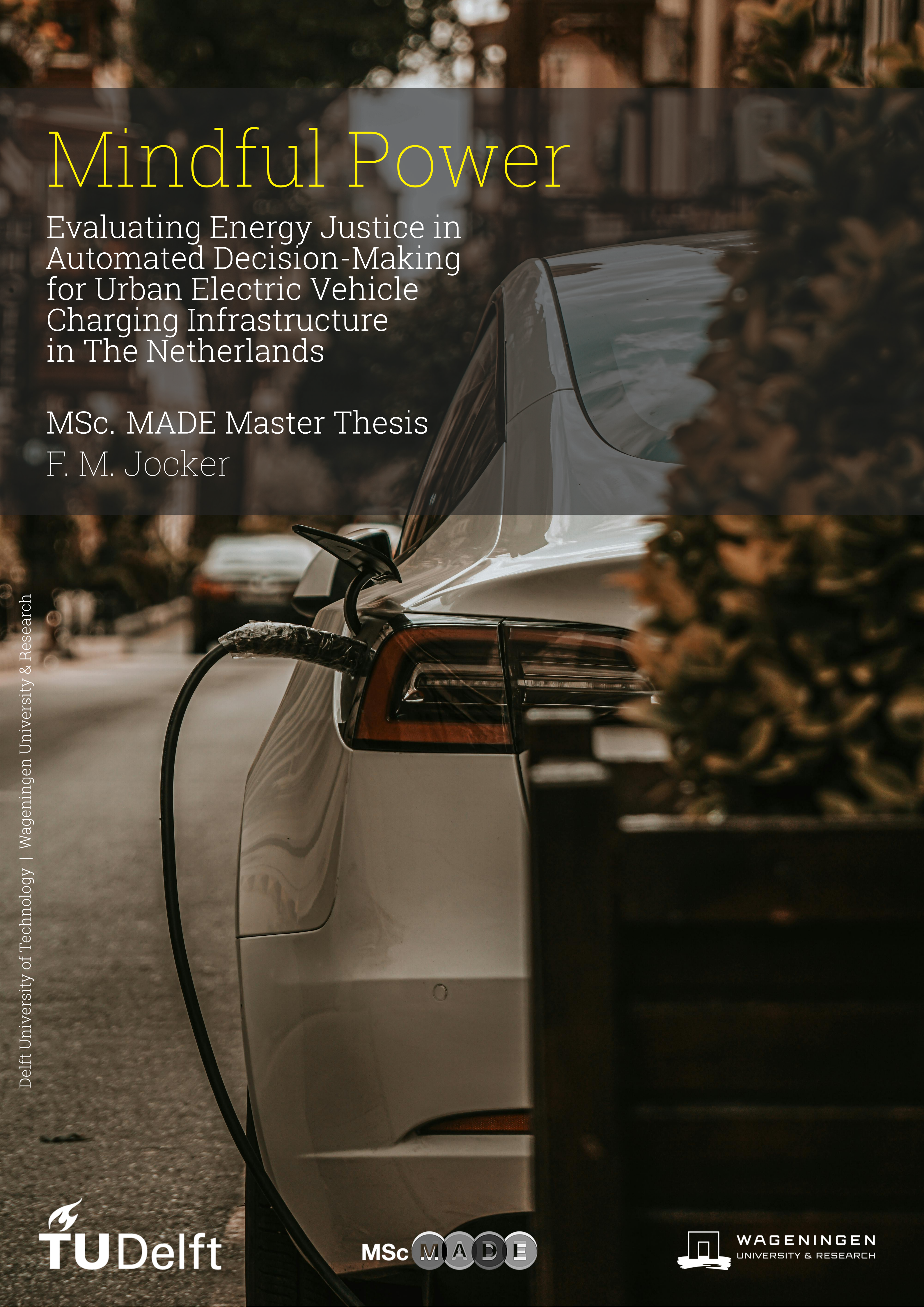

Mindful Power

Evaluating Energy Justice in Automated Decision-Making for Urban Electric Vehicle Charging Infrastructure in The Netherlands

MSc. MADE Master Thesis

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Delft University of Technology | Wageningen University & Research

TU Delft MSc MADE WAGENINGEN UNIVERSITY & RESEARCH

Mindful Power

Evaluating Energy Justice in Automated Decision-Making for Urban Electric Vehicle Charging Infrastructure in The Netherlands

by

F. M. Jocker

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Preface

”The human spirit must prevail over technology” - Albert Einstein

In an era where technology increasingly shapes the fabric of our lives, Einstein’s words feel especially relevant: *”The human spirit must prevail over technology.”* While innovation offers powerful tools to build a more sustainable future, it is crucial to prioritise human values, especially equity, justice, and inclusivity, at the forefront. This study explores the intersection of technology and social justice, aiming to ensure that advancements in electric vehicle charging infrastructure serve all communities fairly and sustainably. I believe that collaborative approaches are not only more effective but essential in addressing the complex challenges of the energy transition. Only by working together can we create a sustainable future that is both equitable and impactful.

Mindful Power captures the idea that Automated Decision-Making systems in Electric Vehicle Charging Infrastructure should optimise energy use without compromising social equity. The concept also highlights the responsibility of regulatory bodies and policymakers to consider the broader social impacts of emerging technologies like Smart Charging and Vehicle-to-Grid, balancing efficiency with justice in energy access.

My interest in this topic stems from a long-standing commitment to integrating social and technological perspectives in tackling complex challenges. I’m driven by a passion for bridging the gap between technologies and the communities they serve, striving to make advancements both accessible and meaningful for all. This study has allowed me to investigate how Automated Decision-Making systems in Electric Vehicle Charging Infrastructure can be designed not only for efficiency but with accessibility, fairness, inclusivity, and transparency at their core.

I am grateful to my supervisors, Gerd Kortuem and Clemens Driessen, for their valuable insights and guidance throughout this journey. Their support and expertise have been instrumental in shaping this research and refining my ideas. I would also like to thank Lars Huizer for his careful proofreading and helpful feedback on grammar and style. Finally, I extend my appreciation to the participants and stakeholders who generously shared their perspectives and experiences, enriching the findings presented in this thesis.

F. M. Jocker
Amsterdam, November 2024

Abstract

This thesis examines the role of Automated Decision-Making (ADM) systems in advancing energy justice within urban Electric Vehicle Charging Infrastructure (EVCI) in the Netherlands. Centred on distributive, procedural, and recognition justice, the study explores how ADM impacts equitable access to EV charging and fair energy distribution amid the rapid electrification of passenger mobility. While ADM promises improved grid efficiency and stability, alleviating congestion, it also risks exacerbating socio-economic disparities in access to essential charging resources and energy, potentially widening existing inequalities.

Using a mixed-method approach encompassing Geographic Information System (GIS) analysis, Scenario Development, and Q-methodology, this research examines ADM's effects on equity, fairness, inclusivity, and transparency across socio-economic groups. GIS findings reveal disparities in EVCI accessibility between affluent and low-income neighbourhoods in Amsterdam, highlighting the need for ADM frameworks that consider socio-economic factors in energy allocation. Scenario Development projects futures where stakeholders must balance individual and community needs, illustrating the critical trade-offs required to achieve equitable energy distribution. The Q-methodology builds consensus among diverse stakeholders, underscoring transparency and procedural fairness in promoting trust and aligning ADM outcomes with public values.

This study contributes to energy justice literature by showing how ADM systems can promote equitable EVCI outcomes that are just and inclusive. Policy recommendations offer a phased roadmap: in the short term, prioritise equitable distribution of EVCI using socio-economic data; in the medium term, develop adaptive ADM models for high-demand and grid-constrained regions; and in the long term, enhance community engagement through accessible platforms. *Mindful Power* envisions ADM systems for EVCI that optimise technological efficiency without sacrificing social justice, supporting a fairer, more inclusive energy transition. Ultimately, this thesis provides a structured roadmap for sustainable, community-centred urban energy solutions, ensuring that the transition leaves no one behind.

Mindful Power

Evaluating Energy Justice in Automated Decision-Making for Urban Electric Vehicle Charging Infrastructure in The Netherlands

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Nomenclature

Abbreviations

Abbreviation	Term
ADM	Automated Decision-Making
AI	Artificial Intelligence
CFA	Centroid Factor Analysis
EV	Electric Vehicle
EVCI	Electric Vehicle Charging Infrastructure
GIS	Geographic Infromation System
PCA	Principal Component Analysis
SC	Smart Charging
V2G	Vehicle-to-Grid

Glossary

Key Term	Definition
Automated Decision-Making	A technology-driven process in which algorithms make decisions, often in real-time, to optimise complex systems. In the context of electric vehicle charging, automated decision-making manages energy distribution and charging priorities based on grid demand and user needs.
Distributive Justice	A dimension within energy justice that emphasises the fair allocation of resources. In electric vehicle charging, it focuses on ensuring equitable access to charging infrastructure across different communities.
Energy Justice	A framework focusing on the fair and equitable distribution of energy resources, emphasising distributive, procedural, and recognition justice. It ensures that all communities benefit from energy systems and that vulnerable groups are not disproportionately affected.
Ethics of Care	An ethical framework that prioritises the responsibilities and relationships between individuals, often emphasising the needs of vulnerable groups. In the context of automated decision-making, it focuses on recognising and addressing the needs of those most affected by energy distribution decisions.
Procedural Justice	A dimension within energy justice referring to the involvement of stakeholders in the decision-making processes that affect them. In automated decision-making systems for electric vehicle charging, procedural justice ensures transparency and accountability.
Recognition Justice	A dimension within energy justice ensuring that the specific needs of vulnerable or marginalised groups are acknowledged and addressed. It requires that ADM systems consider these needs to prevent reinforcing existing inequalities.
Smart Charging	A method of charging electric vehicles that dynamically adjusts charging rates based on grid conditions, energy availability, and user preferences. Smart charging aims to reduce strain on the grid while optimising costs and efficiency.
Vehicle-to-Grid	A system allowing electric vehicles to send power back to the electrical grid. Vehicle-to-Grid enables electric vehicles to act as mobile energy storage units, helping balance grid demand during peak periods.

1

Introduction

Energy Justice and Net Congestion Challenges

The European Commission Green Deal prioritises the goal of becoming the first climate-neutral continent by the year 2050. Achieving this entails the proposal of making the European Union's climate, energy, transport and taxation policies fitting for the reduction of net greenhouse gas emissions by at least 55% by 2030, compared to the levels of 1990 [1] . The coalition agreement of the Dutch Government shares this ambition by requiring all new cars sold to be emission-free no later than 2030. This can be translated to a passenger vehicle fleet of 1,9 million cars which combined would have a charging requirement of 7.100 gigawatt hours. To charge all these cars, a total of 1.7 million electric vehicle charging stations among public, semi-public, and private charging locations would be needed [2]. In comparison, the amount of electric vehicle chargers located in the Netherlands per October 2024 equals 793.350 in total, of which, 617.921 private chargers at homes and 169.906 public chargers [3]. The growth projection for electric vehicles (EV) can be seen in Figure 1.1 on page 2.

This significant rise in the demand for electric vehicle charging infrastructure (EVCI) might suggest a concern about generating enough energy to charge all EV. However, the challenge at hand is not energy generation itself—it is ensuring the grid has the capacity to deliver that energy to all EVs effectively [4]. Adding this charging requirement to the current energy grid will lead to more net congestion due to the capacity of energy supply of the current electricity network already being at its peak, which can also be seen in Figure 1.2 on page 3 [5]. Energy distribution system operator Alliander is heavily investing in strengthening networks but warns that grid congestion could persist for at least another ten years [6]. In this context, the concept of smart cities becomes particularly relevant. Smart cities control interconnected technologies and data-driven systems, such as automated decision-making (ADM) systems and Internet of Things networks, to manage urban resources and infrastructure more efficiently. They are not just about creating efficiencies but also about fundamentally reshaping urban living by embedding technology in every aspect of city management, from transport to energy distribution [7]. Whether "smart cities" will have longevity or be replaced by another label, smart technologies in cities will undoubtedly continue to play a role in governing cities, fostering economic development and mediating daily life [8].

Yet, the deployment of these technologies in urban areas should surpass purely technical and instrumental approaches. It is essential to critically consider the ethics, politics and ideologies that underpin smart city initiatives, as these factors will shape how cities are planned, built and managed [7]. There is a need of reimagining and reframing smart cities to leverage urban technologies in ways that are more emancipatory, empowering, and inclusive, proposing both normative and practical frameworks to address issues such as governance, security and stakeholder engagement. This holistic approach aims to produce cities that serve all citizens, tackling urban challenges while avoiding continuation or deepening of inequalities [7].

The integration of smart charging (SC) and vehicle-to-grid (V2G) technologies in EVCI aligns with this vision of smart cities, offering a way to shift energy demand management from a one-way, top-down approach to a dynamic, consumer-driven system. Such a system is not only a strategic asset in addressing

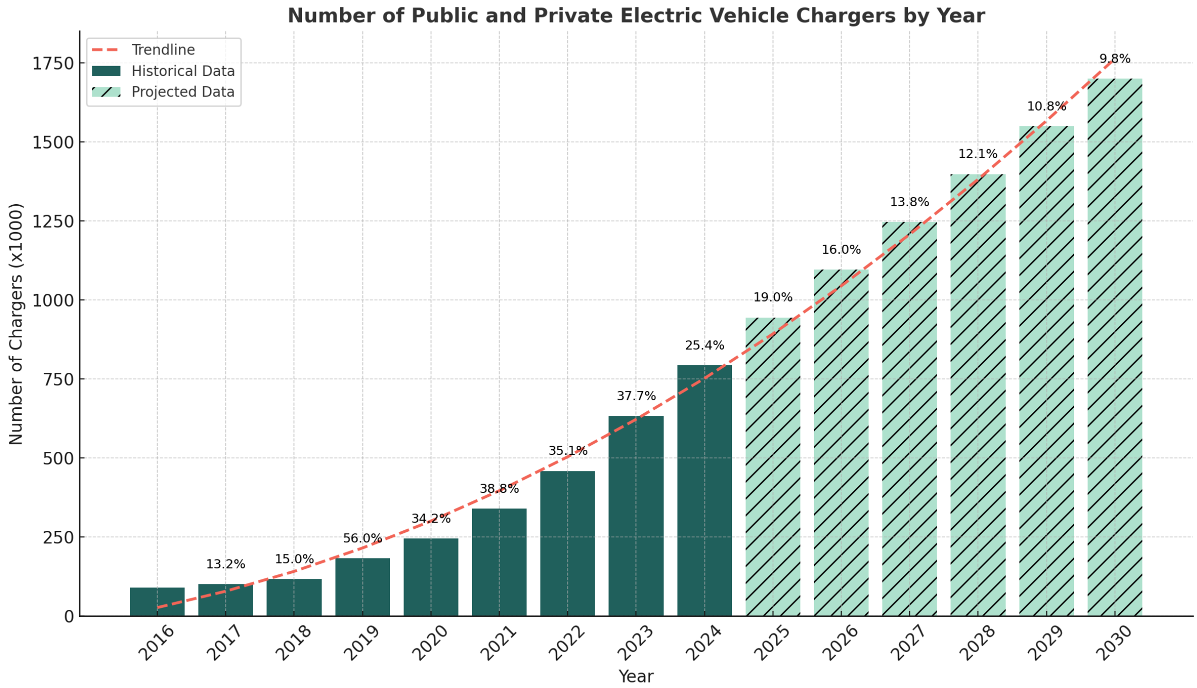


Figure 1.1: Electric Vehicle Growth Projection in the Netherlands. Created using [2], [3].

grid congestion in the short term [9], [10], but it also engages residents in urban resource management, by letting them participate more actively in how energy is distributed, leveraging data from ADM to make more equitable decisions about energy use [4]. With the increasing availability of large amounts of data regarding energy usage of EV chargers, common and frequent tasks like energy distribution can be driven by ADM using artificial intelligence (AI) [11].

However, with SC and V2G technologies offering potential solutions for managing and alleviating net congestion, they also introduce new challenges related to the social acceptance and fairness of energy distribution decisions using ADM. Data-driven incentives align with the fundamentally guiding objective of smart cities to enhance resident's quality of life and is consistent with a shift from a traditional institutional view to an experimental model [12]. First, citizens were viewed as passive sources of data supporting the functioning of urban infrastructure. Now, in the experimental model, it actively involves citizens in managing urban resources, and in this case, determining how AI should conduct the distribution of energy [12]. One major issue of note here would be the trust of society in ADM. Research has already shown that people who feel more in control of their online information are more likely to accept ADM as fair, especially for vulnerable groups in society who were not considered in the past. The acceptance of ADM systems in society could potentially be achieved by giving people the ability in choosing which decisions made by ADM are fair and preferable. The question is under which circumstances people would not only perceive ADM as fair, but also how these automated decisions would be deemed fair, even if they might not always be to the user's advantage. [13], [14]

As ADM systems become central to managing urban infrastructure, it is critical to examine their impact on equity and justice in energy distribution. To effectively deploy smart city technologies, we must move beyond solely technical solutions and address ethical and political considerations involved [7]. By doing so, smart cities can be designed not only to achieve efficiency and optimisation, but also prioritise inclusivity and social justice. This aligns with the European Commission's commitment to reduce greenhouse gas emissions while ensuring that no community is left behind in the energy transition [1]. Through the thoughtful integration of SC and V2G technologies, ADM systems can support a vision of smart cities that foster both sustainability and fairness, paving the way for a just and equitable urban future.

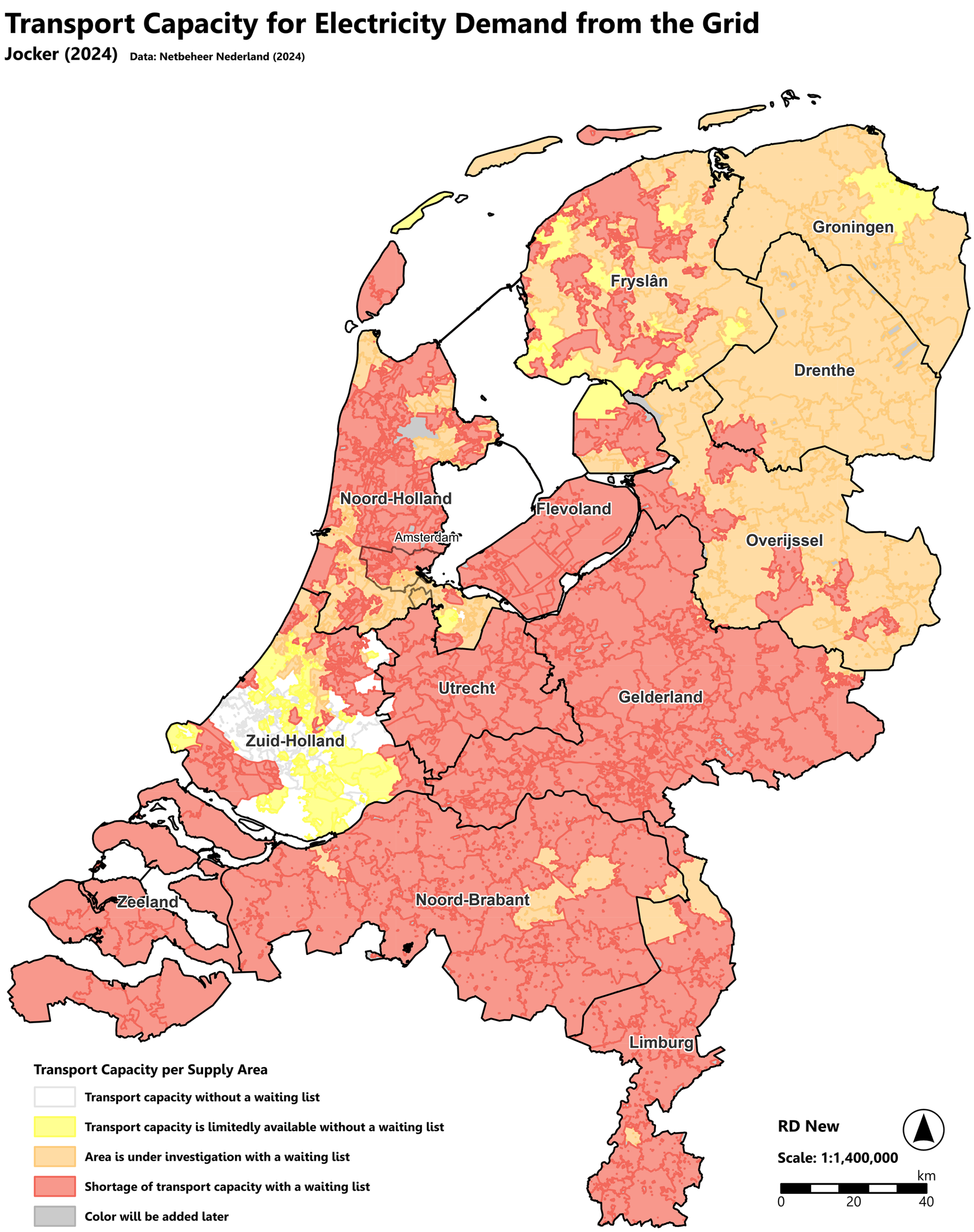


Figure 1.2: Transport Capacity for Electricity Demand from the Grid

This study will address this research gap by exploring the electric vehicle charging infrastructure (EVCI) in the Netherlands and particularly Amsterdam, guided by the framework of energy justice. Specifically, it will examine how equity, transparency, the right to energy, and ethics of care are reflected in and affected by artificial intelligence-driven automated decision-making (ADM) systems in energy distribution. Using a combination of Geographic Information System analysis, scenario development, and Q-methodology, this research aims to capture the perspectives of both electric vehicle users and non-users from diverse demographic backgrounds on the role of automated decision-making. By presenting projected future scenarios and corresponding statements, this study evaluates participants' levels of agreement and explore societal consensus on automated decision-making in electric vehicle charging infrastructure. Ultimately, the findings aim to provide policy recommendations that embrace the concept of 'Mindful Power' to better integrate justice dimensions in the deployment of automated decision-making. This approach seeks to increase awareness of energy justice by addressing the social acceptability and equity implications of automated decision-making within urban electric vehicle charging infrastructure. The following main research question has been posed for approaching this study:

"How can automated decision-making for urban electric vehicle charging infrastructure in the Netherlands be optimised to promote energy justice—ensuring equity, transparency, and the right to energy—while addressing the diverse perceptions and needs of stakeholders?"

Which is accompanied by the following sub-questions:

SRQ 1: "How do equity issues emerge from the expansion of electric vehicle charging infrastructure and its impact on net congestion, and which social and economic groups are most affected by these inequities?"

SRQ 2: "How have energy justice and automated decision-making in electric vehicle charging infrastructure been historically and currently understood in the Netherlands?"

SRQ 3: "What are the perceptions and expectations of stakeholders, including electric vehicle and non-electric vehicle owners, regarding the role of automated decision-making in managing vehicle-to-grid and smart charging technologies in electric vehicle charging infrastructure?"

SRQ 4: "How can interventions in technology, design, and policy improve the equity of automated decision-making in electric vehicle charging infrastructure?"

Given the exploratory nature of this study, the following propositions guide the research on how ADM can be optimised for equity and efficiency in managing energy distribution regarding EVCI in Amsterdam:

P1: The future projected expansion of EVCI, while managed by automated decision-making, may result in unequal access by disproportionately benefiting affluent neighbourhoods while leaving marginalised communities underserved. Existing literature suggest the access to EVCI often being unevenly distributed, with affluent neighbourhoods more likely to benefit from new technologies like ADM. P1 explores the extent of inequality regarding ADM driven EVCI in Amsterdam.

P2: ADM is expected to play a crucial role in improving efficiency of energy distribution to alleviate net congestion. However, the distribution of efficiency gains may not be equitable for all socioeconomic parts of society. With ADM becoming necessary to manage the complexity of energy distribution, P2 investigate whether efficiency is equally realised across different groups and areas.

P3: Stakeholders from particularly marginalised communities, may perceive ADM as less fair and transparent potentially hindering public acceptance unless participatory procedures are introduced. Studies have shown that trust in automated decision-making is often linked to level of transparency and user control. P3 explores in what way different demographic groups perceive the role of ADM in managing energy distribution besides and whether public participation can improve acceptance.

P4: Without intentional design interventions, ADM might prioritise operational efficiency over equity, reinforcing existing inequalities. However, the integration of equity-focused policies into the design of ADM might result in more balanced outcomes. ADM tends to focus on optimisation and efficiency in energy distribution unintentionally favouring those who are already better served in existing infrastructure. P4 explores whether equity can be integrated in the design of ADM.

1.1. Reader's Guide

This thesis is structured to systematically explore the research question of optimising Automated Decision-Making (ADM) for energy justice within urban Electric Vehicle Charging Infrastructure (EVCI). Each chapter builds upon previous sections, guiding the reader through theoretical, empirical, and applied analyses that ultimately answer the study's primary research question. Below is an outline of each chapter, including connections to specific sub-questions, methodologies, key findings and outcomes.

- **Chapter 2 - Background: Key Concepts and Technologies**
  This chapter introduces fundamental concepts, including Smart Charging (SC), Vehicle-to-Grid (V2G) technologies, and ADM, alongside the foundational principles of energy justice. These concepts provide the necessary context for understanding the study's objectives and are consistently referenced throughout the thesis to support theoretical and empirical analyses.
- **Chapter 3 - Literature Review: Reviewing Energy Justice and Stakeholder Dynamics**
  In this chapter, a thorough review of existing research on energy justice, ADM in EVCI, and stakeholder dynamics within the Netherlands is conducted. This review answers Sub-question 2 by examining how ADM aligns with or challenges principles of equitable distribution, transparency, and recognition in energy access. The insights inform the theoretical framework, guide the Geographic Information System (GIS) analysis, and provide context for the Scenario Development.
- **Chapter 4 - Theoretical Framework: Integrating Frameworks with Energy Justice**
  This chapter outlines the theoretical basis for evaluating ADM within EVCI, focusing on the three dimensions of energy justice—distributive, procedural, and recognition justice—alongside relevant ethical frameworks. These frameworks are used as analytical tools, particularly in assessing ADM's role within EVCI in Chapters 6 (Results) and 7 (Discussion). Indicators derived from these frameworks inform the GIS analysis, Scenario Development, and Q-methodology.
- **Chapter 5 - Methodology: Mixing Research Methods for Evaluating Energy Justice**
  This chapter details the mixed-method approach, encompassing GIS analysis, scenario development, and Q-methodology, with each method addressing specific sub-questions:
  - *Geographic Information System (GIS) Analysis*: The first research method investigates spatial disparities in EVCI accessibility, directly answering Sub-question 1 on existing inequities in access to EVCI.
  - *Scenario Development*: The second research method provides future projections, offering insights for Sub-question 3 by exploring different configurations for EVCI expansion implementing SC and V2G technologies and ADM's role in promoting equitable energy distribution.
  - *Q-Methodology*: The third research method captures stakeholder perspectives, addressing Sub-question 3 by evaluating stakeholder expectations and perceptions of fairness within ADM-driven EVCI.
- **Chapter 6 - Results: Spatial and Social Inequities and Stakeholder Views**
  This chapter presents findings from each method. The GIS analysis reveals spatial patterns in EVCI distribution, offering empirical evidence for Sub-question 1 regarding equity in access. Scenario development highlights potential trade-offs between efficiency and equity, suggesting future outcomes of ADM in EVCI. Q-methodology results outline stakeholder perspectives, addressing Sub-question 3 by identifying consensus and divergence in ADM perceptions and priorities.
- **Chapter 7 - Discussion: Challenges and Pathways in Pursuing Energy Justice**
  This chapter synthesises the results, addressing challenges and proposing pathways to integrate energy justice into ADM for EVCI. It addresses Sub-question 4 by suggesting policy and design interventions that could enhance energy justice within ADM systems. Additionally, this chapter discusses the study's limitations and provides directions for future research, facilitating a thorough understanding of the broader implications for ADM in urban EVCI.
- **Chapter 8 - Conclusion: Towards Balancing Efficiency and Energy Justice**
  The final chapter summarises the main findings and presents recommendations for policymakers and EVCI developers, answering Sub-question 4 more in-depth. This chapter returns to the primary research question, offering insights on balancing technological efficiency with social equity to support a fair and inclusive energy transition. The outcomes provide a basis for future policy considerations and identify areas for continued research and development in equitable ADM for EVCI.

2 Background

Key Concepts and Technologies

To effectively examine stakeholder perceptions on the application of ADM in EVCI, an initial understanding needs to be established regarding the technologies that ADM will manage—namely Smart Charging (SC) and Vehicle-to-Grid (V2G)—besides their implications for energy justice, particularly looking at equitable access, distribution, fairness, and the dispersal of benefits and burdens. This Background will provide the essential context for understanding the key technologies used in this study and introduce the energy justice framework, which will underpin the analysis of ADM's role in promoting equitable EVCI.

2.1. Net congestion alleviating technologies

As mentioned in Chapter 1 - Introduction, the integration of SC and V2G technologies within EVCI may present a promising approach to alleviating both current and anticipated grid congestion. By optimising and balancing energy consumption at the neighbourhood level, these technologies can enhance grid stability and improve energy efficiency. SC and V2G enable more flexible and responsive energy management, which is essential as EV adoption grows and places increasing demands on local grids. The following sections will briefly explain how each technology works, outlining their respective roles and potential benefits in reducing grid strain and supporting a more sustainable energy ecosystem.

2.1.1. Smart Charging

Smart charging (SC) can be defined as a technique used by grid operators, energy suppliers and charging station operators to optimise EVCI [14]. It aligns charging time, speed, and method with EV drivers' preferences and market conditions [14]. Thus, SC can be faster and cheaper than normal charging, but the opposite may occur during less optimal periods, such as low energy supply, high demand, high prices, or network overload [14]. Diving deeper in the financial benefit of SC, the effectiveness of SC in reducing charging costs in the case of Europe lies around 15-30% besides decreasing CO_2 emissions up to 600.000 tons per year by 2030 [15]. Moreover, research suggests that in California in 2025, five million EVs using SC, could reduce renewable curtailment by up to 40% compared to traditional charging methods with the same number of EVs and avoid up to 10% of annual grid operating costs [16]. The drawbacks of SC include technical challenges such as pricing mechanisms, privacy and cybersecurity, and ongoing optimization of the ADM-driven SC system through feedback and data analysis [15]. In line with this study, the social challenge mainly arises from the need to engage local residents—both EV and non-EV users—to ensure transparency, trust and acceptance of ADM in EVCI [15]. This includes scheduled charging or fluctuations in charging speed that SC could use to alleviate net congestion. People may respond differently to the usage of ADM in EVCI based on their needs, their knowledge of the system and the transparency given on how the system makes its decisions. Responses to ADM in EVCI vary based on individual needs, system knowledge, and decision transparency. Awareness campaigns and feedback collection could help gauge public perception [15]. An overview of benefits and challenges of SC can be found in Figure 2.1 on page 8.

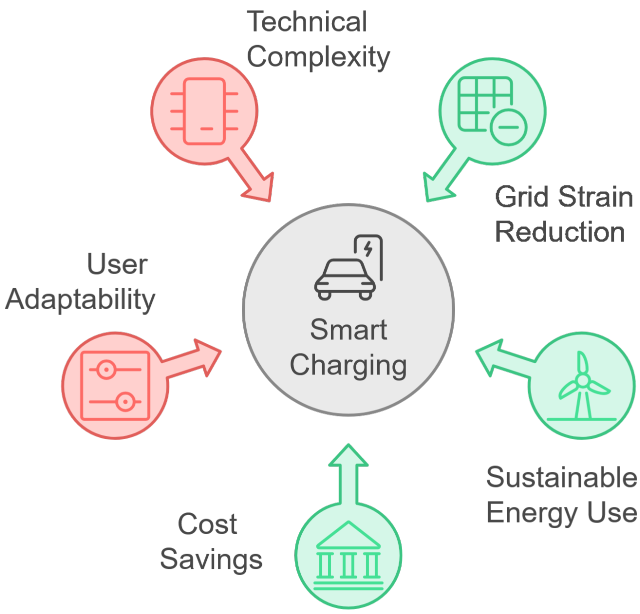


Figure 2.1: Smart Charging: Benefits and Challenges

2.1.2. Vehicle-to-Grid

Vehicle-to-Grid (V2G) technology, also known as bidirectional charging and considered a form of SC, provides a decentralised source of flexibility that has the potential to mitigate the increase in existing peaks in today's electricity patterns. Practices like this are known as peak shaving, and provide solutions to grid congestion involving the brief reduction of power consumption to prevent spikes. Economically, V2G presents a dual opportunity: it can enhance grid resilience and efficiency by providing supplementary services such as frequency regulation and peak load shaving, thus potentially reducing the need for expensive, centralised power plants [17]. For EV owners, it offers the prospect of financial returns by selling back excess energy to the grid at times of high demand due to fluctuating market prices [18]. Therefore, EV owners are regarded as the primary actors for the introduction of large-scale implementation of V2G technology in private EVCI due to their direct involvement and thus the importance to be actively engaged with and taking down perceived barriers of the technology [9], [19]. Risks of V2g concern battery degradation due to an increase in charge cycling. This poses a risk to the economic viability of owning an EV, since potential financial benefits may be lessened due to reduced battery lifespan and increased replacement costs [9], [17]. However, another study argues that the battery management using V2G could optimise battery usage providing the longest lifespan:

> *"The battery management keeps battery charge close to 50% state of charge and charges batteries according to coming traveling distance… …The automatic charging control (or ADM) locates the charging spot, adjust the charging power level and charging time, and checks power grid and battery storage availability to the V2G operations before required charging decision."* [20, p. 6]

Another challenge is the minimum range, which represents the essential distance EVs must reliably cover in situations of unpredictable demand, such as emergencies. Critical considerations related to range management include the *safety threshold*—the minimum range where immediate charging should commence upon reaching a station—and the *target range*, the recommended charge level for ensuring a vehicle is ready for the entire planned trip [9], [17]. Balancing these technical requirements alongside economic opportunities is essential for the effective integration of V2G into the future energy ecosystem. Additionally, when applied effectively, SC and V2G enhance the integration potential of renewable energy sources, particularly in managing grid congestion [9]. These technologies support ancillary services, defined as:

> *"All services required by the transmission or distribution system operator to enable them to maintain the integrity and stability of the transmission or distribution system as well as the power quality."* [21, p. 9]

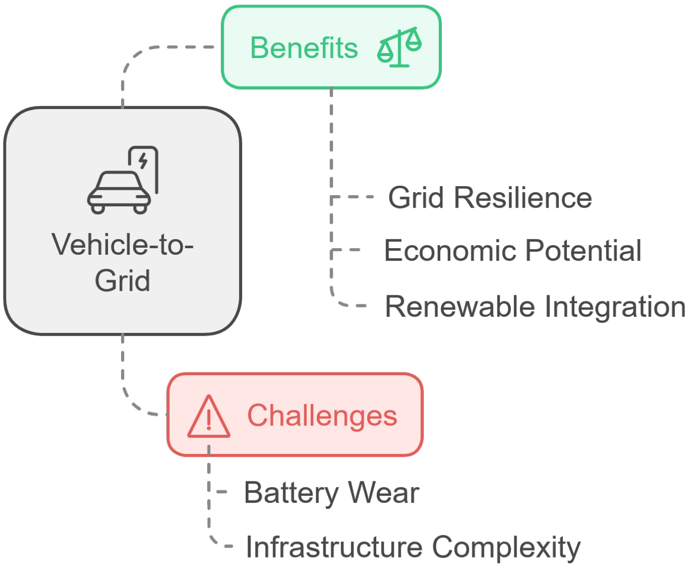


Figure 2.2: Vehicle-to-Grid: Benefits and Challenges

Ancillary services are essential for balancing the demand and supply of electricity, especially with increased integration of intermittent renewable energy sources like solar and wind energy. V2G could provide ancillary services to the grid, reducing the need for stationary utility-scale electricity storage solutions [22]. This will help to maintain a stable power frequency, power quality, and overall reliability of the electricity supply [18]. Countries with a large fleet of EVs, SC and V2G could reduce electricity storage capacity by 35% resulting in a 4% lower system cost [22]. Due to the intermittency of solar and wind energy, the supply of energy fluctuates heavily. A real-world example of managing such fluctuations is the temporary shutdown of offshore wind turbines on the North Sea during periods of peak bird migrations. To protect these migrating birds, the Dutch government coordinates with transmission system operator TenneT, wind park operators, and experts on bird migration, to stop wind turbine operations during times of high activity of predicted migration [23]. The electricity grid must then rely more heavily on ancillary services like SC and V2G to ensure the supply of electricity, highlighting the precarious equilibrium between environmental sustainability and energy security while showcasing the potential of smart technologies to adapt to shifting and unpredictable demands.

2.2. Automated Decision-Making and Energy Justice

The integration of ADM into energy systems represents a transformative shift, leveraging advanced algorithms to optimise energy distribution in real time, while simultaneously raising critical concerns around fairness, equity, and transparency, especially in the context of societal inequalities. ADM refers to the process where decisions are made by algorithmic systems or AI without human involvement, enabling faster, data-driven decisions in real time. ADM systems utilise complex algorithms to analyse extensive datasets, often processing personal or operational data to optimise specific outcomes [24]. In the context of electricity grids, ADM uses machine learning and predictive analytics to manage the complexities of intermittent renewable energy sources. These systems can detect potential grid instabilities, predict energy demand, and adjust energy distribution accordingly, ensuring a more stable and efficient grid. A significant advantage of ADM is its ability to minimise human error and reduce response times in situations requiring dynamic energy adjustments, making it well-suited for managing fluctuating electricity patterns as seen in renewable energy systems. By automating processes like energy load balancing and supply- and demand adjustments, ADM can optimise energy distribution at the neighbourhood level, providing scalability as the demand for EVCI continues to rise [11].

However, the growing reliance on ADM raises significant societal concerns. Several studies raise the question of fairness regarding the process of ADM in EVCI, as it poses risks in terms of equity and access. These concerns include socio-economic implications concerning who receives priority for charging and the effects of dynamic pricing [13], [14]. ADM systems, though designed to optimise efficiency, may unintentionally reinforce existing socio-economic inequalities due to algorithmic biases embedded in

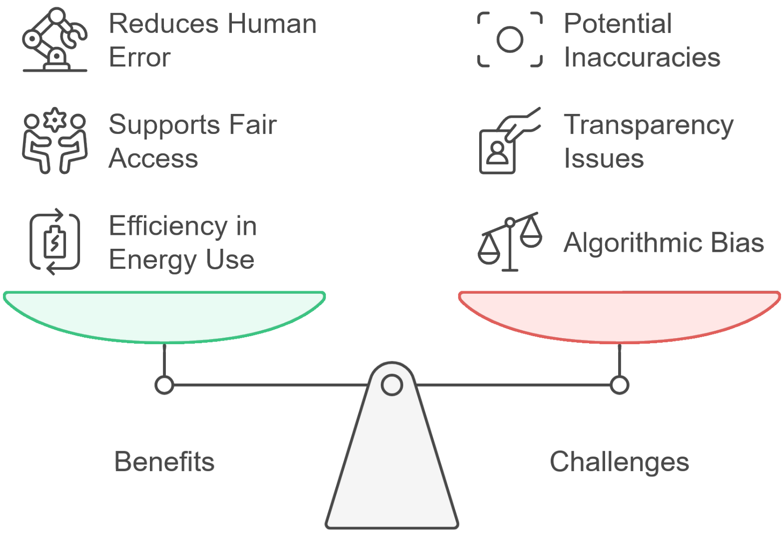


Figure 2.3: Automated Decision-Making: Benefits and Challenges

their design [25], [26]. For instance, ADM focuses on optimising grid efficiency may lead to unequal prioritisation of certain areas or groups for access to energy, favouring wealthier communities that have better access to EVCI, disproportionately disadvantaging lower-income neighbourhoods, exacerbating existing inequities [13]. Moreover, dynamic pricing models enabled by ADM may result in higher energy costs for consumers who lack the flexibility to charge their vehicles during off-peak times, further reinforcing disparities in access and affordability. These concerns are central to *Proposition 2 (P2)* of this study, which investigates whether the efficiency gains from ADM are realised equitably across different socioeconomic groups. Despite these risks, ADM also presents opportunities for improving fairness in energy distribution. By using complex data analysis, ADM could be designed to prioritise marginalised communities or shared EV networks, ensuring that lower-income groups gain fair access to charging infrastructure and energy resources [27]. Additionally, the use of ADM could enable more equitable energy allocation, particularly during times of scarcity, such as prioritising shared EVs or essential services when electricity supply is limited [28]. In this context, ADM has the potential to transform energy systems, not only through technological optimisation but also by reshaping how energy is distributed to address issues of equity and fairness. The challenges associated with ADM relate directly to societal perceptions of distributive and procedural justice, particularly concerning how the costs, risks, and benefits of these automated systems are distributed across different social groups [29].

2.3. Summary and Relevance

This background provides context for understanding the key technologies consisting of SC and V2G that ADM systems will manage within EVCI. By examining the technical and social implications of SC and V2G, it establishes how these technologies are anticipated to alleviate grid congestion, enhance energy efficiency, and support renewable energy integration. SC and V2G enable flexible, neighbourhood-level energy management, essential for meeting the increasing demands on the grid due to EV adoption. Moreover, the energy justice framework is introduced, which examines fairness in energy distribution, procedural transparency, and recognition of diverse needs in energy access. This framework is further explored in the Literature Review (Chapter 3), where the energy justice dimensions—distributive, procedural, and recognition justice—are examined in relation to ADM's role within EVCI. The Literature Review highlights how ADM can either address or exacerbate inequities, especially within socio-economically diverse areas. The energy justice dimensions form the basis of the study's theoretical framework, where they are applied to assess ADM's potential to promote equitable EVCI access across different communities. In the study, the energy justice framework will inform the GIS analysis, Scenario Development, and Q-methodology. Insights from SC, V2G, and ADM in this background help design scenarios that reflect varied stakeholder needs. Additionally, energy justice principles are embedded in the statements used in the Q-methodology. This background section, therefore, functions as a reference, linking the technical potential of SC and V2G with energy justice-focused applications, guiding the study's exploration of ADM's role in fostering a just and sustainable energy transition.

3

Literature Review

Reviewing Energy Justice and Stakeholder Dynamics

This chapter, builds upon the fundamental concepts introduced in Chapter 2 and advances the study's exploration of how ADM systems impact energy justice within EVCI. Specifically, this review addresses Sub-question 2 — *How do equity issues emerge from the expansion of electric vehicle charging infrastructure and its impact on net congestion, and which social and economic groups are most affected by these inequities?* — while also contributing insights relevant to Sub-question 1 regarding the socio-economic disparities in EVCI access further explored in the Geographic Information Systems Analysis. Through an examination of existing literature, the chapter clarifies the ethical and procedural roles ADM can play in balancing efficiency with social equity in energy management.

The chapter first traces the historical evolution of energy justice in Dutch policy, highlighting how past approaches to energy distribution and access have shaped today's challenges. As these policy developments underscore the persistent inequities in energy systems, they provide essential context for understanding ADM's potential to either reinforce or mitigate these disparities. The chapter then reviews ADM's integration in SC and V2G technologies within smart grid systems, using energy justice as a lens to assess ADM's implications for distributive, procedural, and recognition justice (Chapter 4). These three dimensions, central to the energy justice framework, provide criteria for evaluating how fairly ADM systems manage resource distribution, transparency, and stakeholder inclusion.

Additionally, this review draws on the stakeholder salience model to analyse the varied roles and influence of stakeholders within the EVCI system. By categorising stakeholders according to their power, legitimacy, and urgency, the model reveals the dynamics that shape ADM outcomes in both public and private EVCI contexts. This stakeholder perspective is crucial for understanding how ADM can balance the needs of marginalised communities, commercial interests, and policy objectives, thereby addressing procedural justice in energy systems. Together, these insights establish an understanding of ADM's ethical, technical, and social dimensions, setting the stage for the study's theoretical framework (Chapter 4), and providing criteria for the GIS analysis (Section 6.1), Scenario Development (Section 6.2) and Q-methodology (Section 6.3).

3.1. History of Energy Justice in Dutch Energy Policy

Over the past decades, energy justice has emerged as a comprehensive social science framework, integrating justice principles into energy-related issues such as policy, production, consumption, activism and security. It evaluates (a) where injustices emerge, (b) which societal groups are disregarded, and (c) what processes exist to address these issues. Its goals consist of both exposing and mitigating these inequities, aiming to ensure fair energy systems and policies besides inclusivity, especially in the context of the political economy and climate change [30]. This historical evolution sets the stage for contemporary challenges regarding ADM in EVCI, where issues of technology, equity, and access continue to echo past energy policy shifts.

Although energy justice is a relatively recent addition to energy policy, it is historically rooted in concerns about the fairness of policies and the inclusion of diverse actors and their needs [31]. One study provides an overview of how concerns for energy justice have emerged and evolved within the energy policy domain by analysing key policy documents outlining the trajectory of energy policy in the Netherlands from 1974 to 2022 [31]. Between 1974 and 2022, the concept of energy justice in Dutch policy evolved through four significant periods. In the first period (*1974-1995*), energy policy was primarily driven by concerns over economic distribution due to the energy availability crises. During this time, energy justice was interpreted as ensuring stable energy supply to support economic growth. The second period (*1995-2005*) marked the liberalisation of the energy market, with the focus shifting towards economic justice by promoting free market principles as a way to benefit society as a whole, particularly through the privatisation of energy services. As ecological concerns rose globally, the third period (*2005-2016*) integrated green growth, where economic and ecological concerns merged, placing a greater emphasis on sustainable energy distribution and the environmental impacts of energy policy. This period witnessed the rise of concerns around inclusivity and recognition, reflecting a shift towards inclusion and transparency in decision-making processes. Finally, in the most recent fourth period (*2016-2022*), stakeholder recognition, decentralisation of decision-making, and an increased focus on ecological impacts shaped the energy policy, reflecting a more comprehensive view of energy justice that includes social, economic, and environmental dimensions.

This historical progression illustrates how an initial emphasis on economic distribution has evolved to encompass wider issues of ecological sustainability, transparency, and equitable stakeholder involvement, aligning with a more global energy justice framework [30], [32]. This aligns with earlier points regarding the importance of transparency [15] and the recognition of stakeholders in ADM for EVCI [9], [19]. Thus, the view on concerns in energy justice in the fourth period has been continuing in the subsequent years highlighting the continuation of concerns regarding energy justice beyond the fourth period.

3.2. Energy Justice and Automated Decision-Making in Smart Grid Systems

The integration of ADM within smart grids and EVCI raises important questions regarding equity, access, and transparency in energy distribution—a continuation of longstanding concerns in Dutch energy policy. ADM presents both opportunities and challenges for achieving distributive and procedural justice in the transitioning energy landscape. The term ”smart grid” captures the digitisation of power distribution systems, which is central to the broader smart cities initiative aimed at creating more sustainable and resilient urban environments [33]. Smart grids enable real-time communication and data exchange across infrastructure, helping manage energy use more dynamically and efficiently [34]. In this framework, SC and V2G technologies benefit from the capabilities of smart grids, which provide essential infrastructure for real-time communication and smart metering data. This enhances the potential for coordinated charging and discharging of EVs, allowing ADM systems to optimise energy flows, balance supply and demand, and support the broader goals of smart cities, such as reducing carbon emissions, alleviating grid congestion, and improving energy resilience [7]. However, the integration of ADM in these systems also underscores the need to address social concerns, as smart city technologies increasingly influence how citizens access and interact with essential urban services [8]. The potential for SC and V2G to exacerbate existing inequities reflects historical patterns observed in Dutch energy policy, highlighting the ongoing nature of these challenges as new technologies reshape energy distribution. The Energy Justice framework provides a valuable lens through which to examine these issues, focusing on the fair distribution of resources, inclusive decision-making processes, and the recognition of diverse stakeholder needs. In this context, the framework's three dimensions—*Distributive Justice, Procedural Justice, and Recognition Justice*—determine the evaluation the social implications of ADM within EVCI.

3.2.1. Distributive Justice

With the need to deploy ADM to determine energy distribution in these smart grid systems [11], energy justice plays a critical role to ensure equitable distribution. Different studies have highlighted the deployment of EVCI to regularly exacerbate existing inequalities in mainly low-income neighbourhoods. These neighbourhoods facilitate a limited number of charging stations creating inequities in the access to EVCI [35], [36]. Fairness in resource allocation is not simply about equal distribution but rather equitable distribution, which takes into account the needs of different social groups. *Distributive fairness* focuses on allocating resources in a manner that benefits disadvantaged groups to create a just and balanced society. Adapting ADM to these principles could ensure that energy infrastructure is distributed in a way that prioritises underserved communities [37]. This aligns with *Proposition 1 (P1)* as it explores whether EVCI expansions will favour affluent communities leading to unequal access across different socioeconomic groups. ADM could optimise decisions for energy distribution; however, if algorithms are not designed with fairness in mind, they may inadvertently create distributive injustices [38]. For instance, the distributional costs with SC or V2G may disproportionately burden low-income users [33]. ADM may introduce biases favouring the well-served, affluent regions or tech-savvy users. This imbalance could deepen socioeconomic divides, where the deployment of V2G often benefit wealthier populations who can afford EVs and have access to private charging infrastructure, while lower-income and rural communities are left with fewer charging options [35], [38]. Failing to prioritise vulnerable communities in energy distribution not only perpetuates inequities but also infringes on the human right to energy, as equitable access is a basic right. Dynamic pricing schemes in SC can lead to higher costs for users who cannot adjust their charging times caused by work schedules or lack of access to private chargers, particularly affecting lower-income EV owners [39]. Thus, without the careful calibration of ADM, it might prioritise operational efficiency over equity, resulting in the unequal distribution of and access to resources. This aligns with *Proposition 4 (P4)*, which explores how equity-focused interventions could create more balanced outcomes.

3.2.2. Procedural Justice

Besides distributive justice being crucial for fair access to EVCI, *procedural justice* is vital in ensuring that decisions made by ADM are transparent and inclusive. The decision-making process behind the allocation of EVCI, energy distribution, and pricing strategies should be visible and understandable to all stakeholders, not just those with technical expertise, as this is critical in building trust and legitimacy. To achieve this, categorisation of users based on factors such as socio-economic status, EV ownership, and technical familiarity, is needed to ensure that participation mechanisms reflect the distinct needs of each group. The successful implementation of ADM within EVCI depends heavily on understanding and navigating the intricate network of stakeholders involved. Freeman's Stakeholder Theory [40] emphasises that, beyond immediate consumers or investors, all actors affected by a system play a critical role in shaping its effectiveness and equity outcomes. In the context of EVCI, this includes regulatory agencies, energy suppliers, EV manufacturers, and community groups—all of whom bring competing priorities and resources [41]. This can be described as a "polycentric governance" system, where independent stakeholders operate with diverse goals, often leading to policy fragmentation [42]. This fragmentation is especially relevant in public-private partnerships, where balancing public goals of equitable access with private goals of profitability presents ongoing challenges. Understanding and addressing these stakeholder dynamics is thus crucial for designing ADM systems that balance operational efficiency with distributive justice.

Given this complexity, transparency becomes essential in fostering trust by allowing users to see how decisions are made, which helps them understand that the processes are fair and impartial. When stakeholders are confident in the transparency of the system, their perception of fairness increases, which strengthens their trust and acceptance of the ADM systems [43]. The perception of fairness and transparency can be linked to *Proposition 3 (P3)*, which examines how different demographic groups perceive the fairness of ADM. In this context, procedural fairness focuses on the users' perception that decisions are made through impartial and consistent methods, whereas procedural justice goes further by ensuring that these methods contribute to overall legitimacy, trust, and moral alignment within the system. This distinction is particularly important in ADM, where technical complexities often limit public participation, especially among disadvantaged communities [44]. The lack of transparency could intensify existing distrust between consumers and energy providers, especially regarding privacy and data concerns [33]. Thus, procedural justice plays a crucial role in reinforcing legitimacy and compliance in governance processes. Moreover, transparency, combined with participatory decision-making mechanisms, ensures that all communities, particularly marginalised groups, are involved in shaping the development of ADM systems. This inclusion can lead to greater acceptance of the technology as it reflects the needs of all users [45]. Additionally, transparency serves as a safeguard against potential biases in ADM, ensuring that systems designed to manage energy distribution and pricing are seen as equitable. Engaging diverse community groups in these discussions ensures that ADM in EVCI reflects a fair process, especially when end-users feel that their voices are heard and that their data is protected. As research suggests, when people perceive a system as fair, they are more likely to accept the outcomes of ADM, even in cases where the decisions do not immediately benefit them [44].

3.2.3. Recognition Justice

Recognition Justice is essential in ensuring that the specific needs and identities of marginalised or under-represented groups are acknowledged in ADM decision-making. While Distributive Justice addresses the equitable allocation of resources, and Procedural Justice focuses on transparency and inclusion, Recognition Justice emphasises the importance of identifying and valuing the unique circumstances of diverse communities [38]. In the context of EVCI, ADM systems must consider how various social groups, particularly low-income and rural communities, may be disproportionately affected by algorithm-driven decisions [33]. For instance, without adequate recognition of their needs, such communities may be left with limited access to EV charging, as infrastructure expansions often favour affluent areas with higher EV ownership [35]. *Interactional fairness* becomes important here, which is emphasised by respectful and transparent communication between decision-makers and the affected groups. In the context of ADM in EVCI, ensuring that marginalised communities are included in the dialogue around infrastructure planning will help ensure that their needs are met and that they are not left behind in the energy transition [46]. This dimension aligns with *Proposition 2 (P2)*, as it explores whether ADM can account for the diverse needs of different socioeconomic groups, ensuring that those often overlooked are not further disadvantaged. Recognising these groups in ADM design and implementation can help prevent the deepening of socioeconomic divides, facilitating a more equitable transition towards sustainable energy solutions [44].

3.2.4. Barriers to Realising Energy Justice in Practise

While the dimensions of energy justice—distributive, procedural, and recognition justice—provide a framework for ensuring equity in energy systems, achieving these ideals in practice are often met with challenges. The transition from theory to application reveals structural and systemic barriers that can sustain or even exacerbate energy injustice, despite well-meaning efforts. In the context of ADM in EVCI, several factors, such as technology, policy, business models, and political influences, can hinder the equitable distribution of energy resources. Energy injustice arises from a complex interplay of these technological, policy-driven, and economic factors that create disparities in access to energy services. Scholars emphasise that energy systems are often skewed in favour of wealthier populations, with policy models focusing on efficiency rather than equity [47]. This bias is reflected in ADM systems for EVCI, which may prioritise regions with higher existing EV ownership and economic capacity, leaving marginalised communities under-served.

Technological and Policy Failures play a major role in this inequality. Technologies like ADM, while aiming to optimise energy distribution, often continue existing inequities by aligning with data from wealthier areas. This creates a feedback loop where areas with limited infrastructure remain overlooked. Policies focusing on market-driven approaches also tend to favour wealthier regions, exacerbating social inequalities in energy access [47]. There is a need for stronger policy frameworks that incentivise the equitable distribution of charging infrastructure, such as through targeted subsidies or tax incentives to encourage investment in underserved areas [47]. Moreover, *business models* centred around profitability intensify energy injustice. Charging station operators may prioritise investments in areas where usage rates promise higher economic returns, further reducing access to infrastructure in lower-income neighbourhoods. Dynamic pricing strategies tied to ADM can impose higher costs on users who cannot shift their charging times, disproportionately affecting lower-income users. *Institutional and political factors* also reinforce these inequities. Policy decisions often exclude marginalised communities, implementing top-down approaches that fail to recognise the specific needs of vulnerable groups [32]. Thus, when powerful stakeholders influence policy outcomes, it exacerbates the exclusion of marginalised communities and leads to unfair resource distribution, highlighting the need for equity-focused ADM systems that can actively address and mitigate these disparities rather than perpetuate them.

Energy injustice impacts daily life in measurable ways, particularly through disparities in access to EV charging infrastructure. In underserved areas, marginalised groups often face longer travel times to reach public EVCI, leading to increased transportation costs and reliance on less sustainable energy sources [47]. Furthermore, dynamic pricing strategies linked to SC and V2G technologies disproportionately affect lower-income users, who are less able to adjust their charging patterns due to rigid work schedules or lack of access to private chargers [33], [35]. These pricing disparities exacerbate the financial strain on vulnerable populations, undermining the principles of distributive justice by widening socioeconomic divides [48]. This lack of equitable access not only heightens daily challenges for marginalised individuals but perpetuates broader social inequalities, further entrenching systemic energy injustice [33].

3.3. Human Right to Energy

In expanding the dimensions of energy justice, fairness, and transparency in ADM, it is crucial to include the framework of recognising energy access as a fundamental human right, as it supports other essential rights, such as adequate living conditions, health, and education [49]. Energy, as a component of basic subsistence, can be viewed as a derived human right—a necessity for safeguarding more fundamental rights, including housing, health, and a decent quality of life [50]. Access to electricity enables individuals to live with dignity by impacting essential areas such as education, communication, and daily living standards. With the global energy transition advancing through initiatives like EV infrastructure, ensuring equitable access to energy becomes not only a moral obligation but also a legal imperative.

Access to energy is more and more seen as a key driver to social and economic development by being deeply connected to addressing energy poverty and promoting environmental justice [49]. The concept of a 'right to energy' is evolving globally, attracting attention from the United Nations and the European Union. The United Nation's Sustainable Development Goal 7 (SDG 7) highlights the importance of ensuring energy access is available to all, and particularly to under served communities [51]. Moreover, the European Union Electricity Directive recognises the importance of energy services for citizen's well-being and social inclusion [52]. Legal frameworks in Spain and France already go as far by guaranteeing the basic energy supply as a right for citizens [53]. The human right to energy also necessitates procedural justice, ensuring that marginalised groups have a voice in how new energy technologies are implemented. Ensuring fair access to EVCI must therefore align with the broader human rights objectives to avoid the exclusion of certain parts of society from the energy transition which also aligns with *Proposition 1 (P1)*. In consequence, recognising energy access as a human right would strengthen the moral and legal imperatives to create equitable energy systems. With the continuation of increasing EV adoption, ensuring that vulnerable populations are not left behind is essential to achieving a just energy transition. Therefore, policymakers and stakeholders must ensure ADM in EVCI to be inclusive, transparent and aligned with the fundamental human right to energy.

3.4. Equity in Smart Charging and Vehicle-to-Grid Technologies

As discussed in Chapter 2, SC and V2G technologies offer significant potential for enhancing grid flexibility and integrating renewable energy sources. These technologies optimise energy consumption patterns and allow electric vehicles to function as dynamic participants in energy systems. However, despite their technological promises, SC and V2G also raise important questions about equity and sustainability, particularly from the perspectives of energy justice and the human right to energy.

Although the goal of SC and V2G systems is to improve energy efficiency, their implementation may unintentionally make socioeconomic gaps in access to energy services worse. The distribution of EV infrastructure, including SC technologies, frequently favours affluent regions with greater EV ownership rates, depriving marginalised populations of adequate access to infrastructure for charging EVs [35]. This contradicts distributive justice principles, which emphasise equitable resource distribution, as previously discussed in the context of energy justice. SC and V2G technologies run the potential of escalating already-existing disparities if deliberate efforts are not made to allocate resources toward underserved communities. However, lower-income users may be disproportionately affected by *dynamic pricing models*, which enable price fluctuations based on grid demand. This is because these users may find it difficult to adjust their charging habits due to work schedules or lack of access to private EV chargers [48]. This issue is related to the debate about fairness of resource allocation since it suggests that SC and V2G systems can inadvertently create a larger divide between rich users who stand to gain from these technologies and marginalised populations who might have to pay more or have less access to infrastructure. As noted before, recognition justice focuses on acknowledging and addressing the needs of marginalised groups. In the case of SC and V2G technologies, recognition justice is especially relevant, since, if these technologies deployed without inclusive stakeholder engagement, it may prioritise technological optimisation over social inclusivity [33]. This risks marginalising vulnerable groups, whose needs and energy demands may differ significantly from those in more affluent areas. Acknowledging these needs is crucial to ensuring that SC and V2G systems do not reinforce existing social inequalities but instead contribute to a fairer energy system.

To align SC and V2G technologies with the principles of energy justice and the human right to energy, it is critical to ensure that their deployment is not only focused on technological efficiency but also on equity and inclusivity. Energy justice emphasises the need for distributive, procedural, and recognition justice, which must guide the allocation of energy resources, especially in underserved areas. Without conscious attention to these dimensions, SC and V2G could inadvertently perpetuate or deepen existing energy inequalities, particularly if infrastructure investments prioritise affluent regions, as has been noted in the broader context of EV charging infrastructure distribution [35]. The human right to energy underscores the importance of ensuring that all individuals have access to affordable, reliable energy. Yet, if SC and V2G systems employ dynamic pricing models that raise costs during peak demand, lower-income users may face disproportionate economic burdens, reducing their access to the benefits these technologies offer. This reflects a failure to uphold recognition justice, which stresses the importance of acknowledging and addressing the needs of marginalised groups. The alignment of SC and V2G with these frameworks requires that their deployment not only consider technological optimisation but also address the social implications of how energy is distributed, priced, and accessed. Through this lens, SC and V2G technologies can contribute to a more sustainable and equitable energy system if they take into account the diverse needs of different socioeconomic groups. Thus, the future of SC and V2G technologies must prioritise both technological efficiency and social equity to create a sustainable and fair energy system.

3.5. Stakeholder Dynamics and Influence on Energy Justice in EVCI

Achieving equity and inclusivity in SC and V2G technologies requires more than just recognising the importance of distributive and recognition justice—it also calls for a deep understanding of the roles and influence of stakeholders within the EVCI system. Examining stakeholders' varying levels of power, legitimacy, and urgency provides essential insights into their influence on ADM outcomes. By categorising users, such as EV owners, non-EV users, and low-income communities, ADM can address the specific needs and equity concerns of each group, ensuring that decision-making aligns with the principles of energy justice. This type of analysis is based on the stakeholder salience model developed by Mitchell, Agle, and Wood (1997), which categorises stakeholders according to these varying levels to assess their relative influence on decision-making outcomes [54]. At the top of this structure, '7 Definitive Stakeholders—Regulatory Bodies and Local Governments' hold the most substantial influence due to their high power, legitimacy, and urgency. As primary overseers of equitable resource allocation, these stakeholders ensure ADM processes integrate distributive and procedural justice principles. Through their decisions, they shape how and where EVCI develops, impacting both '4. Dominant Stakeholders' and '6. Dependent Stakeholders' below them. Importantly, Definitive Stakeholders establish a structural framework that directs transparency and fair resource distribution. These stakeholders' foundational role makes them crucial in balancing operational efficiency with equity within the EVCI system. The relationships and influence of each stakeholder group are illustrated in Figure 3.1.

In contrast, '4. Dominant Stakeholders', such as Private Energy Providers and EVCI Companies, also command significant power and legitimacy but often lack urgency regarding equity. These groups focus on profitability, a priority that can skew EVCI access toward affluent regions and neglect lower-income areas, thereby challenging principles of distributive justice. Without targeted engagement in equity-oriented ADM frameworks, their influence may perpetuate a resource imbalance, creating underserved communities with limited EVCI access. '6. Dependent Stakeholders', including Community and Advocacy Groups, serve as critical advocates for marginalised communities, holding high legitimacy and urgency but lacking power. Their role is indispensable in promoting Recognition Justice, pushing Definitive and Dominant Stakeholders to recognise and address community needs. By elevating community voices, these stakeholders advocate for inclusive ADM practices that consider fairness in decision-making and resource distribution across diverse populations.

Further layers in this stakeholder ecosystem include groups with varied influence but essential roles in promoting accountability and highlighting equity gaps. '2. Discretionary Stakeholders', such as the General Public, possess legitimacy yet have limited power and urgency. While their influence is more passive, they play a supportive role in fostering Procedural Justice by demanding transparency and fair access to EVCI decision-making processes. Meanwhile, '3. Demanding Stakeholders', such as New EV Owners in Underserved Areas, bring high urgency without power or legitimacy. Their pressing concerns reflect structural gaps in the EVCI system, urging Definitive Stakeholders to focus on underserved areas to prevent further disparities. Similarly, '1. Dormant Stakeholders', including Environmental NGOs and Advocacy Groups not directly involved in EVCI, though currently lacking power or urgency, advocate for long-term justice issues. As public awareness of sustainability and justice in EVCI grows, their influence may expand, potentially motivating other stakeholders to adopt more equitable and environmentally conscious practices.

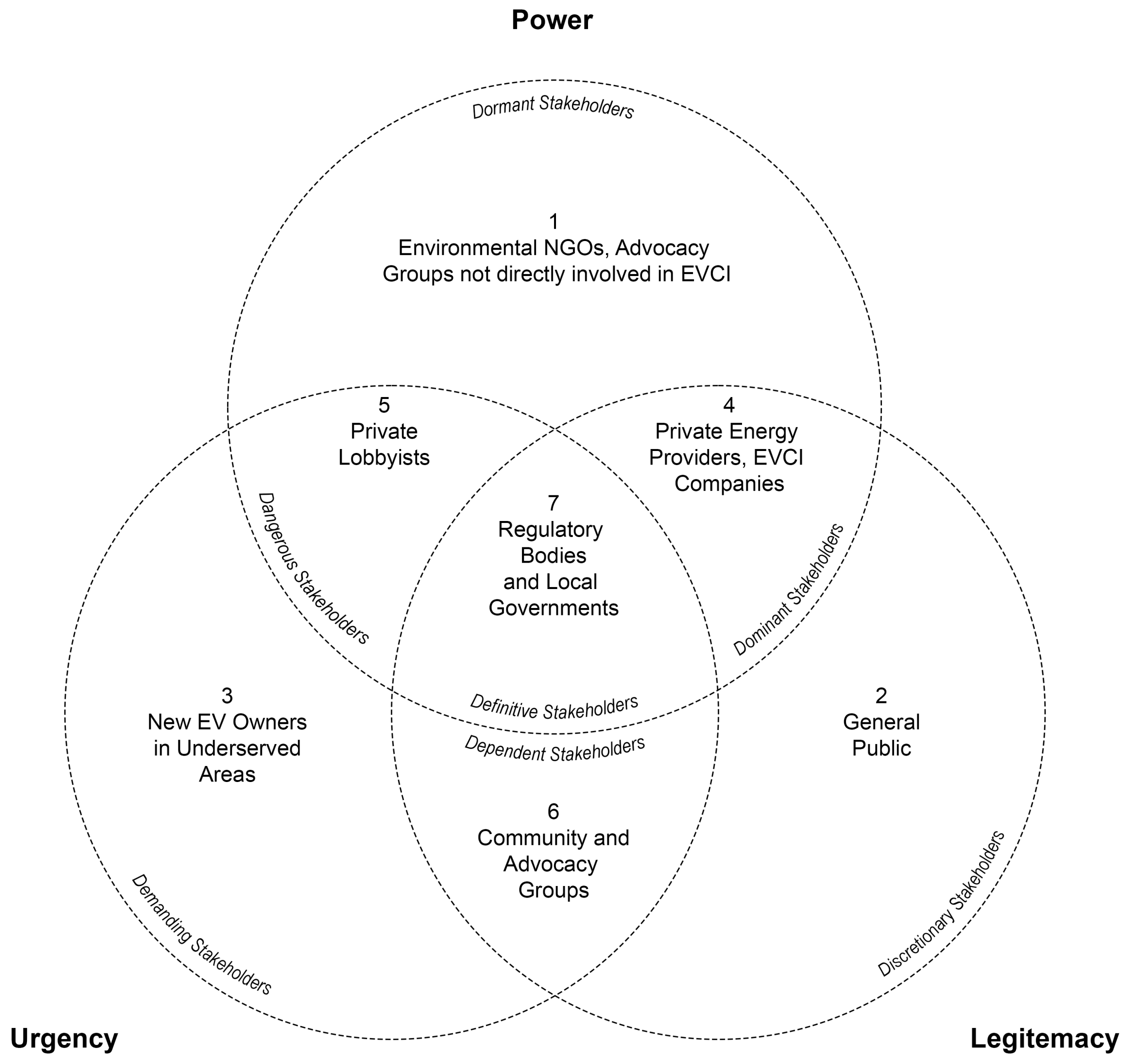


Figure 3.1: Stakeholders Identification supporting the Literature Review

Finally, at the periphery of legitimacy but with notable power, are '5. Dangerous Stakeholders', such as Private Lobbyists and Commercial Interest Groups. These stakeholders often prioritise profit-driven objectives that may undermine equitable outcomes, potentially redirecting ADM results in ways that favour commercial interests over fair resource distribution. If unchecked, their influence could exacerbate inequities within low-income communities and regions with limited EV adoption. Thus, understanding and managing the potential impacts of each stakeholder group is essential for advancing an inclusive, justice-oriented EVCI system. Recognising these interconnected influences, challenges, and opportunities enables stakeholders to work towards a balanced, equitable EVCI grounded in energy justice.

This stakeholder analysis directly influences policy recommendations by identifying where focused interventions are vital for guaranteeing a fair and inclusive EVCI system. Recognising each stakeholder's role and influence helps policymakers craft strategies that better address the diverse interests and motivations in the EVCI landscape. For example, involving Dominant Stakeholders (such as private energy providers and EVCI companies) in equity-centred ADM frameworks can reduce the tendency to prioritise affluent regions, whereas amplifying the voices of Dependent Stakeholders (such as community and advocacy groups) ensures marginalised communities are included in decision-making processes. Furthermore, understanding the urgency of Demanding Stakeholders and the passive but supportive role of Discretionary Stakeholders enables policy actions that properly combine transparency and procedural justice. This stakeholder map reinforces the roadmap for equitable EVCI and highlights the need for ongoing participation to uphold distributive, procedural, and recognition justice principles.

3.6. Summary and Key Findings

This chapter's exploration of energy justice frameworks and stakeholder dynamics in ADM illuminates key themes that addresses Sub-Question 2. First, the historical analysis of energy justice in Dutch policy reveals persistent socio-economic inequities in energy access, underscoring the need for ADM in EVCI to prioritise fairness in distribution. The literature suggests that while ADM has the potential to optimise energy flows in SC and V2G systems, it may inadvertently perpetuate or even exacerbate existing inequalities if designed solely for operational efficiency. This concern is particularly pronounced in dynamic pricing mechanisms, which, if misaligned with equity principles, could increase energy costs for lower-income groups and widen the accessibility gap in EVCI.

The review highlights how the understanding and application of energy justice principles in the Netherlands have evolved from a focus on economic stability and market liberalisation to broader considerations of social equity, transparency, and inclusivity. This progression aligns with a growing recognition of the need to address socio-economic disparities in energy access and distribution, particularly as ADM becomes more integral to EVCI. While ADM offers potential benefits in optimising grid efficiency and managing demand, there are risks that without a deliberate focus on equity, ADM may continue or intensify existing injustices.

In addition to distributive justice, procedural and recognition justice emerge as essential energy justice dimensions for fostering trust and inclusivity in ADM-managed EVCI. The stakeholder salience model applied here underscores the necessity of diverse stakeholder involvement to ensure that ADM reflects community needs and does not prioritise efficiency over equity. This includes engaging with marginalised or under-represented groups whose needs may otherwise be overlooked, especially in public-private partnerships where commercial objectives often differ from public interest.

These findings provide context for the subsequent theoretical framework (Chapter 4), which will incorporate energy justice principles to evaluate ADM's social impacts. The review also serves as a starting point for the GIS analysis (Section 6.1), guiding the selection of socio-economic indicators relevant to EVCI access. Finally, the concepts of energy justice and stakeholder influence identified here inform the Scenario Development (Section 6.2) and Q-methodology (Section 6.3), supporting the construction of potential futures that address both efficiency and equity in ADM-based energy management besides taking into account stakeholder perspectives. In this way, the literature review contributes a foundation for assessing ADM's role in achieving a just and inclusive energy system.

4
Theoretical Framework

Integrating Ethics and Human Rights into Energy Justice

This chapter presents the foundational theories that provide a lens for examining ADM in EVCI. The selection of these theories—energy justice, ethics of care, and the human right to energy—reflects a commitment to understanding how technology can support equitable and inclusive energy distribution. These frameworks are not merely abstract concepts but represent a vision of an energy system that upholds social responsibilities and addresses the diverse needs of all communities.

The energy justice framework provides the needed insights into equitable resource distribution, procedural fairness, and stakeholder inclusion. In contrast, the ethics of care framework introduces a relational approach, emphasising the responsibility to protect and prioritise communities that may be most impacted by technology-driven decisions. The human right to energy completes this triad, framing access to energy as a fundamental entitlement—a critical perspective as ADM's role in shaping access to and control of energy resources continues to evolve.

Given the complex and multidimensional nature of these issues, this research adopts an exploratory approach, employing these theories as guiding principles rather than prescriptive frameworks. An exploratory approach is particularly suited to investigating ADM's broader social implications, allowing for a comprehensive examination of both its potential to enhance efficiency and its capacity to promote equity and justice within the energy landscape. By integrating these theoretical perspectives, this chapter aims to construct an analytical model that foregrounds fairness, inclusivity, and consideration for essential human needs. This foundation establishes the theoretical basis for the research methodology and analysis, providing the groundwork from which to investigate ADM's role in fostering a more just and equitable energy future.

4.1. Energy Justice

Building on the historical context provided in the Literature Review (Chapter 3), energy justice in this study serves as a critical framework for analysing how ADM in EVCI addresses or exacerbates existing inequities in energy access. Scholars have emphasised energy justice as a framework for ensuring equity in the energy system through three key dimensions: *distributive justice*, *procedural justice*, and *recognition justice* [29], [30], [33]. These dimensions provide a lens through which to assess how energy is distributed, whose voices are included in decision-making processes, and how different social groups are recognized and considered. This framework is central to *SRQ 1* and *SRQ 2*, as the study investigates how ADM in EV charging infrastructure distributes energy and who is affected by potential inequalities within these dimensions.

- *Distributive justice* addresses whether ADM fairly allocates energy and EVCI across different socio-economic groups. The human right to energy reinforces distributive justice by framing access to energy as not only a moral concern but a legal requirement. This perspective introduces a layer of accountability that ensures ADM systems must align with both ethical and legal standards, making it insufficient to merely distribute resources equitably. ADM must also guarantee that all individuals, particularly those in marginalised communities, have access to the energy they need to maintain basic living standards. By viewing equitable energy distribution as a moral and legal entitlement, this perspective strengthens the call for fair allocation of resources across different social groups, adding legal and ethical obligations for ADM systems. This is particularly relevant to SRQ1, as the study evaluates this spatial analysis to see if certain neighbourhoods, mostly those with lower income-populations, are underserved in terms of EV charger availability and density. Besides, it aligns with *Proposition 1 (P1)* and *Proposition 4 (P4)* which explore how ADM might mitigate or reinforce inequalities in access and how equity-focused interventions could address these balances.

- *Procedural justice* examines whether the decision-making process in ADM should be transparent and how to make it inclusive. Explored through *SRQ 3*, the Q-methodology helps to understand the perceptions and viewpoints of distinct stakeholders in decisions about energy distribution, pricing, and access to EV charging infrastructure. It further aligns with *Proposition 3 (P3)* which examines how public perceptions are shaped by transparency and opportunities for participation.
- *Recognition justice* addresses the specific needs of marginalised groups, such as those without access to private charging facilities. This dimension can be deepened by integrating the *ethics of care*, which brings relational responsibility and attention to dependency into the discussion. Where Recognition Justice focuses on acknowledging and addressing the needs of marginalised groups, the ethics of care enriches this by emphasizing the interdependence between individuals and the energy systems they rely on, calling for a more nuanced understanding of how ADM decisions impact daily well-being. By integrating the ethics of care into recognition justice, the focus shifts from simply acknowledging marginalised groups to actively addressing their unique dependencies on energy systems. This relational approach ensures that ADM systems account for the specific needs of these groups, particularly in how energy access supports their day-to-day well-being. For instance, ADM could be designed to prioritise energy access for those who rely on it for medical devices or caregiving, recognising that their dependency on energy goes beyond typical consumer needs. This will guide *SRQ 4* by investigating how ADM accounts for these marginalised gr and what technological or policy interventions could be implemented to safeguard their benefits of and access to EVCI.

By addressing distributive, procedural, and recognition justice together, energy justice ensures that ADM systems do not just focus on the fair allocation of resources but also on how decisions are made and whose voices are considered. Neglecting any one of these dimensions could result in blind spots where vulnerable communities are either excluded from decision-making processes or further disadvantaged by inequitable resource distribution. This holistic approach is essential in designing ADM systems that aim for both efficiency and equity in managing EVCI.

4.2. Ethics of Care

The ethics of care, first introduced by Gilligan in 1982 [55] and expanded into the energy system by Gram-Hanssen [56], offers a distinct framework that emphasises rationality, interdependence, and attention to vulnerable groups. Unlike energy justice, which primarily focuses on rights, fairness, and equity, the ethics of care prioritises addressing the dependencies and vulnerabilities that emerge in energy distribution systems [56]. In the energy system, "care" refers to the relational responsibility between individuals, communities, and energy systems, ensuring the well-being of both humans and non-humans [56]. A classical definition describes it as "a species activity that includes everything that we do to maintain, continue, and repair our 'world' so that we can live in it as well as possible" [57, p. 34]. Thus, it focuses on how energy supports everyday activities, such as caregiving, and how energy infrastructure can either enable or disable care work.

Building on this idea of relational responsibility, care ethics introduces the notion of relationality and interdependence as essential in understanding ethical concerns in energy transitions. This perspective challenges frameworks that rely on individual responsibility and choice, instead proposing a relational understanding that highlights shared responsibilities in energy systems [58]. Moreover, it focuses on the ethical significance of these relationships within energy systems, stressing that the decisions made within energy systems must account for the care of vulnerable populations and the interdependencies between various actors. Care ethics highlights how energy enables critical social practices like caregiving, heating homes, and cooking. It draws on theories of energy sufficiency and decent living, focusing on how energy access must meet but not exceed the needs for a decent standard of living [59]. This perspective is particularly relevant in places like Sweden or the Netherlands, where per capita energy use far exceeds what's needed to sustain social welfare. As such, the ethics of care invites a reconsideration of how energy systems are designed, challenging assumptions about efficiency and pushing for a more nuanced approach that considers dependency and vulnerability.[59]

While energy justice primarily frames equity in terms of rights and entitlements, the ethics of care shifts the focus to relationships and dependencies. This shift highlights that energy systems do not operate in isolation but are deeply intertwined with the lives and well-being of individuals. Where energy justice calls for equitable resource distribution, care ethics calls for an active engagement with the needs and vulnerabilities of those dependent on the energy system, creating a more dynamic and responsive approach to managing energy access.

Energy justice and the ethics of care represent distinct, yet intersecting, fields of debate within the energy transition discourse. While they share common concerns—such as ensuring equitable access and preventing the deepening of inequalities—these frameworks are not entirely complementary. Energy justice focuses on distributive fairness and rights-based approaches, often considering energy as a matter of entitlements and equity [30]. In contrast, the ethics of care shifts the focus toward the interdependencies and relational responsibilities that shape how energy systems affect vulnerable communities [56], [60]. This difference leads to tensions between the two approaches, particularly in how they conceptualise energy distribution and the roles of technology, ADM, and infrastructure. For instance, where energy justice might emphasise equitable resource allocation, care ethics would call for more nuanced attention to individual and communal dependencies, potentially leading to different priorities in policy and ADM design [30], [49].

These tensions are not merely theoretical but present real-world dilemmas for stakeholders involved in setting up the energy grid. Stakeholders, including policymakers, grid operators, and community representatives, must navigate competing demands between ensuring efficiency and supporting vulnerable groups [59]. As ADM-driven energy systems like SC and V2G are integrated into EVCI, the ethics of care highlights the complex decisions that must be made regarding energy allocation, pricing, and access. It emphasises that ADM systems must consider the unique needs of those who are most dependent on energy for their daily well-being, such as individuals with medical needs or vulnerable households [59], [60].

While energy justice primarily frames equity in terms of rights and entitlements, the ethics of care shifts the focus to relationships and dependencies, emphasising that energy systems are deeply intertwined with the lives and well-being of individuals. Where energy justice calls for equitable resource distribution, care ethics advocates for a more dynamic approach that actively engages with the needs and vulnerabilities of those dependent on the energy system. This perspective highlights the importance of considering how energy systems, including ADM, must account for the daily well-being of individuals, especially vulnerable groups. The interdependencies between people and energy systems must be acknowledged not only in terms of resource allocation but also in how energy decisions impact lived experiences. In this study, the ethics of care is applied to ensure that ADM takes into account the specific needs of vulnerable users, providing a more nuanced understanding of equity in energy distribution.

- *Care and Relationality*:Provides a lens for analysing how ADM should adress needs of vulnerable users, e.g. those with low-income or medical needs. By contemplating how care ethics apply to ADM, *SRQ 4* explores interventions in policy or technology design ensuring vulnerable populations are considered in the decision-making process, aligning with the participatory aspects of procedural justice.
- *Vulnerability and Dependency*: The ethics of care will inform the study on ensuring ADM accounting for interdependencies within communities related to energy access during peak times or dynamic pricing scenarios. This is central to *SRQ 3* where perceptions of fairness and equity of ADM in EV charging infrastructure will be evaluated through Q-methodology. Moreover, it aligns with *Proposition 2 (P2)* which investigates whether the gains in efficiency due to the enhancement of energy distribution are equally realised across different parts of society.

4.3. Human Right to Energy

The human right to energy provides a distinct moral and legal framework to ensure equitable access to energy [49]. Unlike energy justice, which focuses on rights-based equity within the energy system, and ethics of care, which highlights relational responsibilities and dependencies, the human right to energy focuses on energy as a fundamental right that is essential for the fulfilment of other basic human rights, such as the right to housing, health, and education [50]. It emphasises the moral and legal obligation to ensure access to energy for all individuals, particularly marginalised and vulnerable groups.

In this study, the human right to energy is particularly relevant to *SRQ1* and *SRQ4* and aligns with *Proposition 1 (P1)*. This framework helps evaluate whether ADM in EV charging infrastructure complies with international frameworks, such as the European Union's Electricity Directive and United Nations SDG 7, which emphasise access to clean and affordable energy for all [51]. It adds a layer of accountability that goes beyond the equitable distribution of resources (as in energy justice) and the care for vulnerable populations (as in ethics of care), by framing energy access as a legal and moral entitlement.

- *Universal access*: Provides a foundation for analysing how ADM ensures fair access to EVCI for all users, especially those in under served or marginalised communities besides exploring how ADM might exacerbate inequalities in energy access.
- *Legal and Policy Implications*: The human right to energy requires ADM upholding the principles of equity in energy distribution. By analysing the legal and ethical obligations of ADM in EV charging infrastructure, relevant to *SRQ 4*, the study will inform on how policy interventions can improve fairness and inclusivity.

Thus, while energy justice and ethics of care focus on equity and relational responsibilities within energy systems, the human right to energy shifts the discussion towards legal obligations that ensure universal access to energy. This framework introduces a normative dimension that guides policy interventions and regulatory measures, ensuring that ADM systems are designed not just to optimize efficiency but to uphold fundamental human rights.

4.4. Conceptual Model

The conceptual model in figure 4.1 on page 27 illustrates how ADM for EVCI is influenced by ethical frameworks, justice principles, and stakeholder inputs to ensure equity and efficiency. ADM for EVCI is positioned at the centre of the model, directly impacting resource distribution, decision-making, and recognition of vulnerable groups .The model illustrates bidirectional influence, where ADM in EVCI both impacts and is shaped by ethical frameworks, justice dimensions, and stakeholder perspectives. This feedback loop allows for continuous adaptation, ensuring that ADM systems evolve to meet changing societal and ethical expectations The conceptual model is structured in two parts:

1. *Energy Justice*: Emphasised by the striped box surrounding Distributive Justice, Procedural Justice and Recognition Justice, it shows how ADM influences and is influenced by the principles of energy justice. In this view, ADM in EV charging infrastructure determine:
    - *Distributive Justice*: The fair allocation of EV charging resources. Here, the Human Right to Energy reinforces distributive justice by imposing ethical mandates and legal standards that frame energy access as a fundamental entitlement.
    - *Procedural Justice*: Stakeholder involvement in the decision-making process.
    - *Recognition Justice*: The accounting for specific needs of vulnerable groups supported by the Ethics of Care.

    In addition to Distributive, Procedural, and Recognition Justice, the Ethics of Care and Human Right to Energy frameworks add depth to how ADM should address justice. The Ethics of Care extends Recognition Justice by emphasising connectedness and interdependence, prioritising marginalised communities and their specific dependencies within energy systems. Similarly, the Human Right to Energy reinforces Distributive Justice by framing access as a fundamental right and mandating equitable access, aligning ADM systems with ethical and legal fairness standards. Together, these frameworks ensure ADM systems distribute resources fairly and address the specific needs of vulnerable populations, with obligations to guarantee universal access.

2. *Contextual Drivers*: Encompasses Vulnerable Groups, Stakeholder Perceptions, and Policy Interventions. These elements provide context and feedback to shape ADM design and operation:
   - *Vulnerable Groups*: Highlight specific needs that ADM must address to ensure equity. This is essential for identifying groups that may otherwise be marginalised by automated decisions.
   - *Stakeholder Perceptions*: Provide insights into how ADM is perceived by different stakeholders, including users and communities. Understanding these perceptions allows ADM to be adapted to increase transparency, trust, and system acceptance.
   - *Policy Interventions*: Establish regulatory frameworks and guidelines that ADM must comply with to promote equity and fairness. Here, ethical mandates and the Human Right to Energy align ADM with broader societal goals, such as energy justice and universal access.

   The model includes guiding principles, such as 'Acknowledging Specific Needs' and 'Expressing Views and Expectations,' which direct contextual drivers to ensure ADM systems are responsive and transparent to diverse community requirements. These principles support a participatory approach, allowing stakeholder input to shape ADM's alignment with justice and ethical standards.

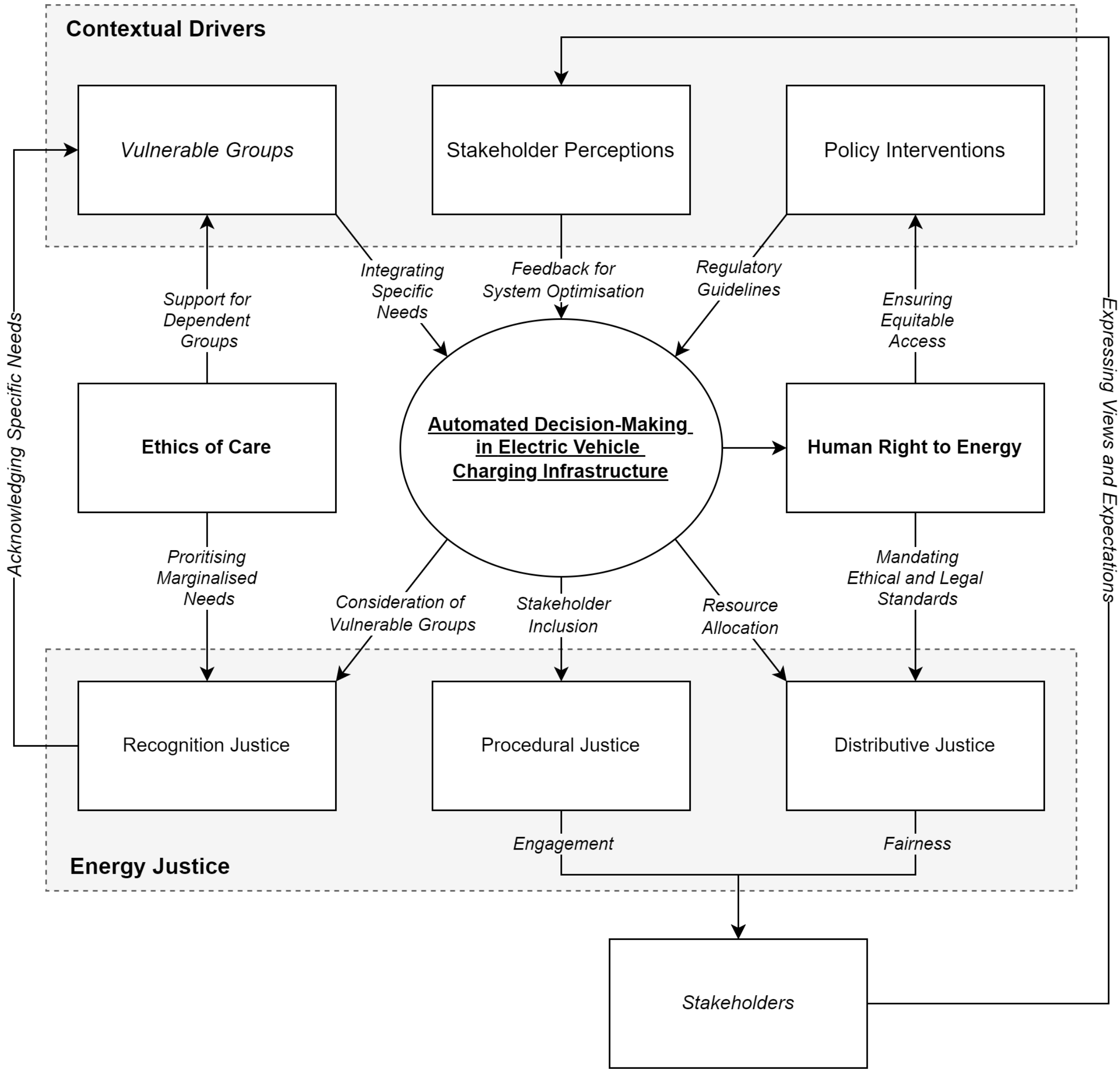


Figure 4.1: Conceptual model of ADM in EVCI

This model illustrates how ADM in EVCI is shaped by justice principles, stakeholder inputs, and ethical frameworks to ensure equity and efficiency. *Energy Justice* (distributive, procedural, and recognition) interacts with ADM, while *Contextual Drivers* (vulnerable groups, stakeholder perceptions, and policy interventions) provide critical feedback to guide its operation and compliance.

4.5. Summary and Theoretical Insights

This chapter has presents the theoretical foundations for examining ADM in EVCI, integrating frameworks of energy justice, ethics of care, and the human right to energy. Each of these frameworks contributes an individual perspective on ensuring equity and fairness within ADM-managed energy systems. Energy justice offers a foundational structure by focusing on distributive, procedural, and recognition justice, emphasising the importance of fair resource allocation, inclusive decision-making, and acknowledgement of marginalised groups. The ethics of care complements energy justice by introducing a relational approach, highlighting the interdependencies and specific vulnerabilities of individuals within energy systems. This perspective underscores the responsibility of ADM systems to account for the nuanced needs of those dependent on equitable energy access for their well-being.

The human right to energy further strengthens these frameworks by framing energy access as a derived human right, adding legal and ethical obligations that demand universal access to energy as a baseline. This normative dimension underscores the accountability of ADM systems, ensuring that they not only operate efficiently but also align with broader human rights standards. Together, these frameworks offer a lens through which ADM's role in EVCI can be evaluated, ensuring that systems designed to manage energy distribution also uphold principles of justice, inclusivity, and care. This theoretical foundation will guide the subsequent methodological approach and analysis, establishing a robust framework for investigating ADM's societal impact within the context of a just and equitable energy transition.

This theoretical foundation directly shapes the methodological approach outlined in the following chapter. The GIS analysis, grounded in the principles of distributive justice and the human right to energy, assesses whether ADM in EVCI equitably allocates resources across socio-economic and geographic divides. The ethics of care and procedural justice guide the application of Q-methodology to capture the diverse perceptions of stakeholders, ensuring transparency and inclusivity in understanding how ADM affects communities. Additionally, Scenario Development draws upon energy justice principles to create equitable future pathways for ADM in EVCI, incorporating considerations of accessibility and inclusivity for marginalised groups. Together, these methods translate the theoretical principles into an actionable framework for systematically evaluating ADM's societal impacts within the context of a just and equitable energy transition.

5

Methodology

Mixing Research Methods for Evaluating Energy Justice

In this chapter, the methodology used to investigate equity in ADM within EVCI is outlined. A mixed-method approach was adopted, combining Geographic Information System (GIS) analysis, Scenario Development, and Q-methodology, all of which align with the theories discussed and conceptual model developed in the theoretical framework. GIS analysis offers insights into spatial disparities in infrastructure distribution, while Scenario Development frames future contexts to inform the Q-sort statements. Q-methodology is then employed to capture diverse stakeholder perspectives, blending qualitative and quantitative data to explore viewpoints on fairness and inclusivity in ADM for EVCI. Figure 5.1 below provides an overview of the study's phases, illustrating how each method is interconnected to assess equity and justice in ADM systems.

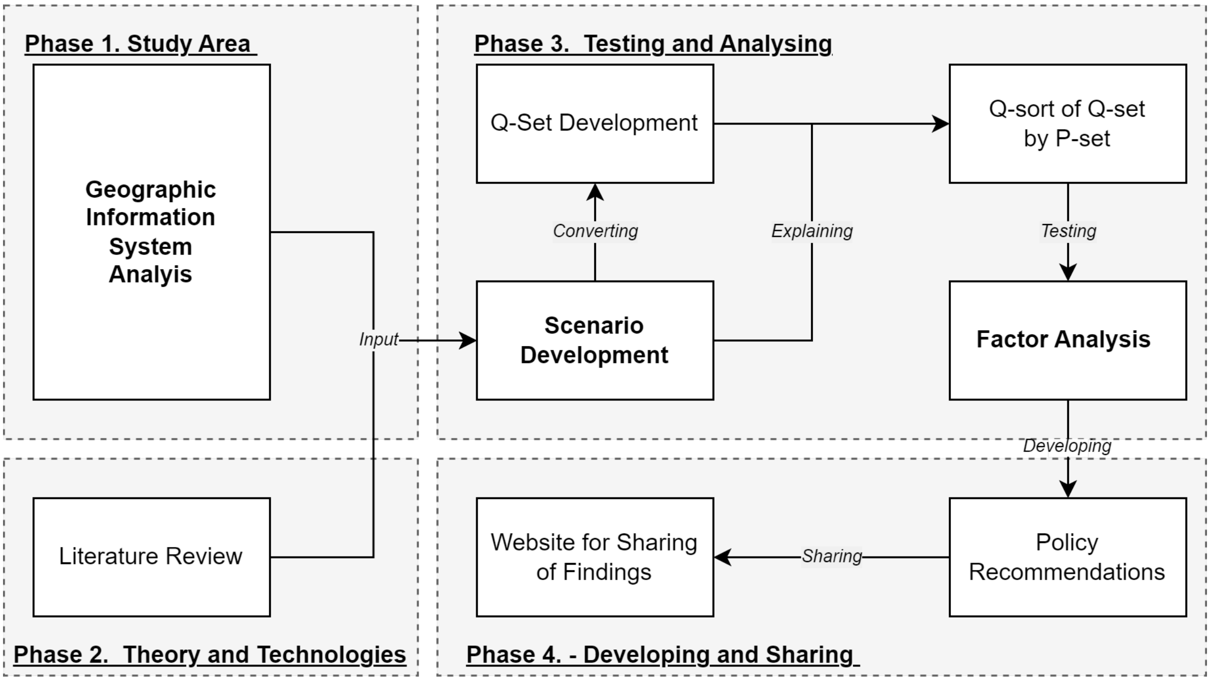


Figure 5.1: Research Flow Diagram

This diagram illustrates the research phases and their interconnections. *Phase 1* (GIS Analysis) and *Phase 2* (Literature Review) provide input for Scenario Development in *Phase 3*. These scenarios are converted into statements for stakeholder evaluation through Q-sort, with results processed via Factor Analysis to compare viewpoints. This analysis informs intervention and policy recommendations in *Phase 4*.

5.1. Conceptual Model Development

The conceptual model, grounded in the core principles of energy justice, distributive justice, procedural fairness, and recognition justice, served as the foundation for the selection of research methodologies in this study. Each dimension of energy justice informed the design and purpose of the applied methods. The GIS analysis was used to spatially examine disparities in the distribution of EVCI, thereby operationalising the dimension of distributive justice. This analysis revealed patterns of inequity in public charging station access, particularly in socio-economically disadvantaged areas, aligning with the model's focus on fair resource allocation.

Scenario development, a tool for organising one's viewpoint on possible future situations in which one's decisions could play out [61], was employed to explore future outcomes concerning procedural fairness. By modelling how different neighbourhoods may experience the deployment of ADM systems in EVCI, the scenarios enable a deeper investigation into how transparent and inclusive decision-making processes might affect energy access. The scenario narratives were particularly useful in presenting real-world applications of ADM and demonstrating how procedural fairness could be achieved or undermined, depending on the approach taken in policy and technology deployment.

Finally, the Q-methodology was chosen for its ability to capture subjective viewpoints, especially those on vulnerable and marginalised groups, thus linking to the recognition justice dimension of the conceptual model. Through the Q-sort, diverse stakeholders were able to express their perspectives on the fairness, accessibility, and inclusivity of ADM systems. This methodology was crucial in uncovering shared viewpoints and differences in how various communities perceive the impact of ADM on their daily lives. By integrating each method with a specific dimension of the conceptual model, the research design ensured a comprehensive exploration of both quantitative spatial data and qualitative subjective insights, grounded in the principles of energy justice. This alignment between the conceptual model and research methods enabled a holistic analysis of ADM's role in promoting or undermining equity in EVCI.

5.2. Geographic Information Systems Analysis

The first phase of this study involved a GIS analysis that produced a nested scale map series to assess the current state of EVCI and projected future EV influx. The GIS analysis, rooted in the principles of Distributive Justice from the energy justice framework, is integral to assessing spatial inequalities in EVCI access. By highlighting disparities in infrastructure across socioeconomic areas, this method directly supports Sub-question 1 by identifying which groups and areas face inequitable access due to current ADM practices. This spatial analysis also incorporates insights from the Human Right to Energy framework, which mandates equitable access as a fundamental right, reinforcing the GIS focus on ensuring just distribution of EV infrastructure across all communities.

Conducted using ArcGIS Pro version 3.0 [62], this analysis focused on spatial inequalities in EVCI distribution, directly addressing *Proposition 1 (P1)* and *Proposition 2 (P2)*. The GIS analysis complements the other methodologies by offering spatial data that identifies disparities in the distribution of EVCI across different neighbourhoods in Amsterdam. Following approaches similar to those of Dorling [63], who used GIS to explore social inequalities, this analysis uncovers how infrastructural imbalances in EVCI reflect broader societal injustices. The results from the GIS analysis are used to inform the development of the scenarios and help identify key areas of inequality. For instance, areas that are found to be underserved by charging infrastructure were directly integrated into the scenario narratives. This spatial analysis, when linked with the qualitative insights from the Q-sort, helps triangulate the findings, providing both quantitative and qualitative evidence for the conclusions drawn about energy justice in ADM systems.

A multi-scale approach was used to create a nested scale map series, progressively zooming in from the regional scale of the Amsterdam Metropolitan Area to a specific city district (postal code area 106). This method allows for an assessment of how EVCI distribution patterns change across various geographic levels, from city-wide trends down to neighbourhood-specific disparities. This approach allows for a deep spatial pattern analysis, enabling the detection of any infrastructural imbalances, by narrowing the focus from the larger metropolitan area to neighbourhoods such as De Akers Oost and Wildeman. These neighbourhoods were chosen for their varied socioeconomic characteristics and existing energy infrastructures, which provide a suitable contrast for investigating the unequal distribution of EVCI within the city.

5.2.1. Data Collection

Various datasets were used to evaluate the current and future situation of EVCI in Amsterdam. These datasets, among others, include Mobility, electricity, and parking data [64]; EV charger's locations in Amsterdam [65], Demographic data per district and neighbourhood [66]; Energy labels and solar panel data [67], [68] and Liander electricity network data for energy distribution networks [69]. Data types included shapefiles, point layers, and GeoJSONs. A more detailed overview of the datasets has been summarised in tableA.1 in Appendix A on page 103.

5.2.2. Spatial Analysis Workflow

The spatial analysis workflow will be explained in the following steps and is accompanied by figure A.1 in Appendix A on page 104 for a visual representation of the workflow.

A Projected Number of Electric Vehicles in 2030: - The first map visualises the projected number of EVs per postal code 3 area in the Amsterdam Metropolitan Area, generated using publicly available data [64]. – Spatial visualisation was performed using polygons representing postal code 3 areas to compare the number of projected EVs in 2030.

B EV Charger Analysis: Using data from Gemeente Amsterdam [65], the locations of existing and planned EV chargers from Equans and TotalEnergies were mapped, assuming all chargers will be operational by 2030. A 400-meter buffer was created around each building polygon (184.491 buildings in total) to represent a five-minute walk at 5 km/h to a charger, following Mashhoodi et al. [70], who noted this approach can significantly reduce implementation costs. The number of EV chargers within each buffer was calculated and spatially joined to building polygons, allowing visualisation of EV charger density within a 400-meter radius per building. It is important to note that a lack of charger data outside Amsterdam's municipal area affected the analysis near its borders. Additionally, the average number of EV chargers within 400 meters was calculated for each neighbourhood and compared to demographic data on the percentage of households within the top 20% of incomes nationally [66]. This relationship was visualised using bivariate colour symbology to show correlations between charger accessibility and household income distribution in a single view [71].

C Demographics in Postal Code Area 106: Neighbourhoods within Postal Code Area 106 were analysed using demographic data to identify patterns regarding income, housing ownership and car ownership from [66]. This allowed for the more in-depth analysis of the neighbourhoods De Aker Oost and Wildeman. For income, the share of private households belonging to the national 40% of households with the lowest household income has been used. The CBS data from 2019 has been used since this was the latest most complete dataset which included the data on car ownership and fuel type.

D Energy Infrastructure and Solar Panel Distribution: Using data from Liander [69] and Gemeente Amsterdam [65], maps were created showing the electricity grid and distribution of (smart) EV chargers in the vicinity of De Aker Oost and Wildeman. Energy label [67] and solar panel [68] data were analysed to get a better idea of energy efficiency and solar capacity in the neighbourhoods individually.

E Building Function and Ownership: By utilising data from AFWC [72] and Gemeente Amsterdam [73], the final analysis looked at the function of buildings marking those with a building function different from residential higher than 50%. Buildings were coloured based on housing corporation or private ownership which led to the distribution of solar panels per ownership category.

5.3. Scenario Development

The second phase of the research involved creating two future scenarios with two primary objectives: first, to serve as a foundation for developing statements to be tested in the Q-methodology, and second, to offer participants a clear and relatable explanation of V2G and SC technologies. These scenarios were crucial in introducing participants to these concepts, illustrating how ADM in EVCI might function in daily life, and highlighting its potential implications on equity, accessibility, and fairness in energy distribution, in line with *Proposition (P2)*. The development of these scenarios was guided by the principles of *Scenario Planning*, a strategic methodology that envisions different future possibilities based on current trends and uncertainties. Scenario Planning was particularly useful in this research to explore various plausible futures without predicting specific outcomes [61]. Unlike extreme or binary scenarios (e.g., positive versus negative), the two scenarios in this study were rooted in the research background, theoretical frameworks, and findings from the literature, allowing for plausible, grounded future outcomes rather than speculative ones.

The development of the scenarios was informed by Distributive and Procedural Justice principles from the energy justice framework. These theories provided a foundation for examining how equitable access to EVCI and inclusive decision-making could be represented across different future scenarios, directly addressing Sub-question 2 by exploring how ADM could impact energy distribution in varied socio-economic contexts. Additionally, the Human Right to Energy framework guided the focus on ensuring equitable access across different neighbourhoods, reinforcing the scenarios' alignment with principles of fairness and inclusivity. The Ethics of Care was also integrated by incorporating a transparent notification system in the scenarios, where the ADM informs users of how their energy choices could support vulnerable community members. This feature encourages participants to consider the needs of their neighbours, promoting a sense of connectedness and shared responsibility in energy decisions. Together, these theoretical perspectives shaped the scenarios by emphasising how ADM-driven EVCI could either mitigate or exacerbate existing disparities, while promoting a culture of mutual care and responsibility.

5.3.1. Literature Review and Data Integration

Both the GIS analysis and supporting literature informed the development of the two scenarios, identifying distinct neighbourhood characteristics that influenced energy distribution and access to EVCI. The GIS results showed disparities in the availability and accessibility of public EV charging stations across neighbourhoods, highlighting that wealthier areas tend to have better access to these facilities. This finding influenced the decision to focus on V2G technology for the more affluent neighbourhood in one scenario, as V2G requires infrastructure like private EV chargers and solar panel systems, which are more commonly found in higher-income areas.

In contrast, the GIS analysis revealed that lower-income neighbourhoods had fewer public charging stations, making SC a more appropriate technology to focus on in these areas. SC technology, which relies on dynamic pricing and multiple public charging points, aligns better with these neighbourhoods' infrastructure constraints and economic realities. The GIS findings about the unequal distribution of EVCI helped clarify where these technologies could be realistically applied, ensuring that the scenarios reflected real-world energy access disparities.

By merging GIS insights with supporting literature [33], [35], the study developed two future scenarios that illustrated how ADM systems for EVCI could evolve under different socio-economic and infrastructure settings. These scenarios, supported by visual aids depicting SC and V2G functions, provided participants with accessible, relatable insights into the potential role of ADM in EVCI. This approach ensured that the scenarios were theoretically grounded and geographically and culturally relevant to the neighbourhoods studied, facilitating participant engagement and understanding in the Q-methodology.

5.4. Q-methodology

The third phase of this research utilises Q-methodology, a mixed-method approach designed to systematically explore subjective viewpoints on a given topic [74]. Developed by Stephenson in 1953 [75], Q-methodology enables the identification of shared perspectives through factor analysis, focusing on the variety of viewpoints rather than population characteristics, as is typical in R-methodology [76]. In Q-methodology, participants are presented with a set of statements and asked to rank-order them from 'agree' to 'disagree,' a process known as 'Q-sorting.' The ranking of these subjective statements from the participant's point of view introduces subjectivity into the data. Although subjective, this data is quantitatively analysed through factor analysis, which reveals distinct shared viewpoints or "factors" within the participant group. This focus on the diversity of perspectives means that large sample sizes are less critical than in other methodologies [77].

Q-methodology was chosen for this study because it combines qualitative and quantitative data to capture the subjective viewpoints of participants, particularly in the complex domain of energy justice in ADM for EVCI. Unlike more rigid quantitative methods such as the Likert scale, which restrict participants to fixed-response options, Q-sort allows participants to rank their opinions more flexibly, encouraging reflection and prioritisation of values. This method aligns closely with Procedural Justice and Recognition Justice principles from the energy justice framework, which emphasise inclusive decision-making and acknowledgment of diverse stakeholder needs. This approach directly addresses Sub-question 3 by systematically capturing and comparing stakeholder perspectives on equity and fairness within ADM systems.

Additionally, the Ethics of Care framework is integrated into Q-methodology by ensuring that the process acknowledges and respects the unique viewpoints and dependencies of various stakeholders, particularly those from marginalised groups. This theoretical foundation provides a way to examine the relational aspects of stakeholder opinions, creating an environment where individual needs and dependencies are considered within the analysis of ADM impacts. The Q-sort approach thus offers a flexible method to understand diverse perspectives on fairness, inclusivity, and equity, combining qualitative insights with statistics to reveal shared viewpoints among stakeholders.

In this study, Q-methodology was applied to explore different stakeholder perspectives on ADM in EVCI, aligning with *Proposition 3 (P3)*. It systematically tested two developed scenarios to understand the shared and contrasting views of participants, with the process following the framework outlined by Van Exel & De Graaf [76]. This allowed for a structured examination of how different stakeholders perceive the role of ADM in ensuring equity in energy distribution.

5.4.1. The Process of Performing Q-methodology

This section will explain the how the Q-methodology has been performed in this study. An overview of the different steps of the Q-methodology can be found in figure 5.2 on page 38.

Development of the Q-set

The Q-set is a comprehensive set of statements representing the full range of perspectives on the topic of ADM and EV infrastructure. This set was developed based on a review of existing literature and two future-oriented scenarios. Specific statements were derived directly from the scenarios to address key issues, such as economic equity (how ADM may impact different economic groups), trust in ADM systems, and the role of fairness in technology deployment. These statements were categorised under relevant themes to ensure a structured approach to the sorting process. Additionally, the statements were organised within each scenario to maintain an equal representation of perspectives.

To ensure that participants with varying levels of technical knowledge could engage equally with the study, narrative scenarios and visualisations were developed to explain the technologies of SC and V2G within the context of two distinct neighbourhoods. These visual aids provided a detailed overview of how ADM in EVCI could function, offering participants without prior knowledge the necessary context to approach the Q-sort statements. Participants with prior knowledge of these technologies were asked to consider the scenarios from the perspective provided, ensuring they evaluated the statements with the same framework as those unfamiliar with the technologies. This approach helped to balance participants' understanding and ensured that the Q-sort data collected reflected perspectives grounded in the same narrative and technical explanations. The final Q-set included twenty-five (25) statements, with an overview provided in table B.1 in Appendix B on page 107, showing the coverage of both developed scenarios and general statements on ADM in EVCI.

Development of the P-set

The development of the P-set involved selecting participants for the Q-sort, referred to as the 'P-set.' To capture a broad range of perspectives, purposive sampling was employed. This approach ensured representation from different stakeholder groups, including residents from diverse economic backgrounds, EV and non-EV users, business owners, urban planners, and community activists. This diversity was essential for gathering a range of views on ADM in EV charging infrastructure, reflecting the study's focus on equity and inclusivity.

In order to ensure that a wide range of perspectives were included in the Q-sort methodology, participants were selected based on a diversity of socio-economic characteristics. The research sought to capture viewpoints from individuals with varying experiences, knowledge, and engagement with EVCI and SC and V2G technologies. The following characteristics were considered during participant selection:

- *EV Ownership*: Participants were categorised based on whether they owned an electric vehicle, as this would likely influence their understanding and opinion on electric vehicle charging infrastructure.

- *Technical Knowledge*: The P-set included both tech-savvy individuals and those with little technical expertise, ensuring that participants had different levels of familiarity with ADM systems and energy technologies.
- *Activism*: Individuals who identified as activists in the realms of community involvement, environmentalism or energy justice were included to capture perspectives that are more critical of current energy practices and more focused on equity and sustainability.
- *Socioeconomic Indicators*: Income and education levels were considered generally as low, medium, or high to further ensure that different socioeconomic groups were represented.

The broad composition of the participant group ensured that the Q-sort analysis would capture a range of subjective viewpoints on ADM in EVCI, from those with direct stakes in the technology to individuals with less personal involvement. A total of ten (10) participants were recruited, consistent with Q-methodology studies [78]. This number was chosen to balance diverse perspectives with a manageable scope for detailed analysis. Each participant contributed unique perspectives to a comprehensive analysis of critical topics in ADM and EVCI. Their backgrounds provided insight into how ADM affects different demographics and socioeconomic groups, contextualising the patterns highlighted in the Q-set.

Q-Sorting Process

Participants were provided with the Q-set and accompanying narrative scenarios to contextualise the statements within potential future applications of ADM technology. Initially, participants were asked to sort the statements into three broad categories: agree, neutral, and disagree. This preliminary sort helped to gauge overall sentiments before moving into a more detailed ranking process.

Subsequently, participants ranked the statements based on their agreement or disagreement strength, using a quasi-normal distribution from -4 (most disagree) to +4 (most agree), as shown in Figure B.1 in Appendix B on page 115. This distribution required participants to prioritise statements, bringing to light those they felt most strongly about. For statements ranked at the extremes (-4 and +4), participants were asked to provide verbal or written explanations, adding qualitative depth to the data. This dual approach to ranking and reasoning improved the dataset by combining quantitative and qualitative findings.

Data Collection and Entry

After completing the Q-sorts, the data from each participant, including their comments on key statements, was collected. This data was systematically organised and entered into Microsoft Excel, allowing for an efficient and accurate analysis process. The prepared dataset was imported into KADE (Ken-Q Analysis Desktop Edition, version 1.3.1), which is specifically designed for Q-methodology analysis [79]. By leveraging KADE's specialised features, the data was rigorously processed to maintain accuracy, providing a strong foundation for identifying shared viewpoints and facilitating robust factor analysis.

Data Analysis

Factor analysis was conducted using KADE software to reveal clusters of shared perspectives, or factors, among participants. To ensure both interpretative richness and statistical robustness, the analysis utilised two approaches: *Centroid Factor Analysis (CFA)*, based on correlation matrix and extraction of shared variance with fewer assumptions about underlying structure, and *Principal Component Analysis (PCA)*, based on maximisation of total variance, focusing on component orthogonality and minimising redundancy.

The analytical process began with inputting the Q-sort data into KADE to generate a correlation matrix that examined relationships between participants' rankings. CFA was first employed to capture overlapping themes and nuanced perspectives that might not emerge in PCA's orthogonal structure. This method's interpretative flexibility aligns well with Q-methodology's goal of exploring complex, subjective viewpoints, providing additional layers of thematic depth. In parallel, PCA was applied to extract factors that maximise explained variance, offering statistically distinct factor structures. To further refine the PCA results, Varimax rotation was applied, enhancing factor clarity. Examining factor loadings in both CFA and PCA enabled the determination of each participant's association strength with each factor, which revealed shared and divergent views on equity, fairness, and the role of ADM in EVCI. Using both methods allowed for a complementary view, where PCA provided statistical clarity and CFA captured subtle thematic overlaps, enhancing the overall interpretative quality of the findings.

Interpretation and Validation of Results

The identified factors from the Q-methodology analysis were interpreted to represent distinct, shared viewpoints on ADM in EVCI. Each factor was described in detail, supported by direct participant quotes to convey the nuances of their perspectives. The findings from both CFA and PCA were compared with the study's theoretical framework, particularly focusing on energy justice and equitable technology deployment principles, to validate the results. This validation technique relied on the interpretations in relevant literature, ensuring that the results were both certain and theoretically valid.

5.5. Application of the Findings: Website for Public Engagement

The findings from this research, along with the problem statement and methodological framework, have been utilised to create a supporting website aimed at enhancing accessibility, transparency, and public awareness regarding ADM in EVCI. [1] Designed in non-academic language, the website is structured to address three key areas: explaining the problem, exploring potential solutions, and guiding actionable steps based on policy recommendations. The website begins by introducing the core problem (the problem statement), outlining socio-economic and spatial challenges identified through GIS analysis that affect equitable access to EVCI. It then examines solution-oriented technologies and scenarios from the research, presenting ADM, SC, and V2G technologies as approaches to managing grid congestion and promoting fair energy distribution. In its final page, the website shares the policy recommendations derived from the Q-methodology findings into practical guidance in the form of a roadmap, demonstrating how Definitive Stakeholders—Regulatory Bodies and Local Governments—can contribute to fostering equitable, inclusive ADM practices. This section outlines accessible pathways for involvement, supporting a more inclusive approach to EVCI planning and development by encouraging transparent, community-supported decision-making and fostering broad awareness.

5.6. Summary of Methodologies

This study employed a mixed-method approach to investigate equity in ADM within EVCI, guided by three interconnected methodologies. First, the *GIS Analysis* examined spatial inequalities in EVCI distribution, addressing Sub-question 1 by identifying areas and communities disproportionately affected by limited access. This method revealed existing disparities, providing a foundation for scenario-based projections. The *Scenario Development* method modelled two possible futures for EVCI distribution, guided by the principles of distributive and procedural justice. By exploring these scenarios, this phase addressed Sub-question 2, examining how ADM's role in energy distribution might impact equity across socio-economic contexts and supporting a deeper understanding of ADM's potential to address or exacerbate inequalities in EVCI.

Finally, by deriving varied statements from the Scenario Development, *Q-Methodology* gathered stakeholder perspectives, capturing diverse viewpoints on fairness, accessibility, and inclusivity within ADM-driven EVCI. Directly addressing Sub-question 3, this method combined qualitative and quantitative insights to highlight stakeholder expectations and areas for improvement in ADM-driven decisions, ensuring that marginalised viewpoints were represented. Sub-question 4 will be addressed in the Discussion and Conclusion chapters (see Chapters 7, 8), synthesising findings and insights derived from the Q-methodology. This final analysis will draw on the study's outcomes to provide recommendations and evaluate ADM's role in promoting equity in EVCI.

[1] `https://mindfulpowerthesis.framer.website/`

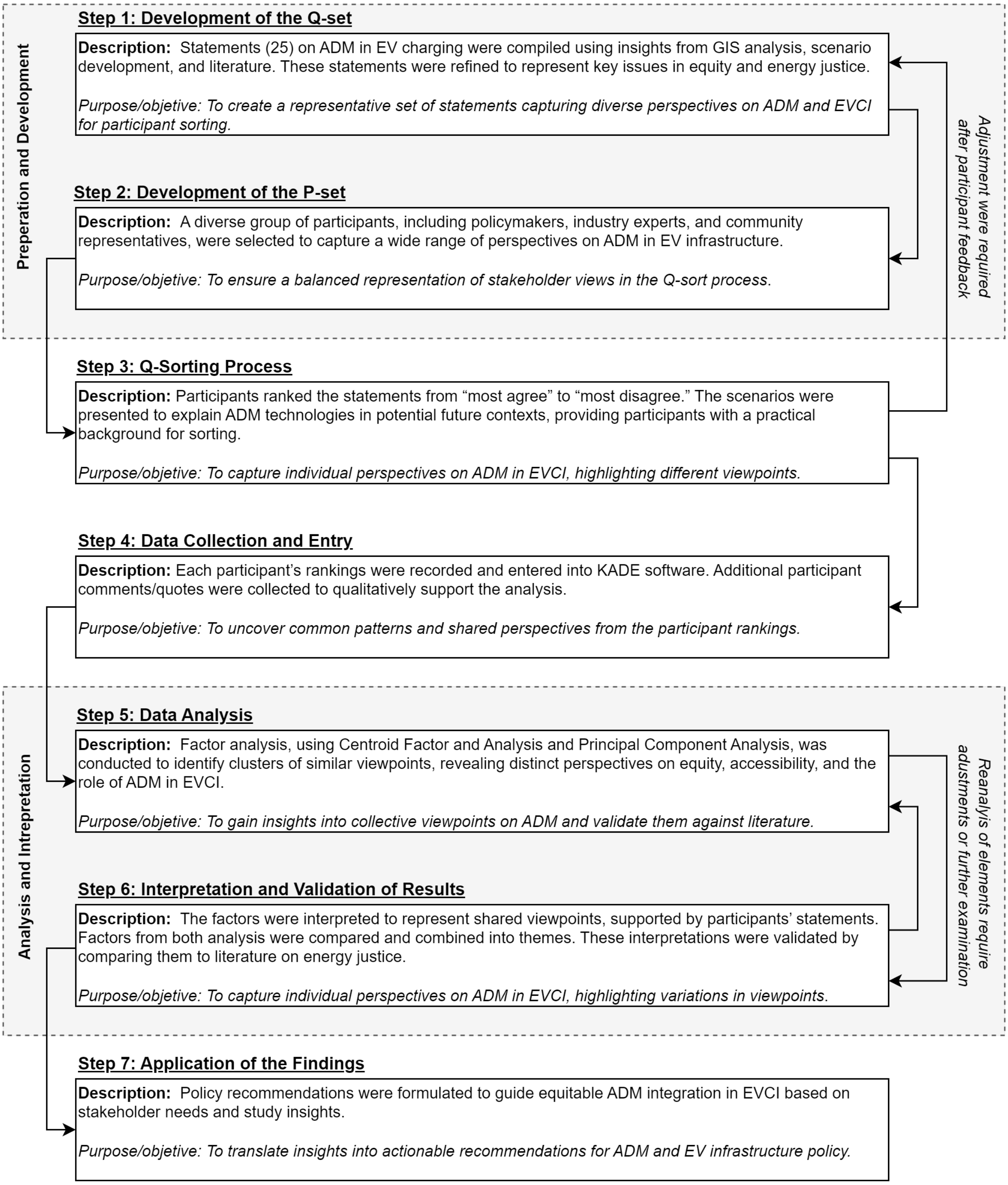


Figure 5.2: Flow diagram showing steps of Q-methodology

This diagram illustrates the seven steps of the Q-methodology process used in this study, organised into five categories: Preparation, Q-Sorting Process, Data Handling, Analysis and Interpretation, and Application of Findings. Each step outlines the specific actions taken, from developing the Q-set of statements to generating actionable policy recommendations based on the findings. Branching arrows indicate feedback loops between interlinked steps, reflecting the iterative nature of the process where participant insights can inform adjustments to earlier phases. This structure ensures an effective approach to analysing personal views of ADM in EVCI.

6 Results

Spatial and Social Inequities and Stakeholder Views

This chapter presents the findings from the GIS analysis, future Scenario Development, and Q-methodology, offering insights into the spatial distribution of EVCI, projected EV growth, and stakeholder perspectives on ADM in EVCI. Each section highlights key results relevant to equity, accessibility, and the role of ADM in managing EVCI, directly addressing several of the study's sub-questions. The *GIS analysis* findings address Sub-question 1 by revealing spatial disparities in EVCI accessibility, examining which social and economic groups are most affected by these inequities. This analysis provides a baseline understanding of how the current EVCI landscape may impact various communities differently.

The *Scenario Development* findings align with Sub-question 2 and Sub-question 3, illustrating potential future configurations of ADM-managed EVCI. Through these scenarios, stakeholders can envision how different ADM implementations might impact fairness and accessibility, with a focus on procedural justice and community inclusion. Finally, *Q-methodology* findings respond to Sub-question 3, capturing the perspectives of diverse stakeholders on fairness, inclusivity, and trust in ADM for EVCI. This method identifies common and contrasting viewpoints on the role of ADM in energy distribution, providing insights into stakeholder expectations and concerns about ADM-driven EVCI management.

6.1. Geographic Information System Analysis

The first phase of this study involved a GIS analysis, used to answer Sub-question 1, that produced a nested scale map series to assess the current state of EVCI and projected future EV influx. Conducted using ArcGIS Pro version 3.0 [62], this analysis focused on spatial inequalities in EVCI distribution, directly addressing *Proposition 1 (P1)* and *Proposition 2 (P2)*. The GIS analysis complements the other methodologies by offering spatial data that identifies disparities in the distribution of EVCI across different neighbourhoods in Amsterdam. Following approaches similar to those of Dorling [63], who used GIS to explore social inequalities, this analysis uncovers how infrastructural imbalances in EVCI reflect broader societal injustices.

Building on insights from the Literature Review (see Chapter 3), this GIS analysis considers documented socio-economic inequities in energy access within the Netherlands, particularly in urban centres like Amsterdam, where infrastructure developments tend to benefit higher-income neighbourhoods, often leaving lower-income areas underserved [31], [35]. Studies suggest that Dutch energy policy has historically prioritised economic growth and stability, sometimes at the expense of social equity, resulting in accessibility gaps in essential services, including EVCI [32], [47]. This spatial analysis, therefore, extends beyond mapping EVCI distribution to also investigate how these infrastructural patterns align with the existing inequalities noted in prior studies.

By overlaying socio-economic data with EVCI availability across Amsterdam's neighbourhoods, the GIS analysis provides a visual representation of energy justice concerns discussed in previous literature. This analysis aligns with the distributive and procedural justice principles, which emphasise fair access to resources and transparent decision-making processes, as underscored in works by Jenkins et al. and others on energy justice [9], [19], [30]. Areas identified as underserved by charging infrastructure have been directly integrated into the scenario narratives developed later in this research. This quantitative foundation complements qualitative insights from the Q-methodology, helping to triangulate findings on how EVCI accessibility impacts different social groups across the city.

A multi-scale approach was used to create a nested scale map series, progressively zooming in from the regional scale of the Amsterdam Metropolitan Area to a specific city district (postal code area 106). This method allows for an assessment of how EVCI distribution patterns change across various geographic levels, from city-wide trends down to neighbourhood-specific disparities. This approach allows for a spatial pattern analysis, enabling the detection of any infrastructural imbalances by narrowing the focus from the larger metropolitan area to neighbourhoods such as De Akers Oost and Wildeman. These neighbourhoods were chosen for their varied socioeconomic characteristics and existing energy infrastructures, which provide a suitable contrast for investigating the unequal distribution of EVCI within the city. The eight maps are summarised in the table 6.1 below.

Table 6.1: Overview of GIS analysis Visualisations

Figure	Map Title
6.1	*Amount of EVs in 2030 per Postal Code 3 in the Amsterdam Metropolitan Area*
6.2	*Public EV Charger Accessibility per Building in Amsterdam*
6.3	*Relation between Income and Public EV Charger Accessibility in Amsterdam*
6.4	*Demography of Postal Code 106 Area regarding Income, Housing, Passenger Cars and Fuel*
6.5	*Electricity Network and (smart) EV Chargers surrounding De Aker Oost and Wildeman*
6.6	*Energy Labels and Solar Panels in De Aker Oost*
6.7	*Building Function, Social Housing and Solar Panels in De Aker Oost*
6.8	*Energy Labels and Solar Panels in Wildeman*
6.9	*Building Function, Social Housing and Solar Panels in Wildeman*

6.1.1. Projected number of Electric Vehicles in 2030

As mentioned in the Introduction (see Chapter 1), a large increase in the number of electric vehicles is expected in the Netherlands negatively influencing the already existing problem of net congestion. To get a better idea of which areas are expected the see the largest increase of EVs in 2030, the map in figure 6.1 on page 46 shows the GIS analysis concerning the amount of EVs in 2030 divided by Postal Code 3 areas in the Amsterdam Metropolitan Area created using the publicly available data from a study on mobility, electricity, and parking data for EVCI in the Amsterdam Metropolitan Area (AMA) [64]. The main attribute extracted from this dataset for the creation of figure 6.1 is the Projected number of Electric Vehicles by 2030.

In general, the map shows a higher projected number of EVs in postal code 3 areas containing larger towns and cities. Places like Amsterdam, Amstelveen, Almere, Hilversum, Hoofddorp, Purmerend and Zaandam will see the highest EV growth and are expected to have the EV highest infrastructure needs The highest projected number of EVs to be in postal code area 106 in the west of the Municipality of Amsterdam with an expected number of 18.458 EVs of a total of 46.145 cars (40%). postal code area 106 has a total of 160.350 inhabitants with 76.470 households. The term ‘Postal Code 106 area’ will be used throughout this document instead of Amsterdam Nieuw West since the boundaries of these areas do not completely align. The chart on the bottom of the figure shows the exact projected number of EVs in 2030 per postal code 3 area with a sum of 400.834 and an average of 5.206 EVs in the Amsterdam Metropolitan Area.

6.1.2. Public EV Charger Accessibility in the Municipality of Amsterdam

With now having the knowledge of which area is projected to have the highest number of EVs in the AMA, the next step consists of finding out what the status of the EV charging infrastructure is in the Municipality of Amsterdam to determine how the addition of more chargers could influence the net congestion of the electricity grid. The map in figure 6.2 on page 48 visualises the EV charger accessibility per building in the municipality of Amsterdam. It shows the overall low accessibility to EV chargers in Amsterdam with the highest number being in the areas west and south of the city centre. postal code area 106 shows an average of twenty (20) public EV charging locations per building which is lower compared to the mean of twenty-seven for the whole municipality. The map clearly displays the variation in accessibility between the inner and outer areas of the neighbourhoods.

The chart on the left in figure 6.2 showcases the number of EV chargers within 400 meters per number of buildings. It shows the distribution of EV chargers being low generally with the outliers being areas with a high amount of EV chargers nearby. The chart on the bottom of Figure 5 shows the average amount of EV chargers within 400 meters of the buildings within a certain postal code 3 area showing an unequal distribution. To explore this inequality further, the next section discusses and shows the relation between the EV charger accessibility and income.

6.1.3. Relation between Income and EV Charger Accessibility

After looking at the accessibility of EVCI in the Municipality of Amsterdam, the map in figure 6.3 on page 50 shows the aggregated building level data on a neighbourhood level. Combining with demographic data on the percentage of households with the highest income [66] the map visualises the relationship between these variables using a bivariate colour scheme. This way, the low and high values are plotted against each other emphasising the neighbourhoods where both variables contain high values with a dark green colour. It becomes apparent that especially neighbourhoods postal code area 107 see this combination of high values of income and accessibility to EV charging infrastructure. The opposite is seen in postal code areas 104 and 110 where values for both income and accessibility are low. The charts on the left and bottom of the figure show the average values for the postal code 3 areas in similar orientation as the bivariate symbology of the map. postal code area 106 sees a mix between neighbourhoods with higher values for income and others for accessibility but not the combination of both. Therefore, the following section and maps will zoom in on postal code area 106 to analyse the demographics of the neighbourhoods falling within in more detail.

6.1.4. Demography of Postal Code Area 106

The goal of focusing on area 106 is to analyse differences and similarities between neighbourhoods in terms of household income, housing type, car ownership, and fuel type. This analysis will help identify two distinct neighbourhoods with varying demographic characteristics but similar car ownership and a lack of EV charging infrastructure, supporting scenario creation and final policy recommendations. The map in figure 6.4 on page 52 visualises key data from CBS [66].

Firstly, the percentage of households with the lowest incomes reveals a clear divide, with Wildeman having a very high percentage, while De Aker Oost shows relatively few low-income households. A similar pattern is seen when comparing the percentage of rental housing and social housing – housing owned by housing associations. Wildeman shows high values for both, while De Aker Oost has much lower values, indicating more privately owned properties. Secondly, in terms of the total number of passenger cars and petrol usage, both De Aker Oost and Wildeman show high values. De Aker Oost has 2,310 passenger cars, or 1 car per household, while Wildeman has 1,325 cars, equating to 0.5 cars per household.

Lastly, the chart on the bottom of figure 6.4 shows the percentages of cars using petrol, rental housing and those owned by housing corporations compared to the average income per income recipient. The graph shows the neighbourhoods De Aker Oost and Wildeman being highly distinct regarding the average income per income recipient and percentage of rental housing and those owned by housing corporations whilst seeing a similar percentage of cars using petrol.

6.1.5. Electricity Network and EVCI surrounding the Focus Neighbourhoods

Earlier, the EVCI accessibility analysis of figure 6.2 showed the average accessibility of EV chargers over the neighbourhoods of the Municipality of Amsterdam. But what is the exact situation surrounding the neighbourhoods De Aker Oost and Wildeman with the projection of the high increase in EV ownership in 2030 in area 106? The map in figure 6.5 on page 54 visualises the electricity network showing a clear interconnectedness between these neighbourhoods on a middle voltage level. With ADM determining energy distribution using the V2G and SC technologies, this distribution is bound to happen between neighbourhoods as well due to this interconnectedness of the electricity network. Additionally, Figure 8 shows the exact location of (smart) public EV chargers in the neighbourhoods themselves and surroundings of De Aker Oost and Wildeman. Due to the projected high increase of EVs owned in this area, many EV charging stations will need to be built to cope with the charging demand, increasing net congestion in these neighbourhoods.

6.1.6. In-depth analysis of De Aker Oost

This section examines the characteristics of De Aker Oost in terms of energy efficiency, availability of EV charging infrastructure, and distribution of solar panels, providing insight into the neighbourhood's capacity for supporting future electric vehicle adoption.

Energy labels, EV Chargers and Solar Panels in De Aker Oost

De Aker Oost is made up of mainly detached and attached housing. The map in figure 6.6 on page 56 visualises the most frequent energy label per building, EV chargers in the neighbourhood and number of solar panels placed on the rooftops. The map shows most buildings containing a good energy label with the most common being 'A' and 'B'. Important to note is the existence of 1.075 secondary buildings – not the main residence or business on a property – which do not have an energy label registered and are therefore not present on the map. Knowing this, the map shows data for 831 out of 1.556 primary buildings (53%). The primary buildings contain 2.199 units, which in essence, means that most buildings contain one unit or address.

Building function, Social Housing and Solar Panels in De Aker Oost

With the average low ratio of units per building, the solar panels on the roof are providing energy to a singular unit or address. Mentioned in the literature review, the implementation of V2G technology goes together with the possession of solar panels if these are owned privately. The map in figure 6.7 on page 58 looks at the different building's functions and social housing besides solar panels in De Aker Oost. The map clearly shows most buildings being owned privately except for the larger apartment buildings and flats. The main function of buildings in the neighbourhood is residential except for the largest building in the north of the neighbourhood. Here houses a shopping centre with residential units on top giving it a mixed use. This building possesses the highest number of solar panels shared among the residential and commercial units within. The chart on the left shows the private and public ownership of solar panels in the neighbourhood. It becomes clear that the majority (87%) of solar panels in the area are owned privately and positioned on singular addresses.

6.1.7. In-depth analysis of Wildeman

This section explores the attributes of Wildeman, focusing on energy labels, EV charging accessibility, and solar panel distribution, to assess the neighbourhood's current energy profile and infrastructure readiness for increased electric vehicle demand.

Energy labels, EV Chargers and Solar Panels Wildeman

Wildeman is made up of mainly row housing and flats. The map in figure 6.8 on 60 visualises the most frequent energy label per building, EV chargers in the neighbourhood and number of solar panels placed on the rooftops. The map shows most buildings containing an average energy label with the most common being 'C'. This neighbourhood only contains 18 secondary buildings compared to the high number in De Aker Oost. Knowing this, the map shows data for 239 out of 389 primary buildings (61%). The primary buildings contain 2.874 units, which in essence, means that a single building contains many different units or addresses. Solar panels are mainly present on buildings who do have a good energy label which gives the suspicion that investment have been made in the renovation of the building to improve insulation and solar panels to partly become self-sufficient for electricity. You could argue that the other buildings will still undergo this transformation in the future improving high electricity demand but increasing electricity supply with the solar panels to the grid.

Building Function, Social Housing and Solar Panels in Wildeman

With the average high ratio of units per building, the solar panels on the roof are providing energy to a multitude of units or addresses. The implementation of SC technology goes together with the existence of a large amount of public parking spots. The map in figure 6.9 on page 62 looks at the different building's functions and social housing besides solar panels in De Aker Oost. The map clearly shows most buildings being social housing spread over four housing corporations and about one-third of the buildings being privately owned. The privately owned buildings contain more than half of the solar panels and the area and function mostly as a facility or workplace. The one exception is the flat owned by de Alliantie which is the only building with social housing having a good energy label and many solar panels on the roof. It seems that this housing corporation invested in the sustainability of the building where others still need to follow. Wildeman has only installed a total of 482 solar panels on the roofs with de Aker Oost currently having 3.672. With a similar number of inhabitants in both neighbourhoods, Wildeman is expected to still see a large change in this amount having a big effect on the net congestion. The implementation of smart technologies for the needed EV chargers in the future will therefore be important to alleviate the congestion.

6.1.8. GIS Analysis Summary and Key Findings

The GIS analysis reveals spatial patterns and disparities in the distribution of EVCI across the Amsterdam Metropolitan Area, with a particular focus on postal code area 106, where a high influx of EVs is projected by 2030. This area, which includes the neighbourhoods of De Aker Oost and Wildeman, generally has low accessibility to EVCI, highlighting an urgent need for expanded charging infrastructure to meet future demand. These findings directly address Sub-question 1, demonstrating how disparities in infrastructure provision lead to unequal EVCI access for different socio-economic groups within Amsterdam.

Within postal code area 106, clear socio-economic contrasts are evident between neighbourhoods. De Aker Oost, characterised by higher income levels, predominantly detached housing, and widespread solar panel installations on privately-owned homes, stands in contrast to Wildeman, a lower-income neighbourhood with a high proportion of social housing and minimal solar energy infrastructure. This difference in housing types and renewable energy capacity suggests that each neighbourhood could benefit from different EVCI technologies: De Aker Oost is well-suited to Vehicle-to-Grid (V2G) systems, which leverage privately-owned solar panels to support the grid, while Wildeman would benefit more from Smart Charging (SC) technology, allowing ADM to dynamically manage public EV charging availability based on demand and affordability. These insights support the literature's emphasis on *Recognition Justice*, highlighting that diverse socio-economic contexts require tailored infrastructure solutions to ensure fair access to energy resources [38].

Additionally, areas closer to the city centre, particularly in the south and west, exhibit the highest levels of EVCI accessibility and also have the highest average income levels. This pattern underscores the correlation between income and infrastructure accessibility, reinforcing findings from recent studies on *Distributive Justice* that show how affluent, centrally-located areas often benefit more from public infrastructure investments—a trend visible in EVCI distribution as well [35], [36]. The generally lower accessibility in postal code area 106 further highlights a gap in equitable EVCI access, with future infrastructure improvements essential for supporting the anticipated increase in EVs, especially in socio-economically diverse neighbourhoods like De Aker Oost and Wildeman.

The findings from this analysis guide the subsequent Scenario Development phase, addressing Sub-question 2 by supporting the creation of two scenarios tailored to the socio-economic and infrastructural characteristics of De Aker Oost and Wildeman. Scenario One centres on implementing V2G technology in De Aker Oost, where private solar panel capacity supports bidirectional energy flow, enabling residents to contribute to and draw from the grid. Scenario Two, focused on Wildeman, applies SC technology through ADM, allowing flexible pricing and charging options at public stations to improve access and affordability for lower-income residents. These scenarios thus explore how ADM-driven EVCI strategies can mitigate existing infrastructure inequities and support energy justice by meeting the needs of each neighbourhood.

In summary, these results validate key points from the literature on energy justice in the Netherlands, demonstrating that socio-economic factors and geographic location significantly impact EVCI distribution. The findings provide a foundation for Scenario Development, illustrating how ADM technologies like V2G and SC can be aligned with energy justice principles to reduce infrastructure imbalances and promote equitable access. This approach aligns with *Procedural Justice* by advocating for inclusive and transparent decision-making processes that prioritise diverse community needs, particularly in underserved areas [40], [44].

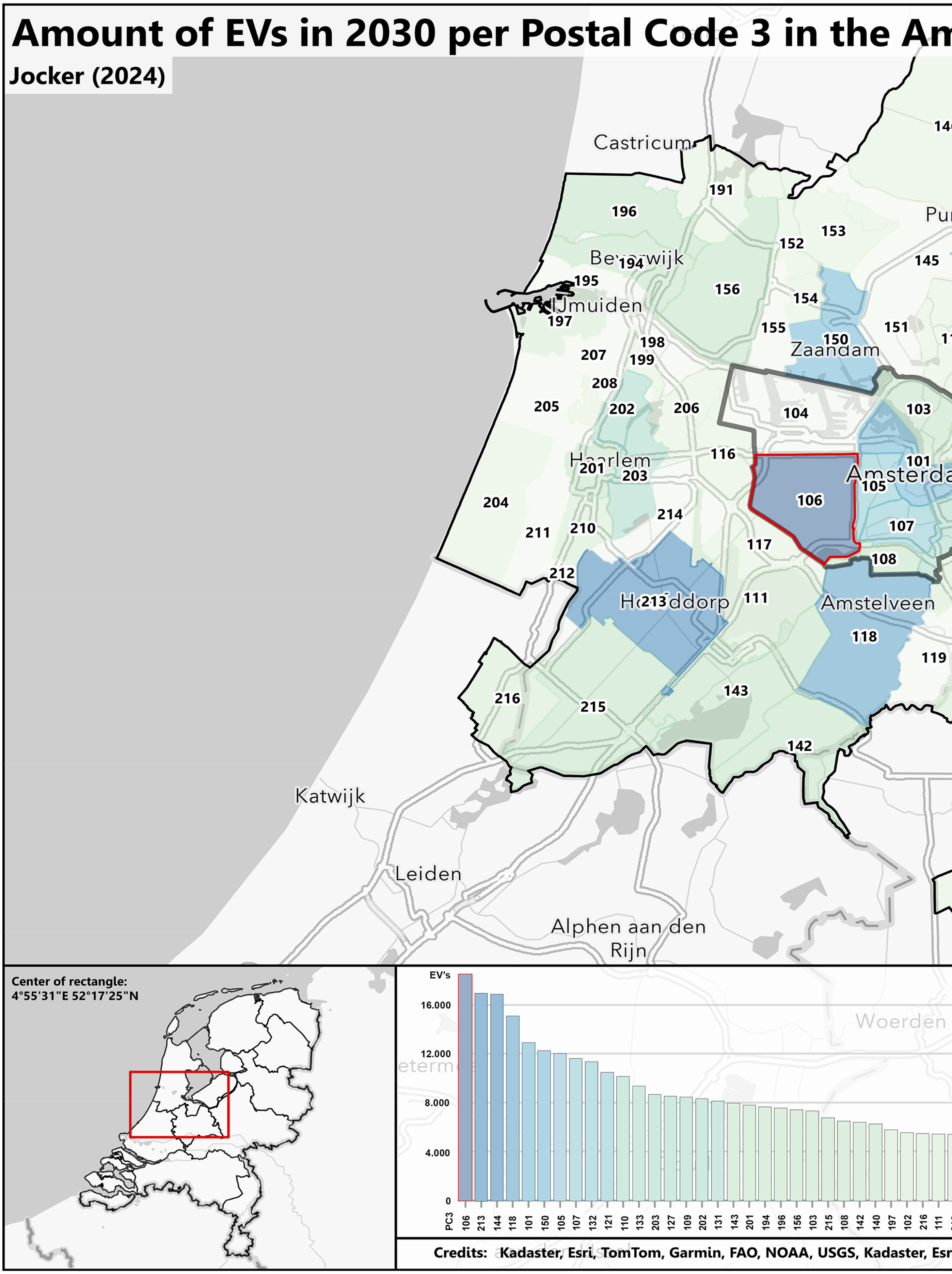
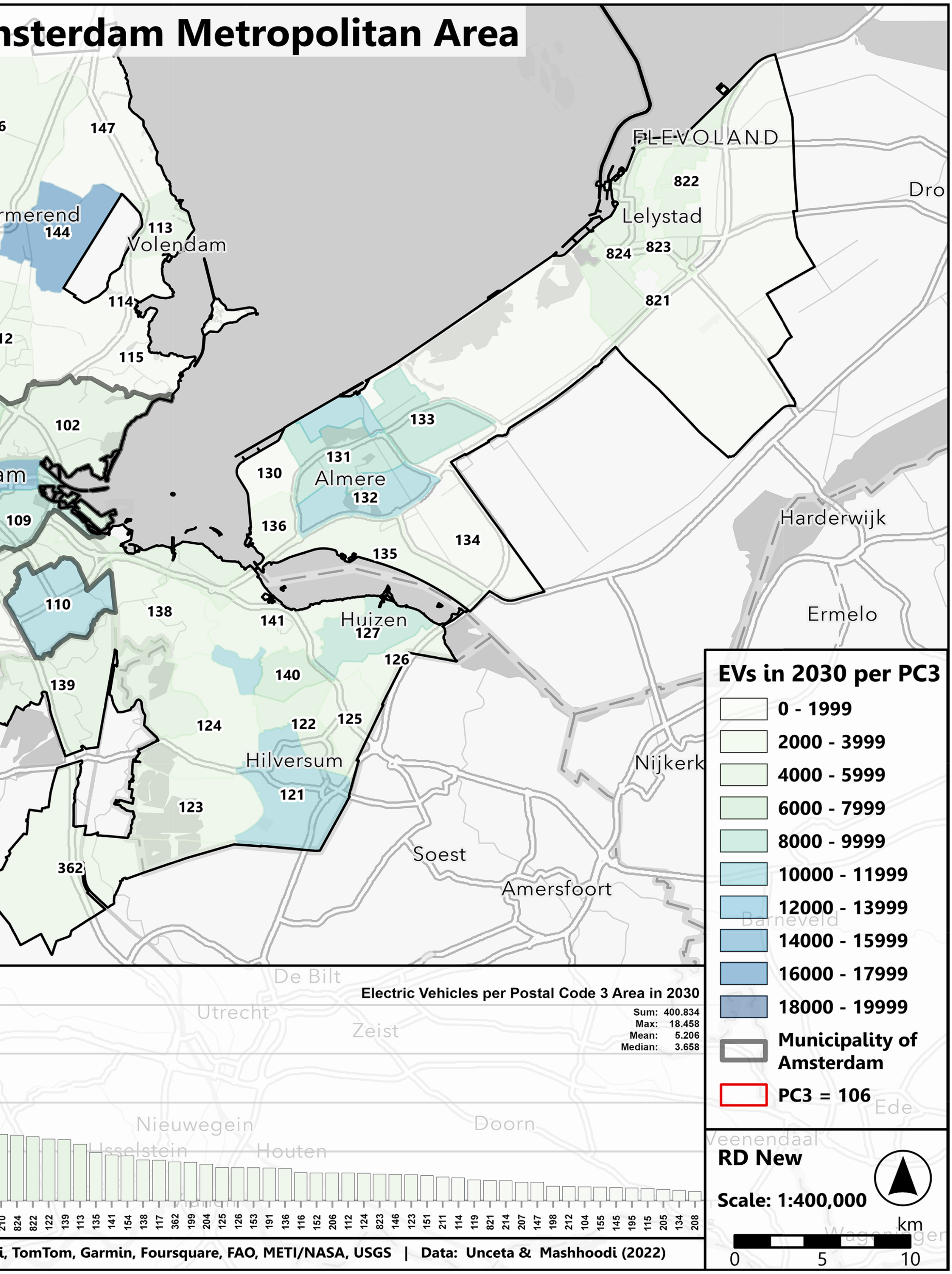


Figure 6.1: Amount of EVs in 2030 per Postal



Code 3 in the Amsterdam Metropolitan Area

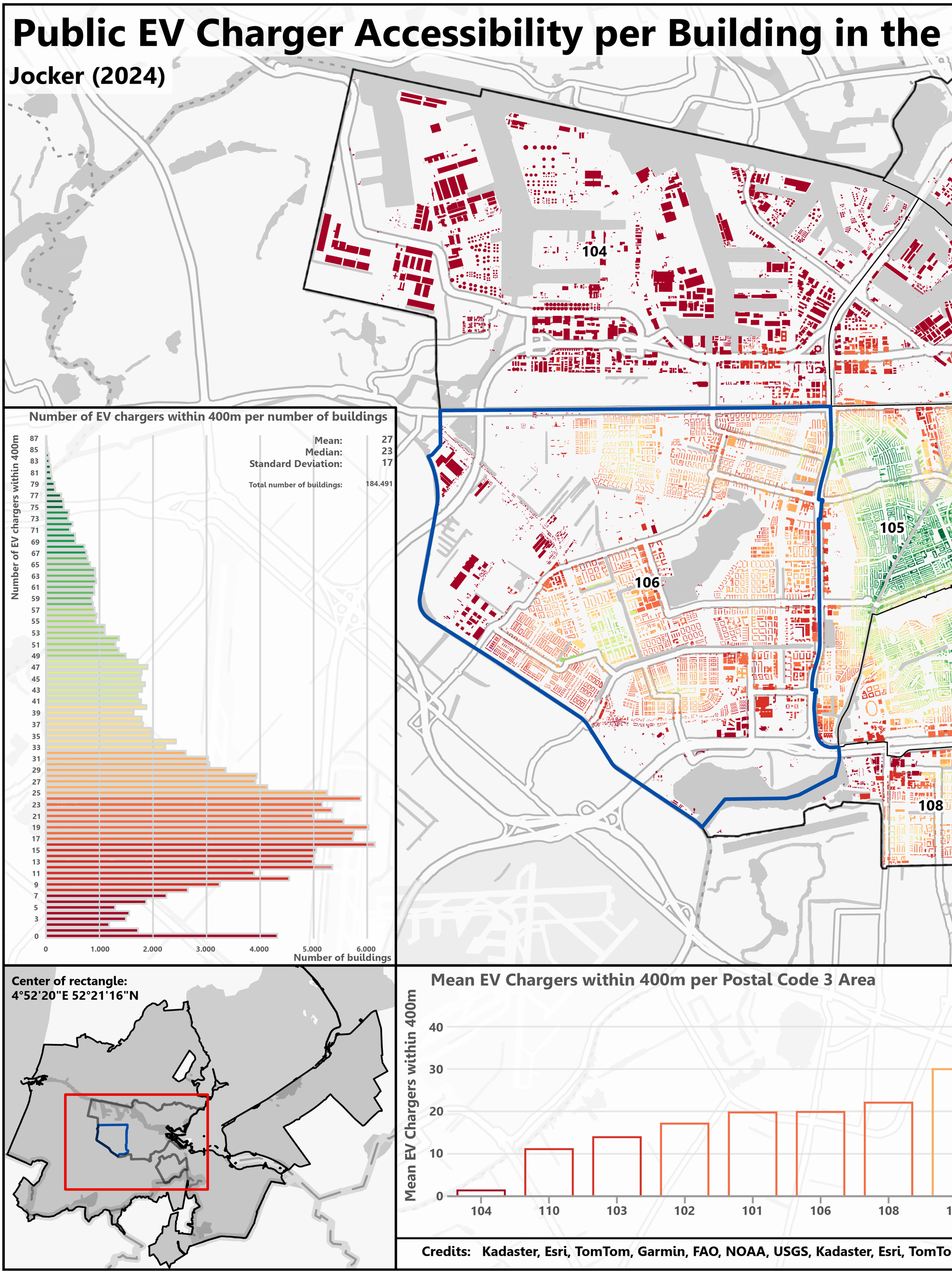
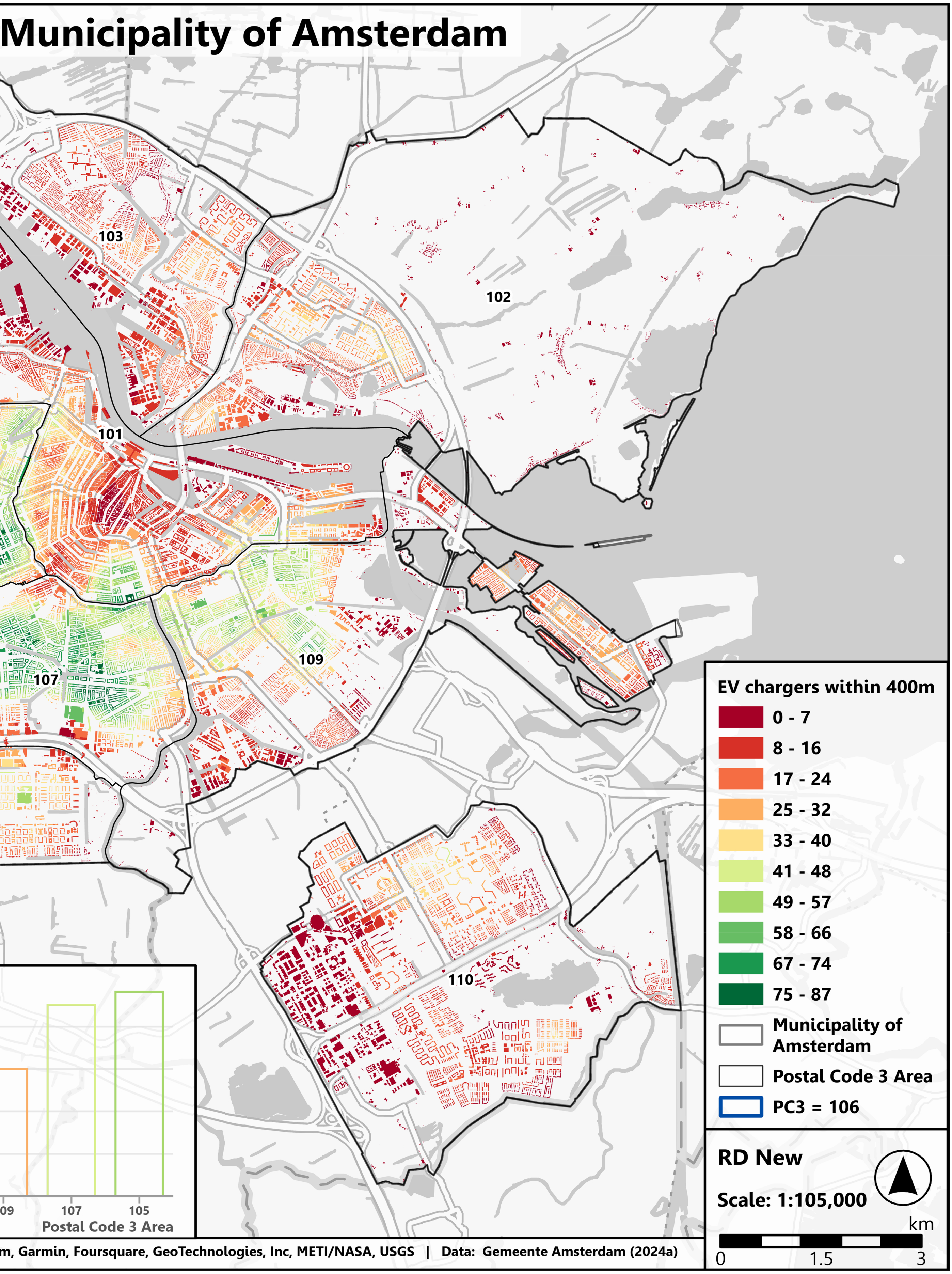


Figure 6.2: Public EV Charger Accessibility



per Building in the Municipality of Amsterdam

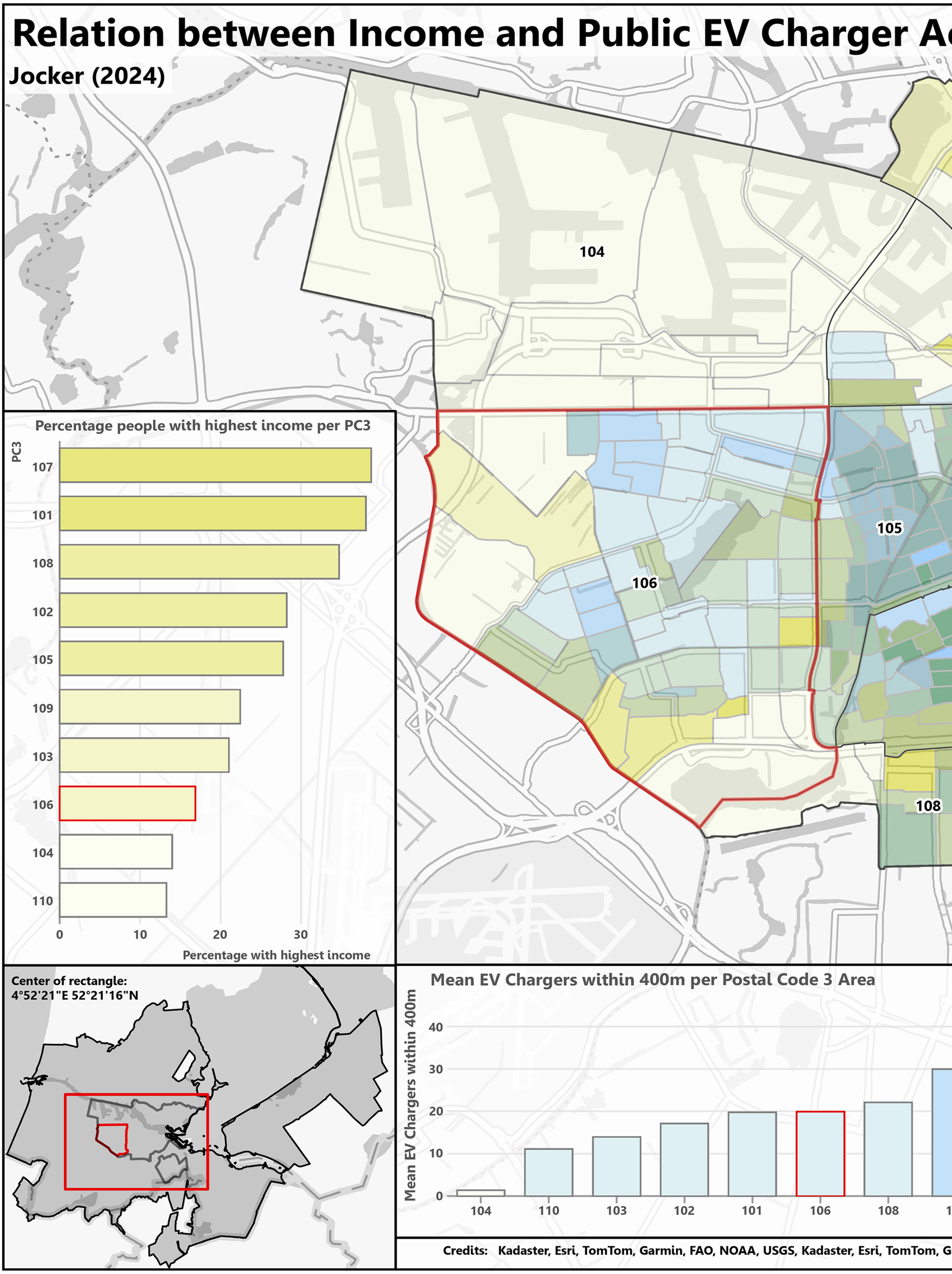
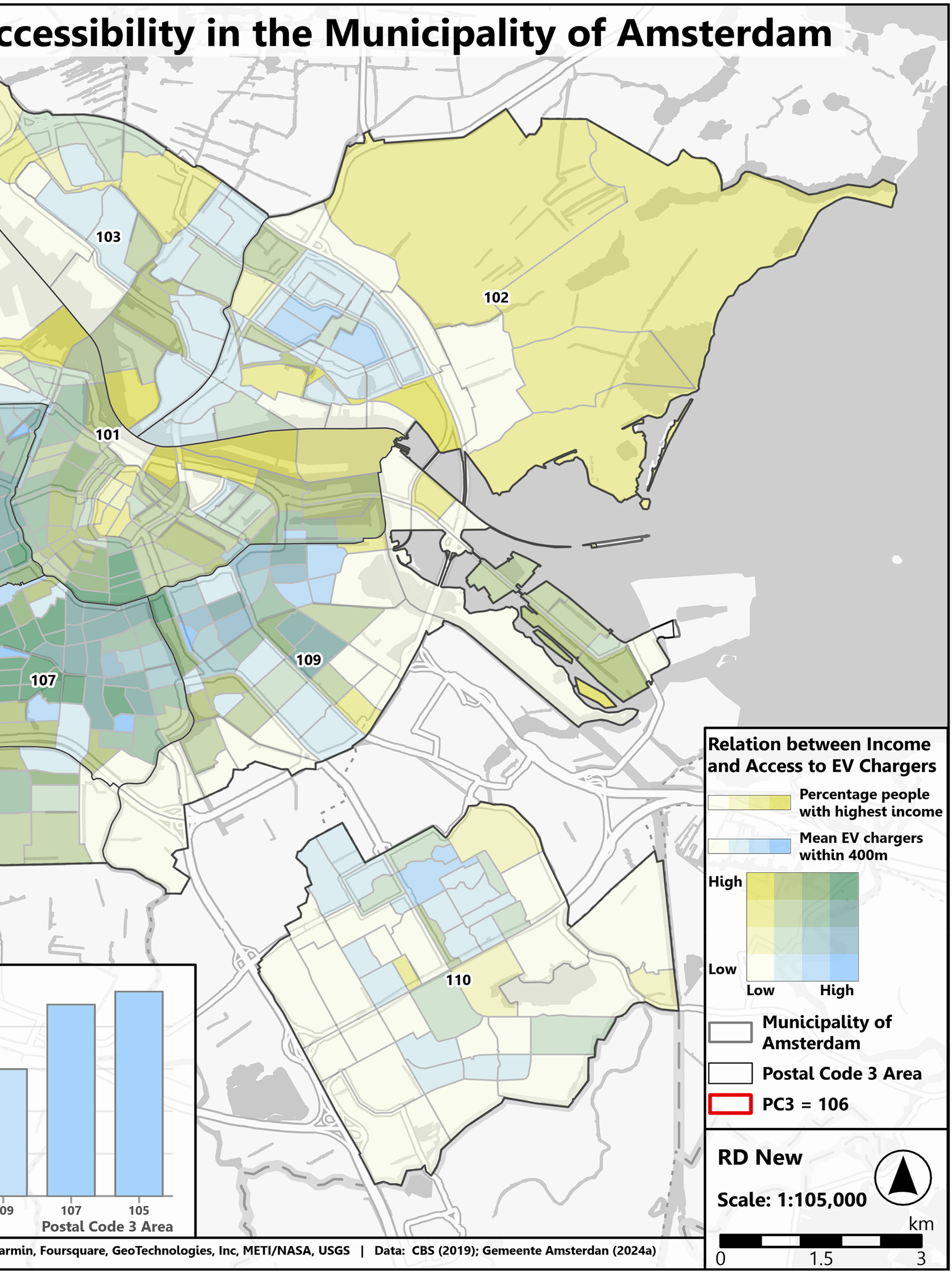


Figure 6.3: Relation between Income and Public



EV Charger Accessibility in the Municipality of Amsterdam

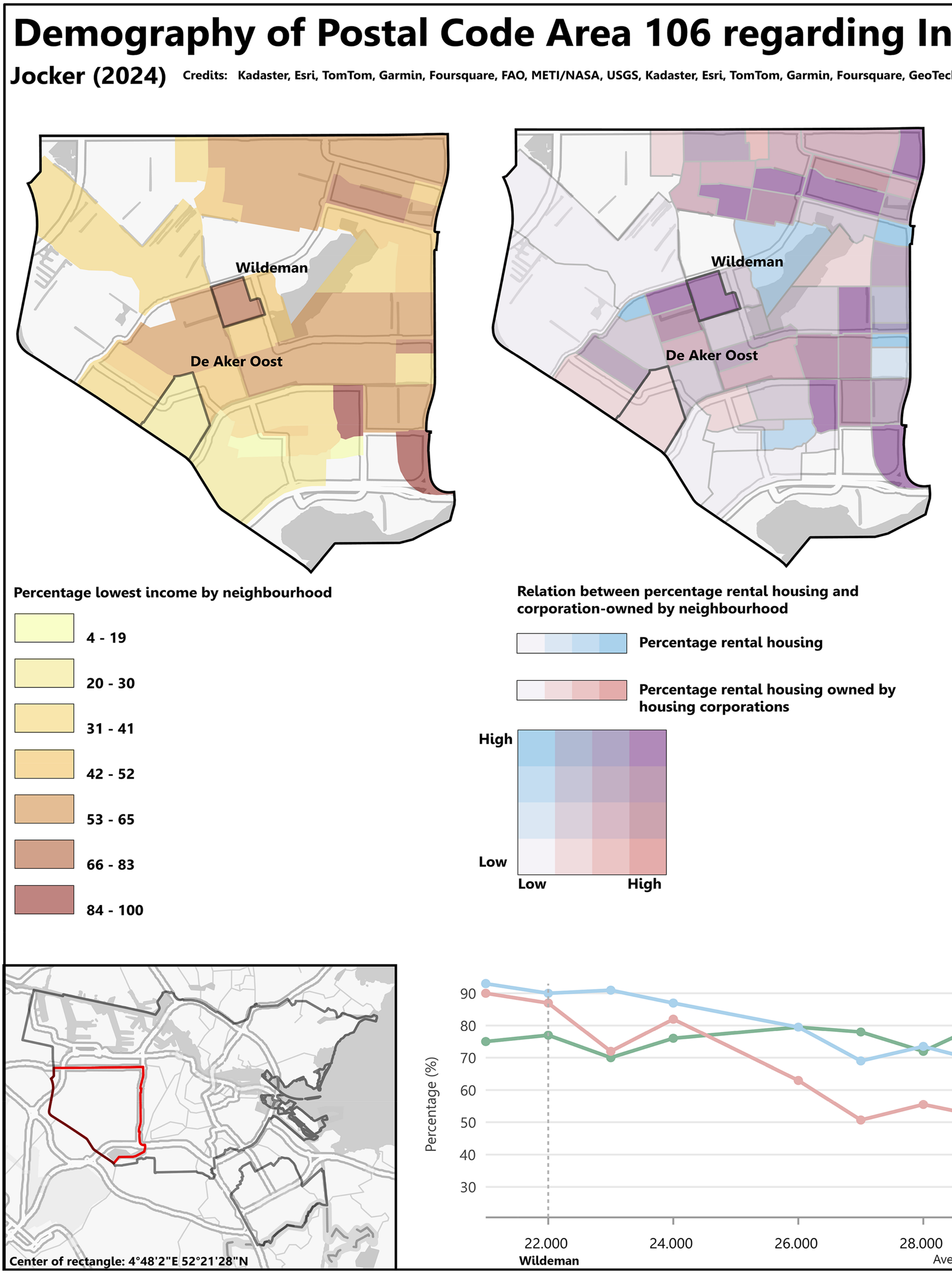
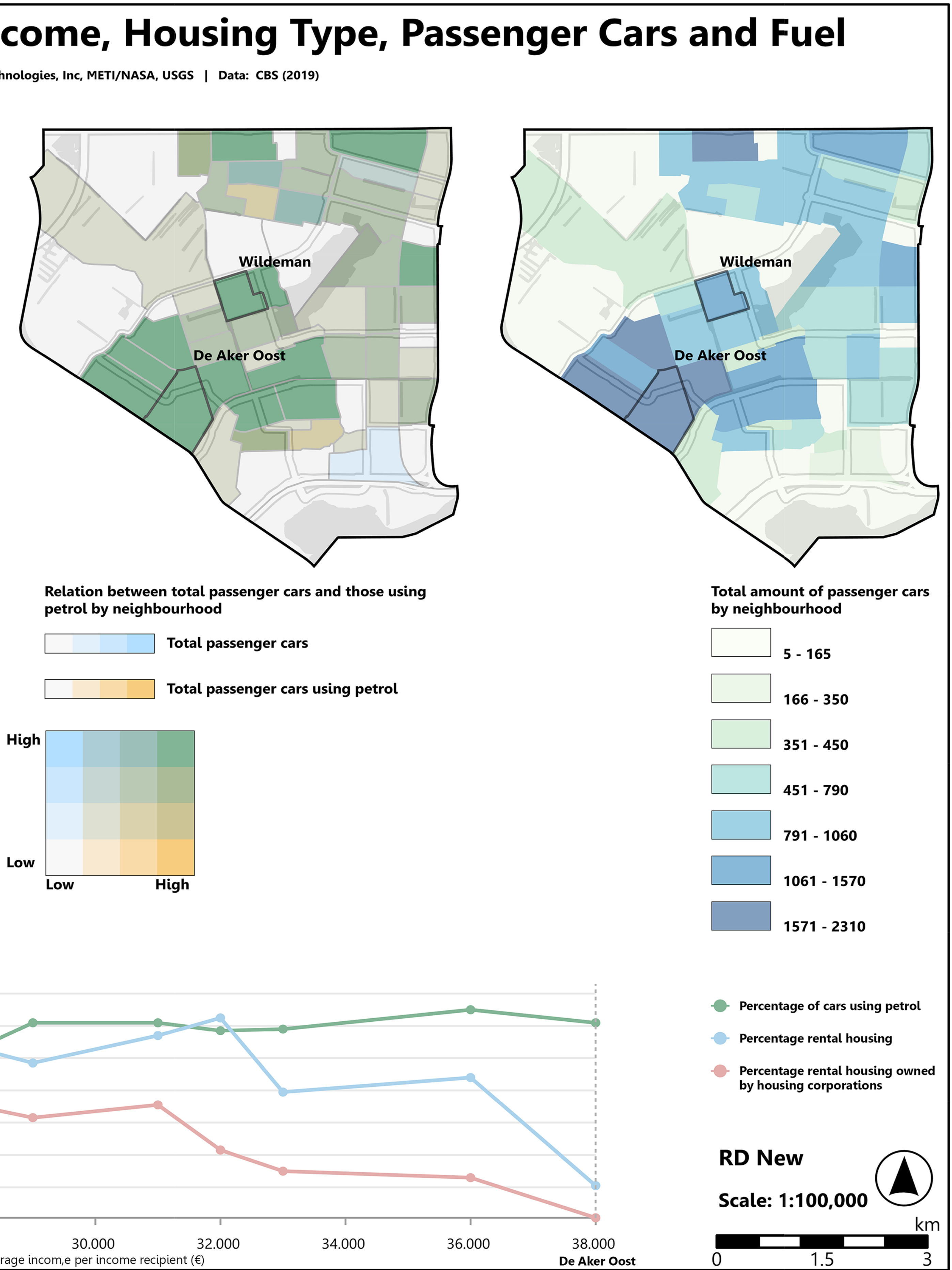


Figure 6.4: Demography of Postal Code Area 106



regarding Income, Housing Type, Passenger Cars and Fuel

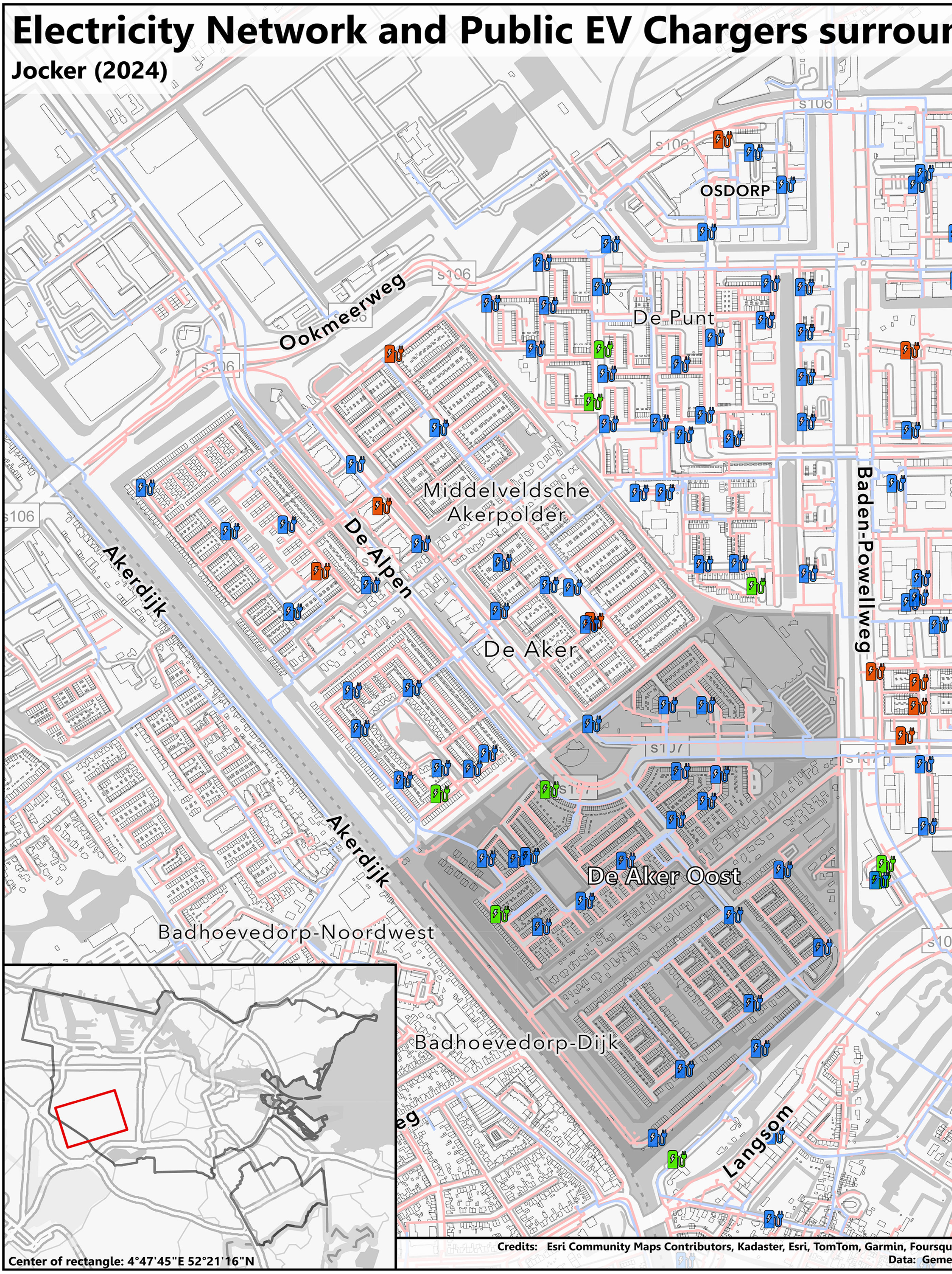
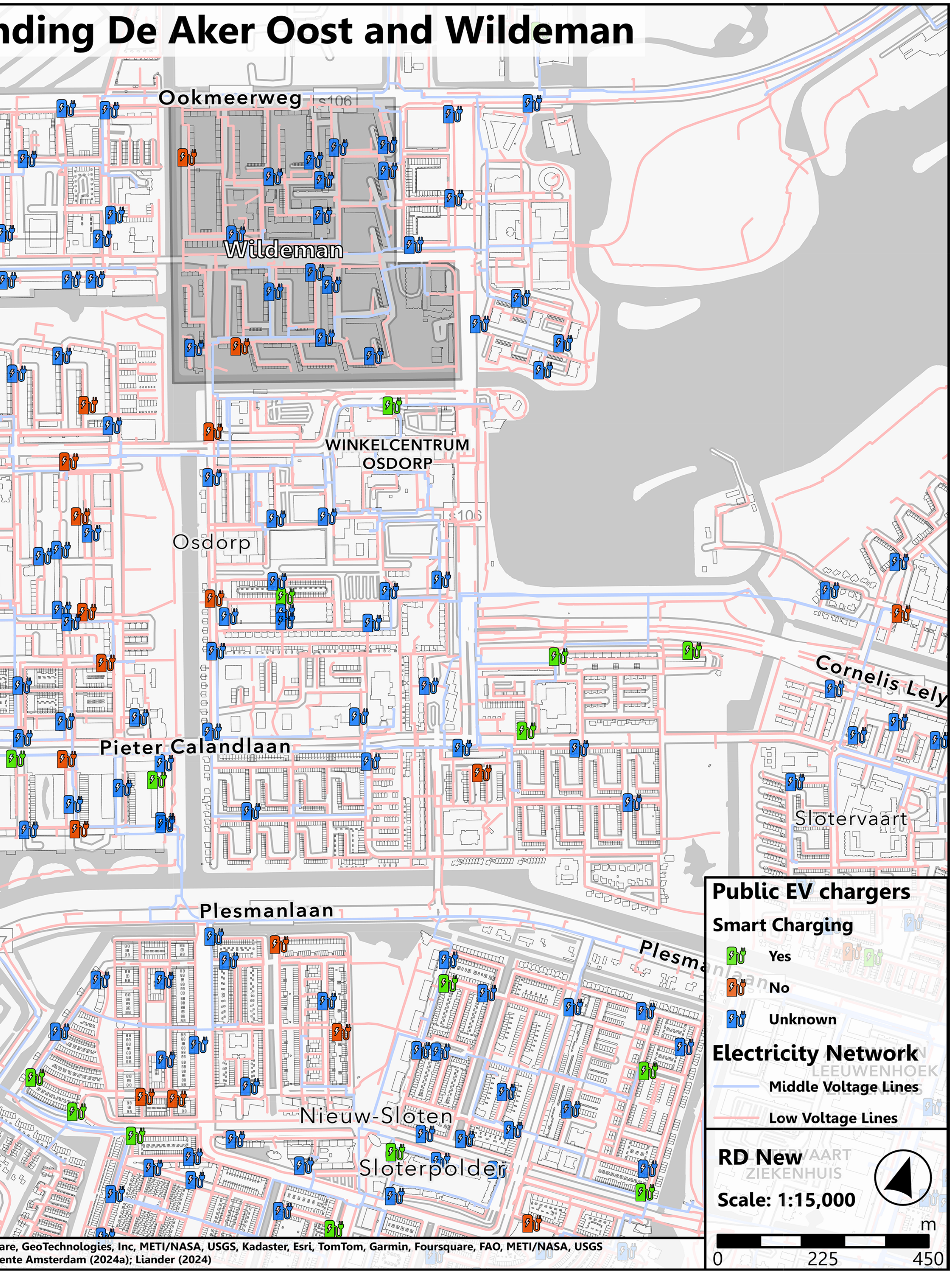


Figure 6.5: Electricity Network and Public



EV Chargers surrounding De Aker Oost and Wildeman

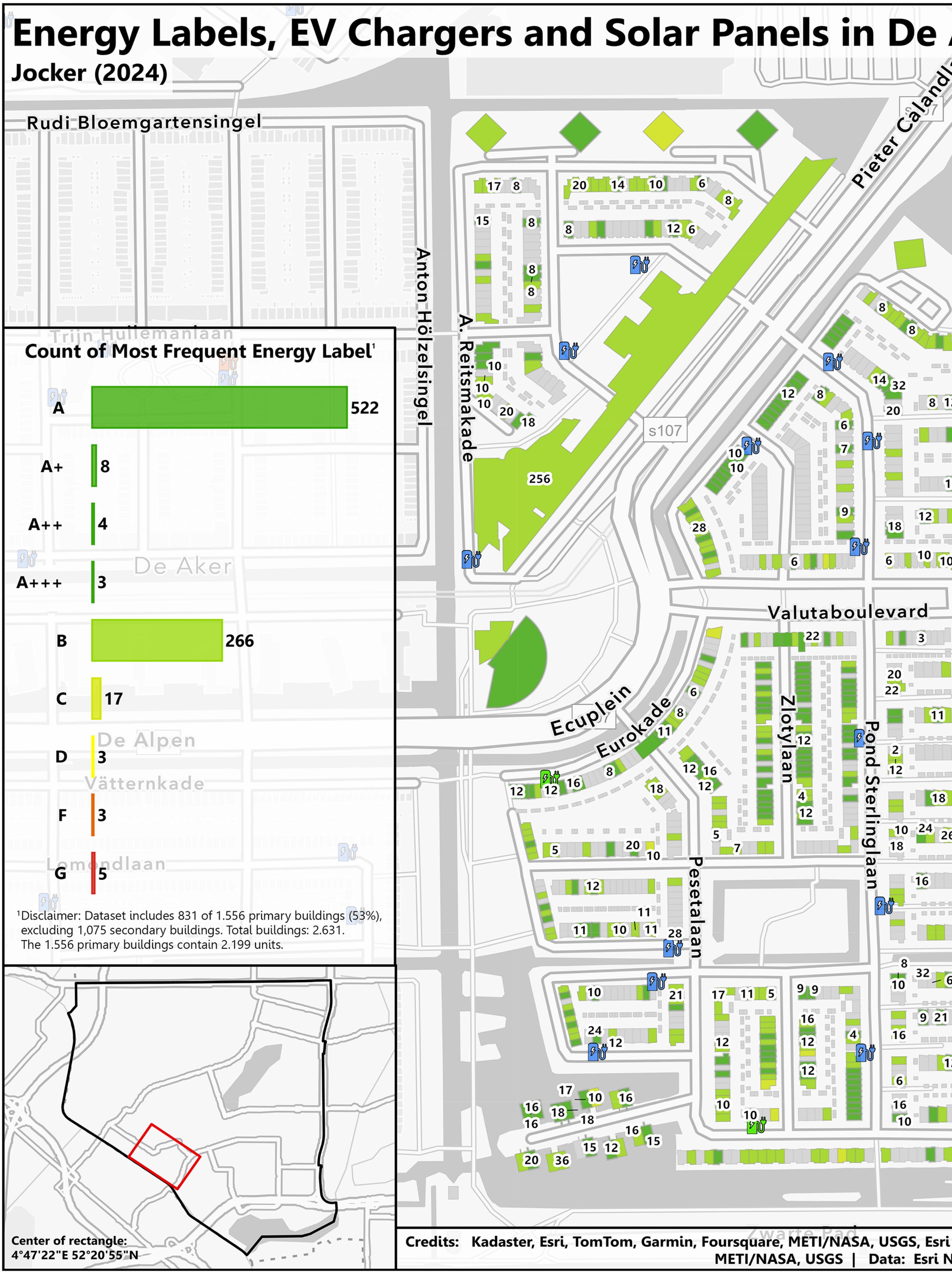
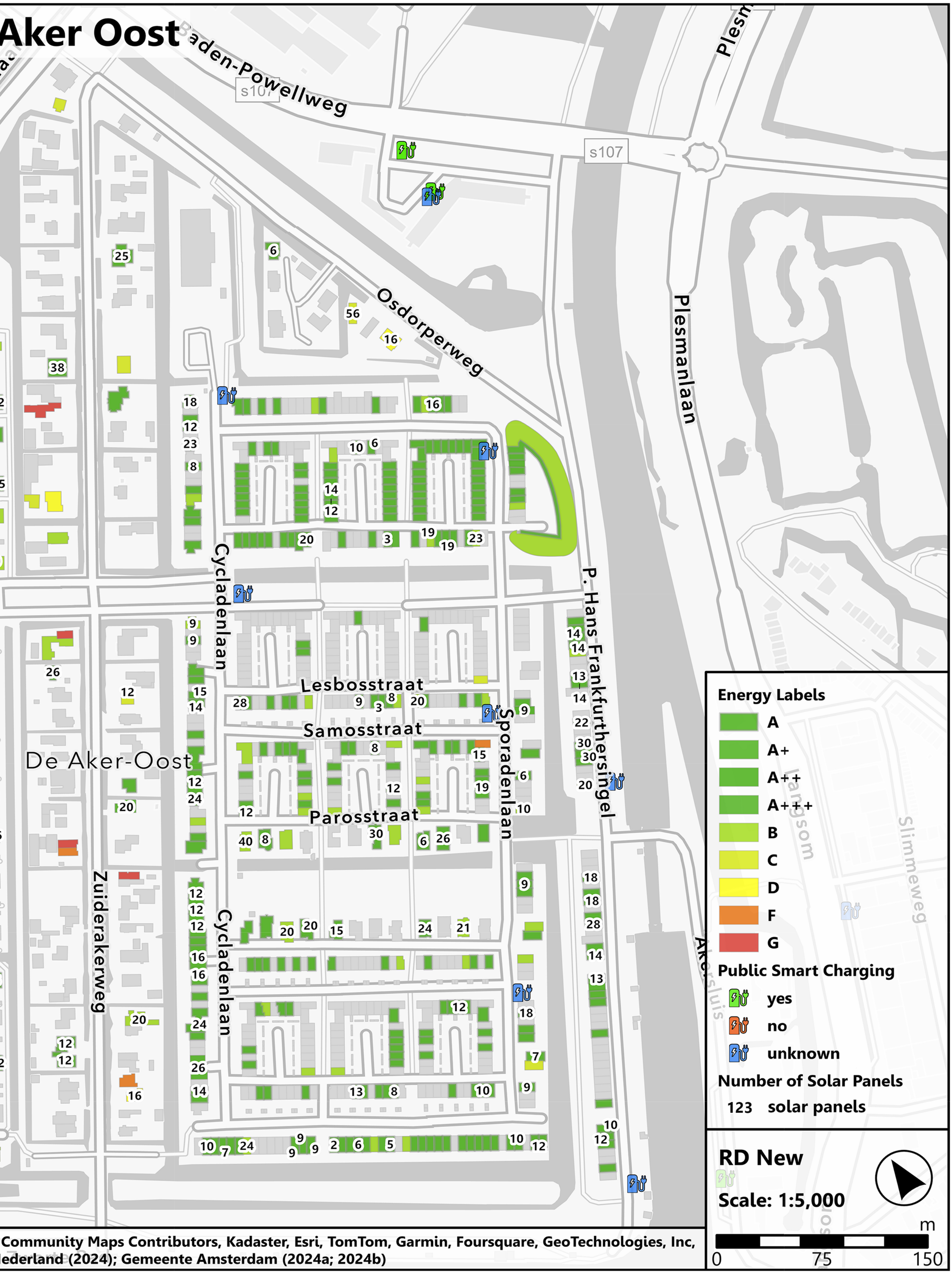


Figure 6.6: Energy Labels, EV Chargers



and Solar Panels in De Aker Oost

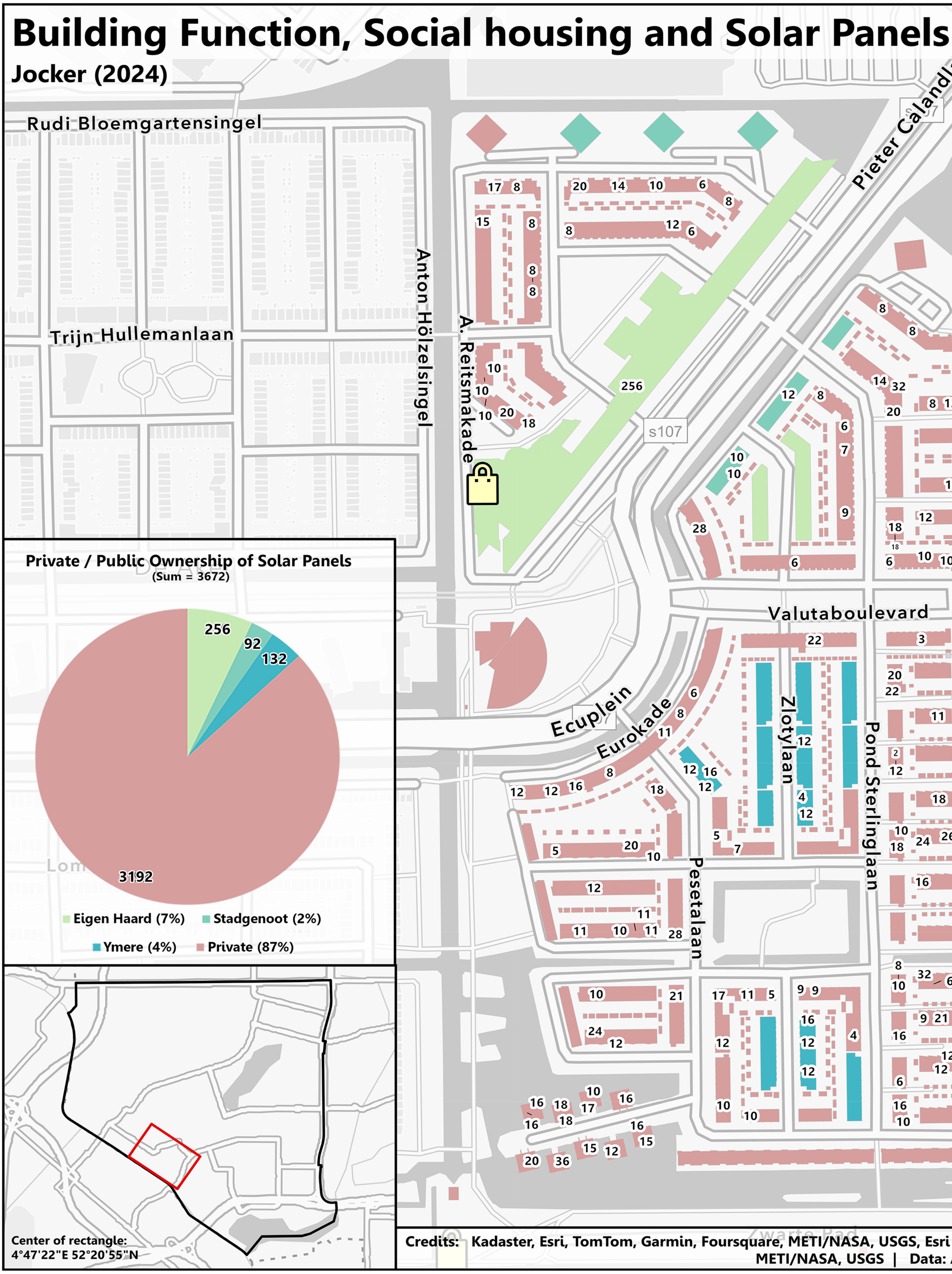
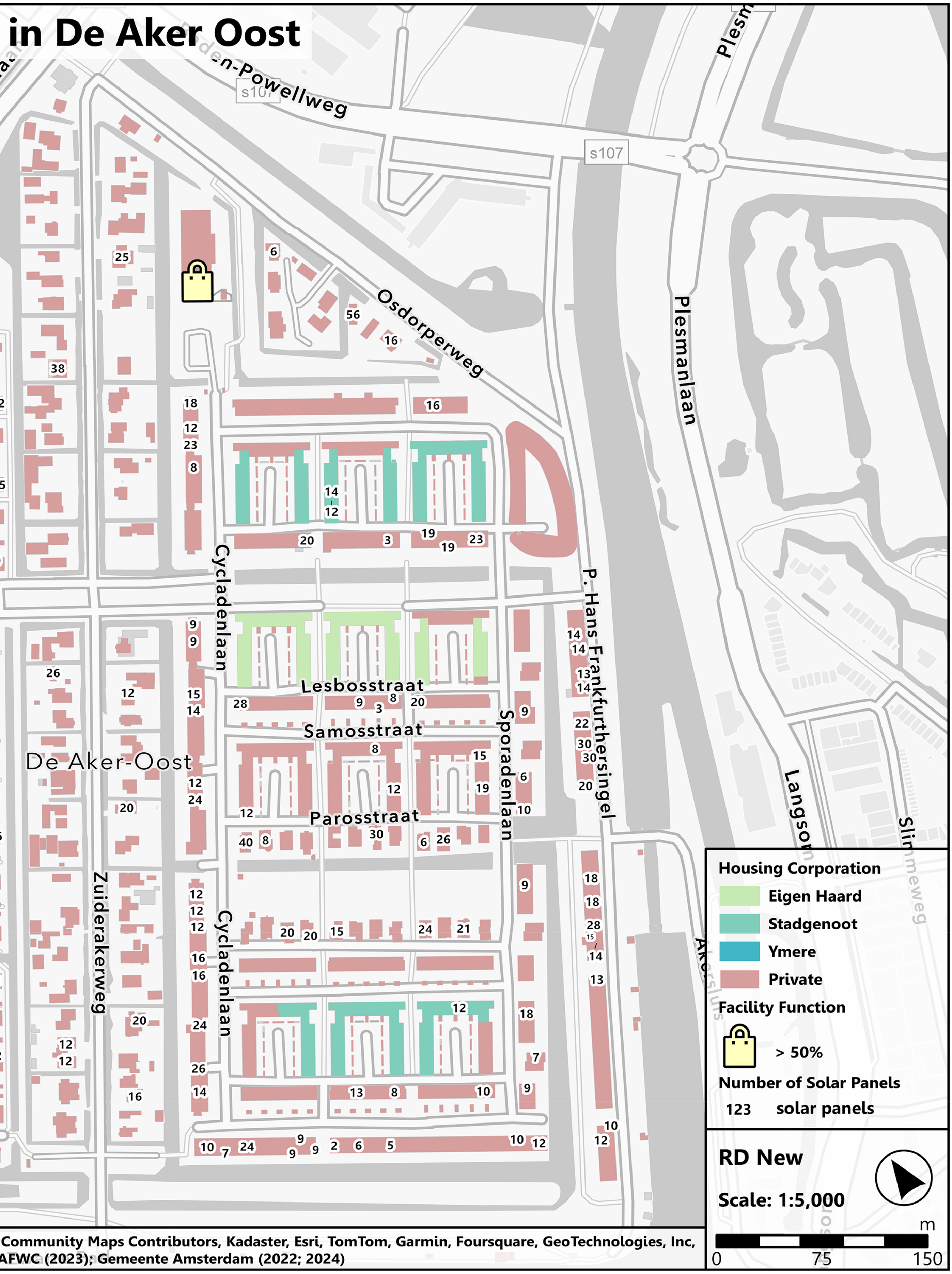
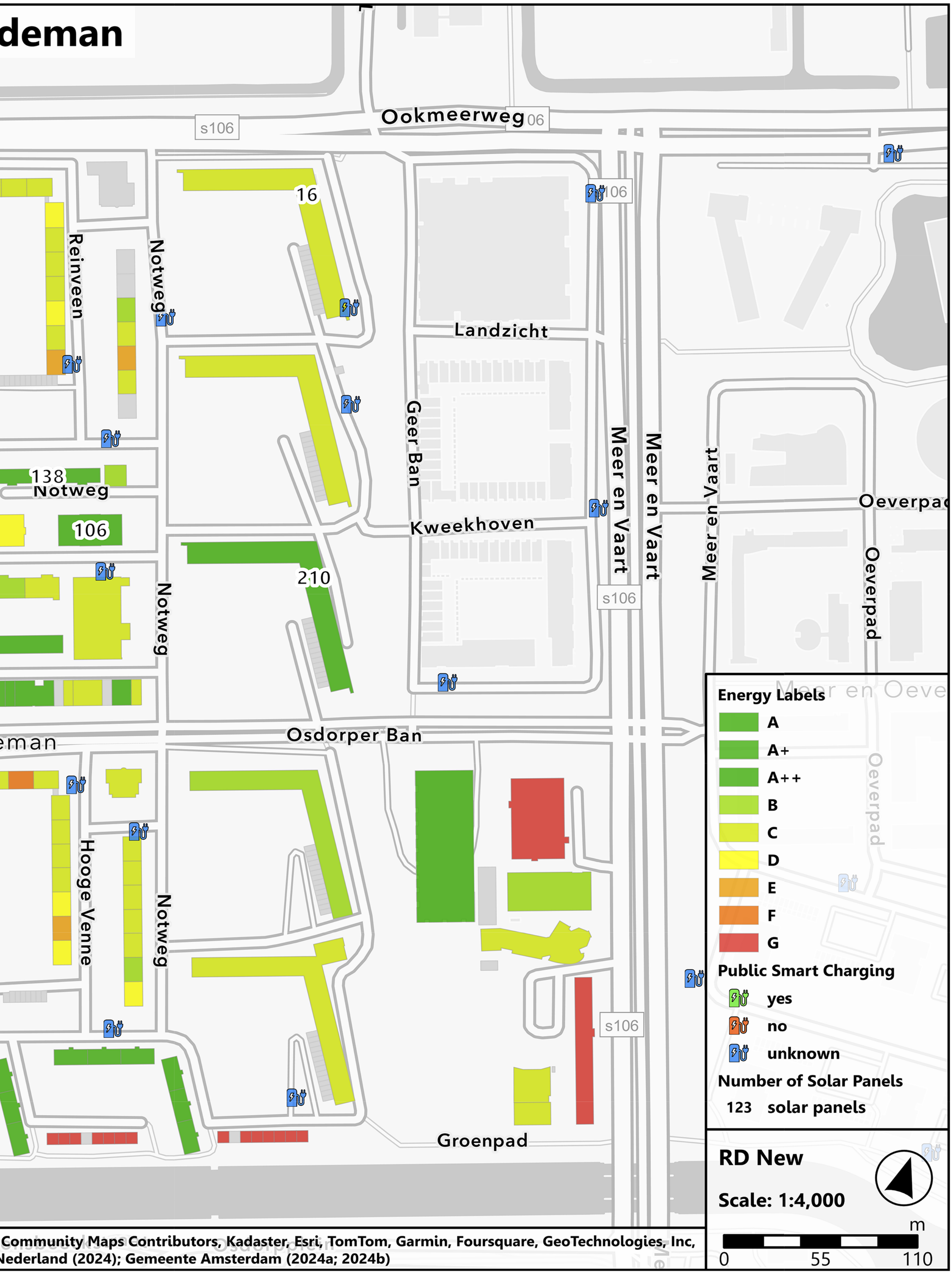


Figure 6.7: Building Function, Social Housing



and Solar Panels in De Aker Oost

Figure 6.8: Energy Labels, EV Chargers



and Solar Panels in Wildeman

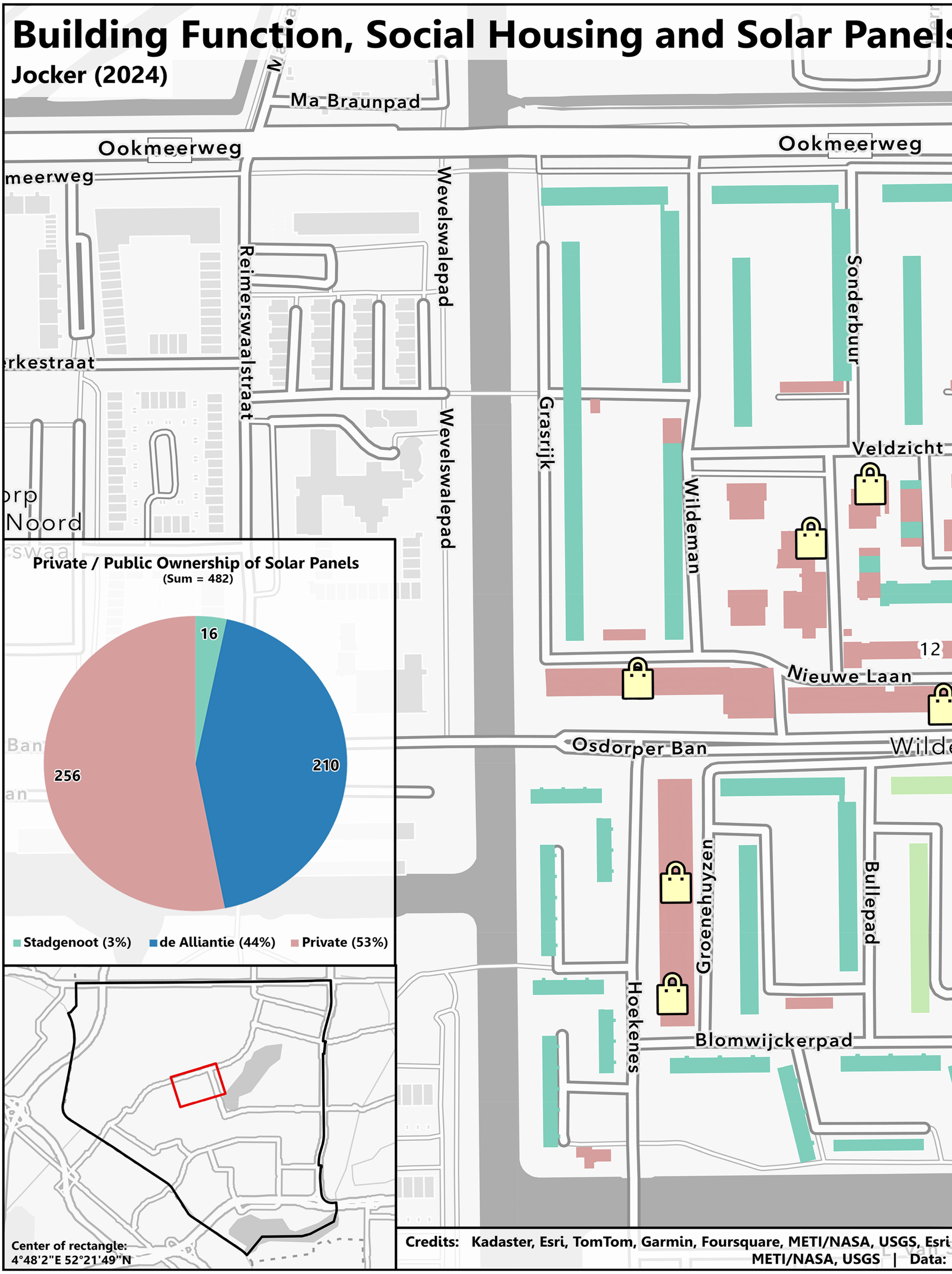
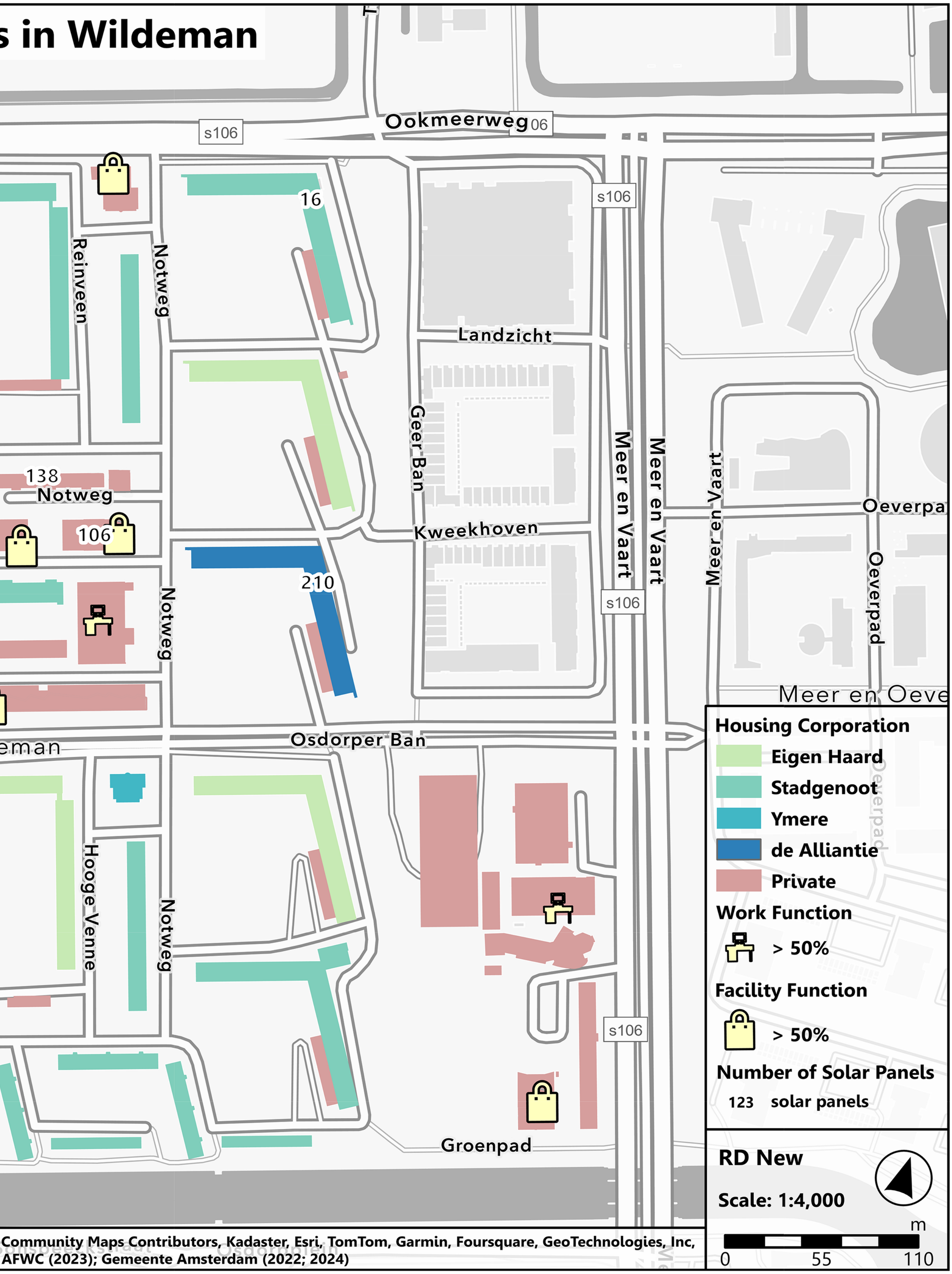


Figure 6.9: Building Function, Social Housing



and Solar Panels in Wildeman

6.2. Two Future Scenarios

The following two scenarios were developed using the GIS Analysis (Section 6.1), Literature Review (Chapter 3), and Theoretical Framework (Chapter 4) guiding this study. Designed to illustrate potential configurations for EVCI, these scenarios explore the role of ADM in supporting equitable energy distribution across diverse socio-economic settings. Scenario Planning was employed as a methodology to develop plausible futures that serve as explorations of ADM's impact, rather than as predictive models. Technically, the scenarios focus on the application of V2G and SC technologies to address urban energy challenges, responding specifically to Sub-questions 2 and 3. The GIS analysis captures variations in neighbourhood characteristics—such as income, housing type, and access to renewable resources—which inform each scenario's unique configuration of ADM applications.

The distinct differences between the neighbourhoods De Aker Oost and Wildeman, summarised in Section 6.1.8, are central to the scenario development. This analysis highlights contrasts in housing types, income levels, and solar panel availability between these areas, emphasising socio-economic diversity and resource disparities that ADM must address to promote equitable outcomes. For example, lower income and limited solar infrastructure in Wildeman underscore the need for ADM in public charging configurations to consider socio-economic sensitivity, drawing on principles of *Distributive Justice* as discussed in the Literature Review [35], [36]. Each scenario incorporates these GIS findings, enabling participants to explore how ADM's role in EVCI might vary across socio-economic and infrastructural contexts, thereby addressing Sub-question 2. Through this approach, the scenarios serve as a bridge between theoretical exploration and participant engagement, directly contributing to an analysis of ADM's impact on energy justice perceptions across diverse groups.

6.2.1. Scenario One: Integration of V2G Technology for Private EV Chargers

In this scenario, private EV chargers are equipped with V2G technology, enabling EVs to act as both energy consumers and energy providers. V2G allows EVs to return electricity stored in their batteries back to the grid when needed, especially during peak demand periods. This bidirectional energy flow helps stabilise the grid by ensuring there's enough power available during high-demand periods. The ADM system is responsible for determining the best times for charging and discharging, based on real-time grid demand, electricity prices, and the user's preferences. V2G technology transforms electric vehicles into mobile energy storage units, charging EVs when grid demand is low and sending stored energy back to the grid during peak demand to reduce grid stress and facilitate renewable energy integration. This process can financially benefit EV owners, who are compensated for supplying energy. ADM systems manage the timing of charging and discharging by analysing factors like grid congestion, electricity pricing, and battery status. ADM uses real-time data and algorithms to balance consumer preferences—such as keeping a minimum charge for emergencies—with the grid's energy needs, ensuring efficient energy distribution while reducing the possibility of human error.

The scenario is based on the notion of energy as a human right, with ADM systems designed to ensure that all users, particularly those relying on their EVs for essential services, have adequate energy access [49]. To reflect *Recognition Justice*, ADM in this scenario is configured to consider the unique needs of community members, especially those with medical or critical energy needs [38] . Additionally, the design allows users to opt out of discharging energy based on their personal needs, which incorporates *Procedural Justice* principles by prioritising individual control and transparency in energy allocation [40]. While this system offers benefits like enhanced grid stability and financial incentives for EV owners, it also considers the literature-based concern of battery degradation, as frequent charging and discharging cycles can reduce battery lifespan and lead to increased replacement costs. Additionally, there are ongoing challenges to ensuring fair participation and compensation in ADM-driven energy management systems [33].

To facilitate participants' understanding and engagement, the technical aspects of V2G and ADM outlined above have been translated into a narrative scenario and visual representation. This narrative integrates the technical functions of V2G into a real-world context, highlighting how ADM might address issues like fair access and grid stability in a private charging environment. The narrative scenario and corresponding visualisation can be found in Figure 6.10 on page 66, providing participants with a concrete and comprehensible way to understand and aid in evaluating ADM's role in energy justice within the context of private EV charging.

6.2.2. Scenario Two: Integration of Smart Charging for Public EV Chargers

In this scenario, smart charging is implemented at public EV charging stations. Smart charging allows the charging process to be dynamically controlled based on several factors, including grid demand, energy pricing, and renewable energy availability. ADM monitors and adjusts charging speeds and times for each vehicle connected to public chargers, helping reduce grid congestion during peak demand times and encouraging users to charge their vehicles during off-peak hours when renewable energy is more available. SC is a system that controls the timing and speed of EV charging based on the grid's needs, allowing charging stations to adjust rates accordingly. For instance, charging can be accelerated when there is an abundance of solar or wind power, or slowed down if the grid is overloaded, shifting charging to times of lower demand. In this setup, ADM uses real-time data from the grid, energy providers, and charging stations to determine the optimal charging time and speed for each EV. ADM's algorithms balance individual user needs—such as having a fully charged car when needed—with the grid's requirements, while also considering electricity prices, enabling users to benefit from off-peak rates. ADM optimises energy distribution by managing charging automatically, reducing the need for consumers to provide human input.

This scenario incorporates *Recognition Justice* principles, ensuring that ADM accounts for the unique needs of vulnerable groups, such as lower-income users in public charging areas, who may be more reliant on public infrastructure [33], [46]. By offering prioritised access to those with critical needs, such as caregiving, the ADM system here also reflects the literature on *Distributive Justice*, highlighting the need to ensure equitable access to resources across different socio-economic backgrounds [35]. While smart charging provides cost savings by encouraging off-peak charging, it also addresses the literature-based concern that dynamic pricing models might negatively impact lower-income users who cannot adjust charging times due to schedule constraints [48]. To provide participants with a tangible reference for assessing ADM's role in public EV charging, the technical details of SC and ADM have been converted into a narrative scenario and visual representation. This narrative contextualises the functions of SC in a public charging environment, emphasising ADM's potential for equitable access and efficiency in a shared infrastructure setting. The narrative and visualisation can be found in Figure 6.11 on page 68, allowing participants to visualise and better understand ADM's impact on public EV charging from an energy justice perspective.

6.2.3. Scenario Development Summary and Findings

The two scenarios provide practical insights into how ADM can be utilised to promote energy justice in EVCI. Each scenario answers specific aspects of the research sub-questions by examining ADM's role in addressing equity, transparency, and accessibility. In *Scenario One*, where V2G technology is applied in private charging contexts within the higher-income neighbourhood of De Aker Oost, ADM is configured to balance individual preferences with broader grid needs. This setup enables users to contribute stored energy during peak demand, thus enhancing grid stability. This approach is based directly on literature findings regarding equity issues in EVCI, specifically how they may emerge and be addressed by incentivising EV owners to support the grid, while ensuring accessibility for users relying on EVs for essential services [35]. Additionally, this scenario incorporates concepts of *Recognition Justice* and *Procedural Justice*, as ADM systems are designed to consider socio-economic barriers in energy distribution and prioritise access for essential uses [38], [40]. By allowing residents with private energy assets to participate meaningfully in the energy system, ADM in this context provides transparency and an inclusive approach, reflecting stakeholder expectations for fairness.

In *Scenario Two*, which focuses on SC within public EV charging infrastructure in Wildeman, a lower-income neighbourhood, ADM is configured to dynamically optimise energy distribution while prioritising equitable access. This scenario emphasises public infrastructure needs, with ADM managing dynamic pricing and access according to user circumstances, such as caregiving responsibilities, aligning with stakeholder expectations of fairness [33], [45]. ADM here also addresses the financial impact of dynamic pricing on lower-income users, answering *Sub-question 2* by illustrating how ADM could mitigate pricing inequities in public EV infrastructure [48]. By adapting SC to the socio-economic context of Wildeman, ADM reflects both *Recognition Justice* and *Distributive Justice* principles, prioritising users who depend on public charging. Together, these scenarios provide an understanding of ADM's potential to manage energy resources equitably across diverse socio-economic contexts. By situating the technical capabilities of ADM within real-world applications, grounded in the literature, the scenarios support a practical framework for examining ADM's role in energy justice. This sets the stage for further analysis in the Q-methodology, which will provide insights into stakeholder perspectives and address *Sub-question 3*.

Scenario One

Solar-Rich and Grid-Strained: Navigating Energy Choices in a Wealthy Suburb

Amelia lives in a wealthy suburban neighbourhood where many residents have installed solar panels on their roofs and their own electric vehicles. These homes are now equipped with *Vehicle-to-Grid (V2G)* technology, which allows EVs not only to charge from the grid but also to send electricity back into it when needed.

One evening, Amelia plugs her EV into the charger in her driveway. Her charger is set to work with an *Automated Decision-Making (ADM)* system, which manages when her car charges or discharges energy based on how much electricity the grid needs and the battery's status. The system calculates the best time for her car to charge, and a message pops up: "Charging will start at 23:00 at night. when electricity is cheaper. Your car will be fully charged by 07:00 in the morning".

Later that night, at 20:00, Amelia receives a notification on her phone: "Due to high electricity demand in your neighbourhood, your car could help support the grid by discharging some power. You'll receive a €5,- credit. Your energy could help maintain electricity for a nearby family with a newborn who needs constant heating due to a medical condition. Would you like to proceed?"

Amelia, knowing that she does not need her car fully charged in the morning, agrees to discharge some energy. She feels good about helping her neighbours and receiving a small reward while still ensuring her car will be ready by the next day.

At the same time, her neighbour Liam receives the same message. However, Liam has a long trip planned for early next morning and worries that discharging too much energy will leave him with insufficient charge. He decides to decline the offer and opts to keep his battery full, knowing that the Automated Decision-Making system allows him to prioritise his own needs.

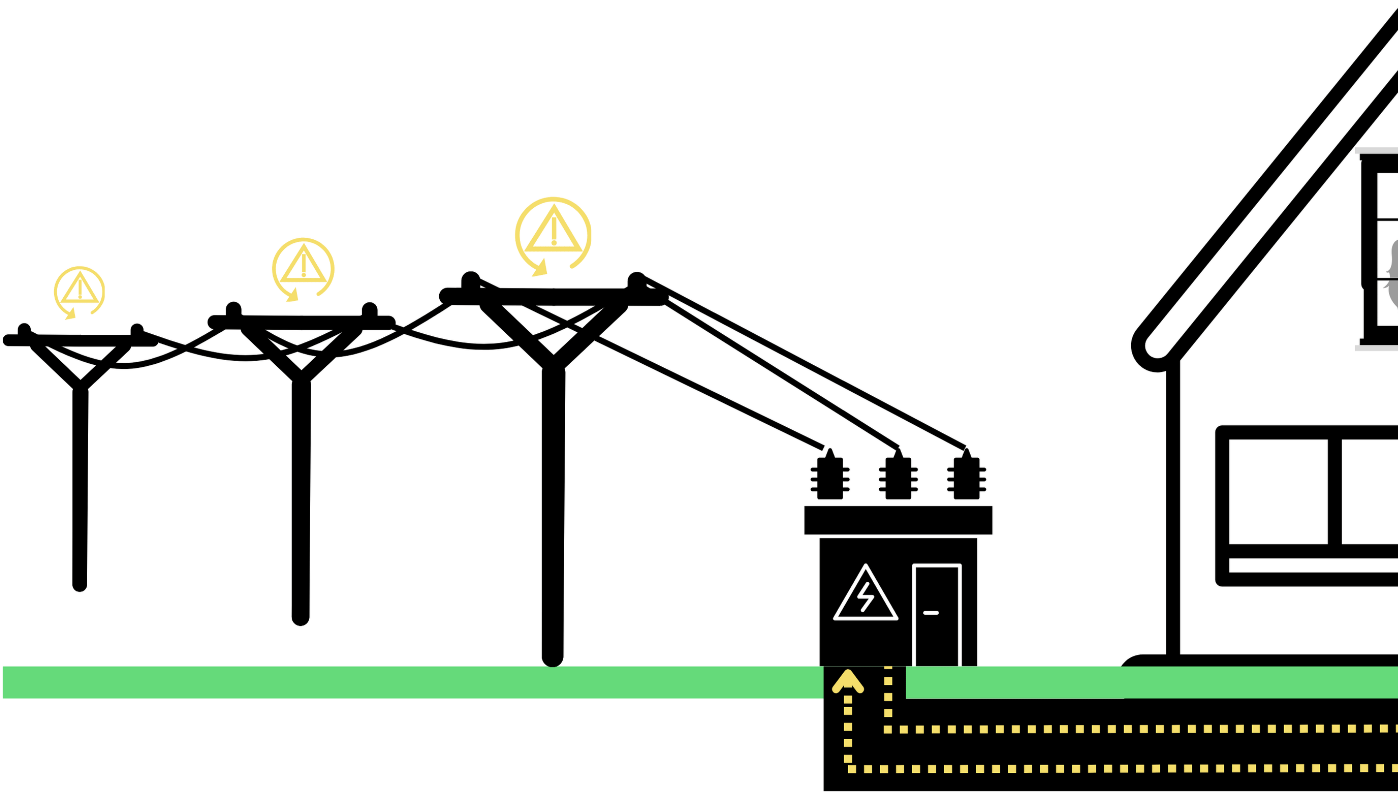
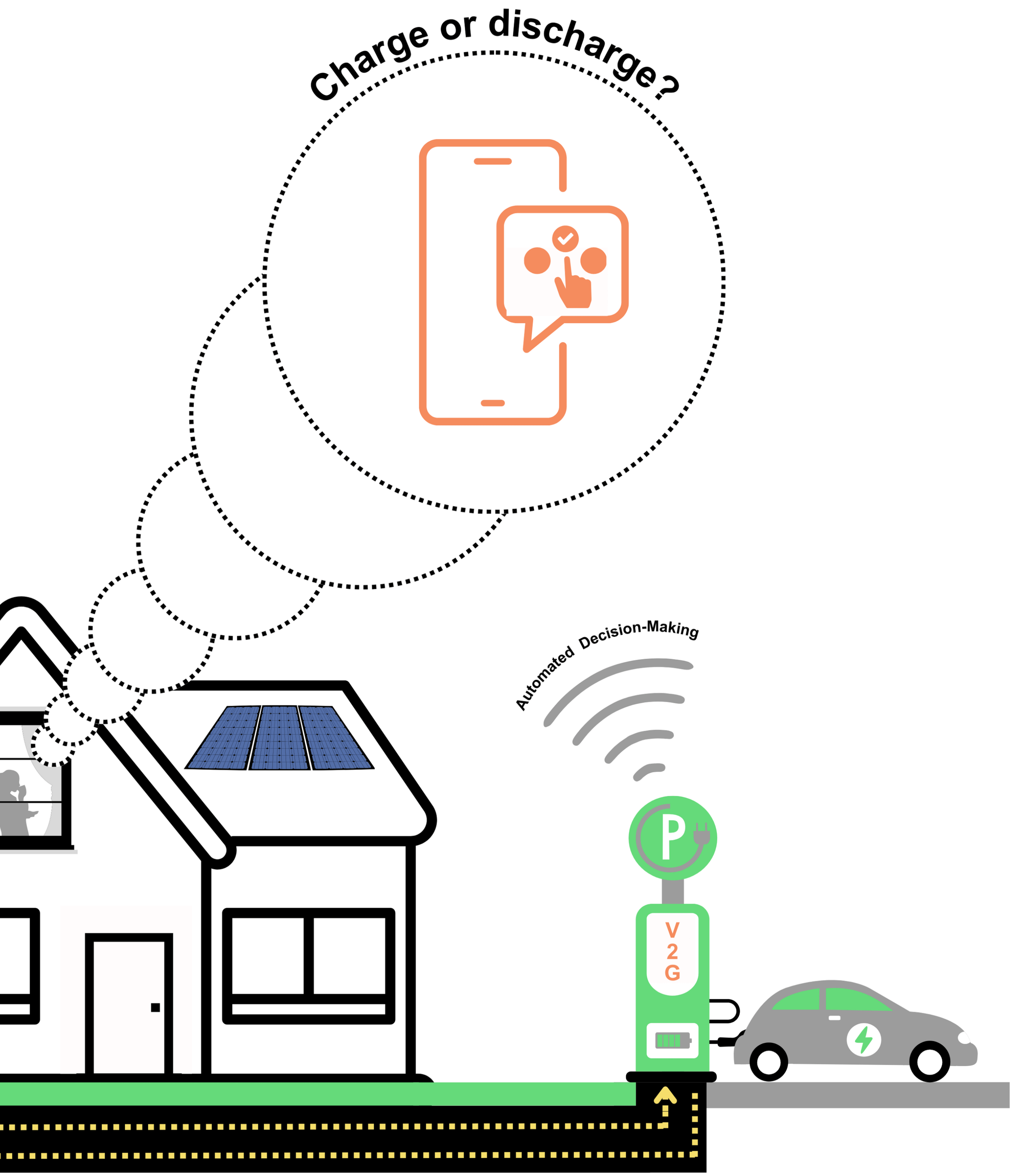


Figure 6.10: Scenario One - Solar-Rich and



Grid-Strained Navigating Energy Choices in a Wealthy Suburb

Scenario Two

Charging Dilemmas: Fairness and Frugality in a Social Housing Community

Rosa lives in a neighbourhood with mostly social housing, where many residents have switched to using electric vehicles to reduce fuel costs. Public charging stations in the area have recently been upgraded with *Smart Charging (SC)* technology, which is managed by an *Automated Decision-Making (ADM)* system. This system controls the speed and timing of each car's charging based on how much electricity the grid can handle and how urgently each car needs to be charged.

After her shift as a nurse, Rosa plugs in her Electric Vehicle at one of the public charging stations. The charging station displays a message: "Due to high demand, charging will be slower. Estimated time to full charge: 3 hours. You can choose priority charging for an additional €2,- fee." As Rosa considers paying the extra fee, another notification appears: "If you choose slower charging, the saved energy could help a nearby resident who relies on medical equipment. Would you like to proceed with slower charging?"

Rosa feels conflicted. She needs her car to be ready for work the next morning but also knows that by choosing the slower option, she could help someone with urgent medical needs. She decides to go for the slower charge, hoping her choice will support her neighbour while still allowing her car to be fully charged by morning.

Meanwhile, Marcus, another resident, also plugs in his Electric Vehicle but opts for the priority charging option. He has an important meeting early in the morning and needs his car fully charged as soon as possible. While Marcus understands the potential community benefit of slower charging, he feels it is unfair to ask people with tight schedules to sacrifice their own needs.

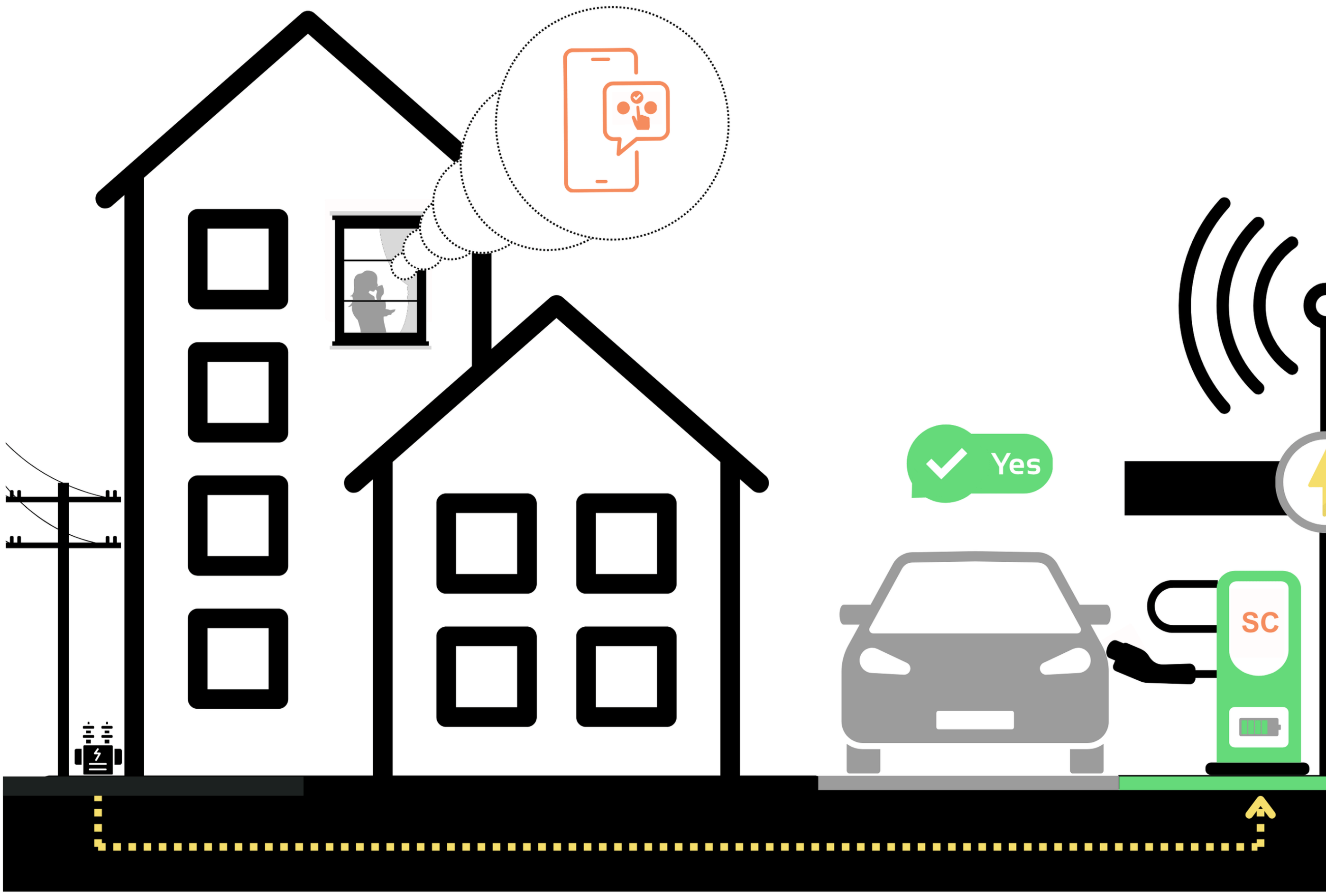
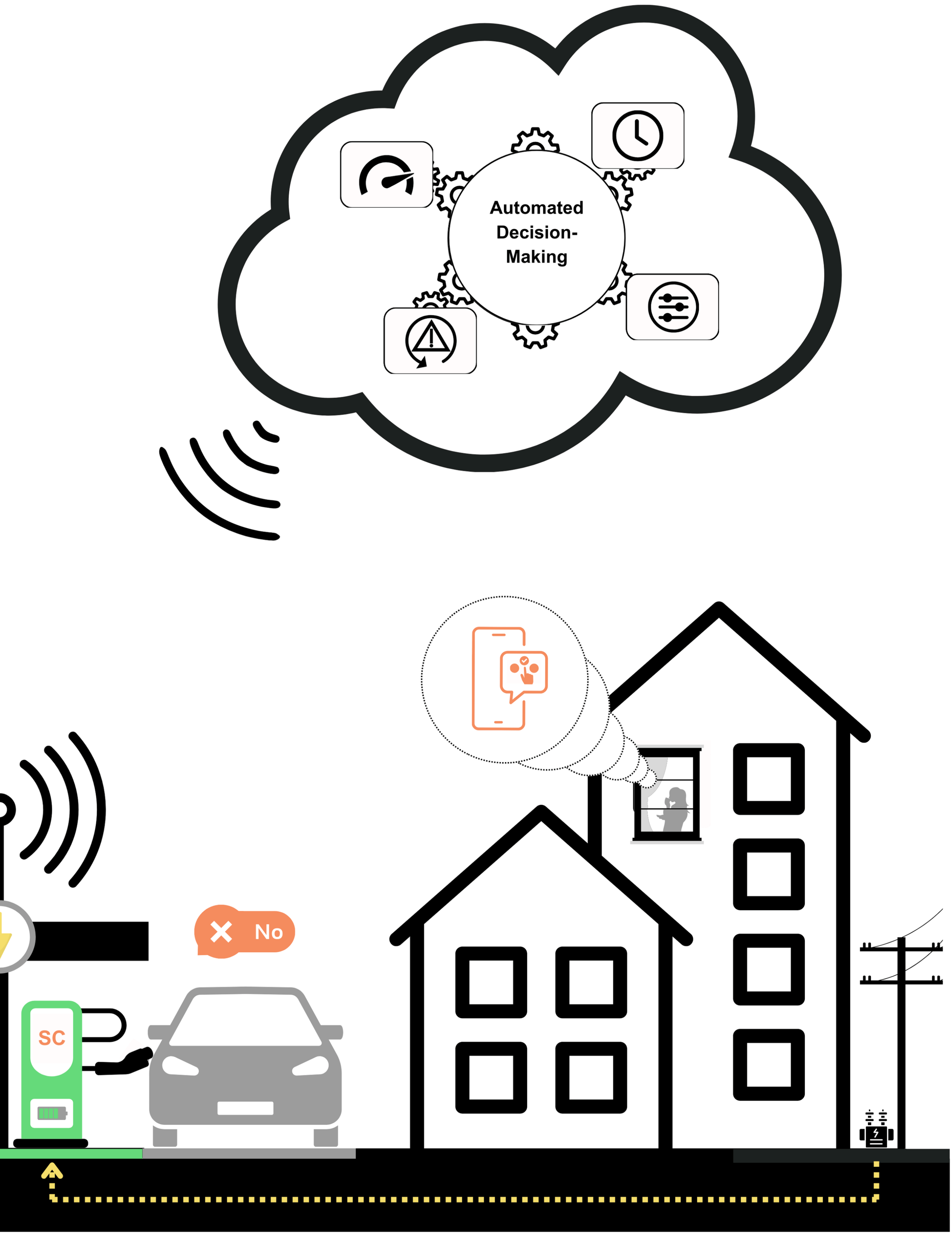


Figure 6.11: Scenario Two - Charging Dilemmas:



Fairness and Frugality in a Social Housing Community

6.3. Q-methodology

The Q-methodology results aim to answer sub-question *SRQ3* by exploring stakeholder perspectives on ADM in EVCI through statements derived from the scenario results. These statements were formulated based on insights from the two scenarios, capturing diverse viewpoints on ADM's role in promoting equitable energy distribution, procedural transparency, and stakeholder inclusivity. To analyse these perspectives, both Centroid Factor Analysis (CFA) and Principal Component Analysis (PCA) were employed. CFA provides interpretative insights, aligning with Q-methodology's emphasis on exploring subjective viewpoints, thereby enabling an understanding of energy management and ADM systems. In contrast, PCA maximises explained variance, facilitating a statistical comparison across participant perspectives. Together, CFA and PCA provide a complementary approach, offering both interpretative depth and statistical differentiation to analyse participant viewpoints. Additionally, the analysis identifies consensus statements—marked in grey—that represent widely shared views across all participant groups. These consensus statements reflect foundational beliefs, providing essential context without distinguishing specific factors. Both distinct factors and consensus statements are based on the same set of Q-sorts from 10 participants, as presented in Appendix C, Table C.1 on page 117.

6.3.1. Centroid Factor Analysis

The CFA identified three primary factors among participants' viewpoints, capturing themes related to equitable energy access, enthusiasm for V2G technology, and trust in ADM systems. Each factor represents a distinct perspective, underscoring the varied priorities participants have regarding ADM and its role in the energy sector. Each factor is described individually below, accompanied by participant quotes to illustrate the core themes within each group. All CFA output tables can be found in C.

Factor 1: Equity in Energy Distribution

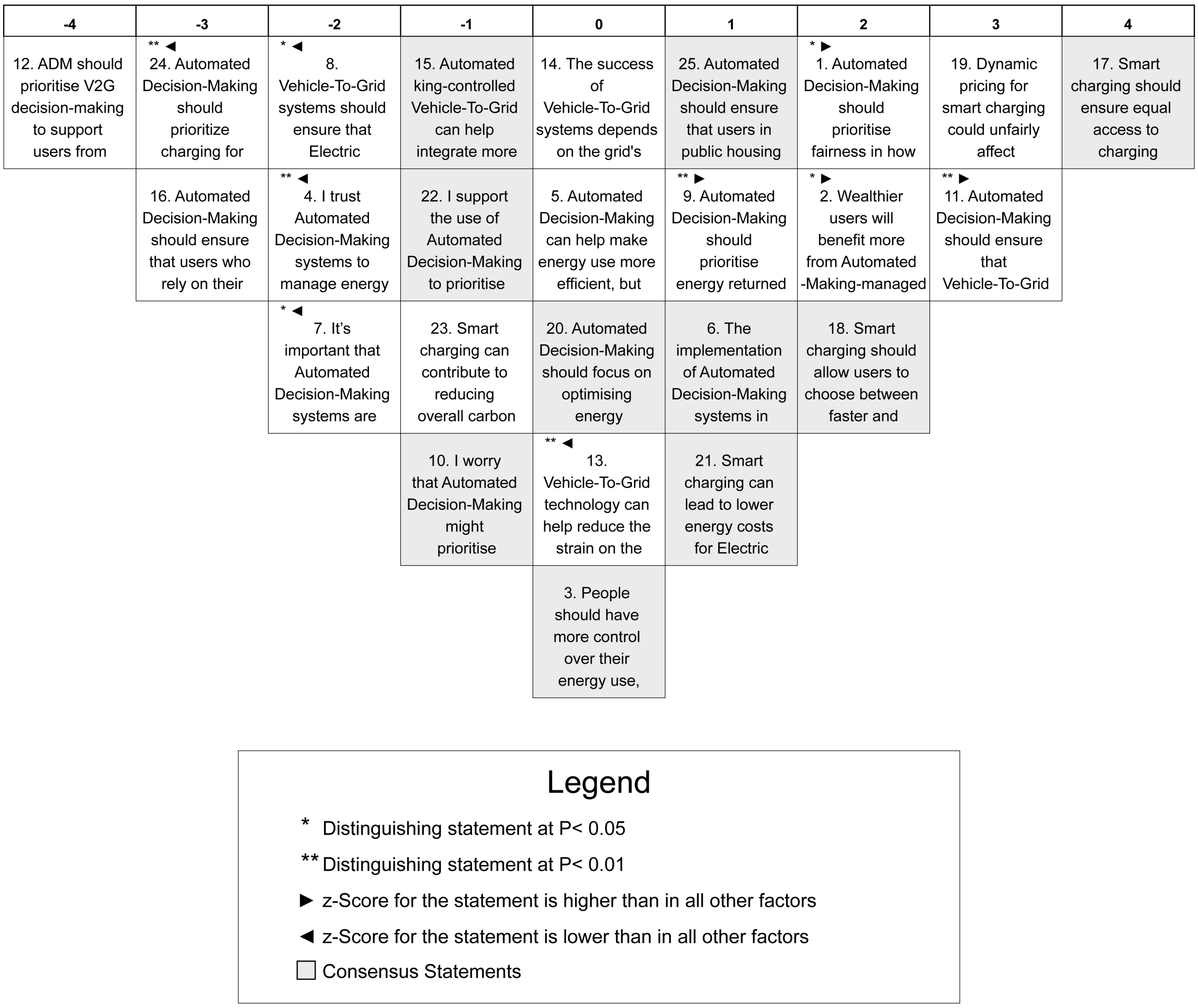


Figure 6.12: CFA - Factor 1: Equity in Energy Distribution

Factor 1 reflects participants' emphasis on equitable energy distribution, particularly through Automated Decision-Making (ADM) systems that address socio-economic disparities and provide fair access to energy resources. Observations from the Composite Factor Visualisation for Factor 1 (Figure 6.12) reveal a strong focus on ensuring that ADM systems contribute to fairness, especially for marginalised communities. In this visualisation, participants' responses are organised on a Q-sort grid ranging from -4 (most disagreement) to +4 (most agreement), illustrating the prioritisation of statements around equity and fairness. For example, Statement 11 (*Automated Decision-Making should ensure that Vehicle-To-Grid benefits are distributed equally across different socioeconomic groups*) was ranked at +4, showing a strong consensus around the importance of ensuring equitable access to V2G technology. Similarly, Statement 1 (*Automated Decision-Making should prioritise fairness in how resources like energy are distributed*) ranked at +3, reinforcing participants' commitment to fairness in resource allocation.

In contrast, statements focused on more specific or narrowly defined benefits received lower rankings. Statement 7 (*It's important that Automated Decision-Making systems are designed to reduce costs for lower-income households*) was placed at -4, indicating that participants placed less importance on cost reduction compared to broader fairness goals. Likewise, Statement 24 (*Automated Decision-Making should prioritise charging for those who rely on their Electric Vehicle for essential travel, such as commuting or caregiving*) was positioned at -3, suggesting reservations about prioritising specific user groups over a more comprehensive approach to fairness. These ranked statements, alongside participant quotes, are summarised in Table 6.2, offering further insight into the reasoning behind their perspectives on energy equity and ADM systems.

Table 6.2: CFA - Factor 1: Equity in Energy Distribution

#	Statement	Q-sort	z-Score	Supporting Quote (Participant)
		Agreement		
11	ADM should ensure that Vehicle-To-Grid benefits are distributed equally across different socioeconomic groups.	3	*1.34*	*"The distribution currently favours wealthier residents. The government must ensure that socially weaker neighbourhoods also benefit from innovation." (P10)*
1	Automated Decision-Making should prioritise fairness in how resources like energy are distributed.	3	*1.05*	*"Prioritise the fair distribution of energy to users." (P5)*
2	Wealthier users will benefit more from ADM-managed systems, which could deepen existing inequalities.	2	0.88	*"In this way, we can help people with a socio-economic disadvantage and prevent the energy transition from affecting them more than others." (P8)*
		Disagreement		
24	ADM should prioritise charging for those who rely on their EV for essential travel, such as commuting or caregiving.	-3	*-1.44*	*"Someone with fixed hours and a lower income is disadvantaged if prices are higher at the moment they need it." (P6)*
7	It's important that ADM systems are designed to reduce costs for lower-income households.	-2	*-1.41*	*"By focusing the system on money, I'm afraid that the system's outcomes for the environment and social aspects will become secondary. " (P9)*

Factor 2: Environmental Responsibility and Grid Reliability

Factor 2 highlights participants' strong support for advancing V2G technology to enhance grid stability. The Composite Factor Visualisation for Factor 2 (Figure 6.13) shows participants emphasising V2G's potential to manage energy flow efficiently, especially during peak demand. They view integrating EVs into the grid as essential for future energy management, with smart systems dynamically meeting demand to support stability and sustainability.

In the visualisation, Statement 14 (*"The success of Vehicle-To-Grid systems depends on the grid's ability to handle large amounts of bidirectional energy flow."*) scored +4, signalling high agreement on V2G's technical importance. Statement 23 (*"Smart charging can contribute to reducing overall carbon emissions from the energy grid"*) scored +3, underlining the perceived environmental benefits. Conversely, Statement 19 (*"Dynamic pricing for smart charging could unfairly affect lower-income users who may need to charge during peak hours"*) scored -4, showing disagreement with concerns about socio-economic impact. Participant quotes illustrating these views are provided in Table 6.3 below.

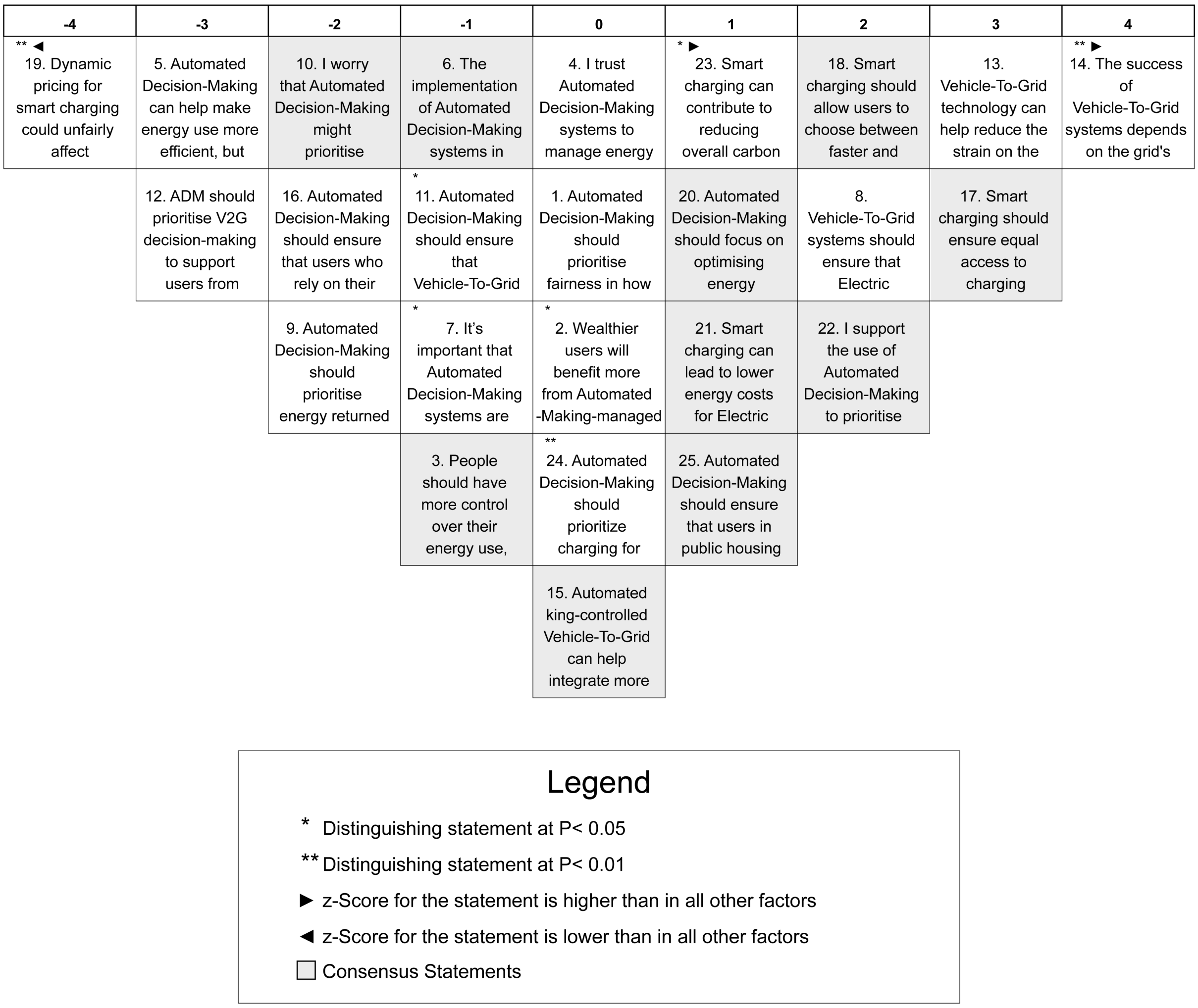


Figure 6.13: CFA - Factor 2: Environmental Responsibility and Grid Reliability

Table 6.3: CFA - Factor 2: Environmental Responsibility and Grid Reliability

#	Statement	Q-sort	z-Score	Supporting Quote (Participant)
		Agreement		
14	The success of V2G systems depends on the grid's ability to handle large amounts of bidirectional energy flow.	4	*1.85*	*"Managing energy quantities is successful if it can be directed back and forth (bi-directional)." (P5)*
23	Smart charging can contribute to reducing overall carbon emissions from the energy grid.	1	0.67	*"Through dynamic charging and discharging, peak hours will blur." (P2)*
		Disagreement		
19	Dynamic pricing for SC could unfairly affect lower-income users who may need to charge during peak hours.	-4	*-1.95*	*"There is a form of scarcity, and money should not play too big a role. Otherwise, inequalities could grow even larger." (P9)*
7	It's important that ADM systems are designed to reduce costs for lower-income households.	-1	-0.44	*"I had the idea that the primary objective of an ADM system ... is to alleviate network strains during peak hours; ... designing the systems around cost reductions for lower-income households specifically could lead to a poor function of the grid." (P7)*

Factor 3: Advocacy for Socioeconomic Sensitivity in ADM

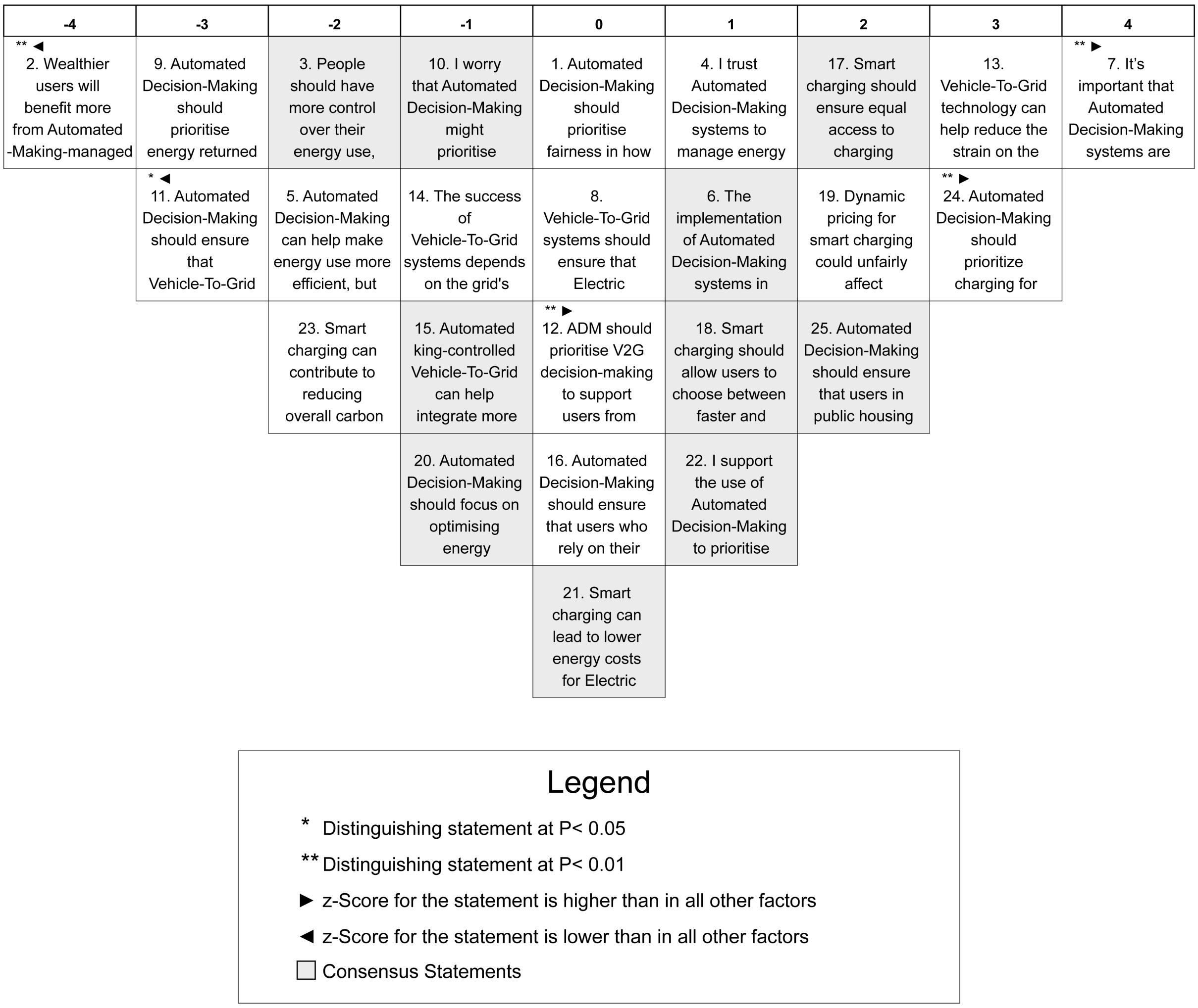


Figure 6.14: CFA - Factor 3: Advocacy for Socioeconomic Sensitivity in ADM

Factor 3 captures the perspectives of participants who place a strong emphasis on trust in ADM systems for equitable and efficient energy management. Observations from the Composite Factor Visualisation for Factor 3 (Figure 6.14) show that participants in this factor value the potential of ADM systems to provide fair access to energy resources by reducing human biases and operational inefficiencies. This group appears to hold confidence in ADM's capacity to make data-driven decisions that support grid reliability while addressing fairness in energy distribution.

In the visualisation, Statement 4 (*I trust Automated Decision-Making systems to manage energy distribution better than humans could*) is positioned at +4, indicating strong agreement on the reliability of ADM systems for energy management. Statement 17 (*Automated Decision-Making should ensure equal access to charging opportunities for all, regardless of socioeconomic status*) was also placed at +3, highlighting participants' views on ADM's role in promoting equal energy access. On the other hand, Statement 9 (*Public and private strains on the energy grid should be managed separately by ADM*) was placed at -4, reflecting disagreement with the idea of prioritising certain user groups over others based on charging infrastructure type. Similarly, Statement 24 (*ADM should prioritise charging for those who rely on their Electric Vehicle for essential travel*) was ranked at -3, suggesting that participants prefer ADM systems focused on broader, unbiased allocation principles rather than specific prioritisation scenarios. Table 6.4 summarises the key statements for Factor 3 and includes supporting participant quotes to provide context to their views on ADM's role in fair and efficient energy management.

Table 6.4: CFA - Factor 3: Advocacy for Socioeconomic Sensitivity in ADM

#	Statement	Q-sort	z-Score	Supporting Quote (Participant)
		Agreement		
7	It's important that ADM systems are designed to reduce costs for lower-income households.	4	*1.96*	*"In this way, we can help people with a socio-economic disadvantage and prevent the energy transition from affecting them more than others." (P8)*
24	ADM should prioritise charging for those who rely on their EV for essential travel, such as commuting or caregiving.	3	*1.47*	*"We must ensure that people in 'essential' professions or with a lower socio-economic status can still get to work. They are especially vulnerable because their work cannot be done remotely. That's why it should be given priority." (P8)*
		Disagreement		
2	Wealthier users will benefit more from ADM-managed systems, which could deepen existing inequalities.	-4	*-1.96*	*"The system (should) ensure(s) the opposite by people helping each other instead of just the wealthier users " (P1)*
11	ADM should ensure that V2G benefits are distributed equally across different socioeconomic groups.	-3	*-1.47*	*"I believe you can use the technology to give people with a socio-economic disadvantage a boost. This doesn't mean equal distribution but rather helping disadvantaged people extra when possible." (P8)*

6.3.2. Principal Component Analysis

The PCA identified four primary factors that reveal varied perspectives on ADM systems, focusing on themes such as technological optimism, environmental benefits, sensitivity to socio-economic issues, and infrastructure resilience. Each factor represents a distinct viewpoint on how ADM should be integrated into energy management, with particular attention to the trade-offs between efficiency, equity, and sustainability. Below, each factor is discussed with supporting participant quotes that illustrate the core themes within each group. All PCA output tables can be found in C.

Factor 1: Trust in ADM for Efficient Energy Management

Factor 1 captures participants' emphasis on trusting ADM to optimise energy distribution effectively. Observations from the Composite Factor Visualisation for Factor 1 (Figure 6.15) show that participants prioritise the role of ADM systems in achieving grid efficiency and reliability. For instance, Statement 14 (*"The success of Vehicle-To-Grid systems depends on the grid's ability to handle large amounts of bidirectional energy flow"*) received a high agreement ranking of +3, indicating that participants view ADM as essential for managing complex energy flows. However, there is notable disagreement on socio-economic issues related to ADM's functionality. Statement 19 (*"Dynamic pricing for smart charging could unfairly affect lower-income users who may need to charge during peak hours"*) was rated -4, suggesting less concern for affordability as compared to efficiency. Table 6.5 presents these ranked statements and includes participant quotes.

Table 6.5: PCA - Factor 1: Trust in ADM for Efficient Energy Management

#	Statement	Q-sort	z-Score	Supporting Quote (Participant)
		Agreement		
13	Vehicle-To-Grid technology can help reduce the strain on the grid during peak hours.	4	*1.88*	*"I see opportunities through the possibilities of returning energy. Peak energy usage (in the evening) is usually not the time when many people use their cars." (P8)*
14	The success of Vehicle-To-Grid systems depends on the grid's ability to handle large amounts of bidirectional energy flow.	3	*1.86*	*"Managing energy quantities is successful if it can be directed back and forth (bi-directional)." (P5)*
		Disagreement		
19	Dynamic pricing for smart charging could unfairly affect lower-income users who may need to charge during peak hours.	-4	*-2.04*	*"Through dynamic charging and discharging, peak hours will blur (solving this problem)" (P2)*
5	Automated Decision-Making can help make energy use more efficient, but I am concerned about its transparency.	-3	*-1.41*	*"Depending on who manages it the most, it should be independent. Then it can work." (P3)*

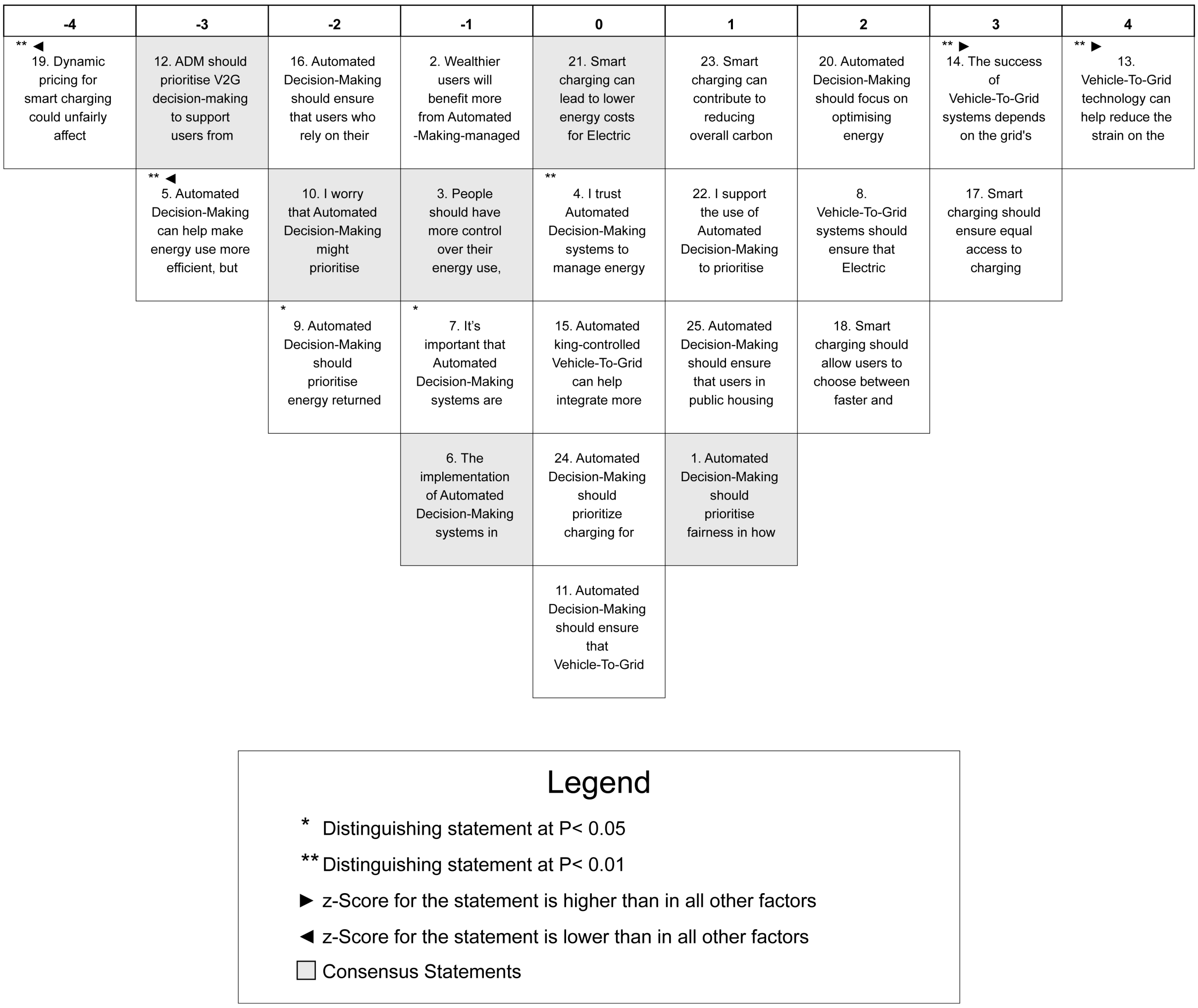


Figure 6.15: PCA - Factor 1: Trust in ADM for Efficient Energy Management

Factor 2: Fairness and Equity in Energy Access and ADM Impact

Factor 2 highlights participants' emphasis on fair energy distribution and ADM's potential to reduce socio-economic disparities. This perspective prioritises public benefits and equitable access over individual advantages, as shown in Figure 6.16. Participants expressed strong support for managing energy with a focus on broad public benefits, evident in the positive rating for Statement 9 (*"ADM should prioritise energy returned to the grid from public chargers, not just private chargers"*) at +2. Additionally, Statement 19 (*"Dynamic pricing for smart charging could unfairly affect lower-income users who may need to charge during peak hours"*) scored +4, indicating a strong concern about pricing policies that might disadvantage lower-income groups, further emphasising the factor's focus on equity and protection for vulnerable users.

In contrast, there was less support for specific user prioritisation. Statement 16 (*"ADM should ensure that users who rely on their Electric Vehicles for work and healthcare are prioritised in V2G decision-making"*) received a rating of -3, indicating a reluctance to single out particular user groups for priority access. This reflects a view that ADM should promote fairness broadly rather than focusing on the needs of select users. Additionally, there is some scepticism about ADM's capacity to replace human decision-making entirely. For instance, Statement 4 (*"I trust ADM systems to manage energy distribution better than humans could"*) scored -2, with participants voicing reservations about over-reliance on automated systems. Table 6.6 provides supporting quotes that further illustrate these perspectives on equitable ADM impact.

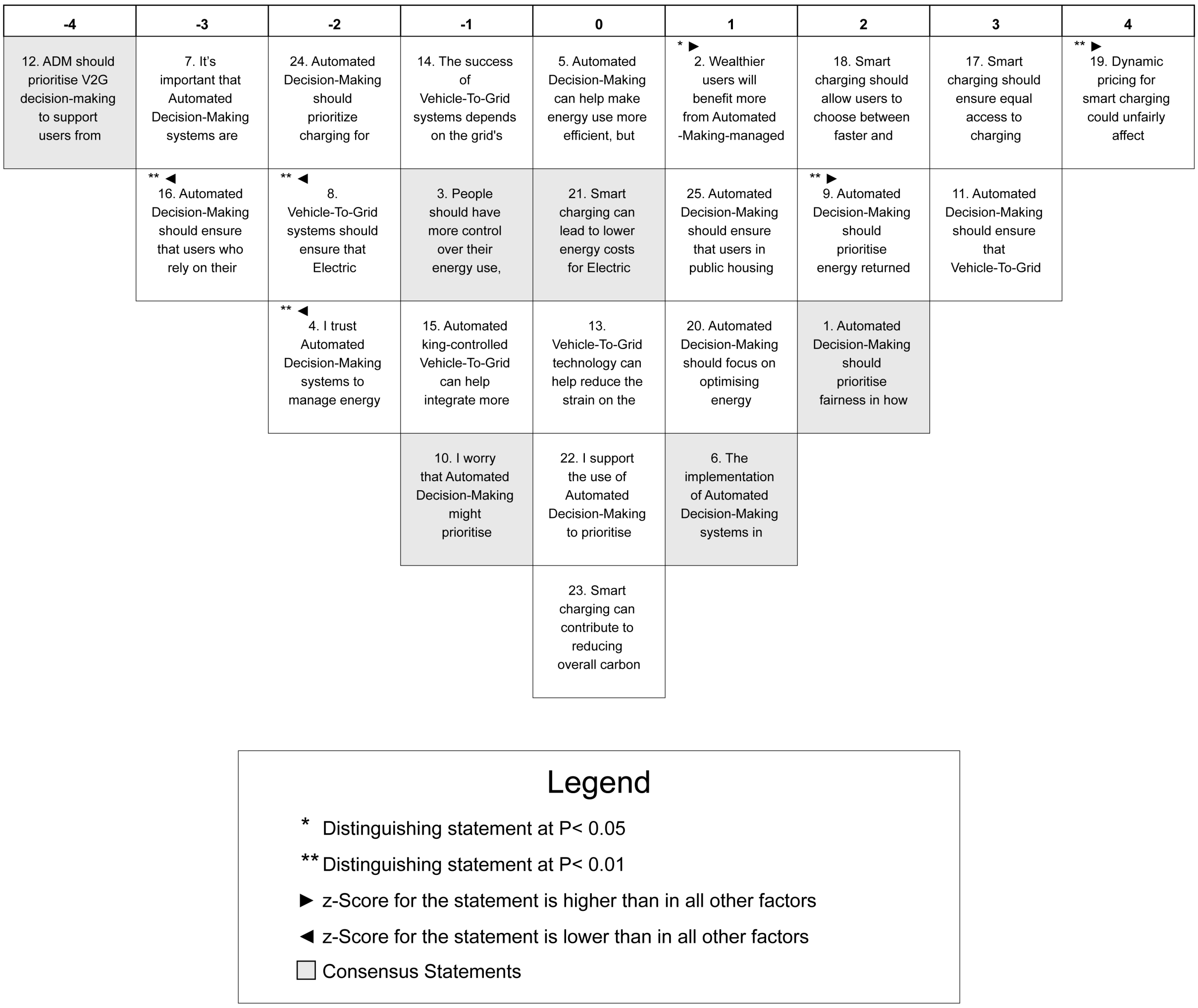


Figure 6.16: PCA - Factor 2: Fairness and Equity in Energy Access and ADM Impact

Table 6.6: PCA - Factor 2: Fairness and Equity in Energy Access and ADM Impact

#	Statement	Q-sort	z-Score	Supporting Quote (Participant)
			Agreement	
19	Dynamic pricing for SC could unfairly affect lower-income users who may need to charge during peak hours.	4	*1.69*	*"Someone with fixed hours and a lower income is disadvantaged if prices are higher at the moment they need it." (P6)*
9	ADM should prioritise energy returned to the grid from public chargers, not just private chargers.	2	*1.11*	*"Based on the two scenarios, it became clear to me that in the returning of energy, an extra choice with financial benefits is being given to private owners." (P9)*
			Disagreement	
16	ADM should ensure that users who rely on their EV for work and healthcare are prioritised in V2G decision-making.	-3	*-1.79*	*"By prioritising certain groups during decision-making, you create a system that can fundamentally be considered unjust. This could, however, be an outcome of discussions with 'all' stakeholders, to the extent that is possible." (P9)*
4	I trust ADM systems to manage energy distribution better than humans could.	-2	*-1.31*	*"I believe we should never be entirely dependent on 'systems'; you always need human aspects." (P6)*

Factor 3: Protection for Vulnerable Users in ADM Implementation

Factor 3 centres on protecting vulnerable users through ADM. The Composite Factor Visualisation for Factor 3 (Figure 6.17) highlights participants' emphasis on equitable resource access for low-income households. Statement 7 (*"It's important that Automated Decision-Making systems are designed to reduce costs for lower-income households"*) scored +4, showing a strong focus on affordability. In contrast, Statement 2 (*"Wealthier users will benefit more from Automated Decision-Making-managed systems, which could deepen existing inequalities"*) was rated -4, indicating opposition to any ADM bias favouring wealthier users. Table 6.7 provides supporting quotes.

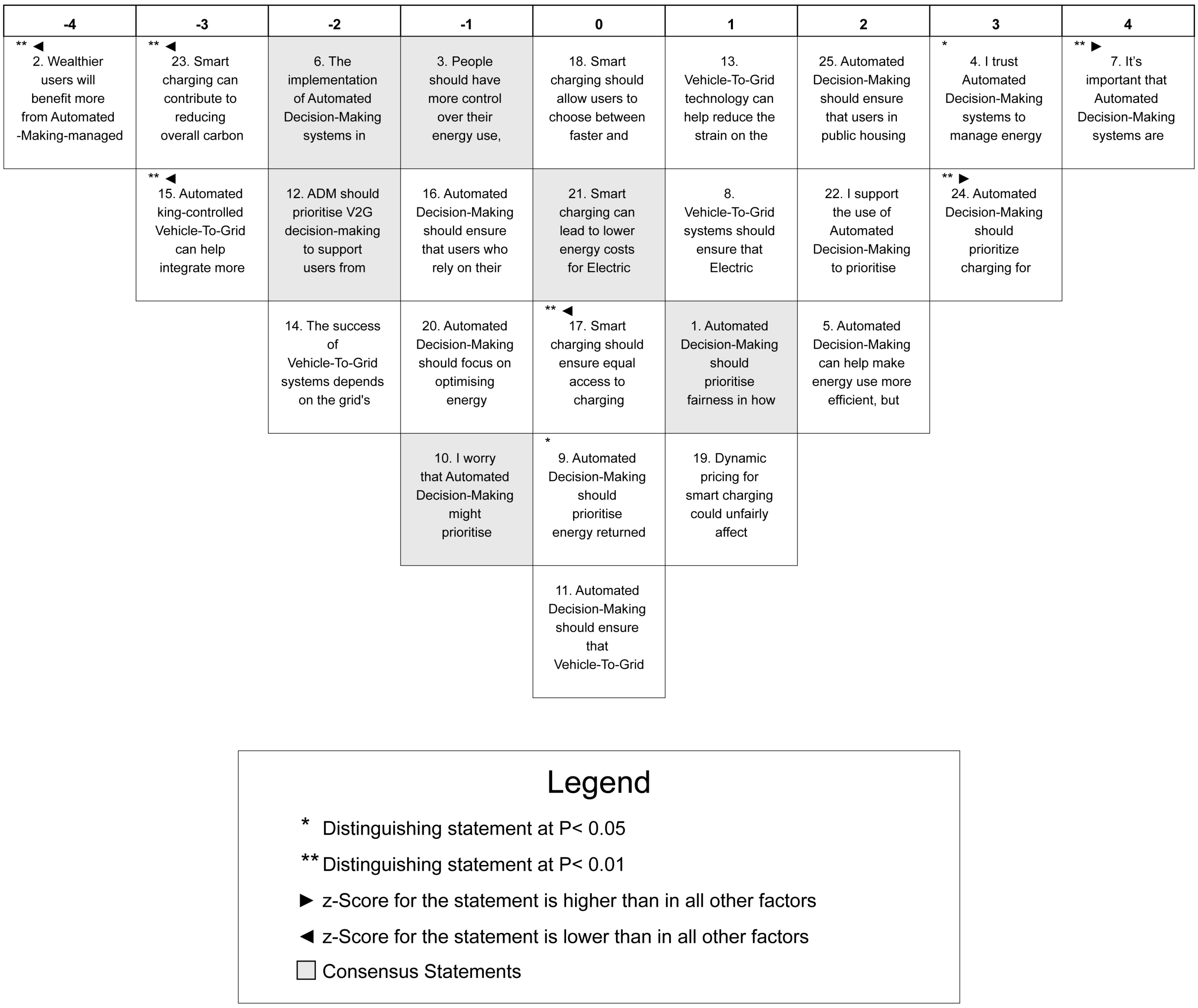


Figure 6.17: PCA - Factor 3: Protection for Vulnerable Users in ADM Implementation

Table 6.7: PCA - Factor 3: Protection for Vulnerable Users in ADM Implementation

#	Statement	Q-sort	z-Score	Supporting Quote (Participant)
		Agreement		
7	It's important that ADM systems are designed to reduce costs for lower-income households.	4	*2.26*	*"In this way, we can help people with a socio-economic disadvantage and prevent the energy transition from affecting them more than others." (P8)*
24	ADM should prioritise charging for those who rely on their EV for essential travel, such as commuting or caregiving.	3	*1.3*	*"We must ensure that people in 'essential' professions or with a lower socio-economic status can still get to work... That's why it should be given priority." (P8)*
		Disagreement		
2	Wealthier users will benefit more from ADM-managed systems, which could deepen existing inequalities.	-4	*-1.87*	*"The system (should) ensure(s) the opposite by people helping each other instead of just the wealthier users." (P1)*
15	ADM-controlled V2G can help integrate more renewable energy sources into the grid.	-3	*-1.75*	*"I do not expect hat soon, because new energy is often developed with commercial interests in mind." (P3)*

Factor 4: Confidence in ADM for Technical and Environmental Goals

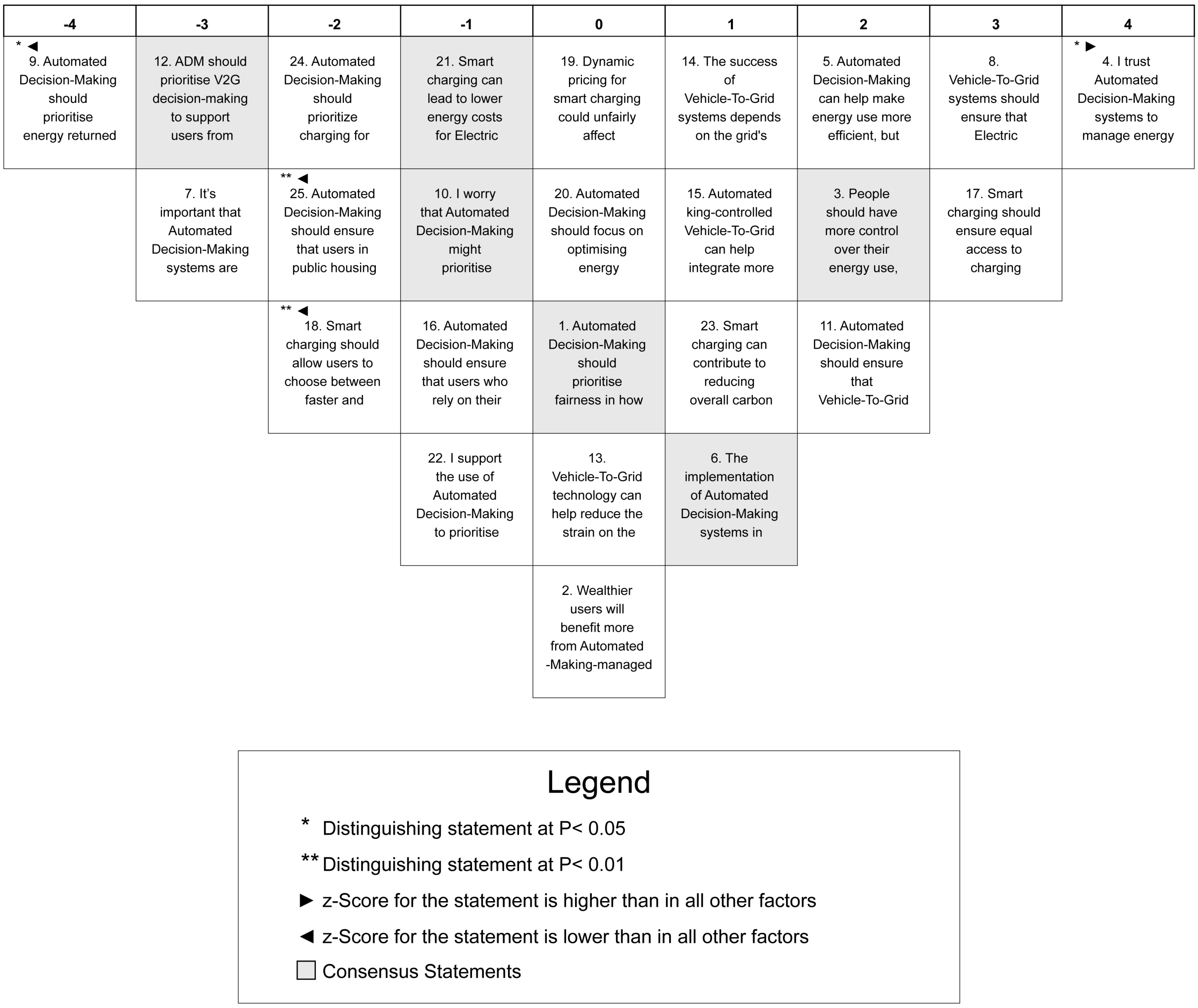


Figure 6.18: PCA - Factor 4: Confidence in ADM for Technical and Environmental Goals

Factor 4 reflects participants' trust in ADM systems for technical efficiency and environmental goals. (Figure 6.18 shows participants believe ADM enhances energy distribution and reduces human error. Statement 4 (*"I trust ADM systems to manage energy distribution better than humans could"*) ranked +4, indicating strong confidence in ADM. Conversely, Statement 9 (*"Automated Decision-Making should prioritise energy from public over private chargers"*) rated -4, suggesting a preference for uniform energy treatment. Table 6.8 includes quotes explaining views on ADM's roles.

Table 6.8: PCA - Factor 4: Confidence in ADM for Technical and Environmental Goals

#	Statement	Q-sort	z-Score	Supporting Quote (Participant)
				Agreement
4	I trust ADM systems to manage energy distribution better than humans could.	4	*2.53*	*"A good system will ensure justice and avoid human errors and flaws (in energy distribution)." (P4)*
				Disagreement
9	ADM should prioritise energy returned to the grid from public chargers, not just private chargers.	-4	*-2.0*	*"I am concerned that people who return charge will monopolise charging stations... This will cause even more charging stations to be needed in an already crowded city." (P8)*
18	SC should allow users to choose between faster and slower charging based on their needs.	-2	*-1.11*	*"The issue with getting to choose is that fast charging will likely come with additional cost structures ... more affordable to high incomes than low incomes, leading to access inequality." (P7)*

6.3.3. Comparative Analysis of CFA and PCA Results

Table 6.9 provides a comparative summary of statements and quotes across CFA and PCA factors, highlighting themes related to equity, environmental responsibility, and ADM efficiency. The agreement and disagreement headers reveal where factors align or diverge within each theme, presenting a nuanced view of ADM's potential impacts. While CFA prioritises socio-economic equity and fairness, PCA offers a broader statistical framework that emphasises systemic benefits, such as balancing efficiency, accessibility, and environmental responsibility. This dual perspective, enriched by participant quotes, illustrates the complementary nature of CFA's qualitative focus and PCA's quantitative scope, demonstrating ADM's capacity to simultaneously advance equity and efficiency in a socio-economically diverse energy system. Together, these analyses underscore ADM's potential to foster a balanced, fair, and ecologically responsible energy infrastructure. A detailed methodological comparison of CFA and PCA approaches, including factor selection, variance explained, and thematic interpretation, can be found in Table C.15 in Appendix C on page 127.

Equity and Fairness

Both CFA and PCA analyses highlight the theme of fair access to energy through ADM systems. CFA emphasises equitable energy distribution, focusing on supporting marginalised groups and ensuring fair access to resources. This is reflected in high factor loadings on statements such as, "ADM systems should support equitable energy access across different socio-economic groups." P3 emphasised the need for *"Prioritise the fair distribution of energy to users."* underscoring the commitment to distributive justice. In contrast, PCA places additional emphasis on safeguarding vulnerable users, particularly those at an economic disadvantage. For instance, P6 remarked on the importance of ensuring that *"Someone with fixed hours and a lower income is disadvantaged if prices are higher at the moment they need it."* suggesting that prioritising essential users could address socio-economic barriers. This illustrates PCA's statistical focus on protecting disadvantaged groups within ADM frameworks. Disagreement within this theme centres on whether prioritising essential workers or other groups could inadvertently reinforce inequalities. P9 pointed out that *"By prioritising certain groups during decision-making, you create a system that can fundamentally be considered unjust. This could, however, be an outcome of discussions with 'all' stakeholders, to the extent that is possible."* highlighting the complexity of balancing operational fairness with the divers needs of users.

Grid Efficiency and Stability

Both CFA and PCA analyses underscore the contribution of ADM to grid stability, with CFA focusing on technical aspects like bidirectional flow in V2G systems. Agreement here suggests that respondents view V2G's technical features as beneficial for grid functionality. For example, P5 expressed the sentiment that *"Managing energy quantities is succesful if directed back and forth (bi-directional)"* which aligns with CFA's technical perspective on grid optimisation. PCA, however, extends the theme by integrating broader environmental impacts, such as emissions reduction and socioeconomic considerations in sustainable energy practices. P4 commented, *"A good system will ensure justice and avoid human errors and flaws (in energy distribution)"* highlighting the broader goals of ADM systems that go beyond technical efficiency. Disagreement emerged concerning dynamic pricing, with P8 cautioning that *"I am concerned that people who return charge will monopolise charging stations from those who want to charge at that moment. This will cause even more charging stations to be needed in an already crowded city."* This disparity between CFA's technical focus and PCA's socio-economic concern points to a tension between efficiency objectives and social equity.

Socioeconomic and Vulnerable Groups

Both CFA and PCA analyses acknowledge ADM's role in serving socio-economically diverse users but with differing focal points. CFA factor loadings highlight ADM's capacity to alleviate costs for low-income households, with P7 expressing that *"In this way, we can help people who with a socioeconomic disadvantage and prevent the energy transition from affecting them more than others."* This reflects CFA's interpretation of ADM as a tool for reducing the financial burden on disadvantaged groups. PCA, meanwhile, agrees with the importance of protecting vulnerable users, especially those relying on EVs for essential travel. P8 remarked that *"We must ensure that people in 'essential' professions or with a lower socio-economic status can still get to work. They are especially vulnerable because their work cannot be done remotely. That's why it should be given priority"* underscoring the broader social fairness that PCA seeks to capture. Disagreement within this theme appears in concerns that ADM-managed systems might benefit wealthier users disproportionately. P1 noted, *"The system (should) ensure(s) the opposite by people helping each other instead of just the wealthier users"* indicating a potential socio-economic imbalance that could arise if ADM systems are not carefully regulated.

Table 6.9: Comparisson of CFA and PCA across Key Themes

#	Centroid Factor Analysis	z-Score	#	Principal Component Analysis	z-Score
				1.1 Equity and Fairness	
	CFA Factor 1 *Equity in Energy Distribution*			PCA Factor 2 *Fairness and Equity in Energy Access and ADM Impact*	
				Agreement	
1	ADM systems should support equitable energy access across different socioeconomic groups. *Quote: "Prioritise the fair distribution of energy to users." (P3)*	*1.05*	**19**	Dynamic pricing for smart charging could unfairly affect lower-income users who may need to charge during peak hours. *Quote: "Someone with fixed hours and a lower income is disadvantaged if prices are higher at the moment they need it." (P6)*	*1.69*
				Disagreement	
24	ADM should prioritise charging for those who rely on their EV for essential travel, such as commuting or caregiving. *Quote: "I don't think that can be determined for people; you never know why someone needs their EV."* (P6)	*-1.44*	**16**	ADM should ensure that users who rely on their EV for work and healthcare are prioritised in V2G decision-making. *Quote: "By prioritising certain groups during decision-making, you create a system that can fundamentally be considered unjust. This could, however, be an outcome of discussions with 'all' stakeholders, to the extent that is possible." (P9)*	*-1.79*
				1.2 Equity and Fairness	
	CFA Factor 1 *Equity in Energy Distribution*			PCA Factor 1 *Trust in ADM for Efficient Energy Management*	
				Agreement	
11	ADM should ensure that V2G benefits are distributed equally across different socioeconomic groups. *Quote: "The distribution currently favours wealthier residents. The government must ensure that socially weaker neighbourhoods also benefit from innovation." (P10)*	*1.34*	**13**	Vehicle-To-Grid technology can help reduce the strain on the grid during peak hours. *Quote: "I see opportunities through the possibilities of returning energy. Peak energy usage (in the evening) is usually not the time when many people use their cars." (P8)*	*1.88*
				Disagreement	
7	It's important that ADM systems are designed to reduce costs for lower-income households. *Quote: "By focusing the system on money, I'm afraid that the system's outcomes for the environment and social aspects will become secondary." (P9)*	*-1.41*	**19**	Dynamic pricing for smart charging could unfairly affect lower-income users who may need to charge during peak hours. *Quote: "Through dynamic charging and discharging, peak hours will blur (solving this problem)" (P2)*	*-2.04*
				2. Grid Efficiency and Stability	
	CFA Factor 2 *Environmental Responsibility and Grid Reliability*			PCA Factor 4 *Confidence in ADM or Technical and Environmental Goals*	
				Agreement	
14	The success of Vehicle-To-Grid systems depends on bidirectional energy flow. *Quote: "Managing energy quantities is successful if directed back and forth (bi-directional)." (P5)*	*1.85*	**4**	I trust ADM systems to manage energy distribution better than humans could. *Quote: "A good system will ensure justice and avoid human errors and flaws (in energy distribution)." (P4)*	*2.53*

#	Centroid Factor Analysis	z-Score	#	Principal Component Analysis	z-Score
			Disagreement		
19	Dynamic pricing for smart charging could affect lower-income users. *Quote: ”There is a form of scarcity, and money should not play too big a role. Otherwise, inequalities could grow even larger.” (P9)*	*-1.95*	**9**	ADM should prioritise energy returned to the grid from public chargers, not just private chargers. *Quote: ”I’m concerned that people who return charge will monopolise charging stations from those who want to charge at that moment. This will cause even more charging stations to be needed in an already crowded city.” (P8)*	*-2.0*
			3. Socioeconomic and Vulnerable Groups		
	CFA Factor 3 *Advocacy for Socioeconomic Sensitivity in ADM*			PCA Factor 3 *Protection for Vulnerable Users in ADM Implementation*	
			Agreement		
7	It’s important that ADM systems are designed to reduce costs for lower-income households. *Quote: “In this way, we can help people with a socioeconomic disadvantage and prevent the energy transition from affecting them more than others.” (P7)*	*1.96*	**24**	ADM should prioritise charging for those who rely on their EV for essential travel, such as commuting or caregiving. *Quote: ”We must ensure that people in ’essential’ professions or with a lower socio-economic status can still get to work. They are especially vulnerable because their work cannot be done remotely. That’s why it should be given priority.” (P8)*	*1.86*
			Disagreement		
2	Wealthier users will benefit more from ADM-managed systems, which could deepen existing inequalities. *Quote: “The system (should) ensure(s) the opposite by people helping each other instead of just the wealthier users.” (P1)*	*-1.75*	**15**	ADM-controlled V2G can help integrate more renewable energy sources into the grid. *Quote: “I do not expect that soon, because new energy is often developed with commercial interests in mind.” (P3)*	*-1.41*

6.3.4. Q-Methodology Summary and Key Findings

The Q-methodology analysis provides a detailed exploration of stakeholder perspectives on ADM’s role in managing energy equity within EVCI, directly addressing Sub-question 3 regarding perceptions of ADM in energy distribution. By employing both Centroid Factor Analysis (CFA) and Principal Component Analysis (PCA), the study reveals three major themes: *equity in energy distribution, environmental responsibility, and sensitivity to socio-economic disparities*. These themes emerged from both analytical methods, offering complementary insights into ADM’s capacity to balance operational efficiency with principles of energy justice. Participants frequently emphasised ADM’s capacity to support fair energy distribution, advocating for systems that ensure equitable access across diverse socio-economic groups. The CFA results highlighted the prioritisation of accessibility for lower-income communities, reflecting concerns about procedural and distributive justice within ADM systems. Meanwhile, PCA reinforced these insights by statistically underscoring the importance of ADM’s role in safeguarding vulnerable users, particularly against the financial implications of dynamic pricing models. This combination of qualitative and quantitative perspectives underscores the importance of ADM in achieving balanced energy access that aligns with stakeholder expectations.

While stakeholders largely agreed on ADM’s positive role in promoting energy equity, differing viewpoints arose regarding the relative importance of operational efficiency versus socio-economic protections. Some participants prioritised ADM’s environmental benefits, such as supporting V2G to reduce emissions, whereas others focused on the need to shield lower-income users from potential cost burdens. This divergence highlights a nuanced balance that ADM systems must achieve, addressing efficiency without excluding socio-economic considerations. These insights form the basis for the policy recommendations provided in the Conclusion (see Chapter 8), aimed at creating a framework that aligns ADM functionalities with principles of equity and inclusivity. By addressing key themes—such as equitable energy access, environmental impact, and protection of vulnerable groups—the policy recommendations will propose pathways for ADM systems that support a fair, inclusive, and sustainable energy transition, directly informing Sub-question 4 to ensure that ADM in EVCI aligns with energy justice.

7 Discussion

Challenges and Pathways in Pursuing Energy Justice

This chapter synthesises the study's findings, limitations, and implications, providing a critical evaluation of the role of ADM in promoting equity within EVCI in Amsterdam. By reflecting on the strengths and constraints of the applied methodologies, it discusses how ADM systems can support both operational efficiency and social justice while identifying areas for future research to enhance these contributions. Each section links findings back to the study's research questions and core principles from the Theoretical Framework (Chapter 4), including distributive, procedural, and recognition justice. The chapter is structured to first acknowledge the study's limitations, followed by an exploration of broader implications for research, policy, and community engagement. Finally, a reflection on the research process and recommendations for future studies underscore ADM's potential to shape an inclusive energy transition.

To already briefly answer the main research question—'*How can automated decision-making for urban electric vehicle charging infrastructure in the Netherlands be optimised to promote energy justice—ensuring equity, transparency and the right to energy—while addressing the diverse perceptions and needs of stakeholders?*'—this study has demonstrated that ADM can promote energy justice by ensuring equitable access, improving transparency, and upholding the right to energy across diverse socio-economic groups. The findings from GIS analysis, Scenario Development, and Q-methodology indicate that ADM has the potential to alleviate disparities in EVCI access, particularly for underserved communities, while also contributing to environmental goals through smart energy management. However, challenges such as socio-economic biases and varying stakeholder expectations highlight the need for careful implementation. These insights provide a foundation for policy recommendations in the concluding chapter, aimed at optimising ADM in EVCI to balance efficiency and equity.

This study proposed a series of propositions to guide the analysis of ADM's role in promoting energy justice within EVCI. These propositions focused on key aspects of energy justice, including distributive, procedural, and recognition justice, as well as the impact of ADM on efficiency and environmental responsibility. The implications section of the discussion examines each proposition in relation to the findings from the GIS analysis, Scenario Development, and Q-methodology, exploring the degree to which they were supported by the data. First, the limitations of the study will be discussed in the following section.

7.1. Study Limitations and Future Scope

This study acknowledges several limitations that impact the findings and interpretations regarding ADM's role in ensuring urban EVCI equity in the Netherlands. Each methodological constraint points to potential refinements that could deepen understanding of energy justice.

First, the GIS analysis is constrained by the geographic boundaries of the available data, limited to Amsterdam's municipal borders. This restriction under-represents charger accessibility for the city's peripheral areas, potentially skewing accessibility assessments by excluding chargers just outside Amsterdam's boundaries. This limitation directly affects findings related to distributive justice, as the analysis cannot fully account for cross-border accessibility, which may be essential for residents on the outskirts. Furthermore, the lack of publicly accessible private EV charger data could impact insights into socio-economic differences in EVCI accessibility, especially in affluent areas where private chargers may supplement limited public infrastructure. It suggests that a comprehensive understanding of accessibility requires both public and private data to capture full access disparities, echoing distributive justice concerns raised in the Literature Review (see Chapter 3).

Next, while Scenario Development provided insights into potential ADM impacts, and, despite the projections being based on literature and the GIS analysis, the speculative nature still limits the ability to address real-world complexities fully. The hypothetical constructs, though useful for exploring possible futures, cannot account for the full range of variables present in practical ADM applications within EVCI. Additionally, the scenarios in this study focused solely on residents as stakeholders, leaving out the perspectives of other relevant groups—such as commercial entities, policymakers, and EV service providers—whose priorities and responsibilities differ significantly. This focus on residents provides a narrower view of ADM's effects, especially regarding procedural and recognition justice, where the diverse needs and expectations of multiple stakeholder groups play a large role. Moreover, the scenarios focused on monetary incentives, which reflect a limited aspect of human motivation in ADM responses. This single-sided view of incentives highlights the importance of a broader approach that considers non-monetary influences—such as prioritised access or environmental prompts—to align with procedural and recognition justice principles by considering diverse user needs.

Moreover, the The Q-methodology faced limitations in achieving a fully diverse participant group, especially in reaching lower-income and marginalised stakeholders. This lack of diversity impacts the inclusivity of stakeholder perspectives, a key component of procedural justice, as it restricts representation across different socio-demographic groups. Although the study included participants with key characteristics in the P-set (as described in Chapter 5 Methodology), achieving a balanced representation proved challenging. Specific communities central to the GIS analysis, such as De Aker Oost and Wildeman, were not directly represented; however, participants with similar attributes were included as substitutes. This limitation emphasises the significance of broad involvement in order to fully capture procedural fairness and guarantee that ADM outcomes reflect varied community perspectives, particularly those from socio-economically disadvantaged areas. This recruitment gap underscores the challenges in aligning ADM systems with principles of procedural justice, as transparent and inclusive design fosters legitimacy and trust—particularly in systems where complex decisions impact various social groups. Freeman's Stakeholder Theory and research on transparency emphasise that a wider stakeholder spectrum is essential for equitable outcomes [9], [15], [19], [40]. Future research should prioritise broader engagement to better understand diverse perspectives and enhance the alignment of ADM in EVCI with energy justice and procedural equity values.

These implications underscore the study's potential to inform ADM research, policy-making, and technology development for EVCI by advocating for systems that harmonise operational objectives with commitments to justice and equity. By addressing practical challenges such as fair distribution of resources, procedural inclusivity, grid stability, and sensitivity to socio-economic disparities, this study lays the groundwork for a more socially responsible and sustainable approach to ADM in the energy sector. Emphasising the need for balanced integration of efficiency and fairness, the findings highlight ADM's potential not only as a technical solution but as a transformative tool that can promote equity, transparency, and environmental responsibility within EVCI. This focus on real-world issues encourages future studies and policy frameworks to consider both the technical and ethical dimensions of ADM, contributing to a fairer, more inclusive energy landscape that aligns with broader goals of energy justice.

7.2. Implications for Automated Decision-Making in Energy Justice

This study's findings extend beyond immediate conclusions, offering implications for future research, policy, and ADM application in EVCI with a focus on energy justice. Each theme addresses core principles from Chapter 4 Theoretical Framework, such as equitable access, transparency, and socio-economic inclusivity. The implications are organised under three themes: *Equity and Fairness*, *Procedural and Recognition Justice*, and *Efficiency and Environmental Responsibility*.

The *GIS analysis* revealed distributional justice concerns by identifying lower accessibility to public EVCI in lower-income neighbourhoods (see Figures 6.2 & 6.3 in Chapter 6). These findings form a data-driven foundation for *Scenario Development*, exploring the deployment of SC and V2G technologies across neighbourhoods with varying income levels and solar panel distribution. Scenario Development visualises the potential for ADM-managed EVCI to promote distributive justice, highlighting opportunities to address socio-economic disparities (see Figures 6.6 & 6.8 in Chapter 6). This aligns with *Proposition 1 (P1)*, which suggested that ADM's equitable infrastructure expansion could prioritise marginalised communities. These results suggest policymakers can address disparities by mandating ADM designs that integrate socio-economic considerations. In particular, establishing guidelines that require ADM to address diversity could foster more inclusive and equitable energy infrastructures.

The Q-methodology provided insights into stakeholder perceptions, highlighting procedural justice as essential for building trust and ensuring inclusivity in ADM-driven EVCI systems. *Proposition 2 (P2)* focused on ADM's capacity to promote procedural fairness by involving diverse stakeholders in decision-making and addressing socio-economic disparities. This study's findings show that ADM systems designed with transparency and accessibility are well-received by stakeholders, especially when procedural mechanisms prioritise vulnerable groups, such as those in lower-income areas or essential workers. However, challenges were noted, such as the risk of prioritising certain user groups at the expense of reinforcing social imbalances. Policymakers should require ADM systems to integrate procedural justice into operational frameworks, enabling ADM to balance stakeholder expectations fairly while prioritising transparency and inclusivity.

Proposition 3 (P3), which concerns how different stakeholder groups perceive the fairness of ADM, is particularly relevant here, as stakeholder trust and perceptions of fairness are crucial for ADM's societal acceptance. Findings from the Q-methodology highlighted diverse viewpoints on ADM's role in energy management, reflecting varying expectations across socio-economic groups. For instance, while some participants valued ADM's efficiency gains, others emphasised socio-economic protections, showing how user perspectives can diverge significantly. By recognising these differences, ADM frameworks can be tailored to accommodate a broad spectrum of stakeholder needs, fostering procedural justice. Policymakers can address Proposition 3 by designing ADM systems that include feedback mechanisms to capture ongoing user perceptions and adjust functionalities to uphold fairness and transparency. Ensuring ADM systems are perceived as fair by diverse stakeholders not only strengthens legitimacy but also aligns with principles of procedural justice by making the decision-making process accessible and comprehensible across social groups.

ADM systems demonstrated a strong potential to support grid resilience and environmental goals, particularly through SC and V2G technologies, which align with *Proposition 4 (P4)*. Scenario Development and Q-methodology findings reflected consensus among stakeholders regarding ADM's technical benefits, such as V2G's capability for bidirectional energy flow, which enhances grid functionality and helps achieve environmental targets. However, concerns about the socio-economic impacts of dynamic pricing highlight the need for policies that balance efficiency gains with protections for low-income users. These results suggest ADM's efficiency benefits can be optimised without compromising access for vulnerable populations. Policymakers should consider implementing socio-economic assessments within ADM frameworks to ensure that efficiency gains do not disproportionately disadvantage low-income users, thus aligning operational resilience with equitable access goals.

In summary, the study's findings provide varied levels of support for the initial propositions, highlighting ADM's potential to inspire a balanced approach in EVCI that integrates technical efficiency with ethical commitments to equity. Proposition 1, concerning equitable access, was partially supported by the GIS analysis, which demonstrated socio-economic disparities in EVCI distribution, indicating that ADM without corrective measures may favour affluent areas. Proposition 2 on procedural fairness was generally supported, with Scenario Development and Q-methodology results highlighting positive responses towards socio-economic inclusivity in ADM decision-making. Proposition 3 underscored the importance of aligning ADM designs with stakeholder perceptions of fairness, suggesting that ADM can foster trust if it accommodates diverse user needs. Proposition 4, which suggested ADM's role in environmental responsibility, received support regarding ADM's technical potential to stabilise the grid and reduce emissions; however, concerns about dynamic pricing effects underscore the need for balanced implementation strategies. Collectively, these insights lay the groundwork for policy recommendations in the concluding chapter, aimed at optimising ADM in EVCI to balance efficiency and equity. This study thus sets a foundation for future research and policy work on ADM in energy justice, positioning ADM as a tool for advancing both the technical and social dimensions of energy management. Through its contributions to themes of equity, procedural justice, and environmental sustainability, this study provides a platform for researchers and policymakers to further explore ADM's role in an inclusive energy transition.

7.3. Research Reflections

This reflection applies Kolb's Reflection Cycle [80] to examine the research journey, focusing on the unique contributions of this study in addressing ADM's impact on equity and justice in energy distribution—an area often overshadowed by technical optimisation. As ADM systems become integral to urban infrastructure, there is a growing need to incorporate ethical and social considerations, ensuring that smart city technologies like SC and V2G advance not only efficiency but also inclusivity and fairness.

Experience: The research process involved a multi-method approach, utilising GIS analysis, scenario development, and Q-methodology to investigate distributive justice in Amsterdam's EVCI landscape. The scenarios, enriched with visualisations, received positive feedback from Q-sort participants, providing them with an accessible understanding of SC and V2G technologies even without prior knowledge. This method effectively conveyed complex ideas, but it did face challenges in recruitment, as some potential participants declined upon encountering the Q-sort format, expecting a more traditional questionnaire. Conducting the Q-sorts in person was crucial for clear instruction, but this also posed challenges in maintaining objectivity while explaining the technologies, stressing the relevance and utility of the scenarios as reference points for answering participants' content and topic-specific questions.

Reflection: Each methodology offered unique insights and presented challenges. GIS analysis identified spatial inequalities but was limited by the lack of private charger data, restricting the study's reach on distributional justice. Scenario development, while effective in conveying future implications of ADM, required careful balancing to ensure technical accuracy without oversimplification. The Q-sort process, which began with an initial sorting of statements into "agree," "neutral," and "disagree" categories (Table C.3 in Appendix C on page 118), revealed participants' tendency to place more statements in the "agree" category and fewer in "disagree." Although this initial sort was only meant to help participants familiarise themselves with the statements, a more balanced initial distribution of statements might have influenced final Q-sort results. This is because the Q-sort grid used a forced sorting structure with equal slots for each category, meaning that statements initially placed in "agree" may have been shifted toward "neutral" or "disagree." Nevertheless, participants noted that the Q-sort encouraged deeper engagement with the topic, as it allowed them to consider the issues from different perspectives compared to an interview or questionnaire. Yet, achieving a diverse sample remained challenging, emphasising the value of methodological flexibility and an inclusive research approach.

Conceptualisation: This research highlights the necessity of linking ADM applications in EVCI with broader concepts of energy justice and stakeholder theory, contributing a new perspective on ADM's social implications in the energy transition. Findings reinforce that ethical considerations must shape technological deployments to avoid the exclusion of disadvantaged communities, aligning with the European Commission's commitment to inclusive and fair climate policies [1].

Action: Insights from this study underscore the need for comprehensive and inclusive ADM methodologies, especially where public infrastructure intersects with social equity. Future research would benefit from combining diverse data sources and fostering more adaptive engagement strategies, such as interactive tools that are accessible and easily understood by various stakeholder groups. Additionally, this research demonstrates the value of translating technical findings into accessible formats to encourage informed public engagement and support for a just energy transition.

In summary, this thesis provided a deeper understanding of ADM's potential to support or hinder equitable energy distribution, depending on its integration with social and ethical frameworks. By addressing a gap in the literature that prioritises justice alongside technological innovation, this study supports the development of ADM systems that contribute to sustainable, fair, and inclusive urban futures.

7.4. Future Research Directions

This study opens numerous pathways for future research, particularly in refining ADM systems within EVCI to better address principles of equity and justice. The rapid expansion of EVCI across urban centres and the critical role of ADM in optimising these systems underscore the need for continued research that is responsive to technological advancements, policy shifts, and social dynamics. By exploring these avenues, future studies can contribute to the development of ADM frameworks that balance operational efficiency with the diverse needs of socio-economically varied communities. The recommendations that follow aim to address the study's identified limitations and build upon its contributions in the interconnected domains of energy distribution, smart cities, and social equity.

Firstly, a wider and more in-depth GIS study could utilise detailed EV charger data, including private charging stations and data from areas beyond Amsterdam's municipal boundaries. Such an expanded dataset would provide a more accurate view of EVCI accessibility across socio-economic groups in Amsterdam, offering the municipality valuable insights into where additional chargers could be added. This extended spatial analysis could potentially identify differences in the availability of public and private chargers, revealing places where fair access to EVCI infrastructure may require focused interventions.

Expanding scenario development to encompass a broader range of urban and rural contexts, as well as diverse stakeholder perspectives, would strengthen future studies by revealing how ADM systems impact various geographical, socio-economic, and operational settings. While this research focused on Amsterdam, investigating ADM deployment across different regions could help policymakers tailor EVCI solutions to regional differences in accessibility, energy demand, and infrastructure needs. For example, contrasting the effects of ADM in densely populated cities with more rural or suburban areas could offer valuable insights, especially given that net congestion affects the entire Netherlands, as illustrated in Figure 1.2 in Chapter 1 Introduction on page 3. Additionally, developing scenarios that incorporate perspectives beyond residents—such as commercial entities, policymakers, and EV service providers—would provide a more holistic view of ADM's equity and operational challenges. These groups, each playing crucial roles in EVCI's implementation and maintenance, are affected differently by ADM-related decisions. Including their varied viewpoints would illuminate the complexities of procedural and recognition justice, highlighting the differing priorities and needs among stakeholders with distinct responsibilities within the EVCI system.

A suggested direction for future research includes further examination of the socio-economic impacts of ADM's integration with dynamic pricing models. This study highlights the risk of socio-economic bias in dynamic pricing, which may disadvantage lower-income users who cannot adjust their charging times easily. Conducting experimental studies or simulations that model the effects of ADM-driven pricing in real-world scenarios could help identify strategies for ensuring that pricing mechanisms do not inadvertently deepen existing inequalities. Beyond monetary incentives, future research could explore alternative strategies within ADM to influence user behaviour, such as prioritised access to charging points for certain user groups, informational prompts that highlight environmental benefits, or gamification techniques that reward sustainable charging habits. The Q-methodology findings also suggest the importance of prioritising access for individuals whose vehicles are essential for work or caregiving responsibilities, offering them charging flexibility that aligns with their critical needs. These non-monetary incentives and prioritisation strategies could be particularly impactful for engaging users who are less responsive to price adjustments, offering equitable ways to encourage participation in energy-saving initiatives while considering both financial benefits and avoiding additional financial burdens. Testing the effectiveness of these approaches in different socio-economic contexts would provide insights into how ADM systems can support a just and inclusive energy transition, accommodating a broader range of user motivations and needs in EVCI management.

Lastly, building on the feedback received regarding the scenarios and visualisations, future research could further refine these tools to enhance public awareness and understanding of ADM in EVCI. This study launched a website as a publicly accessible platform, presenting the scenario-based findings alongside visualisations to engage a broader audience. Such a platform allows complex research outcomes to be conveyed in a more accessible, user-friendly format, offering community members and stakeholders an opportunity to explore ADM and energy justice issues without requiring deep technical expertise. For instance, interactive tools like animated maps, scenario simulations, or simplified guides to ADM's impact on energy equity can provide a more intuitive understanding of these topics than a traditional research paper alone. This approach could help bridge the gap between technical research and community awareness, supporting a more informed and participatory energy transition by sharing information in an engaging, accessible manner.

In summary, future research should aim to broaden GIS data sources, incorporate a diverse range of socio-economic and geographic settings, and refine public-engaging tools to increase accessibility. By addressing these areas, research can contribute to ADM systems that advance not only operational efficiency but also social and environmental equity. A more inclusive approach to ADM within EVCI can support a fairer and more sustainable urban energy infrastructure, benefiting a wide array of stakeholders and enhancing the resilience and accessibility of the energy system across diverse urban settings.

8 Conclusion

Towards Balancing Efficiency and Energy Justice

This conclusion consolidates the study's key insights, illustrating how ADM systems can be structured to advance energy justice within EVCI in urban settings. Positioned as a foundational framework rather than a comprehensive toolkit, this study serves as a starting point to inform and inspire future research and development. By bridging technological advancement with socio-economic awareness, it underscores the necessity for ADM systems to go beyond efficiency and actively promote fairness and inclusivity. By systematically addressing the research questions, this chapter links the study's findings back to the theoretical foundations of energy justice, reinforcing principles of accessibility, fairness, inclusivity, and transparency within ADM frameworks. These insights culminate in a set of phased policy recommendations designed to enhance the effectiveness and equity of ADM systems in EVCI, contributing to a fairer, more sustainable energy transition. Through these recommendations, the study underscores the importance of ADM systems that not only drive technological progress but also promote social equity, supporting a mindful, inclusive approach to the evolving landscape of urban energy management.

8.1. Key Findings of ADM and Energy Justice

This study set out to evaluate the role of ADM systems in promoting equity within EVCI in Amsterdam, focusing on balancing efficiency with fairness and inclusivity principles. This aim responds directly to the research problem identified in Chapters 1 Introduction and 2 Background, where the energy transition and net congestion underscore the need for equitable access to EVCI. With the European Commission and urban policymakers advocating for an inclusive energy transition that leaves no community behind, this research examines how ADM systems can support these goals through a framework of energy justice and comprehensive stakeholder engagement. Drawing on concepts from Chapter 3 Literature Review and 4 Theoretical Framework—primarily regarding the energy justice dimensions of distributive, procedural, and recognition justice—this study employed a multi-method approach, including GIS analysis, scenario development, and Q-methodology, to explore ADM's socio-economic implications. The findings show how ADM in EVCI may be structured to handle these justice dimensions practically, by combining theoretical insights with empirical facts.

The *GIS analysis* demonstrated disparities in public EV charger accessibility across socio-economic neighbourhoods in Amsterdam, with lower-income areas having fewer publicly accessible chargers. This finding aligns with concerns raised in the literature on energy justice, where ADM-induced biases can exacerbate inequities, reinforcing socio-economic divides in infrastructure distribution [35], [36]. By integrating socio-economic data into ADM frameworks, this research offers policymakers actionable insights for equitable EVCI placement, addressing calls from the literature for ADM applications that actively counteract existing inequities [38], [47]. This approach is consistent with *Freeman's Stakeholder Theory*, which underscores the importance of inclusive engagement in resource distribution [40]. The *scenario development* approach effectively communicated the future implications of ADM-managed EVCI to stakeholders, illustrating how SC and V2G could be implemented differently across various urban neighbourhoods. This method aligns with the literature's emphasis on procedural justice by providing stakeholders, regardless of technical background, with an accessible understanding of ADM's impact on equity [40]. This approach also demonstrates ADM's potential to adapt to the unique needs of diverse communities within EVCI, reflecting calls for transparency and inclusive decision-making as essential elements for building trust and legitimacy among stakeholders [15], [33]. Consistent with *Stakeholder Theory*, this engagement-based strategy emphasizes the significance of involving all affected groups to achieve equitable resource distribution and overcome any biases [9], [41]. The inclusion of visualization tools, such as scenario-based outcomes, further supports transparency and allows stakeholders to assess potential impacts more effectively.

Through *Q-methodology*, this study captured stakeholder perspectives on equity in ADM, particularly regarding procedural justice and the prioritisation of essential groups, such as workers and caregivers. Despite sampling limitations, prioritising these groups within ADM frameworks was found to increase perceived fairness, underscoring the importance of recognition justice, as outlined in Chapter 4 *Theoretical Framework*. The importance of incorporating a wide range of stakeholder perspectives [30], [31], [44] was reflected in the Q-sort results, confirming that inclusive decision-making frameworks are essential to address social inequalities in EVCI access. Additionally, the stakeholder dynamics discussed in Chapter 3 *Literature Review* support this approach, as engaging a range of stakeholders—including disadvantaged groups—strengthens legitimacy and trust in ADM processes [54]. This approach aligns with *Freeman's Stakeholder Theory* [40], emphasising the critical role of diverse stakeholder engagement in achieving procedural justice within ADM frameworks. In particular, involving *Dependent Stakeholders*, such as community groups and advocacy organisations, ensures that marginalised communities are represented in decision-making, promoting recognition justice and fairer resource distribution [19], [41]. This insight resonates with broader calls within energy justice literature for equity-oriented ADM frameworks that actively integrate stakeholder input to reduce socio-economic disparities in EVCI [15], [32], [33]. Crucially, *Definitive Stakeholders*—such as regulatory bodies and local governments—play a central role in enforcing these equity-oriented frameworks and policies, directing ADM systems towards inclusive and equitable outcomes across various communities [54].

This study demonstrates how integrating socio-economic considerations, openness, and inclusivity into Automated Decision-Making (ADM) for Electric Vehicle Charging Infrastructure (EVCI) can advance a more equitable energy transition, addressing a gap identified in the Introduction (see Chapter 1). ADM systems in Amsterdam provide an early model for equitable urban infrastructure by combining technical optimisation with social accountability. This approach embodies the concept of *Mindful Power*, the guiding theme of this thesis, which envisions ADM not merely as a tool for enhancing efficiency but as a catalyst for justice-driven energy distribution. *Mindful Power* promotes a dual commitment to operational effectiveness and respect for diverse community needs, balancing technological progress with equity and transparency. Although this study does not serve as a comprehensive toolkit, it establishes foundational principles that policymakers and researchers can build upon to further develop ADM systems that are both efficient and socially responsible. By aligning with energy justice principles and fostering stakeholder engagement, this work supports fair resource distribution and procedural legitimacy, setting a course for ADM frameworks that enable a truly inclusive energy transition.

8.2. Revisiting the Research Questions

This research explored how Automated Decision-Making (ADM) systems in Electric Vehicle Charging Infrastructure (EVCI) can be optimised to promote energy justice within urban contexts, focusing on accessibility, efficiency, fairness, and inclusivity. The study addressed these goals by breaking down the primary research question into four sub-questions, answered using a combination of GIS analysis, Scenario Development, and Q-methodology. The insights derived from these methods collectively address the main research question on how ADM in EVCI can balance efficiency with energy justice principles.

In response to *Sub-Question 1*, findings from the GIS analysis highlighted significant disparities in EVCI accessibility across socio-economic neighbourhoods in Amsterdam, with lower-income areas typically experiencing limited access to publicly available EV chargers. This observation emphasises the need for ADM frameworks that include distributive justice principles, allowing for targeted interventions that avoid reinforcing existing infrastructure inequities. By incorporating socio-economic data into ADM frameworks, policymakers can ensure that ADM actively prioritises equitable access across diverse socio-economic groups, supporting a fair distribution of EVCI resources.

Sub-Question 2 examined ADM's role in promoting efficient and equitable EVCI deployment. The Scenario Development indicated that while ADM can streamline infrastructure placement and contribute to grid optimisation, adaptive strategies are essential to address potential biases, particularly in underserved or grid-congested areas. These findings underscore the necessity for flexibility in ADM models to balance efficiency with justice. Adaptive ADM approaches, support procedural justice by promoting responsiveness to both regional grid constraints and the needs of different socio-economic groups, thereby ensuring that technological progress does not come at the expense of inclusivity.

Regarding *Sub-Question 3*, the Q-methodology results highlighted the critical role of transparency and procedural fairness in fostering public trust in ADM. Participants consistently expressed that transparency is fundamental to ADM's legitimacy, reinforcing the need for clear, inclusive decision-making processes within ADM systems. The study's findings validate the importance of procedural justice principles outlined in the theoretical framework, where inclusive community involvement is essential for ensuring ADM systems are fair and accepted by diverse stakeholders. Clear communication and transparency build stakeholder understanding and trust in ADM, fostering community support.

Sub-Question 4 focused on ADM's potential to enhance EVCI accessibility specifically in underserved areas. Scenario-based insights affirmed the value of equity-focused ADM policies, demonstrating how targeted ADM interventions in lower-income or low-access neighbourhoods can bridge accessibility gaps. By directing ADM to prioritise these areas, policymakers can promote distributive justice and advance a more equitable transformation of urban energy systems. Equity-focused ADM solutions, as detailed in the scenarios, play a pivotal role in closing socio-economic accessibility gaps and aligning infrastructure deployment with the broader goals of energy justice.

Together, these findings address the *Main Research Question* by showing that ADM in EVCI can be optimised for energy justice through policies that prioritise equity-focused, transparent, and inclusive decision-making processes. To achieve a balanced approach, ADM frameworks must be designed to identify and mitigate socio-economic disparities actively, ensuring that all communities benefit from the energy transition. By combining technological efficiency with a commitment to social responsibility, ADM systems can serve as tools of equity rather than reinforcing existing inequalities. These findings support the policy recommendations in the next section, which aim to guide the development of ADM systems that embody the dual goals of operational excellence and energy justice.

8.3. Roadmap for Policy Recommendations

Based on the study's findings, this section outlines a phased *roadmap* for policy recommendations aimed at optimising ADM systems for energy justice within EVCI in urban areas (see Figure 8.1) on page 93. Acknowledging this study as a foundational approach rather than a complete toolkit, these recommendations seek to inspire further research direction and policy development.

In the *short term*, *prioritise equitable EVCI distribution* by ensuring that ADM frameworks integrate socio-economic and geographic data to identify lower-income or underserved areas as high-priority zones for EVCI deployment. Policymakers should mandate that ADM systems actively address disparities, ensuring that infrastructure expansion helps the most vulnerable areas, therefore fostering distributive justice and closing socioeconomic gaps in EV access. Simultaneously, *implement transparency and accountability mechanisms* to foster public trust in ADM systems. Regular public reporting on decision-making criteria—particularly around EVCI allocation and pricing models—should be a key component. Creating dedicated channels for stakeholder and community feedback will reinforce procedural justice, instilling a sense of ownership and trust among the public. ADM developers and local authorities should embed transparency measures into system design from the start.

In the *medium term*, *develop adaptive ADM models* that respond to grid constraints and high-demand areas, accommodating regional variations in grid capacity and socio-economic factors. Adaptive policies should introduce flexibility in ADM frameworks, enabling targeted solutions like prioritising essential services and flexible pricing in under-resourced areas, ensuring ADM efficiency aligns with equitable access. Additionally, *explore and support non-monetary incentives for behavioural engagement* to broaden ADM's appeal across diverse user groups. Incorporating non-monetary strategies, such as prioritised access for essential users, environmental impact prompts, and gamification techniques, can foster equitable participation in sustainable charging behaviours. These approaches ease financial burdens on lower-income users while promoting environmentally responsible practices, promoting a balanced approach to procedural and distributive justice.

In the *long term*, *enhance community engagement through accessible platforms* that make ADM's role in EVCI transparent and participatory. Policymakers should support the development of publicly accessible websites, mobile applications, and interactive platforms that disseminate scenario-based insights and visualisations. Developing a suite of visualisation tools and engaging stakeholders with scenario-based outcomes, especially for non-residential groups like commercial entities and policymakers, would provide a broader view of ADM's diverse impacts. This approach not only supports transparency and engagement but also broadens the scope of future scenario development, providing insights that reflect the diverse requirements of all affected stakeholders. These platforms would allow users to explore ADM's impact on energy equity in their local contexts, contribute their perspectives, and enrich greater understanding of ADM's function in energy management. Such initiatives align with procedural justice principles and further strengthen community involvement in the energy transition, closing the gap between technical research and public awareness.

Together, these phased recommendations provide a roadmap for policymakers, researchers, and stakeholders to create ADM systems that uphold energy justice principles while advancing operational goals. In the spirit of **Mindful Power**—capturing the dual imperative for ADM systems to optimise energy use without sacrificing social equity, while also urging policymakers and regulators to consider the broader social impacts of technologies like Smart Charging and Vehicle-to-Grid—this study advocates for ADM systems that not only enhance efficiency but also respect the diverse needs of urban communities. A dedicated website has been created[1], designed to increase public awareness and share the study's findings in an accessible, non-academic format. Mindful Power calls for a balance between technological potential and social responsibility, ensuring that ADM systems serve as instruments of equity rather than tools that reinforce existing inequalities. By embedding principles of equity, transparency, and adaptability within ADM frameworks, cities can cultivate a fairer, more inclusive energy future. This vision relies on interdisciplinary research and collaborative action, harnessing the power of ADM to support sustainable, community-centred urban landscapes. Ultimately, this approach promises an energy transition in which every stakeholder has a place, affirming that the path to a sustainable future is one that leaves no one behind.

[1] https://mindfulpowerthesis.framer.website/

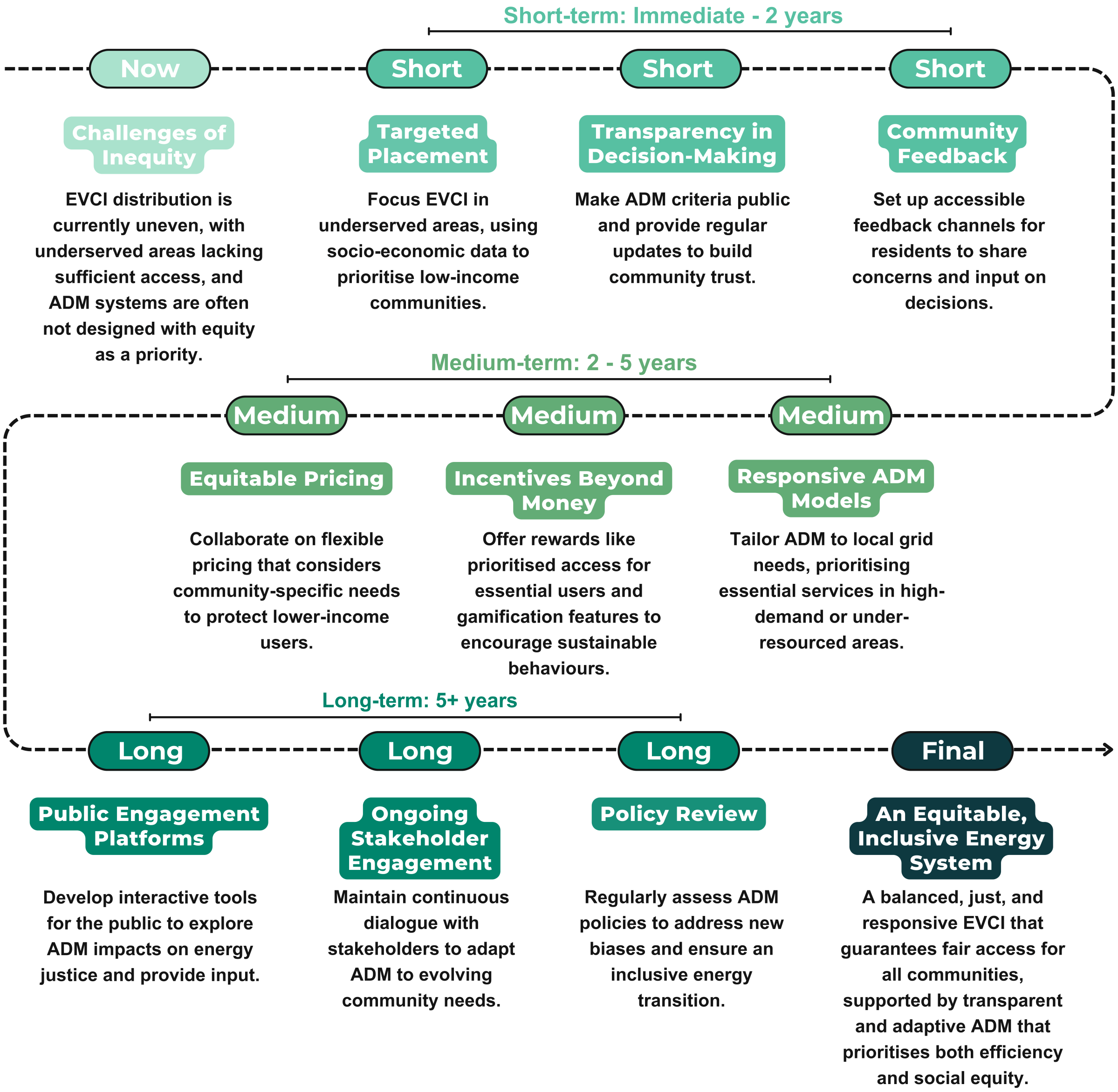


Figure 8.1: Roadmap for the Policy Recommendations based on the Research Findings

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Appendices

A

Geographic Information System Analysis

A.1. GIS Analysis Datasets

Table A.1: Datasets used for the GIS Analysis

Figure(s)	Dataset	Datatype	Year	Source	Explanation
6.1	Mobility, electricity, and parking data for EV infrastructure in the Amsterdam Metropolitan Area	Polygon (shapefile)	2017, 2018, 2019	[64]	EV infrastructure data by three-digit postcode areas in the Amsterdam Metropolitan Area.
6.2, 6.3, 6.5, 6.6, 6.8	Electric charging points in Amsterdam (translated)	Point (GeoJSON)	2024	[65]	Locations of existing, planned, and progressing EV chargers.
6.3, 6.4	Neighbourhoods 2019 – CBS District- and neighbourhood map (translated)	Polygon (Feature Layer)	2019	[66]	Boundaries with income, car ownership, and fuel type data by neighbourhood.
6.5	Liander electricity grids (translated)	Point & Line (ATOM)	2024	[69]	Liander electricity network location data for the service area.
6.6, 6.8	Energy labels (translated)	Polygon (Feature Layer)	2024	[67]	Building energy labels, updated monthly with new data.
6.6, 6.7, 6.8, 6.9	Solar panels (translated)	Point (GeoJSON)	2023	[68]	Solar panel counts by building from aerial images, 2016-2023.
6.7, 6.9	Building function mix (translated)	Point (GeoJSON)	2022	[73]	Building functions data, categorised by residential, facility, and work types.
6.7, 6.9	Housing corporation ownership 2023 Metropolitan Area Amsterdam (translated)	Polygon (GeoJSON)	2023	[72]	Housing corporations' ownership boundaries in the Amsterdam Metropolitan Area.

A.2. GIS Analysis Workflow

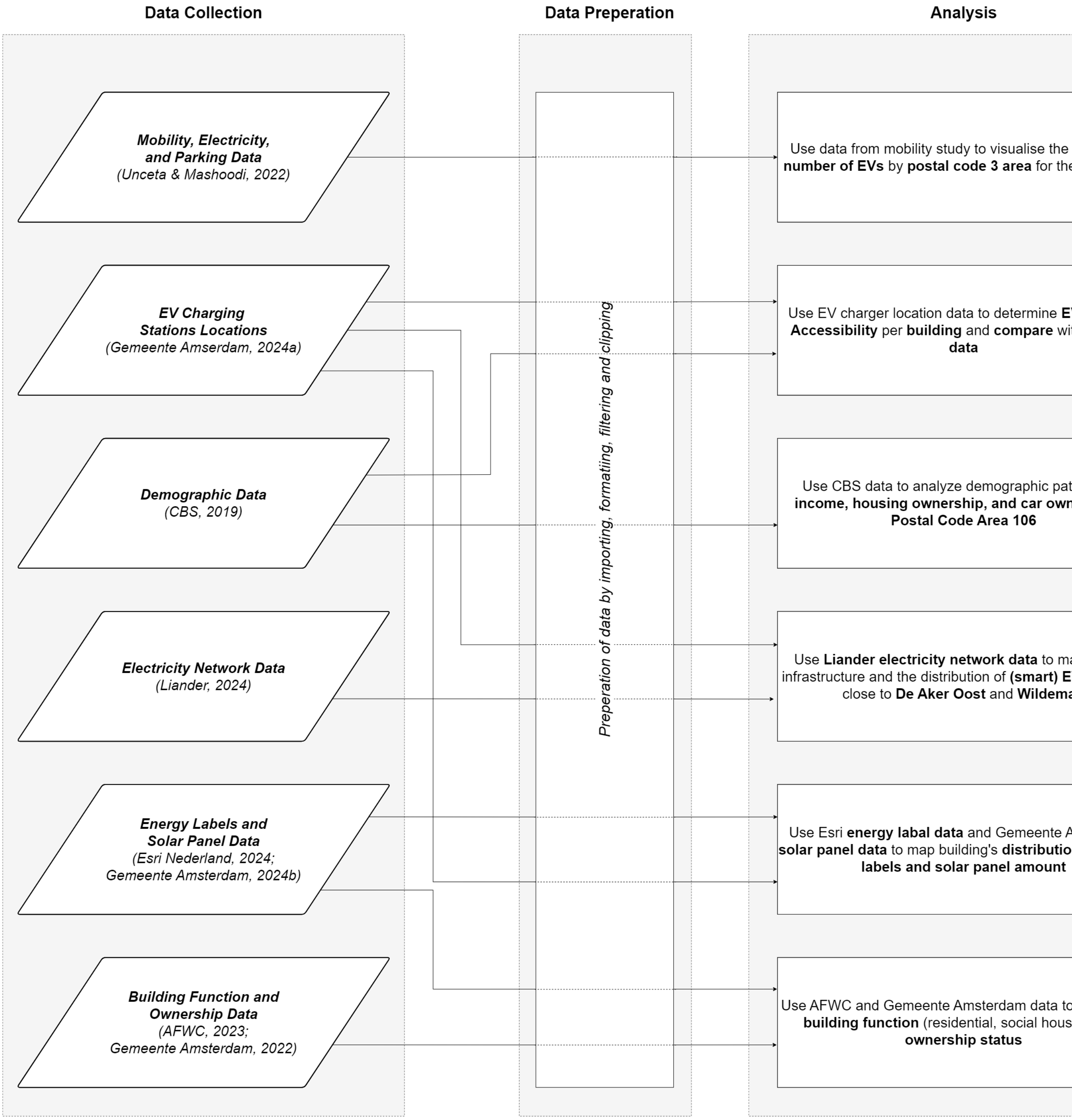

Figure A.1: Geographic Information

System Analysis Workflow

B

Q-methodology: Instructions and Materials

B.1. Q-set: Categorisation of Statements and Explanations

Table B.1: Overview of the Q-set or statements for the Q-methodology

#	Scenario	Category	Statement	Explanation
1	General	Equity and Fairness	ADM should prioritise fairness in how resources like energy are distributed.	Reflects the need for equitable distribution of energy resources (distributive justice).
2	General	Equity and Fairness	Wealthier users will benefit more from ADM-managed systems, which could deepen existing inequalities.	Concerns about equity and wealthier users disproportionately benefiting from ADM systems.
3	General	User Autonomy and Flexibility	People should have more control over their energy use, even if ADM could optimise it for them.	Addresses the tension between automation and user autonomy (procedural justice).
4	General	User Autonomy and Flexibility	I trust ADM systems to manage energy distribution better than humans could.	Public acceptance of ADM relies on trust in complex energy management.
5	General	Trust and Transparency in ADM	ADM can help make energy use more efficient, but I am concerned about its transparency.	Highlights transparency and trust issues regarding ADM systems.
6	General	Trust and Transparency in ADM	The implementation of ADM systems in energy distribution should involve public input and participatory decision-making.	Public involvement in ADM design ensures procedural justice.
7	General	Socioeconomic and Vulnerable Groups	It's important that ADM systems are designed to reduce costs for lower-income households.	Prioritises cost reductions for lower-income households (ethics of care).
8	Scenario 1: Vehicle-to-Grid Technology	Equity and Fairness	V2G systems should ensure that EV users are compensated fairly for contributing energy back to the grid.	Fair compensation for users contributing energy promotes procedural justice.
9	Scenario 1: Vehicle-to-Grid Technology	Equity and Fairness	ADM should prioritise energy returned to the grid from public chargers, not just private chargers.	Emphasises public access to V2G for socioeconomic equity.
10	Scenario 1: Vehicle-to-Grid Technology	User Autonomy and Flexibility	I worry that ADM might prioritise areas with higher EV ownership for V2G deployment, leaving out others.	Concerns about ADM favoring wealthier areas (distributive justice).

#	Scenario	Category	Statement	Explanation
11	Scenario 1: Vehicle-to-Grid Technology	Socioeconomic and Vulnerable Groups	ADM should ensure that V2G benefits are distributed equally across different socioeconomic groups.	Ensures equal distribution of V2G benefits (distributive justice).
12	Scenario 1: Vehicle-to-Grid Technology	Socioeconomic and Vulnerable Groups	ADM should prioritise V2G decision-making to support users from vulnerable socioeconomic backgrounds who rely on their EVs for work and healthcare.	Considers the needs of essential workers (ethics of care).
13	Scenario 1: Vehicle-to-Grid Technology	Grid Efficiency and Stability	V2G technology can help reduce the strain on the grid during peak hours.	Highlights V2G's role in easing grid congestion.
14	Scenario 1: Vehicle-to-Grid Technology	Grid Efficiency and Stability	The success of V2G systems depends on the grid's ability to handle large amounts of bidirectional energy flow.	Addresses technical challenges in managing bidirectional energy flow.
15	Scenario 1: Vehicle-to-Grid Technology	Sustainability and Renewable Energy Integration	ADM-controlled V2G can help integrate more renewable energy sources into the grid.	Supports renewable energy integration and sustainability goals.
16	Scenario 1: Vehicle-to-Grid Technology	Essential Needs and Ethics of Care	ADM should ensure that users who rely on their EVs for work and healthcare are prioritised in V2G decision-making.	Considers essential needs, reflecting ethics of care.
17	Scenario 2: Smart Charging Technology	Equity and Fairness	SC should ensure equal access to charging opportunities for all, regardless of socioeconomic status.	Promotes equal access to SC (distributive justice).
18	Scenario 2: Smart Charging Technology	User Autonomy and Flexibility	SC should allow users to choose between faster and slower charging based on their needs.	Ensures flexibility in SC (procedural justice).
19	Scenario 2: Smart Charging Technology	Trust and Transparency in ADM	Dynamic pricing for SC could unfairly affect lower-income users who may need to charge during peak hours.	Concerns that dynamic pricing may impact low-income users (distributive justice).
20	Scenario 2: Smart Charging Technology	Grid Efficiency and Stability	ADM should focus on optimising energy distribution, even if it means slowing charging at certain times.	Emphasises optimising grid stability and efficiency.
21	Scenario 2: Smart Charging Technology	Grid Efficiency and Stability	SC can lead to lower energy costs for EV users.	SC reduces energy costs by shifting demand to off-peak periods.
22	Scenario 2: Smart Charging Technology	Grid Efficiency and Stability	I support the use of ADM to prioritise EV charging during off-peak hours.	Supports grid stability by spreading charging demand.
23	Scenario 2: Smart Charging Technology	Sustainability and Renewable Energy Integration	SC can contribute to reducing overall carbon emissions from the energy grid.	Reduces carbon emissions by optimising renewable energy use.
24	Scenario 2: Smart Charging Technology	Essential Needs and Ethics of Care	ADM should prioritise charging for those who rely on their EV for essential travel, such as commuting or caregiving.	Prioritises essential travel needs (ethics of care).
25	Scenario 2: Smart Charging Technology	Equity and Fairness	ADM should ensure that users in public housing areas have the same access to SC infrastructure as wealthier areas.	Promotes equal access for low-income areas (energy justice).

B.2. Q-sort instructions and Materials

B.2.1. Consent form

You are being invited to participate in a research study titled "*Mindful Power: Evaluating Energy Justice in Automated Decision-Making for Urban Electric Vehicle Charging Infrastructure in The Netherlands*". This study is being conducted by Florens Jocker from TU Delft and Wageningen University & Research as part of a Master thesis.

The purpose of this research is to explore public perceptions and stakeholder views on the fairness, transparency, and equity of Automated Decision-Making (ADM) in the context of Electric Vehicle (EV) charging infrastructure. Specifically, the study will investigate how ADM systems in Smart Charging (SC) and Vehicle-to-Grid (V2G) technologies impact the distribution of energy resources and the perceived justice in energy access across different communities. The study will take you approximately 20-30 minutes to complete. The data gathered will be used for thesis publication at both universities besides website creation for accessible sharing of results.

We will ask you to participate in a Q-sort activity, where you will be presented with a series of statements related to Automated Decision-Making and Electric Vehicle charging. You will be asked to rank these statements based on your level of agreement or disagreement. The results will help us understand your opinions on how Automated Decision-Making can balance efficiency and equity in energy distribution.

No personally identifiable information (e.g., names, or email addresses) will be collected, and your responses will be anonymised. The data will be securely stored and only accessible to the research team. In the case of publication or presentation, all data will be presented in an aggregated form, ensuring that individual responses cannot be identified.

Additionally, this study follows open data principles, meaning that anonymised data may be shared publicly for the purpose of scientific research and transparency.

Your participation in this study is entirely voluntary, and you may withdraw at any time without penalty. Since the survey is anonymous, we will not be able to remove your data once it has been submitted.

If you have any questions or require more information about the study, you can contact Florens Jocker

By proceeding with this survey, you acknowledge that you have read and understood this information and consent to participate in this research.

B.2.2. Q-sort instructions

RESPONDENT NUMBER: ___

INSTRUCTIONS TO THE SURVEY

Thank you for participating in this study, which seeks to explore how Automated Decision-Making (ADM) impacts the equity and fairness of energy distribution through Electric Vehicle (EV) charging infrastructure. We will guide you through a series of steps to help us understand your viewpoints. Your responses will contribute to evaluating the role of ADM in managing Vehicle-to-Grid (V2G) and Smart Charging (SC) technologies, and their implications for energy justice.

This study focuses on two key scenarios involving Vehicle-To-Grid and Smart Charging technologies that shape the future of energy distribution. We are particularly interested in how these technologies, managed by Automated Decision-Making systems, affect accessibility, fairness, and equity in energy use, especially in diverse communities.

Materials you will need:

- *A set of 25 statements (provided)*
- *The Q-sort grid (provided)*
- *Scenario visualisations (provided)*
- *A pen or pencil*

Objective
You will rank the provided statements about energy distribution, Automated Decision-Making, and Electric Vehicle charging technologies based on how much you agree or disagree with each one, reflecting your own perspective.

Scenario Overview
Before starting the Q-sort, it's important to familiarise yourself with two hypothetical scenarios representing different approaches to Automated Decision-Making in Electric Vehicle charging infrastructure. These scenarios will help you understand the implications of the statements. A visual representation of the scenarios will also be provided.

Scenario One: Solar-Rich and Grid-Strained: Navigating Energy Choices in a Wealthy Suburb
Amelia lives in a wealthy suburban neighbourhood where many residents have installed solar panels on their roofs and their own electric vehicles (EVs). These homes are now equipped with *Vehicle-to-Grid (V2G)* technology, which allows EVs not only to charge from the grid but also to send electricity back into it when needed.

One evening, Amelia plugs her EV into the charger in her driveway. Her charger is set to work with an *Automated Decision-Making (ADM)* system, which manages when her car charges or discharges energy based on how much electricity the grid needs and the battery's status. The system calculates the best time for her car to charge, and a message pops up: "Charging will start at 23:00 at night. when electricity is cheaper. Your car will be fully charged by 07:00 in the morning".

Later that night, at 20:00, Amelia receives a notification on her phone: "Due to high electricity demand in your neighbourhood, your car could help support the grid by discharging some power. You'll receive a €5,- credit. Your energy could help maintain electricity for a nearby family with a newborn who needs constant heating due to a medical condition. Would you like to proceed?"

Amelia, knowing that she does not need her car fully charged in the morning, agrees to discharge some energy. She feels good about helping her neighbours and receiving a small reward while still ensuring her car will be ready by the next day.

At the same time, her neighbour Liam receives the same message. However, Liam has a long trip planned for early next morning and worries that discharging too much energy will leave him with insufficient charge. He decides to decline the offer and opts to keep his battery full, knowing that the Automated Decision-Making system allows him to prioritise his own needs.

Scenario Two: Charging Dilemmas: Fairness and Frugality in a Social Housing Community

Rosa lives in a neighbourhood with mostly social housing, where many residents have switched to using electric vehicles (EVs) to reduce fuel costs. Public charging stations in the area have recently been upgraded with smart charging technology, which is managed by an Automated Decision-Making (ADM) system. This system controls the speed and timing of each car's charging based on how much electricity the grid can handle and how urgently each car needs to be charged.

After her shift as a nurse, Rosa plugs in her Electric Vehicle at one of the public charging stations. The charging station displays a message: "Due to high demand, charging will be slower. Estimated time to full charge: 3 hours. You can choose priority charging for an additional €2,- fee."

As Rosa considers paying the extra fee, another notification appears: "If you choose slower charging, the saved energy could help a nearby resident who relies on medical equipment. Would you like to proceed with slower charging?"

Rosa feels conflicted. She needs her car to be ready for work the next morning but also knows that by choosing the slower option, she could help someone with urgent medical needs. She decides to go for the slower charge, hoping her choice will support her neighbour while still allowing her car to be fully charged by morning.

Meanwhile, Marcus, another resident, also plugs in his Electric Vehicle but opts for the priority charging option. He has an important meeting early in the morning and needs his car fully charged as soon as possible. While Marcus understands the potential community benefit of slower charging, he feels it's unfair to ask people with tight schedules to sacrifice their own needs.

Important notes:

- *This is not a test, and there are no right or wrong answers. We are solely interested in your opinions and viewpoints.*
- *The Automated Decision-Making systems in the scenarios described above are hypothetical but are based on real-world possibilities in Electric Vehicle charging technologies.*

Q-sort instructions

These instructions will guide you through the survey step by step. Please read each step to the end before you start carrying it out.

1. **Initial sorting**
   a) Take the deck of cards [see Annex C] and the score sheet, then sit at a table.
   b) Lay the score sheet [see Annex D] in front of you. All 25 cards in the deck contain a statement about *Automated Decision-Making* in charging infrastructure. We ask you to rank-order these statements from your point of view. Our question: “To what extent do you agree with the following statements?” The numbers on the cards (from 1 to 25) are randomly assigned and are for response administration only.
   c) Read the 25 statements carefully and split them into three piles: one for statements you tend to disagree with, one for statements you tend to agree with, and one for statements you neither agree nor disagree with. Use the “AGREE,” “NEUTRAL,” and “DISAGREE” boxes on the score sheet. Enter the number of cards in each pile, ensuring they total 25.
2. **Refining your choices**
   d) Take the cards from the “AGREE” pile and read them again. Select the statement you most agree with and place it in the box below “4” on the far right of the score sheet. From the remaining cards, select the two statements you next most agree with, placing them in the boxes below “3.” Continue this process for all “AGREE” cards.
   e) Now take the cards from the “DISAGREE” pile and read them again. Select the statement you most disagree with and place it in the box below “-4” on the far left of the score sheet. Repeat this process for all “DISAGREE” cards.
   f) Finally, take the “NEUTRAL” pile and distribute the statements across the middle of the grid (from “-1” to “+1”) based on your level of agreement or neutrality.
3. **Review and adjust**
   g) Once you have placed all the statements on the grid, review your distribution. Adjust as necessary if your perspective changes upon reflection.
4. **Explain your answers**
   h) Please explain why you agree most with the three statements placed below “3” and “4.”

      Card number: ... :

      Card number: ... :

      Card number: ... :

   i) Please explain why you disagree most with the three statements placed below “-3” and “-4.”

      Card number: ... :

      Card number: ... :

      Card number: ... :

5. **Finalise your responses**
   j) Once sorting and explanations are complete, record each card number in its respective box on the Q-sort grid.

B.2.3. Cards with 25 statements

1

Automated Decision-Making should prioritise fairness in how resources like energy are distributed.

2

Wealthier users will benefit more from Automated Decision-Making-managed systems, which could deepen existing inequalities.

3

People should have more control over their energy use, even if Automated Decision-Making could optimise it for them.

4

I trust Automated Decision-Making systems to manage energy distribution better than humans could.

5

Automated Decision-Making can help make energy use more efficient, but I am concerned about its transparency.

6

The implementation of Automated Decision-Making systems in energy distribution should involve public input and participatory decision-making.

7

It's important that Automated Decision-Making systems are designed to reduce costs for lower-income households.

8

Vehicle-To-Grid systems should ensure that Electric Vehicle users are compensated fairly for contributing energy back to the grid.

9

Automated Decision-Making should prioritise energy returned to the grid from public chargers, not just private chargers.

10

I worry that Automated Decision-Making might prioritise areas with higher Electric Vehicle ownership for Vehicle-To-Grid deployment, leaving out others.

11

Automated Decision-Making should ensure that Vehicle-To-Grid benefits are distributed equally across different socioeconomic groups.

12

ADM should prioritise V2G decision-making to support users from vulnerable socioeconomic backgrounds who rely on their EVs for work and healthcare.

13

Vehicle-To-Grid technology can help reduce the strain on the grid during peak hours.

14

The success of Vehicle-To-Grid systems depends on the grid's ability to handle large amounts of bidirectional energy flow.

15

Automated Decision-Making-controlled Vehicle-To-Grid can help integrate more renewable energy sources into the grid.

16

ADM should ensure that users who rely on their EVs for work and healthcare are prioritised in V2G decision-making.

17

Smart Charging should ensure equal access to charging opportunities for all, regardless of socioeconomic status.

18

Smart Charging should allow users to choose between faster and slower charging based on their needs.

19

Dynamic pricing for Smart Charging could unfairly affect lower-income users who may need to charge during peak hours.

20

Automated Decision-Making should focus on optimising energy distribution, even if it means slowing charging at certain times.

21

Smart Charging can lead to lower energy costs for Electric Vehicle users.

22

I support the use of Automated Decision-Making to prioritise EV charging during off-peak hours.

23

Smart Charging can contribute to reducing overall carbon emissions from the energy grid.

24

Automated Decision-Making should prioritise charging for those who rely on their EV for essential travel, such as commuting or caregiving.

25

Automated Decision-Making should ensure that users in public housing areas have the same access to Smart Charging infrastructure as wealthier areas.

B.2.4. Score sheet for Q sorting (Q-sort grid)

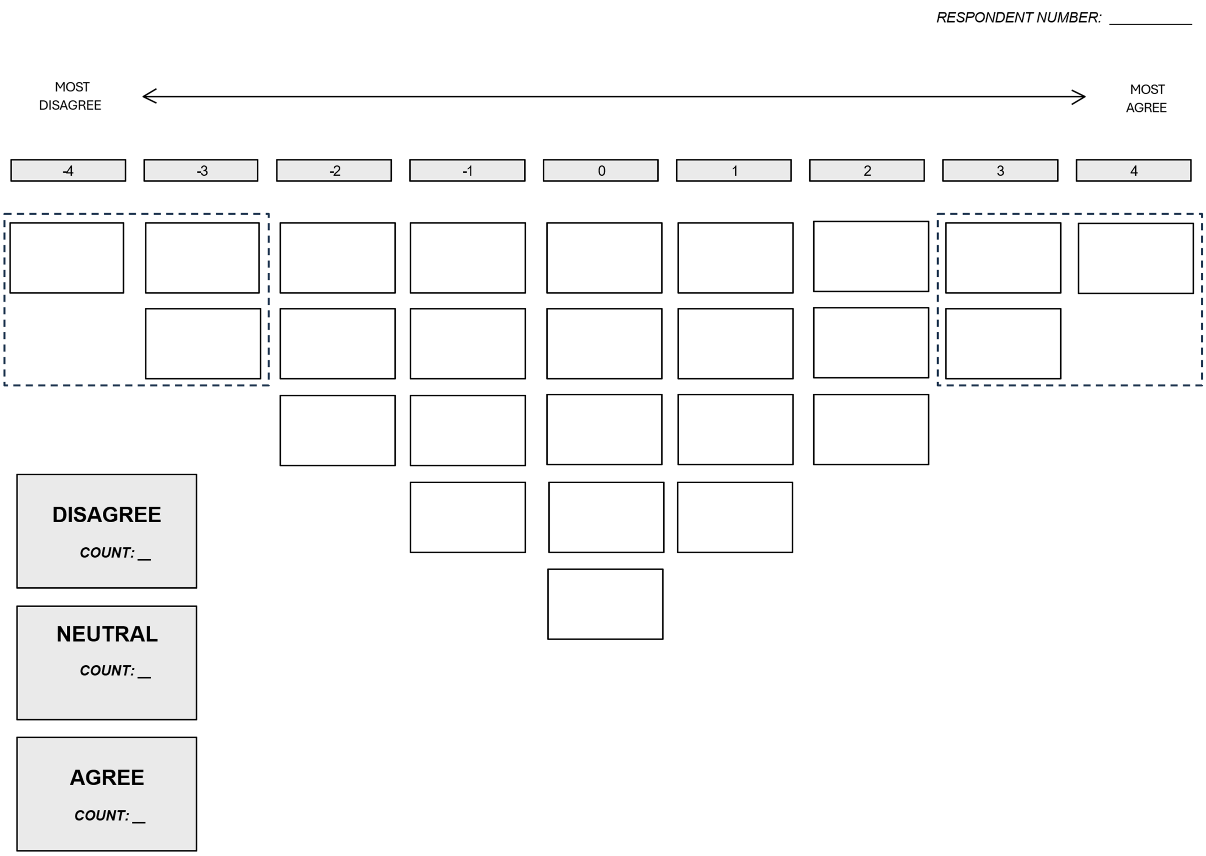

Figure B.1: Q-sort Grid following a Quasi-Normal Distribution.

C

Q-methodology: Analysis and Results

C.1. Participant's Q-sorts Overview and Correlation Matrix

Table C.1: Overview of Participants (P) and Sort Values (S)

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
S1	1	-1	0	1	4	2	2	0	3	3
S2	-3	1	-1	0	-3	2	1	-4	1	2
S3	0	-1	0	0	-1	0	1	-2	-1	-1
S4	3	1	-1	3	-1	-3	4	1	0	-4
S5	3	-2	-3	-2	-2	0	3	-2	-1	0
S6	-2	0	-1	2	-2	1	1	1	2	1
S7	4	-1	0	2	-1	-2	-3	4	-4	1
S8	1	2	1	1	0	-2	2	0	-2	-3
S9	1	-3	1	-2	-2	0	-4	-3	4	2
S10	-1	-1	0	-2	-4	-1	0	-1	-2	1
S11	1	-2	2	-1	0	3	3	-3	1	2
S12	-2	-4	-2	3	1	-3	-1	0	-3	3
S13	0	3	3	-1	3	0	-1	3	-1	-1
S14	-2	4	1	0	3	1	0	-1	-2	-2
S15	-4	0	-3	0	2	0	0	-1	-1	-1
S16	-1	-2	-2	4	1	-2	-1	0	-3	0
S17	-1	2	4	-3	2	4	2	2	0	-3
S18	0	3	-1	-4	0	1	-3	1	1	0
S19	0	-3	-4	-3	-3	3	1	2	2	1
S20	-1	0	3	0	2	-1	0	-1	3	0
S21	0	1	1	2	-1	1	-2	0	1	-2
S22	2	2	0	1	0	-1	-2	1	2	-1
S23	-3	1	2	-1	0	-1	-1	-2	0	-2
S24	2	0	-2	-1	1	-4	-2	3	0	0
S25	2	0	2	1	1	2	0	2	0	4

An Overview Table of Participants and Sort Values (Table C.1) was created, combining all Q-sort grids for each participant into a single table, which served as the primary input for the KADE software. This table provided a structured view of each participant's rankings across statements, ensuring consistent data preparation for subsequent analyses. Using this consolidated table, a correlation matrix (Table C.2) was generated to assess the relationships and similarities in the participants' rankings of statements. This matrix provided a comparative view of inter-participant correlations, serving as the foundation for both the Centroid Factor Analysis (CFA) and Principal Component Analysis (PCA). By examining the correlation values, it was possible to identify areas of consensus or divergence among participants, facilitating the extraction of distinct factors in each analysis. The same correlation matrix was applied to both CFA and PCA to ensure consistency across methods and support a comprehensive interpretation of participant perspectives.

Table C.2: Correlation Matrix of Participant Q-sorts

	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
P1	100	-12	0	6	-11	-21	3	41	0	4
P2	-12	100	44	-13	35	10	-3	21	-2	-60
P3	0	44	100	-11	37	26	-3	0	15	-18
P4	6	-13	-11	100	16	-46	5	11	-32	1
P5	-11	35	37	16	100	1	-1	26	-6	-11
P6	-21	10	26	-46	1	100	28	-18	43	21
P7	3	-3	-3	5	-1	28	100	-22	0	-18
P8	41	21	0	11	26	-18	-22	100	-23	-11
P9	0	-2	15	-32	-6	43	0	-23	100	19
P10	4	-60	-18	1	-11	21	-18	-11	19	100

Before conducting the Q-sort, each participant performed an initial sorting of statements into three categories: ”Agree,” ”Neutral,” and ”Disagree” (see Table C.3). This preliminary sorting was intended to simplify the Q-sort task by allowing participants to initially reflect on their general agreement with each statement. Although the numbers from this initial sort provide insight into each participant's initial preferences, they were not included in the subsequent factor analyses. This step primarily served to streamline the Q-sort process, ensuring participants could engage more thoughtfully with the ranking in the final Q-sort grid.

Table C.3: CFA - Initial Sorting of Statements by Participants

Participant	Agree	Neutral	Disagree
1	16	5	4
2	11	7	7
3	14	7	4
4	14	5	6
5	17	4	4
6	10	11	4
7	15	9	1
8	13	6	6
9	13	8	4
10	16	6	3

C.2. Centroid Factor Analysis

The following appendices provide a detailed account of the steps taken in the Centroid Factor Analysis (CFA), documenting each stage of the process meticulously from the initial Q-sort data input to the final interpretation of extracted factors. This section outlines the key decisions made at each stage, covering the criteria applied for factor extraction, the rotation method selected, and the flagging of participants who demonstrated strong associations with specific factors. Accompanying tables summarise essential data outputs, including matrices and factor loadings, providing a clear view of how participants' responses align with different perspectives. This step-by-step documentation not only ensures transparency in the analysis but also supports the replicability of the CFA procedure within this study. Researchers following this methodology can better understand the rationale behind each decision, making it easier to adapt or replicate these steps in future studies that employ Q-methodology..

C.2.1. Unrotated Factor Matrix and Factor Extraction (CFA)

The Unrotated Factor Matrix (Table C.4) presents the factor loadings for each participant across the three extracted factors. Factor loadings, which represent the correlation of each participant's Q-sort with the underlying factors, serve as a key indicator of how strongly each participant's views align with the themes represented by each factor. Generally, loadings above 0.4 (in italics in the table) indicate a notable association, suggesting that the participant has a strong alignment with that factor's perspective. The eigenvalues displayed at the bottom of the table represent the amount of variance each factor independently explains. Specifically, Factor 1, with an eigenvalue of 1.38, accounts for 14% of the variance; Factor 2 explains 16% (eigenvalue of 1.57), and Factor 3 accounts for 7% of the variance with an eigenvalue of 0.74, resulting in a combined cumulative variance explained of 37%. This breakdown illustrates the degree to which each factor contributes to the overall variance in participants' responses.

Table C.4: CFA - Unrotated Factor Matrix

Participant	Factor 1	Factor 2	Factor 3
P1	-0.3055	0.0918	0.2254
P2	*0.5313*	*0.6363*	-0.0273
P3	*0.5313*	0.3271	0.2850
P4	-0.3316	0.2259	-0.1364
P5	0.1450	0.4131	0.0999
P6	*0.6431*	-0.4847	0.2807
P7	0.1683	-0.0726	-0.1433
P8	-0.1818	*0.5585*	*0.4304*
P9	0.2835	-0.3208	0.3116
P10	-0.1954	-0.4178	*0.4485*
Eigenvalues	1.3825	1.5716	0.7442
% Explained Variance	14%	16%	7%
Cumulative % Explained Variance	14%	30%	37%

With a small sample size of 10 participants and the exploratory nature of this study, a 3-factor solution was considered most appropriate. This choice allowed distinct perspectives to emerge without adding unnecessary complexity to the factor structure. Maintaining a manageable number of factors enabled a balance between interpretative depth and statistical clarity. The 3-factor solution captured the primary themes in the data, allowing the analysis to yield meaningful insights while avoiding overfitting. To enhance interpretative quality, Brown Centroid Factor Rotation was applied, aligning with the goal of capturing nuanced, subjective viewpoints. Prioritising interpretative flexibility over maximising variance, this rotation uncovered subtle, overlapping perspectives in participants' responses. Using this technique deepened interpretative insight within each factor, enabling a layered exploration of participant perspectives, revealing complex, intertwined views without strictly maximising explained variance.riance, which may have reduced the subtleties captured in participant perspectives.

C.2.2. Factor Flagging (CFA)

Participants with factor loadings of 0.4 or higher on a single factor were flagged, indicating a strong association with that factor. This approach enhances interpretative clarity by clearly identifying participants who are closely aligned with particular factors, thereby defining the unique perspectives and thematic distinctions represented by each factor. (see Table C.5)

Table C.5: CFA - Factor Loadings and Flagged Participants by Factor

Participant	Factor Group (FG)	Factor 1	F	Factor 2	F	Factor 3	F
P6	F1-1	0.8032	✓	0.0237		-0.2859	
P9	F1-2	0.5279	✓	-0.0411		-0.0082	
P4	F1-3	-0.396	✓	-0.0301		0.148	
P10	F1-4	0.391		-0.3636		0.3589	
P2	F2-1	-0.0575		0.8066	✓	-0.1842	
P3	F2-2	0.3024		0.6153	✓	-0.0199	
P5	F2-3	-0.0791		0.4328	✓	0.0897	
P8	F3-1	-0.141		0.427		0.5727	✓
P1	F3-2	-0.0854		-0.0565		0.377	
P7	F3-3	0.0472		0.0098		-0.2276	

C.2.3. Factor Loadings (CFA)

Table C.6 provides a comprehensive summary of key metrics derived from the factor analysis, including correlations, characteristics, and standard errors for each factor's z-Scores. Correlations between factors highlight significant relationships, marked in italics to emphasise interpretative value. The Factor Characteristics consist of the number of defining variables, reliability coefficients, composite reliability, and standard errors, with Factor 3's distinctive metrics italicised to draw attention to unique findings. Standard Errors for Differences in Factor z-Scores illustrate variability across the different factors, indicating consistency and reliability in the factor structure.

Table C.6: CFA - Summary of Correlations, Characteristics, and Standard Errors

Correlations between Factor Scores			
	Factor 1	**Factor 2**	**Factor 3**
Factor 1	1	0.1441	-0.2152
Factor 2	0.1441	1	*0.1986*
Factor 3	-0.2152	*0.1986*	1
Factor Characteristics			
	Factor 1	**Factor 2**	**Factor 3**
No. of Defining Variables	3	3	1
Avg. Rel. Coef.	0.8	0.8	0.8
Composite Reliability	*0.923*	*0.923*	0.8
S.E. of Factor z-scores	0.277	0.277	*0.447*
Standard Errors for Differences in Factor z-Scores			
	Factor 1	**Factor 2**	**Factor 3**
Factor 1	*0.392*	0.392	0.526
Factor 2	0.392	*0.392*	0.526
Factor 3	0.526	0.526	*0.632*

Based on flagged participants, KADE generated composite Q-sorts for each factor, which summarise the characteristic rankings of statements within each factor. These composite sorts provide an averaged perspective of participants associated with each factor, highlighting the most and least agreed-upon statements. The highest and lowest-ranked statements within each factor guided the thematic conclusions in the interpretation phase, allowing for a focused exploration of the central themes represented by each factor.

Table C.7: CFA - Q-Sort Composite Scores by Statement and Factor

Statement	Factor 1		Factor 2		Factor 3	
#	z-Score	Rank	z-Score	Rank	z-Score	Rank
1	*1.05*	4	-0.03	12	0	11
2	0.88	5	-0.04	13	*-1.96*	25
3	-0.12	15	-0.44	18	-0.98	20
4	*-1.38*	21	0.12	11	0.49	7
5	0.04	12	*-1.35*	23	-0.98	21
6	0.47	9	-0.32	16	0.49	8
7	*-1.41*	22	-0.44	19	*1.96*	1
8	*-1.09*	20	*0.88*	5	0	12
9	0.65	8	-1.09	22	*-1.47*	23
10	-0.47	19	-0.69	20	-0.49	16
11	*1.34*	3	-0.41	17	-1.47	24
12	*-1.75*	25	*-1.67*	24	0	13
13	-0.04	14	*1.79*	2	*1.47*	2
14	0.13	11	*1.85*	1	-0.49	17
15	-0.12	16	-0.3	15	-0.49	18
16	-1.45	24	-0.95	21	0	14
17	*1.76*	1	*1.51*	3	0.98	4
18	0.82	6	0.93	4	0.49	9
19	*1.62*	2	*-1.95*	25	0.98	5
20	-0.01	13	0.63	8	-0.49	19
21	0.35	10	0.43	9	0	15
22	-0.21	17	0.72	6	0.49	10
23	-0.3	18	0.67	7	-0.98	22
24	*-1.44*	23	-0.23	14	*1.47*	3
25	0.68	7	0.39	10	0.98	6

Table C.8 provides a focused view on statements that strongly differentiate each factor, highlighting those with the highest and lowest z-scores across factors. This contrasts with the overall Factors Table, which presented a broader summary of each factor's composite Q-sort scores. Here, the selected statements are those with statistically significant z-scores, marking them as defining elements of each factor. These distinguishing statements help in understanding the unique perspectives and priorities associated with each factor, offering deeper insight into the specific viewpoints and themes that set one factor apart from the others.

Table C.8: CFA - Q-Sort Statements and z-Scores by Factor

Factor 1: Equity in Energy Distribution				
Threshold	**z-Score**	**Q Sort Value**	**#**	**Statement**
P < 0.005	*-1.44*	-3	24	ADM should prioritise charging for those who rely on their EV for essential travel, such as commuting or caregiving.
P < 0.05	*-1.41*	-2	7	It's important that ADM systems are designed to reduce costs for lower-income households.
P < 0.05	*-1.09*	-2	8	V2G systems should ensure that EV users are compensated fairly for contributing energy back to the grid.
P < 0.0005	*-1.38*	-2	4	I trust ADM systems to manage energy distribution better than humans could.
P < 0.005	-0.04	0	13	V2G technology can help reduce the strain on the grid during peak hours.
P < 0.0001	0.65	1	9	ADM should prioritise energy returned to the grid from public chargers, not just private chargers.
P < 0.05	*1.05*	2	1	ADM should prioritise fairness in how resources like energy are distributed.
P < 0.05	0.88	2	2	Wealthier users will benefit more from ADM-managed systems, which could deepen existing inequalities.
P < 0.0001	*1.34*	3	11	ADM should ensure that V2G benefits are distributed equally across different socioeconomic groups.
Factor 2: Environmental Responsibility and Grid Reliability				
Threshold	**z-Score**	**Q Sort Value**	**#**	**Statement**
P < 0.0001	*-1.95*	-4	19	Dynamic pricing for SC could unfairly affect lower-income users who may need to charge during peak hours.
P < 0.05	-0.44	-1	7	It's important that ADM systems are designed to reduce costs for lower-income households.
P < 0.05	-0.41	-1	11	ADM should ensure that V2G benefits are distributed equally across different socioeconomic groups.
P < 0.05	-0.04	0	2	Wealthier users will benefit more from ADM-managed systems, which could deepen existing inequalities.
P < 0.005	-0.23	0	24	ADM should prioritise charging for those who rely on their EV for essential travel, such as commuting or caregiving.
P < 0.05	0.67	1	23	SC can contribute to reducing overall carbon emissions from the energy grid.
P < 0.0001	*1.85*	4	14	The success of V2G systems depends on the grid's ability to handle large amounts of bidirectional energy flow.
Factor 3: Advocacy for Socioeconomic Sensitivity in ADM				
Threshold	**z-Score**	**Q Sort Value**	**#**	**Statement**
P < 0.0005	*-1.96*	-4	2	Wealthier users will benefit more from ADM-managed systems, which could deepen existing inequalities.
P < 0.05	*-1.47*	-3	11	ADM should ensure that V2G benefits are distributed equally across different socioeconomic groups.
P < 0.005	0	0	12	ADM should prioritise V2G decision-making to support users from vulnerable socioeconomic backgrounds who rely on their EVs for work and healthcare.
P < 0.005	*1.47*	3	24	ADM should prioritise charging for those who rely on their EV for essential travel, such as commuting or caregiving.
P < 0.0001	*1.96*	4	7	It's important that ADM systems are designed to reduce costs for lower-income households.

C.3. Principal Component Analysis

The following sections provide a detailed overview of the steps taken in the Principal Component Analysis (PCA) process. Each stage is documented, from the initial input of Q-sort data to the final interpretation of extracted components. Key decisions made at each step are described, including factor extraction criteria, the selection of rotation methods, and participant flagging based on their component loadings. The included tables summarise essential outputs, ensuring transparency and facilitating the reproducibility of the PCA process applied in this study. The following subsections and tables will help illustrate how distinct participant perspectives emerged through PCA.

C.3.1. Unrotated Factor Matrix and Component Extraction (PCA)

The Unrotated Factor Matrix (Table C.9) presents the unrotated factor loadings for each participant across the four selected factors. These loadings represent the correlation between each participant's Q-sort and each of the retained components, indicating the strength of association. Loadings greater than 0.4, typically considered significant, suggest a notable alignment with the component's theme. The eigenvalues listed at the bottom of the table represent the amount of variance each component independently explains. Specifically, an eigenvalue of 2.1494 for Factor 1 accounts for 21% of the variance, while Factor 2, with an eigenvalue of 2.1293, also explains 21%. Factor 3, with an eigenvalue of 1.3252, contributes 13% of the variance, and Factor 4, with an eigenvalue of 1.1238, explains 11%. Together, these four components capture 66% of the total variance, effectively summarising the main perspectives within the data [81]. By focusing on these components, the analysis achieves a balance between interpretative depth and simplicity, capturing the essential thematic dimensions without excessive complexity.

Table C.9: PCA - Unrotated Factor Matrix First Four Factors

Participant	**Factor 1**	**Factor 2**	**Factor 3**	**Factor 4**
P1	0.1593	-0.3346	*0.5758*	*0.5931*
P2	*0.6511*	*0.5858*	-0.0617	0.0743
P3	0.3356	*0.6416*	0.1935	-0.1443
P4	0.3322	-0.5434	-0.2727	-0.2409
P5	*0.5514*	0.3010	0.0940	-0.4218
P6	-0.4406	*0.7035*	0.1216	0.0831
P7	-0.1319	0.1896	-0.5047	*0.5674*
P8	*0.5818*	-0.2184	*0.5634*	0.1622
P9	-0.4744	0.4820	0.3432	0.0256
P10	-0.6308	-0.2565	*0.4054*	-0.3922
Eigenvalues	2.1494	2.1293	1.3252	1.1238
% Explained Variance	21%	21%	13%	11%
Cumulative % Explained Variance	21%	42%	55%	66%

C.3.2. Factor Flagging (PCA)

Participants with factor loadings of 0.4 or higher on a single factor were flagged, indicating a strong association with that factor. This flagging method clarifies the interpretative structure by identifying participants whose views align closely with specific factors, allowing for a focused thematic exploration. Table C.10 summarises the flagged participants by factor, showing those with a notable association to a particular factor and grouping them within the relevant factor group (FG).

Table C.10: PCA - Factor Loadings and Flagged Participants by Factor

Participant	FG	Factor 1	F	Factor 2	F	Factor 3	F	Factor 4	F
Participant 2	F1-1	0.822	✓	0.0455		0.0715		0.306	
Participant 5	F1-2	0.708	✓	-0.1399		-0.0576		-0.2394	
Participant 3	F1-3	0.6938	✓	0.3153		-0.0026		-0.0417	
Participant 6	F2-1	0.0929		0.8043	✓	-0.2187		0.0866	
Participant 9	F2-2	-0.0396		0.7427	✓	-0.0489		-0.1424	
Participant 4	F2-3	-0.0448		0.7236	✓	-0.0574		-0.0953	
Participant 1	F3-1	-0.2001		0.0254		0.8815	✓	0.054	
Participant 8	F3-2	0.2936		-0.2181		0.7495	✓	-0.1857	
Participant 7	F4-1	-0.1576		0.1219		-0.1294		0.7574	✓
Participant 10	F4-2	-0.5012		0.2471		-0.095		-0.6787	✓

C.3.3. Factor Loadings (PCA)

Table C.11 summarises key PCA metrics, including correlations, characteristics, and standard errors for each factor's z-scores. Correlations between factors, with notable values italicised, highlight interpretive relevance. Factor characteristics cover defining variable counts, reliability coefficients, composite reliability, and standard errors, with specific factor metrics italicised. Standard Errors for Differences in Factor z-scores illustrate variability, showing factor structure consistency and reliability.

Table C.11: PCA - Summary of Correlations, Characteristics, and Standard Errors (PCA)

Correlations between Factor Scores				
	Factor 1	**Factor 2**	**Factor 3**	**Factor 4**
Factor 1	1	0.1067	-0.0137	*0.2239*
Factor 2	0.1067	1	*-0.1852*	0.002
Factor 3	-0.0137	-0.1852	1	-0.0364
Factor 4	*0.2239*	0.002	-0.0364	1
Factor Characteristics				
	Factor 1	**Factor 2**	**Factor 3**	**Factor 4**
No. of Defining Variables	3	3	2	2
Avg. Rel. Coef.	0.8	0.8	0.8	0.8
Composite Reliability	*0.923*	*0.923*	0.889	0.889
S.E. of Factor z-scores	0.277	0.277	*0.333*	*0.333*
Standard Errors for Differences in Factor Z-scores				
	Factor 1	**Factor 2**	**Factor 3**	**Factor 4**
Factor 1	*0.392*	0.392	0.433	0.433
Factor 2	0.392	*0.392*	0.433	0.433
Factor 3	0.433	0.433	*0.471*	0.471
Factor 4	0.433	0.433	0.471	*0.471*

Using flagged participants, KADE generated composite Q-sorts for each principal component, summarising statement rankings. These composite sorts average views for each component, highlighting the most and least agreed-upon statements. The top-ranked statements guided thematic conclusions, enabling focused exploration of each component's main themes.

Table C.12: PCA - Q-Sort Composite Scores by Statement and Factor

Statement	Factor 1		Factor 2		Factor 3		Factor 4	
#	z-Score	Rank	z-Score	Rank	z-Score	Rank	z-Score	Rank
1	0.37	10	*0.92*	6	0.4	8	-0.05	13
2	-0.36	16	0.71	7	*-1.87*	25	-0.15	15
3	-0.47	17	-0.19	17	-0.34	16	0.63	5
4	-0.03	12	*-1.31*	22	*1.35*	2	*2.53*	1
5	*-1.41*	24	0.16	11	0.84	6	*1.11*	4
6	-0.49	19	0.29	10	-0.62	20	0.11	10
7	-0.47	18	*-1.63*	23	*2.26*	1	*-1.37*	24
8	*0.76*	5	*-1.08*	21	0.4	9	*1.53*	2
9	*-1.08*	22	*1.11*	5	-0.12	14	*-2*	25
10	-0.97	21	-0.29	19	-0.56	18	-0.26	17
11	-0.28	15	*1.15*	3	-0.12	15	0.59	6
12	*-1.35*	23	*-1.88*	25	-0.79	21	*-1.16*	23
13	*1.88*	1	-0.02	13	0.51	7	-0.11	14
14	*1.86*	2	-0.12	16	-0.96	22	0.52	7
15	-0.14	13	-0.19	18	*-1.75*	24	0.26	8
16	-0.75	20	*-1.79*	24	-0.4	17	-0.37	18
17	*1.57*	3	*1.57*	2	-0.05	13	*1.53*	3
18	0.74	6	*1.15*	4	0.17	11	*-1.11*	22
19	*-2.04*	25	*1.69*	1	0.34	10	0.11	11
20	*0.81*	4	0.31	9	-0.56	19	0	12
21	0.29	11	0.1	12	0	15	-0.22	16
22	0.6	8	-0.06	14	*0.96*	5	-0.48	19
23	0.62	7	-0.09	15	*-1.53*	23	0.15	9
24	-0.15	14	*-0.87*	20	*1.3*	3	-0.74	20
25	0.49	9	0.35	8	*1.13*	4	*-1.05*	21

Table C.14 highlights statements that best differentiate each component, focusing on those with the highest and lowest z-scores. Unlike the broader summary in the Components Table, this view emphasises statements with statistically significant z-scores, marking them as key elements of each component. These distinctions help clarify the unique perspectives and priorities within each component, offering deeper insights into the specific viewpoints and themes that set them apart.

Table C.14: PCA - Q-Sort Statements and z-Scores by Factor

Threshold	z-Score	Q-Sort Value	#	Statement
Factor 1: Trust in ADM for Efficient Energy Management				
P < 0.005	0.03	0	4	I trust ADM systems to manage energy distribution better than humans could.
P < 0.0001	*-1.41*	-3	5	ADM can help make energy use more efficient, but I am concerned about its transparency.
P < 0.05	*-0.47*	-1	7	It’s important that ADM systems are designed to reduce costs for lower-income households.
P < 0.0005	*-1.08*	-2	9	ADM should prioritise energy returned to the grid from public chargers, not just private chargers.

Threshold	z-Score	Q-Sort Value	#	Statement
P < 0.05	*1.88*	4	13	V2G technology can help reduce the strain on the grid during peak hours.
P < 0.005	*1.86*	3	14	The success of V2G systems depends on the grid's ability to handle large amounts of bidirectional energy flow.
P < 0.0001	*-2.04*	-4	19	Dynamic pricing for SC could unfairly affect lower-income users who may need to charge during peak hours.
Factor 2: Fairness and Equity in Energy Access and ADM Impact				
P < 0.05	*0.71*	1	2	Wealthier users will benefit more from ADM-managed systems, which could deepen existing inequalities.
P < 0.005	*-1.31*	-2	4	I trust ADM systems to manage energy distribution better than humans could.
P < 0.0001	*0.88*	2	8	V2G systems should ensure that EV users are compensated fairly for contributing energy back to the grid.
P < 0.05	*-1.08*	-1	9	ADM should prioritise energy returned to the grid from public chargers, not just private chargers.
P < 0.005	*-1.79*	-3	16	ADM should ensure that users who rely on their EVs for work and healthcare are prioritised in V2G decision-making.
P < 0.0001	*1.69*	4	19	Dynamic pricing for SC could unfairly affect lower-income users who may need to charge during peak hours.
Factor 3: Protection for Vulnerable Users in ADM Implementation				
P < 0.0001	*-1.87*	-4	2	Wealthier users will benefit more from ADM-managed systems, which could deepen existing inequalities.
P < 0.05	*1.35*	3	4	I trust ADM systems to manage energy distribution better than humans could.
P < 0.001	*2.26*	4	7	It's important that ADM systems are designed to reduce costs for lower-income households.
P < 0.05	-0.12	0	9	ADM should prioritise energy returned to the grid from public chargers, not just private chargers.
P < 0.005	-0.05	0	17	SC should ensure equal access to charging opportunities for all, regardless of socioeconomic status.
P < 0.001	*-1.53*	-3	23	SC can contribute to reducing overall carbon emissions from the energy grid.
P < 0.001	*1.3*	3	24	ADM should prioritise charging for those who rely on their EV for essential travel, such as commuting or caregiving.
Factor 4: Confidence in ADM for Technical and Environmental Goals				
P < 0.05	*2.53*	4	4	I trust ADM systems to manage energy distribution better than humans could.
P < 0.05	*-1.11*	-2	9	ADM should prioritise energy returned to the grid from public chargers, not just private chargers.
P < 0.05	*-1.11*	-2	18	SC should allow users to choose between faster and slower charging based on their needs.
P < 0.05	*-1.05*	-2	25	ADM should ensure that users in public housing areas have the same access to SC infrastructure as wealthier areas.

C.4. Comparison between CFA and PCA

Table C.15: Comparative Analysis of CFA and PCA Results

Comparison Criteria	Centroid Factor Analysis (CFA)	Principal Component Analysis (PCA)
Methodological Approach	Based on correlation matrix and extraction of shared variance with fewer assumptions about underlying structure.	Based on maximisation of total variance, focusing on component orthogonality and minimising redundancy.
Factor/Component Selection	3 factors were selected, emphasising interpretative flexibility and allowing subtle overlaps in perspectives.	4 components were retained to capture primary themes with an increased focus on distinct thematic dimensions.
Variance Explained	37% cumulative variance, with Factor 1 contributing the most (14%)	66% cumulative variance across the first four components, with Component 1 explaining 21%
Eigenvalues	Lower eigenvalues due to the emphasis on shared variance over total explained variance.	Higher eigenvalues in earlier components, emphasising unique variance; Component 1 with eigenvalue of 2.15.
Participant Flagging	Participants flagged if factor loadings were ≥ 0.4, linking them closely to interpretative themes without maximising variance explanation.	Participants flagged with a loading threshold of ≥ 0.4 to focus on principal components that maximise unique perspectives.
Factor/Component Reliability	Average reliability coefficient of 0.8 across factors; Factor 1 and Factor 2 had high composite reliability (0.923).	Similar reliability coefficients (0.8), with slightly lower composite reliability for Components 3 and 4 (0.889).
Significant Factor/Component Correlations	Low to moderate inter-factor correlations, indicating overlaps in participant perspectives across factors (Factor 2 and Factor 3 had the highest correlation at 0.1986).	Moderate inter-component correlations, with significant correlations marked between Component 1 and Component 4 (0.2239).
Thematic Interpretation	Factors captured participant values like equity, protection of vulnerable users, and grid stability with nuanced overlaps in perspectives.	Components reflected more distinct themes, with clear delineations in confidence in ADM and energy management focus, attributed to maximised orthogonal structure.
Qualitative Insights	CFA provided insights into participants' overlapping values and allowed for a more fluid interpretation of viewpoints with flexibility in loading structure.	PCA highlighted distinct thematic clusters, focusing on independent viewpoints without as much interpretative overlap, supporting a structured view of participant themes.