inspected, shown in Figure 4.4. From the figure, it can be seen that the vulnerability of families with young children is related to the energy-related needs and practices of these households, the welfare and state support system, participation, energy price, the social network and financial capacity of these families. By assessing each vulnerability indicator, it becomes possible to get an-depth understanding of the multidimensionality of each vulnerability indicator. Each vulnerability indicator and box can be assessed in the created visualization by clicking on, for instance, the vulnerability indicator or vulnerability box of interest. In Figure 4.4 the multidimensionality associated with the Young Children vulnerability indicator was inspected.

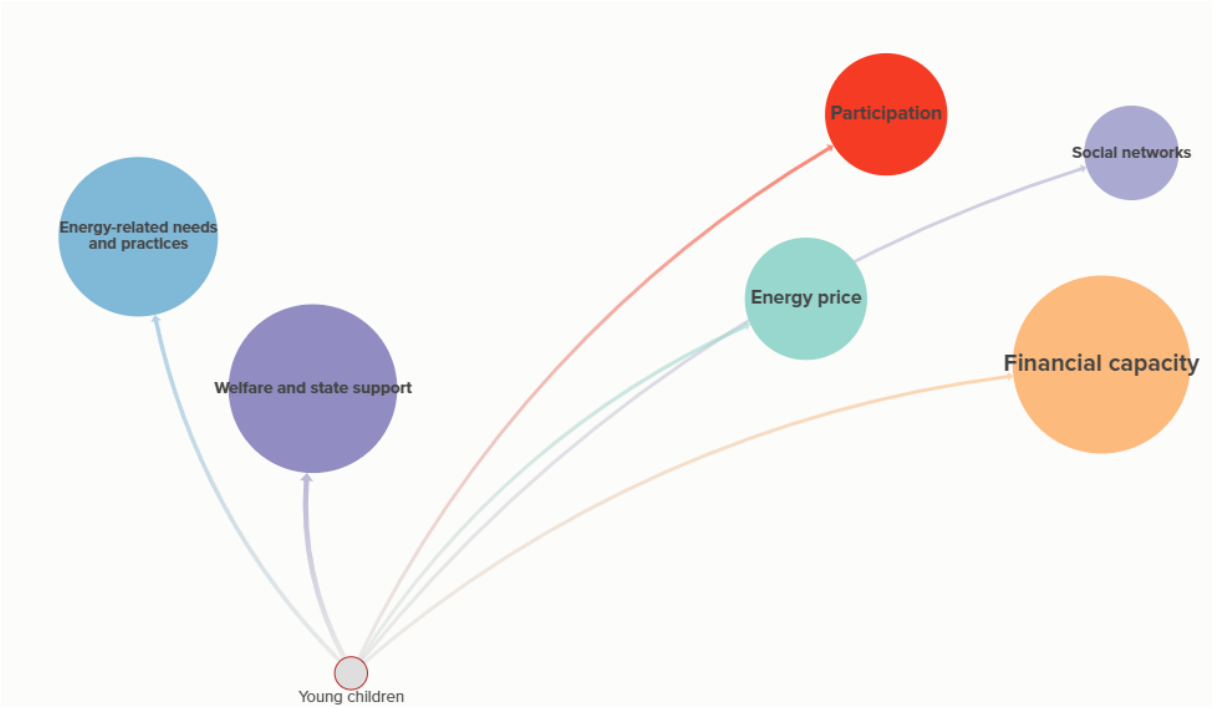


Figure 4.4 In-Depth Inspection of the Multidimensionality of the Young Children Vulnerability Indicator

Note. This diagram has been created with Kumu[4],and shows the multidimensionality associated with the Young Children vulnerability indicator.

4.4 Conclusion of Defining the Socio-Spatial Vulnerability to Energy Poverty

From defining the socio-spatial vulnerability to energy poverty, it can be concluded that current vulnerability frameworks lack the integration of renovation and institutional indicators with socio-economic and energy indicators that enhance the socio-spatial vulnerability to energy poverty and a loss of well-being. Given that the energy demand and loss of well-being of individuals are related to building performance, the current vulnerability framework developed by Robinson et al. (2019) has been extended with vulnerability factors associated with building performance. These factors include ventilation and transmission heat loss, poor indoor quality, property valuation, building year, wind direction and speed, mould, humidity levels, noise levels, housing density, indoor temperatures in summer, and heating requirements during winter. As the system analysis showed that the low renovation rates among vulnerable groups are partially related to participation and willingness, institutional indicators have been included in the vulnerability framework. These institutional factors include, on the one hand, factors related to participation, such as the lack of bottom-up initiatives, lack of social cohesion between the local community and institutions, and inefficient communication that impact the extent to which an individual is willing to participate in the Renovation Wave. On the other hand, the institutional factors relate to the willingness to invest or pay more rent to live in a renovated building and the general interest in the energy transition, enhancing socio-spatial vulnerability to energy poverty. Specifically, this means that these households would prefer not to invest in the renovation as they might not have the financial capacity to invest or are not interested in the energy transition and thereby do not consider renovating their house to improve the energy efficiency of the building and the living conditions.

The evidence of the multiple factors that make a household more vulnerable to energy poverty directed us to use a multidimensional suite of indicators. An index of socio-spatial vulnerability to energy poverty was developed by aggregating multiple indicators to investigate the relative importance of indicators and the spatial distribution of vulnerability. In the context of Amsterdam, 29 vulnerability indicators were identified based on desk research, interviews, and the available data on the neighbourhood level. This approach allows for a socio-spatial analysis, thereby enabling the identification of vulnerable groups and providing insights into the spatial distribution of the vulnerable groups. The index of socio-spatial vulnerability to energy poverty also highlights the multidimensionality of energy poverty, as each vulnerability indicator is associated with a wide range of vulnerability factors presented in the extended vulnerability framework. By visualising how each vulnerability indicator is related to multiple vulnerability factors/ vulnerability boxes shown in the extended vulnerability framework, the understanding of the multidimensionality and socio-spatial vulnerability to energy poverty is enhanced.

5. Results of the Socio-Spatial Analysis

In this chapter, the results of the socio-spatial analysis are presented. As the goal of the socio-spatial analysis was to identify vulnerable groups and gain insights into their socio-spatial distribution across Amsterdam, the results of the identified vulnerable groups and their spatial distribution are discussed in this chapter. Appendix F presents the results of all the methodological steps and accompanying results conducted before identifying vulnerable groups. Section 5.1 show the identified vulnerable groups and spatial distribution across Amsterdam. In Section 5.2, conclusions are drawn on the results of the socio-spatial analysis.

5.1 Identified Vulnerable Groups and their Spatial Distribution

In this section, the results of the identified vulnerable groups and their spatial distribution are presented. As outlined in the model specification of the PCA, which is presented in Appendix F, the PCA analysis yields seven components, each with a recognisable geographical distribution. The loadings of these vulnerability indicators on the finalised principal components provide information about the vulnerabilities a certain component is likely to present. Each of these components has the prospect of representing two dimensions of vulnerability, as the vulnerability indicators can load positive and negative on the components. In the following section, a plus (+) sign is used to represent vulnerabilities related to the positive loadings of the component. In contrast, a minus (-) sign is used to represent vulnerabilities related to the negative loadings of the component. The loadings on the seven components for each neighbourhood are mapped in Figures 5.1-5.15.

5.1.1 Component 1: Non-Western families, Educational Level, Disability, Illness, The Dynamics of Unemployment, and Lack of Social Relations (+)

Component 1 accounts for 28% of the PTV and has strong positive relations with non-western families, disability, illness, the dynamics of unemployment, and a lack of social relations. The component acknowledges how first-generation immigrants with a non-western background have an increased vulnerability as they often have low literacy, low proficiency in Dutch and tend to have a lower educational background as they often came to The Netherlands to earn money and thereby their focus on learning the language and getting a degree was limited. Moreover, these families are often used to living in a high-temperature environment, due to which they usually prefer a high indoor climate which subsequently influences the energy consumption of these households. The component also captures related to the educational level of households and their household size, highlighting the impact of likely inability to understand new technologies and having a large family, which increases the energy demand. Additionally, the component also highlights how individuals with a disability and mental health issues become vulnerable to energy poverty, whereby disability and mental health issues enhance the vulnerability to energy poverty due to a greater need for psychological warmth and other energy services while also enhancing the vulnerability to energy poverty among these groups due to likely unemployment and low incomes (Snell et al., 2015; Gillard et al., 2017, Robinson et al., 2019). The component also sheds light on the lack of social relations, which may enhance the vulnerability to energy poverty. This may increase the probability that households do not know what kind of policies there are and how they may tackle energy poverty by renovation. The practice has also shown that having social relations reduces the vulnerability to energy poverty as having a social network has a positive impact on the willingness of households to renovate as knowing someone who has renovated their house recently or having someone in your network that informs you about the opportunities of renovation covers partially the lack of trust in institutions which changes the often-negative

perspective into a neutral/positive perspective. The component also acknowledges the lack of financial securities, which enhances their unwillingness to invest in energy efficiency and thus enhances their vulnerability to energy poverty. Figure 5.1 shows the spatial distribution of component 1 across the neighbourhoods of Amsterdam. Spatially the component highlights vulnerability in the areas of West and Zuidoost. Zooming in at Zuidoost, the spatial distribution highlights the vulnerability in the neighbourhoods of Bijlmer-Oost and Bijlmer-Centrum which has high rates of non-western immigrants characterised by a high prevalence of low educational levels, no proficiency in Dutch, disability, illness, and consequently unemployment and the unwillingness to invest in energy efficiency.

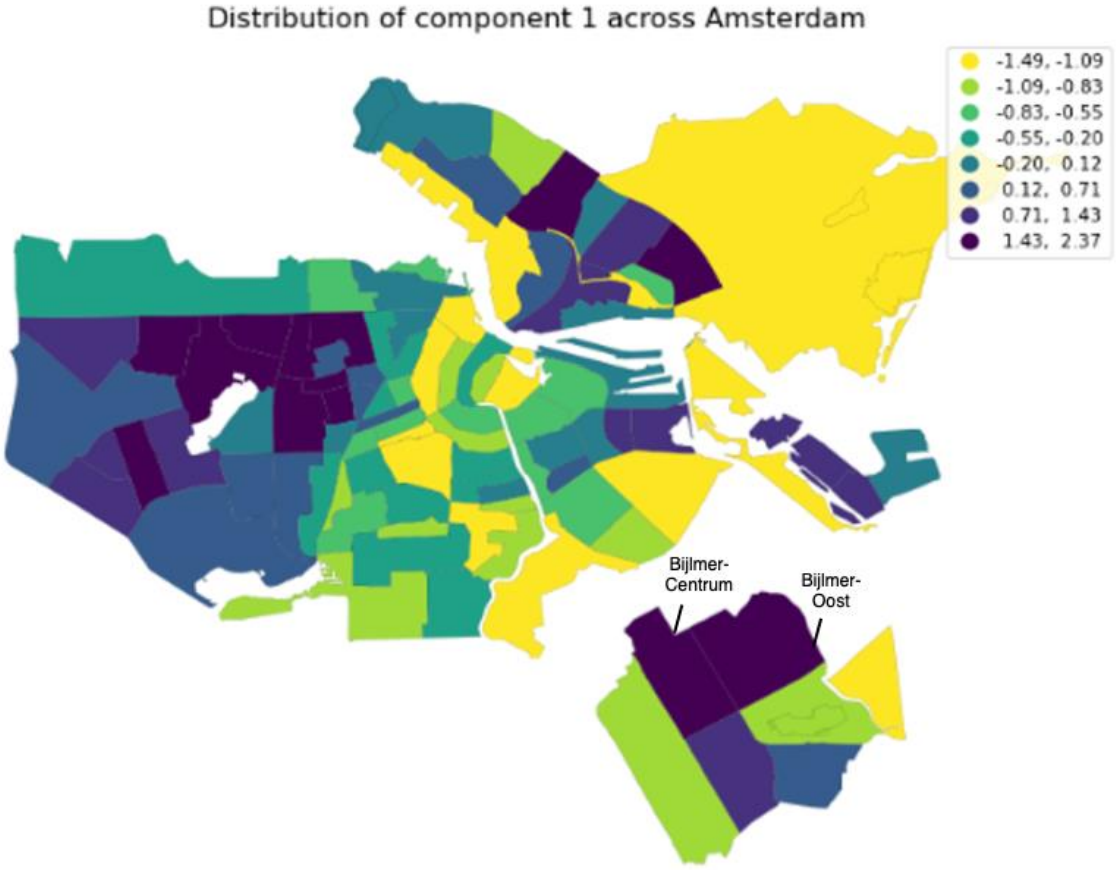
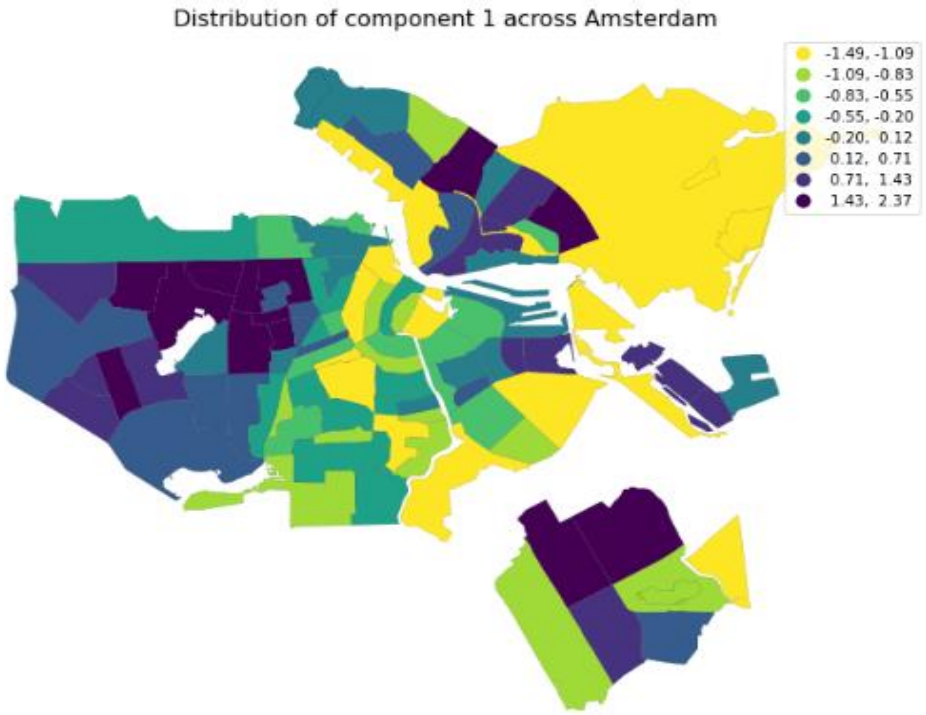
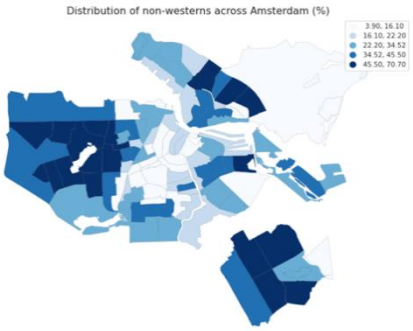


Figure 5.1 Component 1: Non-Western Families, Educational Level, Disability, Illness, the Dynamics of Unemployment, and a Lack of Social Relations (+)

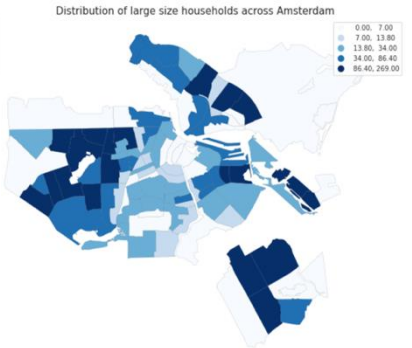
Note. The diagram shows the socio-spatial distribution of component 1. A high score/ purple colour indicates enhanced vulnerability relative to other neighbourhoods.

To further enhance the understanding of the component score and its distribution across Amsterdam, the socio-spatial distribution of each vulnerability indicator that load high on component 1 is inspected, shown in Figure 5.2 and Figure 5.3. From visually inspecting the socio-spatial distribution of vulnerability indicators related to ethnicity, low proficiency in Dutch, health issues, debt assistance, educational level, loneliness, and unemployment, it can be stated that these variables have high scores in Zuidoost and Nieuw-West. More specifically, it can be seen that in Zuidoost, there are relatively high numbers of non-Western immigrants and residents who are less proficient in Dutch and tend to have an enhanced vulnerability to energy poverty. Moreover, it can be seen that the occurrence of disability, mental health issues, debt assistance, and unemployment are relatively high. By visually inspecting the indicators, it can also be seen that these vulnerability indicators are especially apparent in Bijlmer-Oost and Bijlmer-Centrum, which also explains the relatively high component score on component 1 for these two neighbourhoods.

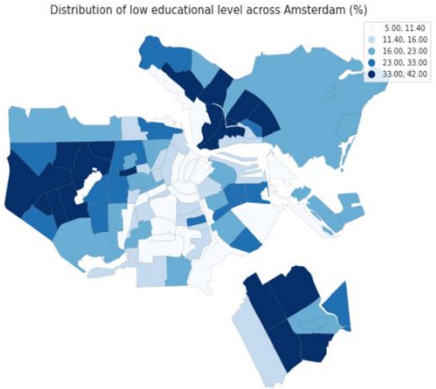




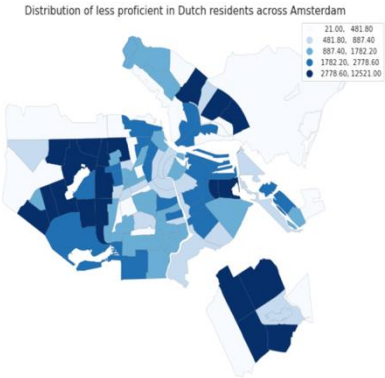
(a) Non-Western Background



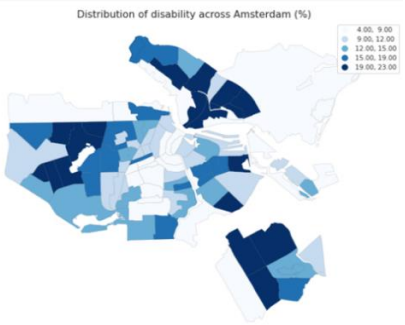
(b) Large-sized Households



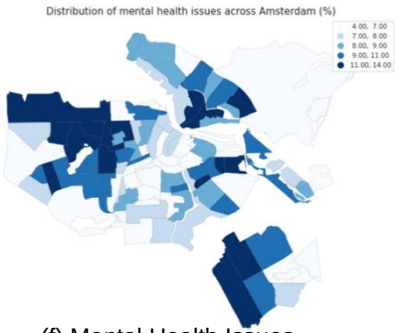
(c) Low Educational Level



(d) Low Proficiency in Dutch



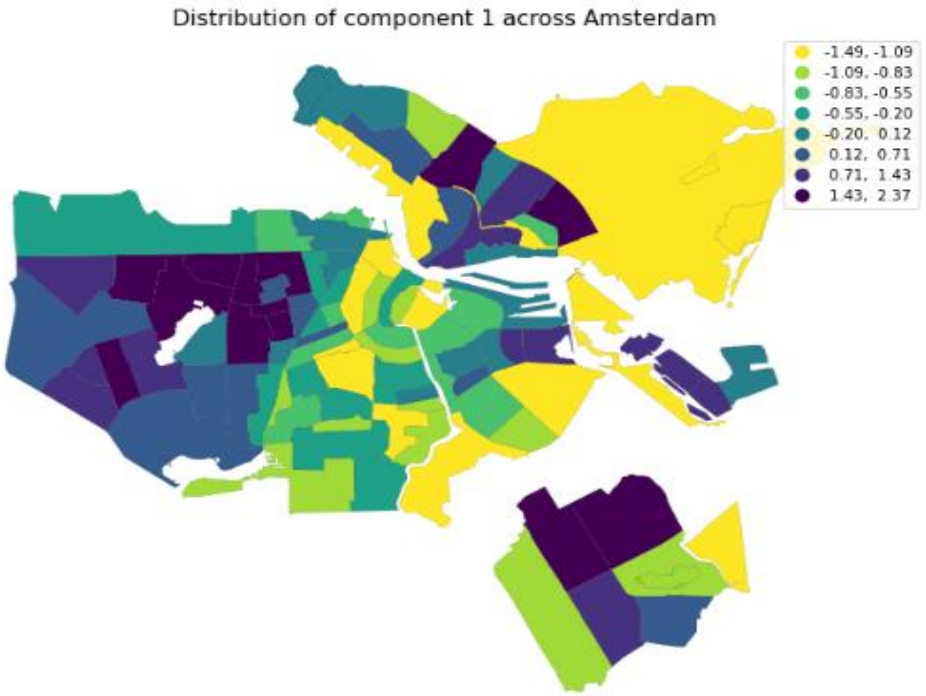
(e) Disability

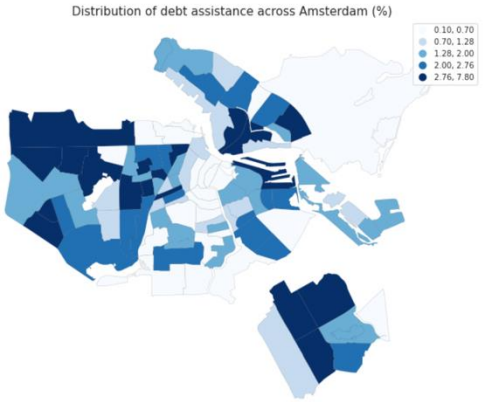


(f) Mental Health Issues

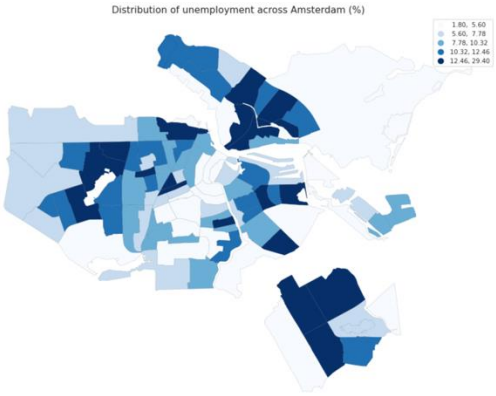
Figure 5.2 Spatial Distribution of Component 1 and Corresponding High Loading Vulnerability Indicators (a)

Note. The figures of the vulnerability indicators are shown for visualization purposes. The socio-spatial distribution of each vulnerability indicator can be found in Appendix F.

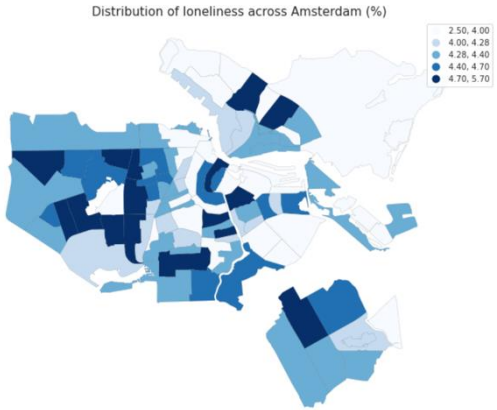




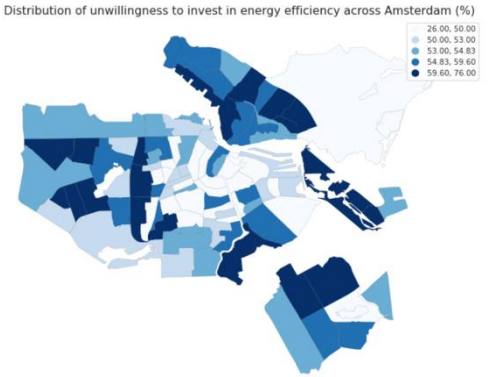
(g) Debt Assistance



(h) Unemployment



(i) Loneliness



(j) Unwillingness to Invest or Pay More Rent

Figure 5.3 Spatial Distribution of Component 1 and Corresponding High Loading Vulnerability Indicators (b)

Note. The figures of the vulnerability indicators are shown for visualization purposes. The socio-spatial distribution of each vulnerability indicator can be found in Appendix F

5.1.2 Component 2: Provision of Unpaid Care, Retirement, and Under-Occupancy (+) and Shared Property and Full-Time Students (-)

Component 2 accounts for 14% of the PTV and has strong relations with the provision of unpaid care, retirement, and under-occupancy. This includes families with young children and retired individuals between 18 and 64 years which requires them to stay at home (Healy & Clinch, 2004; Gingerbread, 2013; Robinson et al., 2019). The strong positive relation acknowledges the lack of financial securities and technology knowledge, making them more likely to not invest in energy services. The component also captures vulnerabilities associated with the provision of unpaid care, recognising the reduced capacity of the carer to participate in employment (George et al., 2013; King & Pickard, 2013). Moreover, the component sheds light on people who require or provide unpaid care are likely to spend more time at home, resulting in higher exposure to energy poverty and a loss of well-being (George et al., 2013; Robinson et al., 2019). Component 2 also underlines vulnerability associated with retirement as these individuals often have a greater psychological need for heat and a large amount of time they tend to spend at home (Ormandy & Ezratty, 2012). Additionally, under-occupancy also increases the exposure to energy poverty as the amount of space that a household must pay to heat the house may be significant for households that rely on support from a single-income of welfare support (Wright, 2004; Burholt & Windle, 2006; O'Neill et al., 2006; Robinson et al., 2019).

Component 2 also sheds light on the vulnerability of transient groups such as full-time students and individuals living in shared properties. In these circumstances, the energy usage and improvements related to energy efficiency are difficult to negotiate with a landlord or other tenants. Moreover, tenants living in student apartments often do not have the power to choose their energy service provider, which reduces the opportunities they have to reduce their energy consumption, energy bill, or invest in energy efficiency. Enhanced vulnerability to energy poverty related to the provision of unpaid care, retirement, and under-occupancy in Zuidoost is likely to manifest in the neighbourhoods of Nellestein, Gein, and Driemond. In contrast, vulnerabilities related to full-time students and shared properties in Zuidoost are likely to manifest in Amstel III/Bullewijk, Bijlmer-Oost, and Bijlmer-Centrum as various schools are located in these neighbourhoods due to which the number of full-time students and shared properties is higher. Moreover, non-western groups tend to live longer within their parents' houses which also increases their exposed vulnerability to energy poverty as their parents often have the power to decide upon energy improvements. Figure 5.4 shows the spatial distribution of component 2.

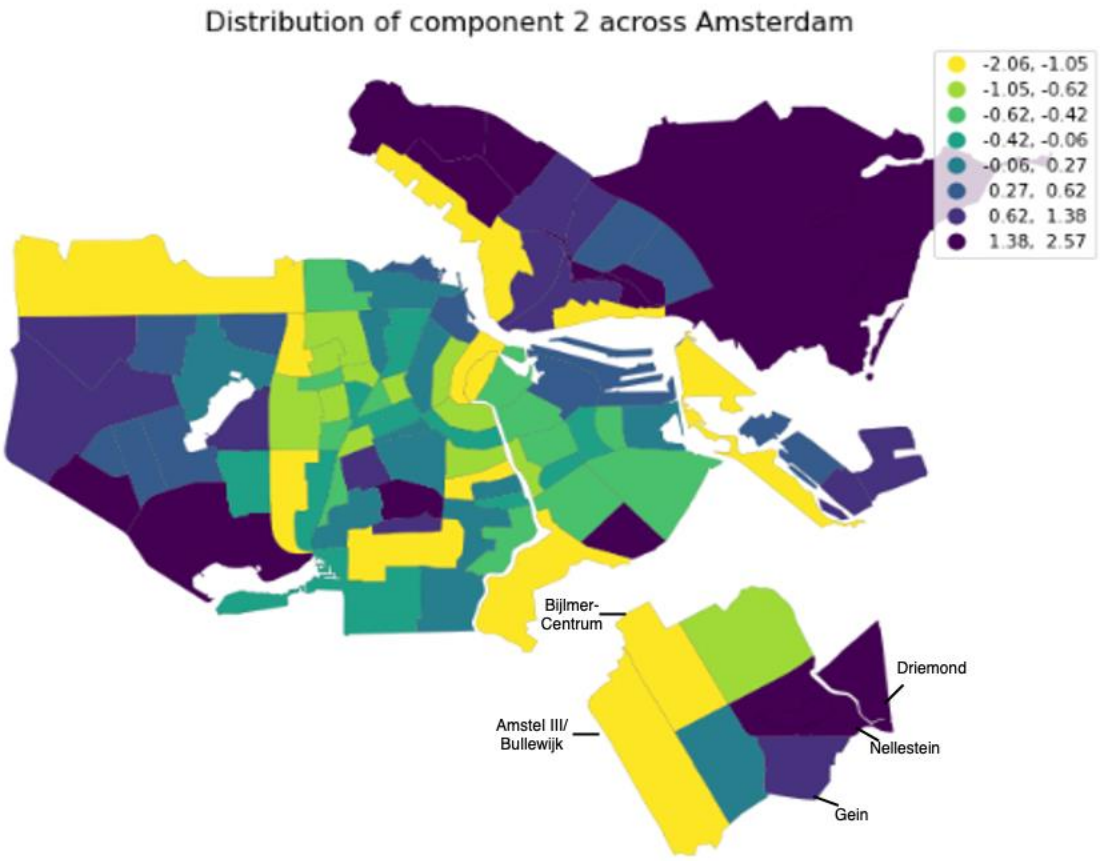


Figure 5.4 Provision of Unpaid Care, Young Children, Retirement, and Under-Occupancy (+) and Vulnerabilities related to Shared Property and Full-Time Students (-)

Note. The diagram shows the socio-spatial distribution of component 1. A high score/ purple colour indicates enhanced vulnerability relative to other neighbourhoods.

To further enhance the understanding of the component score and its distribution across Amsterdam, the socio-spatial distribution of each vulnerability indicator that load high on component 2 is inspected, shown in **Fout! Verwijzingsbron niet gevonden.**. From visually i nspecting the socio-spatial distribution of vulnerability indicators related to the provision of unpaid care, families with young children, retired between 18-64 years old, and under-occupancy, it can be stated that these variables have high scores in the neighbourhoods of Driemond, Nellestein, and Gein. As a component can represent two types of vulnerabilities. Component 2 also expresses vulnerabilities to living in shared properties and being a full-time student. By visually inspecting the vulnerability indicators that load negative on component 2 and shown in Figure 5.5, it can be seen that a relatively large share of the full-time students is living in the neighbourhood of Bijlmer-Centrum and Amstel III/Bullewijk and that in these neighbourhoods relatively more individuals live in shared properties.

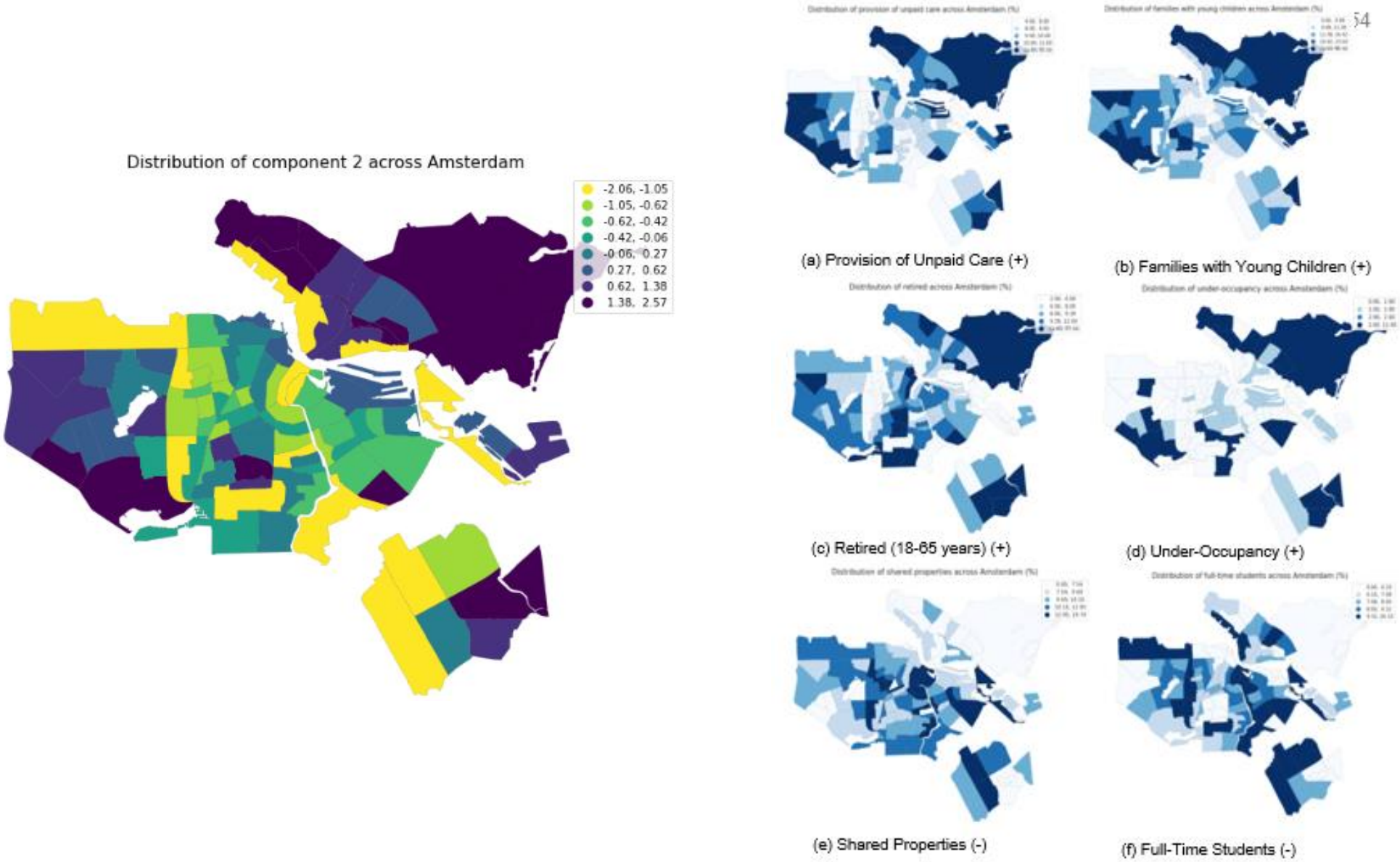


Figure 5.5 Spatial Distribution of Component 2 and corresponding High Loading Vulnerability Indicators

Note. The figures of the vulnerability indicators are shown for visualization purposes. The socio-spatial distribution of each vulnerability indicator can be found in Appendix F.

5.1.3 Component 3: Social Housing and Private Middle Rental Sector Tenants and Energy Consumption (+)

Component 3 accounts for nearly 10% of the PTV and has a positive association with housing tenants and energy consumption. Social housing and private renting in the 'middle' renting sector are strongly related to this component, including a lack of access to new technologies due to reliance on the landlord (Liddel et al., 2012). Studies have shown that energy usage and improvements in energy efficiency are often difficult to negotiate with a landlord. Moreover, tenants in the so-called middle private sector are often underrepresented in energy policies as the focus of energy poverty policies in the form of monetary compensation is usually aimed at groups in the social housing class, highlighting the current misrepresentation in the policy. Spatially the distribution of social housing, middle renting sector tenants, and the relative energy consumption of households to their household income is not largely divergent across the neighbourhoods of Amsterdam and Zuidoost, indicating that the exposure to a vulnerability related to renting a house and the relative energy consumption is roughly equally distributed. Figure 5.6 shows the spatial distribution of component 3.

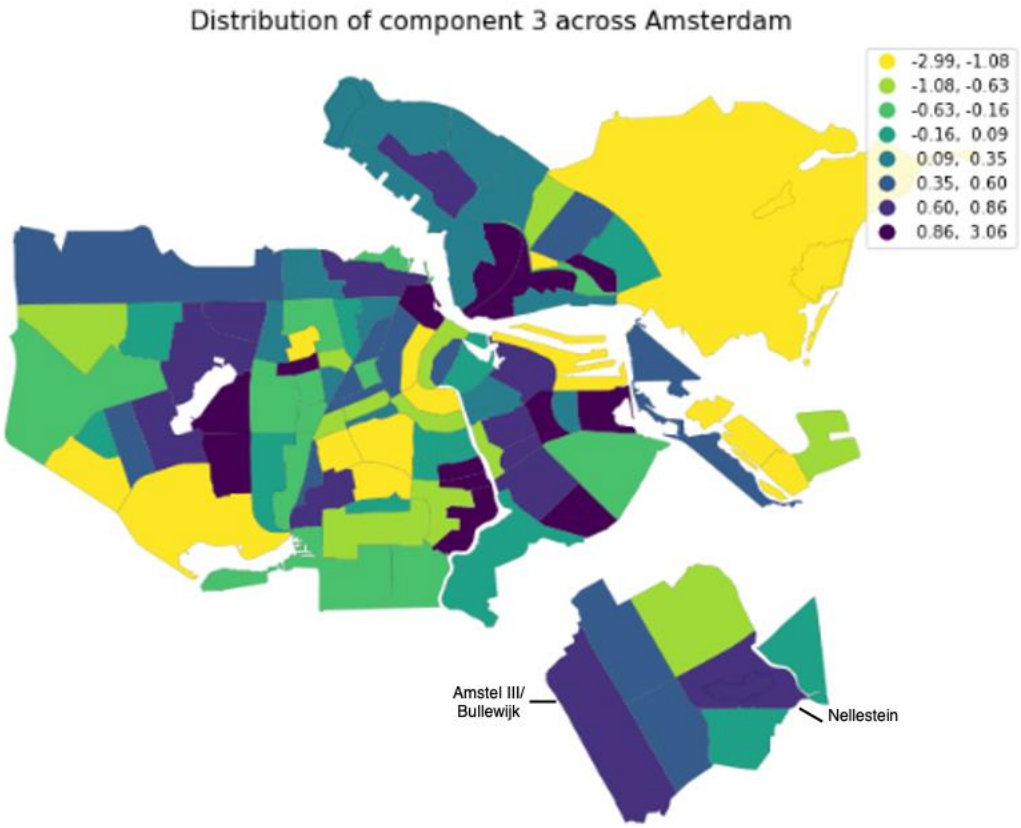


Figure 5.6 Component 3: Social Housing and Private Middle Rental Sector Tenants and Energy Consumption (+)

To further enhance the understanding of the component score and its distribution across Amsterdam, the socio-spatial distribution of each vulnerability indicator that load high on component 3 is inspected, shown in Figure 5.7. From visually inspecting the socio-spatial distribution of vulnerability indicators related to social housing renting, private middle sector renting and energy consumption relative to income, it can be stated that these variables have high scores in the neighbourhoods of Amstel III/Bullewijk and Nellestein, which also explains the relative higher component score of these neighbourhoods.

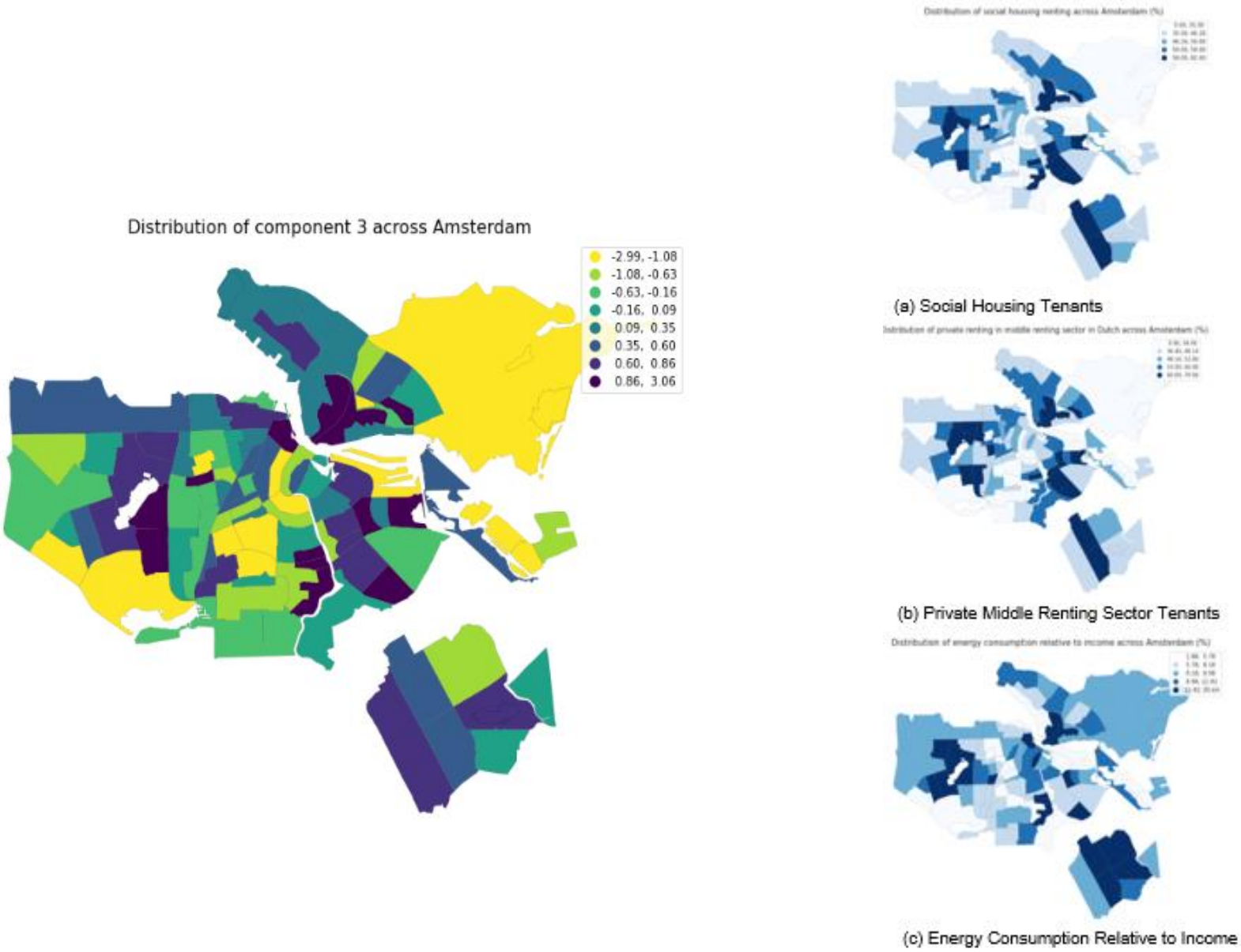


Figure 5.7 Spatial Distribution of Component 3 and corresponding High Loading Vulnerability Indicators

Note. The figures of the vulnerability indicators are shown for visualization purposes. The socio-spatial distribution of each vulnerability indicator can be found in Appendix F.

5.1.4 Component 4: Energy Efficiency and Sustainable Energy Infrastructure (+)

Component 4 accounts for roughly 7 percent of the PTV and has a strong association with energy efficiency and the availability of efficient and sustainable energy infrastructures. The energy-inefficient indicator is strongly related to this component as it portrays the vulnerability associated with having an energy label of E/F/G, which enhances the vulnerability to energy poverty as the energy bills are often high and consequently lead to poor living conditions in the house as these properties often deal with high indoor temperatures in the summer, mould and extreme cold in the winter. Consequently, this leads to a loss of well-being. There is also a positive relation with indicators related to sustainable energy infrastructure, including the usage of old heating systems in residential buildings portrayed by the percentage of heaters and boilers in residential buildings. Moreover, the component also highlights the vulnerability related to not having access to energy-efficient technologies, such as not being able to invest or make use of solar panels to save money on the energy bill. Spatially, it can be noted that neighbourhoods located in the city centre and South of Amsterdam have increased exposure to a vulnerability related to energy efficiency and sustainable energy infrastructure, highlighting how the relative old buildings 'grachtenpanden' in these regions are often not renovated and may increase a household's vulnerability. Remarkably, it can be seen that the vulnerability related to energy efficiency and sustainable energy infrastructure in Zuidoost is relatively lower compared to the other regions, highlighting that although more households are vulnerable to energy poverty in Zuidoost, their vulnerability is not represented in terms of energy efficiency as the buildings are relatively 'new' and thus have higher energy labels or have recently been renovated. These results are crucial for policymakers as solely focusing on energy labels while increasing the renovation policies will not entirely tackle energy poverty for these vulnerable groups. Figure 5.8 shows the spatial distribution of component 4.

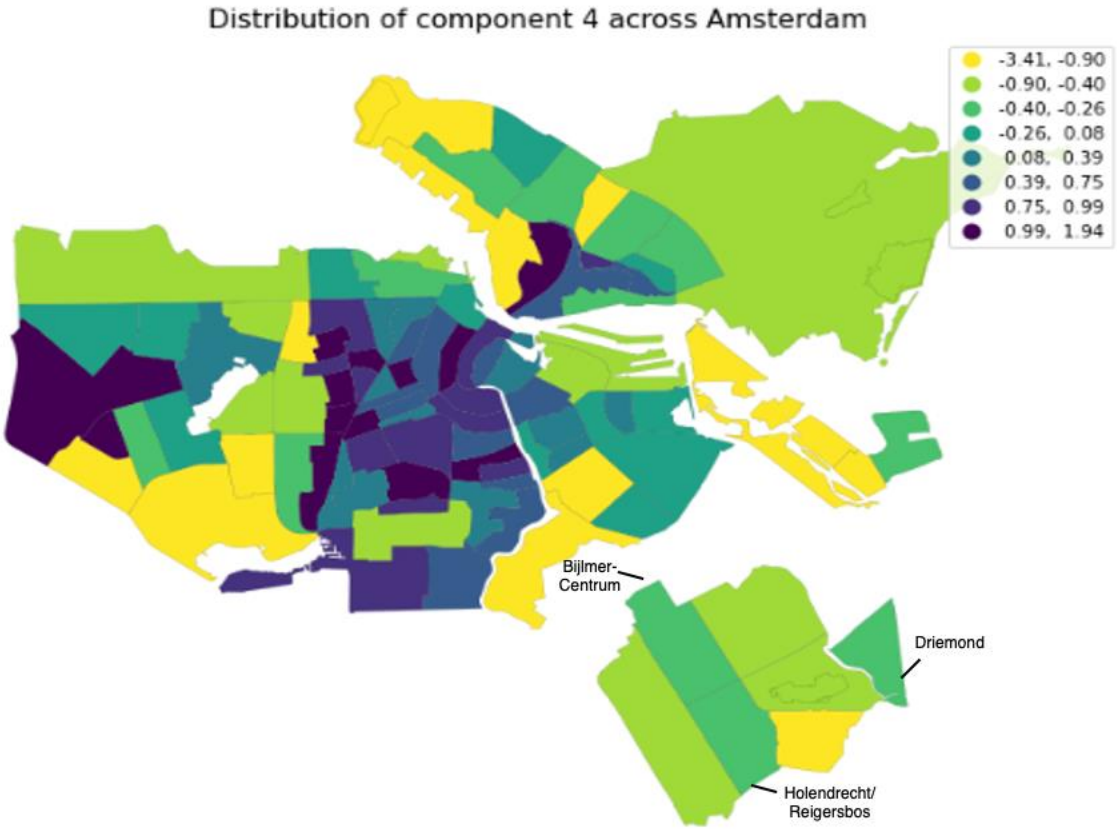


Figure 5.8 Component 4: Energy Efficiency and Sustainable Energy Infrastructure (+)

To further enhance the understanding of the component score and its distribution across Amsterdam, the socio-spatial distribution of each vulnerability indicator that load high on component 4 is inspected, shown in Figure 5.9 From visually inspecting the socio-spatial

distribution of vulnerability indicators related to social housing renting, private middle sector renting, and energy consumption relative to income, it can be stated that these variables perform relatively well in terms of energy efficiency and sustainable energy infrastructure compared to other regions in Amsterdam. Vulnerabilities in Zuidoost relative to the energy efficiency are relatively prominent in Bijlmer-Centrum, Holendrecht/Reigersbos and Driemond.

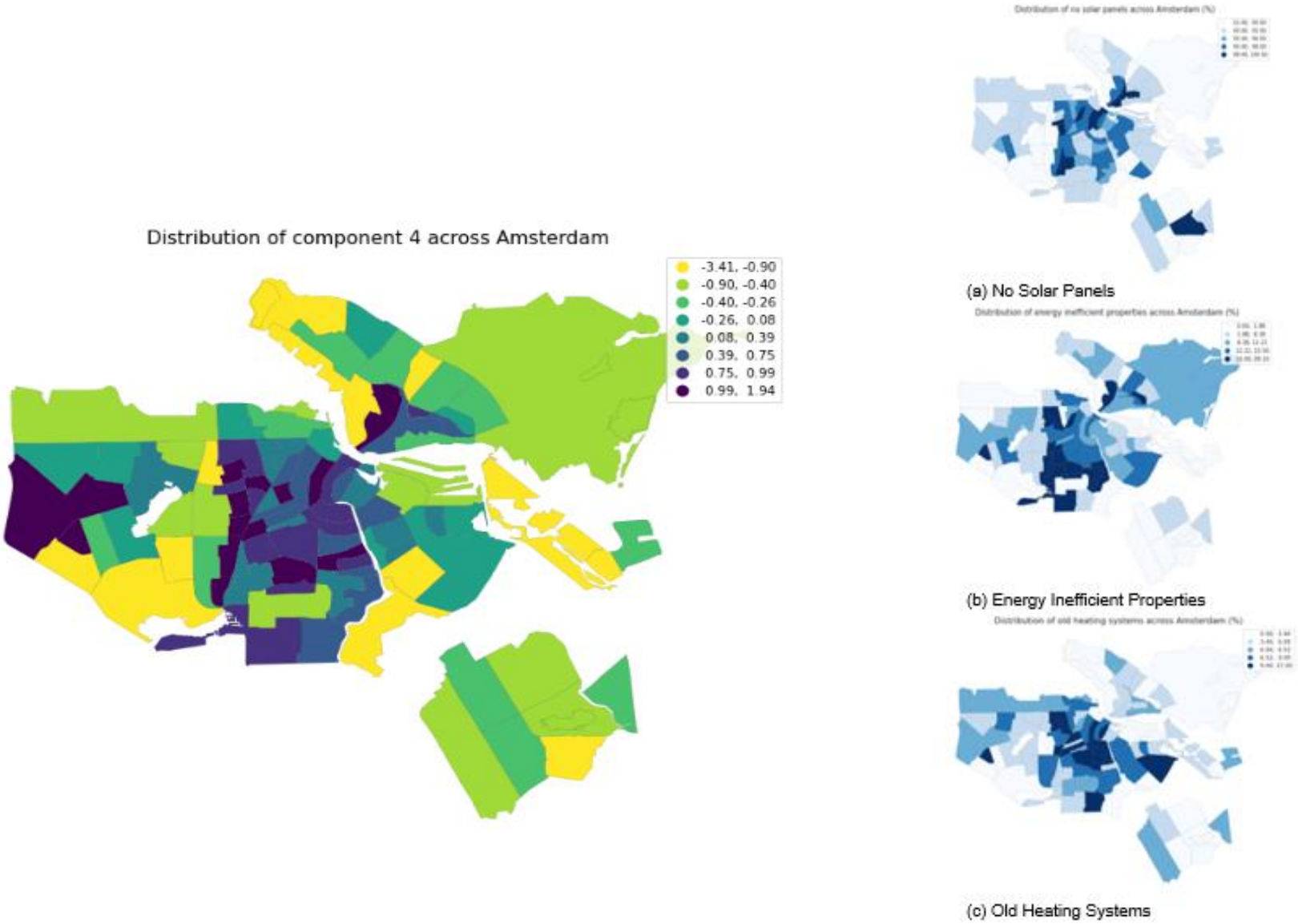


Figure 5.9 Spatial Distribution of Component 4 and corresponding High Loading Vulnerability Indicators

Note. The figures of the vulnerability indicators are shown for visualization purposes. The socio-spatial distribution of each vulnerability indicator can be found in Appendix F.

5.1.5 Component 5: Single-Parent Households, Older Olds, and Females (+)

The fifth component accounts for 6 percent of the PTV and has positive associations with single-parent households, older olds, and females. The component highlights vulnerability related to single-parent households who often need to work part-time or stay at home, acknowledging the lack of financial services among these households that increases the risk that they might not be able to afford or invest in energy-efficient systems. Additionally, the component sheds light on older olds who are living alone at an older age. These individuals often have a greater psychological need for heat during their older age as they often have enhanced exposure to low indoor temperatures after spending significant amounts of time at home during the day (Ormandy & Ezratty, 2012). The component also highlights vulnerability related to gender, where females are more likely exposed to energy poverty as they often have to take care of their families, spend a large amount of time at home, and do not always have a lack of control and choice over their daily livers (Robinson, 2019; Abbas et al., 2020; Respondents 1-4, 2022). Spatially the results show that vulnerabilities related to single-parent households, older age, and females are likely to manifest in areas such as Zuidoost, where Bijlmer-Centrum has the highest exposure, followed by Bijlmer-Oost and Reigersbos. These vulnerabilities are related to ethnic minorities, as in some cultures, the prevalence of single-parent households where females are providing care is significant (Respondents 1,2 & 4, 2022). Figure 5.10 shows the spatial distribution of component 5.

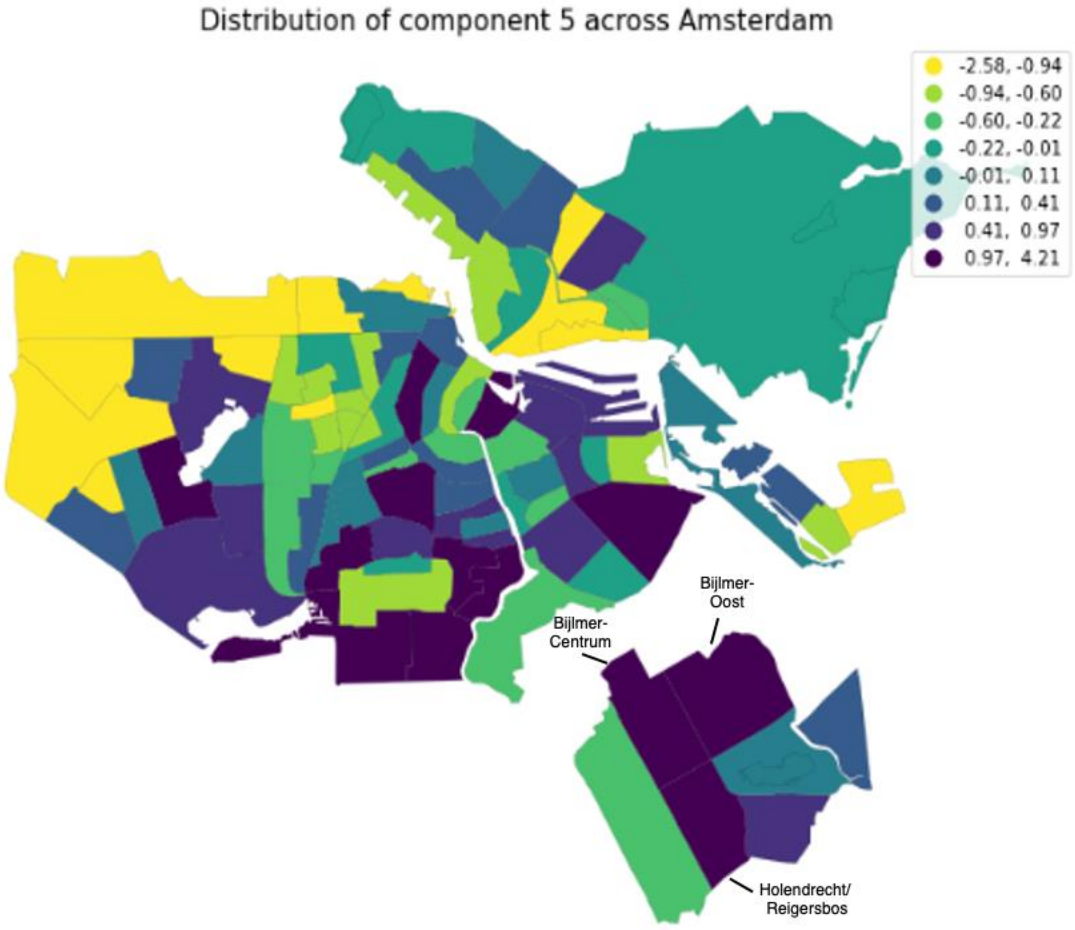


Figure 5.10 Component 5: Single-Parent Households, Older Olds, and Females (+)

To further enhance the understanding of the component score and its distribution across Amsterdam, the socio-spatial distribution of each vulnerability indicator that load high on component 5 is inspected, shown in Figure 5.11. From visually inspecting the socio-spatial distribution of vulnerability indicators related to single-parent households, older olds who are

living alone and females it becomes apparent that in the neighbourhoods of Bijlmer-Centrum, Bijlmer-Oost, Holendrecht/Reigersbos these vulnerabilities are relatively prominent.

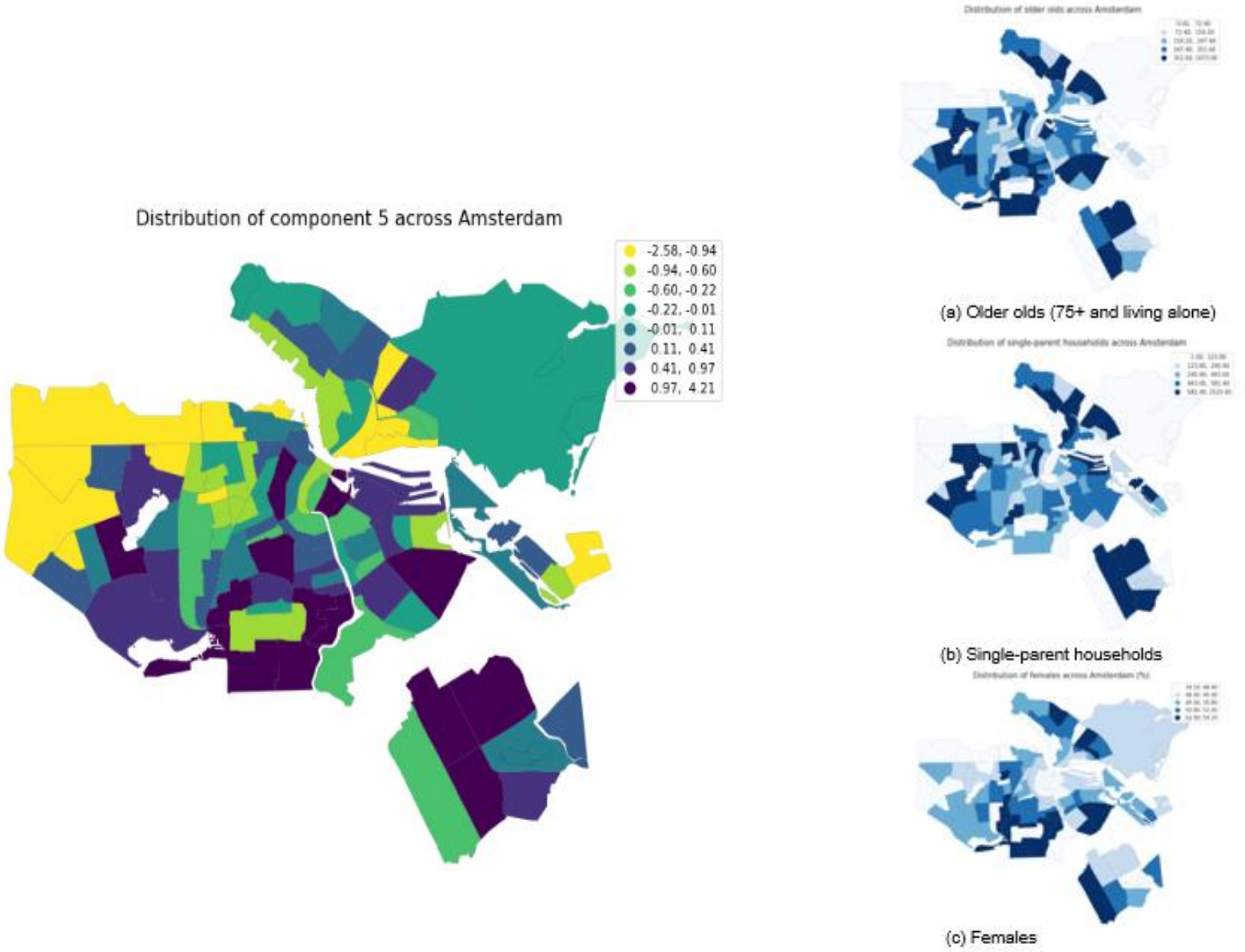


Figure 5.11 Spatial Distribution of Component 5 and corresponding High Loading Vulnerability Indicators

Note. The figures of the vulnerability indicators are shown for visualisation purposes. The socio-spatial distribution of each vulnerability indicator can be found in Appendix F

5.1.6 Component 6: Lack of Income (+) and Participation and Communication Satisfaction Score of the City (-)

Component six accounts for nearly 5 percent of the PTV and is related to a positive relationship with a lack of income, highlighting the increased vulnerability to energy poverty as these households cannot afford or invest in energy efficiency and are often living in poor conditions as they are usually focused on surviving and do not have a high interest in anything related to the energy transition. The groups often also tend to accept high financial risks by, for instance, stopping their insurance to save money, indicating that if a situation occurs in which, for example, there is a fire in their house, all their properties are not insured, leaving them eventually with empty hands (Respondent 1 & 2, 2022). The component also captures vulnerability related to the participation of local residents in policy issues and the extent to which they are satisfied or understand the letters sent by the City, as these influence the extent to which certain social groups are represented in policymaking but also influence the knowledge about energy efficiency improvements and technologies, which eventually impacts their willingness to invest or pay more rent to live in a renovated building. Limited participation is also linked to low interest in energy transition as these households are unwilling to participate actively and join forces to realise an energy transition, negatively impacting the likelihood of bottom-up initiatives (Respondents 1, 2 & 4, 2022). Moreover, satisfaction with the communication of the City also affects the vulnerability to energy poverty, as having ineffective communication tools whereby it is highly likely that not all social groups will understand the letters sent by the City could eventually lead to a situation in which these groups are not represented in policy, have a low interest in the energy transition and are not able to afford or invest in energy efficiency nor understand the technologies. Spatially vulnerabilities related to a lack of income are apparent in Zuidoost but also visible in the Western region of Amsterdam, which is related to the vulnerabilities associated with ethnic minorities and the provision of unpaid care. For the participation and communication satisfaction indicators and no income, these vulnerabilities are likely to manifest in Amstel III/Bullewijk, Bijlmer-Centrum, and Nellestein. Figure 5.12 shows the spatial distribution of component 6.

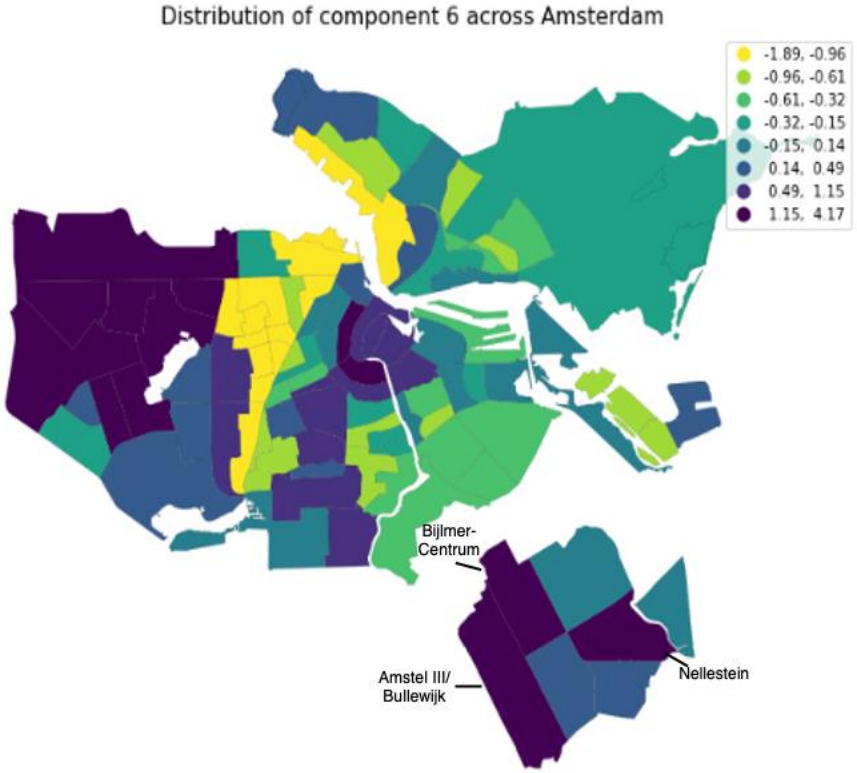


Figure 5.12 Component 6: Lack of Income (+) and Participation and Communication Satisfaction Score of the City (-)

To further enhance the understanding of the component score and its distribution across Amsterdam, the socio-spatial distribution of each vulnerability indicator that load high on component 6 is inspected, shown in Figure 6.13. From visually inspecting the socio-spatial distribution of vulnerability indicators related to the lack of income, it can be stated that these variables have high scores in the neighbourhoods of Bijlmer-Centrum, Nellestein, and Amstel III/Bullewijk. Moreover, as the component can represent two types of vulnerabilities, Component 6 also draws attention to vulnerabilities related to participation and satisfaction with the communication of the City. The visual inspection shows that nearly all neighbourhoods in Zuidoost have a relatively low score on these variables, which indicates that generally, there is less participation and low satisfaction scores, which can also be seen by inspecting the negative loadings of the vulnerability indicators shown in Figure 5.13.

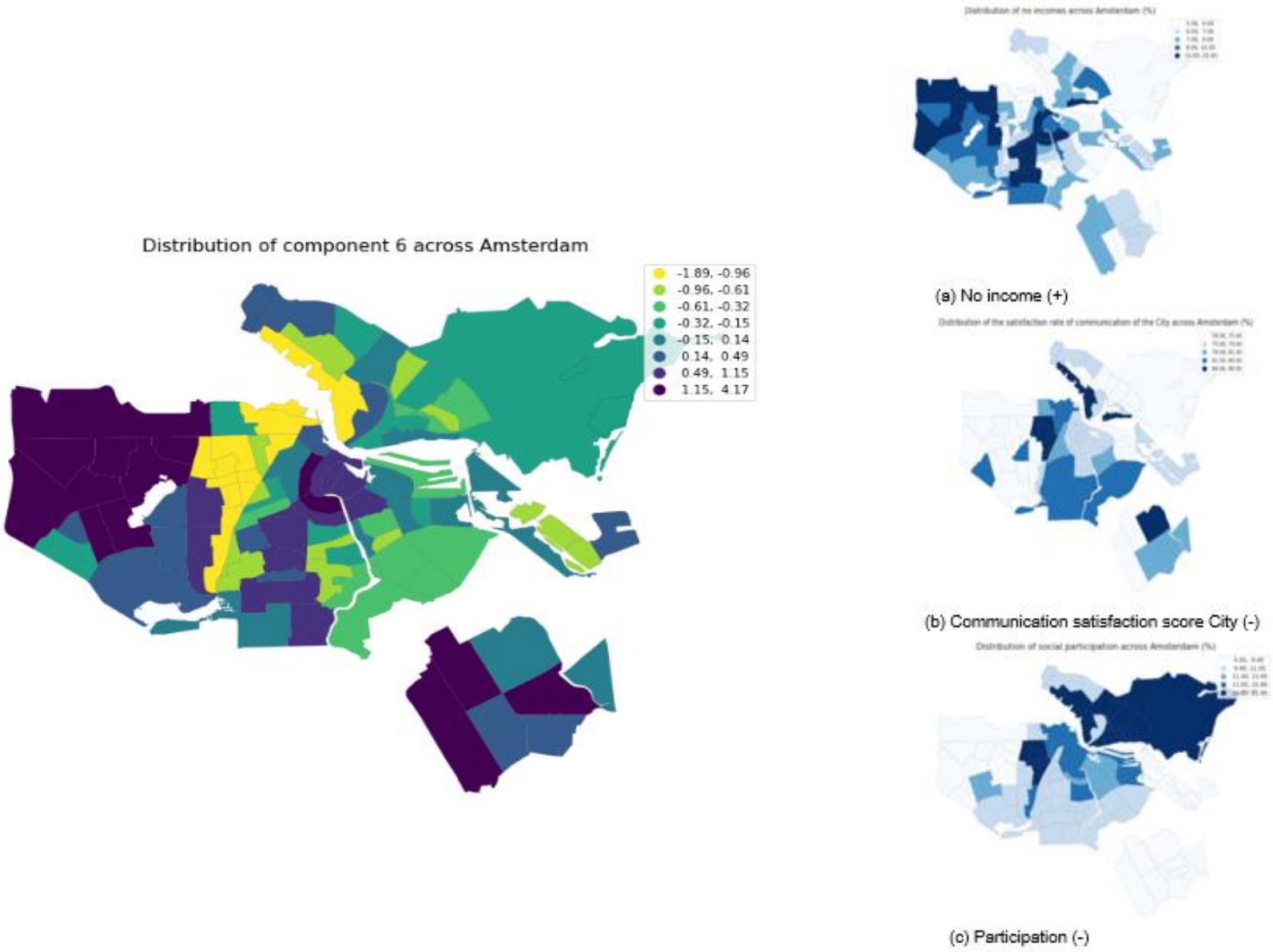


Figure 5.13 Spatial Distribution of Component 6 and corresponding High Loading Vulnerability Indicators

Note. The figures of the vulnerability indicators are shown for visualisation purposes. The socio-spatial distribution of each vulnerability indicator can be found in Appendix F

5.1.7 Component 7: Precarious Families (+)

The last component accounts for four percent of the PTV and has a positive relation with precarious families. The components represent how precarious families often are unemployed or work part-time as they have to take care of their family and ensure their well-being while using care services. These families or individuals also spent a great time at home, increasing the heat required daily for a comfortable living environment. The vulnerability also sheds light on how these individuals who need to make use of care services often do not have control or choice over their daily lives, indicating their inability to invest in energy efficiency and participate in the renovation measures as they rely on others (O'Sullivan et al., 2016; Robinson et al., 2019). Spatially, the vulnerability in Zuidoost is likely to manifest in Bijlmer-Centrum and Holendrecht/Reigersbos, where an increased share of households makes use of care services and experience an increased vulnerability to energy poverty. Figure *5.14* shows the spatial distribution of component 7.

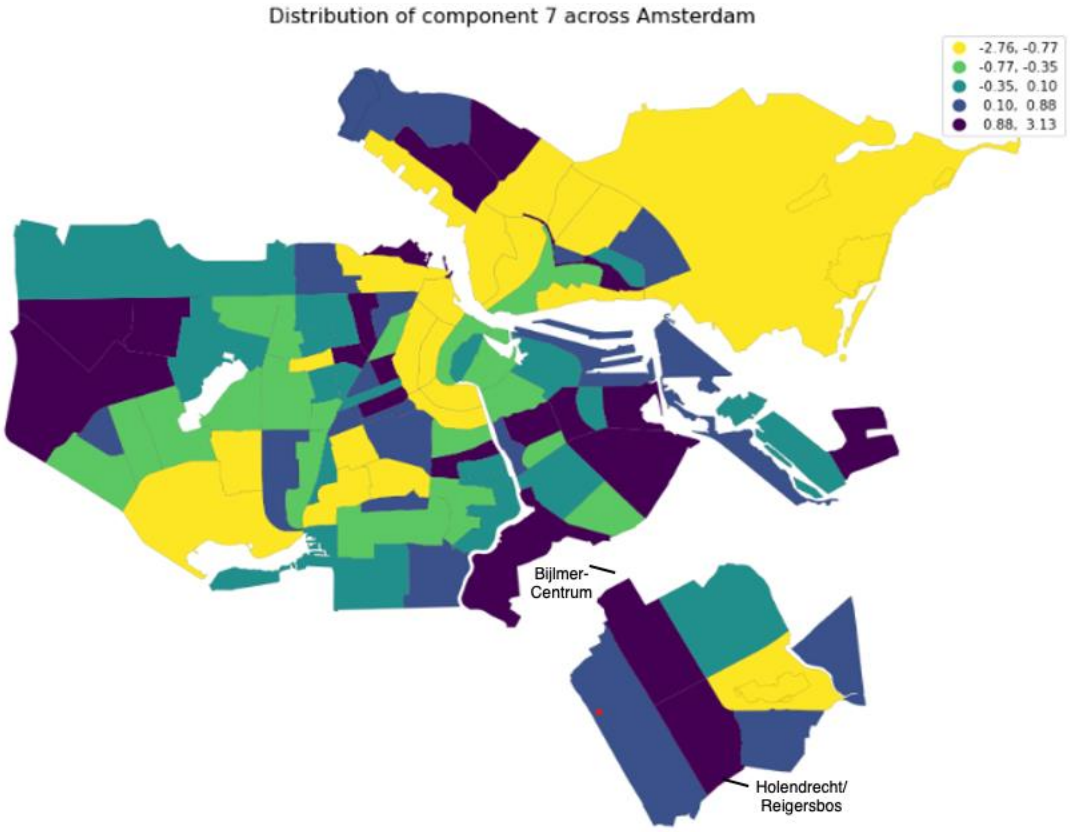
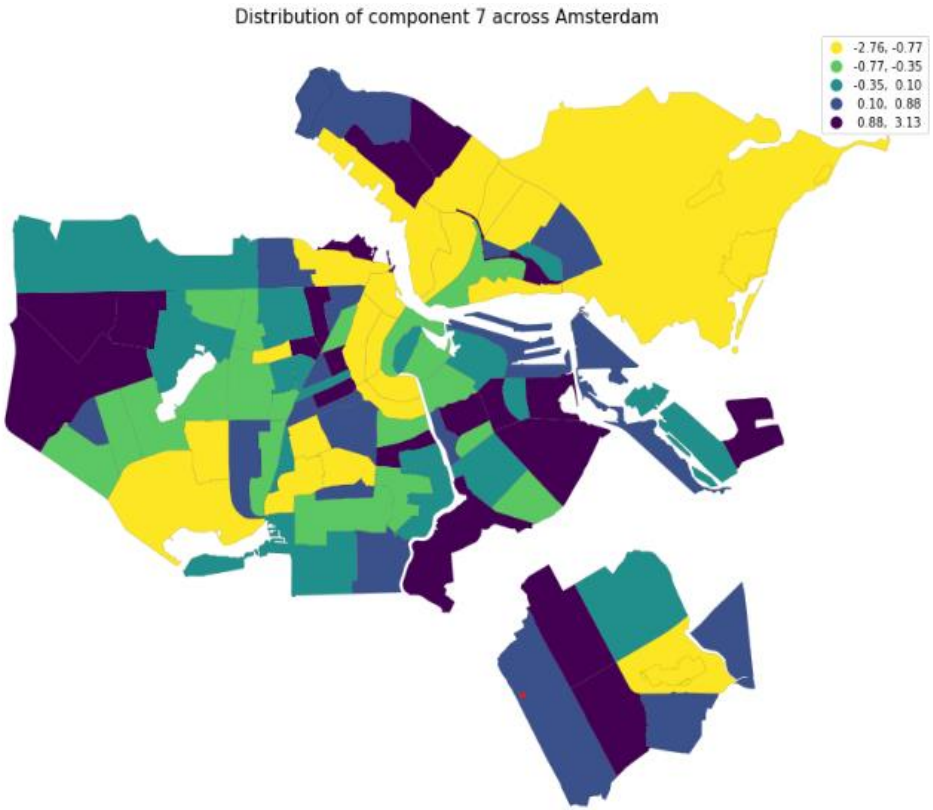
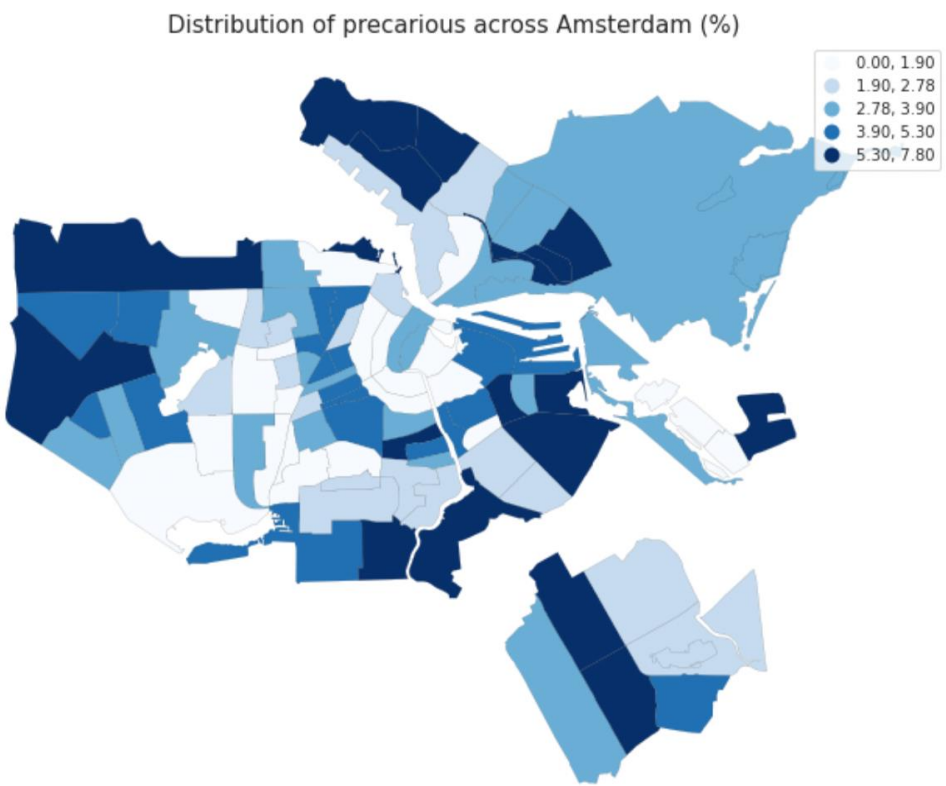


Figure 5.14 Component 7: Precarious Families (+)

To further enhance the understanding of the component score and its distribution across Amsterdam, the socio-spatial distribution of the vulnerability indicator that load high on component 7 is inspected, shown in Figure 5.15. From visually inspecting the socio-spatial distribution of vulnerability indicators related to precarious families it becomes apparent that in the neighbourhoods of Bijlmer-Centrum and Holendrecht/Reigersbos these vulnerabilities are relatively prominent.





(a) Precarious Families (+)

Figure 5.15 Spatial Distribution of Component 7 and corresponding High Loading Vulnerability

5.2 Conclusion of the Socio-Spatial Analysis

The socio-spatial analysis of the socio-spatial vulnerability to energy poverty has shown that seven different vulnerable groups, represented by the components, can be identified within the context of Amsterdam. Table 5.1 provides an overview of the identified vulnerable groups, their characteristics, and their spatial prevalence in Zuidoost. The characteristics of the vulnerable groups provide insights into which factors enhance their vulnerability to energy poverty and allow us to compare the different vulnerable groups.

Table 5.1 Identified Vulnerable Groups and their Characteristics and Spatial Prevalence across Zuidoost

Group	Characteristics	Spatial prevalence
1	Migration background, large-sized families, low educational background, low proficiency in Dutch, disability, mental health issues, unemployment (+)	Bijlmer-Oost and Bijlmer-Centrum
2	Provision of unpaid care, families with young children, retired (18-64 years) and underoccupancy of the home (+) & full-time studying and living in shared properties (-)	Driemond, Nellestein, and Gein (+) & Bijlmer-Centrum and Amstel III/Bullewijk (-)
3	Housing tenants (social housing and private middle rental sector) and energy consumption relative to the income (+)	Amstel III/Bullewijk and Nellestein
4	Energy inefficient building: poor energy label, old heating systems, and no solar panels (+)	Bijlmer-Centrum, Holendrecht/Reigersbos and Driemond
5	Single-parent households, females and older olds (+)	Bijlmer-Centrum, Bijlmer-Oost, and Holendrecht/Reigersbos
6	Lack of income (+) & Low rates of participation and low satisfaction with the City's communication (-)	Bijlmer-Centrum, Holendrecht/ Reigersbos and Nellestein (+) & all neighbourhoods of Zuidoost (-)
7	Precarious families (+)	Bijlmer-Centrum and Holendrecht/ Reigersbos

Note. The table represents the characteristics of each vulnerable group that enhance their vulnerability to energy poverty. The spatial prevalence provides insights into where these vulnerable groups are spatially located and have a higher vulnerability compared to other neighbourhoods of Zuidoost.

The results of the socio-spatial analysis also highlight the multidimensionality of energy poverty and its spatial component, as the vulnerability to energy poverty for each vulnerable group is related to a wide range of vulnerability indicators. For example, the multidimensionality of the first group is highlighted by the fact that individuals with a non-Western background tend to have large-sized families, are often less proficient in Dutch, have a low educational background, and for instance, also deal with mental health issues. These factors combined can enhance the vulnerability of such a household to energy poverty. The results of the socio-spatial analysis also show that nearly 75% of the identified vulnerability indicators are loading high on the first three groups, which indicates that these groups deal with a wide range of factors that further enhance the vulnerability to energy poverty compared to, for instance, group 7 whose vulnerability is related to being precarious and requiring support to live on their own.

The results of the socio-spatial analysis also provided insights into the spatial prevalence of the vulnerable groups. From the results, it can be concluded that six out of the seven (with the third group as an exception) identified vulnerable groups are spatially prevalent in Bijlmer-Centrum, followed by Holendrecht/ Reigersbos. Thus, it can be inferred that in these neighbourhoods, a large share of the residents has an increased vulnerability to energy poverty. Moreover, it can be argued that the vulnerability to energy poverty is distinctive for

each vulnerable group as a different set of vulnerability indicators enhances their vulnerability to energy poverty, represented by the characteristics of these groups.

6. Identification of Policy Strategies to Include Justice in Renovation Policies

In this chapter, the policy strategies identified by stakeholders for including justice in renovation policies are represented. Section 6.1 presents the policy strategies that were identified during the expert session. Section 6.2 compares the identified policy strategies during the expert session and semi-structured interviews to highlight the impact of the CS-MM approach on the identification of policy strategies.

6.1 Identified policy strategies during the expert session

As explained in Chapter 2, an expert session was organised to identify policy strategies which the City of Amsterdam can implement to include justice in renovation policies. The expert session was divided into two parts: (1) the identification of tailored strategies for each vulnerable group based on the results of the socio-spatial analysis and (2) discussing the multi-stakeholder environment and the roles of housing associations and Stichting !WOON and Stichting Co-Force based on the results of the system analysis. A comprehensive explanation of how the expert session was organised and how the results of the system – and socio-spatial analysis were shared to create a shared vision can be found in Appendix G.

6.1.1 Identified Policy Strategies for the Vulnerable Groups

During the first part of the expert session, various policy strategies were identified by exploring which policies the City of Amsterdam can implement to include justice based on the characteristics and needs of the vulnerable groups.

After identifying and writing down the various policy strategies, a plenary discussion was held to discuss the main findings. During this discussion, it became clear that groups 1,6 and 7 can be classified as the ‘lacking the capacity to act groups,’ reflecting their inability or difficulties with tackling energy poverty. Although specific measures have been identified for these groups, it is believed that the same policy measures can be deployed to tackle the vulnerabilities of all three groups. Groups 2 and 5 are characterised as groups in which the households have caretaking roles, whether for children or a sick family member. Thus, during the plenary discussions, these two groups were classified as the ‘burdens groups.’ Groups 3 and 4 can be classified as groups whose vulnerability relates to the residential building and thus can be classified as the ‘building-related groups.’ To enhance the understanding of the identified classifications and policy strategies, Table 6.1 summarises the identified vulnerable groups and their characteristics.

Table 6.1 Overview of the Identified Vulnerable Groups and their Characteristics

Group	Characteristics
1	Migration background, large-sized families, low educational background, low proficiency in Dutch, disability, mental health issues, unemployment (+)
2	Provision of unpaid care, families with young children, retired (18-64 years) and underoccupancy of the home (+) & full-time studying and living in shared properties (-)
3	Housing tenants (social housing and private middle rental sector) and energy consumption relative to the income (+)
4	Energy inefficient building: poor energy label, old heating systems, and no solar panels (+)
5	Single-parent households, females and older olds (+)
6	Lack of income (+) & Low rates of participation and low satisfaction with the City's communication (-)
7	Precarious families (+)

6.1.2 Policy Strategies for the 'Lacking the Capacity to Act' Group

In this section, the policy strategies are discussed that were identified for the 'lacking the capacity to act' group, which exists out of groups 1, 6 and 7. At first, the policy strategies for each group are discussed, followed by an overview of all identified policy strategies for the 'lacking the capacity to act' group.

Group 1: Migration background, large-sized families, low educational background, low proficiency in Dutch, disability, mental health issues, unemployment (+)

The first group can be described as a group that is unable to renovate and tackle energy poverty due to various factors related to ethnicity, a low educational level, low literacy, health issues, and unemployment which enhance their vulnerability to energy poverty. Within these groups, a large share of the residents is first-generation immigrants and non-Western immigrants who can often not speak or read Dutch due to which they do not understand or do not know how to save energy, for instance, and take small renovation measures themselves which impacts their ability to address energy poverty and participate in renovation. Therefore, it is believed that creating audio-visual support and having adjusted communication (letters written in different languages and non-technical terminology) to communicate and share information with these groups will enhance their understanding of tackling their vulnerability. Moreover, it is believed that by educating their children on how they can, for instance, save energy and what the benefits of renovation are, these children can act as ambassadors and inform their parents on what measures they can take.

As these groups also tend to have a general low trust in institutions, it is believed that by engaging with representatives of the local communities and organising more activities through the capillaries of their 'own' network, an increased number of local residents can be reached and informed about the various possibilities to address their vulnerability. Additionally, this will also enhance the 'social infection' as it is believed that if, for instance, one of the community members renovates and shares their experience with other community members, the mouth-to-mouth advertisement will encourage others as well to have an interest and eventually may lead to them deciding to take measures as well or not object renovation plans of housing associations for instance. Facilitating resident support groups that exchange information and tips on saving energy and renovation is also considered an effective measure to overcome the language and general low trust in institution barrier.

Besides, it is believed that by creating so-called 'koppelkansen' social and technical aspects can be connected by which various technical projects that focus on, for instance, energy saving

and renovation are combined with social elements to ensure the technologies are effective for vulnerable groups as well and that these groups can benefit as well from various policy measures. By involving the social domain of the City, it is believed that social and renovation measures can be connected to help vulnerable groups. It is thought that increasing social engagement in the plans of the City will be effective in creating trust and a bond between the local residents and the City.

To tackle unemployment and low educational levels, it is believed that by creating job and education opportunities related to renovation, the vulnerability of this group can be tackled, and jobs are created for the future as the renovation rates will increase in the future with the EU's Renovation Wave.

Group 6: Lack of income (+) & Low rates of participation and low communication satisfaction score for the City (-)

As group 6 involves groups, who do not have an income, have low participation rates, and a low communication satisfaction score, it is believed that having customised communication in the form of personal visits and the usage of visuals will have a positive impact on these groups as the sending letters will not be effective and thereby probability that they will participate in an information session is low. Moreover, it is believed that programs that enhance engagement among various communities and institutions should be promoted to increase their probability of participating and thereby increase their opportunities to tackle their vulnerability. By defining a role in the neighbourhood platforms that focuses on addressing energy poverty, it is believed that these vulnerable groups can be helped. Providing financial help to renovate is considered effective as these groups often rely on no income, thereby limiting their financial means.

Moreover, in practice, these groups are often unaware of the various welfare support measures they can apply for. It is believed that by increasing the awareness, the households will have the financial means to take small measures or, for instance, pay an increased rent after renovation. In practice, the experts have also encountered situations in which groups were unaware of the small measures they could take themselves to, for instance, tackle mould in their house by simply opening windows and ventilating their home. Creating awareness and informing residents on their energy consumption and daily practices is also considered a quick and effective measure to reduce their vulnerability.

Group 7: Precarious families (+)

The seventh group is characterised as individuals who cannot take any measures to renovate themselves; therefore, prioritising them with the FIXbrigade help is seen as an important measure as they are the ones who cannot do it themselves due to health issues. Moreover, it is also believed by renovating their houses when they are made 'WMO ready' will reduce their vulnerability. Deploying the care providers as local ambassadors of renovation and tackling energy poverty is considered effective as they are the ones who are in daily contact with the individual and can help them. Prioritising them in newly built residential buildings is also considered effective, as these buildings already need to comply with the new building regulations due to which they have a high energy label and thereby their vulnerability to energy poverty is decreased.

Table *6.2* provides an overview of the identified policy strategies for each group.

Table 6.2 Overview of the Identified Policy Strategies for the 'Lacking the Capacity to Act' Groups

Group 1	Group 6	Group 7
Organize more activities through the capillaries of their own network	Customed communication (visits/visuals)	Prioritize them in newly built residential houses
Use audio-visual support to communicate with immigrants who are not proficient in Dutch	Promote programmes that enhance engagement	Advance to fixed and variable income
Involve the social domain	Define a role in the neighbourhood platform	Prioritize them on the FIXbrigade help
Create jobs for the future	Same measures as group 1	Renovate while making the residential area 'WMO' ready
Use children as ambassadors	Provide direct financial help	Same measures as group 1
Facilitate resident support groups who exchange information and tips on energy savings and renovation	Increase awareness of welfare support	Deploy care providers as ambassadors
Adjusted communication	Increase awareness on how to use the residential area	
'Social infection'	Provide help with FIXbrigade	
'Koppelkansen': connect social and technical aspects		
Create job and education opportunities related to renovation		
Engage representatives of the local community		
Increase social engagement in the plans of the City		
Renovate when moving to another residential building		

6.1.3 Policy Strategies for the 'Burdens' Group

In this section, the policy strategies are discussed that were identified for the 'burdens' group, which exists out of groups 2 and 5. At first, the policy strategies for each group are discussed, followed by an overview of all identified policy strategies for the 'burdens' group.

Group 2: Provision of unpaid care, families with young children, retired (18-64 years) and underoccupancy of the home (+) & full-time studying and living in shared properties (-)

On the one hand, the second group is characterised by full-time students who often have limited financial means and often live in shared properties, due to which they do not have full control of their energy consumption. It is believed that their vulnerability could decrease by training students at the forefront and promoting informal lectures for students on energy efficiency and renovation measures. Creating a virtual reality environment that shows how a renovated building looks or what kind of small measures individuals can take by themselves is considered an effective measure as it will enhance their understanding of what measures they can take, how it looks in practice and how much energy they can save.

On the other hand, the second group also represents enhanced vulnerabilities for informal caretakers and families with young children. Unburdening these groups by doing it for them is seen as an important measure as they already have to deal with precarity, which already consumes a large share of their energy and time; this can be combined with a 'niet-kunners regeling,' a regulation for individuals who cannot do it by themselves and therefore the measures are for instance taken for them. Promoting FIXbrigade is also considered effective as the measures will then be taken by the FIXbrigade while the individuals themselves will not need to do anything. Moreover, in practice, these groups are often unaware of the various welfare support measures they can apply. It is believed that by increasing the awareness, the households will have the financial means to take small measures or, for instance, pay an increased rent after renovation.

Group 5: Single-parent households, females and older olds (+)

As group 5 includes older olds, who are living alone and often do not have the health to take small measures themselves or be actively involved in the community and thereby gain information on renovation, it is believed that by unburdening these groups, their vulnerability can be tackled. The same holds for women and single-parent households who also have many burdens which they need to deal with, e.g., caring for their child; it is believed that by unburdening them and taking measures for them, they can benefit from renovation measures as well and reduce their vulnerability. The involvement of FIXbrigade is considered important to unburden them. As a share of this vulnerable group is living in large properties, e.g., elderly who are living alone, it is believed that if they move to smaller residential buildings (< square meters) and combine this with renovation, they can tackle their vulnerability as they will have to heat a smaller place which will save energy and the renovated building will also improve their living-conditions.

Moreover, involving the social domain in renovation policies is also considered important to combine renovation policies with tackling energy poverty and improving the living conditions of vulnerable groups. In various neighbourhoods across Amsterdam, women have created informal 'self-help' groups in which there is, for instance, free food provided and informal day-care is organised so that these single moms can accept a job without having to worry about who is going to take care of their children or having to pay money to the daycare. It is believed that creating such self-help groups for tackling energy poverty and renovation will make it possible to create awareness and promote renovation. By strengthening the social network, the City can reach these self-help groups and join forces to address energy poverty and promote renovation, thereby decreasing their vulnerability.

Table 6.3 provides an overview of the identified policy strategies for each group.

Table 6.3 Overview of the Identified Policy Strategies for the Burdens Groups

Group 2	Group 5
Unburdening	Unburdening
Train students on the forefront	Facilitate 'selfhelp' groups (create awareness and help each other)
Provide help for quick fixes	Involve the social domain
Create a VR environment	Move to smaller (< square metres) and renovate
Promote informal lectures for students on energy efficiency	Strengthen social networks
Have a 'niet-kunners regeling/ not capable to arrangement'	Provide help with FIXbrigade
Organize sessions in which additional welfare allowances are explained by the 'buurtteams'	

6.1.4 Policy Strategies for the 'Building Related' Group

In this section, the policy strategies are discussed that were identified for the 'building-related' group, which exists out of groups 3 and 4. At first, the policy strategies for each group are discussed, followed by an overview of all identified policy strategies for the 'building-related' group.

Group 3: Housing tenants (social housing and private middle rental sector) and high energy consumption relative to the income (+)

The third group is characterised as individuals or households living in social housing or the private middle sector and having a high energy consumption relative to their income. Given that these vulnerable groups depend on their landlord to take renovation measures, one of the measures that the City can take to address energy poverty among these groups is to create a focus on energy savings by, for instance, providing energy-saving tips or organising an energy saving challenge. Compensating on the energy bill is also considered a quick measure to lower the burden for these groups. Moreover, private landlords and housing associations can also stimulate their tenants to reduce their energy consumption by providing tips.

Sustainability can also be enforced on landlords due to which they are forced to take renovation measures and thereby the vulnerability to energy poverty for people living in those buildings can be addressed. As the energy label of a large share of buildings owned by housing associations has an energy label of at least D, housing associations are not prioritising the renovation of these buildings as they are focusing on buildings that have an energy label lower than D. This means that in the upcoming years the vulnerable groups living in such buildings will not have a perspective on tackling energy poverty. To tackle this, the City can enforce landlords to undertake quick energy-saving measures between the planned renovation. Moreover, the City can enforce landlords to provide tenants with energy-saving technologies such as insulation tape or LED bulbs. Moreover, as a part of the vulnerability to energy poverty is related to low incomes, increasing the disposable income by lowering 'living costs such as the energy bill is also considered an important policy strategy. Some experts also believe that implementing a basic income in which everyone has the same income will enhance the financial situation of these households, and thereby, their vulnerability to energy poverty will be addressed.

Group 4: Energy inefficient building (poor energy label, old heating systems and no solar panels) (+)

The fourth group is characterised as individuals and households living in energy inefficient property that often has old heating systems and no solar panels. One of the measures that the City can take is to encourage the collective purchase of renovation materials, reducing the total purchase costs. This measure is especially helpful for housing associations or homeowners with the financial means to invest in renovation. For individuals living in a house owned by a housing association, the City can enforce the prioritisation of renovation for these groups in their agreements with the housing associations (convenant). This prioritisation can also focus on the technical side of renovation by, for instance, replacing old heating systems with heat pumps. Moreover, the City can also define a minimum increase in energy label if a household is moving out of a house and new tenants are moving in. Another strategy includes creating a focus on quick energy-saving measures to tackle their vulnerability before their residential building is renovated.

Table 6.4 provides an overview of the identified policy strategies for each group.

Table 6.4 Overview of the Identified Policy Strategies for the Building-Related Groups

Group 3	Group 4
Have a basic income – political	Prioritize the technical side of renovation in these complexes
Create a focus on energy savings	Focus on quick energy saving measures for renovation
Increase the disposable income by lowering ‘burdens’ such as the energy bills	Prioritize the renovation for these groups by the housing associations (including it in the agreement ‘convenant’)
Enforce sustainability to landlords	Define a minimum energy label step if someone is moving out of the house and a new household is moving in
Enforce landlords to provide tenants with energy saving technologies such as LED-bulbs	Stimulate collective purchase of e.g. solar panels, heat pumps and insulation.
Undertake quick energy saving measures between the planned renovations	Collective purchase to reduce costs
Compensate on energy bill	
Stimulate tenants to lower their energy consumption	
Provide energy saving tips or organize a challenge	

6.1.5 Policy Strategies Identified Based on the System Analysis Results

In the second part of the expert session, the focus was laid on the system analysis results. The system analysis made it apparent that multiple stakeholders are involved in tackling energy poverty by renovation and need to collaborate to include justice in renovation policies. During the session, we discussed which parties should improve their collaboration to recognise vulnerable groups and include them in renovation policies. From this discussion, we concluded that housing associations, the different departments related to social, housing, and sustainability policies within the City, local non-governmental organisations, financial institutions, and institutions such as home care institutions should collaborate. By collaborating with organisations that can go behind the front door of vulnerable groups, it is possible to create an image of the current living conditions and how the increased vulnerability to energy poverty manifests inside a house.

The national government has accepted a nationwide strategy that forces housing associations and private landlords to renovate all residential buildings with an E/F/G energy label before 2030 to prevent a situation in which the housing associations are enforced to lower their rental prices (Rijksoverheid, 2022). From visually inspecting the socio-spatial distribution of energy inefficient properties across Amsterdam, it became apparent that Zuidoost has relatively fewer energy inefficient buildings compared to other parts of Amsterdam, while energy poverty is the highest in Zuidoost. This means that a large share of the vulnerable groups will not be able to benefit from renovated buildings as housing associations will focus on E/F/G energy labels which leave a large percentage of the social housing tenants without a perspective on how they can improve their living conditions and tackle energy poverty. Therefore, during the session, we discussed what measures housing associations could take to address energy poverty among these vulnerable groups even though they live in buildings with a relatively high energy label. One of the measures to address the vulnerability of households living in a fairly well building owned by a housing association is that the City makes agreements with housing associations and includes these agreements in the ‘convenant’ (updated every four years). During the discussion, it became apparent that currently, there is a lot of ‘talking’ among the parties, but no rigid concrete agreements are made. Therefore, the City should ensure that strict agreements are made and incorporated into the convenant.

Moreover, housing associations can take a more active role in providing information to their tenants on energy efficiency and also take an active role in tackling the poor or lacking ventilation within houses instead of focusing entirely on insulating. During the discussion, it also became clear that there is a skewed image of the energy label of some residential buildings owned by housing associations. Some buildings have a higher energy label on paper, but these buildings perform worse in practice. Given that these buildings comply on paper with a relatively well energy label, this means that in the upcoming years, the tenants will not have a perspective on renovation and tackling their vulnerability to energy poverty related to the building performance. Moreover, housing associations do not have information on the state of each house, indicating that they do not know, e.g., if there is mould or a lacking thermostat in the building. Therefore, it was discussed that the City should enforce housing associations to have a zero measurement for the liveability, sustainability, and quality of the ‘state’ of each house owned by them and enforce them to have a minimum level. Another measure includes shifting from energy saving to income. A housing association could also determine the rent considering the household income, whereby the burdens are equally distributed. Some experts perceive this as a just measure.

From the system analysis, it also became apparent that Stichting !WOON and Stichting Co-Force can act as mediators between the City, housing associations, and residents to overcome the issues discussed in Chapter 3. From the discussion, it became clear that both parties play a crucial role in including justice in renovation policies and tackling energy poverty as they are

the ones who can go behind the front door and inform local residents on the various policies and measures. Moreover, these parties can also implement small measures commissioned by the City or housing associations. Community building is also an important pillar for both parties by which they can reach local residents. It could be concluded that both parties can be seen as the central point of contact.

6.2 A Comparison of the Identified Policy Strategies during the Interviews and the Policy Strategies Identified during the Expert Session

In this section, a comparison is made between policy strategies that were identified during the semi-structured interviews by the stakeholders and the policy strategies that were identified during the expert session based on the results of the system – and socio-spatial analysis. By comparing the identified policy strategies it becomes possible to highlight the implications of the system - and socio-spatial analysis on the identification of policy strategies. At first, section 6.2.1 presents and discusses the policy strategies that were identified during the interviews. In section 6.2.2 the results are compared and conclusions are drawn on the implication of the conducted analysis in the identification of policy strategies.

6.2.1 Identified Policy Strategies during Interviews

During the interviews, various policy strategies have been proposed to include justice in renovation policies within the context of Zuidoost. Table 6.5 provides an overview of these strategies.

Table 6.5 Policy Strategies Identified During the Semi-Structured Interviews

Policy strategies	
National level	Determining a nationwide strategy
	Receiving support national government
Metropolitan level	Learning from other cities
City level	Creating connections with local community
	Promoting the insulation train
	Creating mutual benefits for involved stakeholders
	Providing free support for renovation to vulnerable groups
	Prioritizing vulnerable groups
	Taking small and quick interventions for energy savings
	Providing subsidies for renovation
	Stimulating bottom-up initiatives
	Improving the communication between the City and local residents
	Encourage deep renovation
	Monitoring energy poverty

Note. The table provides an overview of the policy strategies identified by quantitively coding the interview outputs.

On the national governmental level, it is believed that the national government should support local municipalities in tackling energy poverty by having a nationwide strategy and providing financial aid to tackle energy poverty and encourage renovation. Moreover, a nationwide definition of energy poverty and measure should be deployed to ensure that energy poverty is recognised and measured with the same indicators to gain insights into how large the energy poverty issue is across the country and monitor how energy poverty evolves to encourage justice. This prevents situations where various municipalities across The Netherlands use different definitions and measures, influencing which vulnerable groups are identified and included in energy poverty and renovation policies.

Various cities across The Netherlands are facing the issue of, on the one hand, speeding up the energy transition to realise the Klimaatakkoord's goals and, on the other hand, face the problem of increased exposure to energy poverty by vulnerable groups who often also tend to resist renovation policies; it is believed that by collaborating closely with other municipalities the City of Amsterdam can learn by practice and use the insights obtained in other cities to create policies for including justice in renovation policies and tackling energy poverty.
On the local city level, the City of Amsterdam can provide subsidies for renovation to enhance the probability that households with lower incomes can also take measures to renovate their house and thereby save energy, tackle energy poverty, and include justice in renovation measures. However, in practice, relatively well-off households are using these measures. In contrast, lower-income households rarely use the subsidies, which subsequently increases the risk of social inequity and gentrification. Moreover, the issue with subsidies is also that you need to have money to make use of subsidies as the subsidies, for instance, only cover the purchase costs but cannot be used, for example, to hire a service provider who implements the renovation measures and thereby these strategies are often not suitable for the vulnerable groups as they usually do not have the financial means to invest in renovation.

Prioritising renovation for vulnerable groups is considered an effective measure for including justice in renovation measures as households who are highly vulnerable to energy poverty will be able to benefit from a renovated building and thereby reduce their vulnerability to energy poverty and improve their well-being. To succeed or encourage renovation among vulnerable groups, free renovation support should be provided to them as these groups often do not even have the means to pay the bills for their basic utilities. However, given the high renovation costs, this strategy is not considered viable, as it remains unclear who should pay the costs and if they have the financial means to cover them.

From the system analysis and interviews, it also became apparent that a large share of the vulnerable groups is not interested in renovation, do not have the knowledge to renovate themselves, understand the technologies that are often used in renovation, or do not have the money to take small interventions which can help to save energy. To tackle the last mentioned, the City is providing small packages that include insulation strips, new shower heads, and energy-efficient bulbs to reduce the energy consumption of vulnerable groups and help them save money on their energy bill. However, in practice, these materials are often not used by the most vulnerable groups, which influences the effectiveness of the policy interventions.

The insulation train is another measure with which the City hopes to stimulate the renovation of buildings and tackle energy poverty. The idea of the insulation train is to purchase insulation/renovation materials on a large scale by which the total costs of renovation can be reduced due to economies of scale. Housing associations, private landlords, and homeowners can make use of this measure, and thereby, the City aims to make renovation possible for various social groups; however, given that the most vulnerable groups often do not even have the financial means to cover their basic necessities costs, the effectiveness of this measure in terms of including justice in renovation policies remains questionable as it might be the case that households who are better-off will be making use of this measure, something which has happened in the past with similar measures. Moreover, the willingness of private landlords to invest in renovation in an already rented property is questionable as they will have to spend a large amount of money while they are already receiving rent without investing in renovation.

Given that the letters by the City are sent at the addresses of the property, and the City assumes that the tenants hand over the renovation letter to the landlord, it is questionable whether the landlords receive the letters. All experts consider improving communication between residents and institutions one of the most important measures. Currently, there is a gap between local residents and institutions due to the lack of trust, which makes it difficult for policymakers to reach, engage and involve local residents in the energy transition. During the interviews and various informal sessions that the researcher attended during the present study,

it became apparent that policymakers must try to bond with the local residents to create trust and interest in renovation. This bonding may be in the form of being visible in the neighbourhood, attending events that locals are attending, and talking to those people by not starting with topics related to energy, renovation, or energy poverty but by asking how they are doing and showing real interest in them and speaking 'their' language which will eventually create initial trust and connections between the individuals. This will also help to stimulate bottom-up initiatives as the connection between institutions and residents will help to recognise, engage and empower them to take initiatives and collaborate to achieve common goals such as tackling energy poverty. For this, it is also important to create mutual benefits as by helping each other, the City can achieve its ambitions. At the same time, the local residents can tackle their vulnerability to energy poverty and improve their well-being.

6.2.2 Comparing the Policy Strategies Identified during the Expert Session and Interviews

By comparing the policy strategies that were identified during the interviews and the policy strategies that were identified during the expert session, it can be noticed that the policies identified during the interviews could be categorised as generic policy strategies which are not tailored to the needs of the vulnerable groups but rather policy strategies that are identified in an attempt to address energy poverty by renovating buildings while not considering the effectiveness of the policies and the needs of the vulnerable groups into account. Thus, it is questionable whether these policies will target vulnerable groups. For instance, the thoughts are that by providing free insulation materials to vulnerable groups, they will use the material and thereby, their vulnerability can be addressed; however, in reality, the vulnerable groups often do not even open the door to receive the package, and if they open the door, they often do not use the materials due to a lack of interest or lack of knowledge on how to use and install the materials. During the interviews, it was also observed that there is no clear image of which groups are vulnerable to energy poverty among the employees of the City and researchers as the City of Amsterdam uses the 10% indicator to measure energy poverty, which assumes that energy poverty is only related to the income and energy bill of a household and thereby neglecting the multidimensionality of energy poverty and loss of well-being. This also influences the identified policy strategies as the strategies are either based on the results of the 10% indicator, which shows that energy poverty is prevalent among single-parent households and one-income households, or on some stories they have heard from vulnerable groups living in Zuidoost. Eventually, this results in the identification of policy strategies that are not tailored to the needs of the vulnerable groups. The expectations are that the identified policy strategies will not be highly effective given the issues related to, for instance, the financial capacity of households, willingness to invest, interest in renovation, and lack of trust and knowledge.

Moving on to the policy strategies that were identified during the expert session, it can be concluded that the policy strategies are identified based on the understanding of the multidimensionality of energy poverty, acknowledgement of the need for just renovation policies, characteristics of vulnerable groups, and the importance of housing associations and associations such as Stichting !WOON and Stichting Co-Force in including justice in renovation policies. By specifically identifying policy strategies for each vulnerable group based on their characteristics and needs, it becomes possible to identify tailored policy strategies which also enhance the probability of successfully addressing their vulnerability to energy poverty. For instance, by acknowledging that households with a migration background, large households size, low educational background, and low proficiency in Dutch have an increased vulnerability to energy poverty as they are not capable of taking renovation measures themselves, it becomes possible to identify policy strategies that address their incapability and thereby tailor the policy strategies based on their needs and thus increase the probability of identifying effective policy strategies. Introducing the FIXbrigade is an example where the vulnerability of the 'not capable to' group is eliminated by doing it for them. By visualising the spatial prevalence of the vulnerable groups, it also becomes possible for the stakeholders to

acknowledge how the vulnerability to energy poverty varies over space and provide insights into which neighbourhoods vulnerable groups are prevalent and thus informing them where to find them and thereby recognise and include them in the decision-making and distribution of renovation resources to include justice in renovation policies eventually.

Moreover, it is noticed that by discussing the results of the system analysis and thereby informing the stakeholders how housing associations do not have a high urgency to renovate residential buildings in Zuidoost as the share of energy inefficient buildings is relatively low in Zuidoost compared to other parts of Amsterdam and according to the national government regulations they first need to address the energy inefficient buildings before 2030 to prevent them from receiving lower rents, it becomes possible to identify different responsibilities and roles that housing associations could take to address energy poverty among its residents which results in realistic policy strategies whereby the policy strategies are implementable instead of being unrealistic in the sense of believing that housing associations are willing to invest in renovation if the purchase costs are low or they receive a small subsidy for each house that they renovate. Identifying policy strategies based on the system – and socio-spatial analysis results also allows acknowledging the multi-stakeholder environment of tackling energy poverty and including justice in renovation policies. By organising the expert session, different stakeholders are brought together, and their expertise can be synergised into tailored policy strategies for each vulnerable group while also acknowledging the importance of Stichting !WOON and Stichting Co-Force, who can act as mediators between housing and resident associations and the City of Amsterdam to create an interest in the renovation of residential buildings.

All in all, it can be concluded that organising the informed expert session makes it possible to identify policy strategies tailored to the vulnerable groups' needs and characteristics while also acknowledging the multi-stakeholder environment and the role of housing associations and Stichting !WOON and Stichting Co-Force. Based on this, the probability of effectively including justice in renovation policies can be increased as various vulnerable groups are identified, acknowledged, and policy strategies are identified to include them in the decision-making and distribution of renovation resources. The tailored policies also allow to specifically target the vulnerable groups and thereby include justice in renovation policies as they are recognised. By implementing the identified policy strategies, distributive justice can be included as the renovation resources will be distributed among them, due to which they can benefit from the available resources. Moreover, it could be argued that as the vulnerable groups are recognised, procedural justice can be included in renovation policies as vulnerable groups are encouraged to participate in the Renovation Wave and the decision-making.

7. Conclusion and Discussion

In this chapter, the outcomes of the present study are concluded and discussed. Section 7.1 answers the sub-questions to answer the main research question eventually. Section 7.2 discusses the limitations of the present study. In Section 7.3, the academic discussion is presented, section 7.4, the relevance of the present study is discussed for the EPA program. Finally, in section 7.5, recommendations are made for future researchers and policymakers.

7.1 Conclusion

The goal of the present study was to explore how justice can be included in renovation policies considering the socio-spatial vulnerability to energy poverty. Specifically, the goal of the present study was to answer the main research question: 'Using a Case-Study Mixed Methods (CS-MM) approach, how can justice be included in renovation policies considering the socio-spatial vulnerability to energy poverty?' The question is answered by combining quantitative and qualitative methods to define the socio-spatial vulnerability to energy poverty, identify vulnerable groups, and identify policy strategies tailored to the needs and characteristics of the vulnerable groups. Four sub-questions were formulated to guide the research process and answer the main research question. In the following sections, the sub-questions are answered to answer the main research question.

What is the current system of tackling energy poverty by renovating residential buildings in Zuidoost? What are current policies, which issues can be identified, and which stakeholders are involved in the decision-making?

From the system analysis, it can be concluded that energy poverty is a huge issue in Zuidoost; however, current policies are failing to address energy poverty as current renovation policies do not consider vulnerable groups and are primarily focused on achieving short-term results instead of considering who is benefitting from the various policies. The effectiveness of various renovation measures is low in Zuidoost as typically, there are multiple issues related to the socio-economic status (e.g., lack of trust and language barrier), technical issues (mismatch between renovation technologies and the energy practices of residents living in underprivileged neighbourhoods), willingness to invest, and institutional issues that cause low renovation rates in Zuidoost. Given the low effectiveness of renovation measures in Zuidoost, it could be concluded that there is a mismatch between the residents and the actors who are planning and implementing the various proposed policies. Moreover, as the City uses the 10% indicator to measure energy poverty and thereby fails to identify all vulnerable groups while also neglecting the loss of well-being, it could be argued that the City fails to recognise vulnerable groups to energy poverty and thereby leaves them out of policy measures which reinforces unjust practices. Given these unjust practices and the ambition of the Department of City Development to address energy poverty by renovating buildings, justice must be included in renovation measures. Hereby, justice is defined as distributive (distribution of benefits and burdens), procedural (who has access to the decision-making in underprivileged neighbourhoods), and recognitional justice (identifying vulnerable groups and ensuring that they are recognised and respected by the involved stakeholders).

To include justice in renovation policies and tackle energy poverty, the collaboration between various stakeholders is required ranging from different departments within the City to resident associations, research institutions, energy and service companies, housing associations, and non-governmental institutions such as Stichting !WOON and Stichting Co-Force. From the stakeholder analysis, it becomes apparent that the Department of City Development must collaborate and act jointly with the Department of Housing and Department of Planning and Sustainability to ensure that various measures do not conflict with the objectives of the multiple

departments and prevent the implementation of measures that reinforce already existing inequalities. Moreover, as housing and resident associations tend to reject renovation measures, Stichting !WOON and Stichting Co-Force can act as mediators between the City and the local housing associations and residents to create a shared vision. From a business perspective, financial institutions are considered important stakeholders as they are the ones who can provide financial aid to individuals or associations who are opting to renovate their houses. Close collaboration with energy and service providers could make it more attractive for residents to renovate as the planning and execution will be given out of hand to, for instance, Klimaatmissie Nederland, while Vattenfall as an energy company could stimulate renovation among its clients.

How to define the socio-spatial vulnerability to energy poverty in the context of Amsterdam?

The socio-spatial vulnerability to energy poverty was defined by, on the one hand, extending the current vulnerability framework developed by Robinson et al. (2019) and, on the other hand, defining an index of the socio-spatial vulnerability to energy poverty. Through the literature review and system analysis, it became apparent that current vulnerability frameworks lacked the integration of renovation and institutional indicators with socio-economic and energy indicators that enhance the socio-spatial vulnerability to energy poverty and a loss of well-being. Given that the energy demand and loss of well-being of individuals are related to building performance, the current vulnerability framework developed by Robinson et al. (2019) was extended with vulnerability factors related to building performance. These factors include ventilation and transmission heat loss, poor indoor quality, property valuation, building year, wind direction and speed, mould, humidity levels, noise levels, housing density, indoor temperatures in summer, and heating requirements during winter.

As the system analysis showed that the low renovation rates among vulnerable groups are partially related to participation and willingness, institutional indicators have been included in the vulnerability framework. These institutional factors include, on the one hand, factors related to participation, such as the lack of bottom-up initiatives, lack of social cohesion between the local community and institutions, and inefficient communication that impact the extent to which an individual is willing to participate in the Renovation Wave. On the other hand, the institutional factors relate to the willingness to invest or pay more rent to live in a renovated building and the general interest in the energy transition, which also enhances the socio-spatial vulnerability to energy poverty. Specifically, this means that these households would prefer not to invest in the renovation as they might not have the financial capacity to invest or are not interested in the energy transition and thereby do not consider renovating their house to improve the energy efficiency of the building and the living conditions.

The evidence of the multiple factors that make a household more vulnerable to energy poverty directed us to use a multidimensional suite of indicators. An index of socio-spatial vulnerability to energy poverty was developed by aggregating multiple indicators to investigate the relative importance of indicators and the spatial distribution of vulnerability. In the context of Amsterdam, 29 vulnerability indicators were identified based on desk research, interviews, and the available data on the neighbourhood level.

Based on the defined socio-spatial vulnerability to energy poverty, which groups are identified as vulnerable to energy poverty in Amsterdam, and where are these groups spatially located?

The socio-spatial analysis revealed seven groups who are vulnerable to energy poverty within the context of Amsterdam:

- Group 1 reflects individuals with a migration background, large household size, low literacy, and education level. Mental health issues and disability also enhance the vulnerability of this group.
- Group 2 reflects families who must take care of a family member and full-time students/individuals who are living in shared properties due to which they have limited power to take measures.
- Group 3 reflects households living in the social housing renting and middle rental sector who have limited power to take energy efficiency measures and depend on their landlord.
- Group 4 reflects households whose vulnerability to energy poverty is related to worse-performing buildings that have a low energy label, old heating systems, and do not have solar panels.
- Group 5 is characterised by the elderly living alone, females, and single-parent households.
- Group 6 reflects households who do not have an income and individuals who are not active in the neighbourhood and are generally not satisfied with the communication of the City.
- Group 7 represents precarious families who require governmental support to live independently given their health issues.

The results of the socio-spatial analysis also provided insights into the spatial prevalence of the vulnerable groups. From the results, it can be concluded that six out of the seven (with the third group as an exception) identified vulnerable groups are spatially prevalent in Bijlmer-Centrum, followed by Holendrecht/ Reigersbos. The third group is spatially prevalent in Amstel III/Bullewijk and Driemond. Thus, it can be inferred that in these neighbourhoods, a large share of the residents has an increased vulnerability to energy poverty. Moreover, it can be argued that the vulnerability to energy poverty is distinctive for each vulnerable group as a different set of vulnerability indicators enhances their vulnerability to energy poverty, represented by the characteristics of these groups.

Based on the system - and socio-spatial analysis results, which policy strategies do stakeholders identify in an expert session for including justice in renovation policies?

The results of the expert session revealed that various policy strategies could be identified for each vulnerable group that are tailored to the needs and characteristics of the vulnerable groups. Moreover, from the expert session, it can be concluded that the seven identified vulnerable groups could be clustered into three main groups: the ‘lacking the capacity to act, ‘burdens,’ and ‘building related’ groups. Specifically, this means that the policy strategies identified for each subgroup can also be implemented for the other subgroups. The identified policy strategies are:

- For the ‘lacking the capacity to act’ group, which exist out of subgroup 1,6 and 7, the main identified policy strategies include: improving the communication and connection with the local community, deploying FIXbrigade to provide help with small renovation measures (e.g., insulation and replacing bulbs) and the deep renovation of buildings whenever a household is moving out, or the house is adjusted to make it ‘WMO’ ready.

- For the ‘burdens’ group consisting of subgroups 2 and 5, the main policy strategies include: unburdening these groups by taking measures for them, improving the connection with the local community to inform about renovation and various welfare support allowances and enhancing bottom-up initiatives in the form of self-help groups.

- For the ‘building related’ group, which consists of groups 3 and 4, the main identified policy strategies include: improving the connection with the local community to inform

them on energy efficiency measures, enforcing landlords to invest in renovation measures, having a collective purchase deal to reduce renovation costs for landlords and homeowners.

Moreover, based on the results of the system analysis and the expert session, it can be concluded that housing associations, the different departments related to the social, housing, and sustainability domain within the City, non-governmental, financial, and informal institutions, such as home care providers (who can go through the front door and have an understanding on the lived experience of vulnerability to energy poverty), should collaborate and act jointly to tackle energy poverty and include justice in renovation policies. Stichting !WOON and Stichting Co-Force should play a crucial role, as they are the ones who can go behind the front door and inform local residents on the various policies and measures. Moreover, these parties can also implement small measures on behalf of the City or housing associations. As community building is an important pillar for both parties to reach local residents, it can be argued that both parties could serve as the central point of contact between residents and institutions.

To ensure that vulnerable groups living in a relatively well energy label (>E label) that is owned by a housing association are included in renovation policies, it can be concluded that one of the strategies that the City can implement includes making rigid agreements with housing associations and include these agreements in the 'convenant' (which is updated every four years). Besides, housing associations can take an active role in providing information to their tenants on energy efficiency and take an active role in tackling the poor or lacking ventilation within houses instead of focusing entirely on insulating. Given that housing associations often do not monitor the living conditions of their house, the City should enforce housing associations to have a zero measurement for the liveability, sustainability, and quality of the 'state' of each house and enforce a minimum level for each house.

By synthesising the answers to the sub-questions, it becomes possible to answer the main research question of the present study, which is:

Using a Case-Study Mixed Methods (CS-MM) approach, how can justice be included in renovation policies considering the socio-spatial vulnerability to energy poverty?

The results of the present study showed how a CS-MM approach could be deployed to explore how justice can be included in renovation policies. Justice was in the present study compromised of recognitional (identifying and acknowledging vulnerable groups), distributional (benefits and burdens of renovation resources), and procedural (including the vulnerable groups in the decision-making) justice.

By identifying vulnerable groups based on a locally developed index of the socio-spatial vulnerability to energy poverty and acknowledging their vulnerability, recognitional justice can be included in renovation policies. Besides, identifying tailored policy strategies that, on the one hand, focus on the distribution of renovation resources based on the needs and characteristics of the identified vulnerable groups and, on the other hand, on how the vulnerable groups can be included in the decision-making, distributional and procedural justice can be included in renovation policies.

To prevent a mismatch between residents and actors who are planning and implementing renovation policies, it is important that the policy strategies are identified during an expert session in which involved stakeholders jointly identify policy strategies and discuss the different roles the involved stakeholders could take to include justice in renovation resources considering the socio-spatial vulnerability to energy poverty. The comparison of policy strategies that were identified without considering the socio-spatial vulnerability to energy

poverty and the policy strategies that were identified considering the socio-spatial vulnerability showed how the consideration of socio-spatial vulnerability led to tailored policy strategies, whereas the other policy strategies tried to target the vulnerable groups, while there was no clear image on who the vulnerable groups are, what their needs and characteristics are, and where they are spatially located which led to the identification of policy strategies that are not tailored to the characteristics and needs of vulnerable groups and thereby the effectiveness of the identified policy strategies was questionable as well. Moreover, the multi-stakeholder environment of the expert session also aided in defining different roles for the involved stakeholders and the acknowledgement that a close collaboration is required between involved stakeholders to target vulnerable groups and include justice in renovation policies.

Thus, it can be concluded that including justice in renovation policies requires the identification of vulnerable groups based on a locally defined index of socio-spatial vulnerability to energy poverty, acknowledgement of the socio-spatial vulnerability to energy poverty, identification of tailored policies in a multi-stakeholder environment, and close collaboration between different stakeholders.

7.2 Limitations

In the present study, a CS-MM approach was taken to explore how justice can be included in renovation policies considering the socio-spatial vulnerability to energy poverty. As with every academic research, the present study also has some limitations that must be highlighted. In this section, the limitations of the present study are discussed.

7.2.1 Limitations of the System Analysis

The system analysis entailed desk research, interviews, and stakeholder analysis. Although all research steps were conducted carefully, each step also has limitations. As the present study is limited by time, a careful selection was made of the consulted literature as it was impossible to read all available literature on renovation and energy poverty. It could be that relevant literature has been missed out. Moreover, the stakeholder analysis was primarily conducted based on desk research, and although three experts validated the results, the trustworthiness of the sources of information would have been improved if the researcher had spoken to each stakeholder to investigate their objectives, interest, and power is. The stakeholder analysis also provides a snapshot as the objectives and interests of stakeholders are continuously developing; however, given that there is no concrete agenda and no research project has started currently, it is believed that the snapshot provides a generic image of the current perceptions.

Due to time constraints, only four interviews were conducted in total with experts; it is believed that the representativeness of the present results might be influenced if more interviews were conducted with, for instance, local citizens, landlords, and housing associations to gain insights into their perspectives directly from them. Additionally, the deployment of interviews and quantitative coding as data collection tools also comes with limitations as the results depend on the researcher's interpretation, and the interview questions may influence the interviewees' responses, which may result in bias. Alshenqeeti (2014) also highlights how time and current circumstances vary, which may change the results. It is also important to acknowledge that the interviewees' perceptions are subjective.

7.2.2 Limitations of the Socio-Spatial Analysis

An index of social-spatial vulnerability to energy poverty was developed within the context of Amsterdam to gain insights into which groups are vulnerable and what their geographical location is. This index heavily depended on the available data at the neighbourhood level. Due to this, not all known vulnerabilities from practice and literature, such as house owners reliant on welfare support and part-time employment, could not be included in the analysis. Moreover, not all the data is gathered yearly, due to which the extracted data has been collected from

multiple years while taking the recency into account, as shown in Table *F.1*. The data also contained missing values for various neighbourhoods which were, depending on their distribution, imputed with average or median values. Data on participation and communication satisfaction was only available on a 'gebied' (cluster of neighbourhoods) level, due to which it was assumed that the values within a cluster of neighbourhoods are similar. Given the GDPR regulations, it was unfortunately not possible to receive data on the household level; it is believed that having data on the household level would have allowed us to explore interaction effects and gain an in-depth understanding of the socio-spatial vulnerability to energy poverty. For instance, the results of the socio-spatial analysis showed that component 5 reflects vulnerabilities associated with single-parent families and females.

Given that the data was available on an aggregated neighbourhood level, it was impossible to inspect to what extent there was a connection between being a single-parent family and being a woman. Moreover, the usage of proxy datasets also influences the results as having real data on, for instance, the indoor quality of a building instead of using the energy label as a proxy could highlight vulnerabilities related to the building that goes beyond the energy label determined on paper. A limitation of PCA is that it is not guaranteed that correlations necessarily represent the real or statistical influence of the used sub-indicators on the vulnerabilities each component is representing (Saisana & Tarantola, 2002). However, given the objective of the socio-spatial analysis in terms of gaining insights into which groups have an enhanced vulnerability to energy poverty and acknowledging the spatially varying vulnerabilities, it could be argued that this limitation is not relevant to the present study.

7.2.3 Limitations of the Expert Session

Given the timeframe of 90 minutes for the expert session and the need to create a shared vision before identifying policy strategies, there was limited time to identify and discuss policy strategies that the City could implement to include justice in renovation policies for each vulnerable group. It is believed that if there was more time available for an in-depth discussion on the policy strategies for each vulnerable group, a top 3 ranking could have been made for the policy strategies for each group. Moreover, the identified policy strategies also come with limitations as the strategy depends on the expert's interpretation and the results presented during the expert session by the researcher, which may result in bias. The number of participants was limited to ensure an in-depth discussion. However, it is believed that organising a longer session and inviting relevant stakeholders to the session would have resulted in improved policy strategies as multiple visions could have been synergised to tackle energy poverty and include justice in renovation policies.

7.2.4 Limitations of the Energy Justice Framework

In the present study, the energy justice framework has been used to define the concept of justice. A limitation of this framework is that it highlights the Western theoretical focus on energy justice, emphasizes anthropocentric concepts defined by concerns with ethics and morality among and between humans, and the lack of geography in the discussion (Bouzarovski & Simcok, 2017; Sovacool et al., 2017). To mitigate these limitations, the concept of socio-spatial vulnerability to energy poverty has been considered in the present study by defining socio-spatial vulnerability and acknowledging the spatial component of energy poverty. Moreover, by engaging with local stakeholders, setting up truth and reconciliation strategies in the form of expert validation, and moving beyond conventional strategies of using simple demographics and expenditure-based energy poverty indicators, the needs and characteristics of the various vulnerable groups have been identified and validated (Williams & Dovon, 2019). Based on the limitation of the energy justice framework, it is therefore believed that the deployment of a CS-MM approach contributed to addressing these limitations.

7.3 Academic Discussion

The work presented in the present study marks an important step toward using a CS-MM approach to include justice in renovation policies, considering the socio-spatial vulnerability to energy poverty. The inclusion of justice in renovation policies lies on the edge of energy poverty, socio-spatial vulnerability, and energy justice science which is an active field of research. The active academic debate revolves around the question of how justice can be included in renovation policies, defining the socio-spatial vulnerability and multidimensionality of energy poverty, and the identification of vulnerable groups. The present study contributes to this debate by highlighting how justice can be included in renovation policies considering the multidimensionality and socio-spatial vulnerability to energy poverty. In doing so, a novel CS-MM approach was applied to display how concepts of socio-spatial vulnerability, the multidimensionality of energy poverty and justice can be combined to capture the complex field of including justice in renovation policies and identifying vulnerable groups. The results of the present study are a proof of concept for using a CS-MM approach for including justice in renovation policies considering the multidimensionality and socio-spatial vulnerability to energy poverty. The present study contributed to the usage of a CS-MM approach in energy justice studies and encourages the academic community to use a CS-MM approach for exploring how justice can be included in other energy domains as well.

A more specific contribution of the present study is the finding that the socio-spatial vulnerability to energy poverty is, besides relating to socio-economic and energy indicators, also related to renovation and institutional indicators. The results of the system analysis and defining the socio-spatial vulnerability to energy poverty showed how renovation indicators related to the building performance could enhance the vulnerability to energy poverty and a loss of well-being for individuals living or using the building. Moreover, institutional indicators related to participation, willingness to invest or pay more rent to live in a renovated building and general interest in renovation and the energy transition can enhance the socio-spatial vulnerability to energy poverty. Consequently, this led to the extension of the vulnerability framework developed by Robinson et al. (2019) and a newly developed index of socio-spatial vulnerability within the context of Zuidoost. The methodological approach to researching, defining socio-spatial vulnerability to energy poverty and identifying vulnerable groups can also be applied to other geographical contexts as well.

The results of the present study also contribute to and address the academic debate on the comprehensiveness and challenges related to formulating effective policy strategies to address energy poverty in renovation policies. The literature review results revealed how current renovation policies do not target energy-poor households as they often have a technical focus and lack an intersectoral integration of energy, social and renovation policies. Moreover, the results of the system analysis showed how the various issues related to the technical, socio-economic, decision-making and willingness to invest or pay more rent make it difficult to formulate effective renovation policies. The literature review and system analysis also revealed how expenditure-based indicators had been used to identify energy-poor households neglecting the multidimensionality and socio-spatial vulnerability to energy poverty. The present study aimed to address these issues by, on the one hand, acknowledging the multidimensionality and socio-spatial vulnerability of energy poverty and developing a new index of socio-spatial vulnerability by combining socio-economic, energy, renovation and institutional indicators to adequately identify vulnerable groups who are in great need of renovation to address energy poverty and improve their well-being. On the other hand, the results of the study showed how tailored policy strategies could be formulated by identifying vulnerable groups considering the socio-spatial vulnerability and multi-stakeholder environment of renovation. Therefore, the results of the study open up the debate on the need for tailored policies and a multi-stakeholder collaboration to address the challenges related to formulating effective policy strategies to include justice in renovation policies.

7.4 Relevance for the EPA Program

The present study was conducted as part of the Engineering and Policy Analysis (EPA) Master thesis at the Delft University of Technology and focused on themes related to the multidimensionality and socio-spatial vulnerability to energy poverty and justice in renovation policies. Given that current renovation policies have failed to target energy-poor households and identify vulnerable groups, the present study explored how justice can be included in renovation policies by deploying a novel CS-MM approach considering the socio-spatial vulnerability to energy poverty. The research outcomes contribute to the academic debate on how justice can be included in renovation policies, defining the socio-spatial vulnerability and multidimensionality of energy poverty, and the identification of vulnerable groups. Moreover, it introduces the deployment of a CS-MM approach and contributes to the active academic debate on the comprehensiveness and challenges related to identifying effective policy strategies to include justice in renovation policies. From a societal perspective, the research outcomes provide insights into how to identify vulnerable groups and gain insights into the spatial distribution of vulnerable groups and show how tailored policy strategies can be identified that enable local decision-makers to include justice in renovation policies considering the socio-spatial vulnerability to energy poverty. Given the themes covered in the present study, research approach, and academic and societal relevance, it can be argued that the present study fits all the requirements of a thesis project for the EPA program.

7.5 Recommendations

In this section recommendations are made for future research and policymakers.

7.5.1 Recommendations for Future Research

In the current research approach, vulnerable groups are identified based on the socio-spatial analysis of the defined index of socio-spatial vulnerability. Given that the development of the index of socio-spatial vulnerability heavenly depends on the available data, it is recommended to address this limitation by including ethnographic research in the research approach and exploring how the insights obtained from the socio-spatial analysis can be combined with the results of the ethnographic research. It is believed that the understanding of vulnerability to energy poverty can be enhanced as next to the identified vulnerable groups, lived experiences will provide a clear perspective on what being vulnerable to energy poverty means in practice, and it also provides the opportunity to validate the results of the socio-spatial vulnerability.

Due to time constraints in the present study, it was not possible to organise an expert session in which all relevant stakeholders were invited to identify policy strategies for including justice in renovation policies. The expectations are that if all the relevant stakeholders were invited, this would have led to new insights and improved policy strategies as synergies could have been created. Future research could explore how participatory trajectories can be designed and incorporated into the current research approach to ensure that all stakeholders are involved, prevent a mismatch between residents and actors who are planning and implementing policies, and prevent situations in which, for instance, the City assumes that housing associations are keen to make use of the subsidies provided by renovation policies but realise in practice that the housing associations are not interested and have their own agenda, resulting in failing policies.

The present study aimed to explore how vulnerable groups in need of renovation can be identified to include justice in renovation policies. By defining the socio-spatial vulnerability to energy poverty and conducting a socio-spatial analysis, vulnerable groups have been identified with an increased likelihood of experiencing energy poverty and a loss of well-being. However, the results do not allow measuring or monitoring whether a household is energy poor. Therefore, it is recommended to research how socio-spatial vulnerability to energy poverty concepts can be conceptualised and deployed to assess and monitor whether a

household is energy poor. Future research could also involve deploying the vulnerability framework in other Dutch cities to assess its applicability in different contexts.

Moreover, as aggregated data on the neighbourhood level has been used to identify vulnerable groups, it is recommended to explore how the understanding of vulnerable groups can be enhanced based on household-level data. Questions such as: how does the vulnerability of households who own a house differ from households living in social housing within the same neighbourhood can be answered. By exploring the results of this analysis, in-depth knowledge of the characteristics of the vulnerable groups can be created.

7.5.2 Recommendations for Policymakers

The results of the present study could benefit local policymakers who are involved in renovating residential buildings and have to deal with including justice in renovation policies.

The literature review results revealed how expenditure-based indicators have often been used to identify vulnerable groups. Still, they failed to identify all vulnerable groups, and thereby those vulnerable groups are neglected in energy poverty policies. Additionally, the system analysis showed how the City is deploying the 10%-indicator to identify energy-poor households. Based on this indicator, a study conducted by the City showed that single-parent households and one-income households have an increased vulnerability to energy poverty within the context of Amsterdam. Specifically, this means that the City is neglecting the associated loss of well-being related to energy poverty and fails to recognise the multidimensionality and socio-spatial vulnerability to energy poverty as the vulnerability to energy poverty is solely assessed based on the income and energy bill of a household.

Moreover, the socio-spatial analysis revealed seven vulnerable groups within the context of Amsterdam whose vulnerability to energy poverty varied over a wide range of factors and spatially varying and is currently not represented in the study of the City and the resulting energy poverty policies. Based on these results and the need to include justice in renovation policies which starts with identifying vulnerable groups, it is recommended that policymakers deploy the methodological approach applied in the present study to define the socio-spatial vulnerability to energy poverty and identify vulnerable groups. Moreover, using the extended vulnerability framework as an overview of the various pathways via which a household becomes vulnerable to energy poverty and a loss of well-being could aid policymakers in understanding the multidimensionality of energy poverty and provide insights into the so-called hidden energy poverty, which is present in practice but not captured by the 10%-indicator.

The comparison of policy strategies identified based on the expertise of the interviewees during the interviews and policy strategies identified during the expert session revealed the significance of using the CS-MM approach to explore how justice can be included in renovation policies considering the socio-spatial vulnerability. The effectiveness of the policy strategies identified during the interviews was questionable as those were identified without an enhanced understanding of the vulnerable groups. The mismatch between residents and actors planning and implementing renovation policies was highlighted again. This was also confirmed during the interviews as various interviewees questioned the effectiveness of policy strategies identified by other interviewees. In contrast, the policy strategies identified during the expert session were based on the system and socio-spatial analysis results and therefore allowed to identify tailored policy strategies for each vulnerable group based on their needs and characteristics. As the identified policy strategies are tailored, the effectiveness of the policy strategies will be larger than those identified solely by the expertise of the experts. The interactive discussion of the identified policy strategies during the expert session also revealed how, based on the synergised expertise of the stakeholders, three main groups (burdens, lacking the capacity to, and building-related groups) could be identified and within the three main groups the identified policy strategies applied to the other groups. Thus, it is recommended that policymakers deploy the CS-MM approach taken in this research to identify

tailored policy strategies to ensure that distributional and procedural justice can be included in renovation policies.

On the other hand, it will aid policymakers in identifying vulnerable groups and tailoring renovation policies based on the characteristics and needs of the vulnerable groups. This will allow policymakers to add justice to renovation policies. It is recommended to combine social, energy, and renovation policies to ensure that current renovation policies include tackling climate change and energy poverty by including vulnerable groups in the energy transitions and renovation of buildings. This will also decrease the risk of social injustices and gentrification.

The system analysis revealed how including justice in renovation policies operates in a multi-stakeholder environment in which collaborations between stakeholders are required to include justice in renovation policies and prevent the implementation of conflicting policies from having justice in renovation policies. Given the multi-stakeholder environment of tackling energy poverty and the renovation of buildings, it is recommended that policymakers establish a long-term relationship with key stakeholders to ensure that justice can be included in renovation policies. Moreover, as the system analysis revealed how housing and resident associations tend to resist renovation measures and have a low interest in including justice in renovation policies, the role of organisations, such as Stichting !WOON and Stichting Co-Force, are highlighted. These organisations could act as mediators between stakeholders and organise co-creation sessions with key stakeholders to create a shared vision, define roles and responsibilities, and policy strategies. Thus, it is recommended that policymakers research which associations could act as a mediator to ensure that all stakeholders get interested and a long-term collaboration can be established. Lastly, it is recommended to monitor the socio-spatial vulnerability to energy poverty to assess the effectiveness of measures and ensure that all vulnerable groups are included in policies.

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Appendix

A Search Table

In this appendix, the search table is shown in Table A.1. To come up with search queries, the concepts were combined with AND, and the search terms were combined with OR as recommended by the TU Delft Library.

Table A.1 Search Table

	Concepts		
Search Terms	Energy Poverty	Renovation	Europe
	Fuel Poverty	Retrofitting	European Union
		Vulnerability	EU
			Energy Justice

The used literature was primarily drawn from the following databases: Scopus and ScienceDirect. These databases are selected as they provide a broad overview of the literature on energy poverty and an interface that makes the selection of literature easy to execute (Sarja et al., 2021). Additional articles are found using the snowball method, by which relevant keywords are found. Moreover, the Connectedpapers[1] platform is used as a tool to get an overview of strongly related articles and gain insight into how authors used or built upon scientific knowledge.

B Research Methods and Required Data

In this appendix the required data and research methods are briefly discussed. Section B.1 discusses the required data and tools, whereas section B.2 provides an overview of the research methods.

B.1 Data Requirements and Tools

In this section the required data and tools are described.

B.1.1 Peer-Reviewed Literature

Peer-reviewed literature formed the foundation of the present study Using peer-reviewed literature ensured the quality standards of the conducted research (Rowland, 2002). Hence, it can be assumed that the consulted literature meets academic standards and provides reliable information. The peer-reviewed literature was gathered from scientific databases, publishers, and snowballing.

B.1.2 Grey Literature

Grey literature complemented the selection of peer-reviewed literature. The assumption was that, as the distribution of renovation resources is a policy problem, relevant contextual information about current policies and strategies of policymakers would be available in non-peer-reviewed literature, such as reports published by public entities and organisations (Adams et al., 2016). Moreover, contacted policymakers and experts might would have pointed out valuable non-peer-reviewed information sources. Gathering grey literature is usually limited by time as, just like peer-reviewed literature, it was not possible to read all available documents. Therefore, a careful selection of the literature was made (Adams et al., 2016).

B.1.3 Contact Data of Stakeholders

To conduct the interviews and organise the expert session, stakeholders in the energy and renovation domain were consulted. For the interviews and sessions, stakeholders had to be selected and had to be willing to assist in the research. Moreover, it was essential to obtain contact information and identify suitable stakeholders for the proposed purpose of the interviews and sessions. Hereby, the stakeholders were selected carefully to prevent bias in the research. The contact information and selection of stakeholders were discussed with A. Nienhuis, who, as an external supervisor and employee of the City of Amsterdam, had the contact information and network to identify, select and invite stakeholders.

B.1.4 Data for the Socio-Spatial Analysis of Vulnerability to Energy Poverty

To identify vulnerable households, data was required on the socio-economic, energy, and renovation indicators that have been identified in the extended vulnerability framework. For the vulnerability indicators shown in Table *4.1*, data was required at the neighbourhood level of Amsterdam, as the socio-spatial analysis mapped the socio-spatial distribution of vulnerable groups across the neighbourhoods of Amsterdam. A limitation of this approach was that data was not available for all vulnerability indicators. One way to address this limitation was to analyse the data quality and select a strategy to deal with missing data values based on the findings. These strategies were determined during the process and validated by discussing the applied strategies with the first supervisor. Jupyter Notebook and SPSS was used as a tool to gather, clean, and analyse the data.

B.2 Research Methods

In this section the research methods are discussed.

B.2.1 Desk Research

Desk research is often used in qualitative research approaches, whereby researchers use existing data from various sources to collect, combine and compare existing knowledge. In this way, new knowledge can be created as the resources are widely available and researcher bias is reduced. Desk research was conducted to answer sub-question 1,2, and 3 using peer-reviewed and grey literature. To ensure data validity, the recency of grey literature was tracked. In contrast, the citation score and strongly related work of peer-reviewed literature was tracked to ensure that the data is not outdated.

B.2.2 Semi-Structured Interviews

Stakeholders were consulted given the complexity of including justice in renovation policies. By interviewing these stakeholders, it was possible to collect information and complement the desk research approach by mitigating its limitations. The interviews were semi-structured and analysed with ATLAS.ti. The interviews were documented to ensure transparency.

B.2.3. Expert Sessions

An expert session was organised to combine the key findings of the socio-spatial analysis and system analysis and identify policy strategies to include justice in renovation policies. By inviting stakeholders, expertise from different backgrounds could be brought together to identify policy strategies. An advantage of this method was that multiple stakeholders were involved, which allowed them to share their perspectives; this also enhanced the quality and applicability of the identified policy strategies. Flipovers were used to facilitate the expert session and the session was moderated by the researcher.

B.2.4. Unsupervised Machine Learning

Unsupervised Machine Learning methods were used to perform a socio-spatial analysis of the extended vulnerability framework. Based on these results, vulnerable groups were identified, and insights were obtained into the characteristics of vulnerable groups and how the characteristics of vulnerable groups are spatially and socially variable. An advantage of this method is that it provides an understanding of the spatial distribution of vulnerable gives and provides insight into which set of indicators enhance the likelihood of being vulnerable to energy poverty (Robinson et al., 2019).

C Research Flow Table

In this appendix the research flow table is shown in Table C.1. The table provides an overview of the various research phases, the corresponding methodology, required data and the data analysis tool.

Table C.1 Research Flow Table

Research phase	Input	Process	Output	Research question	Method	Data	Data analysis tool	Name of practitioners
1. System analysis: reviewing current policies, identifying current issues and involved stakeholders	• Grey literature on current policies and issues • Contact data of practitioners	Stakeholder analysis and desk research & preparing and conducting interviews on current policies and issues	Analyzed system	Sub-question 1	Desk research & semi-structured interviews	• Peer-reviewed literature • Grey literature • Contact data of practitioners	ATLAS.ti	1. Energy poverty expert (Stichting !WOON) 2. Expert in social sciences and policy (UvA/ Energie Lab ZO) 3. Expert in energy poverty in The Netherlands (TNO) 4. Officer in energy poverty policy (City of Amsterdam)
2a. Extending current vulnerability framework with renovation indicators to define socio-spatial vulnerability to energy poverty	• Current vulnerability framework developed by Robinson et al. (2019) • Peer-reviewed literature on retrofit indicators • Grey literature on retrofit indicators • Contact data of practitioners	Desk research & preparing and conducting interviews to identify renovation indicators and extend current vulnerability framework and defining the socio-spatial vulnerability to energy poverty	Extended vulnerability framework and defined socio-spatial vulnerability	Sub-question 2	Desk research & semi-structured interviews	• Peer-reviewed literature • Grey literature • Contact data of practitioners	ATLAS.ti	1. Energy poverty expert (Stichting !WOON) 2. Expert in social sciences and policy (UvA/ Energie Lab ZO) 3. Expert in energy poverty in The Netherlands (TNO) 4. Officer in energy poverty policy (City of Amsterdam) 5. Expert in housing quality and process innovation (TU Delft)
2b. Socio-spatial analysis of vulnerability to energy poverty	• Output phase 2a • Data for the socio-spatial analysis • Grey and peer-reviewed literature on conducting socio-spatial analysis	Familiarization and conducting socio-spatial analysis	Identified vulnerable groups and spatial distribution of the identified vulnerable groups	Sub-question 3	Desk research & unsupervised machine learning	• Peer-reviewed literature • Grey literature • Data for socio-spatial analysis	Jupyter Notebook and SPSS	
3. Identifying policy strategies to include justice in renovation policies	• Output phase 1, 2a and 2b • Contact data of practitioners	Preparing and organizing expert session to identify policy strategies based on the insights from phase 1 and 2	Identified policy strategies	Sub-question 4	Expert session	• Contact data of practitioners	n.a.	1. Energy poverty expert (Stichting !WOON) 2. Expert in social sciences and project leader JUST-PREPARE (HvA/ Energie Lab Zuidoost) 3. Local citizen + part of Stichting Co-Force 4. Three employees of the City (City of Amsterdam)
4 Conclusion and recommendations	• Output phase 1 till 3	Integrating and analyzing outputs to derive conclusions and make recommendations	Conclusion, answer to main research question and recommendations for policymakers on including justice in retrofit policies	Main research question	n.a.	n.a.	n.a.	n.a.

D Stakeholder Analysis

In this appendix the results of the stakeholder analysis are presented to gain insights into the key stakeholder's and possible collaborations.

D.1 Specifying Objectives and Interests

In this section the objectives and interest of the stakeholders are specified to gain insights into the problem specific objectives and level of interest of involved stakeholders. The strategic objectives define the general objectives and interest of a stakeholder, for a commercial company this often entails increasing their profit and continuity of business. The problem specific objectives specify the problem related objective and interest of the stakeholder. The interest specifies the level that issues related to the problem matter to the stakeholder. By specifying the strategic, problem specific and interest level of the stakeholders insights can be obtained in the interest and objectives of the involved stakeholders. Table D.1 provides an overview of the strategic, problem specific and interests of each stakeholder.

Table D.1 Stakeholder's Objectives and Level of Interest

Stakeholders	Strategic Objectives	Problem-Specific Objectives	Interest in Problem (high-medium-low)
City of Amsterdam, Department of City Development	Ensure a sustainable and attractive city (Gemeente Amsterdam, 2022)	Stimulate the renovation of buildings to improve energy efficiency savings and living-conditions, without a top-down approach (Gemeente Amsterdam, 2021).	High, the department wants to use renovation as a lever to realize its ambition of becoming energy neutral by 2040 (Gemeente Amsterdam, 2021) .
City of Amsterdam, Department of Planning and Sustainability	Ensure a sustainable and attractive city (Gemeente Amsterdam, 2022)	Stimulate the renovation of buildings to ensure that the buildings are gasfree	Medium, the department does want to stimulate the renovation so that buildings are gas free however the interest in tackling energy poverty is lower
City of Amsterdam, Department Housing	Ensure a pleasant housing environment in Amsterdam (Gemeente Amsterdam, 2022)	Stimulate the renovation of buildings to improve energy efficiency savings and living conditions (Gemeente Amsterdam, 2021).	Medium, the department wants to improve the living conditions of buildings. However, is less interested in tackling energy poverty.
Ministry of Economic Affairs and Climate Policy	Realize a climate neutral society and a strong and open economy (Ministerie van Economische Zaken en Klimaat, 2022).	Renovatingting of residential buildings to reduce greenhouse gas emissions and save energy (Ministerie van Economische Zaken en Klimaat, 2021).	Low, the ministry wants to stimulate the renovation of buildings to save energy, however local governments are responsible to select their own local strategy (Ministerie van Algemene Zaken, 2021).
European Commission	Contribute to the sustainable development, eradication of poverty, peace and protecting human rights (European Commission, 2021).	Tackle energy poverty, improve living-conditions of people living and using the buildings and creating additional green jobs in the construction sector by renovating residential buildings (European Commission, 2021).	Low, the EC wants to promote the renovation of buildings to tackle energy poverty and climate change, however EU member states can select their own national strategy (European Commission, 2021).
Financial institutions (ABN Amro)	Ensure high customer experience, promote and encourage sustainability and being a future-proof bank (ABN AMRO, n.d.)	Become part of by tackling social inequalities and improving the livability together with the City (ABN AMRO, 2021; Convenant ABN AMRO, 2021).	Low, currently ABN Amro is focused on realizing a sustainable office and providing financial help to local residents who have debts and encouraging local residents to join the bank as an employee (ABN AMRO, 2021).

Energy service company (Vattenfall)	Enable fossil-free living and increase profits (Vattenfall, n.d.)	Collaborate with the City to make Amsterdam naturally gas-free and encourage renovation of buildings (Vattenfall, 2021).	Medium, Vattenfall is focused more on heat nets than renovation buildings to save energy and improve living-conditions (Vattenfall, 2021).
Service providers (Klimaatmissie Amsterdam)	Contribute to the natural gas-free transition of residential buildings and increase profit (Klimaatmissie Nederland, 2022).	Act as a service provider for the residents to renovate their buildings (Klimaatmissie Amsterdam, 2022).	High, Klimaatmissie collaborates with the City to offer homeowners a renovation plan and provide the services required for renovation. As the profit of the company also depends on the amount of renovation plans the company develops, they are highly interested in the renovation plans in Zuidoost (Klimaatmissie Amsterdam, 2022).
AMS Institute,Energie Lab Zuidoost (TU Delft, HvA, UvA)	To create and share knowledge on the sustainable renovation of homes, low temperature heat networks and local smart energy systems to contribute to the realization of a social energy transition (AMS Institute, n.d.)	Create and share knowledge on deep renovation of residential buildings and bringing insights into the problem perceptions of residents, housing associations and other related stakeholders (AMS Institute, n.d.)	High, the Energie Lab Zuidoost is highly interested into the renovation in Zuidoost as one of the main focus areas of the lab is to create and share knowledge and bring stakeholders together to enable renovation of buildings to support vulnerable groups in Zuidoost (AMS Institute, n.d.).
Stichting !WOON	Support tenants, homeowners and home seekers with renting, buying, saving energy, organisation and participation (Stichting !WOON, n.d.).	Support local vulnerable residents in Zuidoost with renovation, tackling energy poverty and represent their voice (Stichting !WOON, 2021).	High, Stichting !WOON is actively engaged in Zuidoost to help local residents with renovation to improve their living-conditions and alleviate energy poverty (Stichting !WOON, 2021).
Stichting Co-Force	Contribute to a just social energy transition and support local initiatives in Zuidoost (Stichting Co-Force, n.d.).	Represent local residents/users in decision-making and ensure that the living-conditions of vulnerable groups improve and energy poverty is tackled (Stichting Co-Force, n.d.).	High, Co-Force is actively involved to ensure that vulnerable households are recognised and involved in the decision-making of renovation policies and to make sure that energy poverty is also tackled (Gemeente Amsterdam, 2021).
Housing associations (Stadgenoot, Eigen Haard and Rochdale)	Rent affordable houses and increase profit (Stadgenoot, n.d. ; Eigen Haard, n.d. ; Rochdale, n.d.)	Renovate buildings for maintenance and increased market value.	Medium, housing associations are holding back on actively renovation buildings in Zuidoost; only a few buildings are considered.
Resident association (tenants, houseowners and VVE's)	Improve the livability and economic viability of the neighbourhoods and represent the needs and values of local residents.	Increase energy savings, improve living-conditions, additional green jobs and represent the local residents.	Low, local residents tend to reject renovation policies and are not actively making use of the renovation policies.

D.2 Specifying Problem Perceptions

Problem perceptions specify the gap between the perceived existing situation and the desired situation and includes ideas about causes and possible solutions. In this section the problem formulation of the different stakeholders is systematically drafted by specifying the existing or expected situation and gap, causes, favoured solutions and specifying the alignment with the problem owner's interests and objectives. Table D.2 provides an overview of the problem perceptions.

Table D.2 Overview of Stakeholder's Problem Perceptions

Stakeholder	Existing or Expected Situation and Gap	Causes	Favoured Solutions	Alignment with the Problem Owner? (Support, neutral, opposition)
City of Amsterdam, Department of City Development	Renovation policies are often rejected by vulnerable groups and current policy plans increase risk of gentrification and currently existing social inequalities.	General lack of trust in government and internal conflict with Program Aardgasvrije Wijken, in which vulnerable groups are often neglected. Restrained housing associations and lack of bottom-up initiatives.	- Increase trust in renovation policies and tackle energy poverty - Include just transition mechanisms in current energy transition plans - Realise a social energy transition - Increase bottom-up initiatives with low governmental involvement	X
City of Amsterdam, Department of Planning and Sustainability	Renovation policies are often rejected by vulnerable groups and current policy plans increase risk of gentrification and currently existing social inequalities. High pressure to speed up	Klimaatakkoords pressure to reduce greenhouse gas emissions and increase the rate of gasfree neighbourhoods. General of interest and trust in government and renovation policies among vulnerable social groups.	- Increase current rates of renovation - Include just transition mechanisms in current energy transition plans - Realise an energy transition as soon as possible - Increase bottom-up initiatives with low governmental involvement	Medium, one hand the Department PLANNING AND SUSTAINABILITYwants to increase the renovation policies and contribute to a just energy transition and on the other hand they want to increase renovation policies to maximise energy savings without taking into consideration which social groups are making use of renovation policies.
City of Amsterdam, Department Housing	Poor living conditions in many residential buildings with high levels of energy poverty and low interest in renovation.	General lack of trust in government and internal conflict with Program Aardgasvrije Wijken, in which vulnerable groups are often neglected. Restrained housing associations and lack of bottom-up initiatives.	- Increase trust in renovation policies and tackle energy poverty - Improve living conditions in residential buildings - Realise a social energy transition - Increase bottom-up initiatives with low governmental involvement	Support, the Department Housing wants to improve the living conditions of people living in buildings and decrease levels of energy poverty.
Ministry of Economic Affairs and Climate Policy	No clear renovation policies on national level and current renovation policies on local governmental level increase social inequity and increase the risk of gentrification.	Pressure from Klimaatakkoord's mission to reduce greenhouse gas emissions fast and no clear policy that also considers equity or just practices in renovation policies.	- Local governments actively contributing to achieve the Klimaatakkoords mission - Soft energy saving policies (subsidies for insulation or compensation for high energy bills - Increase renovation rates - Homeowners/housing associations actively make use of subsidies and loans to renovate	Support, the Ministry aims to support local decision makers by providing them power to tackle renovation and energy poverty on neighbourhood level.
European Commission	A lot of residential buildings have a high energy usage and are often in poor living-conditions. COVID-19	Old residential buildings are and will be in use in the future and the impact of COVID-19 on the	- Increased renovation rates - Increased awareness of tackling energy poverty by renovation in EU - Create additional green jobs in	Support, EC aims to support local initiatives for renovation policies and alleviation of energy poverty by recognizing vulnerable

	pandemic has further raised the risk of social inequity and the risk of unemployment has increased/	society in terms of poverty and inequity.	the construction sector	groups and helping them through renovation.
Financial institutions (ABN AMRO)	Current liveability in Zuidoost is low, the amount of local employees at the bank is low and low rates of loans taken by local residents for renovation/sustainability and generally high rates of debts.	High poverty and unemployment rates, various ethnic backgrounds who generally have a lack of trust in governments and local institutions	-Improved livability in neighbourhood -Increased amount of local employees -Increased prosperity in Zuidoost in terms of low poverty and low unemployment rates - Increased rates of renovation	Support, ABN AMRO aims to support and collaborate with the City to increase the livability in the neighbourhood and alleviate poverty
Energy service company (Vattenfall)	High energy consumption and greenhouse gas emissions in Zuidoost. Residents are not actively making use of green energy sources.	High poverty and unemployment rates, lack of knowledge and lack of trust in governments and local institutions	-Increased usage of green energy sources -Increased renovation measures -Improved livability	Support, Vattenfall wants to collaborate with the City to reduce greenhouse gas emissions, reduce energy consumption and increase trust in organisation.
Service providers (Klimaatmissie Amsterdam)	High energy consumption and greenhouse gas emissions in Zuidoost. Residents are not actively making use of green energy sources.	High poverty and unemployment rates, lack of knowledge and lack of trust in governments and local institutions. Lacking knowledge on renovation policies and benefits.	-Increased usage of renovation policies by residents -Increased profit -Increased trust in institutions	Support, Klimaatmissie Amsterdam wants to collaborate with the City to renovate buildings as it will increase their profit.
AMS Institute,Energie Lab Zuidoost (TU Delft, HvA, UvA)	Low scientific knowledge on how renovation can match with the practices of various residents and current renovation policies are reinforcing already existing inequalities meaning that a social energy transition becomes more difficult to achieve	Renovations often have a technological focus, neglecting households energy practices and thus often leading to ineffective renovation results. Current low rates of renovation in underprivileged neighbourhoods is also increasing the risk of social inequity and gentrification.	-Increased renovation rates in underprivileged neighbourhoods -Increased scientific knowledge on how renovation measures can fit the energy practices of different household types (ethnicity/composition) -Realisation of a just energy transition	Support, Energie Lab Zuidoost is an important collaborator as it creates scientific knowledge on how the City can renovate and realise a just energy transition.
Stichting !WOON	Current renovation policies are shaped among institutional stakeholders with little to no involvement of residents. High rates of energy poverty and poor living-conditions in a lot of residential buildings and low rates of renovation among these groups.	Lack of trust in governmental institutions, high rates of unemployment and poverty. A large share of households in underprivileged neighbourhoods have high rates of debts and thus are not waiting to take a loan or invest in renovation.	- Increased rates of renovation for vulnerable groups -Increased trust in governmental institutions -Improved living conditions for vulnerable groups	Neutral, Stichting !WOON is an important collaborator as it informs local residents especially in underprivileged neighbourhoods on how they can save energy and what the benefits of renovation are for them. However, they are not happy with current renovation measures as they are ineffective among vulnerable groups and pledge the City to take them into consideration.
Stichting Co-Force	Current renovation rates are low among residents living in underprivileged neighbourhoods, renovation policies are still shaped among key actors without the involvement of	Lack of trust in governmental institutions, high rates of unemployment and poverty. A large share of households in underprivileged neighbourhoods have high rates of debts	- Increased rates of renovation for vulnerable groups -Increased trust in governmental institutions -Improved living conditions for vulnerable groups -Decreased stigmatisation and increased involvement of local residents from different ethnical	Neutral, Stichting Co-Force is an important collaborator as it represents local residents especially in underprivileged neighbourhoods in decision making and informs them on how they can save energy and what the benefits of renovation are for them.

	residents and high rates of energy poverty and poor living conditions for a lot of residents who are currently not making use of renovation measures.	and thus are not waiting to take a loan or invest in renovation. High rates of stigmatisation of underprivileged neighbourhoods among local policymakers and low local representatives engaged in renovation policies.	groups in decision making.	However, they are not entirely supporting the City as there is a lot of stigmatisation among local policymakers and they pledge the City to step away from the stigmatisation and actually involve and recognize various vulnerable groups.
Housing associations (Stadgenoot, Eigen Haard and Rochdale)	Current renovation rates are low as residents need to move to other buildings and at least 70% of the residents need to vote for renovation. Private landlords are willing to buy houses for a lot of money which is in terms of profit more attractive than renting social houses.	-High market prices for houses -Low renovation interest among residents -Low institutional trust among residents -High preparation and execution time of renovation and a lot of paperwork	-Increased institutional trust among residents -Decreased preparation and execution time of renovation	Against, the long preparation and execution time, risk of rejecting measures by residents and the increased profit by selling houses to private landlords make housing associations hesitant to actively support renovation policies and tackle energy poverty.
Resident association (tenants, homeowners and VVE's)	City is promoting renovation policies however the costs are high, lack of knowledge in technology, currently poor living conditions and high rates of energy poverty experienced. A lot of paperwork and high preparation and execution times. Overall low interest in sustainability and a large of households is busy with 'surviving' (low incomes/high unemployment/high costs and high debts)	-lack of trust in governmental institutions -High rates of unemployment and poverty -Poor living conditions - Low involvement in decision making and stigmatization experienced	-Increased institutional trust-Decreased preparation and execution time of renovation -Decreased stigmatization -Increased knowledge on technology and residents practices matched with the technologies	Against, given the current lack of trust, high rates of poverty and unemployment local residents are resisting renovation measures and not actively making use of the opportunities

D.3 Analysing Interdependencies

The importance of a stakeholder is determined by three things, namely the importance of resources to the problem owners, the extent to which those resources are replaceable and the degree to which the interests and objectives of other stakeholders are similar. Moreover, by knowing how important and urgent the problem is to other stakeholders, insights can be obtained into whether stakeholders are likely to be willing to play an active role in tackling the policy problem.

The degree to which a problem owner depends on an actor is related to the resources and replaceability of resources of that actor. The resources of a stakeholder are the formal and informal means available to the stakeholder which they can use to achieve their objective, whereby formal means often refer to authority and instruments (subsidies) and informal means are for instance related to manpower, knowledge, and position in the network.

Table D.3 provides an overview of the resources, replaceability, dependency and identifies whether a stakeholder is a critical stakeholder. The criticality of a stakeholder is determined by assessing whether a stakeholder is important for their power of realisation or for their blocking power.

Table D.3 Identification of Critical Stakeholders based on Resources of the Stakeholders

Stakeholders	Resources (short description of each)	Replaceability (yes, no)	Resource dependency (low, medium, high)	Dependency: Critical Actor? (yes/no)
City of Amsterdam, Department of City Development	- Provide subsidies for renovation - Provide loans for renovation - Prioritise renovation for vulnerable groups to tackle energy poverty - Support bottom-up initiatives for renovation and tackling energy poverty	-	-	-
City of Amsterdam, Department of Planning and Sustainability	- Provide subsidies for renovation - Provide loans for renovation - Support bottom-up initiatives for renovation - Prioritise neighbourhoods where renovation is actively promoted and gasfree residential buildings are promoted	No	High	Yes
City of Amsterdam, Department Housing	- Provide subsidies for renovation - Provide loans for renovation - Prioritise renovation for vulnerable groups with poor living conditions and tackle energy poverty - Support bottom-up initiatives for renovation and tackling energy poverty	No	High	Yes
Ministry of Economic Affairs and Climate Policy	- Increase subsidies for renovation in cities - Develop national strategy for tackling energy poverty by using renovation as a lever	No	High	Yes

	and prioritising vulnerable groups - Ban usage of non-renovated buildings in future			
European Commission	- Increase subsidies for tackling energy poverty by renovation -Develop EU strategy for recognizing and prioritising vulnerable groups to include justice - Encourage jobs in the construction sector - Encourage bottom-up initiatives	No	High	Yes
Financial institutions (ABN Amro)	- Provide vulnerable groups with loans for renovation - Hire local employees from Zuidoost to increase employment rates and lower poverty rates	Yes	Low	No
Energy service company (Vattenfall)	-Collaborate with Department for making Zuidoost natural gas-free - Provide security of supply to residents of renovated buildings - Connect renovated buildings to heat networks	No	Medium	No
Service providers (Klimaatmissie Amsterdam)	- Lobby to the Department by making natural gas-free plans for local residents and mapping their needs, values and concerns.	No	High	No
AMS Institute,Energie Lab Zuidoost (TU Delft, HvA, UvA)	-Lobby between stakeholders to create a common base for negotiation and realisation of just renovation policies - Create and share knowledge on renovation and tackling energy poverty	No	High	Yes
Stichting !WOON	- Collaborate with the housing associations, stichting Co-Force and residents association to form an united front to lobby to the Department for including justice in renovation policies and tackling energy poverty	No	Medium	No
Stichting Co-Force	- Collaborate with the housing associations, stichting !WOON and residents association to form an united front to lobby to the Department for including justice in renovation policies and tackling energy poverty	No	Medium	No

Housing associations (Stadgenoot, Eigen Haard and Rochdale)	- Lobby to the Department of Public Service for more budget to make neighbourhoods more attractive to tourists	No	High	Yes
Resident association (tenants, homeowners and VVE's)	-Lobby to the Department for including justice in renovation policies and tackling energy poverty -Reject renovation measures - Support renovation measures - Collaborate with Stichting Co-Force, Stichting !WOON, housing associations and other resident associations to make their voice heard	No	High	Yes

D.4 Mapping Interdependencies

To provide an overview of the different types of stakeholders on whom the City depends on a larger or lesser degree, the interdependencies are mapped. Table D.4 provides an overview of a generic overview table and insights into the behaviour of stakeholders based on their interest and importance. A dedicated stakeholder is a stakeholder who will be affected directly by the problem or possible solutions, whereas a non-dedicated stakeholder is not directly affected and therefore difficult to mobilize.

Table D.4 Generic Classification of Interdependencies (Enserink et al., 2010)

	Dedicated actors		**Non-dedicated actors**	
	Critical actors	Non-critical actors	Critical actors	Non-critical actors
Similar/ supportive interests and objectives	Actors that will probably participate and are potentially strong allies	Actors that will probably participate and are potentially weak allies	Indispensable potential allies that are hard to activate	Actors that do not have to be involved initially
Conflicting interests and objectives	Potential blockers of certain changes (biting dogs)	Potential critics of certain changes (barking dogs)	Potential blockers that will not act immediately (sleeping dogs)	Actors that need little attention initially (stray dogs)

Based on the results from the previous sections, the interdependencies are mapped. Table D.5 provides an overview of the interdependencies.

Table D.5 Overview Table of Stakeholders and their Positions Relative to the Department of City Development

	Dedicated stakeholders **(high interest)**		**Non-dedicated** stakeholders **(low interest)**	
	Critical Stakeholders (important resources	**Non-critical Stakeholders (no important resources)**	**Critical Stakeholders (important resources)**	**Non-critical Stakeholders (no important resources)**
Supportive stakeholders (objectives well aligned)	-AMS Institute, Energielab Zuidoost -Financial institutions - City of Amsterdam, Department Housing	-Stichting !WOON -Stichting Co-Force - Klimaatmissie Nederland - Vattenfall	-European Commission -Ministry of Economic Affairs and Climate Policy	
Opposing stakeholders (conflicting objectives)	-Resident associations -Housing associations - City of Amsterdam, Department of Planning and Sustainability			

D.5 Power-Interest Grid

A power-interest grid allows to visualize and categorize stakeholders based on their interest and power into the problem perception. The categorization of stakeholders can provide various insights. For instance, the overview of actor dependencies might form a reason to modify the problem formulation, by identifying key interests of other stakeholders that need to be taken into account, in addition to those of the problem owner. The overview can also be used to identify coalition and alliances that need to be established, encouraged, or discouraged in relation to the dedicated and non-dedicated critical stakeholders. An advantage of a power-interest grid is that it allows a quick illustration of important patterns in the actor environment of the problem owner. In a PI-grid the powers and interests of stakeholders are used to classify different stakeholders, whereas pluses and minuses are used to indicate if an actor supports or opposes the main interests and objectives of the problem owner. Critical stakeholders are those with a high power, whereas dedicated stakeholders are those with a high level of interest in the problem. Figure *D.1* provides a general overview of a PI-grid.

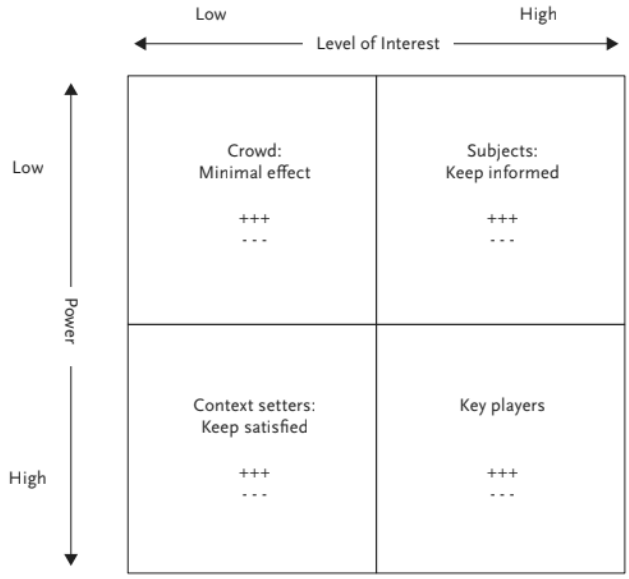


Figure D.1 Generic Power-Interest Grid

Based on the overview table presented in the previous section a PI-grid is made to visualize and categorize the interests and power of the relevant stakeholders. Figure 3.4 shows the PI grid.

From the PI-grid four categories can be distinguished in terms of interdependencies:

1. Players (high power - high interest)
   These stakeholders are both interested in including justice in renovation policies and have resources which provides them with means to exert high level of power. They will be actively engaged in including justice in renovation policies. These parties include departments of the City of Amsterdam, financial institutions and Energie Lab Zuidoost.
2. Context setters (high power - low interest)
   These stakeholders have important resources due to which they can influence to what extent justice can be included in renovation policies. However, they do not have direct interest in including justice in Zuidoost and thus they will not intervene easily. These parties include the European Commission and the Ministry of Economic Affairs and Climate Policy.
3. Crowd (low power - low interest)
   These stakeholders have low power and low interest in including justice in renovation policies. From the list of identified relevant stakeholders such an actor has not been identified.
4. Subjects (low power- high interest)

These stakeholders have low power to influence renovation and energy poverty policies but are highly interested in the issue. These parties include Klimaatmissie and Vattenfall as they are easily replacable by other service providers and energy companies but are highly interested in being part of the renovation policies and contributing to a social energy transition. Stichting !WOON and Stichting Co-Force are highly interested in including justice in renovation policies and representing the local residents, however they do not have formal resources and thus have low power as they can primarily lobby to the City.

E Defining the Socio-Spatial Vulnerability to Energy Poverty

In this section an overview of the defined socio-spatial vulnerability to energy poverty is provided. Table E.1 provides an overview of the identified vulnerability indicators. For each vulnerability indicator, the associated vulnerability factors are shown in the second column of Table E.1. These associations have been identified based on desk research and the conducted interviews; the corresponding references are shown in the third column. The last column represents the data set indicator, which has been used to measure each vulnerability indicator. For instance, the first row of the table shows how the vulnerability indicator of 'older old' represents individuals who are older than 75 and live alone. Moreover, based on literature and the interview results, it becomes clear that these individuals are often dependent on the provision of care, are less able to benefit from new technologies, and are underrepresented in energy poverty policy.

Table E.1 Identified Vulnerability Indicators as an Index of Socio-Spatial Vulnerability

Indicator	Associated vulnerability factors	References	Data set indicator
Older old	Inability to access appropriate fuel types; less able to benefit from new technologies; dependents and provision of care; high energy use per capita; physiological need for energy services; spend large proportion of time at home; unhealthy warmth-related practices; lack of awareness of support; lack of control and choice over daily lives; reduced autonomy over energy services; lack of social relations in/ outside home; living alone; underrepresented in fuel poverty policy	Day & Hitchings (2011), Healy & Clinch (2004), O'Neill et al. (2006), Ormandy & Ezratty (2012), Chard & Walker (2016), Respondents 1-3 (2022)	Percentage of the population aged 75+ and living alone.
Young children	Dependents and provision of unpaid care; high energy use per capita; lack of financial support for energy bills; under-or misrepresented in policymaking; physiological need for energy services; spend large proportion of time at home; large household size; lack of control and choice overdaily lives; lack of social relations in/outside home; low interest in bottom-up initiatives	Bhattacharya et al. (2003), Yohanis et al. (2008), Walker & Day (2012), O'Sullivan et al. (2016), Respondents 1-3 (2022)	Households: % with children

Disability or limiting illness	Reliant on state provision of welfare; high energy use per capita; lack of financial support for energy bills; income from state support reduced; under-or misrepresented in policymaking; physiological need for energy services; spend large proportion of time at home; mismatch between needs and services; lack of control and choice over daily lives; lack of social relations in/outside home; lack of interest in energy transition; unable to benefit from new technologies	Walker & Day (2012), George et al. (2013), Snell et al. (2015), Gillard et al. (2017), Respondents 1-3 (2022)	Health: % physical impairment
Mental health issues	Reliant on state provision of welfare; high energy use per capita; lack of financial support for energy bills; income from state support reduced; under-or misrepresented in policymaking; physiological need for energy services; spend large proportion of time at home; mismatch between needs and services; lack of control and choice over daily lives; lack of social relations in/outside home; lack of interest in energy transition	Walker & Day (2012), George et al. (2013), Snell et al. (2015), Gillard et al. (2017), Respondents 1-3 (2022)	Health: % serious psychological problems
Lone parent	Precarious or part-time employment; reliant on a low income; reliant on a single income; dependents and provision of unpaid care; under- or misrepresentation in policy; spend large proportion of time at home; lack of control and choice overdaily lives; unaffordability of owner-occupancy	Healy & Clinch (2004), Gingerbread (2013), Respondents 1-3 (2022)	Households: single-parent family
Retired	Reliant on state pension; spend large proportion of time at home; under-represented in fuel poverty policy	Healy & Clinch (2004), Respondents 1-3 (2022)	Income: pension (18-74%)
Provision of unpaid care	Precarious or part-time employment; unemployment; dependents and provision of unpaid care; spend large proportion of time at home; lack of control and choice overdaily lives; low interest in energy transition; under-represented in fuel poverty policy	King & Pickard (2013), George et al. (2013), Norman & Purdam (2013), Respondents 1-3 (2022)	Informal caretakers (%)

Precarious	Precarious or part-time employment; unemployment; dependents and provision of unpaid care; spend large proportion of time at home; lack of control and choice over daily lives; under-represented in fuel poverty policy; unable to benefit from new technologies	O'Sullivan et al. (2016)	Care services (% 18-65 yrs.)
No income	Reliant on low income; unemployment; inability to invest in energy efficiency; acceptance of high financial risks	O'Sullivan et al. (2016), Respondents 1-4 (2022)	Income: none (%18-74)
Unemployment	Reliant on low income; unemployment; inability to invest in energy efficiency; significant time spent at home	Healy & Clinch (2004), Middlemiss & Gillard (2015), Respondents 1-3 (2022)	Registered unemployment (%)
Proficiency in Dutch	Inability to switch to cheaper tariffs; lack of social relations in/outside home; lack of interest in energy transition; under- or misrepresented in policymaking; lack of bottom-up initiatives	Bouzarovski (2014), Gemeente Amsterdam (2021), Respondents 1 -3 (2022)	First generation non-western
Ethnicity	Reliant on low income; precarious living arrangements; under- or misrepresented in policymaking	Bouzarovski (2014), Abbas et al. (2020), Jacques-Aviñó et al. (2022), Respondents 1-3 (2022)	Migration background: % non-western
Full-time student	Reliant on low income; inability to switch to cheaper tariff; inability to investing energy efficiency measure; lack of housing rights; under- or misrepresented in policymaking	Healy & Clinch (2004), Butler & Sherriff (2017), Petrova (2017), Abbas et al. (2020), Respondents 2 (2022)	Registered full-time students MBO/HBO/WO (%)
Underoccupancy	Underoccupancy of the home	Yohanis et al. (2008), Kwon & Jang (2017), Abbas et al. (2020), Jacques-Aviñó et al. (2022) Respondents 1 & 2 (2022)	Occupancy rating of +1 bedrooms
Shared property	Inability to invest in energy-efficiency measures; limited availability of energy-efficiency measures; reduced autonomy over energy services	Cauvain & Bouzarovski (2016), Butler & Sherriff (2017), Respondents 1-3 (2022)	Shared property
Large household size	Large household size	Healy & Clinch (2004), Yohanis et al. (2008), Itard & Visscher (2015), Respondents 1-3 (2022)	Households with >4 children
Private renting	Inability to switch to cheaper tariff; limited availability of efficiency measures; inability to invest in energy efficiency; lack of housing rights;	Boardman (2012), Walker & Day (2012), Ambrose (2015), Middlemiss & Gillard (2015), Abbas et al. (2020), Jacques-	Private rent: % middle

	precarious living arrangements; unaffordability of owneroccupancy; under- or misrepresentation in policy; reduced autonomy over energy service	Aviñó et al. (2022), Respondents 1-3 (2022)	
Social housing renting	Inability to switch to cheaper tariff; limited availability of efficiency measures; inability to invest in energy efficiency; lack of housing rights; precarious living arrangements; unaffordability of owneroccupancy; under- or misrepresentation in policy; reduced autonomy over energy service; inability to switch to cheaper tariff; reliant on low incomes	Boardman (2012), Walker & Day (2012), Ambrose (2015), Middlemiss & Gillard (2015), Abbas et al. (2020), Jacques-Aviñó et al. (2022), Respondents 1-3 (2022)	Social housing rent (%)
Old heating system	Inability to access appropriate fuel types; inefficient energy conversion by appliances; energy inefficient appliances; high energy use per capita; High ventilation heat loss; High transmission heat loss; Poor indoor quality; Low property valuation; Old building year; Wind direction and speed; High rates of mould; High humidity levels; High noise level; Low housing density; High indoor temperature summer; High heating requirement winter; reliant on low income	Burholt & Windle (2006), Boardman (2013), Respondents 1-3 (2022)	heater / boiler (%)
No solar panels	Inability to access appropriate fuel types; inability to switch to cheaper tariff; energy inefficient appliances; unable to benefit from new technologies; Inaccurate targeting of support; high energy use per capitaHigh ventilation heat loss; High transmission heat loss; Poor indoor quality; Low property valuation; Old building year; Wind direction and speed; High rates of mould; High humidity levels; High noise level; Low housing density; High indoor temperature summer; High heating requirement winter; reliant on low income	Respondents 1-3 (2022)	1- Solar / heat pump (%)
Energy inefficient property	Energy-inefficient appliances; High ventilation heat loss; High transmission heat loss; Poor indoor quality; Low property valuation; Old building year; Wind direction	Walker (2008), Yohanis et al. (2008), Stockton and Campbell (2011), Dowson et al. (2012), Rudge (2012), Boardman (2013), Hansen et al. (2019),	Energy label E/F/G (%)

	and speed; High rates of mould; High humidity levels; High noise level; Low housing density; High indoor temperature summer; High heating requirement winter; high energy use per capita;	Meijer et al. (2019), Respondents 1-4 (2022)	
Energy consumption	Physiological need for energy services; Significant time spent at home; Household size; Mismatch between needs and services; Unhealthy warmth-related practices; Lack of awareness of support; Lack of control over choice over daily life; Reduced autonomy over energy; Energy-inefficient appliances; High ventilation heat loss; High transmission heat loss; Poor indoor quality; Low property valuation; Old building year; Wind direction and speed; High rates of mould; High humidity levels; High noise level; Low housing density; High indoor temperature summer; High heating requirement winter; reliant on low income	Itard & Visscher (2015), Hansen et al., (2019), Meijer & Visscher (2019), Respondents 1-4 (2022)	Average monthly energy costs in proportion to a household's monthly income
Educational level	Unable to benefit from new technologies; Unhealthy warmth-related practices; Lack of awareness of support; Lack of trust institutions; reliant on low income; low interest in energy transition	Majcen et al. (2013), European Parliament (2016), Meijer & Visscher (2018), Abbas et al. (2020), Jacques-Aviñó et al. (2022), Respondents 1-3 (2022)	Education low (%)
Debt assistance	Reliant on low income; Precarious or part-time employment; Unemployment; Reliant on state provision of welfare; Reliant on state pension; Reliant on single income; Dependents and the provision of care; Significant household debt; Acceptance of high financial risks; inability to invest in energy efficiency; lack of trust; low interest in energy transition; lack of social relations	Longhurst & Hargreaves (2019), Wang et al. (2022), Respondents 1-3 (2022)	Debt assistance (%)
Loneliness	Lack of social relations in/out of home; Living alone; Acceptance of high financial risks; lack of social cohesion local community and institution; low interest in energy transition	Longhurst & Hargreaves (2019), Wang et al. (2022), Respondents 1-3 (2022)	Social cohesion score (1-10)

Participation	Lack of bottom-up initiatives; Lack of social cohesion local community and institution; Lack of trust institutions; Inefficient communication; Inability to access appropriate fuel types; Unable to benefit from new technologies; mis- or underrepresented in fuel poverty policy	Hoppe et al. (2016), Bakker et al. (2020), Beenakker et al. (2022), Respondents 1,2 & 4 (2022)	Political influence (%)
Satisfaction score communication	Willingness to invest in energy efficiency; Willingness to pay more rent to live in a renovated building; Low interest in energy transition; Lack of bottom-up initiatives; Lack of social cohesion local community and institution; Lack of trust institutions; mis- or underrepresented in fuel poverty policy	Respondents 1,2 & 4 (2022)	Understands written information by municipality (%)
Gender	Precarious or part-time employment; unemployment; dependents and provision of unpaid care; spend large proportion of time at home; lack of control and choice overdaily lives; mis- or underrepresented in fuel poverty policy	Robinson (2019), Abbas et al. (2020), Jacques-Aviñó et al. (2022), Respondents 1,2 & 4 (2022)	Female (%)
Unwillingness to pay more rent or invest in renovation	Low interest in energy transition; Lack of bottom-up initiatives; Lack of social cohesion local community and institution; inefficient communication; unable to benefit from new technologies; reliant on low income; mis- or underrepresented in fuel poverty policy' poor building performance	Gemeente Amsterdam (2022), Jacques-Aviñó et al. (2022), Respondents 1,2 & 4 (2022)	Unwillingness to invest or pay more rent to live in renovated building (%)

F Analysing the Socio-Spatial Vulnerability to Energy Poverty

In this chapter, background information on the deployed vulnerability indicators for the socio-spatial analysis is presented. Moreover, the methodological steps required for the identification of vulnerable groups and the accompanying results are presented.

F.1 Background Information on Deployed Vulnerability Indicators

In this section background information is provided on the deployed vulnerability indicators in the socio-spatial analysis, shown in Table F.1. For each vulnerability indicator, the indicator data set, a description, variable code, and year of data extraction is shown.

Table F.1 Background Information on Deployed Vulnerability Indicators

Indicator	Indicator data set	Description	Variable code	Year
Older old	Percentage of the population aged 75+ and living alone.	Number of people aged 75 and over that live alone.	BEV1P75PLUS	2021
Young children	Households: % with children	Percentage of households: couple with children	BEVPAARMKINDHH_P	2021
Disability or limiting illness	Health: % physical impairment	Percentage of the population aged 18 and over with a physical impairment and have severe trouble with at least 1 of 7 activities that concerns hearing, seeing, or moving	WZOESO_P	2020
Mental health issues	Health: % serious psychological problems	Percentage of the population aged 18 and over with serious psychological problems.	WZDEPR_P	2020
Lone parent	Households: single-parent family	Number of household's type: single-parent family	BEVEENOUDERHH	2021
Retired	Income: pension (18-74%)	Percentage of the population aged 18 to 74 that receives a pension income.	PPENSIOEN_1874_P	2021

Provision of unpaid care	Informal caretakers (%)	Percentage of the population aged 19 and over that give informal care for a period of at least three months and / or for at least 8 hours a week at the moment of filling in the questionnaire.	PMANTEL_P	2020
Precarious	Care services (% 18-65 yrs.)	Percentage of 18- to 65-year-olds that use at least 1 care provision (outpatient, indoors/housing and transport) under the Wet Maatschappelijke Ondersteuning (law: WMO).	WZZORG18_65_P	2020
Unemployment	Registered unemployment (%)	The registered unemployment is the percentage of the population aged 15 to 65 that receive one of the following allowances: *Social welfare (wwb levensonderhoud, wwb bbz, oiaw ioaz) *Partially (<80%) unfit for work (AO) *Unemployment law (WW).	PREGWERKL_P	2020
No income	Income: none (%18-74)	Percentage of the population aged 18 to 74 that has no income.	PGEENINK_1874_P	2021
Proficiency in Dutch	First generation non-western	Number of people registered in Amsterdam born in a non-western country.	BEVEGNW	2021
Ethnicity	Migration background: % non-western	Percentage of the population born in Morocco, Turkey, Surinam, the (former*) Dutch Antilles or other African, Latin-American, and Asian countries, or with at least one parent born in Morocco, Turkey, Surinam, the (former*) Dutch Antilles or other African, Latin-American, and Asian countries (Indonesia and Japan excluded).	BEVNW_P	2021
Full-time student	Registered full-time students MBO/HBO/WO (%)	Registered full-time students MBO/HBO/WO (%)	OSTUDMBO_P +OSTUDHBO_P + OSTUDWO_P	2020
Underoccupancy	Occupancy rating of +1 bedrooms (%)		WIMRA 2.7	2021
Shared property	Shared property (%)		WIMRA 2.4	2021
Large household size	Households: 4+ children	Number of households with 4 or more children.	BEVHH4PLUSKIND	2021
Private renting middle class	Private rent: % middle	Percentage of the housing stock with a middle high rent. Determined every year. 2019: 720-1009 euro	WHUURMIDDEN_P	2020

Social housing renting	Social housing rent(%)	Percentage of housing stock with a rent below the limit for rent subsidy. Determined every year. 2019: <720 euro	WHUURTSLG_P	2021
Old heating system	heater / boiler (%)	Percentage of homes that are heated by a gas or wood heater and use a water heater or electric boiler. Numbers are only available for areas with at least 50 respondents.	DBOILER_P	2021
No solar panels	1- Solar / heat pump (%)	Percentage of homes with solar panels and / or a heat pump / hot-water heat recovery system. Numbers are only available for areas with at least 50 respondents.	1- DZON_P	2021
Energy inefficient property	Energielabel E/F/G (%)	Percentage of homes with energy label E, F or G.	WLABELEFG_P	2021
Energy consumption	Average monthly energy costs in proportion to a household's monthly income	Average monthly energy costs/ household's monthly income	WIMRA	2021
Educational level	Education low (%)	Percentage of the population aged 15 to 74 with a low level of education (Maximum level: preparatory vocational education (VMBO)).	BEVOPLLAAG_P	2020
Debt assistance	Debt assistance (%)	Percentage of the population aged 18 and over that receive debt assistance Numbers are only available for areas with at least 10 clients.	ISHV_P	2017
Loneliness	Social cohesion score (1-10)	The score for social cohesion is based on the level of agreement with the following statements: *The people in this neighbourhood hardly know one another. *The people in this neighbourhood have a pleasant relationship. *I live in a nice neighbourhood where there is a lot of solidarity. *I feel at home with the people living in this neighbourhood. The reactions are recoded to report marks. Numbers are only available for areas with at least 50 respondents. Except for the numbers about buurten, those are a three-year-average based on at least 30 respondents.	10 - LSOCCOH_R	2021

Participation	Political influence (%)	Percentage of the population aged 18 and over that (totally) agree with the statement: I have influence on the actions of the district council. Numbers are only available for areas with at least 50 respondents.	BINVLOED_P	2019
Satisfaction score communication	Understands written information by municipality (%)	Percentage of the population aged 18 and over that are able to understand letters and other written information of the municipality without the help of others	DSCHRIFT_P	2019
Gender	Gender: % female	Female population percentage on January 1st of the base year.	BEVVROUW_P	2021
Unwillingness to pay more rent or invest in renovation	Willingness to invest or pay more rent to live in renovated building (%)		WIMRA	2021

F.2 Pre-Processing

In this section an overview is provided of the various step taken to pre-process the data are discussed. missing values and how they were dealt with. Moreover, the shape of the final 'clean' dataframe is shown.

F.2.1 Missing Values

As the goal of the socio-spatial analysis was to gain insights into which characteristics enhance the vulnerability to energy poverty for various groups in Amsterdam the socio-spatial distribution was analysed. To be able to conduct this analysis it was important to deal with missing values. Therefore, at first the number of missing values were inspected to gain insights into which variables contain missing values. Figure F.1 shows the total number of missing values for each indicator in the BBGA and WIMRA dataset. The geographical dataset did not contain any missing values, shown in Figure F.2.

```
sdname                              0
Wijkcode                            0
neighborhoodcodename                0
neighborhoodname                    0
Older_old                           0
Young_children                      0
Lone_parent                         0
Mental_health_issues                0
Disability                          0
Precarious                          2
Proficiency_in_Dutch                0
Ethnicity                           0
Large_household_size                0
Private_renting                    13
Social_housing_renting             13
Gender                              0
Energy_inefficient_property         0
Old_heating_system                 15
No_solar_panels                    14
No_income                           1
Retired                             3
Provision_of_unpaid_care            0
Loneliness                         11
Debt_assistance                     0
Energy_consumption                 17
Shared_property                    15
Under_occupancy                    14
Full_time_student                   2
Satisfaction_rate_communication     0
Social_participation                0
Unemployment                        3
Educational_level                   1
Unwillingness_invest_EE            15
dtype: int64
```

Figure F.1 Overview of Missing Values for the BBGA and WIMRA Data Set

```
Wijkcode          0
Wijknaam          0
Stadsdeelcode     0
Oppervlakte_m2    0
WijkID            0
geometry          0
dtype: int64
```

Figure F.2 Missing Values for the Geographical Data Set

To select a strategy, the distribution of the variables that contain missing values was inspected. Based on the distribution of these variables an accompanying strategy was selected. Figure F.3 the distribution of the variables that contain missing values.

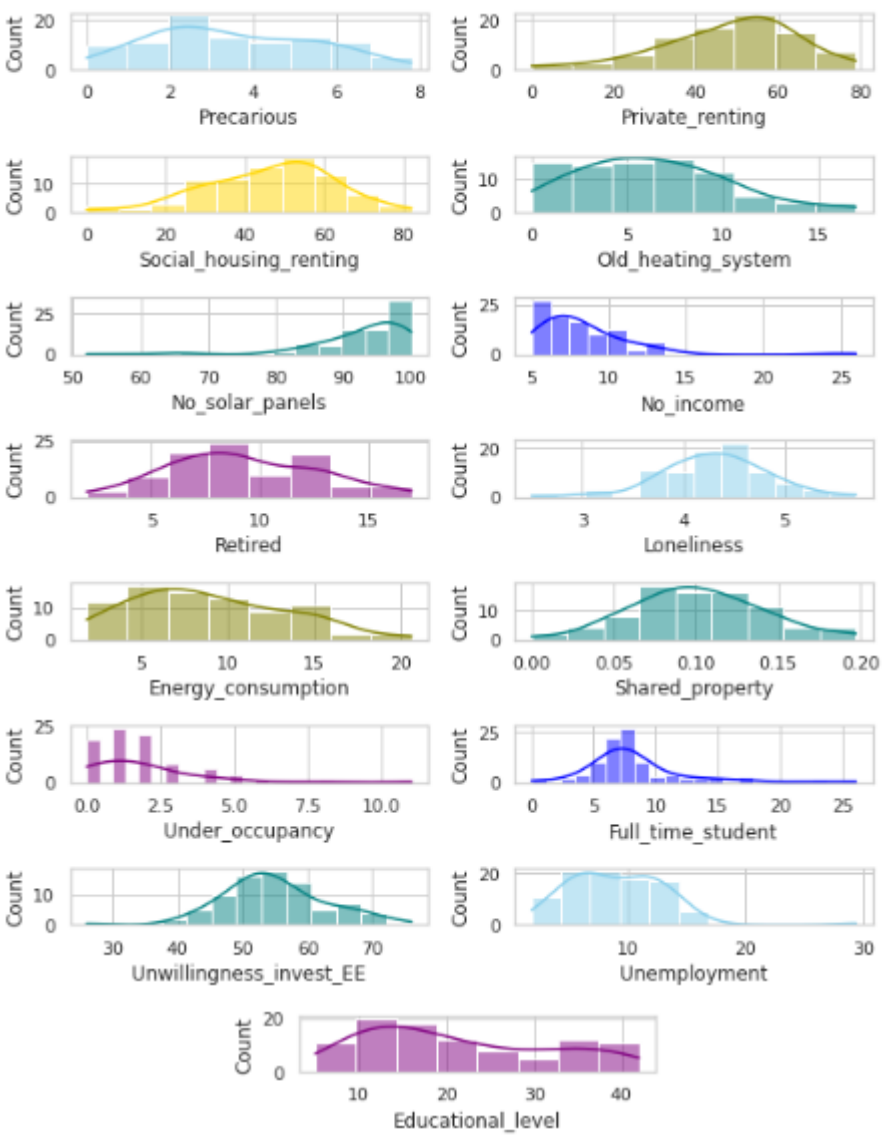


Figure F.3 Distribution of Variables with Missing Values

Precarious, private renting, social housing renting, old heating system, retired, loneliness, energy consumption, shared property, educational level and unwillingness to invest in energy efficiency are not heavenly skewed and approach a normal distribution thus it is decided to replace the missing values for the variables with the mean.

The variables unemployment, under occupancy, full-time student, and no income are skewed to the left, whereas no solar panels is skewed to the right. Therefore, it is decided to replace these missing values with the median.

As shown in Figure F.4, the dataframe did not contain any missing values anymore after replacing the missing values with the median or mean.

```
Neighborhood_Code                0
Districtcode                     0
geometry                         0
Districtname                     0
Older_old                        0
Young_children                   0
Lone_parent                      0
Mental_health_issues             0
Disability                       0
Precarious                       0
Proficiency_in_Dutch             0
Ethnicity                        0
Large_household_size             0
Private_renting                  0
Social_housing_renting           0
Gender                           0
Energy_inefficient_property      0
Old_heating_system               0
No_solar_panels                  0
No_income                        0
Retired                          0
Provision_of_unpaid_care         0
Loneliness                       0
Debt_assistance                  0
Energy_consumption               0
Shared_property                  0
Under_occupancy                  0
Full_time_student                0
Satisfaction_rate_communication  0
Social_participation             0
Unemployment                     0
Educational_level                0
Unwillingness_invest_EE          0
dtype: int64
```

Figure F.4 Overview of Missing Values for the Final Dataframe

After dealing with the missing values and following all the pre-processing steps, the final dataframe contains all the neighbourhoods in the rows of the dataframe and all the 'properties' in the columns Figure F.5 shows the format of the cleaned dataframe.

neighborhoodname	Neighborhood_Code	Districtcode	geometry	Districtname	Older_old	Young_children	Lone_parent	Mental_health_issues	Disability	Precarious	...
Burgwallen-Oude Zijde	A00	A	POLYGON ((4.90242 52.37715, 4.90242 52.37715, ...	A Centrum	73	4.2	110	8	9	3.1	...
Burgwallen-Nieuwe Zijde	A01	A	POLYGON ((4.89131 52.37632, 4.89391 52.37870, ...	A Centrum	72	4.0	72	8	8	2.8	...
Grachtengordel-West	A02	A	POLYGON ((4.88478 52.37653, 4.88817 52.38022, ...	A Centrum	172	9.0	140	6	7	0.4	...
Grachtengordel-Zuid	A03	A	POLYGON ((4.89388 52.36729, 4.89394 52.36724, ...	A Centrum	150	10.1	117	6	7	0.7	...
Nieuwmarkt/Lastage	A04	A	MULTIPOLYGON (((4.90291 52.37643, 4.90352 52.3...	A Centrum	386	7.9	356	7	12	1.4	...

5 rows × 33 columns

Figure F.5 Overview of Final Cleaned Dataframe

F.3 Exploratory Data Analysis (EDA)

EDA was carried out to gain an understanding of the properties of the data and to maximize insights into the dataset, visualize potential relations between indicators, and detect outliers. At first general descriptives were inspected, such as the mean, minimum, and maximum, to gain insights into the distribution and type of indicators in the data frame; from this analysis, it became apparent that the data frame contained 'objects' for the geographical information and all the vulnerability indicators were numerical variables (floats or integers). As the goal was to conduct PCA, it is important to gain insights into the correlation between variables to assess whether the indicators are correlated and thus suitable for performing a PCA analysis. A heatmap was made to visualize the relationship between vulnerability indicators, as shown in Figure F.6.

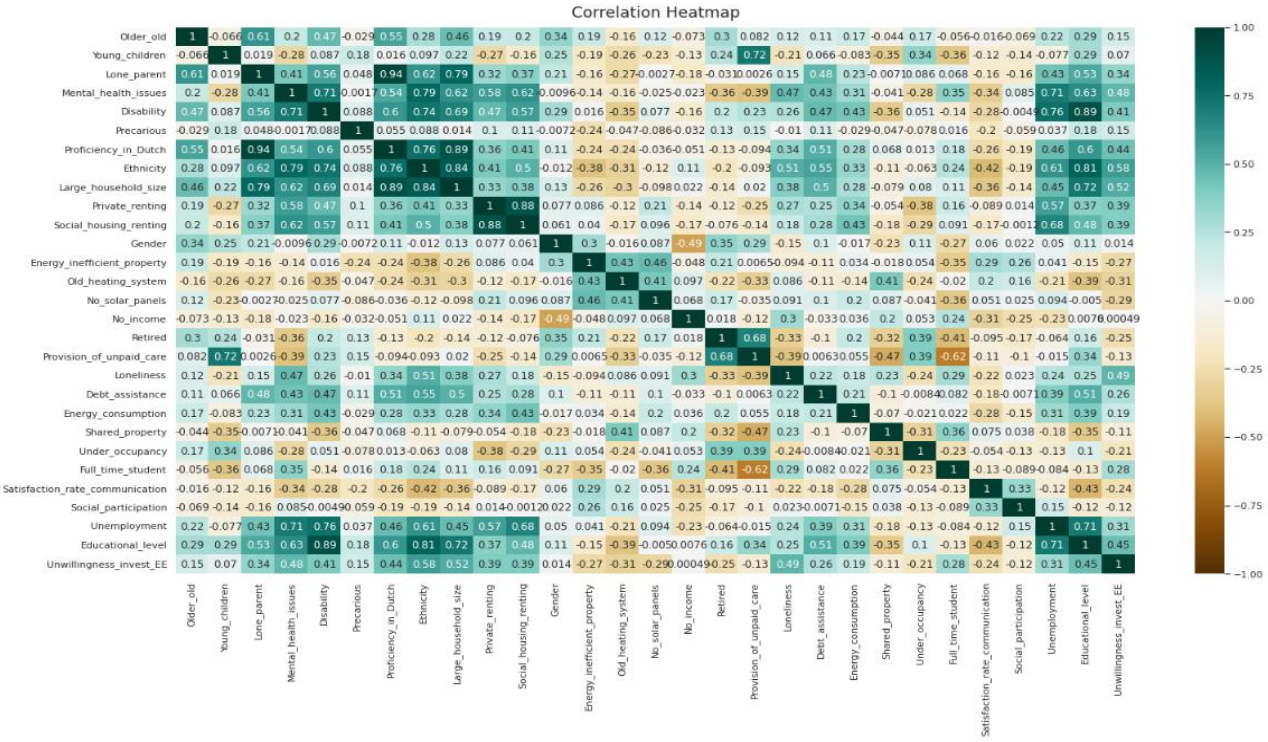
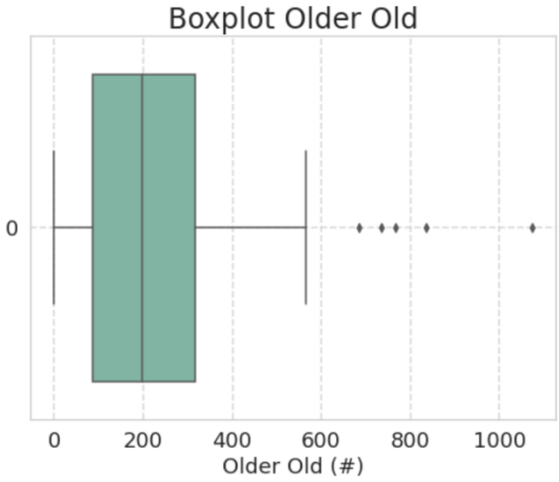
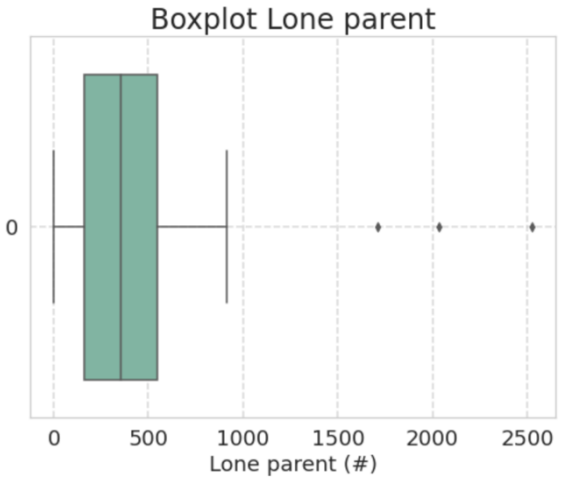


Figure F.6 Heatmap Representing the Correlations Between Variables

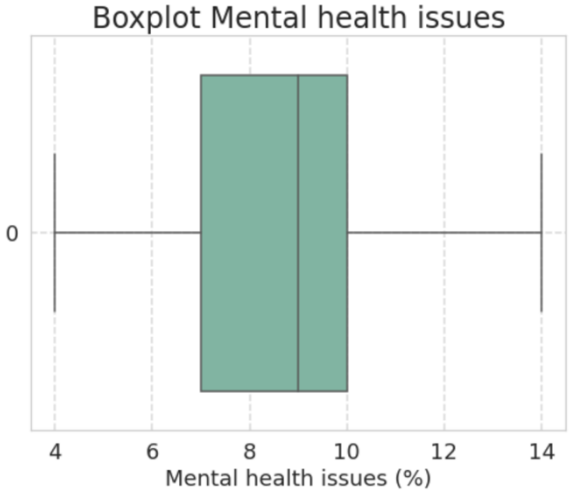
As MIT Critical Data (2016) recommended, boxplots were made to gain insights into the distribution of the vulnerability indicators and detect outliers. The boxplots are shown in Figure F.7. From the boxplots; it can be concluded that the dataset contains outliers for various vulnerability indicators; however, as these outliers represent real values that are useful for gaining insights into the spatial distribution of vulnerability indicators, it was decided to retain the outliers and not deal with them.


Boxplot Older Old
0
0
200
400
600
800
1000
Older Old (#)

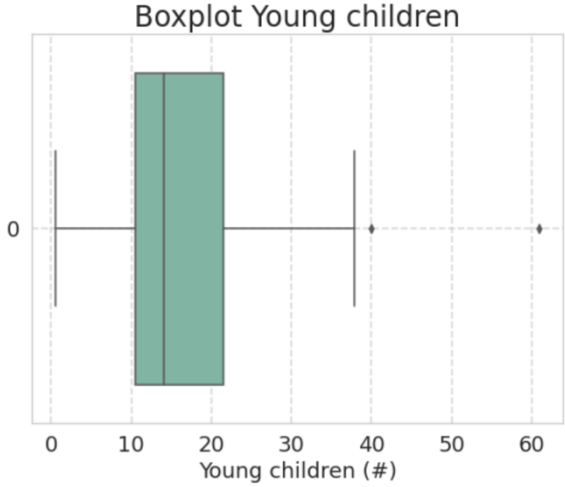
(a)


Boxplot Lone parent
0
0
500
1000
1500
2000
2500
Lone parent (#)

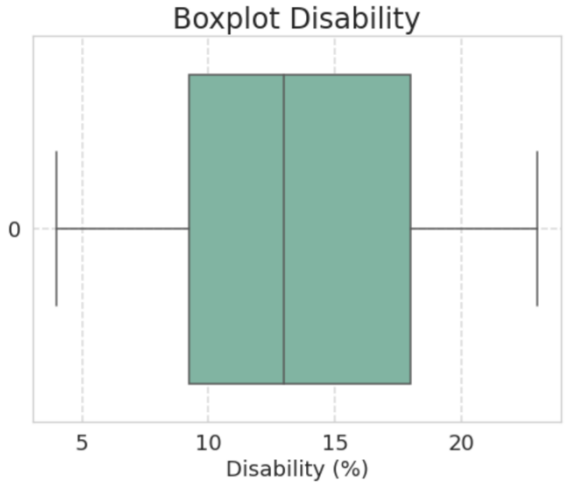
(b)


Boxplot Mental health issues
0
4
6
8
10
12
14
Mental health issues (%)

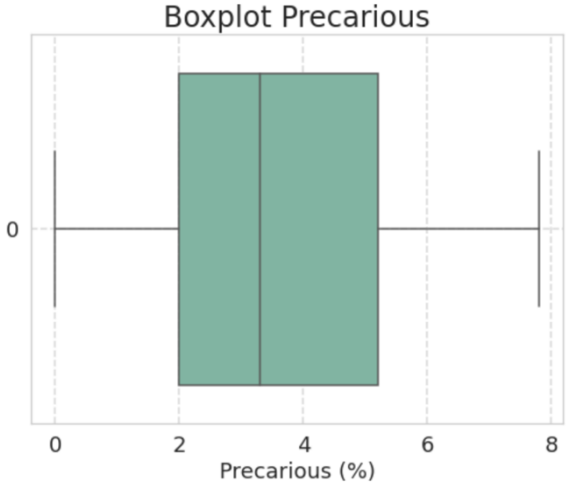
(c)


Boxplot Young children
0
0
10
20
30
40
50
60
Young children (#)

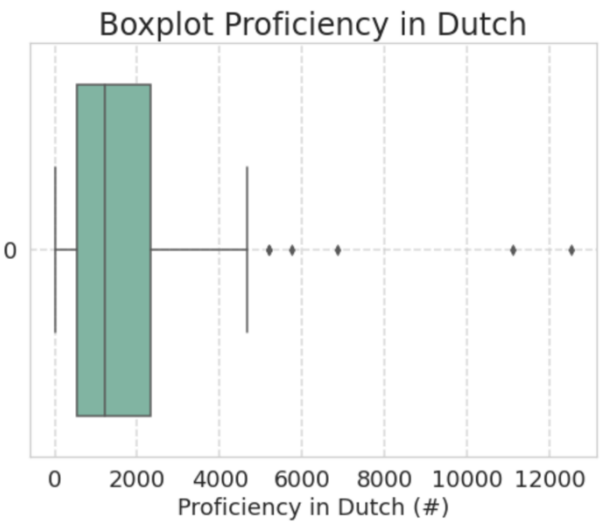
(d)


Boxplot Disability
0
5
10
15
20
Disability (%)

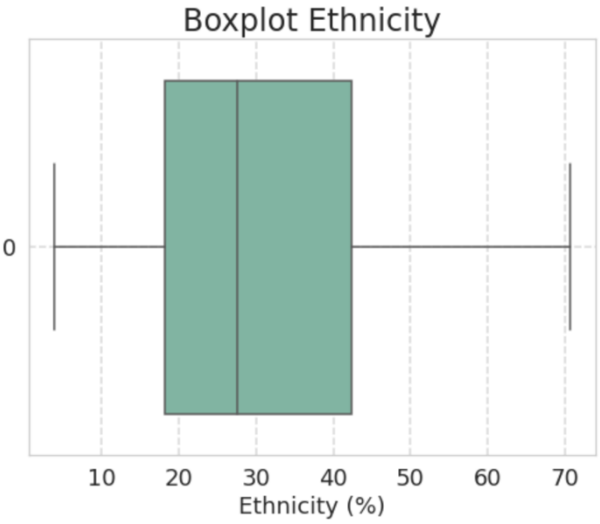
(e)


Boxplot Precarious
0
0
2
4
6
8
Precarious (%)

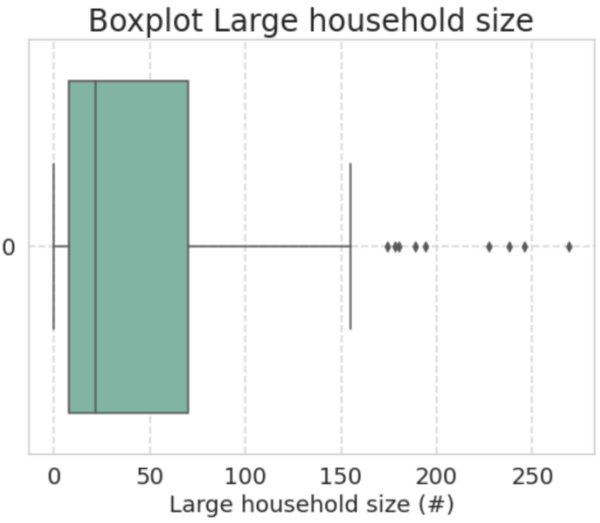
(f)


Boxplot Proficiency in Dutch
0
0
2000
4000
6000
8000
10000
12000
Proficiency in Dutch (#)

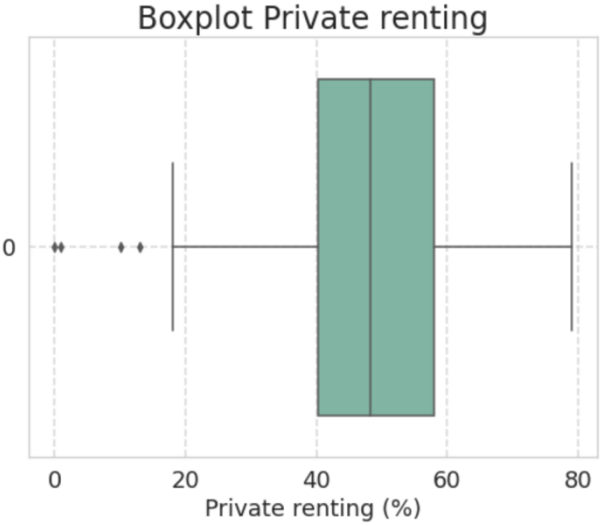
(g)


Boxplot Ethnicity
0
10
20
30
40
50
60
70
Ethnicity (%)

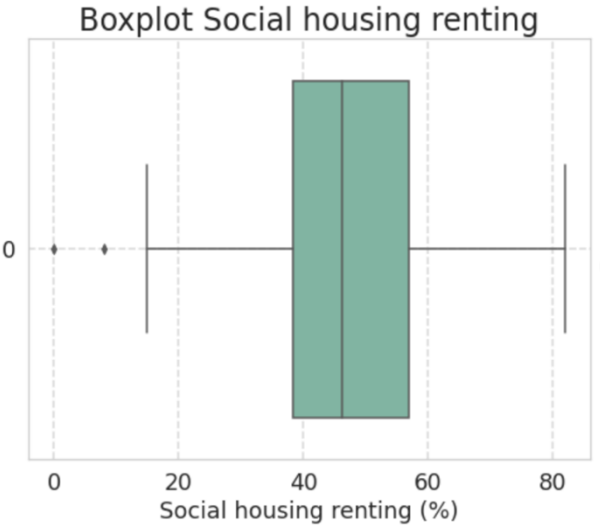
(h)


Boxplot Large household size
0
0
50
100
150
200
250
Large household size (#)

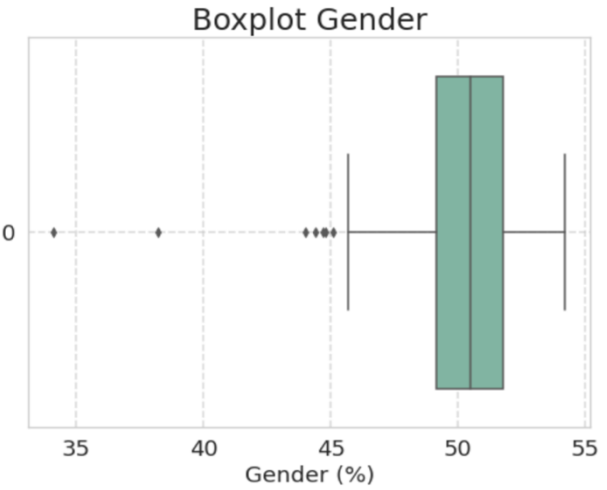
(i)


Boxplot Private renting
0
0
20
40
60
80
Private renting (%)

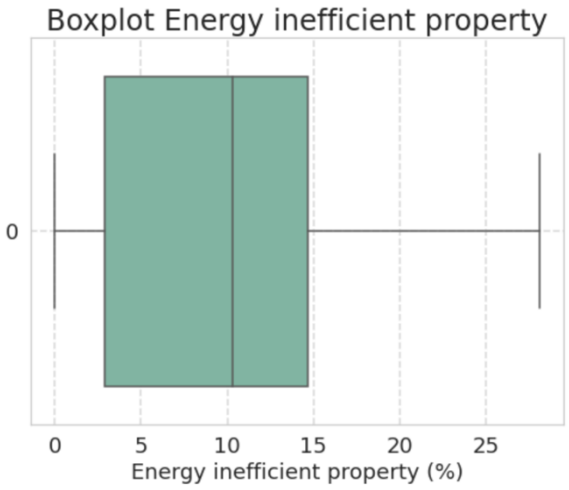
(j)


Boxplot Social housing renting
0
0
20
40
60
80
Social housing renting (%)

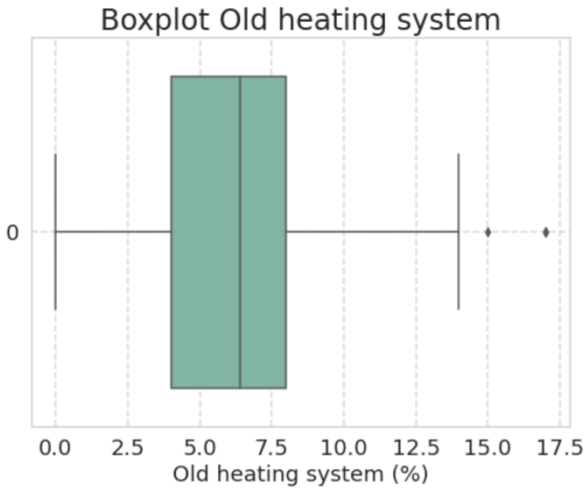
(k)


Boxplot Gender
0
35
40
45
50
55
Gender (%)

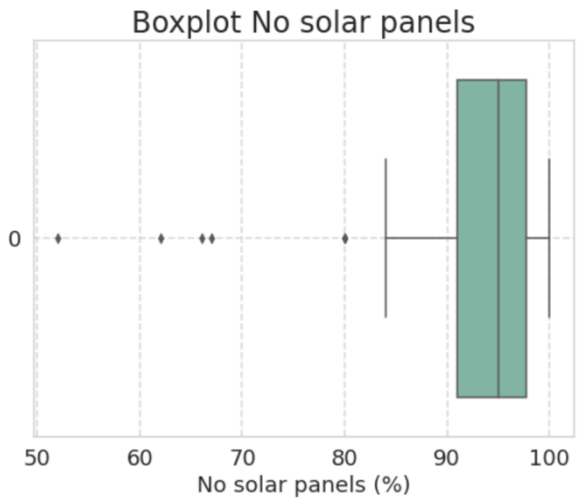
(l)


Boxplot Energy inefficient property
0
0
5
10
15
20
25
Energy inefficient property (%)

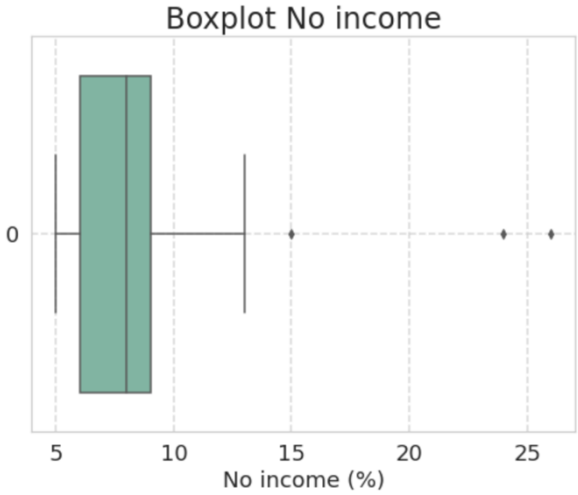
(m)


Boxplot Old heating system
0
0.0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
Old heating system (%)

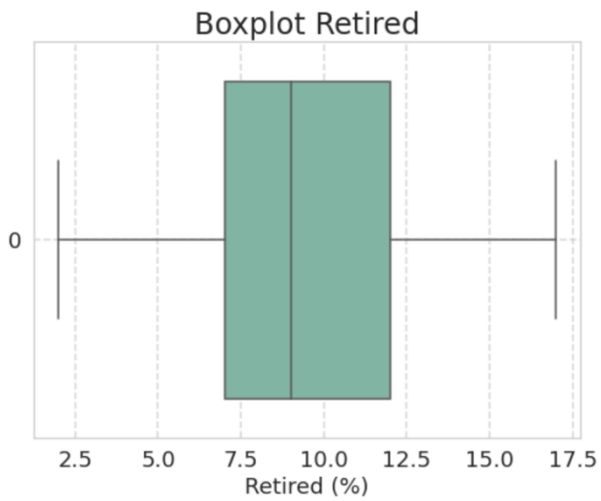
(n)


Boxplot No solar panels
0
50
60
70
80
90
100
No solar panels (%)

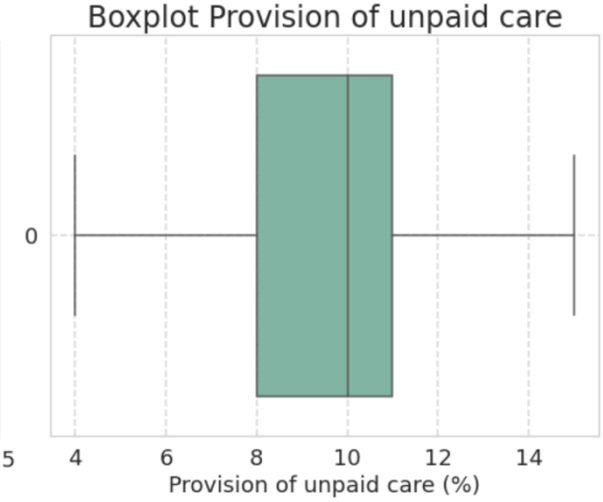
(o)


Boxplot No income
0
5
10
15
20
25
No income (%)

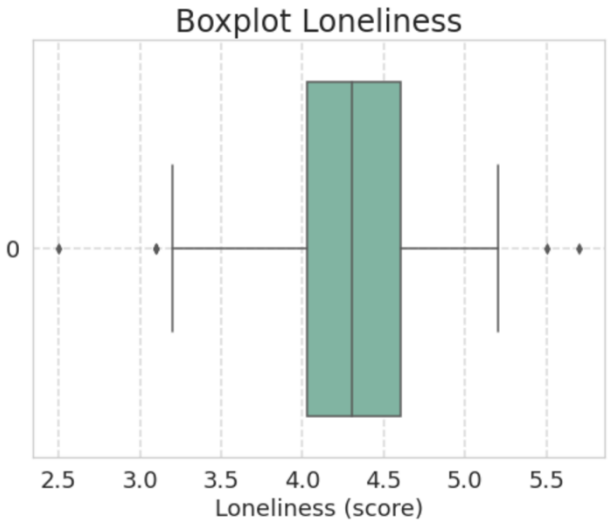
(p)


Boxplot Retired
0
2.5
5.0
7.5
10.0
12.5
15.0
17.5
Retired (%)

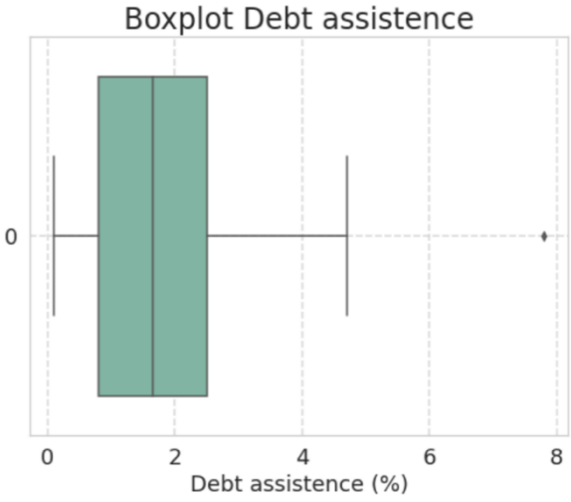
(q)


Boxplot Provision of unpaid care
0
4
6
8
10
12
14
Provision of unpaid care (%)

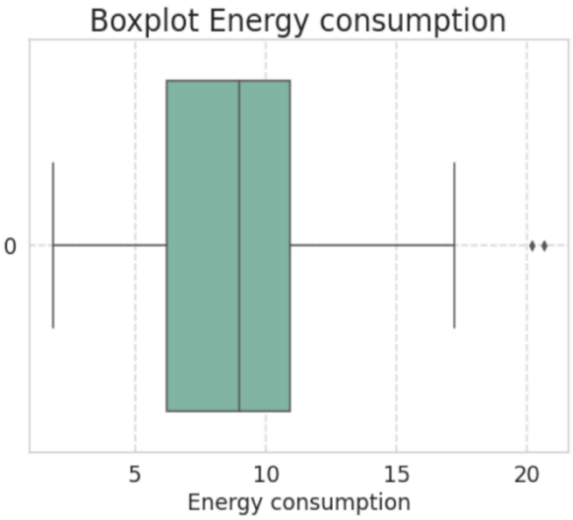
(r)


Boxplot Loneliness
0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
Loneliness (score)

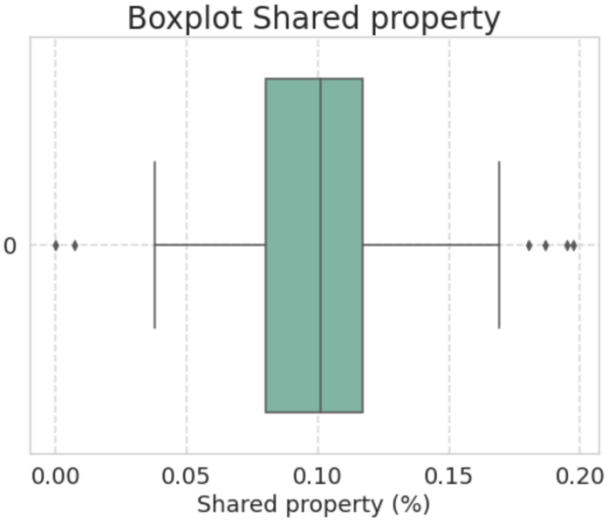
(s)


Boxplot Debt assistence
0
0
2
4
6
8
Debt assistence (%)

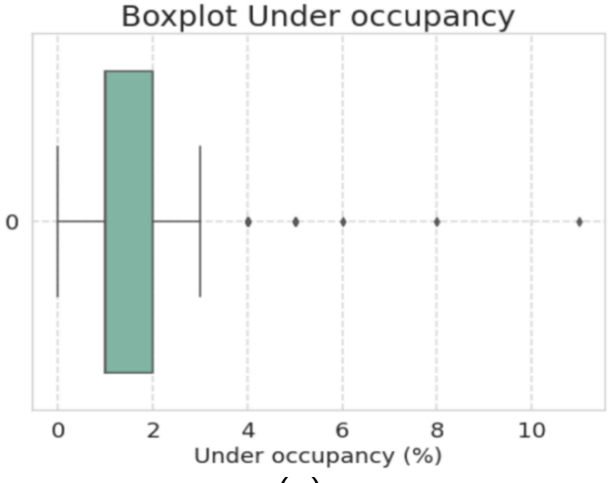
(t)


Boxplot Energy consumption
0
5
10
15
20
Energy consumption

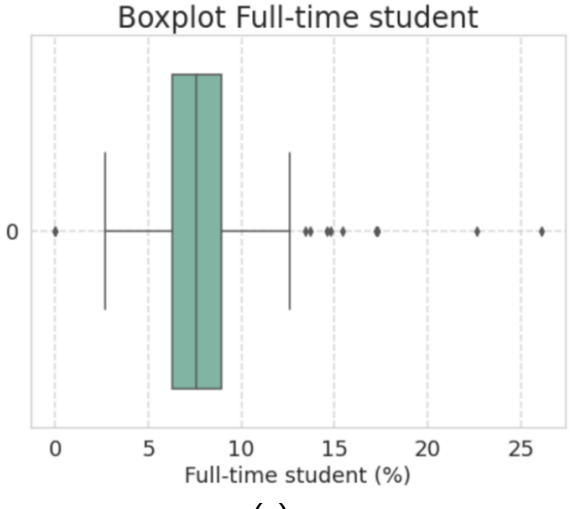
(u)


Boxplot Shared property
0
0.00
0.05
0.10
0.15
0.20
Shared property (%)

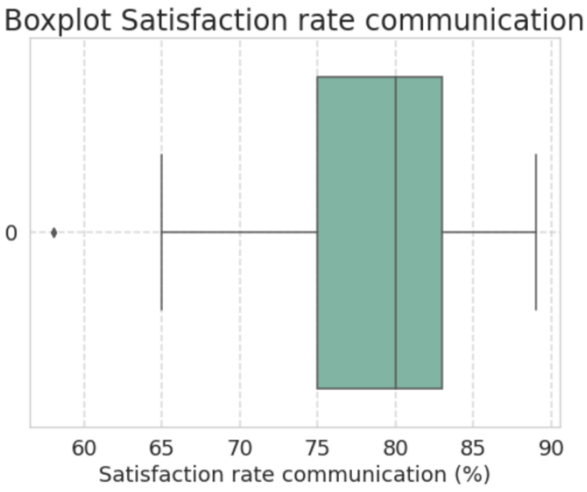
(v)


Boxplot Under occupancy
0
0
2
4
6
8
10
Under occupancy (%)

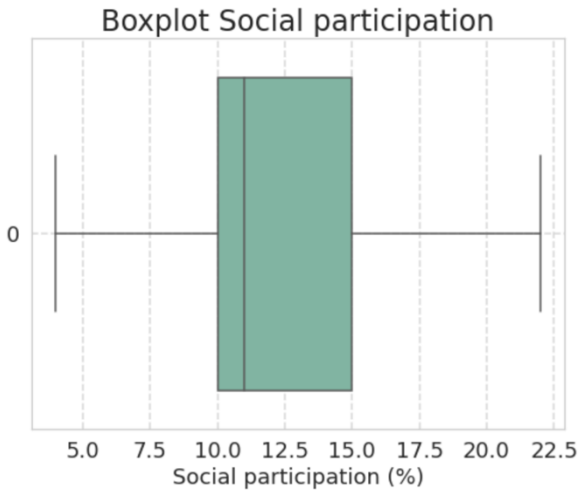
(w)


Boxplot Full-time student
0
0
5
10
15
20
25
Full-time student (%)

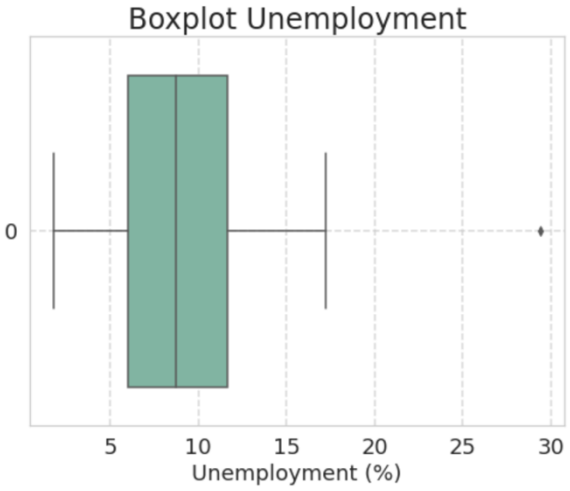
(x)



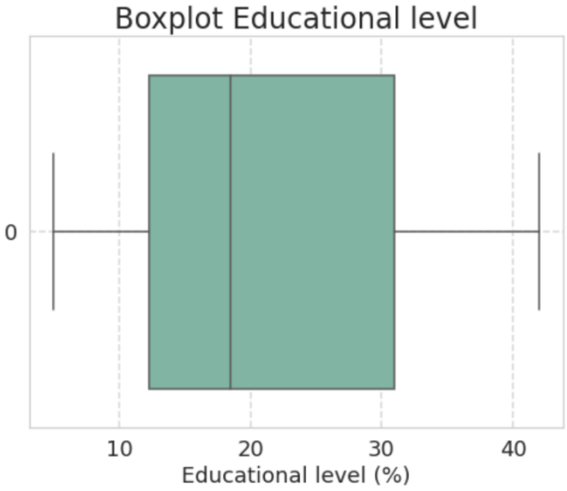
(y)



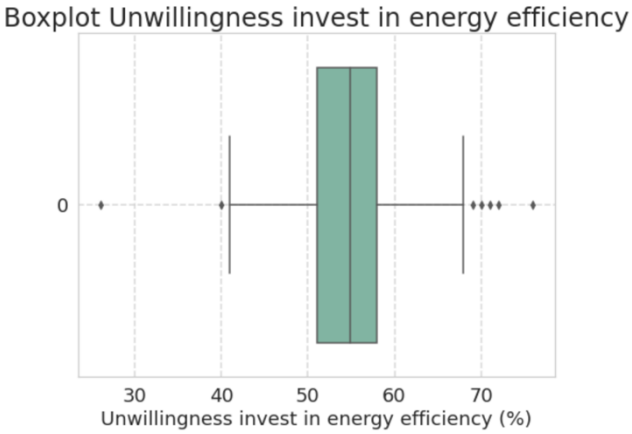
(z)



(a1)



(a2)



(a3)

Figure F.7 Boxplots for All Vulnerability Indicators

F.4 Exploratory Spatial Data Analysis (ESDA)

To gain insights into how the various indicators are geographically distributed across Amsterdam, ESDA was carried out. ESDA tools provide functions to describe and visualize spatial distributions, enhancing the discovery of spatial patterns and spatial outliers (Steiniger & Hunter, 2013). ESDA was performed using the Pysal package. In this research, the spatial distribution of all vulnerability indicators was explored. As plotting the spatial data requires defining the number of clusters that you want the data to split into, Sklearn's K-means package was used as it tries to minimize the distance between the points in a similar cluster. To enhance the understanding of the number of clusters (=k) used in the analysis, the Elbow method was used, whereby the number of clusters used in the analysis depends on the point where there is the sharpest drop and increasing the number of clusters does not impact the distortion score (Scikit, n.d.). As shown in Figure F.8, the sharpest drop can be seen at k=3, and after k=5, the impact of the number of clusters added is negligible. As the goal is to identify spatial patterns, it is decided to select five clusters for spatial mapping.

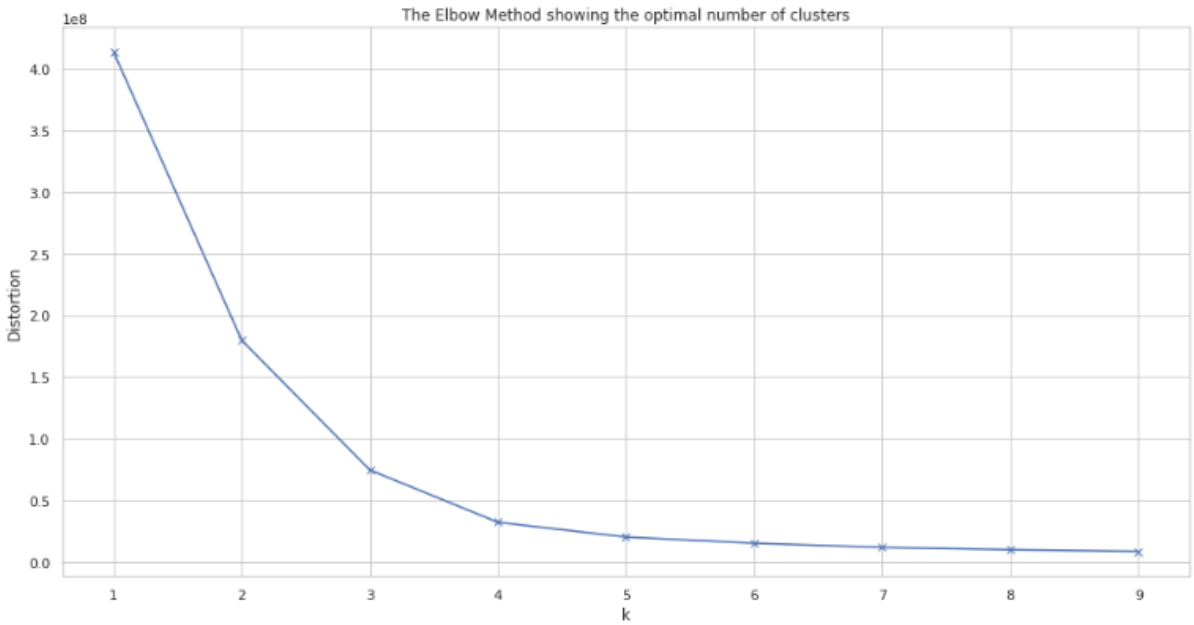


Figure F.8 Results K-means Clustering for ESDA

In the following section the spatial distribution of each vulnerability indicator is presented to gain insights in the distribution of each vulnerability indicator across Amsterdam.

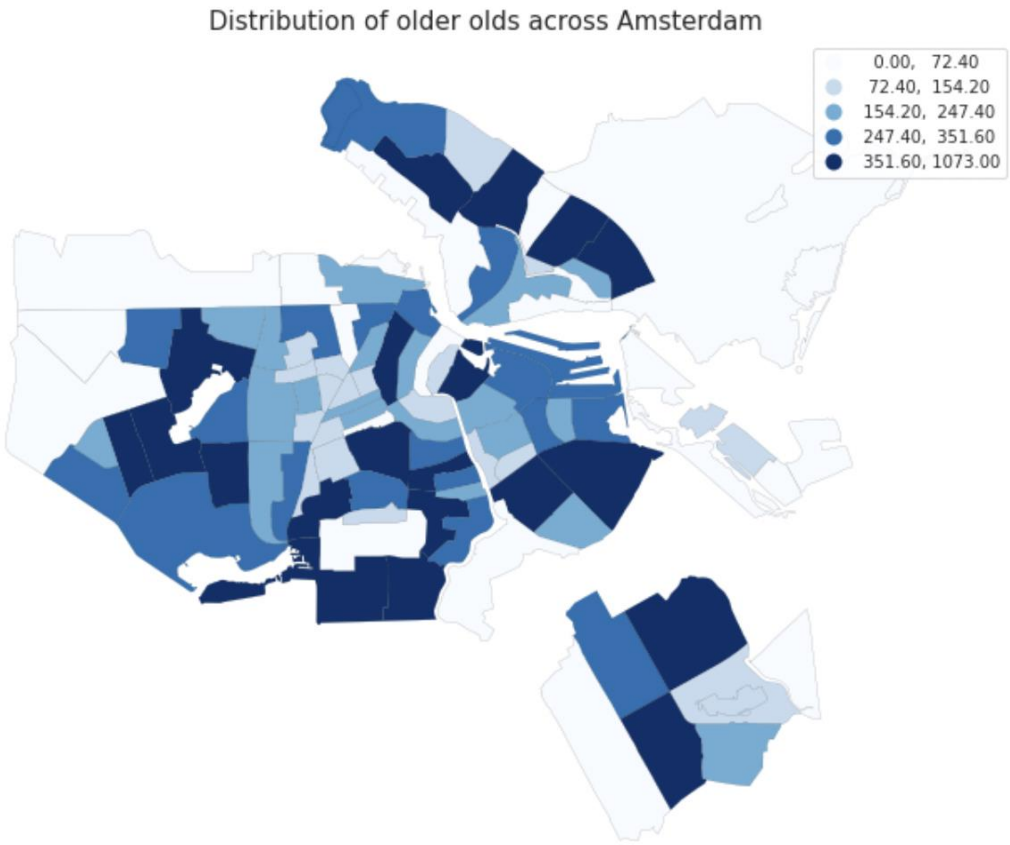


Figure F.9 Spatial Distribution of Older Olds Across Amsterdam

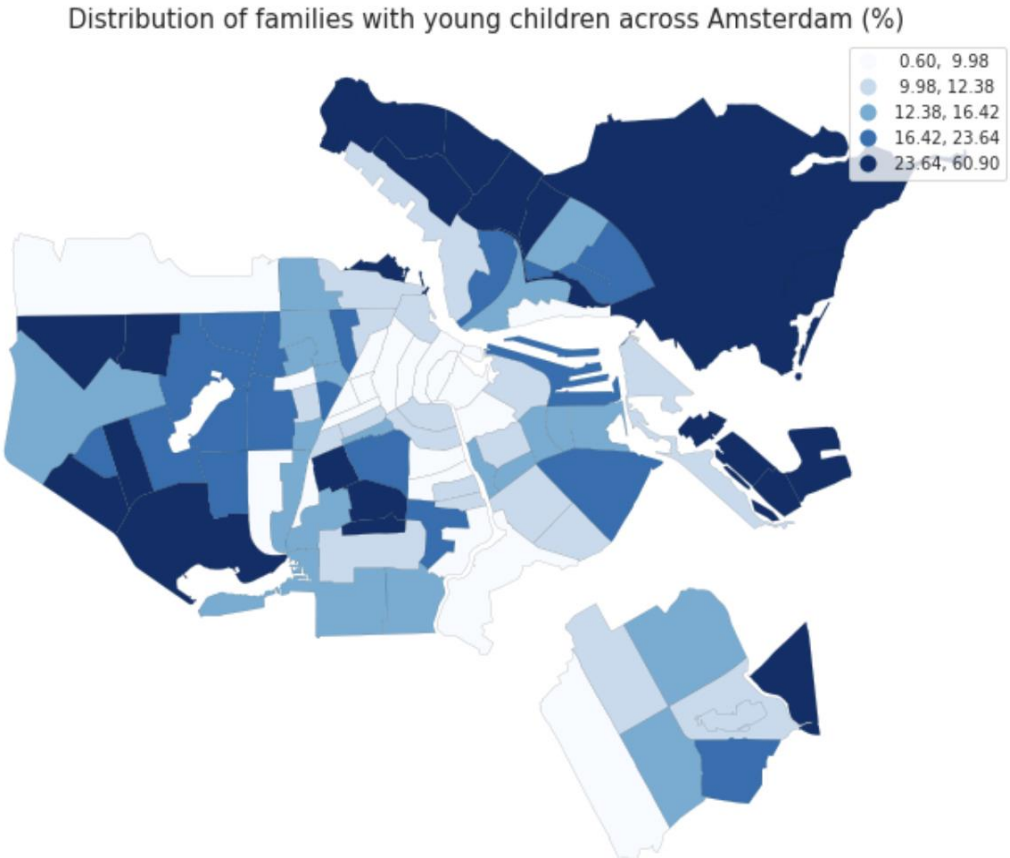


Figure F.10 Spatial Distribution of Families with Young Children Across Amsterdam

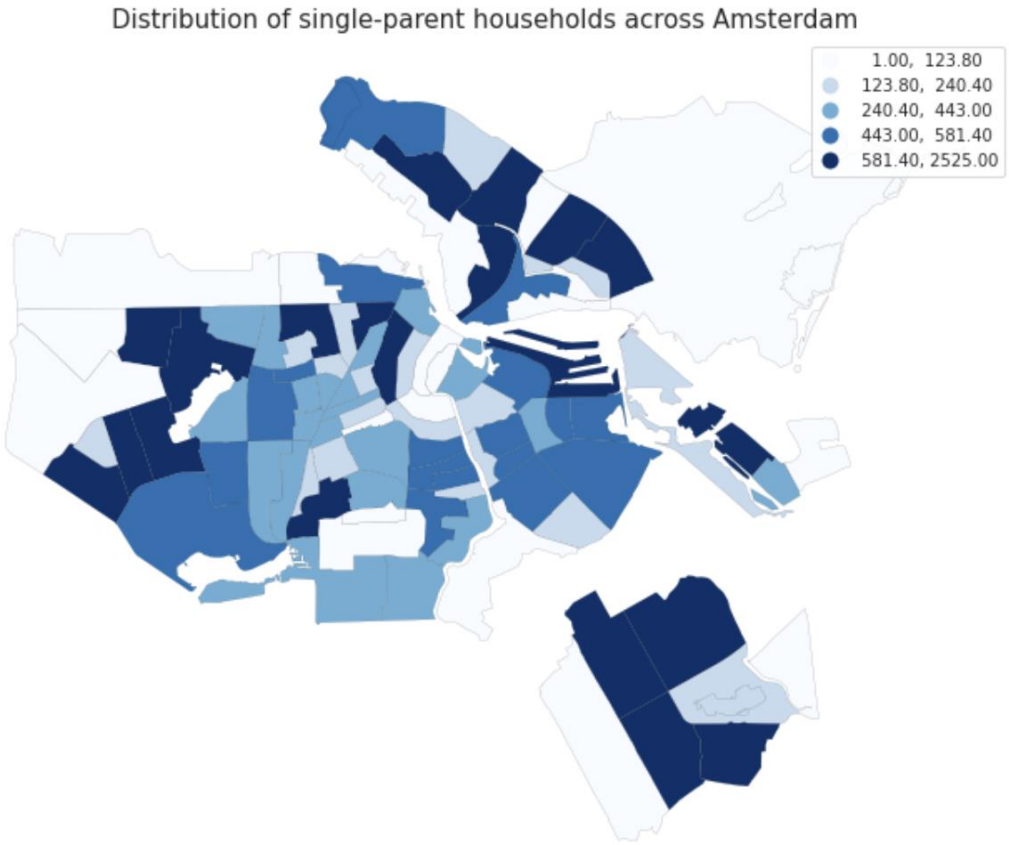


Figure F.11 Spatial Distribution of Single-Parent Households Across Amsterdam

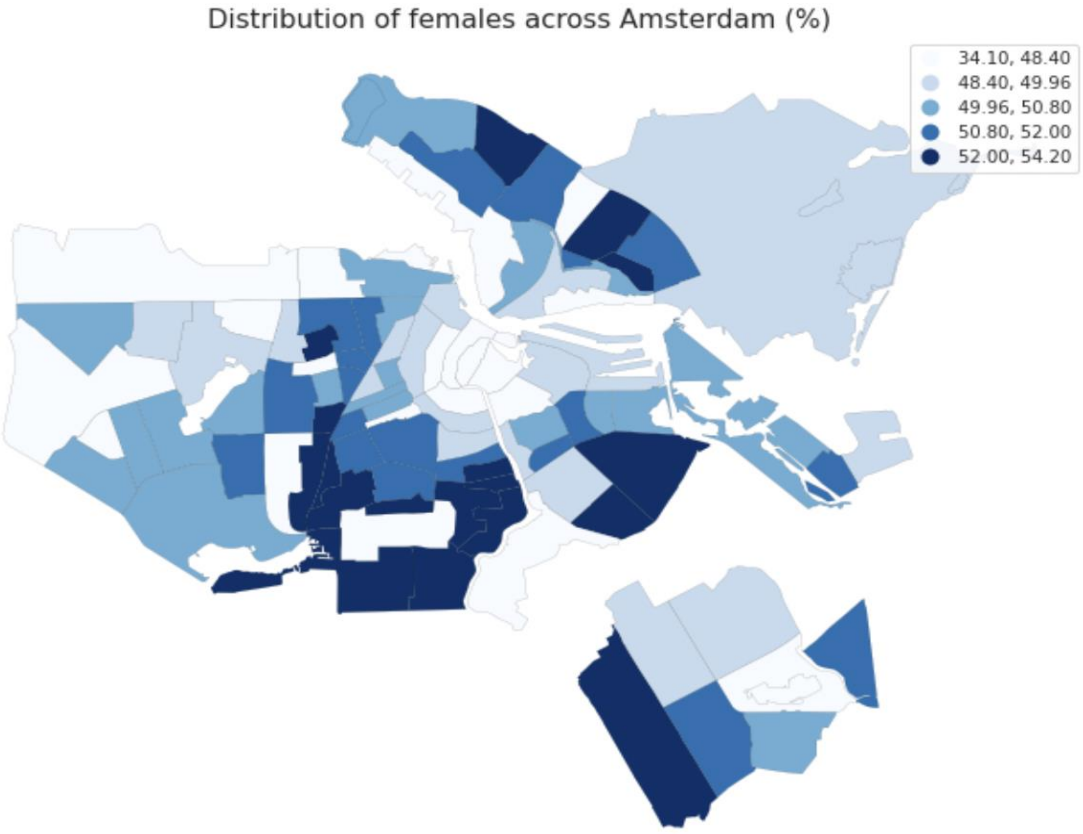


Figure F.12 Spatial Distribution of Females Across Amsterdam

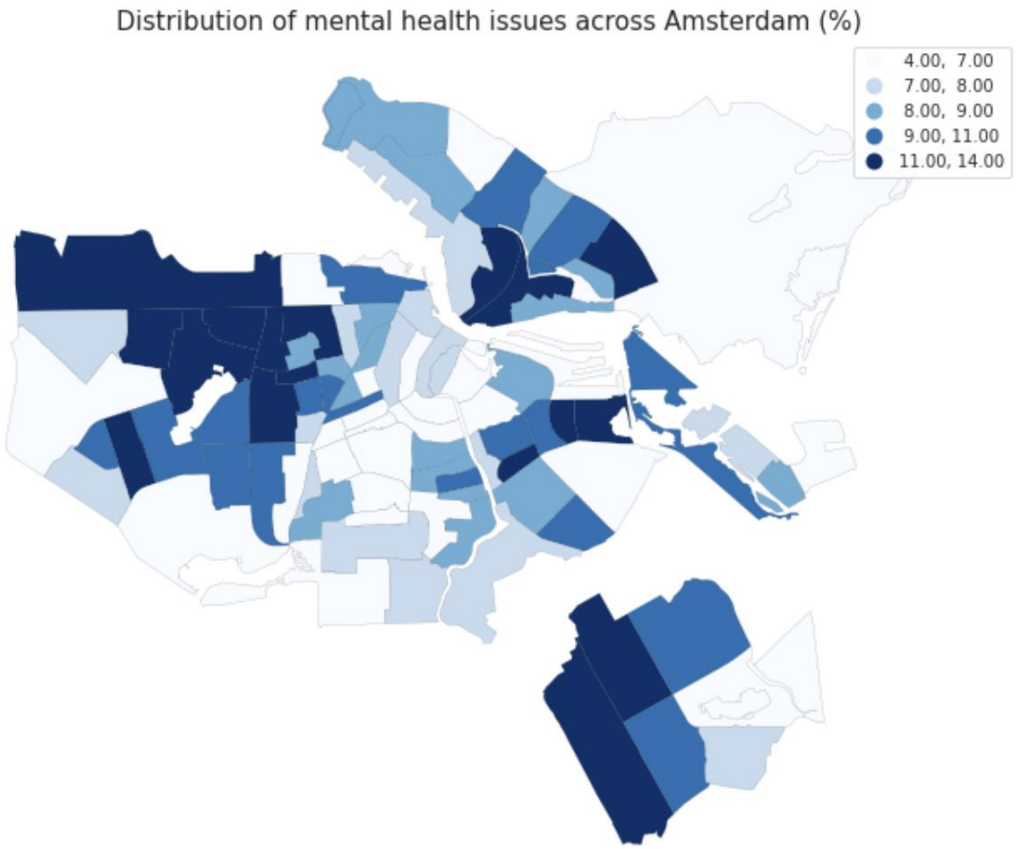


Figure F.13 Spatial Distribution of Mental Health Issues Across Amsterdam

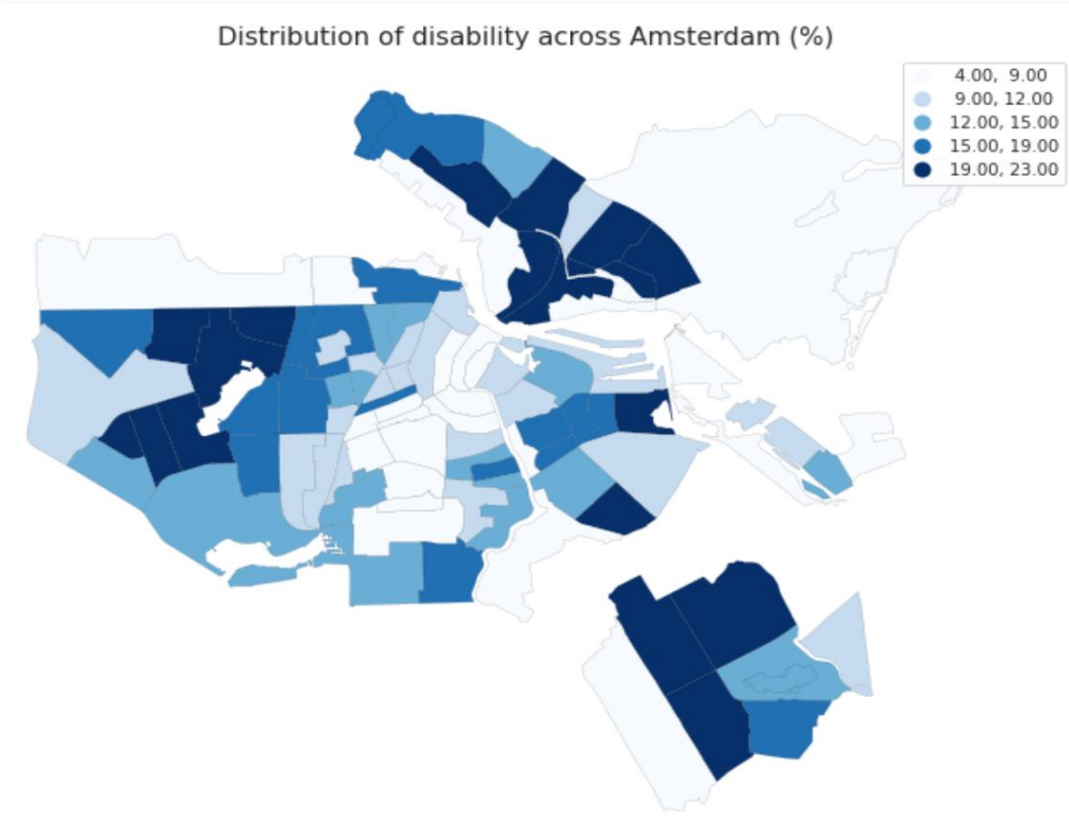


Figure F.14 Spatial Distribution of Disability Across Amsterdam

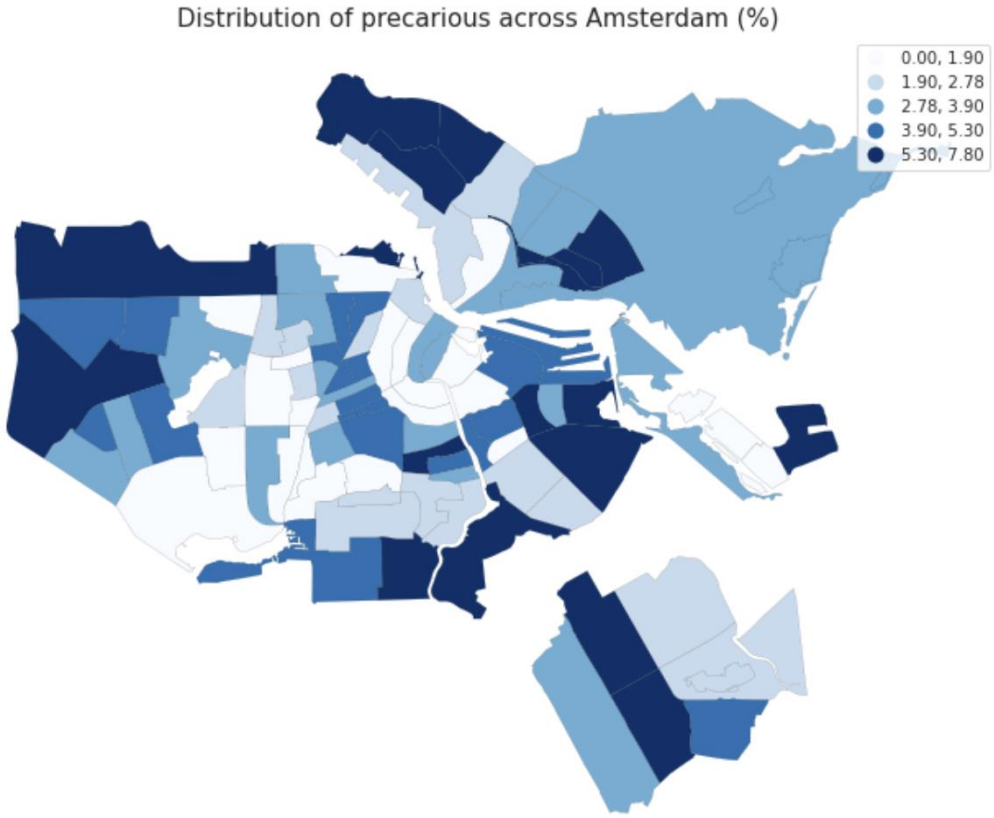


Figure F.15 Spatial Distribution of Precarious Across Amsterdam

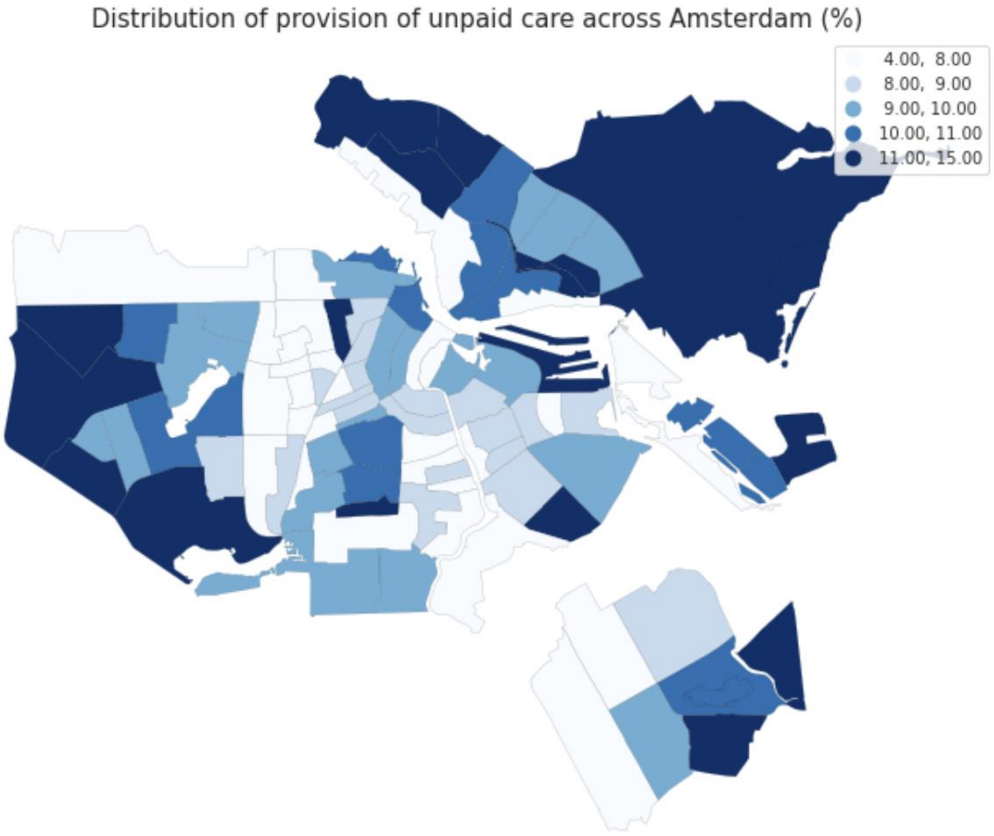


Figure F.16 Spatial Distribution of Unpaid Care Across Amsterdam

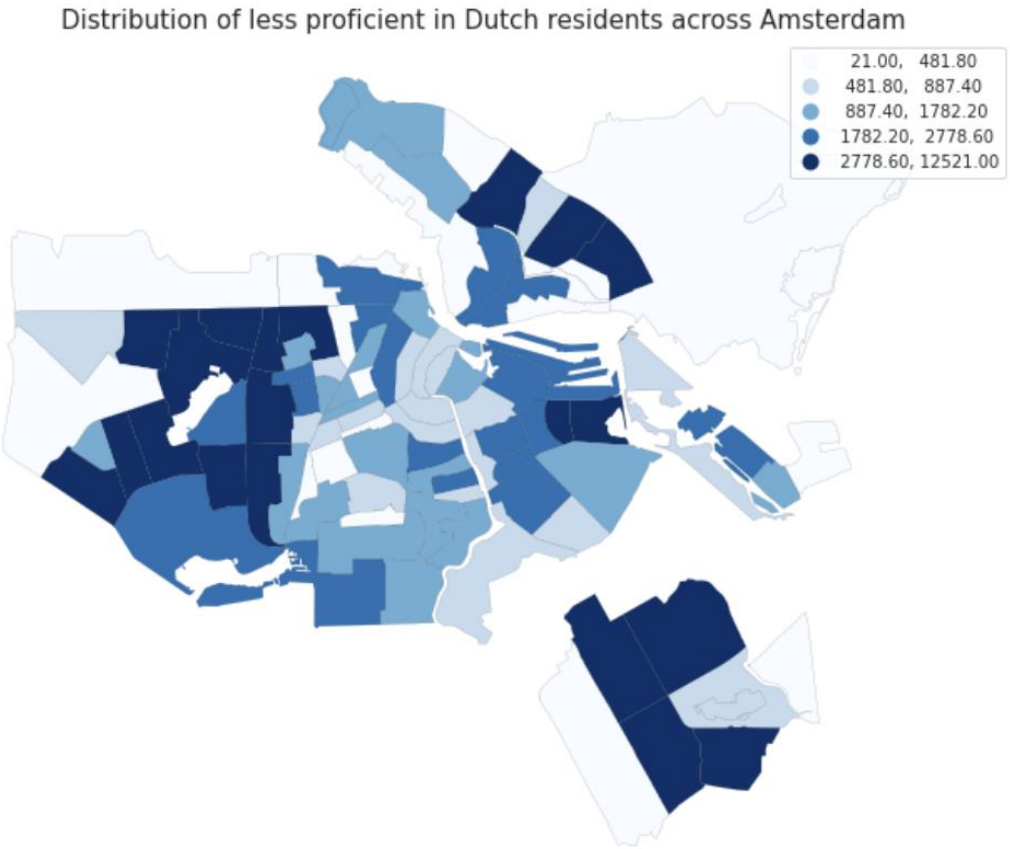


Figure F.17 Spatial Distribution of Low Proficiency in Dutch Across Amsterdam

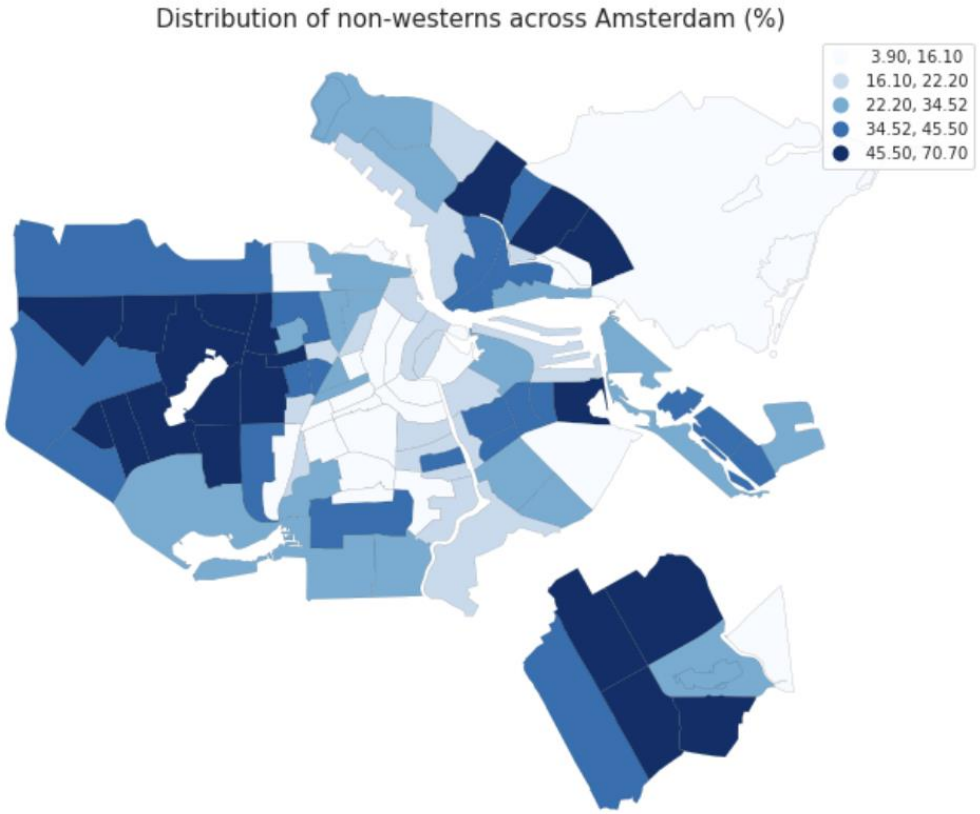


Figure F.18 Spatial Distribution of Non-Western Families Across Amsterdam

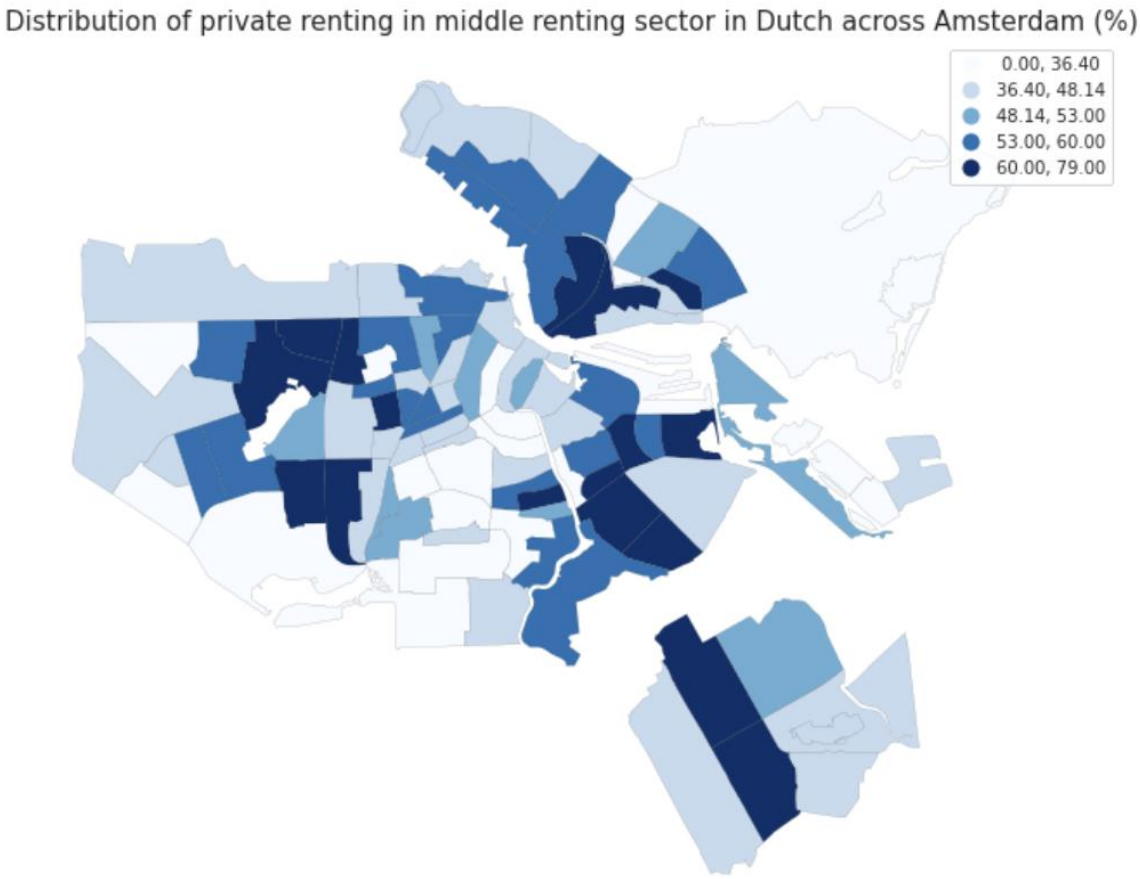


Figure F.19 Spatial Distribution of Middle Private Sector Across Amsterdam

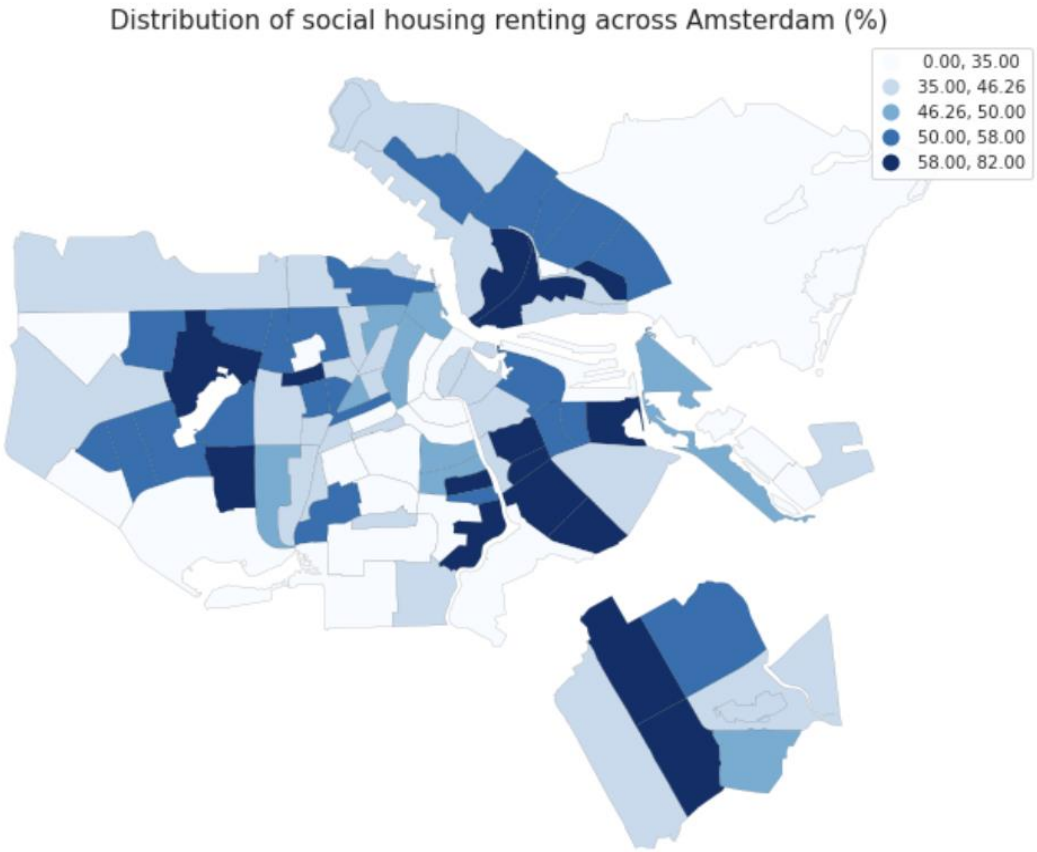


Figure F.20 Spatial Distribution of Social Housing Across Amsterdam

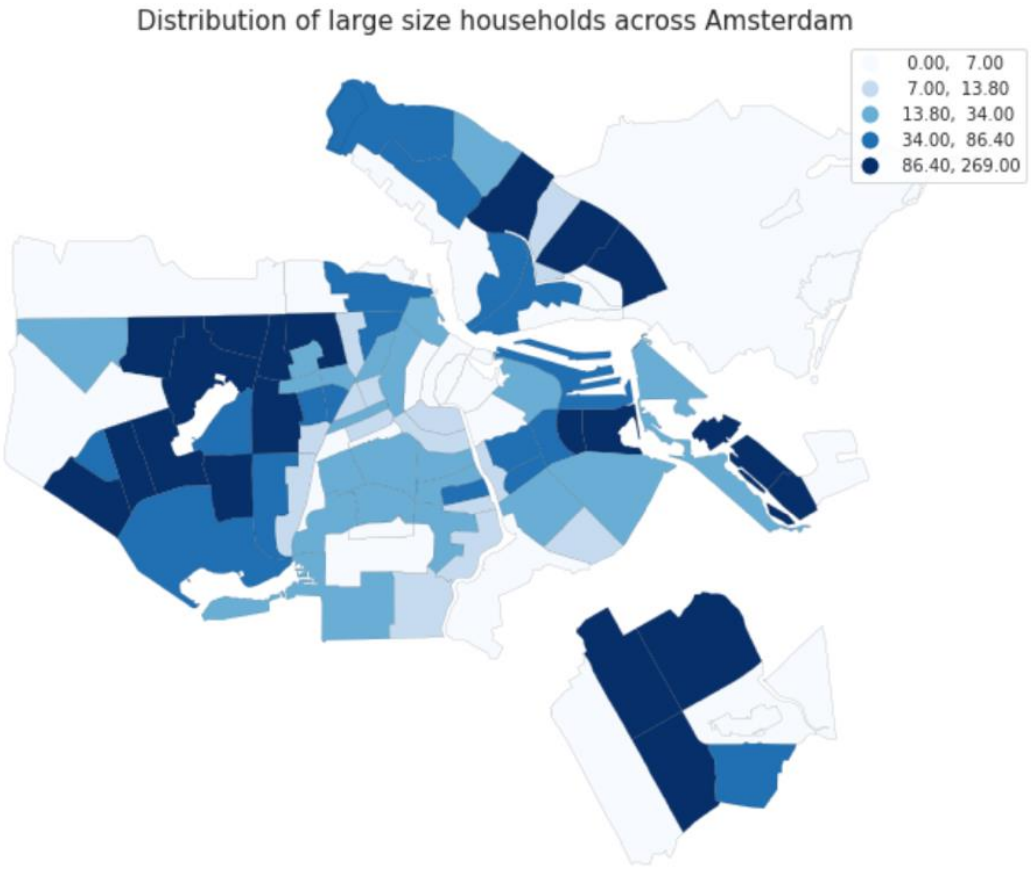


Figure F.21 Spatial Distribution of Large Sized Household's Across Amsterdam

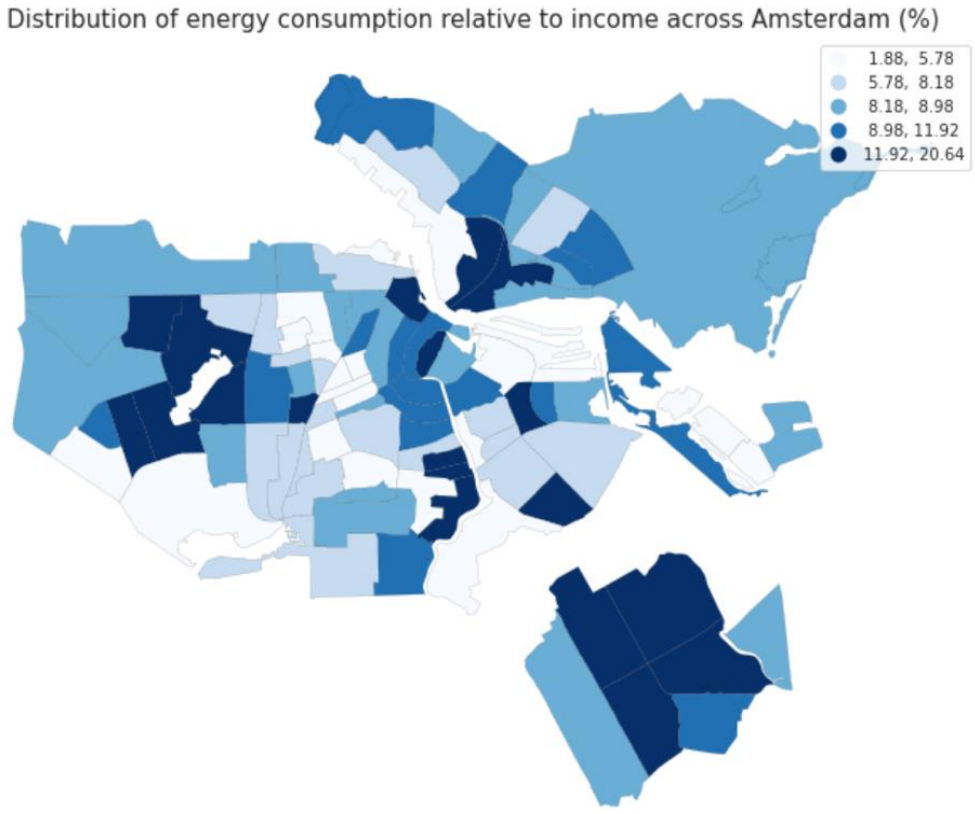


Figure F.22 Spatial Distribution of Energy Consumption Relative to the Income Across Amsterdam

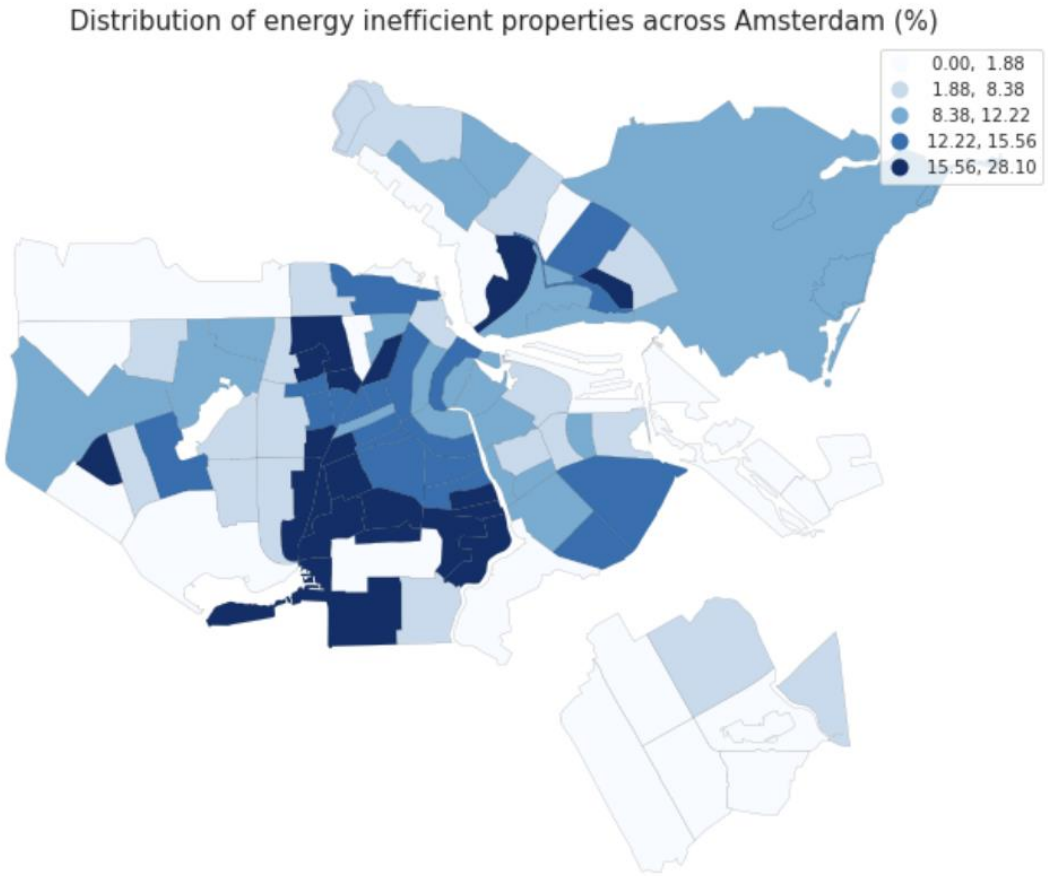


Figure F.23 Spatial Distribution of Energy Inefficient Properties Across Amsterdam

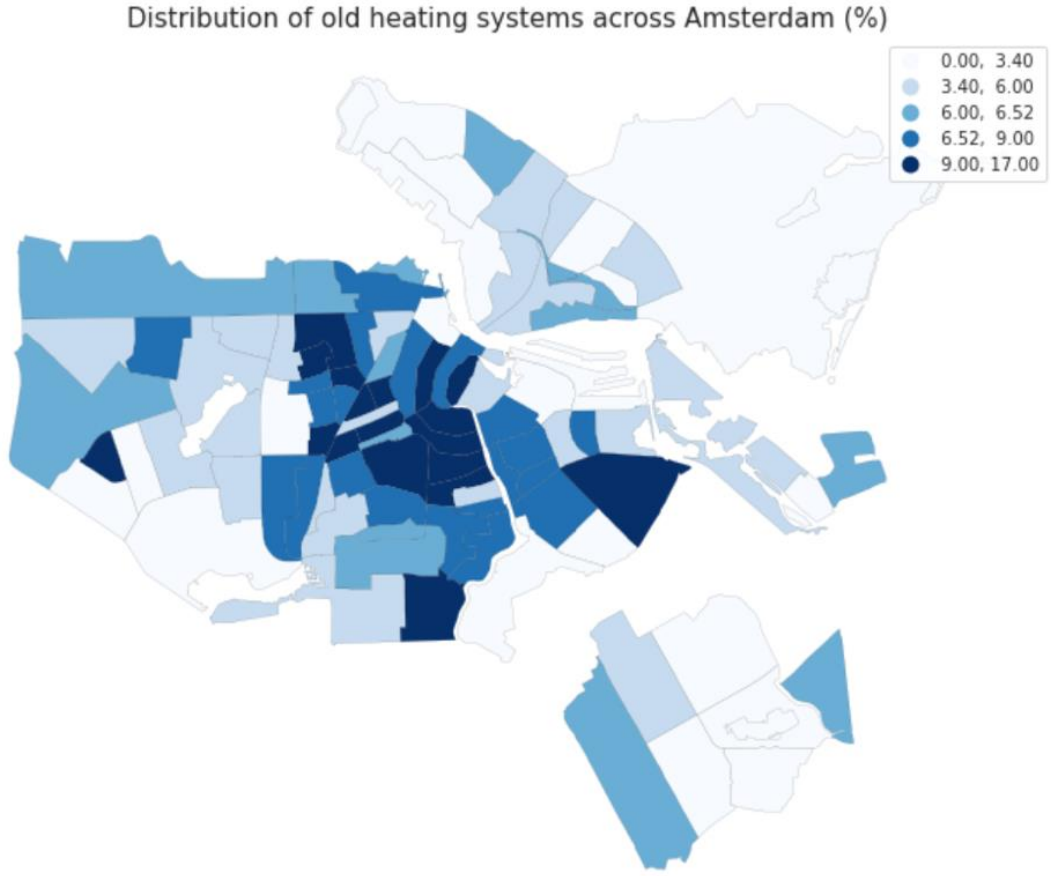


Figure F.24 Spatial Distribution of Old Heating Systems Across Amsterdam

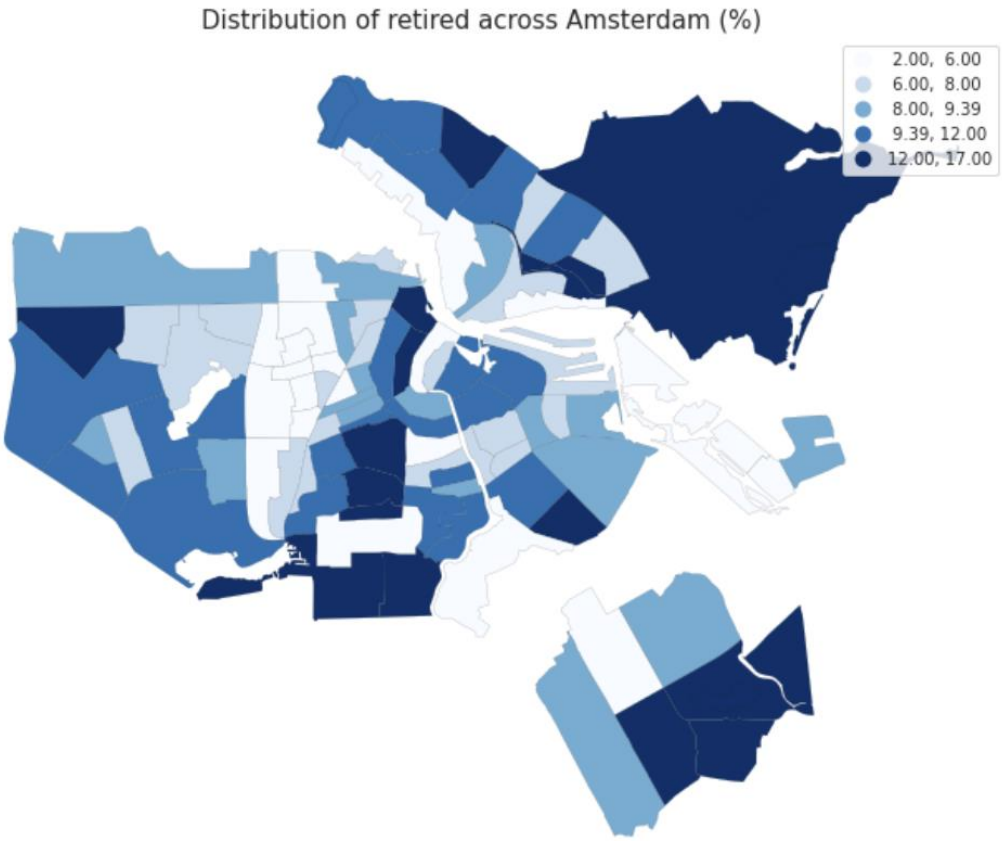


Figure F.25 Spatial Distribution of Retired Across Amsterdam

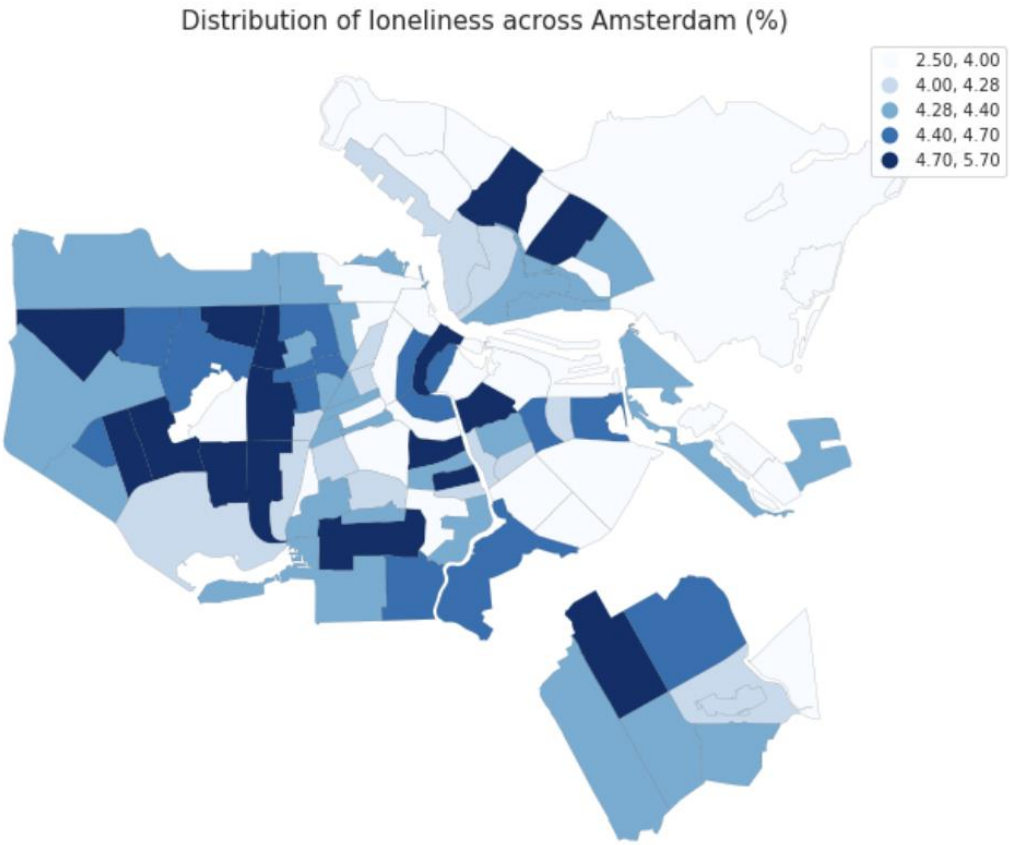


Figure F.26 Spatial Distribution of Retired Across Amsterdam

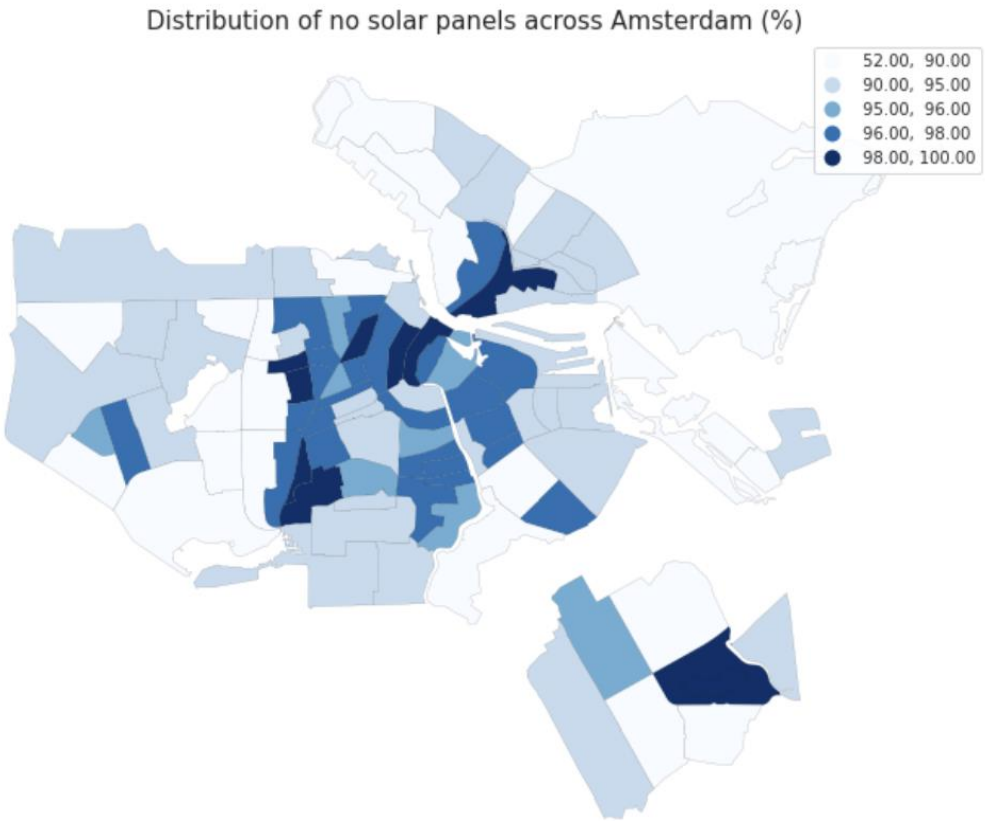


Figure F.27 Spatial Distribution of No Solar Panels Across Amsterdam

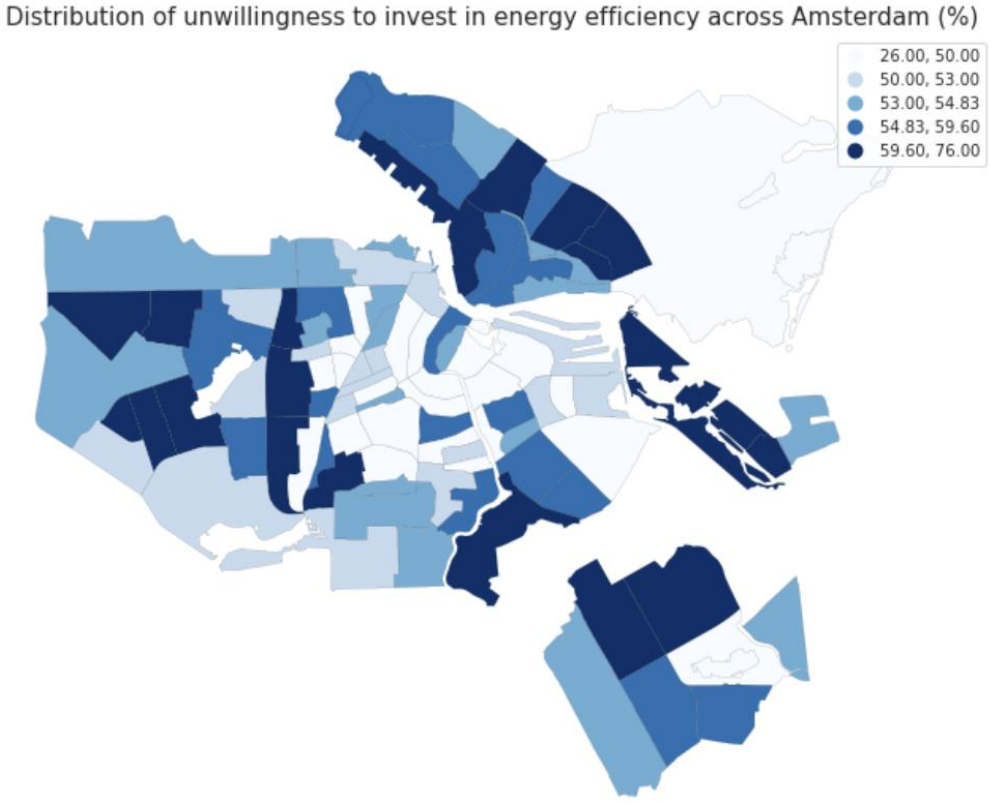


Figure F.28 Spatial Distribution of Unwillingness to Invest in Energy Efficiency Across Amsterdam

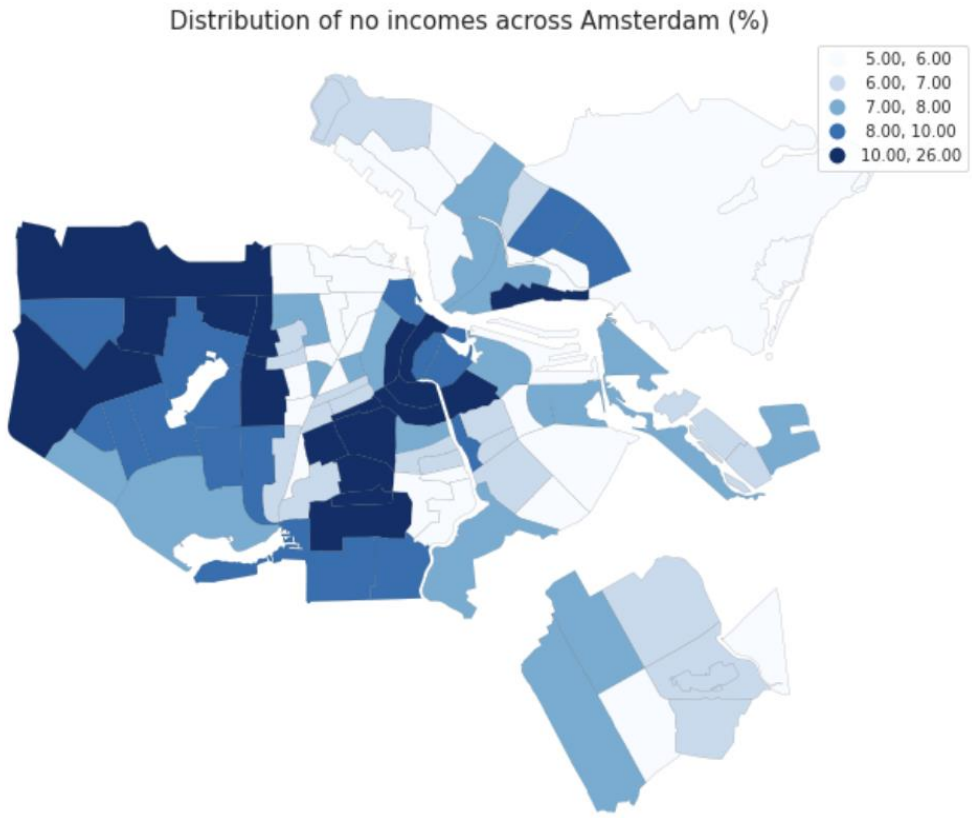


Figure F.29 Spatial Distribution of No Incomes Across Amsterdam

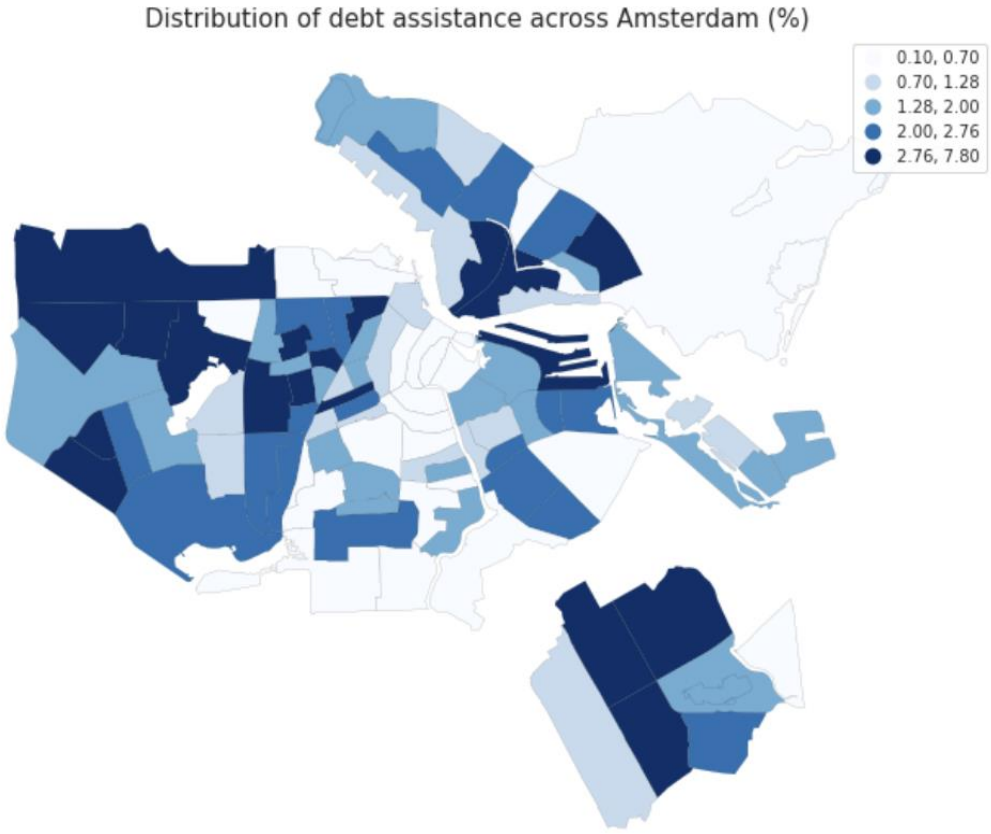


Figure F.30 Spatial Distribution of Debt Assistance Across Amsterdam

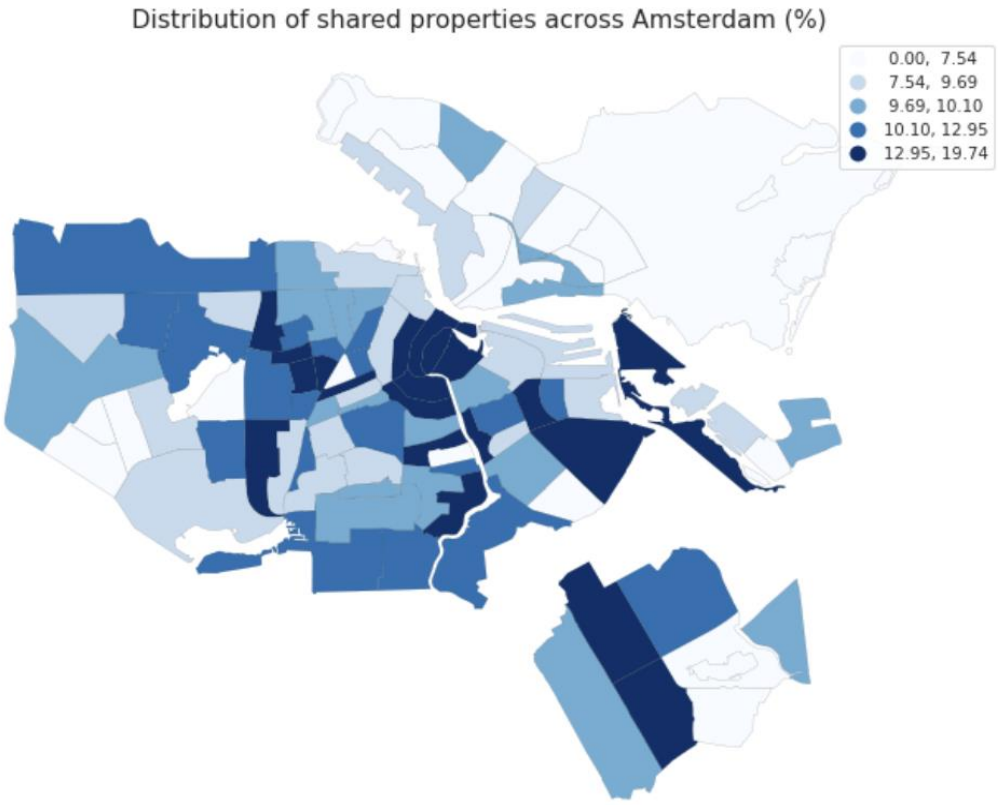


Figure F.31 Spatial Distribution of Shared Properties Across Amsterdam

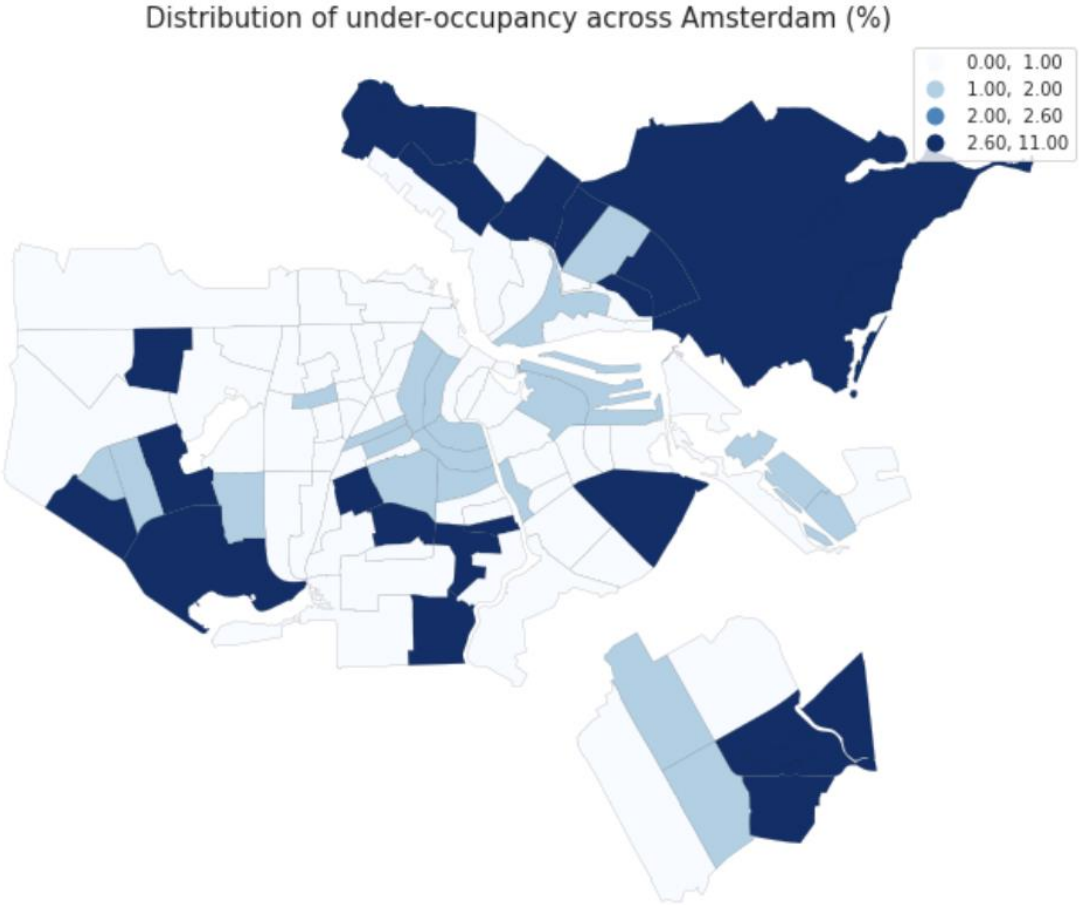


Figure F.32 Spatial Distribution of Under-Occupancy Across Amsterdam

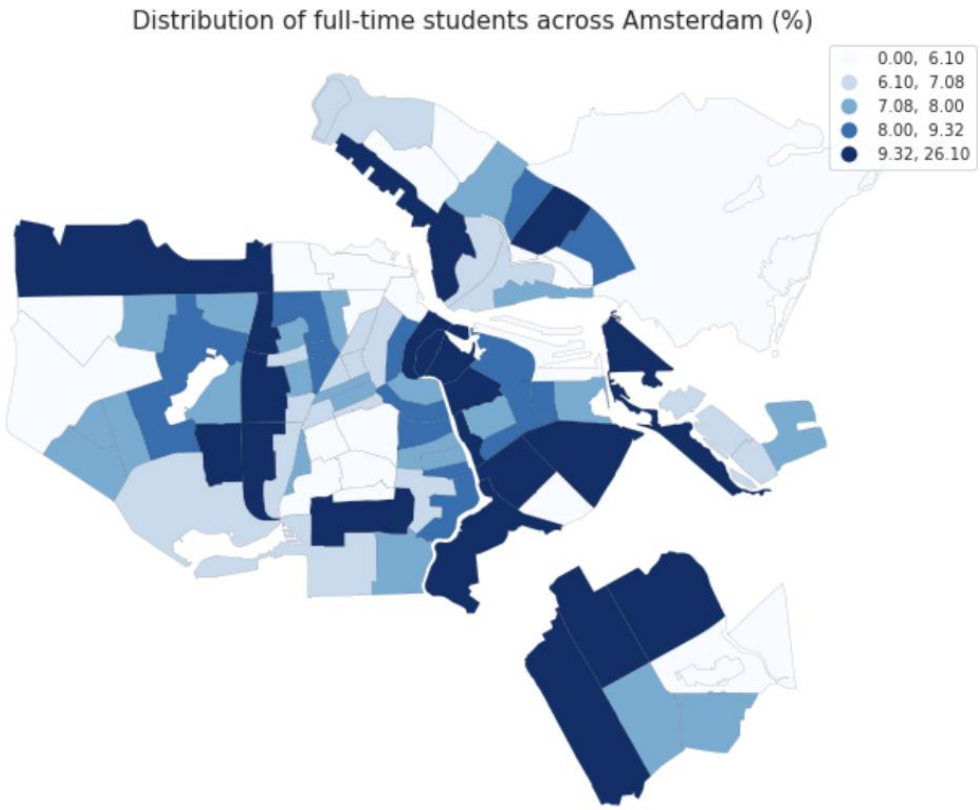


Figure F.33 Spatial Distribution of Full-Time Students Across Amsterdam

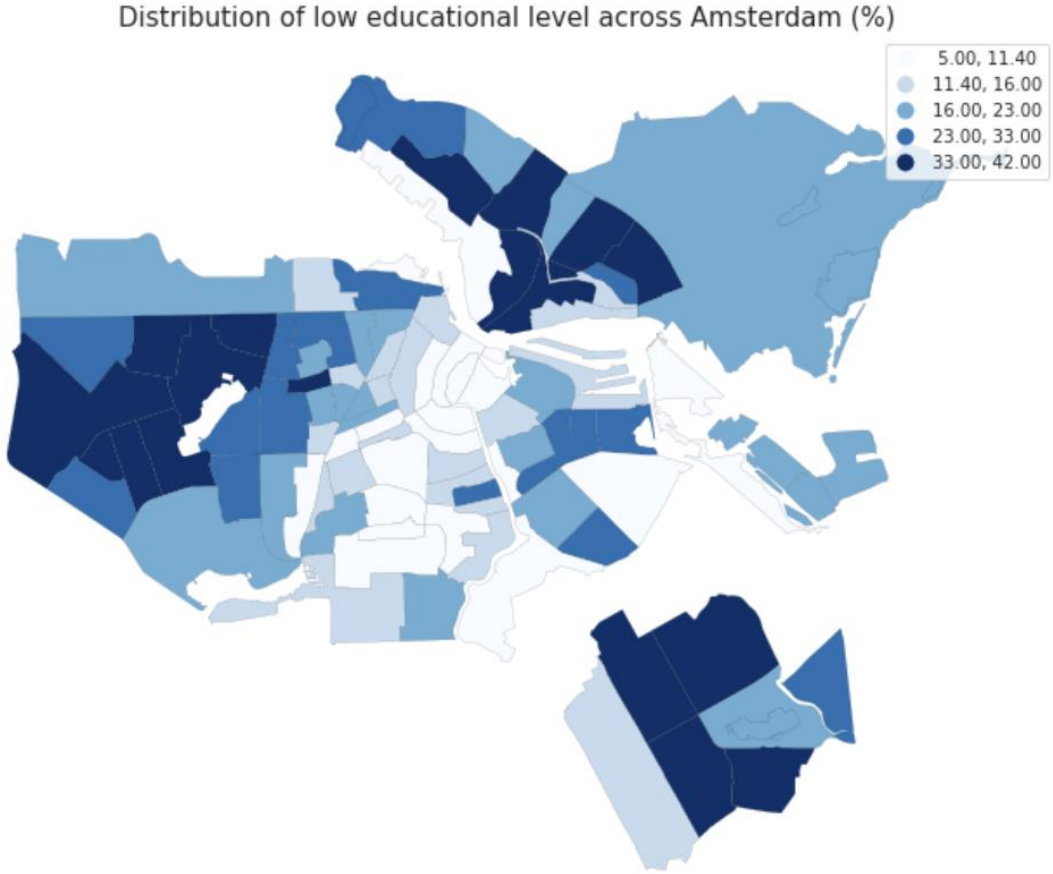


Figure F.34 Spatial Distribution of Low Educational Level Across Amsterdam

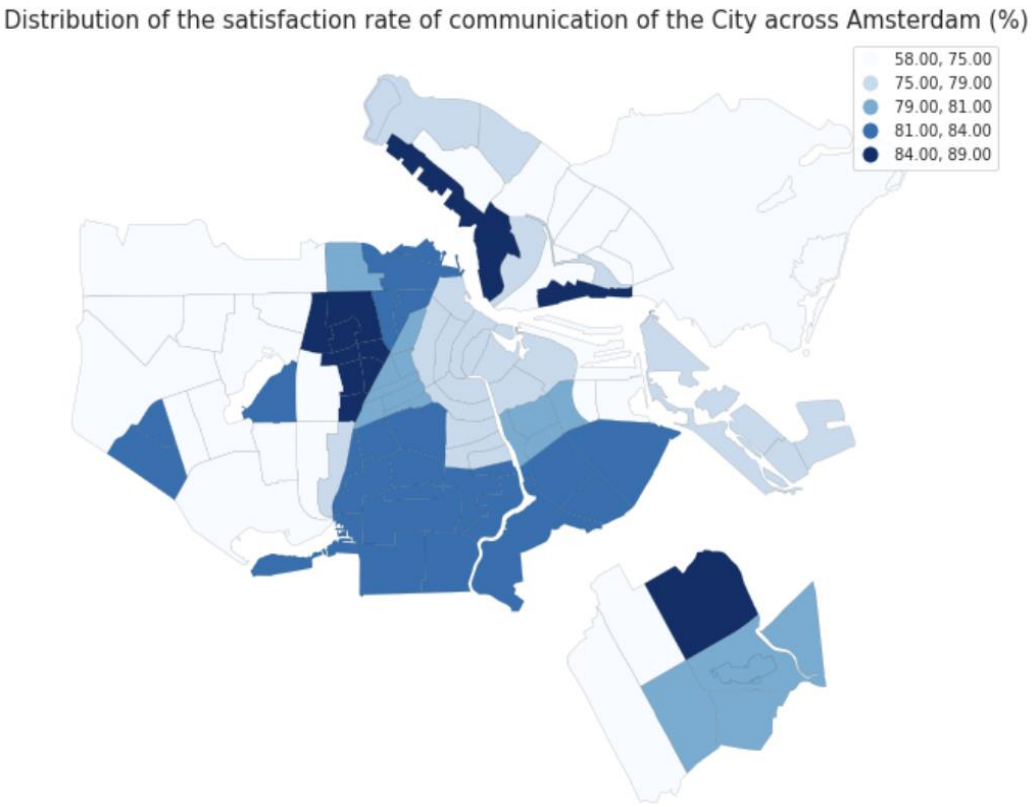


Figure F.35 Spatial Distribution of the Satisfaction Score of the City's Communication Across Amsterdam

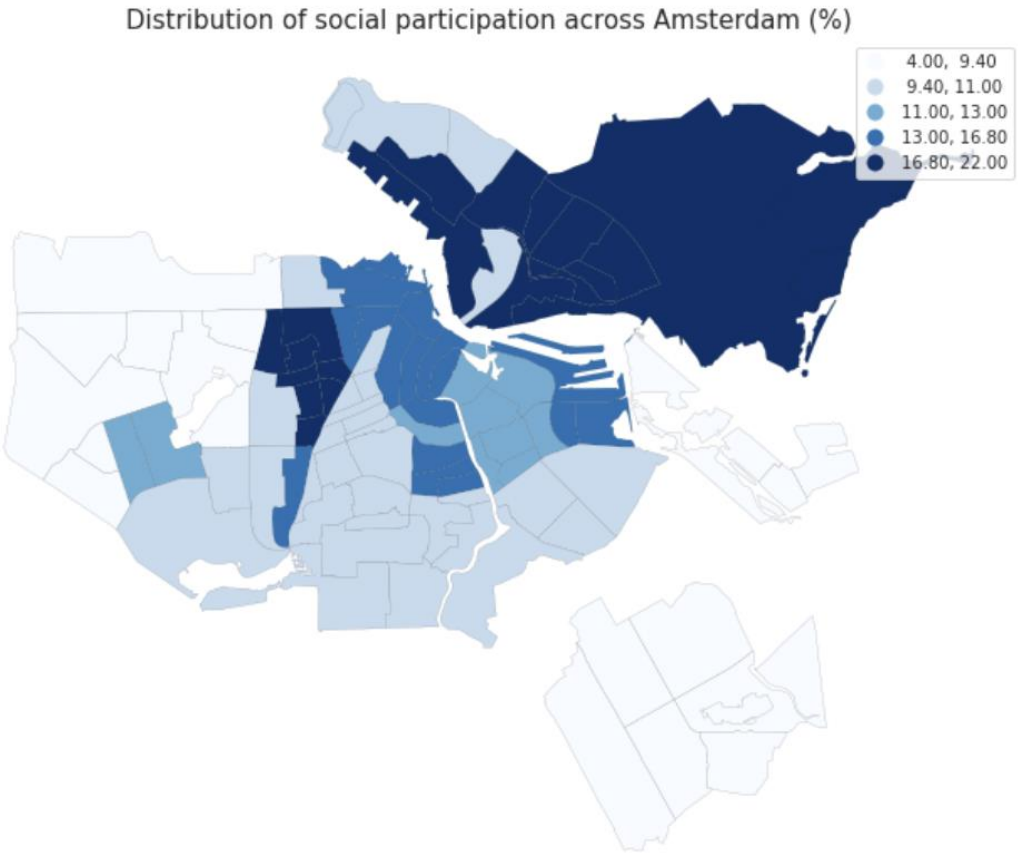


Figure F.36 Spatial Distribution of Participation Across Amsterdam

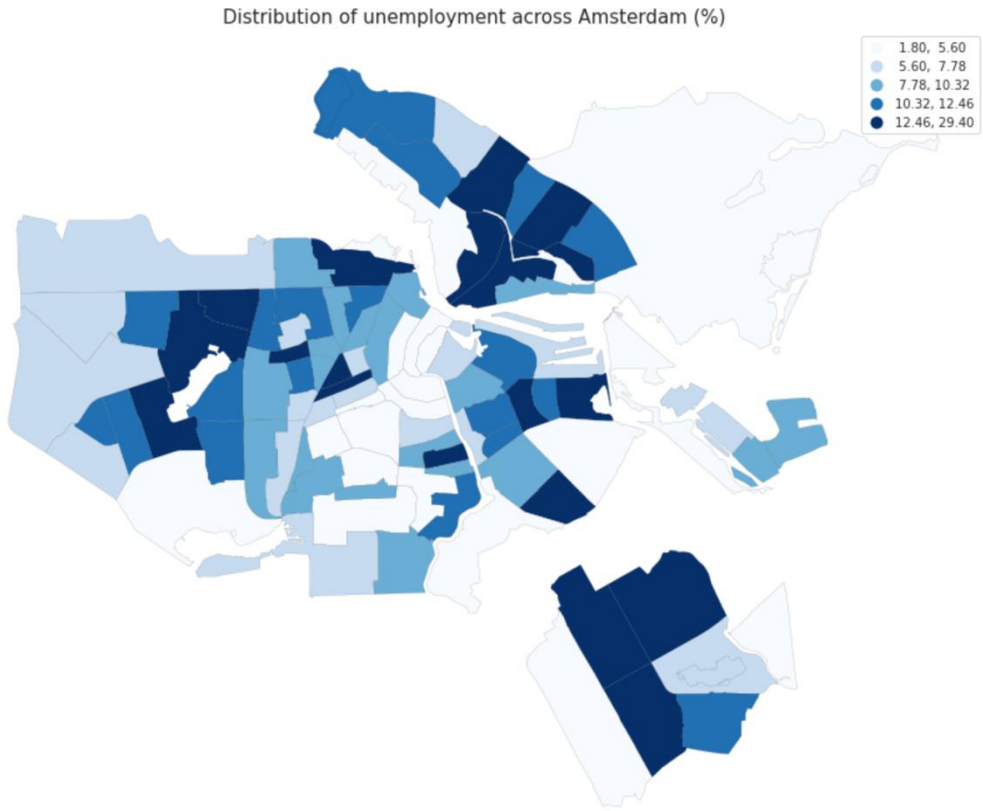


Figure F.37 Spatial Distribution of Unemployment Across Amsterdam

F.5 Principal Component Analysis

A socio-spatial analysis was conducted to gain insights into which characteristics enhance the vulnerability to energy poverty and a loss of well-being and where these vulnerable groups are located geographically. Methodologically, vulnerability indexes have used principal component analysis (PCA) to assess the relative vulnerability between areas (Jolliffe, 1986). PCA is a statistical analysis that allows the reduction of a large multivariate set of vulnerability indicators into principal components while retaining key statistical information and spatial patterns (Jollife, 1986). These components have loading values that are associated with each of the vulnerability indicators in the data set. The loadings portray the type (positive or negative) and strength of the relationship between a principal component and an indicator and thus provide information about the patterns of vulnerability within the data that each component is likely to represent. PCA is often referred to as a global data reduction technique whereby it produces one set of components for the whole data set, representing the whole of Amsterdam in this research. To get an understanding of the spatial distribution of the vulnerability that each principal component and locales in which the vulnerability is likely to enhance can be mapped by the component loadings. However, these loadings are spatially stationary and thus cannot account for spatial effects (Openshaw, 1984; Lloyd, 2010; Harris et al., 2011; Demšar et al., 2013). The PCA is carried out in IBM's SPSS program.

F.5.1 KMO and Bartlett's test

The built-in Kaiser-Meyer-Olkin Measure of Sampling Adequacy (KMO) and Bartlett's test is conducted to assess the suitability of the vulnerability indicators for PCA. KMO represents the proportion of variance in all variables that underlying factors might cause. Values between 0.5-1 indicate that the results of the PCA will be useful. Bartlett's sphericity test assesses whether all variables in your dataset are unrelated and, therefore not useful for feature reduction. Values smaller than 0.5 indicate that the data might be suitable (IBM, 2021). Table F.2 shows the results of these tests. From the results, it can be concluded that the data set is likely suitable for PCA.

Table F.2 KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		,733
Bartlett's Test of Sphericity	Approx. Chi-Square	2524,712
	df	406
	Sig.	<,001

F.5.2 Communalities

Next, the communalities are inspected to assess the proportion of variance accounted for the variable in the component solution. Small values (<0.25) indicate that the variables do not fit well with the component solution, whereby these variables should be dropped. As shown in Table *F.3*, the communalities for all variables are high enough to retain them in the analysis.

Table F.3 Communalities

	Initial	Extraction
Older_old	1,000	,734
Young_children	1,000	,747
Lone_parent	1,000	,870
Mental_health_issues	1,000	,863
Disability	1,000	,898
Precarious	1,000	,668
Proficiency_in_Dutch	1,000	,924
Ethnicity	1,000	,923
Large_household_size	1,000	,897
Private_renting	1,000	,819
Social_housing_renting	1,000	,841
Gender	1,000	,578
Energy_inefficient_property	1,000	,714
Old_heating_system	1,000	,753
No_solar_panels	1,000	,739
No_income	1,000	,753
Retired	1,000	,785
Provision_of_unpaid_care	1,000	,873
Loneliness	1,000	,568
Debt_assistance	1,000	,494
Energy_consumption	1,000	,516
Shared_property	1,000	,635
Under_occupancy	1,000	,618
Full_time_student	1,000	,709
Satisfaction_score_communication	1,000	,582
Participation	1,000	,572
Unemployment	1,000	,779
Educational_level	1,000	,924
Unwillingness_invest_EE	1,000	,538

Note. Extraction Method: Principal Component Analysis.

F.5.3. Eigenvalues Extraction and Total Variance Explained (TVE)

In the next two steps, the eigenvalues are extracted to determine how many components the solution should retain. In the present study, only components with an eigenvalue higher than one are restored as they represent more variance than the variable itself can represent. Table F.4 shows the results of the analysis. From the table, it can be seen that 7 components have an eigenvalue higher than one, and they cumulatively explain nearly 74% of the data.

Table F.4 Total Variance Explained

	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
Component	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	8,083	27,871	27,871	8,083	27,871	27,871	5,905	20,363	20,363
2	4,189	14,443	42,314	4,189	14,443	42,314	3,995	13,775	34,138
3	2,863	9,872	52,186	2,863	9,872	52,186	3,307	11,404	45,542
4	1,905	6,567	58,754	1,905	6,567	58,754	2,465	8,499	54,042
5	1,791	6,176	64,930	1,791	6,176	64,930	2,261	7,796	61,838
6	1,299	4,478	69,408	1,299	4,478	69,408	2,096	7,227	69,065
7	1,184	4,083	73,490	1,184	4,083	73,490	1,283	4,425	73,490
8	,964	3,323	76,813						
9	,862	2,972	79,785						
10	,757	2,610	82,395						
11	,702	2,421	84,816						
12	,655	2,260	87,076						
13	,548	1,890	88,966						
14	,528	1,822	90,789						
15	,474	1,634	92,423						
16	,426	1,470	93,892						
17	,356	1,227	95,119						
18	,265	,912	96,031						
19	,248	,855	96,886						
20	,231	,797	97,683						
21	,185	,637	98,320						
22	,155	,535	98,854						
23	,096	,331	99,185						
24	,076	,263	99,449						
25	,058	,201	99,650						
26	,033	,113	99,763						
27	,029	,101	99,863						
28	,022	,075	99,938						
29	,018	,062	100,000						

Extraction Method: Principal Component Analysis.

A scree plot is shown in Figure F.38, visualizing the eigenvalue for each component.

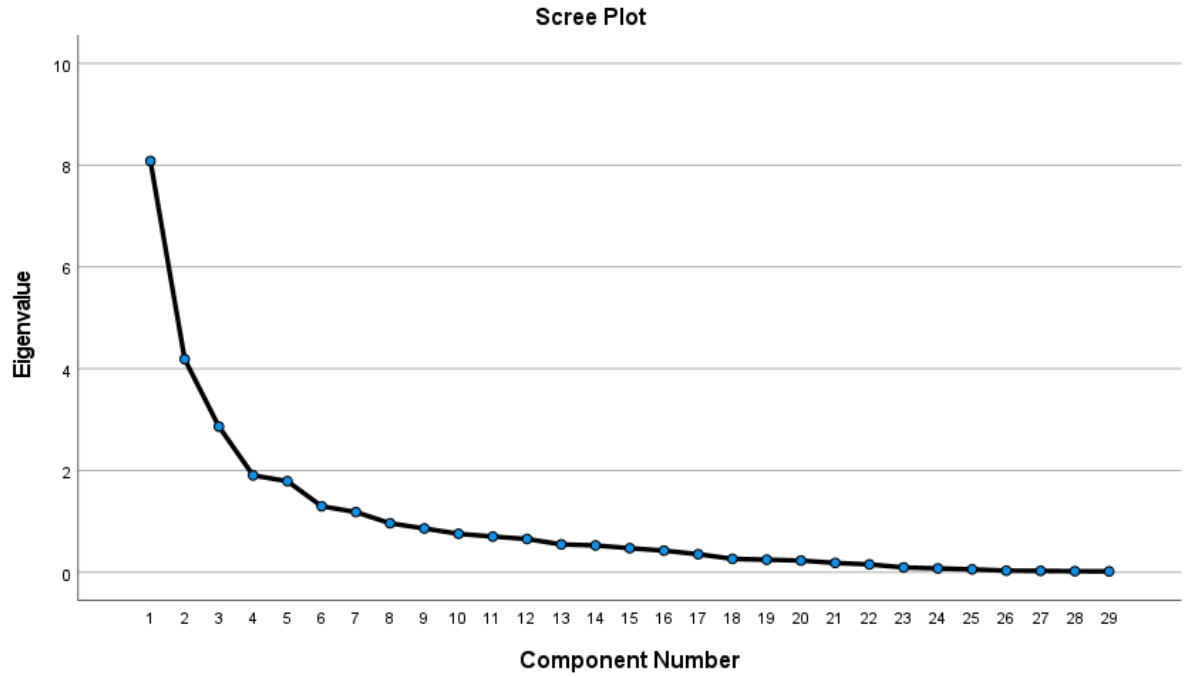


Figure F.38 Scree Plot Visualizing the Eigenvalue versus Components

F.5.4 Component Loading

To assess how much each variable loads onto each of the seven components, the component loadings are inspected. To ease the interpretation, the loadings are rotated orthogonally, sorted by size, and coefficients below 0.3 are suppressed. Table F.5 shows the loading of the vulnerability indicator on the various components.

Table F.5 Rotated Component Matrix[a]

	Component						
	1	2	3	4	5	6	7
Older_old	,865						
Young_children	,841				,375		
Lone_parent	,792	,393	,329				
Mental_health_issues	,730				,579		
Disability	,711	,329	,485				
Precarious	,695		,523				
Proficiency_in_Dutch	,681						
Ethnicity	,613		,583				
Large_household_size	,531	-,436					
Private_renting	,490			-,407			
Social_housing_renting		,907					
Gender		,705			,312		
Energy_inefficient_property		-,691					
Old_heating_system		-,680		-,440			
No_solar_panels		,659	-,366				
No_income		,533	-,351				-,367
Retired	,326		,842				
Provision_of_unpaid_care			,820				
Loneliness			,526			,391	
Debt_assistance				,837			
Energy_consumption				,715			
Shared_property		-,406		,685			
Under_occupancy					,782		
Full_time_student	,610				,688		
Satisfaction_score_communication		,349			,479	-,409	
Participation						,768	
Unemployment	-,333					-,618	
Educational_level					-,325	-,611	
Unwillingness_invest_EE							,796

Extraction Method: Principal Component Analysis.
Rotation Method: Varimax with Kaiser Normalization.

a. Rotation converged in 11 iterations.

F.5.5. Component Interpretation

Based on the rotated component matrix, the name for each component is determined. Variables that load the strongest on a component are used to determine the name. Table F.6 provides an overview of the names.

Table F.6 Component Interpretation

Component	Interpretation
Component 1	Migration background (+)
Component 2	Provision of unpaid care (+) and full-time studying (-)
Component 3	Housing tenants (+)
Component 4	Energy efficiency building (+)
Component 5	Single-parent households and alone living older olds (+)
Component 6	Lack of income (+) participation and communication satisfaction score municipality (-)
Component 7	Precarious families (+)

Note. The components are interpreted based on the vulnerability indicators that load high on each component while loading lower on other components

F.8.6 Component Score Calculation

Finally, the factor score for each neighbourhood on each component was calculated to gain insights into the geographical distribution of vulnerabilities related to the identified components. These scores were determined by first calculating the standardized values for each indicator and multiplying the loadings of each component by the accompanying standardized value to determine scores for each component per neighbourhood, which complies with linear regression SPSS automatically calculates this.

F.6 ESDA Component Score

To gain insights into how the various components are geographically distributed across Amsterdam, ESDA was carried out. ESDA tools provide functions to describe and visualize spatial distributions, enhancing the discovery of spatial patterns and spatial outliers (Steiniger & Hunter, 2013). ESDA was performed using the Pysal package. As plotting the spatial data requires defining the number of clusters that you want the data to split into, Sklearn's K-means package was used as it tries to minimize the distance between the points in a similar cluster. To enhance the understanding of the number of clusters (=k) used in the analysis, the Elbow method was used, whereby the number of clusters used in the analysis depends on the point where there is the sharpest drop and increasing the number of clusters does not impact the distortion score (Scikit, n.d.). As shown in Figure F.39 there is no sharp drop; thus it is decided to set k equal to 8. The results of the spatial distribution of each component in Amsterdam are shown and discussed in the next session.

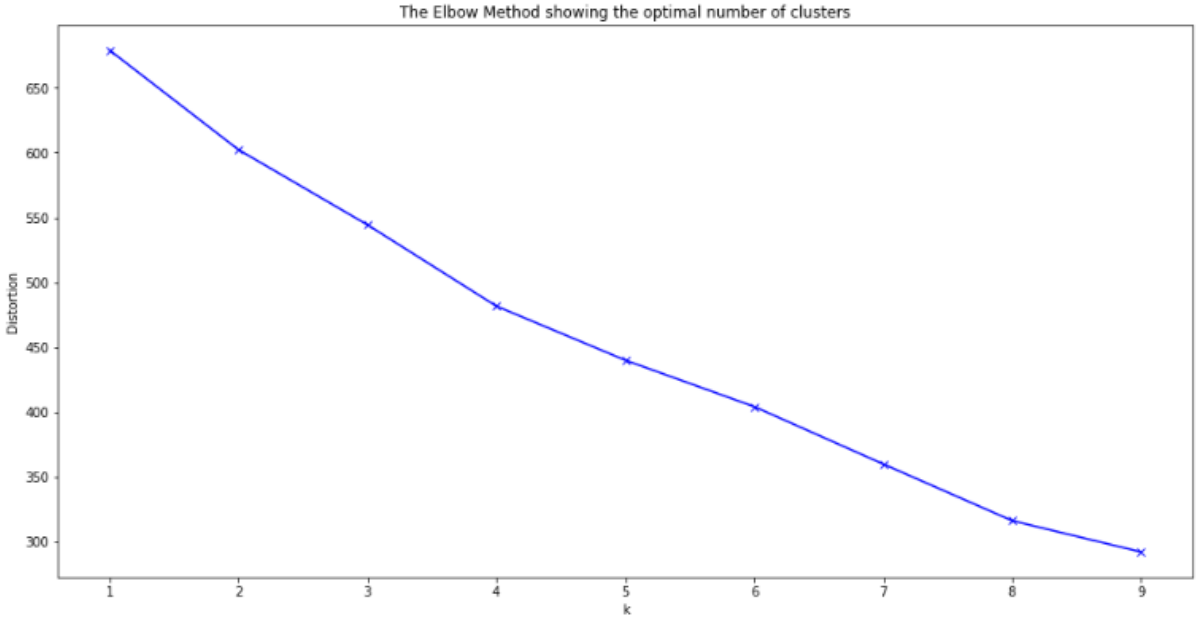


Figure F.39 Results K-means Clustering Components

G Identification of Policy Strategies

To identify policy strategies various experts were invited to the expert session. The maximum number of participants was limited to 6 persons to ensure an in-depth interactive session in which there is enough time for each participant to share their point of view and clarify any point of view whenever needed. To ensure that the expert session will allow everyone to participate a set of guidelines were created which were considered by the researcher while preparing the expert session. The guidelines include:

1. To set out the expectations for the expert session the facilitator starts with introducing herself and explaining the agenda for the expert session to ensure that everyone knows what the planning is and knows what to expect. (What we will try to do in the next 90 minutes is to identify policy interventions which the City of Amsterdam can implement to include justice in renovation policies by tackling energy poverty and explore the common ground for these interventions between your opinions)

2. To foster early trust and a feeling of comfortness between the participants, the facilitators ask everyone to introduce themselves (name, organisation and link to energy poverty in Zuidoost) and ask them about their hobby.

3. To create a shared vision, the facilitator presents the results from phase 1 and 2 to the participants to ensure that all participants have the same understanding of the issue. During the presentation the participants can ask clarifying questions. Questions or comments related to the content and/or analysis can be asked at the end of the presentation. To prevent too much time spent at the first part a maximum of 10 minutes is reserved for questions.

4. The next part of the session focuses on the identification of policy interventions to include justice in renovation policies. The facilitator describes the procedure for the second part.

5. It is important that the participants demonstrate respect for different ideas, thoughts and values and must not interrupt each other. The emphasis should be on expressing ideas on policy strategies, explaining, and clarifying personal points of view and not on immediately debating them. Each participant should have time to express and explain their point of view but due to the limited time and limited attention spans the maximum budget for explaining a point of view is around 1-3 minutes per participant.

6. To get closer to the bottom of the iceberg, explanatory questions can be asked, such as: ‘What are the reasons behind the suggestion?’ and ‘Why is this the most important issue?’

7. If participants use abstract or general terms clarifying questions are asked such as: ‘What do you mean by this?’

8. In situations in which participants do not know or do not want to further explain their motivation, the facilitator can ask again for more clarification such as why it is difficult for them to explain and if they want to add something else.

9. To ensure that interventions are identified based on the various insights obtained from phase 1 and 2, policy strategies need to be identified for each identified group or each presented statement.

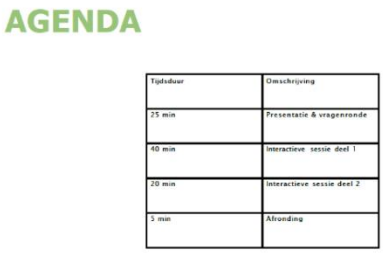
10. To ensure that each participant feels comfortable to express their point of views the participants are asked to be open to nuances whereby they should try not to agree or disagree immediately but see the source of the disagreement as a starting point of sharing their point of view or ask for clarification.

11. A productive environment is relevant as well as to ensure interventions are identified. The facilitator will ask each participant to write down their ideas on post-it notes to ensure everyone participates and can share their point of view. The facilitator can also go round by asking the participants about their most important idea or point of view.

12. At the end of the session the list of interventions is shared with the participants via email and each participant is informed that the results from the expert session will be evaluated and the results will be shared with them in the form of the Master thesis report.

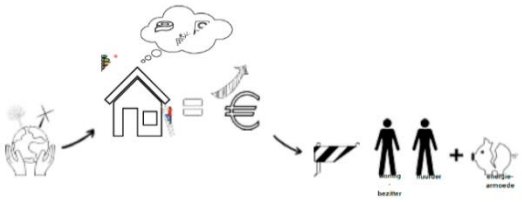
Given time constraints the expert session was limited to 90 minutes, whereby the results from phase 1 and 2 were shared first to ensure that all experts have a shared vision and the same starting point before starting with the identification of policy strategies. After creating a shared vision, the interactive session started. In the first part of the interactive session the participants identified policy strategies which the City could implement to include justice in renovation policies based on the characteristics of the vulnerable groups. Each participant received a booklet which presented the identified vulnerable groups and their socio-spatial distribution across Amsterdam, to ensure that each strategy is identified based on the characteristics of the vulnerable groups. Post-it notes and various pens were also provided to the participants on which they could write down the policy strategy and stick on the corresponding flipover sheet. Moreover, to ensure that the policy strategies are realistic and executable within the sphere of the City or key stakeholders, conditions for the identification of policy strategies were presented as well. During the second part various statements were presented and the participants were asked to identify for instance the roles which other key stakeholders could take to include justice in renovation policies. The session was conducted in Dutch as the native language of all participants is Dutch. It is assumed that by organizing the session in Dutch the participants will not have difficulty in expressing their point of view as they will not have to translate in English. Given that their daily work is in Dutch as well, conducting the session in Dutch was considered reasonable. Figure G.1 provides an overview of the slides used during the expert session to create a shared vision and guide the interactive session.

1



2

VERDUURZAMEN VAN DE WONING



3

ENERGIEARMOEDE

4

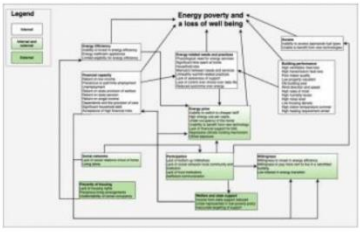
RECHTVAARDIG RENOVATIEBELEID

5

ENERGIEARMOEDE IN AMSTERDAM

6

VULNERABILITY FRAMEWORK

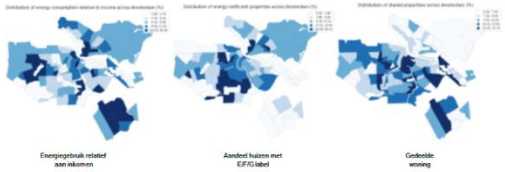


7

KWETSBAARHEIDSINDICATOREN

8

KWETSBAARHEIDSINDICATOREN



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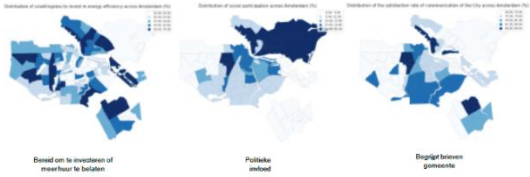

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EXPERTSESSIE

GEÏDENTIFICEERDE KWETSBARE GROEPEN

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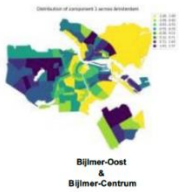
GROEP 1



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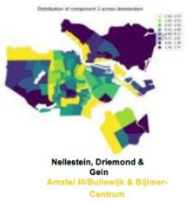
GROEP 2



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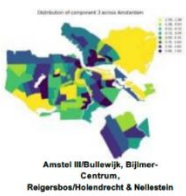
GROEP 3



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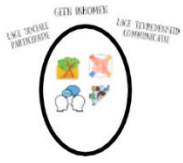
GROEP 4

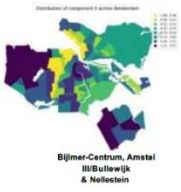
15

GROEP 5

16

GROEP 6





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GROEP 7

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EXPERTSESSIE

INTERACTIEVE SESSIE

Deel 1

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RANDVOORWAARDEN MAATREGELEN

- De maatregelen moeten binnen de invloedsfeer van de gemeente liggen:
  - In eerste instantie van de gemeente zelf.
  - In tweede instantie met de ondersteuning van de woningcorporaties, (aanvullende) hulpverlening en andere samenwerkpartners op dit thema.
- De maatregelen moeten het energiegebruik, woonomstandigheden/wooncomfort of de energierekening verlagen
- De maatregelen moeten uitvoerbaar zijn

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STELLING

Kwetsbare groepen moeten voorrang krijgen in het renovatiebeleid

Opdracht: Identificeer per kwetsbare groep welke beleidsmaatregelen de gemeente Amsterdam kan nemen om deze groepen te erkennen en mee te nemen in het renovatiebeleid.

30 min

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EXPERTSESSIE

INTERACTIEVE SESSIE

Deel 2

22

VRAAG

Welke partijen kunnen beter samenwerken om de kwetsbare groepen te erkennen en mee te nemen in het renovatiebeleid?

- Wat zouden de woningcorporaties kunnen doen om deze groepen, ondanks goede energielabels(specifiek probleem benoemen)(vormen van energiearmoede)
- Welke rollen zou Stichting Co-Force en Stichting !WOON daarbij hebben?

15 min

23

EXPERTSESSIE

BEDANKT VOOR JULLIE AANWEZIGHEID

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Figure G.1 Presentation Slides Prepared for the Expert Session to Create a Shared Vision and Moderate the Session

To facilitate the expert session flipover sheets, post-it notes, pens, vulnerable groups booklet and snacks were provided. Figure G.2 gives an impression of the preparation.

(a)

(b)

Figure G.2 Preparation of the Expert Session Prior to the Arrival of the Participants