USERS AND THE UPSCALING OF INNOVATION IN SUSTAINABILITY TRANSITIONS

THE CASES OF CAR-SHARING AND ELECTRIC VEHICLES

TOON MEELEN

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The cases of car-sharing and electric vehicles

Gebruikers en het opschalen van innovaties in duurzaamheidstransitities
De casus autodelen en elektrische auto's

(met een samenvatting in het Nederlands)

Proefschrift

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Content

Chapter 1

Introduction

On 26 February 2018, in a cafeteria in the Dutch city of Eindhoven, I had an interview with an EVangelist. He was not telling me anything about the word of God, for he had not earned his sobriquet EVangelist by spreading religion, but by converting many people to the Electric Vehicle (EV). In his own words, he had made hundreds of people buy a Tesla as well. He had preached to them about the benefits of electric driving, and let them make test drives in his own car. This user could not be seen as acting alone, as behind him there was a whole community of EV owners and enthusiasts. A few years earlier, when I was working with survey data of sharing economy users, I was struck by the varieties of economic, environmental and social motivations that drive them to engage in this innovation. Such accounts of users are an important part of the transition towards a more sustainable society. Yet they are only starting to be told more prominently. In the societal and scientific debate surrounding sustainable innovations, one still gets the impression that all that matters for their upscaling are companies such as Tesla, SnappCar, Uber, or governments forging climate agreements. Some researchers do, however, address the users in transitions towards sustainability, or provide research perspectives, which allow us to more fully appreciate them. On their works, I build in this thesis to examine the role of users in the upscaling phase of transitions towards a sustainable society. The focus is on users in all their variety, from EVangelists to car-sharers who merely rent out their vehicle to earn some extra money.

1.1 Users in the upscaling of innovation in sustainability transitions

Our society faces a number of challenges related to environmental sustainability. Major causes of these challenges are the use of fossil fuels and inefficient use of resources. The first challenge is climate change. The burning of fossil fuels causes CO_2 emissions that contribute to climate change, exemplified in rising sea levels and more extreme weather conditions (IPCC, 2014). Transport is responsible for about 25% of CO_2 emissions, and emissions from this sector are expected to rise considerably in the coming decades (IEA, 2009). A second challenge is ambient air pollution. The negative effects of air pollution on the general health of citizens and premature deaths in cities around the world are becoming ever more apparent. Around 3 million annual deaths are estimated to result from ambient air pollution worldwide (WHO, 2016). As a third challenge, current use of materials and scarce resources is far from efficient, increasing waste, and exemplified in statistics suggesting that cars stand idle more than 95% of the time (Bates & Liebling, 2012). All in all, on a variety of environmental sustainability dimensions, persistent problems remain.

To address these challenges, systemic transformations are needed that involve the widespread use of sustainable innovations such as electric vehicles or car-sharing. Such sustainability transitions (Loorbach et al., 2017; Geels et al., 2018; Geels & Johnson, 2018) are hard to achieve, because they involve changes in socio-technical systems that consist of networks of actors, technology and infrastructures. Over time, in many sectors interactions between social and technical elements have led to a situation of lock-in into a "regime". This socio-technical regime is a semi-coherent rule-set that guides the behaviour of actors (Rip & Kemp, 1988; Geels, 2002). It forms the "deep structure" that stabilizes existing systems (Geels, 2011, p.5). Examples of regime rules are user expectations, shared meanings and social norms. In the case of transport, one can think of the dominant regime of fossil-fuel powered privately owned cars. Associated "rules" are the status attached to car ownership, the user conception that a car should be able to drive long distances or the ideas of engineers about how to construct a car. Such rules imply that most innovations will be incremental, well in line with the current regime. Innovations that could break the status quo do emerge, but oftentimes they remain in niches. These niches are protected spaces such as specific application domains, in which the innovation is relatively shielded from selection pressures of the regime (Smith & Raven, 2012). Because of the dominance of socio-technical regimes, sustainable innovations often struggle to grow out of these niches. An example of a niche experiment is a government- and industry-sponsored demonstration project of hydrogen buses in a city, to reduce local air pollution (Carvalho et al., 2012).

Recently, some innovations have developed beyond initial niche experimentation, and started to diffuse in certain countries. This phenomenon has led to a rise in attention for upscaling in the sustainability transition literature (STRN, 2017, p. 12; Naber et al., 2017; Geels et al., 2018; Geels & Johnson, 2018). From a transition perspective, we should see upscaling as a double development: it concerns the development of endogenous momentum of the niche innovation, as well as the societal embedding of the innovation in wider contexts. Upscaling in sustainability transitions brings about distinct problems (Geels et al., 2018; Geels & Johnson, 2018). Innovations in transitions address concerns about the public good of sustainability. They often appeal less to private interests of mainstream users, as they can be more expensive and perform less on key dimensions. In a broader sense, innovations scale up against structures that can form strong barriers to their widespread use. Most notably, this concerns the socio-technical regime of the established technology with which the innovation competes. Thus, a certain degree of reconfiguration of this existing regime is required for the spread of the innovation.

The shift from initial emergence towards upscaling brings users to the center of the transition debate in two ways. These two avenues form the key research challenges to which this thesis contributes. The first concerns the need for more refined characterizations of users in the upscaling process in transitions. McMeekin and Southerton (2012) describe how the transitions literature initially only made a distinction between “special” niche users, and the mass of all other ordinary users who follow the socio-technical regime. Drawing on a practice perspective, McMeekin and Southerton (2012) propose a further differentiation between different social groups of users, each with their own consumption practices that are also formed in interaction with other social groups. Geels (2018, p. 227) argues that “perhaps because of an excessive fear of using reified analytical categories” crossovers between the transitions field and socio-psychological and traditional adoption models such as Rogers’s diffusion of innovation framework (2010) remain underexplored. In a study of biomass diffusion in Austria, Geels and Johnson (2018) advocate a modular approach that accommodates a wide range of diffusion models, including socio-psychological adoption models, in a transition framework. They find that particularly in early upscaling phases, user characteristics such as environmental awareness and local pride help explain adoption.

A second debate has emerged regarding the active contribution that users can make to the upscaling of innovation in transitions (Schot et al., 2016; Hossain, 2016; STRN, 2017, p. 23-24). It is now widely acknowledged that users contribute to the emergence of innovation in niches. Users engage in technological developments, develop use patterns and provide legitimacy for innovations (Truffer, 2003; Ornetzeder & Rohracher, 2006; Schot et al., 2016). However, the extent to which users can also take up meaningful roles in the upscaling phase of transitions is debated. Particularly in the field of studies that address grassroots communities – idealistic user communities working on sustainable alternatives – the limitations to users’ roles in upscaling are pointed out (Smith et al., 2014; Seyfang & Hossain, 2016; Longhurst, 2016). User communities lack resources needed for upscaling such as funding, skills and well-defined plans for growth (Hossain, 2016). The innovative solutions users develop are often highly tied to specific socio-spatial contexts, making it hard to translate them to different user segments (Smith et al., 2014; Korjonen-Kuusipuro et al., 2017; Ruggiero et al., 2018). Users also lack the power to meaningfully change the existing socio-technical regime, and if they want to have wider impact they have to weaken their sustainability focus. Such barriers are exemplified in the study of Truffer (2003) on user-driven car-sharing initiatives in Switzerland. User-run maintenance became troublesome during upscaling, and idealistic conceptions of user types and organizational structure limited growth.

On the other hand, some studies have shown that users can contribute in the upscaling phase of transitions as well (Dewald & Truffer, 2011, 2012; Schot et al., 2016) and that an increase in online user activities might have alleviated barriers to user involvement (Hyysalo et al., 2018). Schot et al. (2016) provide a typology of users’ roles over different phases of transitions. In the upscaling phase, user-consumers contribute by inventing different use practices while user-intermediaries align different actors, and user-citizens lobby against the regime and other niches. Kanger and Schot (2016) illustrate their perspective in a historic case study of the development of the automobile. Users contributed to upscaling by inventing new use practices such as longer commutes and escapes from parental supervision. They equally set up powerful associations that lobbied politicians to engage in construction projects to accommodate more cars. Also for the case of solar energy in Germany, Dewald and Truffer (2011, 2012) demonstrate how local citizen collectives built up markets and provided political support for the feed-in tariff, which helped further accelerate solar growth. A notable recent development is the rise of online user communities, which may empower the role of users in upscaling (Hyysalo et al., 2018). The virtual structure enables direct communication between geographically dispersed users. This helps to overcome inherent user community limitations and enables the quick and large-scale leverage of user resources. For a virtual community of heat pump users in Finland, Hyysalo et al. (2018) show how they contribute to upscaling by articulating demand, providing better information about the working of a technology than market actors, and by tailoring the technology to different contexts.

Finally, a few clarifications regarding the terms of sustainability and upscaling. In line with the academic field of sustainability transitions to which this thesis contributes (STRN, 2017), I concentrate on the environmental dimension of sustainability. The innovations I study do not necessarily also contribute to enhancing social and economic sustainability. I reflect on this focus in the final section of this thesis. The phenomenon of upscaling became under increased scrutiny only recently. So there is still some ambiguity surrounding the terms for indicating more widespread innovation use beyond initial R&D and niche experiments in transitions. Tied to the idea that niches may become regimes, the term upscaling is traditionally used in the transitions field (Coenen et al., 2010; Koehrsen, 2018) and I will use it as well. Naber et al. (2017) see upscaling as a process and note that upscaling can take multiple forms. They mention the upscaling patterns of growth of a niche experiment, replication of the experiment in other contexts, accumulation in which the experiment links with others and transformation in which it enables institutional change. Some studies, notably in the field of grassroots innovation, take a more restrictive view of the term upscaling, and see it as a form of growth that exists next to replication and translation of grassroots experiments to other contexts (Seyfang & Longhurst, 2016). In this thesis I follow the broad conception of upscaling of Naber et al. (2017). I define upscaling as the expansion of the innovation and its associated socio-technical system beyond initial niche experimenting. Geels et al. (2018) talk about "diffusion", and Geels & Johnson (2018) use the term "system diffusion", stressing that diffusion in transitions involves socio-technical systems and not discrete products. The term diffusion can be encountered in chapter Five, because there I reflect on the assumption that niches upscale toward regimes.

The process of a transition has been divided in different phases (Rotmans et al., 2001; Geels et al., 2011; Schot et al., 2016). For example, a distinction can be made between predevelopment, take-off, acceleration and stabilization (Rotmans et al., 2001). In the predevelopment phase the focus is on R&D and experimentation, and in the take-off phase the focus is on real world deployment and the installation of green solutions. Here the innovation starts gathering momentum in some countries (Geels, 2013). In the acceleration phase the momentum of the innovation then further increases, as do the interactions with the existing socio-technical regime. I have defined upscaling as growth beyond initial niche experimenting. Accordingly, when I refer to an upscaling phase, this can be compared to the take-off and acceleration phase identified by Rotmans et al. (2001). Schot et al. (2016) and Hyysalo et al. (2018) draw different boundaries between phases[1], and concentrate on the acceleration part of upscaling. However, given that these boundaries between phases should not be seen as overly strict separations, and that their descriptions of upscaling are relatively well in line[2] with mine, I also use the term upscaling when referring to their work.

To summarize, fundamental transitions of existing socio-technical regimes are needed to overcome persistent environmental sustainability problems. These transitions involve the widespread use of sustainable innovations. Recently, some of these innovations have started to scale up beyond initial deployment in niches. This development has engendered a lively debate regarding upscaling in the sustainability transition literature, which has brought users center stage.

1.2 Research questions

The goal of this thesis is to develop more refined characterizations of users in upscaling as well as to advance our understanding of the contribution users can make to upscaling. The focus on users in upscaling is important for conceptual development of the academic field concerned with sustainability transitions, which is currently exploring how users can be better included in transition analyses (STRN 2017, pp. 29-33). More specific insights about users as well as their active forms of participation in transitions are also important for policy-makers who seek to accelerate diffusion processes, as well as for firms searching for closer involvement with users beyond specific niche experiments.

[1] They see the take-off phase as part of a start-up phase.

[2] For example Schot et al. (2016 p.5) write about the acceleration (upscaling) phase: "Niches enter the mainstream market and start to compete with the incumbent regime. Increasing diffusion is accompanied by redefinition of rule-sets, and thus also of user needs, leading to collective learning processes and, if successful, eventually to new stable rule sets."

I engage in the search for more differentiated understandings of users in upscaling beyond simple distinctions between special niche users and ordinary regime users. I answer calls to look outside the field of transitions studies (Geels, 2018), and use literatures that have concentrated on socio-psychological and socio-demographic characterizations of users in upscaling. I also intend to contribute to the debate concerning the active contributions of users to upscaling. This debate concerns the limitations of user involvement in upscaling (Smith et al., 2014; Hossain, 2016), the described active roles that users can take in upscaling (Truffer, 2003; Schot et al., 2016), and the extension of user activity towards the online domain (Grabher & Ibert, 2013; Hyysalo et al., 2018). Accordingly, the following main research questions guide the thesis:

1. How can users in the upscaling phase of sustainability transitions be characterized?
2. How do users actively contribute to processes of upscaling?
3. What implications can be drawn for a more user-centered perspective on upscaling in the sustainability transitions field?

1.3 Case selection

This study looks at users of two innovations in the domain of transport: car-sharing and electric vehicles. Transport is a sector that has shown to be reluctant to large-scale changes and is a major contributor to CO_2 emissions and local pollution (IEA, 2009; Geels, 2012). Both innovations I study have the potential to contribute to environmental sustainability and their widespread adoption would involve a transition of the current socio-technical regime, involving changes in user practices, market structures and institutions. A case can also be made for a more environmentally sustainable transport system that goes entirely beyond cars, for example based on (autonomous) public transport in combination with improved planning and walking and cycling facilities. However in this thesis, because of I my interest in users and upscaling, I wanted to study two innovations that are currently scaling up. Both car-sharing and electric vehicles break on key dimensions (respectively personal car ownership and gasoline propulsion) with the current dominant mobility regime. Hence it can be expected that the results provided in this thesis can also be insightful for other developments of the transport system towards sustainability.

By lowering car-ownership and reducing car use, car-sharing contributes to a more environmentally sustainable society (Loose, 2010; Martin & Shaheen, 2011; Nijland & Meerkerk, 2017). Two forms of car-sharing are investigated in this thesis. In business-to-consumer (b2c) car-sharing an organization owns a fleet of cars that are stationed at different designated locations that are distributed across neighbourhoods or cities, and users can rent a locally available car. In peer-to-peer car-sharing, users rent a car from an individual car owner in their neighbourhood through an online two-sided platform bringing together supply and demand.

Although around for more than a century, the electric vehicle has recently embarked upon an upscaling trajectory (IEA, 2018). The electric vehicle can reduce local pollution to zero, and contributes to reductions in CO_2 emissions, because of the efficiency of its engine and the possibility to generate electricity from renewable sources. The electric vehicle case concentrates on an online community of electric vehicle users. Given recent debates on how virtual communities alter the users' role in transitions (Hyysalo et al., 2018), this seems an appropriate case to investigate contributions that users can make to transitions.

The geographical focus of this study is on The Netherlands. The choice for a focus on users from a specific country is supported by the importance of national socio-spatial contexts in EV development as well as the national focus of car-sharing firms. Examples of socio-spatial factors are e.g. charging point availability and national subsidy schemes (Sierzchula et al., 2014). In the Netherlands both car-sharing and electric vehicles have left the phase of initial niche experimenting, and started to scale.

The two innovations are both scaling up, yet have not reached widespread diffusion. During the 2013-2017 period the number of electric vehicles grew from 7,410 (of which 4,348 Plug-in Hybrid Electric Vehicles (PHEVs)) in December 2012, to 119,332 (of which 98,217 PHEVs) in December 2017 (NEA, 2014, 2018). The average market share was 5.6% in The Netherlands over the 2013-2017 period. In the same period the number of shared b2c and p2p cars grew from 5,000 to approximately 30,000 (Crow-KPVV, 2018). As of 2017, the largest p2p car-sharing platform in The Netherlands reported 250,000 members (Snappcar, 2017). In both cases, this acceleration indicates a process of scaling up, even if it is still uncertain whether car-sharing and electric vehicles will eventually grow out to become an alternative regime to the current regime based on private car ownership and gasoline cars. Compared to the empirical studies of upscaling of Finnish heat pumps of Hyysalo et al. (2018) (analysis of upscaling till 50% of the identified market potential), and biomass heating of Geels & Johnson (2018) (analysis of upscaling till 9%[3] of households uses this form of heating) this thesis concentrates on the early stages of upscaling.

[3] Own calculation based on information provided in the paper.

1.4 Theoretical Approach

This thesis explores users from a sustainability transitions perspective (Markard et al., 2012; Geels et al., 2018). My engagement with this perspective throughout this thesis can be summarized as: taking a step back, further refinements, going beyond. The role of users in upscaling is becoming more prominent on the agenda of transition researchers (Schot et al., 2016; STRN, 2017, p. 32). However, the attention for users in upscaling is also still in its infancy. It therefore makes sense to start this thesis taking a step back by drawing on perspectives that have studied users of innovation for decades, and have also turned towards studying sustainable innovation. The potential contribution that those literatures can make to understanding users in relation to sustainability transitions consists of a much more refined analysis of socio-demographic and socio-psychological characteristics as well as motivations of users during upscaling. I draw on the socio-demographic characteristics (such as age and income) described to influence innovation adoption by Rogers (2010) and in an associated literature of more applied adoption studies (e.g. Saarenpaä, 2013; Coll et al., 2014). Relatedly, studies from the socio-psychological tradition are employed, which emphasize factors such as environmental awareness and social drivers in their characterizations of users of sustainable innovation (Hamari et al., 2016; Tussyadiah, 2016).

I also engage with current sustainability transition frameworks to better accommodate users in upscaling. Drawing on recent works that develop more refined conceptualizations of the geographical dimensions of transitions (Späth & Rohracher, 2012; Hansen & Coenen, 2015) and regimes (Fünfschilling & Truffer, 2014), I argue for a transition perspective equally emphasizing the spatial heterogeneity of niche, regime and landscape levels. As we will see, this allows for a geographically differentiated understanding of the user base. It also enables to see how this user base adopts innovations that have different relations with the socio-technical regime, influencing upscaling. Subsequently, I synthesize existing transition literature to work out three upscaling dimensions: system-building, geographical circulation and reconfiguration of the existing socio-technical regime. These are instructive in analyzing the contribution of users to upscaling.

In the end, then, I aim to go beyond current transitions literature and turn to assemblage thinking to analyze users in upscaling. Assemblage thinking has its roots in the works of Deleuze and Guattari (1977, 1987), and has been adapted and transformed into a more coherent framework by DeLanda (2006, 2016). Assemblage refers to a process of composition in which heterogeneous elements co-function (Anderson et al., 2012; DeLanda, 2016). An assemblage perspective invites us to think differently about socio-technical systems as temporary stabilizations, which include many opportunities for change. Accordingly, it is useful in conceptualizing roles of users in upscaling in transitions, by showing how users can enact changes from within existing assemblages, and contribute to upscaling processes.

The overall theoretical approach I take in this thesis is well in line with the "modular" approach advocated by Geels & Johnson (2018) to study upscaling. In such a modular approach insights from different analytical perspectives are combined, each of them highlighting specific aspects of users in upscaling. Given the range of complex patterns involved in upscaling, it makes sense to study them from such a multidisciplinary perspective. As in the work of Geels & Johnson (2018), the theoretical perspectives in this thesis stem from different ontological traditions. Accordingly, I do not aim at integrating them into one coherent framework explaining the users' role in upscaling. Rather, I will discuss the insights they provide to the two key outlined challenges in the sustainability transitions perspective: the characterization and active contribution of users during upscaling.

1.5 Methodological approach

While methodological details are provided in the subsequent thesis chapters, some general remarks can be made about the overall approach to methods and data collection. Hitherto, the sustainability transitions field draws mostly on qualitative approaches (STRN, 2017, p. 45). In particular, narrative approaches have proven useful to analyze the complex dynamics of transitions. As a data source, interviews or historic data sources are often employed. For the study of users in upscaling, drawing solely on interviews is not feasible, given the large number of geographically dispersed users involved. I therefore explore some alternatives. In general, the research design can be categorized as a mixed-method approach, including both quantitative (survey, spatial analysis), and qualitative methods (an internet ethnography, interviews).

As for the quantitative methods, I could use the data of a stated preference survey into sharing economy behaviour that was conducted in the city of Amsterdam in 2013. I also collected data regarding the location of all cars that were shared in The Netherlands in 2014. In a spatial econometric analysis, I link these data to socio-demographic characteristics of neighbourhoods. In this way, I am able to analyze larger groups of geographically dispersed users. In terms of qualitative analysis, I consider forum threads on an internet forum of electric vehicle users. This data source has the advantage of providing both "breadth and depth", as it allows for in-depth analysis of user discussions, for a relatively large number of users from geographically dispersed locations. Moreover, all forum posts are annotated with date, time and location of the user at the city level, which is very helpful in constructing the narrative of upscaling. I also performed 13 interviews with EV users active in the online community to different extents. Finally, for both the car-sharing and EV case, I could draw on various sector reports, as the developments for both innovations are well-documented in The Netherlands.

1.6 Thesis outline

This thesis analyzes users and their role in transitions beyond initial niche experiments. To better understand users in upscaling, it explores some conceptual and methodological additions to the transitions field. Chapter Two draws on classical innovation adoption theory and socio-psychological works to characterize users of car-sharing among other sharing economy forms. Important insights of the conducted survey are the variety in user motivations: each form of the sharing economy is driven by a unique combination of motivations, a combination which differs per socio-demographic group. Still, sharing economy forms that are able to connect to the current socio-technical regime, such as car-sharing, have more upscaling potential.

Chapter Three establishes the geographical variety in the niche, socio-technical regime and landscape level of the multi-level perspective. A spatially heterogeneous user base is included in the landscape level. Two types of car-sharing are considered in the analysis. The results show the influence of a geographically heterogeneous regime and landscape on patterns of adoption of the two distinct innovation variants.

In Chapter Four, by means of a virtual ethnography, I consider the contribution to upscaling of a user community that formed around the Electric Vehicle (EV), The Tesla Motors Club forum. I find that the community plays an important and distinctive role in fostering electric vehicle upscaling. Although in an ad-hoc and unorganized manner, users contribute to a broad range of system-building work, ranging from infrastructure development to institution-building. Users also participate in the geographical circulation of the innovation as well as reconfiguration of the existing socio-technical regime.

Chapter Five takes a perspective based on assemblage thinking to explore the agency of users in transitions. Drawing on the case of the electric vehicle user internet forum, it is shown how the users' many connections provide them with an opportunity to act, and how a vibrant community emerges that fosters upscaling.

Chapter Six summarizes the main findings and offers conclusions. It assesses the contribution of the thesis to the field of sustainability transitions, and reflects on the various perspectives used. An outlook for further work is equally provided.

Finally, it should be noted that the chapters of this thesis are each separate papers (see table 1.1 and table 1.2). The conception, conceptual developments and analyses are primarily the work of the author of this thesis. Chapter Two draws on a pre-existing survey, for which data was collected by Pieter van de Glind and the municipality of Amsterdam, the Netherlands. Co-author

Lars Böcker has contributed to the empirical part of this chapter by providing a means of drawing the triangles with motivations and working on the final analysis in Stata. Stephan Hobrink has provided help in data collection for Chapter Three. Feedback from Tim Schwanen was useful in further elaborating the assemblage perspective in chapter Five. Koen Frenken, Bernhard Truffer and Tim Schwanen provided feedback on the writing in various chapters.

Table 1.1: Overview contributions of other authors

	Chapter Two	Chapter Three	Chapter Four	Chapter Five
Conception and design of the study				
Conceptual developments				Tim Schwanen
Data collection	Pieter van de Glind[4]	Stephan Hobrink		
Analysis and interpretation of data	Lars Böcker			
Feedback on writing	Koen Frenken[4], Lars Böcker	Koen Frenken	Koen Frenken[4], Bernhard Truffer, Tim Schwanen	Koen Frenken[4], Bernhard Truffer, Tim Schwanen

Table 1.2: Chapters and publication status

	Publication status
Chapter Two	Böcker, L., & Meelen, T. (2017) (alphabetical order). Sharing for people, planet or profit? Analysing motivations for intended sharing economy participation. *Environmental Innovation and Societal Transitions*, *23*, 28-39.
Chapter Three	Meelen T., Frenken, K., Hobrink S. (2017*)* A weak spot for car-sharing? The geography of socio-technical regimes and the adoption of niche innovations. Accepted: *Energy Research and Social Science*
Chapter Four	Meelen, T., Truffer, B., Schwanen T. (2017) Virtual user communities contributing to upscaling innovations in transitions: the case of the electric vehicle Accepted: *Environmental Innovation and Societal Transition*s
Chapter Five	Meelen, T., Schwanen. T. (2018) Assemblages and diffusion in transitions: a case of electric vehicle users In preparation for journal submission Conference paper at: IST, 9th International Sustainability Transitions Conference, Manchester, UK, June 2018

[4] Not a co-author on the paper, acknowledged in the acknowledgements section of the respective paper.

Chapter 2

Sharing for people, planet or profit? Analyzing motivations for intended sharing economy participation

Abstract

The sharing economy is a fast-growing and heavily debated phenomenon. This study provides an overview of motivations of people willing to participate in different forms of the sharing economy. A survey was held amongst 1,330 respondents from Amsterdam, the Netherlands. Using stated preference data, we investigate the relative importance of (1) economic, (2) social and (3) environmental motivations to participate in peer-to-peer sharing. Hereby we consider differences between (a) sectors of the sharing economy, (b) socio-demographic groups, and (c) users and providers. Results are descriptive as well as based on ordered logit models. Notable differences are observed in the motivations for sharing between sectors. To a lesser extent there is variety in sharing drivers between socio-demographic groups. Finally, users seem more economically motivated than providers of goods.

2.1 Introduction

The sharing economy has grown in both scale and scope in the past years (Owyang, 2013; Belk, 2014b). In a variety of sectors, internet-facilitated platforms have emerged that enable people to share their underutilized assets. Examples include Airbnb for apartments, Blablacar for cars and Peerby for tools. These sharing platforms increasingly form a threat to existing businesses operating in the respective sectors (Gansky, 2010; Owyang, 2013). Apart from having economic consequences, the sharing economy is claimed to have positive environmental and social effects (Botsman & Rogers, 2011). More efficient use of goods can save scarce resources otherwise needed for production. The act of sharing could bring people together and stimulate social cohesion in neighbourhoods (Agyeman et al., 2013). However, the sharing economy has also caused considerable controversy, for example related to rising rents for local residents because of accommodation sharing (Frenken et al, 2015; Martin, 2016).

Despite a recent surge in attention for the sharing economy, little is known about the motivations for people to participate (Grassmuck, 2012; Tussyadiah, 2015). Insights in motivations would be instrumental in developing a better understanding of the so far underexplored decision-making processes of users (Piscicelli et al., 2014; Tussyadiah, 2015) and can also foster the general discussion around the sharing economy (Grassmuck, 2012; Martin, 2016). Given that the sharing economy is often regarded as an innovation with sustainability benefits, studying the various motivations for adoption also contributes to the emerging debate around the end-user in the literature on sustainable innovations and societal transitions (Kemp & van Lente, 2011; McMeekin & Southerton, 2012). This debate focuses on consumer preferences and practices needed to achieve a transition towards a more sustainable society. The sharing economy here is a particularly interesting case, because in contrast to many other sustainable innovations, certain sharing economy sectors are scaling up very rapidly.

A few early sharing economy scholars have suggested drivers for participation. Bardhi & Eckhardt (2012) claim that economic motivations are dominant in the case of car-sharing platform Zipcar. This finding is replicated by Belotti at al. (2015), who study users from a range of peer-to-peer platforms. Other authors, however, argue that environmental motivations underlie sharing economy participation (Gansky, 2010; Botsman & Rogers, 2011). Botsman and Rogers (2011) suggest social motivations drive sharing economy participation as well. People would for example engage in accommodation sharing, because they want to interact with their local hosts (Tussyadiah, 2015).

Quantitative research into sharing economy motivations is still largely lacking. Most existing studies only consider one form of the sharing economy (Piscicelli et al., 2014; Tussyadiah, 2015; 2016), one of the few exceptions being Möhlmann's (2015) study of both car and accommodation sharers. Other studies assume the existence of one sharing economy and do not distinguish between different forms (Hamari et al., 2015). However, it is likely that motivations to share for instance a power drill are different from those to share an apartment. Moreover, Hellwig et al. (2015) show that motivations for sharing economy participation can differ for various socio-demographic groups. Finally, users could have other motivations than providers of goods in the sharing economy, given that the activities of providing and using are substantially different (Van de Glind, 2013).

This study aims to provide a more comprehensive understanding of the motivations for participation in the sharing economy. Synthesising from previous sharing economy studies, and in line with a sustainability approach, economic, environmental and social motivations are considered. Expanding current research, the relative importance of these motivations for sharing economy participation is investigated for different types of goods, socio-demographic groups and roles as user or provider. Five forms of sharing are taken into account: car-sharing, ride sharing, accommodation sharing, tool sharing and meal sharing. Analyses draw on a stated preference survey held among 1,330 participants in the city of Amsterdam, The Netherlands.

The rest of the paper is structured as follows. Section 2.2 reviews the literature on sharing economy motivations, and hypothesises the relative importance of these motivations under various circumstances. Section 2.3 discusses the data collection and analytical strategy. Section 2.4 presents the results. Section 2.5 concludes, and discusses limitations of the study as well as implications for the sharing economy and sustainable innovation fields.

2.2 Theory

Many terms and definitions circulate to describe the so-called "sharing turn" in the economy: the trend that more and more products are shared rather than privately owned (Grassmuck, 2012; Botsman, 2013; Nesta, 2014). This paper focuses on peer-to-peer exchanges of goods between consumers. We use the term "sharing economy" rather than "access-based consumption" (Bardhi & Eckhardt, 2012) or "collaborative consumption" (Belk, 2014b), because the latter two also refer to large-scale business-to-consumer services such as Spotify or Zipcar. We define the sharing economy as "consumers granting each other temporary access to their under-utilized physical assets ("idle capacity"), possibly for money" (Meelen & Frenken, 2015). Examples of sharing ventures that fit this definition are Airbnb and Couchsurfing for apartment sharing, Getaround and Relayrides for car-sharing, and Blablacar for ride sharing.

In the nascent literature on the sharing economy, there is an increasing interest in the motivations driving participation. Of the many motivation theories that exist Self Determination Theory (SDT) (Deci & Ryan, 2000; Ryan & Deci, 2000) is frequently drawn upon in sharing economy studies (Hamari et al. 2015; Belotti et al., 2015; Tussyadiah, 2016). In this perspective behaviour is driven by intrinsic motivations, which emerge from inherent satisfactions of the activity, and by extrinsic motivations, which relate to outcomes that are separate from the behaviour. Hamari et al. (2015) and Tussyadiah (2016) refer to Lindenberg (2001) to further distinguish between intrinsic motivations coming from enjoyment of the activity and from the internalized value of conforming to the norm. From the latter category, environmental concern has been most prominently related to sharing economy participation (Hamari et al, 2015; Belotti et al., 2015; Tussyadiah, 2016). People would initiate sharing economy activities to reduce their use of scarce natural resources. As an extrinsic driver of sharing economy participation, monetary rewards have often been mentioned (Bardhi & Eckhardt, 2012; Tussyadiah, 2015; 2016).

Mindful of these categorizations of motivations, in this research we employ a sustainability framework and distinguish between economic, environmental and social motivations. With such a framework we are able to contribute to the current sharing economy debate and the wider literature on environmental innovation and societal transitions. Tussyadiah (2015) categorizes motivations mentioned in the existing sharing economy literature as part of “economic benefits”, “sustainability” and “community”. Slightly adapting from this, and largely in line with the well-known triple-p (people-planet-profit) framework of sustainability (Elkington, 1997), in this paper a distinction is made between economic, environmental and social drivers of sharing economy behaviour. This perspective allows us to systematically assess claims within the ongoing sharing economy debate (Martin, 2016), regarding whether sharing economy growth is driven by more intrinsic environmental and social or extrinsic economic motivations. It also contributes to the wider literature on sustainable innovations and societal transitions. In this field, recently more attention has been given to the importance of consumer preferences for achieving sustainability transitions, particularly as innovations scale up (Kemp & van Lente, 2011). In current transition research a distinction is often only made between a group of niche users, who have a very particular set of motivations, and all other “mainstream” users. Authors have therefore called to acknowledge more heterogeneity in user groups (McMeekin & Southerton, 2012). Our research contributes to both of these issues, by mapping out consumer motivations and exploring differences in these motivations between various socio-demographic groups.

Let us first consider economic drivers for sharing economy participation. In this context, although concrete evidence is lacking, the rise of the sharing economy and financial crisis of 2008 are often linked. Faced with financial difficulties, people would rethink their consumption patterns and the value they attach to ownership (Gansky, 2010). The empirical literature tends to find at least some support for economic motivations in sharing economy behaviour. A survey of members of the online sharing platform Sharetribe shows that economic benefits stimulate intended sharing economy participation (Hamari et al., 2015). On the other hand, in a study comparing renting to ownership, Moeller & Wittkowski (2010) find no evidence of "price consciousness" to drive this decision. It should be noted however that in their study it might not always have been clear which option was cheaper. Regarding specific sharing economy sectors, Tussyadiah (2015; 2016) finds that economic motivations are an important driver for using accommodation sharing in two US surveys. Möhlmann (2015) surveys car and accommodation sharing users, and finds that "cost savings" increase satisfaction, but do not affect intention to use the service again. Finally, Bardhi and Eckhardt (2012), in an interview-based study into motivations of clients of car-sharing platform Zipcar, show that utilitarian motivations such as saving money underlie Zipcar participation.

In the sharing economy discourse, its presumed environmental advantages are often stressed (Schor, 2014; Martin, 2016). Potentially, the sharing economy can, as an alternative economic model, make a contribution to environmental sustainability (Heinrichs, 2013). An important mechanism is the increased efficiency in the use of goods, which helps to spare scarce resources that would otherwise have been necessary for the production of new goods. However, it is yet far from clear what the environmental effects of the sharing economy will be. Several motivational studies find a role for environmental drivers of sharing economy participation. Piscicelli et al. (2014) find that 32% of their respondents indicate "to be green" as the main reason to join sharing platform Ecomodo. Also Hamari et al. (2015) show that perceived sustainability has a small indirect effect on intended sharing behaviour. In a US survey Lawson (2010) finds a positive effect of environmental consciousness on intention to engage in "fractional ownership". Contrastingly, in their interview-based study Bardhi and Eckhardt (2012) find environmental concern not to be among the main motivations of Zipcar car-sharing users. In surveys on accommodation sharing (Tussyadiah, 2016) and on accommodation as well as car-sharing (Möhlmann, 2015) no influence is found of environmental drivers on the intention to use these services again. Similarly, Moeller and Wittkowski (2010), in a survey among users of an online peer-to-peer network, find no effect of environmentalism on preferring renting instead of owning goods. In sum, there is no conclusive evidence regarding the link between environmental motivations and participation in the sharing economy.

Social aspects of sharing could also drive sharing economy participation (Ozanne & Ballantine, 2010; Botsman, 2013). Interactions between users and providers of goods are at the heart of many sharing economy forms. For example, in the case of peer-to-peer car-sharing people meet up to exchange the car keys and discuss the exact conditions of the exchange. With accommodation sharing people meet their local hosts, who can introduce them into the local community. The ability to get to know new people and make friends is claimed to stimulate sharing economy participation (Botsman & Rogers, 2011). Ozanne & Ozanne (2011) find that both for children and their parents, socializing is a driver for toy library participation. In their accommodation sharing study, Tussyadiah (2015) show that motivations of getting to know local people and interacting with them are important participation drivers. In another study this result is not replicated, an explanation being that some accommodation sharing users are specifically looking for places to stay that do not involve social interaction (Tussyadiah, 2016).

In the remainder of this paper, we quantitatively assess the relative importance of the aforementioned economic, environmental and social motivations for participation into different sectors of the sharing economy. As shown above, current research is not univocal about the role of these sharing motivations, most notably the environmental one. An important reason for these discrepancies might be that different motivations underlie different forms of sharing, and that motivations differ between participants. Expanding current sharing economy research, we therefore specifically investigate variation in motivations between shared goods, socio-demographic groups, and the role people take up as either a user or provider of goods.

Manifold goods are shared. It is expected here that a relationship exists between the characteristics of the shared good and the importance of different motivations. Shared goods differ largely in terms of their economic value, the (assumed) environmental impacts of sharing them, as well as the degree of social interaction involved in the process of sharing. First, considering the economic value of the good that is shared, accommodation sharing stands out. Because of the high price of accommodation, people can charge a substantial amount of money for letting others stay in their property, especially if it is situated in a popular location. Compared to the alternative of the hotel, this form of sharing also provides a considerable financial benefit to users in absolute terms (Guttentag, 2015). Hence, we expect that economic motivations are relatively important for accommodation sharing. The car is another expensive good to own, with considerable financial savings to be made by adopting car-sharing. In line with this, Bardhi and Eckhardt (2012) find that economic motivations are dominant in the choice to use the car-sharing platform Zipcar. With peer-to-peer-sharing – the focus of this study – in addition car owners could potentially earn back (part of) the car ownership costs by providing their car to others (Fraiberger & Sundararajan, 2015). Hence, it is likely that economic motivations play a large role for users and providers of this form of the sharing economy. Second, the different shared goods also differ in the extent to which they contribute to environmental sustainability. Car-sharing seems the sharing economy form with the most apparent environmental benefits. The negative environmental impacts of car production and car-ownership are well known. It has also been repeatedly shown that car-sharing can contribute to alleviating these problems (Firnkorn & Müller 2011; Nijland et al., 2015). As an addition, car-sharing historically has many links to the environmental movement (Truffer, 2003; Martin & Shaheen, 2011; Shaheen & Cohen, 2013). Hence, it is expected that environmental motivations are important for car-sharing. Third, social motivations may be more prominent for sharing forms that involve clear social interaction. Ride-sharing is a sharing economy form which involves prolonged social interaction (when people are together in a car). Additionally, meal sharing refers to people cooking an extra portion of a meal for their neighbours. It likely involves a discussion between people about the meal and how it was prepared. Moreover, in the Dutch context of this study, meal sharing has been associated in popular media with taking care for elderly or sick people in the neighbourhood that are not able to prepare a meal themselves[5]. To sum up, it is hypothesized that characteristics of the good relate to the importance of economic, social and environmental motivations for sharing economy participation.

Motivations to participate in the sharing economy are likely not uniform across population categories. Hellwig et al. (2015) propose a market segmentation for the sharing economy, in which the identified types of sharers (among other factors) differ in socio-demographic composition and motivations. Considering the relationship between these, first, an influence of age on motivation is expected. Older people have more frequent neighbourhood contacts (Cornwell et al., 2008). Given the neighbourhood character of many sharing economy initiatives, it is therefore expected that their use for older people is more embedded in local social activity. Moreover, Cornwell et al. (2008) suggest that to make up for a decrease in interpersonal network connectedness, older people engage in associational networks to develop new social ties. Also involvement in a sharing economy platform can be seen in this light. Hence, it is expected that social motivations for joining the sharing economy are more dominant amongst older as compared to younger people. With regard to gender, environmental psychology studies consistently find that women are more environmentally aware then men (Diamantopoulos et al.,2003). Consequently, it is expected that women show higher environmental motivations for joining the sharing economy. Similarly, Hellwig et al. (2015) find an overrepresentation of women (67%) in the cluster of *sharing idealists,* who are highly intrinsically motivated to share.

Environmental concern is also more prevalent among higher income and highly educated groups (Shen & Saijo, 2008). This finding is often explained by Maslow's (1970) hierarchical needs theory. Environmental concern is then seen as a higher order need, which is only strived for when basic material needs are met. Given their higher environmental concern,

[5] E.g. https://www.nudge.nl/blog/2014/01/16/kook-jij-mee-voor-ouderen-in-je-buurt/.

it is expected that environmental motivations are more important in the decision-making process of people with high education and income. Furthermore, we expect that lower income groups are more economically driven to join the sharing economy. The sharing economy can provide this population category access to goods they previously were not able to own. Additionally, sharing may help to avoid high ownership costs or enables to earn on products owned. Accordingly, Fraiberger and Sundararajan (2015) predict that most welfare gains of the sharing economy will be obtained by low income groups. In terms of cultural background, given that non-Western cultures are often more collectivist (Hofstede et al, 2001), people from non-Western origins might show higher social motivations for sharing economy participation. Finally, household types have shown different patterns of social contact (Li, 2005). Hence it might be that certain households, such as those composed of singles, show higher social drivers of sharing economy participation than others. In sum, it is hypothesized that there is a relationship between socio-demographic group and the importance of economic, social and environmental motivations in the sharing economy.

Motivations may also differ between users and providers of the same good. This is expected to concern mainly economic motivations. Asymmetries may exist in the economic benefits of using and providing. Specifically, these asymmetries result from the relatively large economic benefits the user can have if she opts for renting or borrowing instead of buying the good. This mechanism seems most pronounced in the case where the good is relatively expensive, but the use of the good by the sharing economy user is very limited in terms of time or total capacity of the good[6]. Tool sharing is the most relevant example in our study. If a user borrows or rents a drill from a neighbour a large amount of money can be saved compared to the option of buying a drill. However, if a provider lends or rents out a drill to someone, none or only a small amount of money is charged. Accordingly, for tool sharing it is expected that economic motivations are higher for the user than for the provider. In line with this reasoning, Belotti et al. (2015) find that peer-to-peer platform users mention (even) more extrinsic motivations than providers. In contrast to economic motivations, we do not expect differences in social and environmental motivations between users and providers. Social interaction concerns per definition both the user and the provider. Environmental gains result from the act of sharing, to which both user and provider participate. Summarizing, it is hypothesized that users show higher economic motivations than providers in the sharing economy. No differences are expected in social and environmental motivations between users and providers.

[6] The provider could make up for this by renting out the good many times, but then also faces transactions costs every time the good is rented out.

2.3 Research Design

2.3.1 Study area

This study explores the motivations to participate in the sharing economy based on an online stated preference survey held in 2013 amongst 1,330 respondents in Amsterdam, The Netherlands. A panel of 2,500 respondents was invited by e-mail, so a response rate of 53.2% was obtained. Amsterdam was selected as a pilot area for exploring motivations to share for two main reasons: First, Amsterdam positions itself as a front-runner in the sharing economy. It was the world's first municipality to develop regulations around Airbnb. Moreover, local politicians and stakeholders promote initiatives in the sharing economy locally, nationally and internationally under the label of Amsterdam Sharing City. This increases the knowledge base regarding the sharing economy amongst the general population, which is required to study the relatively new phenomenon. Second, the area has rich population diversity in terms of age, ethnicity and socio-economic status. This allows for exploring how motivations to share differ between different population categories.

Table 2.1 describes the sample composition in relation to the general Amsterdam population according to several key demographics. The sample is diverse and well balanced on several key demographics, such as gender, household income and household type. Young people are under-represented. Although the sharing economy is often linked to younger generations, this sample allows the authors to complement the existing knowledge with specific insights into middle- and older-aged people's motivations to participate in the sharing economy. As with most existing studies also lower educated and non-Western ethnicities are underrepresented. Both groups are nevertheless included in the analyses because little is known about their motivations to participate in the sharing economy.

Table 2.1: Sample composition and representativeness

		Sample (N=1,330)	Amsterdam population[7]
Age	15-24	1.1%	13%
	25-44	17.6%	35%
	45-64	58.3%	25%
	65+	23.0%	12%
Gender	Male	47.0%	49%
	Female	53.0%	51%
Ethnicity	Non-Western	4.0%	35%
	Dutch or other Western	96.0%	65%
Education	Lower	11.7%	27%
	Middle	18.9%	34%
	Higher (professional / academic)	32.0% / 37.4%	39% (combined)
Net monthly household income	Lower (< €1,750)	18.9%	-
	Middle (€ 1,750 – 2,999)	26.5%	-
	Higher (≥ €3,000)	29.0%	-
	Unknown	25.5%	-
	Average	-	€ 2600
Household type	Single	39.5%	55%
	Couple	33.1%	21%
	Family with children	25.3%	25%
	Other	2.2%	-

2.3.2 Data and modelling techniques

In this study we investigate motivations to participate in five sectors of the sharing economy: car, ride, accommodation, stuff and meal sharing. These five sectors have been selected because they are in line with our definition of the sharing economy as enabling the utilization of some form of idle capacity. Moreover, these were the five sharing economy sectors most easily accessible to Amsterdam inhabitants at the time of survey. With regard to tool sharing, we will investigate one of the most popular items shared in Amsterdam on stuff sharing platform "Peerby": the power drill (Peerby stuff cloud, 2013).

[7] Data for the municipality of Amsterdam in 2012. Based on (CBS 2015; Van de Glind, 2013).

The rationale for utilizing a stated preference research design is threefold: First, stated preferences allow exploring the sharing motivations amongst the general population. This is important to investigate the sharing economy's upscaling potential. In contrast, the alternative of studying actual revealed sharing practices, would, at this time, only have been possible amongst a specific group of early adopters. This is exemplified by statistics on our respondent sample indicating that, accommodation sharing excluded, only between 0.2% (ride sharing) and 3.2% (meal sharing) of the respondents is a registered sharing economy user. Second, a stated preference technique enables the authors to differentiate between the motivations *to use* and *to supply* shared assets. Both roles are prerequisites for peer-to-peer sharing, but especially the latter is often overlooked. Third, by using stated preferences it is possible to cross-compare respondent's motivations to participate in different sectors of the sharing economy. This study distinguishes five sectors[8], all involving the sharing of overcapacity of underutilized assets: car, ride, accommodation, tool and meal sharing. To avoid respondent fatigue, each individual respondent is only asked to state his or her motivation to participate in four[9] randomly selected sectors. In total, all five sectors are however sufficiently covered.

Before inquiring respondents about their sharing motivations, they were first asked to state their intention to use or share the asset in question. Table 2.2 lists the questions used to operationalize this intention. All questions mention a monetary compensation for access to the good. We excluded answers by respondents that indicate with a score of 0, 1 or 2 a neutrality, unlikeliness or highly unlikeliness to use or provide a shared asset. Answers by respondents that indicate with a score of 3 or 4 a likeliness or highly likeness to use or provide an asset in question have been included for further analyses[10]. In a second stage these respondents are asked about the importance of economic, social and environmental motivations underlying their willingness to share. Hereto, they are asked to rate on a 0-4 scale (from negligible to very much) how the following three considerations affect their decision: *financial benefit*, *meeting people*, and *contributing to a healthy natural environment*. The answers to these questions form the dependent variables in our analyses. It should be noted that these three considerations were kept short to avoid respondent fatigue, but do not capture all dimensions of economic, environmental and especially social motivations to possibly participate in the sharing economy.

[8] Originally seven sharing economy sectors were included. *Skill sharing* was excluded because it does not fit our definition of *sharing overcapacity of an underutilized asset*, but rather is a form of exchange of services. *Garden sharing* was excluded because its data record turned out to be incomplete upon verification.

[9] In the original seven-sector questionnaire each respondent answered questions regarding 4 out of 7 sectors.

[10] After selecting only (highly) likely to share answers, our sample for further analysis constitutes of the following number of cases: 107 answers for drill user; 103 for drill provider; 250 for car user; 160 for car provider;168 for ride user; 196 for ride provider, 201 for meal user; 136 for meal provider; 458 for accommodation user; 104 for accommodation provider. Drill user and provider have a relatively low n because in the original survey fewer respondents had been asked this particular question. The n for accommodation provider is relatively low because fewer respondents are willing to provide this asset for sharing (see Figure 2.1).

There are several observations per respondent, as they answer questions for multiple sharing economies.

Table 2.2: Operationalization of willingness to participate

Sector	Respondent question (translated from Dutch)
	How likely on a 0-4 scale would you use the following shared goods/services in the following situations, imagining that insurance issues are all taken care of and the transaction is 100% secure?
Car	Imagine you temporarily need a car and the possibility exists to rent a car in the neighbourhood.
Ride	Imagine you need to go somewhere and someone in your neighbourhood offers you a lift in his/her car for a fee.
Accom.	Imagine you are travelling and local residents offer the possibility to rent their home.
Tool	Imagine you need a power drill and it is possible to rent this in the neighbourhood.
Meal	Imagine someone in the neighbourhood is cooking a meal and you can buy a portion.
	How likely on a 0-4 scale would you provide the following shared goods/services in the following situations, imagining that you own the good in question, insurance issues are all taken care of, and the transaction is 100% secure?
Car	Imagine someone in your neighbourhood needs a car and you are able to rent out yours.
Ride	Imagine someone in your neighbourhood needs a ride and you are able to let this person drive with you for a fee.
Accom.	Imagine renting out your home in your absence to a tourist.
Tool	Imagine someone in your neighbourhood needs a power drill and you are able to rent out yours.
Meal	Imagine it is possible to sell a portion of a meal cooked by you to someone in your neighbourhood.

In the multivariate analysis we estimate the effects of (1) socio-demographic variables, (2) a set of dummies for different sharing economies, and (3) a user/provider dummy, on the five-point (0, 1, 2, 3, 4) score for each motivation as the dependent variable. This approach is similar to the interactionist approach on motivations as employed by Oreg and Nov (2008), in which both personal (in our case socio-demographics) and context (in our case sector and role) variables are linked to motivations. The relationships between socio-demographics and motivations are causally clear. However, this study cannot establish strict causality between motivations and the role of user/provider or the sharing economy sectors. The relationships between these factors and motivations should therefore be interpreted as associations, rather than strict cause and effect.

As statistical modelling technique, use is made of ordered logit models, each with another motivational item as the *dependent variable*. Ordered logit models are preferred over multinomial logit models, to avoid losing valuable information on the order of scores. Ordered logit models are preferred over ordinary OLS regression, because the scores, although ordered, are no continuous outcomes, and neither are they normally distributed. We use a clustered sampling technique, via the Stata software's "vce-cluster" command, to estimate robust standard errors for all (non-independent) answers that belong to one respondent. By correcting for intragroup correlation this technique relaxes the usual requirement that all observations need to be independent (Wooldridge, 2002). To verify the models presented in this paper we have also explored whether and how the effects of socio-demographics on motivations differ for different combinations of sectors and roles. We tested for interaction effects between socio-demographics and sharing economy sectors, but these were largely non-significant and led to no new insights. Additionally, separate models were run for the different combinations of sharing economy sectors and roles, but these were ultimately excluded due to the low number of cases and poor model fits.

2.4 Results

2.4.1 Descriptive analysis

Before exploring respondents' motivations to share, we first briefly report on the share of respondents who state that they are either likely or highly likely to use or provide different goods for sharing (Figure 2.1). Considerable differences in sharing potential are identified between different sharing sectors, as well as between users and providers. While the majority of respondents report likeliness to *use* shared power drills, rides and accommodation, fewer are likely to *use* shared cars and meals. A similar picture arises regarding the reported likeliness to *provide* these goods for sharing, with the exception of accommodation, which is least likely to be offered.

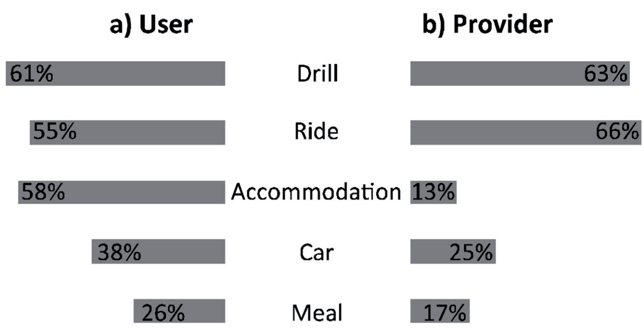


Figure 2.1: Share of respondents (highly) likely to use (a) and provide in (b) various sharing economy sectors

2

We continue with motivations to share for those reporting likeliness to do so. Figure 2.2 maps out the relative importance of economic, social and environmental motivations to participate in the sharing economies as a user (a) or provider (b), for different sharing goods. This relative importance is based on the ratio between the raw 0-4 scores for each of the motivational items. Percentage axes in the triangle indicate the relative importance of environmental, economic and social motivations. For example, if for "accommodation sharing" the average environmental score is 1, social score is 2 and economic score is 3, the score ratio is 1/6, 2/6 and 3/6, thus 17%, 33 % and 50%. These three percentages determine the location of "accommodation sharing" on the diagonals of the triangle. A central position indicates that for the indicated good all three motivations are equally balanced. Locations close to a corner indicate a higher relative importance of that particular motivation.

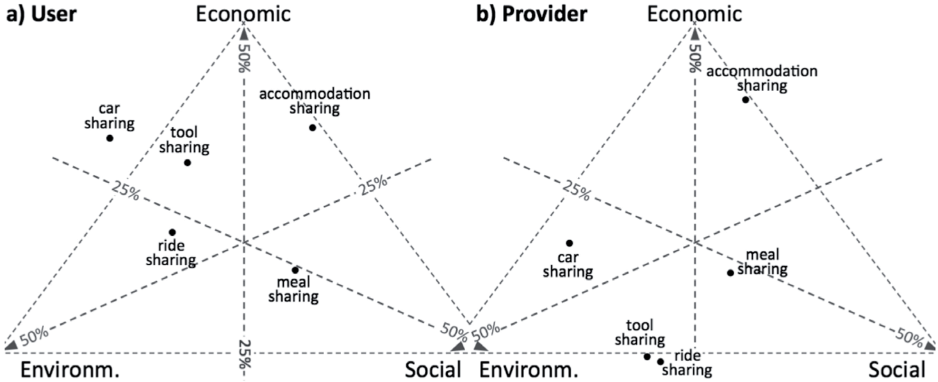


Figure 2.2: Motivations to participate in different sectors of the sharing economy, per sharing economy sector

Figure 2.2 presents an overview of the relative importance of economic, social and environmental motivations for the use (a) and provision (b) of different types of goods. Overall, there are pronounced differences between the motivations for sharing the goods. As hypothesized, the sharing of the expensive asset accommodation is predominantly economically motivated. Although secondary to economic motivations, social motivations also seem to play a role in accommodation sharing. Environmental motivations are relatively important in the decision to join car-sharing. Finally, the two forms of sharing with a large social interaction component, ride sharing and meal sharing, are indeed relatively strongly driven by social motivations. Some differences can be observed when comparing the motivations for using and providing goods. As hypothesized, the difference is particularly large for tool-sharing. The provision of tools is mostly environmentally and socially motivated. However, the use of shared tools is much more strongly economically motivated. As explained before, this discrepancy could be related to the larger direct financial benefits of sharing this good for users as compared to providers. A similar pattern of stronger economic motivations for users is observed for car and ride sharing, although the differences are smaller. Finally, for accommodation sharing and meal sharing, there is hardly a difference in motivation between users and providers.

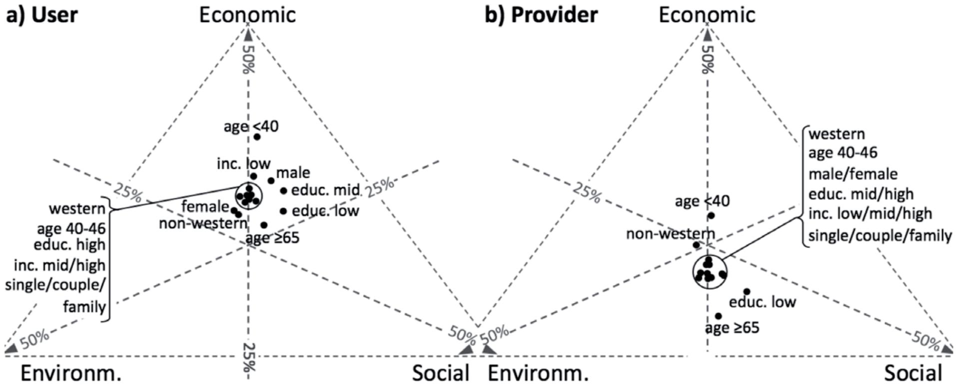


Figure 2.3: Motivations to participate in different sectors of the sharing economy, per socio-demographic group

Figure 2.3 presents an overview of the relative importance of economic, social and environmental motives, similar to Figure 2.2, but this time among different social groups. While the above-documented differences in motivations to use or provide between sectors are relatively large, differences between different socio-demographic groups are smaller. Overall, for each population category the three motivational items are relatively well balanced. Nevertheless, differences between socio-demographic groups can be identified. When looked at the *use* of shared assets (Figure 2.2a), it seems that men and low or middle educated groups are less environmentally motivated than women or highly educated groups respectively. Additionally, younger age groups (under 40 years old) and, to a lesser extent, low-income groups seem more economically motivated than older and middle- or high-income groups respectively. When looked at motivations to *provide* assets for sharing (Figure 2b), a somewhat similar picture arises, except for that the whole cluster of subgroups shifts downwards on the economic axis. This indicates that, over the board, economic motivations are less important for the provision than for the use of shared assets.

2.4.2 Multivariate analysis

Table 2.3 provides an overview of the relationships between socio-demographic backgrounds, sharing economy sectors and the role of user or provider and motivations to participate in the sharing economy. Three separate ordered logit models are estimated: for economic, social and environmental motivations. The parameter estimate (B) indicates the log odds change in the respective motivational score for a one-unit increase of the predictor (in the case of the continuous variable *age*) or for the indicated dummy variable relative to the reference category (for all other categorical variables), considering that all other variables remain constant. The z-statistic indicates the ratio between the parameter estimate and the robust standard errors clustered per respondent (see paragraph 2.3.2).

Table 2.3: Model output on motivations to participate in the sharing economy

	Ordered logit: Motivations to use / provided shared assets								
	Economic (N=1,810)			Social (N=1,790)			Environm. (N=1,739)		
	B	z		B	z		B	z	
Age	-0.025	-4.54	***	0.016	2.57	**	0.011	1.73	
Male (ref = female)	0.066	0.59		-0.118	-0.93		-0.502	-3.94	***
Non-western ethnicity (ref = western)	0.002	0.00		0.016	0.05		0.355	1.07	
Education (ref = low)									
Middle	-0.392	-1.61		-0.117	-0.49		0.246	1.05	
High professional	-0.165	-0.73		-0.371	-1.78		0.310	1.45	
High academic	-0.310	-1.33		-0.617	-2.84	**	0.257	1.19	
Household income (ref = lower)									
Middle	-0.703	-4.07	***	-0.418	-2.32	*	-0.304	-1.69	
Higher	-1.027	-5.34	***	-0.564	-2.75	**	-0.399	-1.91	
Unknown	-0.945	-4.92	***	-0.094	-0.48		-0.236	-1.15	
Household type (ref = family)									
Single	-0.186	-1.17		-0.086	-0.54		-0.133	-0.84	
Couple	-0.184	-1.17		-0.271	-1.68		-0.318	-1.93	
Other	-0.169	-0.45		0.132	0.39		0.174	0.41	
Sector (ref = accommodation)									
Car	-0.552	-4.85	***	-1.190	-9.85	***	1.652	12.29	***
Tool	-1.440	-8.60	***	-0.963	-6.15	***	0.891	5.47	***
Ride	-1.531	-10.95	***	-0.572	-4.07	***	1.460	11.26	***
Meal	-1.704	-12.23	***	0.303	2.16	*	0.638	5.13	***
User (ref = provider)	0.935	8.56	***	-0.135	-1.49		0.059	0.65	
Model fit:									
Wald chi2(df.)	384.7(17)		***	210.0(17)		***	236.4(17)		***
R^2 (McKelvey & Zavoina)	0.245			0.130			0.147		

* α=.05; ** α=.01; *** α=.001

The multivariate model results complement the descriptive results presented in the triangles in the figures 2.2 and 2.3. Older people are significantly less economically motivated and significantly more socially motivated, even when controlled for aspects such as income level. Considering gender, environmental motivations are significantly more important for women than for men. Unexpectedly, higher educated are significantly less socially driven to join the sharing economy. Instead, it was expected that higher educated would be more environmentally motivated to join the sharing economy. However, no significant relationship can be identified between education level and the importance of environmental motivations. More in line with our hypothesising, both middle and higher-income groups are significantly less economically motivated to participate in the sharing economy than low-income groups. In addition, middle and high-income groups are also less socially motivated. Ethnicity and household type have no significant effect on motivations to participate in the sharing economy. Regarding ethnicity, this may however be related to the low number of non-Western respondents.

Although some of the socio-demographics show important significant effects on motivations to share, most of the statistical variance in the models appears to be explained by differences between the sharing economy sectors. Compared to the reference category of accommodation sharing, in all other sectors economic motivations are less important. This is especially the case for ride, tool and meal sharing. As expected, meal sharing is the most socially motivated sector, followed by the reference category of accommodation sharing and ride sharing. For especially tool and car-sharing, social motivations are of lesser importance. As noticed in paragraph 4.1, environmental motivations are especially important for car and ride sharing and least important for accommodation sharing.

Finally, there is a difference in economic motivation between users and providers. Overall, users are more driven by economic motivations than providers. A possible mechanism behind this discrepancy was outlined before: for many objects, users can save a relatively large amount of money by renting instead of buying it. However, for providers the economic gains for renting out their objects are often small in comparison to the purchase price of the object. As hypothesised, no significant differences in social and environmental motivations between users and providers are observed. The environmental benefits result from the act of sharing, to which user and provider together participate. Also the social aspect of sharing concerns per definition both users and providers.

2.5 Discussion and conclusion

With the recent growth in scale and scope of the sharing economy, scientific, societal and political interest into this phenomenon has increased sharply. However, a deeper understanding of what motivates people to participate in different parts of the sharing economy has been largely lacking. This paper provides a comprehensive quantitative investigation of the relative importance of (1) economic, (2) social and (3) environmental motivations to participate in peer-to-peer sharing, with respect to differences between (a) sectors of the sharing economy, (b) socio-demographic groups, and (c) users and providers. Analyses draw on a stated preference survey amongst 1,330 respondents from Amsterdam.

Our findings reveal that motivations to participate differ between socio-demographic groups, between users and providers, and especially between different types of shared goods examined in this study: cars, rides, accommodation, tools and meals. Although this difference in motivations to participate in different sectors of the sharing economy is not necessarily surprising – i.e. the different types of goods compared in this study are quite different from each other – it underscores the importance to not conceive the sharing economy as one coherent phenomenon. The sharing of the expensive good of accommodation is highly economically motivated. Environmental motivations are important particularly for car and ride-sharing. For meal sharing, a sharing economy form with a high personal interaction component, social motivations play a large stimulating role. In contrast to sectorial differences and differences between users and providers, socio-demographic differences in motivations are of lower magnitude. Nevertheless, some significant effects are identified. Younger and low-income groups are more economically motivated to use and provide shared assets; younger, higher-income and higher-educated groups are less socially motivated; and women are more environmentally motivated. Finally, using different types of shared assets appears more economically motivated than providing.

The emerging literature on the sharing economy has approached this complex phenomenon from a variety of theoretical perspectives. Let us first discuss our results in the light of prior studies that use some form of motivation theory. In current studies most support is found for extrinsic motives of sharing economy behaviour (Bardhi & Eckhart, 2012; Hamari et al., 2015; Tussyadiah, 2016). With its cross-sectoral comparison of sharing economy sectors this study provides a more nuanced picture. Indeed, for the sharing economy forms of accommodation sharing and car-sharing, extrinsic, economic motivations are dominant. However, for meal, tool and ride sharing more intrinsic social and environmental motivations play an important role. The combination of motivations behind sharing economy participation thus is highly dependent on sharing economy sector. With regard to socio-demographic characteristics, the result that women are more environmentally driven resonates with Hellwig et al. (2015) who observe women being overrepresented among the group of intrinsically motivated *sharing idealists*. The finding that users are more economically motivated than providers is largely in line with the explorative study of Belotti et al. (2015). They employ a categorization of needs similar to Maslow's hierarchy (1970) and find that users tend to participate in the sharing economy predominantly for satisfying "basic needs", whereas the motivation of providers is somewhat more mixed, and includes also altruistic and community-oriented elements.

The findings also have implications for the definition of the sharing economy as voiced by Belk (2014a; 2014b). He distinguishes between "sharing" and "pseudo-sharing" or collaborative consumption. True sharing is associated with lending driven by social concerns and pseudo-sharing with renting out mainly for economic gains. In the light of our results this dichotomy seems too simplistic. Different combinations of motivations drive participation in each of the sectors of the sharing economy. Even if monetary exchange is involved in the process of sharing, environmental and social motivations can still be important. The configurations of different motivations for sharing economy participation of this study, resonate with the variety of logics Scaraboto (2016) observes on a user-initiated sharing economy platform. She sees sharing platforms as instances of hybrid economies, with a range of logics ranging from market-based exchange to altruistic gift-giving. There is a constant struggle between these logics, whereas at the same time various forms of hybrid logics are developed to overcome tensions. Contestations between logics are more pronounced when there are large differences in motivations between participating groups, such as between users and providers in the case of tool-sharing in this study. For platforms facilitating such exchanges, continuous "boundary work" to reconcile different motivations and logics seems thus required.

Our results also provide insights for the wider literature on sustainable innovation and societal transitions. First, in contrast to many transition studies, we have specifically distinguished between various user groups and their motivations. This provided insights particularly with regard to upscaling and diffusion, an increasingly important topic in this field (Shove et al., 2014; Geels & Johnson, 2015). The slow diffusion of many sustainable innovations (Negro et al., 2012) contrasts sharply with the fast spread of sharing economy forms such as accommodation sharing and ride sharing, which have shown exponential growth patterns in the past few years. The rapid growth of the sharing economy is generally attributed to the fact that it is based on existing capacity that is under-utilized, which explains why scaling can occur so fast. However, the variety in motivations driving sharing economy participation as identified in this paper, also seem an important explanation for the rapid growth of sharing practices. Sharing economy forms like peer-to-peer car-sharing provide direct economic as well as, to a certain extent, social benefits to adopters. These diverse benefits make "that there is something in it for anybody", leading to adoption far beyond a group of environmentally aware citizens.

This brings us to a second, and related, point: the investigation of user motivations is important for analyzing whether the innovation can really induce a transition towards a more sustainable society. Kemp and van Lente (2011) argue that sustainability transitions involve a dual challenge: the change of both systems (e.g. of transportation, agriculture) and of consumer criteria. Transitions that fail to change consumer criteria will not lead to sustainability because of rebound effects and other impacts. The sharing economy seems a very insightful case on this point. In our study it was found that accommodation sharing was the sharing economy form mostly driven by economic motives. Not surprisingly, accommodation sharing has also been linked most prominently with negative sustainability effects, such as rebound effects caused by increased travel frequency (e.g. Tussyadiah & Pesonen, 2015). Motivations can change over time. People who start sharing for utilitarian reasons might later come to appreciate social and environmental aspects of sharing, or vice versa. A worthwhile transition research project seems therefore to study the co-evolution of innovation forms and motivations over time, hereby distinguishing between motivations for different groups of participants.

This research provides a comprehensive quantitative cross-comparison of motivations to participate in different sectors of the sharing economy. However, the broad scope of this research has some limitations to be addressed in further research. *First*, in order to cross-compare motivations to use and provide different shared assets among one sample of respondents we have opted for a stated preference survey technique. This has the drawback that even though many respondents state a willingness to share, it is unclear whether they will actually start sharing in the near future and if yes, whether their motivations to do so will still be the same. As the sharing economy gradually upscales, further cross-sectional research could cross-compare motivations of actual sharing economy participants and perhaps triangulate these with stated motivations for those interested amongst the general population. *Second,* alternative research designs, possibly longitudinal, may be used to model in more detail the patterns of causality that exist between motivations to share, sharing intentions and actual sharing behaviours. Additionally, large-scale quantitative studies may explicitly study the possible interaction effects between socio-demographic factors, sharing economy sectors and roles as user or provider in explaining motivations to share. *Third*, following earlier research (e.g. (Tussyadiah, 2015)) we set out to explore economic, social, and environmental motivations to share. This is obviously only a limited number of motivations. Further research could explore other motivational dimensions of participation, as well as barriers, for example drawing on Social Exchange Theory (Kim et al, 2015).

Chapter 3

A weak spot for car-sharing? The geography of socio-technical regimes and the adoption of niche innovations

Abstract

A geographical analysis of sustainability transitions allows one to better understand the emergence and upscaling of sustainable innovations. We first theorize about the spatial heterogeneity of regime, niche and landscape within the Multi-Level Perspective and then apply our framework to car-sharing adoption across all Dutch neighbourhoods. We distinguish between business-to-consumer and peer-to-peer car-sharing, which differ in terms of business model and greenhouse gas reducing impacts. For these two innovations, we demonstrate how the relation between niche innovation and the socio-technical regime of private car ownership affects adoption patterns. Our study can be read as a plea for full-fledged geographical analysis of sustainability transitions equally emphasizing the spatial heterogeneity of niche, regime and landscape.

3.1 Introduction

In the face of climate change, academic interest in possible pathways to sustainable consumption and production has increased rapidly over the past decade. There is a widespread consensus that a sustainable economy will require major socio-technical transitions in the technologies and practices currently employed across the globe. Such transitions will not automatically unfold even when sustainable alternatives are present in specific niches. The prime reason for such inertia holds that pre-existing technologies and practices are maintained due to vested values, routines and interests associated with current unsustainable regimes (Rip & Kemp, 1998; Geels, 2002).

To understand better the sources of inertia and change, scholars have started to look at the geographies of sustainability transitions (Coenen et al., 2012). In every transition, one can observe places where innovations pop-up and alternatives are tried out, and other places where the current regime is strictly maintained and sometimes even strengthened. These differences stem from local processes of learning and politicking, which in some contexts may favour niche developments while in other contexts support the continuation of the regime technology. To give one example, the popularity of solar panels in Germany differs considerably across regions, which has been attributed to differences in local user activity and subsequent policy responses at different spatial scales (Dewald & Truffer, 2012).

By studying where innovations occur and scale up – so the promise of the geographical turn in the study of sustainability transitions – it can also become clear how and why transitions occur. However, a recent review of geographical studies of sustainability transitions suggests that this program has not yet entirely lived up to its promise (Hansen & Coenen, 2015). While a large number of case studies has convincingly shown that place-specificity matters for niche development, such "highly idiosyncratic case stories of specific places" do not "add up" to provide a coherent understanding of transition processes in an entire sector (Hansen & Coenen, 2015, p. 93). Indeed, there are only few studies that compare places across an entire sector and spatial system (Dewald & Truffer, 2012; Feola & Nunes, 2014). Though some studies look at multiple places where niche activity develops and how these places get entangled through various types of networks (Sengers & Raven, 2015; Fontes et al., 2016), a truly "symmetric" approach would be to study a multitude of places including those in which niche activity is entirely absent.

We argue below that in a multi-level perspective (MLP) on sustainability transitions, an understanding why certain places are breeding grounds for sustainable innovations does not translate into an understanding why many other places remain inactive in innovation development. Inactivity does not necessarily reflect the absence of local supportive conditions, but can also stem from particularly strong regime forces. Thus, we should move away from the implicit assumption that a regime is spatially homogeneous as if regime technologies are equally pervasive across places (Späth & Rohracher, 2012; Bridge, 2018). Innovative activity, or the absence hereof, should be understood as stemming both from innovation-supporting factors contesting a regime and from vested regime forces maintaining a regime. Both these supporting and constraining factors have a distinct geography: supporting factors stem from local conditions and initiatives as well as landscape factors that play out favourably in a local context, while constraining factors depend on the pervasiveness of the current regime as well as landscape forces.

As any regime will show variations in its pervasiveness across local contexts, one can also compare *multiple* niche innovations in terms of their sensitivities to vested regime forces. It has been noted before that some niche innovations are fundamentally challenging a regime, while others become integrated over time within the dominant regime (Geels & Schot, 2007; Geels et al., 2016). Also the potential to reduce greenhouse gas emissions of these types of innovations may differ (Nijland & van Meerkerk, 2017). In sectors where multiple innovations are being developed in parallel, our framework will allow to assess the sensitivity of innovations vis-à-vis regime presence by analyzing to what extent innovation occurs *most* in places where a regime is the *least* pervasive.

Our empirical context is that of car-sharing in The Netherlands. Car-sharing is a suitable case to apply our framework to as it has the potential to transform the transport system into more sustainable directions (Martin et al. 2010; Meyer & Shaheen, 2017), emerges against a dominant existing regime, and has two main variations with different relations to the regime. We will look at spatial variations in car-sharing adoption across all Dutch neighbourhoods. We distinguish between the two dominant business models that currently occupy a niche in the car mobility market: business-to-consumer (b2c) car-sharing, where users rent a locally available car from a car-sharing organization and the more recent peer-to-peer (p2p) car-sharing, where users rent a car from an individual car owner in their neighbourhood through an online platform. B2c car-sharing is found to have a larger impact on environmental sustainability than p2p car-sharing (Nijland & van Meerkerk, 2017).

Zooming out from single niches in single places to multiple niches across all places in a spatial system asks for a method that allows for comparing many localities. We therefore rely on a spatial-econometric approach where we count the number of shared cars of both niche types (b2c and p2p) in each Dutch neighbourhood as our variable to be explained. Data was collected for all cars shared via the two business models in The Netherlands. As explanatory variables we collected variables indicating influencing factors at the niche and landscape level as well as a variable indicating the pervasiveness of the vested regime based on individual car ownership. In this way, we are able to apply the multi-level framework for an entire spatial system.

3.2 Theoretical framework

Developed against the backdrop of societal challenges such as climate change and air-pollution, and rooted in evolutionary economics and science and technology studies, the sustainability transitions perspective is well-suited for the analysis of potentially transformative sustainable innovations such as car-sharing (Geels, 2012). In the sustainability transitions perspective, the objects of study are socio-technical systems that provide a certain function in society, such as health, water, food and mobility. These systems consist of networks of actors that interact with artefacts, technologies, and resources, guided by a semi-coherent set of rules that is called the *regime* (Rip & Kemp, 1998; Geels, 2002). The rules of the regime include norms, user expectations, legislation, as well as search heuristics of engineers.

In the case of mobility, one can conceive of the dominant socio-technical system as that of private car ownership, with key actors including car manufacturers, car dealers, car owners and civil servants working on traffic policy. Examples of regime rules are the image of the car as a status symbol, daily mobility habits of commuters and ideas of engineers about how to construct a car (Geels, 2012). The "rules" of the regime ensure that socio-technical change will mostly be incremental. Radical innovations do emerge, but remain confined to *niches*, which are "protected spaces, i.e. specific markets or application domains, in which radical innovations develop without being subject to the selection pressure of the prevailing regime" (Markard et al., 2012, p. 957).

From time to time, socio-technical systems and regimes do change substantially. These changes are enabled by developments on the so-called "landscape" level, that is, the wider context that influences niches and regimes. Relevant for our geographical analysis, the landscape is conceived as landscape in both its literal and metaphorical sense (Rip & Kemp, 1998; Geels, 2012; Geels et al., 2016). It includes spatial structures such as urban form, natural environment and physical resources, but also societal trends, ideologies and other influences (for example awareness about climate change or economic structures). Once a sector experiences a large-scale system change in a sustainable direction, one speaks of a sustainability transition: "a long-term, multi-dimensional, and fundamental transformation process through which established socio-technical systems shift to more sustainable modes of production and consumption" (Markard et al., 2012, p. 956). An example of such a transition would be the change from a mobility system based on car ownership towards one based on car-sharing. Importantly, the regime does not have to be entirely replaced for a transition to occur; instead various transition pathways are possible (Geels & Schot, 2007; Geels et al., 2016). Innovations can for example become integrated as an add-on to the existing regime.

The sustainability transitions field has recently experienced a "geographical turn" (Coenen et al., 2012; Hansen & Coenen, 2015). Here, the interest lies in understanding where transitions occur and how they evolve at different geographical scales. A recent review of empirical studies showed that most studies identify place-specific factors stimulating niche development, while the regime and landscape are conceptualized as spatially homogenous entities (Hansen & Coenen, 2015). This is noticeable and somewhat surprising since the strength of the multi-level perspective lies particularly in explaining how interactions between developments on niche, regime and landscape levels lead to the success and failure of sustainable innovations (Geels, 2002; Geels et al., 2017). Below, we explore the spatial dimensions of landscape, niche and regime level, and theorise how locally-varying factors at each level can influence the geographical adoption of sustainable innovations. Our framework, then, is made operational by collecting neighbourhood-level statistical data associated with each of the three levels.

Let us first develop a spatially heterogeneous conceptualization of the regime. While early transition studies implicitly assumed the existence of a regime in a sector equally present in every place, recent studies challenged this assumption by emphasizing that the regime may be unstable or even absent in some places. These include places in developing countries where formal transport systems or energy infrastructure are underdeveloped (Verbong et al., 2010; Sengers, 2016) or remote areas. Späth & Roharcher (2012), for example, study a remote mountain area without gas infrastructure, which is "off the radar" for incumbent actors of the gas energy regime.

Fünfschilling and Truffer (2014; 2016) provide a more refined conceptualization of regimes, and see them as institutionalized to a certain degree. We have defined the regime in this study as the rule-set structuring the behaviour of actors. For the rule-set to be effective it has to be present in routines, practices and technologies. Different degrees exist to which the regime is translated in practice (i.e. institutionalized), and herewith has impact on actors (Fünfschilling & Binz, 2017). So instead of being either totally dominant or absent – as in the case of the remote mountain region in the study of Späth and Roharcher (2012) – we can now see the presence of the regime as a variable, and indicate for each place to what extent the regime is institutionalized. Importantly, given that the regime has less impact on actors in places where it is less institutionalized, these places are expected to be the ones where niche innovations emerge and scale up.

We hence conceptualize the geographically heterogeneous regime as a patchwork of localities in which the regime is more or less institutionalized. The spatial heterogeneity of the regime stems from varying degrees of fit with the local context. For example, van Welie et al. (2017) show how the regime of the sewage system is less embedded in disadvantaged neighbourhoods in Nairobi, because of the poor fit with local socio-spatial conditions related to income, land ownership and physical terrain. For the car regime, Nykvist & Nilsson (2015) note that it is partly global, with international rule sets such as safety standards, but they maintain that for a transition analysis also the regime at the national and local scale has to be considered. In their example, local municipalities that construct infrastructure are important regime actors. Given the influence of local socio-spatial context structures on the institutionalization of the regime, we expect to observe differences in the institutionalization of the regime even at the local level. At the local level, we will then also be able to identify places where innovations emerge and upscale thanks to a lower pressure of the regime on actors.

In contrast to regimes, niches are in the transitions literature commonly associated with specific places (Bulkeley, 2010; Hansen & Coenen, 2015; Longhurst, 2015). Particular characteristics of a place can provide protection for the innovation to develop and scale up. For example, Dewald and Truffer (2012) show how in certain German regions engaged end-users were present, who initiated solar energy collectives enhancing adoption. Niches can also be actively constructed by policy actors (Smith & Raven, 2013). A typical example are municipal policies stimulating the development of sustainable transport innovations through subsidies, regulations and experiments (Coenen et al., 2010; Carvalho et al., 2012). Note, however, that in some cases niche protection also occurs at higher spatial scales. Although niches are often linked with specific localities, niches can also be formed by countries (Johnson & Silveira, 2014) or by multi-scalar networks (Sengers & Raven, 2015). Assuming that policies have an effect, their spatially heterogeneous implementation will influence the geographical adoption pattern of sustainable innovations. In this study, factors associated with the niche level are specific protective conditions that are expected to directly contribute to the adoption of the innovation under study. We expect that niche protection is especially important for innovations that challenge a regime rather than complement it.

Finally, in the MLP, the landscape level refers to the wider context that is largely exogenous to the evolution of a socio-technical system in a sector, yet nevertheless affects the chances of sustainable innovations to occur and to scale-up. The landscape can stabilize or destabilize the existing socio-technical regime, providing legitimization for the sustainable innovation or reversely hinder its adoption (Geels, 2011). As for the levels of niche and regime, the landscape level can also be thought of as spatially heterogeneous. Geels et al. (2016) point out the importance of spatial "static" landscape factors when comparing the electricity transition between Germany and the United Kingdom. The static landscape refers to socio-spatial context factors that differ between the two countries. In their example, in Germany environmental awareness, an active civil society, a cooperative institutional structure and the presence of manufacturing industries led to a more radical shift towards renewable energy than in the UK. Also at a more fine-grained spatial scale we can identify such varying socio-spatial context factors possibly influencing the adoption of sustainable innovations, such as income and education levels of the population (Kwan, 2012; Coll et al. 2014). Hence, it is expected that the geography of the landscape level will be reflected in the spatial adoption pattern of sustainable innovations.

3.3 The case of car-sharing

In this study, we analyze the adoption of two types of car-sharing in the context of the current regime of individual car ownership (Geels, 2012). Car-sharing is a relevant case to apply our theoretical framework to because a) it is an innovation that, at least *potentially*, could transform the fairly stable car mobility system into a more sustainable one (Shaheen, 2012; Meyer & Shaheen, 2017), b) it emerges in the context of a clear regime, namely private car ownership, c) it comes in two main varieties, each with a different relation the regime. The oldest form of car-sharing has become known as traditional or business-to-consumer (b2c) car-sharing which emerged in The Netherlands during the 1990s. In this type of car-sharing, a car-sharing organization owns a fleet of cars that are stationed dispersedly over residential neighbourhoods and users can rent a locally available car. A more recent type of car-sharing, that has emerged in the early 2010s, is peer-to-peer (p2p) car-sharing. In this business model, users rent a car from an individual car owner in their neighbourhood through an online two-sided platform bringing together supply and demand. The latter kind of sharing is generally considered as part of the sharing economy in which consumers rent out their under-utilized assets to other consumers (Fraiberger & Sundararajan, 2015; Frenken and Schor, 2017).

The key difference between b2c car-sharing and p2p car-sharing holds that a p2p platform does not own any vehicle. Instead, the platform leverages the idle capacity of cars already owned by individuals. Many car owners do not make daily use of their car and thus may choose to offer it for rent for particular days via the platform. This holds *a fortiori* for households owning multiple cars. The leverage of idle capacity of cars could explain why p2p car-sharing, despite its recent emergence, already outnumbers b2c car-sharing[11] Since the supply of cars on a p2p-platform does not require investment in cars by the platform nor investments of the car owner, p2p

[11] Note, however, that the utilization rate of cars rented out via the b2c model is considerably higher than of cars rented out via the p2p model. The reason for this difference in utilization rate holds that a business that rents out cars will only place cars in neighbourhoods with sufficient demand, while a car owner may supply his/her car even if local demand is low given zero marginal costs.

car-sharing can scale up relatively easily. As such, p2p car-sharing builds on the current regime of car ownership as it provides car owners the possibility to recover part of the fixed costs of owning a car by occasionally renting it out. B2c car-sharing, by contrast, was setup to provide infrequent car owners with an alternative to car ownership by providing locally available cars on a 24/7 basis.

The two forms of car-sharing also differ in their sustainability impacts. Shaheen (2012) reviewed 18 North-American b2c car-sharing studies and found that most studies report around 25% of participants selling their car after joining the program. However, there is considerable variation in the observed reduction in kilometres driven, with findings ranging from 3 to 79.8 %. Nijland and Meerkerk (2017) compared the impacts of p2p and b2c car-sharing. They surveyed 363 Dutch users who engaged in car-sharing for at least one year. They find on average no reduction in car ownership for the p2p users, while a reduction is observed for b2c. What is more, the decrease in car kilometres driven in a year for p2p car-sharing is only around half of that of b2c car-sharing users. The stronger sustainability profile of b2c car-sharing resonates with reports of b2c car-sharing organizations that started as environmentally motivated cooperatives (Truffer, 2003; Vaskelainen and Münzel, 2017; Münzel et al., 2017). It is also evident in the name of the market leader in the Dutch market ("Greenwheels").

In our analysis, we measure the local pervasiveness of the private car ownership regime by a neighbourhood's motorization rate, which is the average number of cars owned per inhabitant. The regime is defined in this study as the rule-set that comes into effect in local routines, practices and technologies (Fünfschilling & Binz, 2017). We consider the motorization rate as the most direct and locally available measure of the regime. The measure encompasses multiple regime dimensions, as the socio-cultural (e.g. image of car ownership as a status symbol), cognitive (e.g. number of driving licences) and legislative (e.g. car regulation) elements of the regime eventually all materialize in a certain motorization rate i.e. the degree of private car ownership in a neighbourhood. Given the differences between the two car-sharing business models, our *key hypothesis* holds that b2c car-sharing is most popular in neighbourhoods where the current regime of car ownership is weak. If few cars are being owned, people are more inclined to use alternative transport forms such as car-sharing (Coll et al., 2014). The relationship between p2p car-sharing and regime presence is more complex. On the one hand, a low motorization rate may lead to a larger demand for car-sharing, including for cars that are being shared among peers. On the other hand, a higher motorization rate means that more cars are available in a neighbourhood that are potentially offered for rent through a p2p platform.

On the niche level, we expect two factors to influence spatial adoption. Local policies have been used as the primary *explanans* for geographical differences in sustainability transitions (Hansen & Coenen, 2015). With regard to car-sharing, municipalities have developed information–related policy instruments to stimulate public awareness around car-sharing (Enoch & Taylor, 2006). A typical example is the "Utrecht shares" campaign in which the Dutch municipality of Utrecht provided information about car-sharing in various media, which also received input of local car-sharing firms (MunofU, 2014). It is expected that municipalities that have implemented these policies show higher adoption levels of the respective form of car-sharing. We further expect university towns to provide niche protection for car-sharing.[12] These localities provide exceptional opportunities for car-sharing as students are over-represented (Shaheen et al., 2009). University students can be expected to be among early users, being young and highly educated, and generally aware and open to sustainable innovation. What is more, most universities are located in medieval city centres or on campuses with parking restrictions, and are well served by public transport. Car-sharing provides students with an alternative for occasional car use to supplement their daily use of bikes and public transport.

The place-specific factors associated with the landscape level are not influenced in the short-run by regime actors nor by those supporting a niche (Geels, 2011). Yet, some of these exogenous factors may affect adoption, both positively and negatively. Population density and distance to facilities (such as retail or schools) are two landscape factors in the literal sense. These can be expected to vary highly between neighbourhoods, especially across rural, suburban and urban areas. Note that, over the past century, the car regime contributed itself to these factors, especially to the rise of suburbia with low population density and long distances to facilities (Urry, 2004). Nevertheless, we consider these two factors to be part of the wider landscape given their durability and given that many other factors besides car ownership have contributed to population density and distance to facilities (see also Geels, 2012).

We expect that population density only affects the adoption of b2c car-sharing. For this form of car-sharing, a certain population density is necessary to ensure a user base that is large enough to cover the cost for a rental organization to place a dedicated car-sharing vehicle (Millard-Ball et al., 2005; Coll et al., 2014). For p2p car-sharing, instead, a density requirement is absent, because the supply of one's own car comes at very low marginal cost. Hence, no effect of population density on local p2p car-sharing is expected.

[12] Amsterdam, Delft, Eindhoven, Enschede, Groningen, Leiden, Maastricht, Nijmegen, Leiden, Rotterdam, Utrecht, Tilburg, Wageningen.

Neighbourhoods with many facilities have been found to have higher levels of car-sharing (Coll et al., 2014), so we expect that a larger distance to these facilities negatively affects car-sharing adoption.

Next to the literal landscape factors, other landscape factors may affect the adoption of car-sharing at the neighbourhood level. Notably, car-sharing is known to appeal to people with higher environmental awareness (Millard-Ball et al., 2005). Hence, we expect that both forms of car-sharing are adopted more often in localities with a higher share of people who are environmentally aware. A similar positive effect on car-sharing adoption sharing is expected for localities with many highly educated people and younger people who tend to be more open to innovation more generally (Rogers, 1962).

Concerning income, higher income households generally have higher likelihoods of innovation adoption given their purchasing power. However, the effects of income on car-sharing adoption are still unclear (Zhou & Kockelman, 2011; Coll et al., 2014). Particularly, when looking at p2p car-sharing, cost-saving considerations are an important motive to supply one's car. In that case, one would expect lower incomes in neigbourhoods to be associated with a higher number of p2p shared cars (Fraiberger & Sundararajan, 2015; Böcker & Meelen, 2017).

We consider two further landscape factors that are expected to affect b2c and p2p car-sharing adoption alike. First, it has been claimed that car-sharing particularly suits expatriates, as car-sharing provides them with a temporary mobility solution (Grunn, 2007). Finally, Celsor and Millard-Ball (2007) look at household characteristics and find that the percentage of one person households correlates positively with the number of shared cars. A likely explanation holds that families with children have special requirements for their car such as children seats or large trunks which makes them less likely to engage in car-sharing.[13] Hence, one would expect that neighbourhoods with a lower average household size, have higher adoption levels of car-sharing.

Table 3.1 shows a summary of all expected effects of the niche, regime and landscape factors we discussed and distinguishing between b2c and p2p car-sharing adoption.

[13] Coll et al. (2014) on the other hand, did not find more use of car-sharing in areas with many one-person households, but they studied a car-sharing program where all cars were equipped with children seats.

Table 3.1: Expected effects of regime, landscape and niche factors on car-sharing adoption

	b2c car-sharing	p2p car-sharing
Regime		
Motorization rate	-	+/-
Niche		
Municipal car-sharing policy	+	+
University city	+	+
Landscape		
Population density	+	
Distance to facilities	-	-
Environmental awareness	+	+
Age group 25-45	+	+
Highly educated	+	+
Income		-
Household size	-	-
Immigrants from Western countries	+	+

3.4 Methodology

As we aim to explore the two niches and the regime across a whole spatial system, we use a quantitative method in our analysis. Not yet often used in sustainability transition studies, our method allows for the comparison of developments in a transition across many localities as well as for an assessment of the relative importance of each of the variables by using statistical tests. As such, our approach can be considered as an attempt to build bridges between the geography of transitions literature and the field of quantitative innovation adoption studies.

In the analyses, the dependent variables are the number of b2c and p2p shared cars in Dutch neighbourhoods. The data were collected at the postal code area (4-digit) for the entire country of The Netherlands during the months of March, April and May 2014. The Netherlands is divided in 4047 of such postcode areas, which have on average approximately 4000 inhabitants. Data about the location of shared cars was obtained via the websites of car-sharing firms. These websites publicly list the addresses of the cars. From one car-sharing firm the data could be obtained directly. All firms that were, to our knowledge, active in car-sharing in The Netherlands were included.[14]

[14] Firms included are Car2Go, CareCar, Connect Car, Drive, Greenwheels, MyWheels, SnappCar, StudentCar and WeGo.

The independent variables are the place-specific factors associated with the regime, landscape and niches as discussed in the previous section. In addition, to control for the varying number of inhabitants per postcode area, the number of inhabitants was added as a control variable in all models. Data for the variables were collected from the Dutch statistical office (CBS, 2011; 2013a;b;c;d). For the environmental awareness variable, the number of members of a large environmental organization was taken. For the policy variable in all Dutch municipalities (n=408) the presence and content of car-sharing policies was investigated. Hereto, during the summer months of 2014, we systematically searched for the terms of *autodelen* or *autodate* (most common Dutch terms for car-sharing) on municipal websites, and for the combination of these terms and the municipality name in the newspaper database LexisNexis and on Google Search. A dummy variable was created indicating the presence of an information-related policy, i.e. communication about car-sharing through a municipal website or other communication channel. Table 3.2 reports descriptive statistics of the variables.

We use zero-inflated negative binomial models to model the spatial adoption patterns of p2p and b2c car-sharing (Cameron & Trivedi, 2013). The dependent variable in the models is a count (the number of cars in a postcode area). When dealing with count data Poisson or negative binomial models are typically used. The negative binomial model is preferred over the Poisson model if overdispersion is present (i.e. if the conditional variance is larger than the conditional mean). As this was the case for our dependent variable, the negative binomial model was chosen.[15] More specifically, we opted for the zero-inflated negative binomial model (ZINB), able of handling the large amount of zeros (postcode areas with no shared cars in our data). Vuong (1989) tests showed that the zero-inflated negative binomial model indeed fits the data better than the negative binomial model. A ZINB model consists of two parts. First, a logit model (zero-inflated part) for estimating the probability of a postcode having zero shared cars. Second, a negative binomial model for estimating the counts of shared cars for postcode areas with a non-zero probability for having shared cars. Hence, the ZINB model allows us to investigate separately 1) what factors influence the availability of the of p2p car-sharing and b2c car-sharing in an area (zero-inflated part) 2) For the areas in which it is likely that cars are shared, what factors influence the numbers of cars that are shared (see Kwan et al., 2012; Coll et al., 2014). In the models, the standard errors are clustered at the municipal level (Cameron & Miller, 2015).[16]

[15] The significant values for the overdispersion parameter indicate that the negative binomial model fits the data better than the Poisson model.

[16] By clustering standard errors at the level of municipalities, we take into account correlation of the errors within municipalities and remain conservative in our assessment of significance. This approach is similar to using a spatially robust variance matrix taking into account neighbouring units (Cameron & Miller, 2015). Recently, count regression models have been developed with more complex spatial error structures (Liviano & Arauzo-Carod, 2014). These models are mostly developed in a Bayesian context and will not be employed in this study.

Table 3.2: Descriptive statistics

Variable	Description	N	Mean	Standard Deviation	Min	Max
Shared cars (p2p)	Number of cars per postcode area shared via the peer-to-peer model	4,028	2.078	4.476	0	61
Shared cars (b2c)	Number of cars per postcode area shared via the business-to-consumer model	4,026	0.569	3.141	0	55
Motorization[17]	The number of cars per 100 inhabitants	3,910	49.267	9.642	7.727	97.849
Population density (x1000)	The number of inhabitants per km2	4,033	1.684	3.015	0	44.230
Distance to facilities	The average of the standardized distance to a child care center, primary school, high school for vocational education, high school and supermarket	3,837	-0.000	.787	-1.111	5.784
Environmental awareness (as measured by % members environmental organization)	The percentage of people member of a large environmental organization	4,025	2.649	1.658	0	30
Household size	The average number of people in a house-hold	4,033	2.346	0.349	1	5
Income (x1000)	The average house-hold income	3,575	35.899	6.662	11.800	106.800
% Highly educated	Percentage of people in postcode holding a higher vocational, bachelor, master or PhD degree	2,623	18.442	9.035	4	60

[17] The data also includes cars registered on behalf of some lease and car companies. The Dutch statistics agency has also published a cleaned dataset with only private cars on the “neighbourhood” (N=3096) level (CBS, 2016). This is on a slightly higher, yet still comparable aggregation level as the (N=4048) postcode areas of this study. In the cleaned dataset the maximum motorization level in a neighbourhood was 0.952 cars per inhabitant. Values in our dataset above 1 car per inhabitant were therefore considered as resulting from the presence of lease and car companies and excluded from the analysis (116).

Table 3.2: continued

Variable	Description	N	Mean	Standard Deviation	Min	Max
% age 25-45	Percentage of people between 25 and 45 years old	4,024	23.626	6.932	0	100
% Immigrants from Western countries	Percentage of people from a country in Europe (excl. Turkey), North America, Oceania, Indonesia or Japan	4,025	7.745	5.481	0	66.67
Municipal car-sharing policy (p2p)	Dummy variable (0/1) for the presence of an information-related policy for car-sharing in the municipality	4,019	0.137	0.344	0	1
Municipal car-sharing policy (b2c)	Dummy variable (0/1) for the presence of an information-related policy for car-sharing in the municipality	4,019	0.207	0.405	0	1
University city	Dummy variable (0/1) for university city	4,047	0.099	0.298	0	1
Population (x1000)	Number of inhabitants of the postcode area (to control for the varying number of inhabitants per postcode area)	4,033	4.160	4.134	0	28.600

3.5 Results

Before turning to the results of our statistical analysis, we provide some historical context about the growth of car-sharing in The Netherlands. As noted before, p2p car-sharing was initiated later than b2c car-sharing, but has already overtaken it in terms of available cars. This is also clear from figure 2.1, which depicts the growth in the number of b2c and p2p shared cars. As of July 2014, 8369 cars were shared via the p2p model, whereas 2290 cars were shared via the b2c model in The Netherlands. B2c car-sharing has been around since the mid1990s, but has seen relatively limited growth. In the past years, the number of cars shared via the b2c business model has remained relatively stable. P2p car-sharing, on the other hand, grew rapidly. Growth percentages of the number of available p2p cars were about 200-300% in the years before 2014.

To get a better understanding of this upscaling process, Figure 2.2 shows the spatial heterogeneity of the socio-technical regime, as well as the adoption levels of b2c and p2p car-sharing. The regime is strongest in the rural areas in the east and north near the border. It is weaker in the urbanized west, with the notable exception of some commuter towns. Stark differences can also be observed in the geographical adoption patterns of p2p and b2c based car-sharing (figure 3.3A and 3.3B). As one familiar with the geography of the Netherlands would recognize the adoption of business-to-consumer car-sharing is restricted to the major cities in the Netherlands, and particularly clustered around the capital city of Amsterdam. The adoption of p2p car-sharing is higher in and around the main cities, but p2p car-sharing is also present outside the large cities, even in rural postcode areas in the east and north of the country. A pattern thus emerges of b2c car-sharing supply that is concentrated in cities, while the supply of a p2p shared cars occurs anywhere where car owners live, including rural areas.

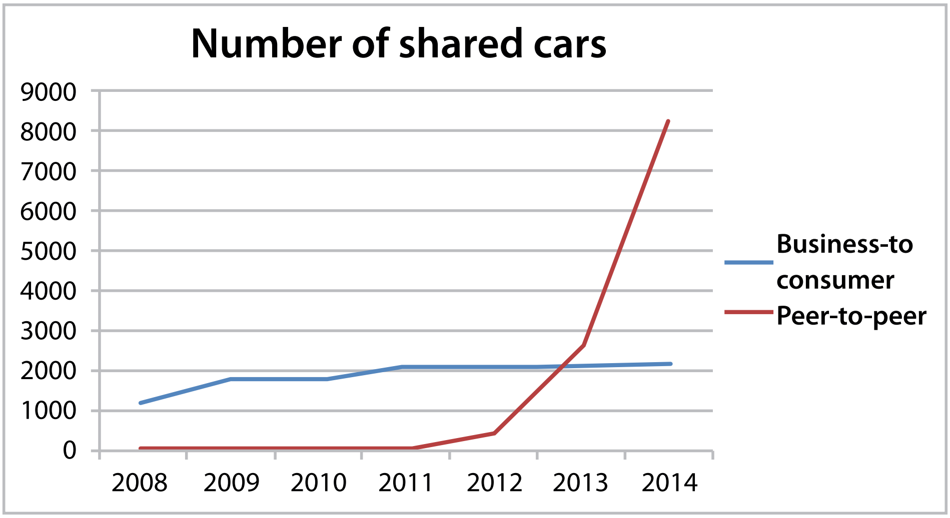


Figure 3.1. The uptake of business-to-consumer and peer-to-peer car-sharing in the Netherlands (Crow-KPVV, 2014)

We now turn to the results of the Zero-Inflated Negative Binomial (ZINB) models. These models allow us to analyze the simultaneous influence of various factors on adoption. The ZINB models consist of two parts: one to estimate the probability that zero cars are shared in an area (zero-inflated part), and one to estimate the count of cars in areas where it is likely that cars are shared (see Kwan, 2012). The results of the zero-inflated part of the models are shown in table 3.3. Here the probability is estimated for postcode areas to belong to the "strictly zero group" (postcode areas without shared cars).

A stronger socio-technical regime increases the likelihood of the non-availability of b2c car-sharing. As can be seen in table 3.3, the higher the motorization level, the higher the likelihood of having no shared cars in the neighbourhood. On the other hand, there is no such relationship between the socio-technical regime and the non-availability of p2p car-sharing. This indeed indicates that the b2c car-sharing niche is stronger in areas where the existing regime is less pervasive, while the p2p car-sharing niche – making use of existing idle capacity of private cars – does not mirror the weakness of the car regime.

Some landscape factors affect the adoption of business to consumer car-sharing: a larger average household size increases the chances for zero shared cars, as expected. Higher environmental awareness and higher education decrease the probability of having zero shared cars, also as expected. Strikingly, for p2p car-sharing no significant effect of any landscape factor is observed.

Finally, the niche level factors affect neither form of car-sharing. The chances of zero shared cars in a neighbourhood are unaffected by municipality policies nor by university presence.

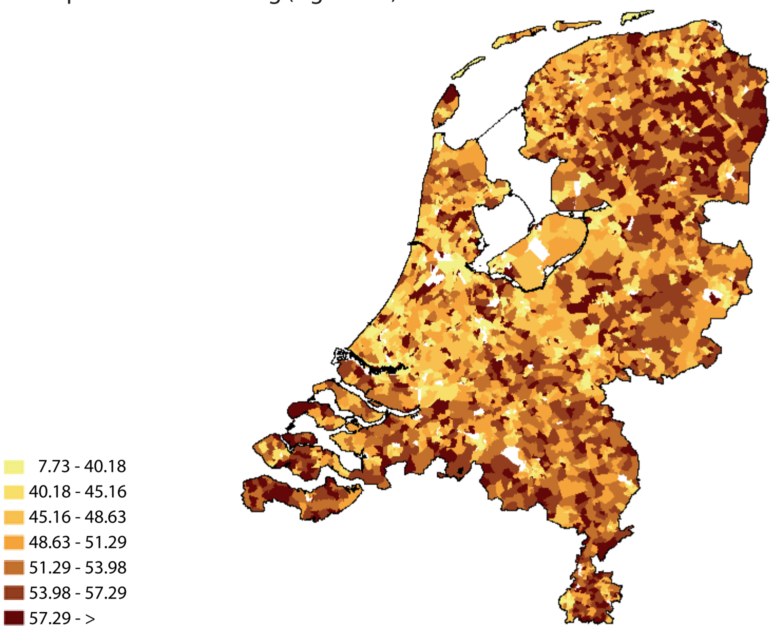
To sum up, the sheer presence of b2c shared cars in an area relates to certain regime and landscape factors. In areas where these are unfavourable, this form of car-sharing is less likely to be present. On the other hand, for p2p car-sharing none of the landscape, regime or niche factors influences the sheer presence of p2p shared cars.

Table 3.4 shows the results of the negative binomial part of the models. As described in section 3.3, the ZINB model splits the postcode areas into two groups. The negative binomial part of the models estimates the counts of shared cars for the group of postcode areas for which it is likely that cars are shared. Let us first consider the effect of the socio-technical regime on the expected number of shared cars. As expected, for b2c car-sharing, the number of shared cars is lower in areas where the existing regime, as measured by the motorization rate, is stronger. Table 3.4 also gives some impression of the magnitude of the effects. If the number of cars owned per hundred people is one car higher, this leads to a decrease of 2.4% in the expected number of shared cars. For p2p car-sharing, a weaker (but also negative) relation between the motorization regime and the presence of p2p car-sharing is found. As can be seen in table 3.4, if one car more is owned per hundred persons in a neighbourhood, this leads to a decrease of the expected number of cars with one percent.

Let us now turn to the landscape level. When coming to the literal landscape, for b2c car-sharing no clear effect of population density and distance to facilities on the number of cars is observed. For p2p car-sharing, the distance to facilities (such as supermarkets and schools) in an area has a negative influence on the number of shared cars. Considering the metaphorical landscape, a large positive effect of environmental awareness on b2c car-sharing adoption is observed. If the percentage of people who are members of the environmental organization used in this study is one unit higher (e.g., 3.5 instead of the average of 2.5 percent of the population), this results in a 51% increase in the number of shared cars in the postcode area. A positive effect is also observed for p2p car-sharing. Contrary to our expectation that car-sharing is less prevalent among households with children, no effect of household size on the number of shared cars was observed for both forms of car-sharing. Income is found to have a positive effect on the number of cars shared for both forms of car-sharing. Also areas with an overrepresentation of 25-45 years old have a higher number of shared cars. For b2c car-sharing, in line with claims that expatriates make more use of car-sharing services, the percentage of Western immigrants positively influences the number of shared cars. However, this is not the case for p2p car-sharing where a negative effect is observed.

Finally, niche level factors are considered. Municipal information-related policies are positively associated with the adoption of both forms of car-sharing. No difference between university cities and other areas was found.

When comparing the results for p2p car-sharing and b2c car-sharing, most differences are observed in the zero-inflated part of the model. Whereas the regime (and some landscape) factors influence the non-availability of b2c car-sharing, none of the factors in this study did so for p2p car-sharing. The results of the negative binomial part of the model indicate that the motorization regime hampers the scaling of both car-sharing niches, but more so for b2c sharing than for p2p sharing. P2p car-sharing thus is less constrained by the prevailing regime based on private car ownership than b2c car-sharing, which is also in line with the rapid growth of p2p sharing and the much slower development of b2c sharing (Figure 3.1).



Number of cars owned per 100 inhabitants

Figure 3.2 The motorization regime

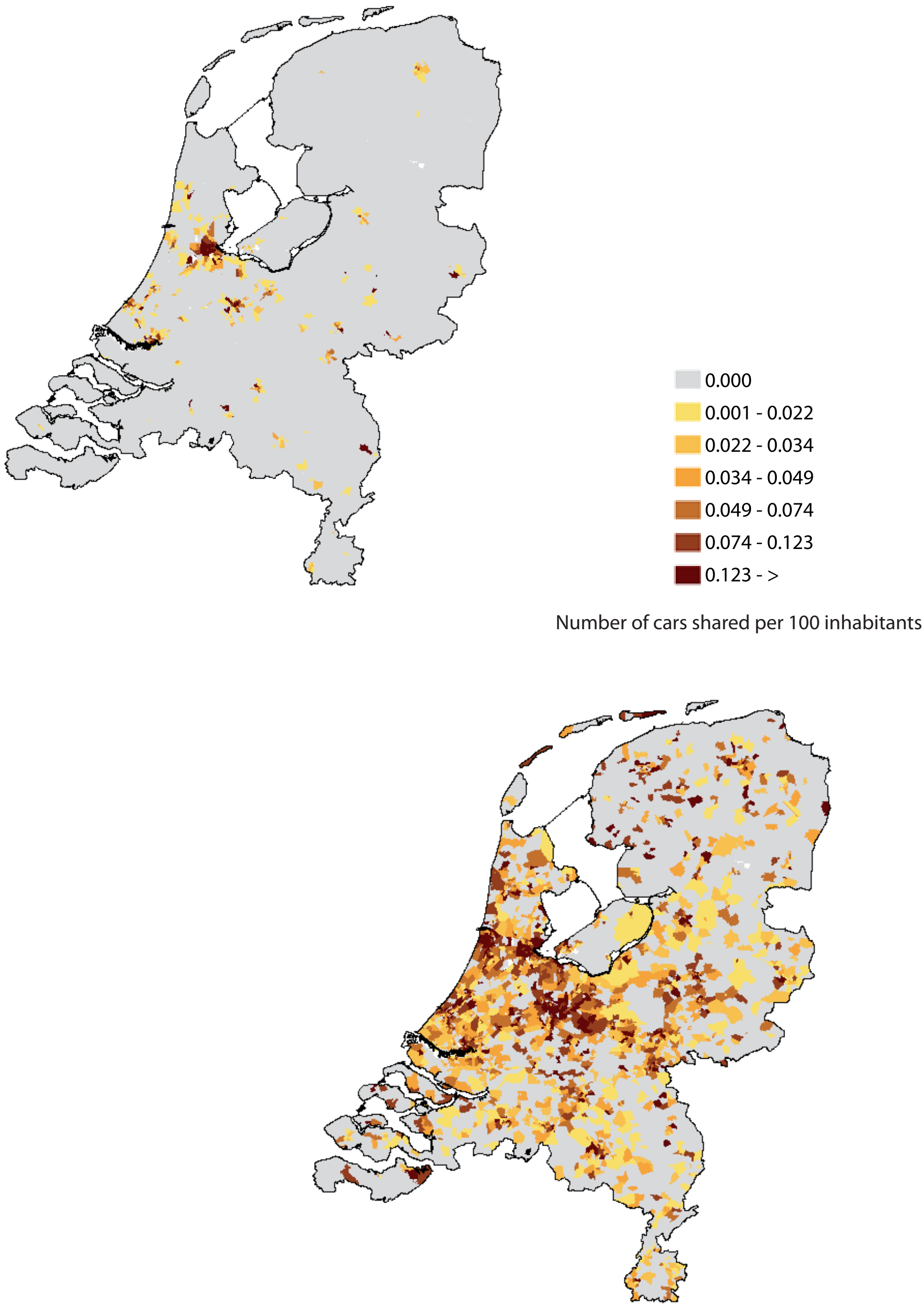


Figure 3.3 The adoption of business-to-consumer (top image) and peer-to-peer (bottom image) car-sharing

Table 3.3 Coefficient estimates for the zero-inflated model part.

	Business to consumer-car-sharing		Peer-to-peer car-sharing	
Regime				
Motorization rate	0.147**	(0.0487)	0.0237	(0.0203)
Landscape				
Population density (x1000)	-0.0104	(0.0730)	-0.0667	(0.119)
Distance to facilities (standardized composite measure)	0.0279	(1.414)	-0.0696	(0.280)
Environmental organization membership (%)	-1.012**	(0.342)	-0.0570	(0.158)
Household size	3.434*	(1.392)	0.994	(0.912)
Household income (x1000)	0.0327	(0.0752)	-0.0616	(0.0502)
Highly educated (%)	-0.193*	(0.0957)	-0.0366	(0.0275)
Age between 25-45 (%)	-0.0429	(0.0575)	-0.0224	(0.0336)
Western immigrant (%)	0.0464	(0.0571)	0.0175	(0.0336)
Niche				
University city (yes/no)	1.202	(0.639)	-0.443	(0.519)
Policy (yes/no)	-0.697	(0.520)	-0.199	(0.500)
Control				
Population (x1000)	-0.0968	(0.0582)	-0.578**	(0.194)
Constant	-7.333	(5.035)	0.964	(2.524)
Observations (total model)	2,516		2,516	

*** $p<0.001$, ** $p<0.01$, * $p<0.05$

Table 3.4 Estimates for the count (negative binomial) model part.

	Business to consumer car-sharing			
	Coefficient		% expected change in count per unit increase	% change in count per standard deviation increase
Regime				
Motorization rate	-0.0248**	(0.00825)	-2.4	-19.3
Landscape				
Population density (x1000)	-0.0246	(0.0156)	-2.4	-7.8
Distance to facilities (standardized composite measure)[18]	-0.549	(0.371)	-42.3	-27.7
Environmental organization membership (%)	0.415***	(0.0543)	51.4	62.0
Household size	-0.441	(0.497)	-35.6	-13.0
Household income (x1000)	0.0414*	(0.0197)	4.2	30.5
Highly educated (%)	-0.0256	(0.0151)	-2.5	-20.7
Age between 25-45 (%)	0.0542***	(0.00994)	5.6	35.7
Western immigrant (%)	0.0756***	(0.0213)	7.9	43.9
Niche				
University city (yes/no)	0.487	(0.290)	62.8	17.7
Policy (yes/no)	0.583***	(0.150)	79.1	29.3
Control				
Population (x1000)	0.136***	(0.0181)	14.6	71.0
Constant	-4.551***	(0.792)		
Observations (total model)	2,516			

*** p<0.001, ** p<0.01, * p<0.05

[18] The distance to facilities variable is composed of the standardized versions of variables measuring the distance to multiple facilities (such as schools, daycare etc.). The "Per unit" value can therefore not be interpreted as kilometer distance.

Table 3.4 (continued) Estimates for the count (negative binomial) model part.

	Peer-to-peer car-sharing			
	Coefficient		% expected change in count per unit increase	% change in count per standard deviation increase
Regime				
Motorization rate	-0.00991*	(0.00441)	-1.0	-8.2
Landscape				
Population density (x1000)	0.00274	(0.0131)	0.3	0.9
Distance to facilities (standardized composite measure)	-0.280***	(0.0709)	-24.4	-15.2
Environmental organization membership (%)	0.271***	(0.0312)	31.1	37.0
Household size	-0.147	(0.140)	-13.7	-4.5
Household income (x1000)	0.0146*	(0.00732)	1.5	9.8
Highly educated (%)	0.0108*	(0.00516)	1.1	10.3
Age between 25-45 (%)	0.0370***	(0.00490)	3.8	23.2
Western immigrant (%)	-0.0231**	(0.00730)	-2.3	-10.5
Niche				
University city (yes/no)	-0.0393	(0.0634)	-3.8	-1.3
Policy (yes/no)	0.192*	(0.0748)	21.2	7.6
Control				
Population (x1000)	0.110***	(0.00896)	11.6	54.3
Constant	-1.351***	(0.366)		
Observations (total model)	2,516			

*** p<0.001, ** p<0.01, * p<0.05

3.6 Concluding remarks

The geography of sustainability transitions is a rapidly emerging topic of scientific interest (Coenen et al., 2012; Hansen & Coenen, 2015). We applied this framework to the study of car-sharing against the background of the current regime of private car ownership. The main novelties in our study are 1) the development of a spatially heterogeneous notion of the regime, niche and landscape levels of the Multi-Level Perspective (MLP), b) the analysis of two competing niche innovations and their respective relations to the current regime, and c) the deployment of a quantitative approach to sustainability transitions by studying the adoption of all cars shared via the b2c and p2p model, in all Dutch neighbourhoods.

The findings show that the geography of the regime indeed affects the adoption of car-sharing across neighbourhoods. In areas with lower rates of motorization we find a higher number of shared cars. A stronger regime also increases the chances of having zero shared cars in a neighbourhood. Importantly, this latter finding was confined to b2c car-sharing as the availability of p2p car-sharing is insensitive to the motorization rate. These findings indicate that p2p car-sharing can be understood both as challenging the regime of private car ownership by allowing people to rent cars from peers instead of owning cars and as extending the current regime by enabling car owners to draw on the existing idle regime capacity of cars. We further found that the niche-creation policies by municipalities indeed stimulate the adoption of shared cars. Their information campaigns stimulate both types of car-sharing. Finally, we were able to explore multiple landscape factors ranging from physical factors such as population density and distance to facilities to attitudes towards sustainability and more classic socio-demographic factors. These findings exemplify the soft pressures exerted by generic landscape factors that are largely exogenous to the specific development of niches in the context of a regime. Out of these factors, environmental awareness had a large significant impact on car-sharing adoption, confirming the role of ideological motivations among car sharers found in previous studies (Truffer, 2003; Millard-Ball et al., 2005).

This study enhances our understanding of transition processes in the following ways. First, we conceptually and empirically demonstrate the geographical heterogeneity of the socio-technical regime. Herewith we contribute to a further unpacking of the regime concept. In this study the global regime of private car ownership is seen as institutionalized to different extents locally. With our approach we also identify the weak spots in the regime that form an environment conducive to the emergence and upscaling of innovation (Haarstad & Wanvik, 2016). Second, the paper demonstrates the influence of the innovation-regime relationship on spatial adoption. It is shown how an innovation that is largely symbiotic with the regime is more likely to emerge in a variety of places, and also where the regime is strong. Herewith we provide insight in the pathways through which transitions unfold (Geels & Schot, 2007, Geels et al., 2016). Geels et al. (2016) point out how static landscape factors (i.e. the socio-spatial context), influence transition pathways. We add here that this influence of the socio-spatial context is dependent on the innovation-regime relationship. Niche innovations that are more symbiotic with the regime depend less on specific landscape-level influences, and hence emerge in a larger variety of places. Third, many of the landscape variables we took into account were based on the characteristics of the user base. In the (geography of) transition literature users and market structures remain understudied (Hansen & Coenen, 2015). With our inclusion of user characteristics we hope to stimulate more acknowledgment of differences between user groups and their importance for innovation upscaling in transition studies.

This research has taken a quantitative approach to transitions. Our study thus speaks to recurrent calls for more methodological diversity in transition studies (Genus & Coles, 2008; Geels, 2011; Turnheim, 2015). This study exploits the geographical variation at all levels of the MLP to explain the transition to car-sharing. This is an addition to current process-based approaches dominant in transition studies. These explain transitions almost exclusively using sequences of events in time, which risks an overemphasis on historical particularities. Our approach allows to compare all places cross-sectionally, also including places where innovative activity is absent, and to analyze the effect of niche, regime and landscape factors as these vary across places. Particularly now that various sustainable innovations have started to scale up, our perspective is relevant as it enables to go beyond the study of one or some particular niche experiments. Specifically, for the geography of transitions field our approach not only enables us to show *that* place-specificity matters, but also *how* it matters across areas by identifying relevant factors that influence adoption (Hansen & Coenen, 2015).

We also hope to show that the Multi-Level Perspective has something to offer to classic adoption studies. Prior spatial adoption analyses generally use solely a set of socio-demographic factors in combination with built-environment variables to analyze adoption (Kwan, 2012; Saarenpäa et al., 2013; Coll et al., 2014). A critique of this approach is that it ignores the institutional embeddedness of the innovation adoption process (Lyytinen & Damsgaard, 2001). The contribution of the MLP lens, then, is to explicitly take into account the embeddedness of the adoption process in the context of an existing socio-technical regime. By doing so, it also allows one to analyze multiple niche innovations and their respective relations with the current regime.

Studying a complex phenomenon such as a sustainability transition in a quantitative manner necessarily involves simplifications and focus. First, from the many factors associated in the literature with niches, regimes and landscapes (politics, markets, infrastructure, values, technologies, actors etc.) in our explorative study only some were operationalized. In particular, the strength of the socio-technical regime, was only measured by the motorization rate. Future research might use an approach consistent with the recent operationalization of regimes as developed by Fünfschilling and Truffer (2014) and map the strength of multiple regime dimensions (i.e. their institutionalization) in multiple localities. Second, we were only able to investigate the number of the shared cars, and not the intensity of their use over a certain time period. Such data are, however, not made publicly available. Our modelling approach was limited to the static analysis of regime, landscape and niche factors on the adoption of car-sharing. Future research could attempt to model feedback loops between developments on regime, niche and landscape levels over time, for example using structural equation modelling (which allows for modelling of various causal pathways). This would also help to better single out the direction of causality in the case of the motorization and policy variables. In the case of motorization, with the growth of car-sharing, there could be an increasing effect of car-sharing adoption on motorization levels. Third, the problem of "ecological fallacy" is inherent to our type of research that makes use of aggregates such as postcode areas (Robinson, 1950). Although the four-level postcode is a fairly detailed level of analysis, it should be reminded that we measure the averages for the postcode areas and do not study individual users. There is thus always a risk of misinterpretation when analyzing characteristics of users and adoption. For further research on car-sharing adoption, it would be worthwhile to gather data on individual car-sharing users instead.

Coming to policy development, both the multi-level approach to the geography of sustainability transitions and its combination with a quantitative methodology can provide guidance. From establishing the regime as a spatially heterogeneous entity influencing local adoption processes, it follows that apart from policies stimulating niches, complementary local policies that weaken the regime can be equally important. Examples of regime–weakening policies in the case of car-sharing could be increasing the cost of private ownership (e.g., by raising taxes on ownership or residential parking fees) and withholding of parking permits of second or third cars per household. As shown, also niche level policies fostering car-sharing awareness can have a positive effect on adoption. For policy practitioners and entrepreneurs, our quantitative approach can be useful for identifying locations suitable for the execution of niche experiments by taking into account not only niche opportunities but also regime and landscape factors. Our analysis here is helpful in the identification of leverage points for stimulating transitions at a highly disaggregated scale.

Chapter 4

Virtual user communities contributing to upscaling innovations in transitions: the case of the electric vehicle

Abstract

Users are increasingly acknowledged as important actors fostering those fundamental socio-technical innovations needed to achieve a sustainable society. In the literature, users have so far been portrayed mostly to play a role in early phases of technology formation. However, more recently users seem to have become important players in the upscaling of various innovations. With the advent of new social media, users may interact effortlessly across large distances, exchange knowledge and so increase their contribution to upscaling. We investigate the new potential of virtual user communities. Conceptually, we build on recent insights from socio-technical transition studies to identify different upscaling dimensions. We perform an internet ethnography of a large virtual community that formed around the Electric Vehicle (EV). Based on these data, we present virtual community characteristics and core mechanisms of participation in upscaling. We find that the community plays an important and distinctive role in fostering electric vehicle use.

4.1 Introduction

Widespread adoption of sustainable innovations helps to address persistent problems such as global climate change, local air and water pollution, and fossil fuel dependence. In the past few years, a number of these innovations have begun to move out of their early market niches and scale up into larger markets. However, this diffusion seems still focused on particular user segments. A main reason for the limited uptake is that, in contrast to conventional products, sustainable innovations represent systemic innovations, which require the building up of an entire support system of actors, networks, infrastructure and institutions, across geographical scales and contexts (Hekkert et al., 2007; Bergek et al., 2008; Geels et al, 2018).

This systemic nature also implies that consumers or end-users often play a different role in sustainability-oriented products. In conventional products, users can be portrayed as passive evaluators (the market), judging the suitability of new offerings, in terms of serving established preferences and routinized use patterns. In the context of sustainability oriented innovation processes, users have often been described as much more proactive contributors to the shape and meaning of new technologies (Truffer, 2003; Ornetzeder & Rohracher, 2006; 2013). Especially in early development phases, their contributions could span the creation of new supply structures, the shaping of specific technology characteristics, the development of new use patterns and preferences of prospective users, and the shaping of the social image of specific use forms. Beyond these early formation phases, user communities typically encounter a number of inherent limitations (Truffer, 2003; Hossain, 2016). Strong ties to a specific local milieu often limit scaling into other user segments. A major challenge is also the lack of appropriate capabilities to scale up the business model from arm's length interactions in early community-based operations to managing rapidly scaling companies. However, some recent studies have stressed that user communities can still have an important role to play in maturing innovation systems (Dewald and Truffer 2011,2012; Kanger & Schot 2016; Randelli & Rocchi, 2017), as they mobilize support for the innovation, align different actors, and embed the innovation in their daily practices.

In addition, the advent of the internet and new social media facilitates interaction between like-minded pioneer users all over the world with no time delay. This holds promise to overcome some of the essential limitations that traditional user communities encounter and enables to leverage user generated resources to the innovation process much quicker and at a larger scale. The emergence of virtual user communities therefore is interesting as it potentially enhances the role of users in the innovation process (Grabher & Ibert, 2013; Hyysalo et al., 2013; Hyysalo et al., 2018).

To assess the role that virtual user communities can potentially play in the upscaling of innovations requires a broad understanding of how new socio-technical systems emerge and mature. This has been the main occupation of the field of sustainability transitions studies (Markard et al., 2012; Bergek et al., 2015; Geels et al., 2017). The present paper aims to identify potential roles that virtual user communities can play in the upscaling of systemic innovation. Drawing on an extensive case study, we identify the agency and core mechanisms of change enacted by a virtual community, in the context of an overall system perspective on socio-technical innovations. We describe virtual community characteristics and specify detailed mechanisms of user contributions to three core development dimensions of socio-technical transitions: System build-up, geographical circulation, and reconfiguration of incumbent technological regimes.

The case study conducted focuses on a virtual user community that formed for Electric Vehicles (EV) and we use an "internet ethnography" (Garcia et al., 2009; Kozinets, 2015). Threads from the Tesla Motors Club online forum are analyzed. Discussions on this forum are not limited to Tesla cars, but include a broad range of general EV-related topics. The focus of this study is on EV users from The Netherlands. This is a suitable case as the Netherlands have seen an increasing adoption of EV beyond initial niche experiments (NEA, 2018). Importantly, the studied interactions on the Tesla Motors Club forum are not exclusively between these Dutch users, but also between Dutch users and users of other countries.

The paper is structured as follows. In section 4.2, we discuss relevant literature on sustainability transitions and (virtual) user communities. Section 4.3 describes the methodology. Section 4.4 presents the results. Section 4.5 discusses the findings critically, lines out avenues for further research and concludes.

4.2 Conceptual starting points for assessing the role of virtual communities

In order to identify potential contributions that virtual communities may make to the upscaling of innovation in transitions, we have to first specify the vantage point from where such an assessment can be undertaken. Drawing on Science and Technology Studies (STS) and evolutionary and institutional thinking, the sustainability transitions field has extensively studied the development of systemic innovations (Markard et al., 2012). We draw on recent insights of the sustainability transitions field in order to derive basic upscaling dimensions that should be considered. Studies in the sustainability transition field also pay increasing attention to users (Truffer, 2003; Schot et al. 2016). Accordingly, we review the literature on users in transitions following the identified upscaling dimensions. We then draw on studies into virtual user communities, to explore how the virtual aspect of the community could potentially change user contributions. This provides us with a starting approach for analyzing user contributions from our case study.

4.2.1 A socio-technical systems perspective on user communities in upscaling

The sustainability transitions literature has provided a large number of detailed explanations about the success conditions of early formation processes of sustainable technologies. The analysis of rapidly scaling innovations has started more recently, on par with the rapid growth of a number of renewable energy technologies such as wind and solar PV. Unlike conventional diffusion processes observed for discrete products, exhaustively captured by the classical diffusion literature (Rogers, 2010), the upscaling of systemic innovations needs to take account of an entire socio-technical system of actors, supporting infrastructures and institutions across geographical contexts. Institutions are defined here as "sets of common habits, routines, established practices, rules, or laws that regulate the relations and interactions between individuals and groups" (Edquist & Johnson, 1997, p. 46). Regarding the analysis and assessment of growing and maturing socio-technical systems, the TIS literature (Technological Innovation System) has been most explicit within the transitions tradition (Hekkert et al., 2007; Bergek et al., 2008; Suurs, 2009). The TIS approach posits that successful innovation processes are characterized by balanced *system-building,* that can be captured in a number of core processes or functions: the generation of new knowledge, entrepreneurial experimentation, guidance of search, the mobilization of different kinds of resources, the formation of appropriate markets and the creation of legitimacy for the technology. The MLP (Multi-Level Perspective) on transitions also describes endogenous processes fostering system-building, including learning economies, the development of complementary infrastructures and the development of positive cultural discourses (Geels et al., 2017). When developments in the different processes are well-aligned, they result in patterns of cumulative causation or "momentum" driving upscaling (Hillman, 2008; Suurs & Hekkert, 2009; Geels et al. 2017).

User contributions to *system-building* in upscaling have been described in most detail for the specific process of market formation. Truffer and Dewald (2011, 2012), for instance, have studied how civic cooperatives were instrumental in the build-up of the German PV sector in the 1990s and 2000s. They challenge a linear conception of market development with an account of interacting complementary processes (knowledge generation, legitimacy creation, resource mobilization) in various market segments. Randelli and Rocchi (2017) find, for the case of organic food in Italy, that users can provide contributions to all system-building processes identified in the TIS literature. Zooming further out, Schot et al. (2016) provide a framework of the changing roles of users during the entire "life cycle" of a technology. In the upscaling phase, users contribute to system-building by acting as user-intermediaries, which help aligning the various elements of socio-technical systems. They also act as user-consumers, embedding the technology in daily practices.

The limitations of system-building by users have received more attention in the literature on innovation by grassroots communities – idealistic user communities working on all sorts of sustainable alternatives (Smith et al., 2014; Seyfang et al. 2014; Hossain, 2016). Hossain (2016) presents a long list of challenges that grassroots communities can face, ranging from network building, to capabilities and the ability to attract financial resources. These are also reflected in the work of Truffer (2003) on user-initiated car-sharing initiatives in Switzerland. Here, the user-based organizational set-ups were increasingly challenged in the upscaling phase. Some members voiced strong preference for continuing as small cooperatives instead of accepting a more market oriented organizational form and growth strategy. Hence, there also seem to exist some inherent restraints to the contributions users can make to system-building.

In a sustainability transitions perspective, upscaling of new socio-technical systems does not occur in a void, but in interaction with various context structures (Bergek et al., 2015; Geels et al., 2018). We consider the geographical context in which the innovation develops and the prevailing socio-technical regime in a sector as particularly important in relation to user contributions. Regarding geographical context, scholars have noted how innovations are often deeply rooted in specific local environments (Coenen et al., 2012; Hansen & Coenen 2015; Temenos et al., 2017). A common geographical upscaling pattern described in the transitions literature consists of the development of aggregated forms of knowledge that are then circulated and recontextualized to fit different circumstances (Geels & Deuten, 2006; Geels & Johnson, 2018). Sengers and Raven (2015) describe how in the diffusion of Bus Rapid Transit global and local processes are intrinsically connected. Place-specific factors influence the local implementation of the innovation, as well as the overall global upscaling journey. In the case of electric vehicles, Bakker et al. (2015) show the importance of connections between localized niches to come to charging standards. These studies point to processes of *geographical circulation* as part of upscaling in systemic innovation. These are not linear processes of abstraction, but iterative processes in which the innovation is continuously decontextualized and recontextualized in different localities.[19]

[19] The pattern of circulation/decontextualization/recontextualization as employed in the transition literature is one among different possible patterns of geographical scaling. It assumes the existence of a global or "cosmopolitan" level at which knowledge is aggregated (Geels & Johnson, 2018). Particularly in the Actor Network Theory literature, employing a flat ontology, other patterns are described. For example, Latour (1993) describes in his work on Pasteur how knowledge traveled by recreating the conditions of Pasteur's lab in many other sites.

The role of users in geographical circulation in upscaling is often described as limited. User collectives have developed remarkable and successful sustainable alternatives in a variety of domains such as renewable energy and sustainable buildings (Ornetzeder & Rohracher, 2006; Hargreaves et al, 2013). Yet the socio-technical configurations they develop are often tailored to a specific geographical context and rooted in local communities (Smith et al., 2014; Hossain, 2016; de Vries et al., 2016). Some organizations have emerged that aim at connecting local user initiatives, such as the Transitions Town Network (Feola & Butt, 2017). However, such organizations are often lacking and, those that exist typically face difficulties in aggregating highly contextualized forms of user knowledge (Ruggiero et al., 2018).

The second form of context to which the innovation emerges is the socio-technical regime, the current set of rules guiding actor behaviour in a sector. Apart from endogenous system growth, upscaling also entails a certain degree of reconfiguration of existing socio-technical regimes (Geels et al., 2017; Geels et al., 2018; Naber, 2018). In the phase of upscaling, the innovation may get confronted with barriers to growth that relate to the current dominant system. These regime barriers include vested interests or institutions that are not compatible with the innovation. For example, the status users attach to personal car ownership can hamper the transition to car-sharing (Truffer, 2003). Accordingly, for the innovation to upscale, changes in institutions are required (Fünfschilling & Truffer, 2016). Smith and Raven (2012) identify two mechanisms of interactions between innovations in niches and regimes: "fit-and-conform" in which the niche innovation aims to become competitive within the existing environment and "stretch-and-transform", in which it fundamentally alters the regime. Geels & Johnson (2018) find a temporal sequence in these patterns. They describe a change from "regime-to-niche" towards "niche-to-regime" influences over time in their case of biomass diffusion in Austria. In later stages of upscaling, a powerful lobby was initiated, and actors related to the innovation were increasingly able to reconfigure the existing socio-technical regime.

Some instances of users contributing to reconfiguration of existing socio-technical regimes have been described, but there also seem considerable challenges for users to contribute to lasting regime change. Dewald and Truffer (2011,2012) show for the case of photovoltaics in Germany how citizen groups provided initial legitimation and continuing political support for the German feed-in tariff, the installation of which further accelerated PV diffusion. Kanger and Schot (2016) describe for the case of the fossil fuel car how users set up powerful user organizations lobbying for the interests of automobile drivers in an initially hostile environment. In the literature on grassroots communities barriers to users' contribution to regime change are emphasized. These user communities often develop in relative isolation from existing socio-technical regimes, hence lacking the connections and resources to meaningfully change them (Seyfang & Smith, 2007; Hossain, 2016). If user communities aim at diffusing their projects into the mainstream, they face challenges related to watering down sustainability ideals and losing control (Seyfang & Longhurst, 2016).

All told, we identified three major domains in which users could contribute to the growth and maturation of socio-technical systems: providing support and resources for system build-up, enabling the geographical circulation of the innovation, and reconfiguring the existing socio-technical regime to reduce barriers to development. In the following we want to elaborate the way in which virtual communities particularly can contribute in these areas.

4.2.2 The new potential of virtual user communities

The rise of virtual communities seems to increase, or at least alter, the role of users in upscaling (Grabher & Ibert, 2013; Hyysalo et al., 2018). Virtual user communities are communities of geographically dispersed users who share an interest in a certain technology and use the internet as primary mode of interaction (Hyysalo et al., 2017). Here we review studies that have taken an in-depth look at innovation in virtual user communities, following the main domains of upscaling as described above: *system building, geographical circulation and reconfiguration of the current socio-technical regime.*

The virtual community seems to allow for some new roles in *system-building* during upscaling. Hyysalo et al. (2018) investigate the role of energy internet forums in the diffusion of small-scale renewable energy technologies in Finland. They find that these communities provide information about the workings of the technology, not available from other market actors, and that they help articulating market demand. The provision of information reduces uncertainty, which is important in market expansion beyond environmental enthusiasts. In contrast to accounts of strongly embedded and homogenous local user groups working on innovation, more heterogeneity is reported for virtual communities (Füller et al., 2007; Hyysalo et al., 2013; Rullani & Haefliger, 2013). Virtual user communities have a core of highly-skilled expert users who engage most heavily. Yet, there is also an influential peripheral group, able to steer the direction of innovation. Then there is a large group of "lurkers" who do not actively contribute but are still aware of developments and also share these in their own networks (Takahashi et al., 2003; Sun et al., 2014). Füller (2007) discusses how the variety of users builds upon each other's contribution in a constant improvising process of trial and error. This resembles the process of "bricolage", defined by Baker and Nelson (2005, p.333) as "making do by applying combinations of the resources at hand to new problems and opportunities". In sum, user communities seem to contribute to system-building by developing knowledge among a variety of participants.

The virtual nature of the community is expected to change the role of users in the *geographical circulation* of the innovation during upscaling (Grabher & Ibert, 2013). As described above, traditionally many user collectives have been locally organized, with their embeddedness becoming a barrier in the upscaling process. The virtual community can here form a bridge between localities, for example by connecting geographically dispersed users and serving as a centralized knowledge archive (Grabher & Ibert, 2013). The other way around, the virtual community is also helpful for recontextualizing innovations in local environments. Users here build on the generalized solutions of others, and tailor them to their specific contexts of use (Hyysalo et al., 2016). As an illustration, the internet forum users studied by Hyysalo et al. (2018), made changes to the heat pumps to make them work in the cold Finnish climate. It is unclear as to what extent the virtual nature of the community might influence the ability of users to engage in *reconfiguration of the current socio-technical regime.* Hyysalo et al. (2018) observe that forum users discuss heat pumps in "neutral" economic and technological terms, stressing their conformation to the existing regime. An important point to note, though, is that virtual communities are often "hybrid" communities encompassing both lay users and professional actors (Grabher & Ibert, 2013). The occupational background of forum participants is not directly shown, which reduces formal status and power differences that normally influence conversations. Grabher and Ibert (2013) give the example of doctors and patients interacting on more equal terms on a drug development internet forum than they would do in a traditional conference setting. These more equal interactions between different actor types may also facilitate discussion between users and actors associated with the socio-technical regime, such as companies or governments.

To sum up, although many conventional grassroots user communities seem to struggle in upscaling, there are clear indications that users can play important roles in the upscaling phase of transitions. Specifically, the rise of virtual communities seems to increase the potential role that users can play in the upscaling phase. We therefore aim at describing the composition of types of actors that participate in these virtual communities. Based on this, we will empirically investigate how virtual user groups contribute to the core domains of system maturation that we derived from the transition studies review, namely their contribution to internal *system-building,* the facilitation of *geographical circulation,* and their impact on *reconfiguring existing socio-technical regimes.*

4.3 Methodology

In line with our research aims, we considered the systemic innovation of the electric vehicle. The electric vehicle (EV) contributes to environmental sustainability by reducing greenhouse gas emissions as well as local pollution. Its widespread adoption involves a transition of infrastructures, markets and institutions (Aguirre et al., 2012; Van Bree et al., 2012). The focus of this study is on EV users from The Netherlands. The studied interactions are not only between Dutch users, but sometimes also between Dutch users and users of other countries. The Netherlands is a frontrunner country in EVs. Both qualitative and quantitative indicators demonstrate that the EV in The Netherlands has grown beyond precarious and dispersed niche experimenting. Qualitatively, multiple mass production models are available and European standardization processes are ongoing (Bakker et al., 2015). Quantitatively, there is a large growth in Plug-in Hybrid Electric Vehicles (PHEVs, which can also run partly on gasoline) and also the number of regular EVs has increased considerably. The total number of EVs in The Netherlands grew from 7,410 (of which 4,348 PHEVs)) in December 2012, to 119,332 (of which 98,217 PHEVs) in December 2017 (NEA, 2014, 2018). The average market share was 5.6% over the 2013-2017 period (IEA, 2018).

The main data source of this study are internet forum threads. The forum analyzed is the Tesla Motors Club forum (www.teslamotorsclub.com). Virtual communities are very fuzzy social phenomena, with fluid boundaries (Grabher & Ibert, 2013). They often span multiple internet forums, as well as other mediums such as Facebook and Twitter. We thus had to make a very careful decision for the medium to analyze (see Kozinets, 2015, p.168). Eventually, the Tesla Motors Club forum was chosen for three reasons. First, it is a large forum with ample daily activity as well as international reach. At the start of the analysis in June 2016, it counted approximately 60,000 threads, 1.5 million messages and 40,000 members (TMC, 2016). Its international reach is exemplified by subsections dedicated to EV developments in specific (groups of) countries, in various languages. Second, it is a well-established forum, enabling longitudinal analysis. It has been around since 2006 and has attracted substantial numbers of members for years. This makes it preferable over the alternative to forum threads of e.g. EV Facebook groups, which have mostly been initiated much more recently. Finally, in terms of content, it is not strictly limited to a discussion of Tesla cars. Topics cover all kinds of EV developments, charging infrastructure and wider discussions about sustainability. There is no comprehensive overview of forum user demographics. From names, introduction discussions and pictures it is clear that the users are overwhelmingly male. Importantly for our analysis, the geographic location of almost all users is known at the city level.

To get some indication of the participation of EV users in internet forums, we included two questions on forum use in a general EV survey that was sent out to members of an organization concerned with placing public charging points for EV owners in April and May 2015 (see Peters et al. 2018, for details on the survey). Out of the 251 respondents, 67% had been active as a reader, 28% had been active as a writer on an internet forum about electric vehicles. Particularly the reading of internet forums can hence be regarded as an activity that is common among electric vehicle owners in The Netherlands.

The second data source for this study were 13 interviews with forum participants that were conducted at the end of 2017 and beginning of 2018. The interviewees were selected partly based on the forum analysis. They were sampled in order to obtain diversity in participation levels as well as role fulfilled on the forum (e.g. a user that devotes much time at helping beginner EV drivers, a user that also sells charging points). As a third data source we drew on sector reports and scientific articles about EV in The Netherlands (e.g. the monthly reports released by the Netherlands Enterprise Agency). For the in-depth analysis of the internet forums we conducted a virtual ethnography, tracing back the role of the online community in upscaling (Garcia, 2009). Compared to traditional ethnography, the internet forum as research site has the advantage that it is both archival and showing live communication (Kozinets, 2015). It is also well-annotated, as the exact date and time of each post, as well as the location of the poster, are noted. This was particularly helpful for our reconstruction of user activity in time and space (Yin, 2013). It should be noted that the majority of forum visitors are not actively posting on the forum, but merely "lurking" (Sun, 2014). However, these visitors do follow the activity on the forum.

Considering the vast size of the forum, a pre-analysis was completed to identify those threads that were most related to the development and use of EVs and had a substantial number of replies and views, and involved Dutch EV users. In certain cases threads are short with only a few replies to the thread starter, but they can also consist of hundreds of pages and remain active for multiple years. To identify relevant threads, we went through the headers and first posts of all threads active in the subsection "Belgium and The Netherlands (Dutch)" between January and May 2016 (N=360) and the most replied threads in this section since its conception in 2012 (N=50). This forum section contains posts from Dutch users, as well as from users in the Dutch-speaking part of Belgium. Before 2012, there was no Dutch subsection and Dutch EV users replied in international threads. To find these we selected some "dinosaur" Dutch contributors (active since the first Tesla model Roadster came out around 2009), and went through the headers and first posts of the threads they contributed to. Based on this pre-analysis N=26 threads were selected for in-depth analysis. We categorized these into 10 broad themes related to upscaling, such as *charging points* and *technical* issues. We then went back to the titles and first post of the 410 first selected threads to see if they fitted into one of these themes. They did, which assured us that the 26 selected threads for in-depth analysis provided an apt overview of the breadth of upscaling topics discussed on the forum.

We then proceeded with the in-depth analysis using NVivo 11. The analysis followed a constant iterative process between data and theory. We first used an open coding strategy to be able to get an overview of the topics discussed in the forum threads. Per group of related threads we also made summaries and notes about the topics discussed, to get a better grasp of the user's activity in the often long threads. Here we also made our initial links with theory, using the meso-level upscaling processes of *system-building, geographical circulation* and *adaptation of the existing socio-technical system* as sensitizing concepts. With these concepts in hand we went back to the data, to see to what extent users were active in these processes. We interpreted the data in terms of the content of the contribution of users and the specific strategies they employed. In this way we could identify specific mechanisms such as *institution building in practice* and *quasi-effortless knowledge production & sharing,* linked to the meso-level processes of upscaling. Eventually, we identified seven core mechanisms through which the user community contributes to the upscaling processes. Apart from these core mechanisms, we also observed specific (changing) characteristics of the virtual community actor. Because of their importance for understanding the role of the virtual community, we decided to include them prior to the mechanisms in the results section.

The interviews were used as a source of data triangulation. The round of interviewing occurred after the main analysis of the forums. The interviews were coded using the same codes as used in the forum analyses, with some additions. In general, the findings from the forum analysis were confirmed, but small adaptations were made. The interviews also allowed for the inclusion of additional examples related to the emerging concepts. They allowed for greater exploration of the community aspect of the forum and the relationships between online and offline activities, which are harder to understand from the forum analysis alone. We also used "member checking" (Lincoln & Guba, 1985) and asked two forum participants to reflect on our findings and concepts, in order to increase the reliability of this research. Finally, the sector reports and scientific articles were used throughout the research to assist in understanding the context of the forum discussions, as well as to track the general developments in the scaling of EV in The Netherlands.

4.4 Results

4.4.1 Virtual community characteristics

Before elaborating on the core mechanisms by which the virtual community participates in upscaling, we will first describe some key characteristics of the virtual community we studied. In the community, we observed a relatively large *participant diversity*, albeit on some specific dimensions. We also observed a strong *sense of community*.

In terms of socio-demographic background of the user participants, there is little diversity. The *introduce yourself* thread gives an impression of the demographics of the virtual community.

The participants are predominantly white males. The average age is around 40 years old. Virtual community members are often entrepreneurs or small business owners. Of the users who share their profession, about half work in the IT sector. Diversity was particularly marked in terms of the "professionality" of participants. On one end of the spectrum "pure" users can be placed, on the other end professional actors. Of the latter actors, let us first consider Tesla. In our analyzed threads, it was very rare that a Tesla employee would publicly intervene in the discussion. However, there is ample evidence that employees of Tesla both read the forum and act upon the observed discussion. For example, a user posts on the forum for help with some problem with his car and is then phoned by the Tesla Service Center to make an appointment to have his car checked. Charging point companies are active in similar ways. The virtual user community is particularly useful for Tesla and other system actors, because it discusses not only systematic barriers but also possible solutions.

Policy-makers are surprisingly absent from the forums, as we did not find any instance of a policy-maker intervening in the discussions. During the interviews we spoke to a policy consultant who reads the forums to inform himself about charging locations as well as barriers related to charging. Officially, commercial activity on the forum is not allowed. However, there are various users who take up a "hybrid" role. Apart from being a Tesla user, they also have a side business that sells, for example, charging points or car accessories. Oftentimes, these hybrid roles emerge from the forum: users discuss upscaling barriers, which are then perceived by some as entrepreneurial opportunities. For example, a user who already has online shops becomes aware of difficulties with the delivery of charging cables. He then organizes an initial group purchase via the forum, and later opens a charging point shop. He does not advertise on the forum, but community members know how to find him. Here, the forum stimulates users to become system-builders in the upscaling process.

A second dimension of diversity concerns the knowledge levels regarding the EV. Especially the earlier threads, such as the one about the international standardization of charging plugs, contain long, high-level technical discussions. Here many users with expert technical knowledge participate. Users also become more knowledgeable about EV technology while reading the forum. During the process of upscaling, however, the forum is joined by more users with lower levels of technological and topical knowledge of EVs. They also have more mainstream expectations of an EV. Experienced community members however continue to be active and provide knowledge to newcomers.

Among the online users, we find a strong sense of community, which at times leads to the organization of "real world" events. Yet, the community aspect is limited to a specific group of forum members. Online users can easily opt out of community activities and use the forum as a functional source of knowledge only. This even holds for members with a high number of posts. The sense of community on the forum centers around shared feelings about pioneering and experienced barriers. Users feel part of a group of pioneers who take part in a development that will have major influences on society. Users perform joint activities such as road trips and enthusiastically report about them on the forum and blogs. They make fun of fossil fuel cars and occasionally call them "dino-juice-burners". Not everything is rosy, however. A large share of the threads in the virtual community starts with some barrier experienced by a user. In these cases, the community is like a support group for EV drivers. Users try to help each other in finding solutions for experienced online and offline problems. For example, a relative of a forum member drops someone off at an airport in the South of the Netherlands. The charging poles there are out of service and he risks running out of range. A message is sent to forum members. A member who lives nearby replies and the person can charge at his house and gets a coffee. Such actions are illustrative of the community spirit found amongst core forum members.

4.4.2 Building the system

Influenced by its distinctive actor characteristics the virtual user community takes some form of action. Seven core mechanisms through which the virtual user community participates in the upscaling process have been identified in the empirical analysis. Three of these are linked to system building: quasi-effortless knowledge production & sharing, infrastructural bricolage and institution building in practice.

4.4.2.1 Quasi-effortless knowledge production & sharing

An important part of the contribution of the virtual community to upscaling concerns knowledge. In the knowledge development by the virtual community during upscaling we observe two developments. First, digital technology has made it very easy to make minor changes to products or to monitor their performance under various circumstances. Examples of such small user actions are changing the settings of the vehicle and see what happens to its electricity use. Second, the internet forum facilitates sharing these small changes and their effects with the wider user community. All in all, the effort of performing and sharing an activity that makes a meaningful contribution to the process of upscaling is drastically lowered. This can be illustrated with the example of energy use. Given the limited range of the electric vehicle, a main issue among users is finding out factors that influence their energy use, as well as ways to improve their vehicle's range. Table 4.1 lists a number of activities the users of the virtual community have performed in this regard, ordered in terms of the dedicated effort they put in: Developing knowledge during day-to-day driving, by trial and error during driving, by performing a systemic analysis during driving, by participating in joint testing events, and by building tools and models. This list illustrates the relative ease with which knowledge production and sharing in the online community can occur. Action 4 and 5, respectively a joint testing session and the building of a model, still require dedicated time and effort. However, the first two actions, in which people drive around for trips they would make anyway and make some notes about the performance of their EV, can hardly be classified as dedicated innovative user actions. These are simple actions that users conduct during their normal routines without much additional effort. Because the results of these actions are now so easily shared and discussed within the community at large, they still affect the emerging driving practices of other users, and consequently the upscaling process.

Table 4.1: User activity in knowledge development presented on the forum, ranked in terms of dedicated effort spent

User effort level	**Example**
1. Day-to-day driving	*"I have been to Amsterdam today and noticed quite a strong wind at 5.00 AM. I saw an energy use of 255Wh/km at 120km/h at that time. As soon as I left Zeeland energy use lowered to 230Wh/km. From Dordrecht on I changed my driving speed to 110 km/h and energy use dropped to 206Wh/km"*[20]
2. Trial-and-error	*"As I was interested, I drove with 80km/h behind a lorry on the A12 Den Haag-Gouda yesterday. I reached an average of 140Wh/km"*
3. Systematic analysis	*"Yesterday I made an 'energy use drive' Amersfoort-Harderwijk-Amersfoort; this is what I found for 100 and 120km/h."* The user then presents a detailed table with energy use against speed and possibly range influencing factors such as: temperature, airco on/off, tire pressure, driving mode and preheating temperature
4. Joint testing events	Seven users come together to compare the energy use of their Tesla and identify various range influencing factors such as tires and heating. Results are presented in graphs and tables on the forum
5. Tool and model building	Application developed by users to extract data from the Tesla to other devices and construct for example graphs and models of energy use and speed

The forum users refer to the knowledge they develop as "true" or "real" knowledge, because it is based on experience. They see it as a middle way between the, according to them, optimistic knowledge provided by EV and charging point companies, and the arguably negative stories about EVs that appear in the press. This holds particularly for more controversial issues, such as

[20] The forum is accessible for everyone with an internet connection and forms a public space. We did not mention any online names used when quoting. Quotes are translated (by the authors). Additionally, small modifications are made to forum quotes of users whom we did not also interview.

the range of the EV in different circumstances, and technical problems of the Tesla.
Three dominant types of knowledge sharing in the virtual community can be distinguished. Firstly, there is request-based knowledge sharing. This is by far the most common form of knowledge sharing on the forum. A user has a specific problem with their electric vehicle and asks the community for help. For example:

"Someone experience with charging in Spain? Can it be compared to France? I see you can get there easily with super-chargers, but charging locally would also be nice"

Users from the community then answer based on their own experience. Second, there is spontaneous sharing of knowledge that a user has developed with regard to EVs. Third, there is synthesizing knowledge sharing. Users then try to create a systematic overview of the knowledge produced by other users on the forum.

The dominance of request-based knowledge sharing exemplifies some of the limitations of the virtual communities. At least two obstacles complicate the process of knowledge sharing and learning. First, the forum threads are often very long, due to all the requests by individual users. Less active users complain on multiple occasions that they have had to read many pages before finding appropriate answers. Even creating a synthesis of knowledge on a certain topic is not always helpful, because users have to find it first. For overviews of knowledge, users therefore resort to using separate blogs or websites, for example with a user's guide for new Tesla owners. Second, the nature of the knowledge users share is often very context-specific as well as subjective. On the one hand, this is an asset because it is often practical and experiential knowledge (for instance about the performance of a charger in a specific place with a certain charging card), that non-users cannot easily develop. On the other hand, the practical and experiential nature of the knowledge also makes it hard to decontextualize and aggregate the knowledge developed of the forum.

4.4.2.2 Infrastructural bricolage

The virtual user community does not engage in large-scale, coordinated efforts to build charging infrastructure. Yet, in their day-to-day lives and with whatever resource they have available, the members of the virtual community try to improve the material elements of the EV system. First, users engage in day-to-day charge point lobbying. If they go to a certain place, they approach hotels or other organizations beforehand with requests about charging facilities. On the internet forum they discuss strategies for convincing companies to place chargers. At a certain point, they have a list of organizations approached for charging facilities. However, these actions are largely ad-hoc and targeted at companies that users encounter at some point in their daily life, and not a structured infrastructure-building effort.

Second, the virtual community has a dedicated "plug club" thread in which they share plugs that are needed when going abroad. Virtual community members in this way do not solve the problem of different charging standards in Europe, but work around this problem by carrying an array of plugs on holidays and sharing them with each other. Third, users help each other with the installation of home chargers. These are still not off-the-shelf products. In particular, they require a specific installation and configuration in the house, often together with other devices such as a smart meter. On the internet forum, the virtual community members discuss possible configurations. Users with greater expertise in electricity comment on the safety and feasibility of proposed solutions. As a sign of the community spirit on the forum, the users offer each other to try out their charging point (configurations) before they get their car delivered, enabling them to start driving without hick-ups straightaway.

4.4.2.3 Institution-building in practice

As part of the upscaling process, institutions are created to enable coordination between the actors engaged with the systemic innovation. The virtual user community contributes by institution-building in practice. As an important institution, users work out the "optimal" way of driving their electric vehicle. When the EV users go on business trips and holidays in Europe, the limitations of their car in terms of range and charging time become most apparent. In the "holidays" thread users post detailed accounts of their trips with the chargers used, charging times and conditions such as driving speed, weather and number of passengers. Some users start taking stock and "rules" for driving an EV emerge (e.g. 110 km/h is the optimal speed), which are endorsed by other forum members. The user-developed knowledge thus forms the basis for the development of practice rules. However, as an indication of the instability of the practice-in-development, the emerging rules are also continuously challenged by forum members. The driving context (i.e. other factors in the socio-technical system) is also changing with, for instance, more charging points becoming available. In the development of rules forum members also use simple modelling tools, with input parameters based on their experience. For instance, one user has developed and shared an Excel sheet for calculating the optimal speed for driving on long distances, taking into account various parameters (figure 4.1). The sheet yields the general "rule" for charging during long-distance journeys (>250 km) in Europe, which is then (at least for a while) accepted in the community:

"With a distance of 200 km between super chargers the optimum is charging till 70% and driving at 120km/h'"

	A	B	C	D	E	F	G	H	I	J	K	L	M
1	**Variables**												
2	-	Minimum state of charge battery	**5**	% (max 40%)									
3	-	Distance between super-chargers	**200**	km									
4	-	Distance	**10000000**	km									
5	-	Overhead-time	**0.25**	hour	0:15	minutes							
6	-	Battery	**70**	kWh efffective use									
7	-	Speed (km/h)	80	90	100	110	120	130	140	150	160	170	
8		Energy use (Wh/km)	**150**	**160**	**175**	**195**	**215**	**240**	**270**	**305**	**340**	**380**	
9		range (km/h)	467	438	400	359	326	292	259	230	206	184	
10													
11	**Average speed (distance / totale time)**												
12	**(km/u)**	10%	20%	30%	40%	50%	60%	70%	80%	90%	100%		
13	80 km/h	n/a	n/a	n/a	n/a	65.5	66.0	65.6	64.9	64.2	61.1		
14	90 km/h	n/a	n/a	n/a	n/a	n/a	71.7	71.2	70.4	69.5	65.6		
15	100 km/h	n/a	n/a	n/a	n/a	n/a	76.3	75.7	74.7	73.6	68.9		
16	110 km/h	n/a	n/a	n/a	n/a	n/a	n/a	79.0	77.7	76.5	70.8		
17	120 km/h	n/a	n/a	n/a	n/a	n/a	n/a	81.5	80.0	78.6	72.0		
18	130 km/h	n/a	n/a	n/a	n/a	n/a	n/a	n/a	81.0	79.4	72.0		
19	140 km/h	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	79.0	70.9		
20	150 km/h	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	68.8		
21	160 km/h	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a		
22	170 km/h	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a		
23													

Figure 4.1 User-developed excel sheet for calculating the optimum speed and charging pattern in order to drive long distances as fast as possible

Dedicated parking places for EVs, which are equipped with chargers, are not yet a strong institution. Within the community of electric vehicle drivers the main discussion is whether someone should free up their charging point when they have completed charging, to make it available to others. In the virtual community, new users are informed about the accepted practice, a process that contributes to strengthening the institution.

".. but then the question remains whether I should wake up to move my car in the middle of the night, when it is fully charged. Is that the common practice?"
"I do that. If you would have a gasoline car you wouldn't park at the gasoline station for a night either. It also depends on circumstances. At fast chargers one should not park after charging. In a public parking area you can use the card [with phone number, ed.] and people can always call you if needed. If you can move your car after charging I would always do that."

4.4.3 Geographical circulation

The virtual user community is active in processes of geographical circulation during upscaling, by means of the core mechanisms of trans-local interactions & facilitating use across geographical contexts.

4.4.3.1 Trans-local interactions

In the upscaling of electric vehicles different charging standards form an important barrier. When rumours emerged in 2011 that the Tesla Model S would not support the European form of 3-phase charging, virtual community users took action. Figure 4.2 shows the geographical location of the users involved in the forum thread on the potential compatibility of the Tesla with the European 3-phase standard. The tread was started by a Dutch Tesla user. American users on both coasts joined in and the virtual community became a platform of exchange between users from different geographical niches. Long discussions followed about the different electricity and charging systems in various countries, as well as on how the Tesla should be able to deal with them. Eventually a collective letter was sent to Tesla, with supporters from multiple geographical regions, in order to ensure that the Tesla Model S would become compatible with European charging systems. In the same internet forum thread, a vice-president of Tesla then confirmed it would.

The interaction patterns between users from different geographical contexts changes during the upscaling process. Initially, users from various localities around the globe reply in the same threads. As local user bases grow, gradually national subforums are created. Most users in this study are only active in the Dutch subforum. However, certain users are active in the international forum and national subforum(s). They perform a gatekeeper function by sharing topics between subforums as well as other mediums such as WhatsApp and YouTube.

Figure 4.2 Trans-local niche network: locations of electric vehicle users active in the discussion on making the Tesla Model S compatible with European charging standards, created using Gephi.

4.4.3.2 Facilitating use across geographical contexts

The difference in charging standards between countries as well as a large variety in charging passes that are to be used across countries and regions in Europe, pose barriers to Dutch EV users going on holidays. One of the most active threads on the forum is the "holidays" thread, with also separate threads dedicated to specific countries. The virtual community works hard to enable the EV users to also drive their EV in other geographical contexts, by sharing information, charge plugs and passes. In terms of circulation, the practice to EV driving is hence brought to places where it is less or differently embedded. This also affects the local establishment of other system elements, for example when users lobby for specific charging points at their holiday destinations throughout Europe. Notably, users send requests for the placement of specific Tesla-sponsored chargers to hotels throughout Europe. For these chargers no particular local charging passes or plugs are needed.

4.4.4 Reconfiguration of the existing socio-technical regime

The electric vehicle emerges in the context of the existing socio-technical regime of the fossil fuel car. Some regime parts simply carry over to the EV (e.g. the status attached to personal vehicle ownership). Other regime elements, however, are in conflict with EV. The virtual community participates in reconfiguration with the mechanisms of empowerment to challenge the regime and regime-adapting activities.

4.4.4.1 Empowerment to challenge the regime

The virtual community users are often reminded that the innovation they have adopted does not conform to the existing regime. For example, they are told that their car is not a real car, because it makes a different sound or only has a limited range. The EV users often get into discussion with conventional vehicle owners about how EVs fare compared to fossil fuel cars. The forum then empowers them by offering a series of possible arguments that can be used in such discussions. For example, a forum user develops an excel sheet that can be used to demonstrate that EVs are not more expensive than comparable fossil fuel cars if costs in the long run are considered. Another user develops a detailed post about the CO_2 emissions of electric vehicles, after media reports have appeared that they have no or only limited benefits for the environment as compared to fossil fuel cars. Users discuss strategies for answering critical questions about EVs.

"I use the following answer for questions about charging time: 'I don't know. It is just always full when I need it.' This is not entirely true, but it comes closer to the truth than when I say: 'well if it is totally empty, about 9 hours.' Because people then start looking worried, and you have to explain that it occurs very rarely that you arrive at your destination totally empty. Most of the time charging only takes a few hours at the end of the day."

Forum members employ these strategies in their own social circles, but also to comment on other sites and blogs, as well as by sending letters to newspapers that according to them are too much on the side of the fossil fuel car regime.

4.4.4.2 Regime-adapting activities

As EVs scale up, some conflicts with the existing regime emerge. A good example are dedicated parking spots for EVs, equipped with chargers. These were mostly parking places for fossil fuel cars before. Fossil fuel car users still park on these spots, preventing EVs to charge. Formal signifiers such as road signs are often not yet available, making the parking places even more contested. On the internet forum the virtual community develops some activities to make these parking places more accepted. Leaflets (figure 4.3) are shared to make conventional car owners aware of their behaviour. Such leaflets are printed out by virtual community members, and put on the fossil fuel cars that block EV parking places every time a virtual community member sees one. Additionally, a wide variety of activities (ranging from press action to calling the police) and their effectiveness are discussed.

Figure 4.3 Leaflets shared in the virtual community to be used for the policing of EV charging spots

The virtual community also works on reconfiguring some highly institutionalized associations of the current regime. Most notably, this concerns the idea that a car that is able to drive long distances has to be a fossil fuel car. Virtual community members organize various activities that demonstrate that EVs are also able to drive long distances. For example, there is a yearly EV rally, which attracts national media attention. Then there are various international road trips organized among forum members, which are enthusiastically reported on the forum and blogs. These mostly do not receive large-scale media attention, but can help people interested in EV "cross the line". They are also found to stimulate existing EV owners in the virtual community to make longer trips, including their yearly holiday, with an EV instead of a fossil fuel car.

4.5 Discussion and conclusions

4.5.1 Roles of virtual user communities in upscaling

Following increased debate over the role of users in transitions (Schot et al, 2016), as well as the virtual nature of user communities nowadays (Grabher & Ibert, 2013; Hyysalo et al. 2013; Hyysalo et al. 2018), this paper set out to explore the role of the virtual user community in the upscaling of systemic innovation. Approached from a socio-technical perspective, a case study has been conducted of an Electric Vehicle (EV) user community. The results describe key community characteristics as well as core mechanisms by which users participate in upscaling (summarized in figure 4.4). Distinctive characteristics of the virtual community are not only a strong sense of community but also large diversity in terms of participants ranging from "pure user" to professional actor, as well as in terms of knowledge levels about EV. Three core mechanisms have been identified by which the user community contributes to system-building. The introduction of digital technology has facilitated knowledge-related activities for users and hence quasi-effortless knowledge production and sharing is a main virtual community occupation. Although they do not engage in large-scale charging point development, users provide their contribution to developing the material dimension of the innovation system in the form of infrastructural bricolage. By engaging in institution-building in practice, users contribute to the development of shared rules, for instance about how an EV should be used, that help to hold the scaling system together. In terms of geographical circulation, on the internet forums fruitful trans-local interactions occur and users are active in facilitating use across geographical contexts. Two ways were identified in which users play a role in reconfiguration of the existing socio-technical regime. Community members are empowering each other in the process of challenging the existing regime. Additionally, from the forum emerge various regime-adapting activities, aimed at changing some taken-for-granted institutions of the regime.

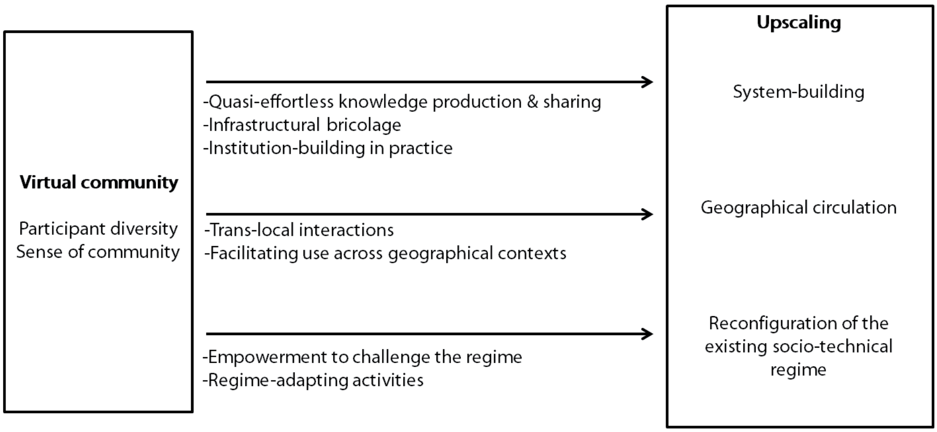


Figure 4.4: The participation of the virtual community in the upscaling of systemic innovation

These findings add to the emerging work on virtual communities in transitions. One of the few cases hitherto described in this regard is that of virtual communities related to heat pumps in Finland (Hyysalo et al., 2013; Hyysalo et al., 2017; Hyysalo et al., 2018). The quasi-effortless knowledge development and sharing process we observe is well in line with Hyysalo et al.'s (2018) findings on the heat pumps case. It demonstrates how the community provides more balanced market information, develops solutions to upscaling barriers, and articulates demand to other market actors. Hence, it reduces uncertainties for more mainstream users during upscaling. As a difference, in the case of the Finnish heat pumps, the virtual community shared much knowledge regarding physical adaptations to the heat pumps. Such classical "tinkering" was hardly observed in the virtual community we studied. This is probably due to the EV being a highly technologically advanced product, and consequently not so "tinkerable". Interestingly, however, there was some digital tinkering going on, with users making apps for the Tesla screen. It should be noted that on the American Tesla forums, which we did not study in detail, classical tinkering occurs, enabled by the presence of some highly technologically skilled users and the availability of spare Tesla parts.

For the virtual community we studied, it was most noticeable that users contributed beyond simple knowledge sharing, and participated in system-building activities in the domains of infrastructure and institutions. Insights in user activity in these domains are a main contribution of this study as compared to the case of the Finnish heat pumps forums, in which such activities are only reported on a limited scale (Hyysalo et al., 2018). In their own ad-hoc way, which we describe as infrastructural bricolage, the user community contributes to infrastructure development, for example by lobbying for chargers when people go on holidays. These findings fit well with recent work that stresses the importance of bottom-up processes driving infrastructure development, contrasting the dominant view on infrastructure development as resulting from top-down and centralized steering processes (Egyedi & Mehos, 2012). Most users in our study had a Tesla model S, which is a luxury EV with higher performance than other EVs. This being a limitation of our research, we performed a basic cross-check with the Nissan Leaf internet forum (a more middle class EV), and included people active on other forums among the interviewees. It emerged that the issues addressed in other EV communities are largely similar, except that for other EVs, there is more activity related to infrastructure, because the low range of these EVs makes charging a more important issue. By means of institution-building in practice, the virtual community is instructive in the establishment of rules and practices among EV users. This role has particular relevance in the upscaling phase, in which many new users join. It also seems hard to be taken up by other intermediary actors, which lack the shared experiences and trust that emerge in the user community.

The virtual user community also participates in the reconfiguration of the existing socio-technical regime. In their study of Finnish heat pump forums, Hyysalo et al. (2018) note there is hardly discussion about sustainability. Instead people discuss the heat pump in economic and technological terms. On the EV forum, this is only partly the case. Although EV users go through great lengths demonstrating that their EV is on par with fossil fuel cars in terms of price and performance, there is also discussion about environmental sustainability, and the sustainability of regime actors such as car companies is questioned. Yet, following the user typology of Schot et al. (2016), we expected to see more activity of the EV community in "hollowing out" the existing regime than actually observed. This lower activity might reflect that the electric vehicle transition is still earlier in the upscaling phase and has not yet enough momentum to take on the existing regime. Taken together, an underlying discussion here is the extent to which virtual communities activities in regime reconfiguration tend more to what Smith & Raven (2013) call "fit and conform" to the existing regime or "stretch and transform" of its fundamental values and structures. This is a valuable question to explore further.

4.5.2 The specific nature of virtual user communities

Our case study suggests that a virtual user community differs in two ways from other user communities in abilities to engage in upscaling. First, digital platforms facilitate knowledge sharing and, hereby, the collective production of knowledge among a wide variety of participants. In our case, the knowledge developed is taken up by users who already have an EV, prospective EV users and market actors active in the sector. It is also remarkable that during the influx of new users a relatively strong sense of community is maintained for a considerable group of users. This contrasts with accounts of tensions between initial users and more mainstream users in the literature on local grassroots communities (Truffer, 2003; Hossain, 2016). An explanation might be that, paradoxically, in a virtual community it is much easier to opt out of community activities if one is not interested, which is also easily accepted.

Second, as expected, the virtual community is able to build bridges between otherwise geographically isolated users. This is a major difference with local communities as described in the grassroots literature, which are heavily embedded in specific socio-spatial contexts. It is noticeable that the trans-local interactions on the internet forum do not only concern knowledge sharing but can also result in international collective action, for example related to charging standards. During upscaling, national subforums become more dominant, which reduces the frequency of international contacts between users. On these national forums, there is still considerable activity related to the use of EVs in different geographical contexts. Certain users take up a gatekeeper role as they are active on multiple forums with different geographical focus areas, or on multiple mediums, such as Facebook, WhatsApp, YouTube and blogs.

Before the virtual user community is hailed as the panacea for the upscaling of systemic innovation, two main limitations of its role have to be acknowledged. The first of these concerns the development and sharing of knowledge. Whilst the virtual community is undeniable a valuable source of knowledge for (aspiring) EV drivers and other system actors, the knowledge sharing process is also far from perfect. This is partly for technical reasons. In contrast to what Grabher and Ibert (2013) have observed, the "archival" function of the internet forum does not function well and users have to go through large amount of texts to find useful knowledge. (This problem is even worse on other social media, such as Facebook, on which the virtual community has also become increasingly active.) Also, the context-specific and subjective nature of the practice-based and experiential knowledge shared hampers its aggregation during upscaling. Second, the users mostly do not solve upscaling barriers permanently. They are relatively unorganized and rather work around the problems with whatever resources at hand in their everyday lives. In the Dutch context of our study there are policy-makers that recognize the potential of virtual communities, but the unorganized, ad-hoc, and subjective nature of these communities make it very hard to better include them in the policy development process.

4.5.3 Users in transition and innovation processes

At a more general level, our study provides some insights in overall transition dynamics and the role of users herein. Following the growth of various sustainable innovations beyond initial niche exploration, transition scholars have started to explore upscaling in transitions (Naber, 2018; Geels & Johnson, 2018; Hyysalo et al., 2018). If there is one thing on which these studies agree, then it is that niches after initial development will not simply continue to grow smoothly, as suggested by the diffusion of innovation model of Rogers (2010). To highlight differences with diffusion, Hyysalo et al. (2018) proposed to use the term "innofusion" (Fleck, 1988), defined as "the development of the sociotechnical characteristics of technology during its diffusion" (Hyysalo et al., 2018, page p. 882). Even more than in the innofusion pattern as described by Hyysalo et al. (2018), the activities we observed the user community performing concerned the system, practices and institutions around the technology rather than the technological artefact of the vehicle itself. Accordingly, the dimensions of the upscaling pattern we used as starting point, namely *system-building, geographical circulation,* and *reconfiguration of the existing socio-technical regime* proved useful for capturing the variety in upscaling activity. Another point to note is that new roles and actors will emerge during upscaling. As Schot et al. (2016) have described, users take up various roles in the different phases of a transition. Additionally, we should not forget that broad societal trends and technological developments change divisions of roles between actors and create new ones. In our case, because of a coming together of the rise of EV from niches and developments in social media technology, the virtual community we studied emerged. It altered the role of users in upscaling, most notably by increased blurring of the role of user-producer and user-intermediary (knowledge development and sharing among a wide variety of participants), as well as enhancing the role of user-intermediary (contributions in terms of institutions and infrastructure).

Finally, our results speak to the literature on user innovation (von Hippel, 2009; de Jong et al., 2015). In the user innovation community, scholars have started to explore the limited role of users in diffusing their innovations (de Jong et al., 2015). This limited role is explained by motivation. When users have developed a user innovation for themselves they are satisfied, and see no need for further diffusion of the innovation. Interestingly, in our case of systemic innovation, users have a lot to gain from the diffusion of the EV. This occurs because of *increasing returns to adoption*: when more users have an EV, more charging points and other systemic resources will become available (Arthur, 1989). Moreover, users do not merely act as rational actors. Community-related drivers, such as the feeling of being part of a group of pioneers that help each other, are also important motivations in diffusion-related activities.

4.5.4 Conclusion

To conclude, our research demonstrates the participation of the virtual user community in the upscaling of systemic innovation. The virtual user community makes a distinctive contribution to the work needed in the upscaling process. It is able to perform a broad scope of upscaling work, ranging from infrastructure development to institution-building.

Knowledge is more easily developed and shared among a wide variety of participants than in local user communities. In terms of geography, the virtual community enables interactions between dispersed users in a variety of geographical contexts. The virtual user community also empowers its members to challenge the socio-technical regime of fossil fuel cars. At the same time, the virtual community also acts in an ad hoc manner, is unorganized and subjective, and generates solutions to upscaling barriers that are often only workarounds. Still, the uncertainty around EV that it reduces, the driving practices that it establishes and explains, and the empowerment vis-à-vis fossil fuel car proponents that it brings make that more mainstream users can "cross the line", and become EV users as well.

Chapter 5

Assemblages and diffusion in transitions: a case of electric vehicle users

Abstract

This paper begins to develop a new conceptualization of the diffusion of innovation in transitions. Driven by observations of actually diffusing innovations, as well as the urgency attributed to climate change, the sustainability transitions field has recently started addressing diffusion in more detail. We draw on "assemblage thinking", particularly as it has been developed in Human Geography, to develop insights in diffusion during transitions. An assemblage perspective draws attention to the instabilities and agency potential in the world. We illustrate our perspective with a case study in the field of automobility, often characterized as a highly stable field, but currently changing due to, among others, the ascent of the electric vehicle. We explore the agency potential of the users of electric vehicles – a group of actors not normally considered to play an important role in global transition processes.

5.1 Introduction

Attention is shifting from the emergence of innovations and niches towards the diffusion of systemic innovations in the literature on sustainability transitions (Loorbach et al., 2017; Geels et al., 2018; Geels & Johnson, 2018). The diffusion of such innovations is much more complex than that of discrete products because it demands and entails changes in user behaviours, infrastructures and institutions (Lyytinen & Damgaard, 2000; Geels et al., 2018). It is often also relatively slow and characterized by strong geographical variation. The increasing interest in diffusion is partly a consequence of the perceived urgency of societal challenges such as climate change, and partly a reflection of actually occurring sustainable innovation processes. An "acceleration phase" has been identified for innovations, such as solar photovoltaics, wind energy, district heating, Bus Rapid Transit and to a lesser extent electric vehicles (e.g., Geels et al., 2017).

Most sustainability transition studies draw and build on existing theoretical perspectives when examining diffusion processes. Diffusion is commonly conceptualized as consisting of two distinct processes: the deconstruction of the existing regime(s) as well as niche-innovations building up momentum to scale rapidly (Geels et al., 2017). Reliance on established theoretical frameworks, such as Strategic Niche Management and the Multi-Level Perspective (Schot and Geels, 2008; Geels et al., 2017) can be helpful. It allows researchers to work with insights about dynamics obtained during the emergence of niche-innovations and to benefit from recent re-conceptualizations of the regime as not so much homogenous and stable, but as differentially institutionalized, spatially heterogeneous and sometimes dissembling (Fünfschilling & Truffer, 2014; Sengers, 2016; Meelen et al., 2017a; Bridge, 2018).

Yet, reliance on existing frameworks also raises challenges, particularly in light of ongoing debates about the extent to which transition studies are more inclined to explain stability than processes of change (Geels et al., 2011; Fünfschilling & Truffer, 2016; Gillard et al., 2016). Such debates will become more prominent when innovations that promise to enhance environmental sustainability diffuse more widely (Pesch, 2015; Geels et al., 2018). There is, then, room for new conceptualizations of diffusion in transitions. One set of conceptualizations is offered by relational perspectives in Human Geography, where research on policy mobilities has seen a surge of interest in recent years (Peck, 2011; McCann & Ward, 2011; Ward, 2018). Here authors study how policies travel between cities, mutate on the move, and also transform the places where they arrive. Increasingly, this perspective is employed to study the travels of innovations in transitions (Sengers & Raven, 2015; Affolderbach and Schulz, 2016; Schwanen, 2016).

In this paper we elaborate the contributions that assemblage thinking, which is closely related to relational thinking in Human Geography, can make to understanding diffusion in transitions. Assemblage thinking is rooted in the work of Deleuze and Guattari (1977, 1987), has been adapted and transformed into a more coherent framework by DeLanda (2006, 2016), and is applied in different variations across Human Geography (Anderson et al., 2012). Assemblage – the imperfect translation of the French *agencement* – is a concept with many definitions (DeLanda, 2016) but is widely used to describe a process of composition in which heterogeneous elements co-function (Anderson et al., 2012; DeLanda, 2016). Assemblage thinking highlights the transformative potential in the world (Gillard et al, 2016). It invites us to understand what transition scholars call socio-technical systems or regimes as at most temporary stabilizations, as constantly reconfiguring, and as replete with opportunities for radical change. This does not mean that in an assemblage perspective anything is possible or everything is in flux. Instead, assemblage thinking can help us think in a more structured way about the interplay between stability and change in diffusion processes (see also Haarstad & Wanvik, 2017).

Assemblage thinking is now commonly used to analyze complex, changing constellations of social and material elements like cities (McFarlane, 2011; Dovey 2012). Although not yet specifically in relation to diffusion processes, it has also been drawn upon in transition studies. Haarstad and Wanvik (2017) have taken an assemblage perspective to study global oil production networks. They find that socio-material landscapes of oil, called "carbonscapes", are considerably more instable and open to change than transition perspectives, with their focus on regimes, tend to suggest. A key factor in this regard is that, according to assemblage thinking, parts of assemblages have a relative freedom to join other assemblages (Delanda, 2006, 2016; Haarstad & Wanvik, 2017). Accordingly, in this paper we propose to understand the diffusion of a systemic innovation as the process by which an increasing number of assemblage parts join new assemblages.

We apply our assemblage perspective to a case study in the field of automobility, often characterized as a highly stable field, but currently changing due to, among other changes, the rise of the electric vehicle. We explore the agency potential of a group of actors not normally associated with a large role in global transition processes, i.e. the users of electric vehicles. We have studied an online forum of electric vehicle users and analyzed mainly its Dutch part, using internet ethnography (Kozinets, 2002; Garcia, 2009) as method.

5.2 Diffusion in transitions

5.2.1 Assemblage thinking

This section introduces the main tenets of an assemblage perspective and provides links to recent sustainability transitions literature, specifically the MLP (Multi-Level Perspective) and TIS (Technological Innovation System) strands, where relevant. Some limited comparisons to Actor Network Theory (ANT) – sometimes referred to as a cousin of assemblage thinking – are also provided, although more elaborate discussions on this point are available elsewhere (Müller, 2015; Müller & Schur, 2016; Briassoulis, 2017). Based on the works of Deleuze and Guattari (1977; 1987), DeLanda (2006; 2016) has developed a theory of assemblages to understand the development and functioning of complex entities such as social networks and cities. DeLanda's interpretation of Deleuze and Guattari's thinking is certainly not the only one (see, for example, Buchanan, 2017). Neither do we argue for a total adoption of DeLanda's framework by transition scholars. However, his version of assemblage thinking offers insights that are directly relevant to the study of diffusion.

5

Assemblage is used as descriptor, ethos and concept (Anderson & McFarlane, 2011; Anderson et al. 2012). As descriptor, it has come to refer to the cofunctioning of heterogeneous parts in a provisional, open whole. For example, Haarstad and Wanvik (2017) study oil distribution infrastructure assemblages, which are fluctuating wholes of social and material elements such as pipelines, railways, trucks, and political interests. As an ethos, assemblage represents an orientation towards the process of composition and complexity of phenomena, and the potential for novelty in a situation of continuity. So Haarstad and Wanvik (2017) argue that, on the one hand, oil distribution infrastructures have become highly embedded in existing landscapes and thus persisting over time. On the other hand, they are also located in conflict-prone areas and being contested by various organizations, providing room for change. Finally, as a concept, assemblage provides means of thinking about the interplay between stability and change. Thus Haarstad and Wanvik's (2007) oil distribution assemblage has a specific type of relation, called extensive (see below), to other assemblages, such as the global oil market, which make it susceptible to change whilst it simultaneously seeks to persist in its being. We can now spell out some key elements of assemblage thinking in more detail.

Scale and boundaries. Assemblages vary in size; they can even be as small as two elements. When an Electric Vehicle (EV) user is charging her car, we can think of the EV-charger-user assemblage. This assemblage can be seen as part of a larger EV assemblage, consisting of EV users, infrastructures, manufacturers, governments, and driving as well as charging practices, in scale comparable to transition studies' socio-technical systems. Next to being part of the EV assemblage, the EV user is also part of many other overlapping assemblages, such as social networks and the city where she lives. The EV assemblage therefore has no clear boundaries; its elements are integrated into various other assemblages that both enable and constrain each of them (Delanda, 2016; Haarstad & Wanvik, 2017). The Technological Innovation Systems (TIS) literature has recently introduced the notion of "structural couplings" (Bergek et al. 2015). These are links that arise because elements are part of the TIS and of other systems, such as a car manufacturer that produces both EVs and conventional cars. The inclusion of such couplings in the analysis resonates with assemblage thinking. As a difference, the TIS perspective still emphasizes the importance of system boundaries, in order to identify systemic resources, which arise from distinct interactions that are internal to the system.

Symbiosis and frictions. The coming together of the different elements that constitute an assemblage is an achievement, and it requires labour to be maintained (Anderson et al., 2012). There are always frictions, and the assemblage is vulnerable to reconfiguration. The unity of an assemblage is thus different from an organic whole or a total system, in which the parts work together smoothly. Consider, for instance, the awkward combination of newcomers such as Tesla and traditional car manufacturers in the EV assemblage, together involved in processes of standardization of chargers (Bakker et al., 2015). As a biological illustration symbiosis can be used, for example as between plants and pollinating insects, pointing to a relation between heterogonous elements that keep their own identity (Delanda, 2016, p.3). Two differences with current sustainability transitions thinking can be observed. In current sustainability transitions thinking there is an emphasis on smoothly working systems, as exemplified in explanations of system growth in which multiple endogenous drivers (such as learning and the creation of positive discourses) together create "momentum" or "virtuous circles" (Suurs & Hekkert, 2009; Geels et al. 2017). Further, current literature suggests a linear trajectory of structuration over time (Geels, 2004; Raven, 2012). While niches are still seen as instable and less coherent entities, over time systems are stabilized by the emergence of socio-technical regimes, structuring the behaviour of actors. Assemblages, in contrast, are always involved in processes of stabilization and destabilization. Their degree of stabilization at a certain point in time can only be assessed empirically. As shown by Haarstad and Wanvik (2017) for fossil fuel infrastructures, mature assemblages are also and continuously subject to important processes of destabilization, and these are largely endogenously driven.

Relations. DeLanda (2006; 2016) describes connections between elements in assemblages as "extensive relations" or "relations of exteriority". This means that assemblage parts are not fully determined by the relations in which they exist and the wholes of which they are part. First, they have a relative autonomy to act differently than other parts or leave assemblages and join others. Second, assemblage parts are always more than their current actualization in a certain assemblage (Anderson et al., 2012). When engaged in different relations, assemblage elements can exercise other parts of their capacities and thus take up new roles. DeLanda (2016, p.73) gives the example of a knife, which has a certain property, for example that it is sharp. With this property it can be a simple tool as part of the "kitchen assemblage". However, when it is part of the "army assemblage", it becomes a lethal weapon. Overall, the notions that elements have a relative freedom to leave their assemblages and join others, and can exercise different capacities when they connect to different elements, add a virtual layer of potentiality to the assemblage analysis. There is, then, always a surplus, a 'more' to an assemblage. This constitutes a potential for change, novelty and surprise that is inherent in the current situation.

At this point some differences become evident between assemblage thinking and ANT (Müller, 2015; Briassoulis, 2017). First, the extensive relations are different from network relations as specified in ANT.[21] The individual elements in assemblage thinking exceed their relationships, opening a potential for change inherent in any moment. Such a realm of potential is not present in much ANT literature, which restricts itself to describing the actual (Müller & Schurr, 2016). A second distinction has become somewhat blurred in the various studies that combine assemblage thinking and ANT. Yet, whereas ANT is centrally concerned with the ontological symmetry of human and non-human actors (Law, 2004), assemblage thinking pays more attention to specifically human intentions and reflexivity (Müller, 2015; Briassoulis, 2017).

The basic tenets of the assemblage approach advanced here can be summarized as follows: Assemblages are socio-material compositions of elements. They have no clear boundaries as elements are also part of other assemblages. The assemblage is a provisional co-functioning, constantly engaged in processes of stabilization and destabilization. Assemblage parts have a freedom to leave assemblages and join others. When they interact with different elements, they can exercise different, previously unobservable capacities. We will now further specify our assemblage perspective in order to address diffusion in transitions. We will do so by outlining drivers of diffusion from an assemblage point of view, by describing diffusion processes, and finally by arguing that diffusion also carries over to other sustainable innovations.

[21] Some parts of the ANT literature are closer to assemblage thinking here. For instance, Mol and Law (1994) discuss fluid spatialities, in which relations can gradually change while the terms that are being related stay intact.

5.2.2 Drivers of diffusion: lines of flight and transversal connections

The perspective employed here questions the hegemony of powerful assemblages, by showing that any and each assemblage is contingent and does not necessarily have to be as it is; there are always certain ways out (Müller, 2015). We already noted that assemblage parts have a relative freedom to leave assemblages. Radical change is not achieved in a heads-on confrontation with powerful existing assemblages but by fleeing from them and engaging in a creative process of exploration and experimentation (Purcell, 2013a). In pursuing such a "line of flight" (Deleuze & Guattari, 1987) people (or other agents) disrupt dominant practices by showing the creative possibilities within them (May, 1994; Scott-Cato & Hillier, 2010; Nail, 2013). In the context of transitions, one can think of grassroots initiatives in which people explore various sustainable alternatives such as more self-sufficient agriculture (Longhurst, 2015; Gillard, 2016). Such alternatives do not immediately result in large-scale changes. Elements that flee can be, and often are, recaptured, among others because assemblages also strive to persist in their being. As Purcell (2013a) notes, the metaphor of a prison break is useful in this context. The prisoner escapes, but then lacks the resources to remain free for long and is caught up in the penitentiary system again. Recapture is exemplified in the context of diffusion in transitions by radical car-sharing initiatives that have to water down sustainability ideals or face a loss of users when they expand (Truffer, 2003).

Only if elements join up with other elements that are fleeing can they evade recapture (Purcell, 2013a, 2013b). The likelihood of success of a new assemblage thus depends on its ability to form connections. In research on the anti-globalization movement, Raunig (2002) has referred to links between fleeing elements as transversal connections. Any new assemblage wanting to challenge an existing hegemonic assemblage has to cut transversally across social groups (or other kinds of assemblages). With regard to transitions, many grassroots user innovations fail to diffuse because of their attachment to specific groups of highly environmentally aware people and limited appeal beyond those (Hossain, 2016). Grassroots user innovations need transversal connections that link up the aspirations and activities in different social groups. In line with an assemblage perspective, the effects generated by transversal connections should not be understood as holistic wholes from which contradictions have disappeared (Purcell, 2013b), but as "a multitude of temporary alliances, as a productive concatenation of what never fits together smoothly, what is constantly in friction and impelled by this friction or caused to evaporate again" (Raunig, 2002, p.4). To facilitate the emergence of transversal connections that cut across established identities, suitable communication mediums are needed. Often mentioned here is the internet, which could be such a medium and hence foster the transversal connections that contribute to diffusion in transitions (see Vieira & Ferasso, 2010).

5.2.3 Diffusion processes: parts joining the new assemblage

Having described diffusion as driven by elements that pursue lines of flights and generate transversal connections, we can now further specify processes of diffusion. We first describe how an assemblage perspective emphasizes how new assemblages emerge out of existing ones. We then turn to describing assemblage converters, which are important elements in influencing diffusion. Finally, we discuss how the new assemblage evolves over time.

The new assemblage emerges in an immanent and creative process out of existing assemblages, as destabilizations and exclusions from different assemblages are harnessed (Nail, 2017). It thus also emerges out of the destabilizations of what transition scholars would call the current socio-technical regime (Haarstad & Wanvik, 2017). As the new assemblage forges transversal connections between different parts of society, more and more parts of existing assemblages join the assemblage of the innovation. Joining new assemblages is facilitated by the ability of parts to exercise different capacities when they enter into new relations. As an illustration of this process, abandoned natural gas distribution infrastructure can be employed for the transport of hydrogen (Haeseldonckx, & D'haeseleer, 2007). Another example of elements of existing assemblages taking up a new role, for the case of the electric vehicle assemblage, are street lamp-posts exercising their capacity to be electric vehicle charge points as well (Cass et al., 2018). All in all, the assemblage perspective stresses that a new assemblage emerges out of existing ones, and emphasizes the ability of elements to join that new assemblage.

In this process of parts joining the new assemblage, assemblage converters are well-placed elements that either speed up the process of diffusion considerably or reverse it (Wanvik, 2014; Haarstad & Wanvik, 2017). Such converters point out the non-linearity of the diffusion process. In much innovation studies literature, including transition thinking, diffusion is assumed to follow an S-curve, characterized by an acceleration phase of exponential growth (Schot et al., 2016). Assemblage thinking does not deny S-curved diffusion patterns but points out that this is only one of very many trajectories; the growth can also be halted or even reversed. As an example of an assemblage converter, Haarstad and Wanvik (2017) discuss the nuclear incident in Fukushima, as a strong push accelerating the *Energiewende* in Germany. Strong local resistance movements against wind energy, on the other hand, can be seen as assemblage converters that slow down the diffusion of renewable energy considerably (Enevoldsen & Sovacool, 2016).

A final qualification is needed regarding the evolvement of assemblages during diffusion. The notion of assemblage converter might suggest that assemblages only change because of some highly influential elements. This is not the case as the agency of assemblages tends to be distributed over the different composing elements (Bennett,2004; 2005). Bennett (2005) draws attention to the agency of more mundane actors in assemblages, in particular the "thing-power" of material elements (i.e. their capacity to act) while still allowing for differences between non-human and human elements. She describes a large black-out of the American electrical grid assemblage as emergent outcome of a multitude of assemblage actors: electricity itself, a fire, old wires, greedy energy companies, regulators, consumers and their thirst for cheap energy, as well as their interactions. As far as innovation diffusion is concerned, recent studies stress the importance of looking beyond actors traditionally seen as powerful (e.g. governments and large companies) and emphasize that mundane actors such as users can play equally important diffusion roles (Schot et al. 2016; Hyysalo et al. 2018).

In the productive processes driving diffusion, we can expect each of the assemblage parts to have an "energetic pulse" that is somewhat "off" with that of the rest of the assemblage, making it an open-ended entity (Benett, 2005). Often this will be related to elements being part of multiple assemblages, or what are known as "context structures" in the TIS framework (Bergek at al. 2015). These differences between assemblage elements are instrumental in fostering diffusion, as they are a source of novelty and access to new assets. Instabilities also occur when innovations have broken out of the niche that protects them. Studying the diffusion of heat pumps in Finland, Hyysalo et al. (2018) argue that diffusion in transitions resembles an "innofusion" pattern in which the sociotechnical characteristics of the technology change during its diffusion (Fleck, 1988). For example, users living in the Finnish climate adapted the heat pumps, to make them work with the cold temperatures there as well.

5.2.4 Change does not stop here

Assemblage elements are parts of multiple assemblages, which implies that changes may not be limited to one particular assemblage (Haarstad & Wanvik, 2017). In relation to the diffusion of innovations such as EVs, this means that elements that moved into EV assemblages after following a particular line of flight may also become attracted to other innovations such as, for instance, PV solar panels on one's roof in order to generate green electricity. Thus, the line of flight associated with the EV can harness an ethos of experimentation and open up ways of living in which creative experimentation with sustainability carries over to domains beyond transport (cf. Purcell, 2013). This does not mean that elements can break free from all unsustainable assemblages straight away. For example, people switching to solar panels may be more environmentally sustainable in terms of energy use, but the production of solar panels can still pollute the environment (Tsoutsos et al., 2005). The development of related sustainable innovations is then again dependent on the forging of transversal connections between different actors, an example being an initiative by a sustainability researcher to work on more sustainably produced solar panels with a variety of participants (ECN, 2014).

5.3 Case background and methodology

We apply our assemblage perspective to a case of electric vehicle users. More specifically, we studied users active on the Dutch part of an internet forum dedicated to electric vehicles. The case of the electric vehicle has been discussed in the transitions literature previously (van Bree, 2012), which is helpful for evaluating the potential added value of taking an assemblage perspective. The EV is also an innovation that at least in certain countries, including the Netherlands, is experiencing accelerated adoption (IEA, 2016). We concentrate on the activities of the users on the Tesla Motors Club forum (https://teslamotorsclub.com/). On this internet forum, users and enthusiasts discuss a wide range of topics related to EVs. The forum has fuzzy boundaries and its users are active on other platforms as well, both online and off-line. As a geographical focus, we consider EV users from the Netherlands. Transition studies have shown that many issues in the diffusion of EV are related to socio-spatial factors at the national level, such as subsidies and charging point standards (Sierzchula et al., 2014; Bakker et al, 2015), and much of the discussion on the internet forum we have studied takes place between users of the same nationality. Furthermore, the Netherlands is a frontrunner country when it comes to EV adoption: over the 2013-2017 period the number of electric vehicles grew from 7,410 (of which 4,348 Plug-in Hybrid Electric Vehicles (PHEVs)) to 119,332 (of which 98,217 PHEVs[22]) (NEA, 2014, 2018). During this period, the average market share was 5.6%. The Dutch user group is also one of the most active on the internet forum we study.

The empirical material for the case study is collected from a so-called internet ethnography (Kozinets, 2002; Garcia, 2009) of the Dutch part of the Tesla Motors Club internet forum, 13 interviews with users active on this EV forum, and scientific literature and reports about the development of EV in The Netherlands and beyond (see Meelen et al. (2017b) for more details). The internet ethnography traces back the role of the internet forum users in the diffusion of EVs through space and time. It takes advantage of some unique characteristics of the internet forum: it is archival and shows live communication at the same time. Furthermore, the forum is well-annotated, as the exact date and time of each post, as well as the location of the poster, are noted.

For the present study, we analyzed forum threads, mainly on the Dutch section of the Tesla Motors Club forum, spanning the 2009-2016 period. Threads are basically discussions about a particular topic (such as charging an EV abroad or EV insurance). These threads are sometimes

[22] PHEVs can also operate on gasoline. PHEVs in the Netherlands benefitted from a combination of tax schemes considerably reducing their lease or purchase price, such as an exemption from circulation tax and registration tax (initially equal to schemes for "pure" EVs, later more limited) (NEAA, 2014).

short with only a few replies to the thread starter, but can also go on for years and consist of hundreds of pages. The analysis proceeded in various steps, given the large size of the forum. We first went through the headers and first post of threads showing activity in the January-May 2016 period (360), the most replied threads since 2012 (50) and additional international threads from before 2012 in which Dutch users participated. These were ordered in categories and eventually 26 threads were selected for in-depth analysis. The data was coded according to the content and methods of work of the internet forum users. The empirical material was then assessed using the concepts from our emerging theoretical framework on assemblages.

Additionally, at the end of 2017 and during the first months of 2018, 13 interviews with internet forum users of around one hour each were conducted. Interview candidates were selected partly based on posts identified in the previous stage of the research. A purposive sampling strategy was adopted in order to obtain a strongly diverse group of forum members in terms of experience (number of posts on the forum) and role fulfilled (e.g. a user that also sells charge points, a user that is a "critical" voice on the forum, a user that organizes particular events). The interviews were coded according to the now more clearly developing framework on assemblages.

Finally, as a form of data triangulation and contextualization, scientific studies, sector reports and other documents about EVs were consulted throughout the research process. It is important to note here that the EV transition in The Netherlands is very well documented. There are, for instance, various EV newsletters, including by the semi-governmental Netherlands Enterprise Agency (in Dutch: Rijksdienst voor Ondernemend Nederland, RVO) which every month disseminates a detailed report concerning the adoption of all different types of EVs and charging points. These sometimes include specialized reports on topics such as user charging behaviour.

5.4 Case study

5.4.1 Electric vehicle users on the forum

The emergence of the internet initiated bulletin boards, mailing lists, and later internet forums dedicated to the discussion of almost any topic of interest, from drug development, religion to IKEA furniture (Holtz, 2012; Grabher & Ibert, 2013). The Tesla Motors Club forum was set up in 2006 by a recent high school graduate who was interested in both high performance cars and alternative energy, and wanted to discuss the future of Tesla Motors and electric vehicles (TMC, 2018). The forum has grown considerably over the years. At the start of our analysis in 2016, it consisted of about 60,000 threads, 1.5 million messages and 40,000 members. In initial threads, pioneer users of the Tesla Roadster sports car, as well as other EV enthusiasts from the US and various European countries jointly discuss EV-related issues. In 2012 a specific thread was started in Dutch to discuss developments in The Netherlands. Various threads are subsequently clustered in the sub-forum "Belgium and the Netherlands", which is central in this study. Users become aware of the existence of the forum when they search for information about electric vehicles online or when they meet other EV users at charge points. They usually read the forum first for some time, and some of them start making posts as well. To get some grasp of the prevalence of forum activity among EV owners, we included a question on forum use in a survey sent out to EV owners. It turned out 67% had been reading some EV forum, 28% had written on an EV forum (Meelen et al., 2017b).

The forum on which the users are active can be seen as an assemblage. It is a complex socio-material composition of Tesla users, other EV users, EV enthusiasts, as well as their EVs, charging points, practices, norms and values, facilitated by digital technologies. The users on the forum are also part of a larger EV assemblage that includes EV manufacturers, EVs, charging infrastructure and policy makers. In fact, the EV forum assemblage is tied to many other assemblages and has no clear boundaries. Its participants are also members of other clubs, inhabitants of cities, maybe even parts of the fossil fuel car assemblage, and users of communication technologies. Regarding the latter, changes in this assemblage, i.e. the rise of the smartphone, has led to an increase of Whatsapp and Facebook groups. These allow for even more quick and direct conversations than the forum does, leading some forum users to become active on these mediums as well, and sometimes to quit the forum altogether. Evidently, then, constant processes of stabilizing and destabilizing occur. There is an increased bonding as members get to know each other better online and sometimes start organizing real-word events such as an EV-rally. In general there is a supportive and friendly atmosphere, and users help each other solving the problems of their EV. On the other hand, the forum is also destabilizing constantly. Fierce discussions can emerge, for example when people are very disappointed by the performance of their Tesla. Notably the forum is destabilized by the influx of many new members. These constantly open new forum threads in which they ask basic questions about EV, making the forum increasingly hard to read. At some point, to counter this issue, forums users launch a website on which beginning users can find answers to their questions.

5.4.2 Drivers of diffusion: lines of flight and transversal connections

Users following lines of flight meet on the forum. The internet forum stimulates the creativity of the mass of users in pursuing their projects, while also facilitating a form of bonding between the members. The forum is accessible to many. People can contribute by opening a new thread or reacting to an existing one. The forum unleashes creative ideas, from people starting their own charging point company, to people making joint, long road-trips with their EV to demonstrate the feasibility of the EV as an alternative to gasoline cars. Over time, the internet forum has become a knowledge sharing collective. For example, in a topic on charging, users work out their own do-it-your-self solutions for connecting their EV. Users post descriptions of their solutions, an EV driver who also happens to be an electric engineer comments on the safety of the construction, other users react, and so on. And still, with the influx of many new users during diffusion, discussions become longer and unreadable, leading some users to explore other possibilities for connecting with fellow EV users.

Transversal connections between users emerge from the internet forum. From our interviews with people who buy a Tesla, it becomes clear that they come from different segments of society, and buy the car for a variety of reasons. There is the self-declared 'petrol head' entrepreneur who bought a Tesla after his dad had bought one upon renting a hybrid car, the former Apple retailer lured by the design and software focus of the Tesla, and the self-employed part-time installer of solar panels and heat pumps who is strongly into sustainability. In fact, across the forum a very rough split of one third each between car, technology and sustainability enthusiasts can be observed. One user remarks:

"*I also thought the user group was very fun and diverse, because there were petrol heads in there, but also huge tree-huggers, that went all well together. A disadvantage of internet is often that people are really opposed. Here was something common that connected the difference between people. That's what I thought was sympathetic"*

This quote illustrates what is meant when an assemblage is referred to as a symbiosis. On the internet forum there is no homogenous entity emerging. There are still considerable differences between petrol heads and environmentally driven users, which are also reflected in discussions. Still, for some time, these different types of users are bound together by their common cause of fostering the EV.

Initially, the EV forum triggers trans-local interactions, as users from many countries and regions join discussions. Later in the diffusion process, many national subforums are created. Discussions then become shaped more strongly by the respective countries of origin of the participants. We can see this as a spatial reconfiguration of the transversal potential of the forum. Whereas there were first many connections between users from different localities, the creation of different regional subforums creates more opportunities for transversal connections in specific localities, for example with local motoring clubs.

5.4.3 Diffusion processes: parts joining the new assemblage

Having established how the EV internet forum contributes to diffusion in the form of stimulating users' lines of flight and transversal connections, we can now study how processes of diffusion further unfold. Following our assemblage perspective, we consider how new assemblages emerge out of existing ones, how assemblage converters considerably speed up or reverse this process, and how the newly formed assemblage engages in diffusion.

The electric vehicle emerges in the context of a variety of assemblages. Parts are not totally determined by the assemblages they are currently in and have a relative freedom to join new assemblages, in which they can exercise different capacities. A self-proclaimed petrol head on the forum declares about the new practice of driving his EV (which cannot be driven at very high speeds for a long time):

"*I also note that I feel less urgency to drive fast on the left lane. Cruising at 110 and listening to the fantastic audio is much more relaxing. (Is this me saying this?).*"

Moreover, the newly formed EV assemblage emerges out of many other assemblages, with parts taking up a new role and thus exercising new capacities. Our analysis revealed various instances of this occurring; here we limit ourselves to three examples. One of these is a technologically savvy blogger who started producing videos about his Nissan Leaf and so actualized his capacity to become an EV promotor. Another is of an insurance middleman active on the forum who goes to great lengths to ensure that there are forms of suitable insurance for EVs. Finally, we identified a web shop owner who started selling charging points to fellow EV owners on the forum, because he saw a demand. He thus exercised his capacity to be an infrastructure provider.

The users and their discussions on the forum are heavily influenced by assemblage converters in the diffusion of the EV. As explained in section 5.2.3, diffusion in an assemblage perspective does not necessarily follow an S-curve, but is often steered by influential elements, assemblage converters. In the case of the EV in The Netherlands, subsidies have been an important assemblage converter. Electric Vehicles and particularly Plug-in Hybrid Electric Vehicles, benefitted from generous subsidy schemes (NEAA, 2014). These subsidy schemes are adjusted every year, with an overall trend of becoming less generous. On the forum users discuss how to best make use of the subsidies, for example by timing the purchase of an EV. Interestingly, the influence of this assemblage converter is also very visible in the overall pattern of EV diffusion in The Netherlands. For example, the market share of EVs went up and down from 5.4% in 2013, to 3.9% in 2014, to 9.7% in 2015, to 6.4% in 2016 and to as low as 2.7% in 2017 (IEA, 2018).

The low value of 2017 is due to a drop in the sale of PHEVs, likely related to a strong decrease in subsidies. Even within years, there is a strong sales peak in December, in which users take advantage of the then still existing subsidies for that year (NEA, 2014; 2018).

Finally, we can consider the agency of the user forum in diffusion as distributed, with each of the assemblage parts slightly out of sync with the rest. The EV forum is a vibrant assemblage. People share knowledge, go on road trips together, become friends or get into fierce discussions about the best ways of charging EVs. The assemblage is capable of many things thanks to the interaction of its members. The user forum lobbies governments and organizations for more charging points. Enthused, users let others drive in their EV and try to convince them to buy one as well. This is a very common practice. A user develops a tool in which the total cost of ownership of an EV can be calculated and compared to alternatives to facilitate buying an EV. Another enthusiast develops a detailed overview of the environmental benefits of EVs, enabling the users to win discussions with proponents of fossil fuel cars more easily. Some users even become self-proclaimed “EVangelists”. One user makes more than hundred others buy a Tesla as well and is rewarded by Tesla for this. Increasingly, his own project becomes more out of touch with the rest of the forum, with some forum members believing he is only pursuing his own desires, interested in the rewards of Tesla, instead of in fostering the cause of EVs.

Although the assemblage is not a coherent totality, this user’s actions contribute to diffusion. The same holds for drivers of plug-in hybrid EVs (that can drive on both gasoline and electricity). Their status is controversial. Are they part of the movement? On the internet forum they are often blamed for occupying charging points that they not really need (while “pure” EV drivers do). On the other hand, it is acknowledged that their large numbers have a positive influence on the diffusion of charging points in The Netherlands. The same holds for the manufacturers making the plug-in hybrid cars in the broader EV assemblage. With these specific cars they are productive parts of the EV assemblage, but they are also, part of a fossil fuel assemblage that moves in a very different direction.

5.4.4 Change does not stop here

On the internet forum there are many discussions on various sustainable energy solutions. Now they have an EV, some have also become interested in other sustainable alternatives. On the internet forum the users share knowledge on these alternatives and some users are also active as suppliers of, for instance, solar panels. A forum user recounts:

"*If people are used to drive in an EV, then they start being surprised: why is this truck not yet electric, why is this plane not yet electric, why is this not electric?"*

A former petrol head declares:

"In the Tesla I became more environmentally aware actually, I became more green, that is quite a remarkable spin-off that sometimes does not get that much attention, and I have delved into solar panels and heat pumps."

It is not that anything is possible, not that every other sustainable alternative now co-diffuses rapidly. Yet, people are enticed to perform activities in more sustainable directions. The previous petrol-head continues:

"I would like to have solar panels on the company roof as well, only then you wear two hats. Someone who likes to act sustainably and someone who has to run a company with positive results. That I do not get completely figured out yet."

As with the diffusion of EVs, an important driver of diffusion for the other sustainable innovations again are the formation of transversal connections between different actors. The forum can be of some help here. For example, via the forum a session is organized in which a specialist in heat pumps discusses their possible applications with a varied group of potentially interested users.

5.5 Discussion

Innovations that may result in socio-technical transitions towards sustainability have started to diffuse. Together with the urgency posed by sustainability challenges such as climate change, this has spurred interest in processes of diffusion in transitions (Naber et al., 2017; Geels et al., 2018). In this paper we have explored an assemblage perspective to understand innovation diffusion within broader transition processes. This perspective draws attention to the instabilities and agentic potential in the world and concentrates on processes of assembling, i.e. how assemblages come into being, change, remain more or less stable and evolve. We have introduced assemblages as socio-material compositions, with no clear boundaries, that never fully stabilize. Their parts have a relative freedom to leave assemblages and explore alternatives. By forming transversal connections with elements in other assemblages like human actors from different social groups, diffusion processes are fostered. The diffusion process strongly builds on existing assemblages. During the process of diffusion, assemblage converters are well-placed elements that can either speed up or slow down the diffusion process considerably. Finally, the diffusion of one sustainable innovation can also carry over to others.

A case study of electric vehicle users on an internet forum has been presented. We looked at the role played by the forum and its members in the diffusion of electric vehicles. A useful aspect of the assemblage perspective here was that it allows for the inclusion of the relations between elements and other assemblages. So we could look at the forum electric vehicle users not only as parts of the forum assemblage, but also explore links with the broader socio-technical assemblage of the electric vehicle, as well as other assemblages. Because of the mutual dependency of developments in these assemblages, the inclusion of these connections adds to our understanding of diffusion. A notable observation were the transversal connections created on the forum between the former petrol-head car enthusiasts and environmentally driven users, particularly given that such connections are deemed important for diffusion in an assemblage perspective. The assemblage perspective also allowed to show how forum users worked together and were able to build on each other's solutions. However, the forum did not become a coherent totality, as each of the forum users worked slightly in their own way. Obviously, the focus of the case study was still on a particular type of actor, the user. So we should be attentive to distinctive characteristics of this actor in diffusion in transitions. In our perspective and case study, there is an emphasis on how actors are capable of joining new assemblages. This makes sense, as users do not perish during transitions, they start using the new innovation. The same does not hold for all other actors, such as companies. These could go bankrupt or otherwise disappear during diffusion in transitions. The case study in this article has not allowed us to explore what insights our assemblage perspective generates about the role of firms in innovation diffusion.

This study relates to two topical debates in the transitions field. The first of these concerns a shift in analysis from coherent and delineated systems to systems that are explicitly connected to other systems (Bergek et al. 2015; Markard, 2018). Authors working in the TIS (Technological Innovation System) tradition have started to include context structures in analyses more systemically with the notions of "external links", and "structural couplings", elements shared between a TIS and context structures (Bergek et al. 2015). Still, the importance of system-internal synergies and system delineation is stressed in TIS thinking. An assemblage perspective can be helpful in this context because it starts from the assumption that there is not necessarily a smooth-running coherent system needed for diffusion. For example, think of the EVangelist user, whose project to convince others to drive EV moved increasingly out of sync with the rest of the active EV users but still contributed to EV diffusion. More than TIS studies the assemblage perspective stresses the generative character of connections with other assemblages, even if they are very different (see Bergek, 2015). Consider, for instance, conventional car manufacturers producing plug-in hybrid electric vehicles, which contribute to the further development of charging infrastructure for all EVs.

A second debate concerns the stability of socio-technical systems (Genus & Coles, 2008; Fünfschilling & Truffer, 2014; Gillard et al, 2016; Avelino, 2017). In the transitions literature these tend to be portrayed as stabilizing over time with the emergence of socio-technical regimes, semi-coherent rule-sets structuring the behaviour of actors. In response to criticism of the regime being seen as overly homogenous and stable, some started emphasizing that regimes are institutionalized only to a certain extent in a spatially heterogeneous pattern, with parts of the regimes sometimes even dissembling (Fünfschilling & Truffer, 2014; Sengers, 2016; Meelen et al. 2017a; Bridge, 2018). In our perspective, we see socio-technical assemblages as inherently unstable entities, engaged in constant processes of stabilization and destabilization. Parts have a relative freedom to leave assemblages. By joining up with other elements, they can induce radical change. This process is fostered by the ability of parts to exercise new capacities when they join new assemblages. For example, a user with experience in web shop development starts a charging point shop when joining the EV assemblage, hence exercising their capacity to become an infrastructure provider. Thus, as compared to the notion of the regime, the assemblage perspective qualifies socio-technical entities as inherently unstable, as there is ample room, at the micro-level, for actors and technologies to reconfigure in new ways which sometimes may foster radical change.

Overall, by studying the role of the user internet forum in diffusion with assemblage thinking we are first of all able to offer a perspective on innovation diffusion that stresses the importance of both relations between actors and the ability of individual actors to be and to act differently. Within the TIS tradition it is by now well recognized that diffusion means that interactions between previously separated systems increase, as is the case when multiple technologies – for instance, EVs and solar panels – diffuse concurrently (Markard et al. 2018). In that sense a focus on ever-larger systems is a sensible analytical move. However, it also entails the risk of obscuring the role of specific actors in transitions. The perspective employed here, which stresses that actors are always more than the systems of which they are part, and can also act differently from other system elements, can thus be helpful for analyzing transition dynamics. It allows us to see how diffusion results from both the actions of individual actors, as well as from aggregated developments in assemblages.

Second, an assemblage perspective strongly emphasizes the immanent development logic of new assemblages. They emerge from within existing assemblages, with assemblage converters being important elements speeding up or slowing down the process. This can help us go beyond strict distinctions between niche, regime and landscape levels as used in the transitions field.

It brings us closer to dominant evolutionary notions of innovation as the recombination of existing elements (Arthur, 2009). One could argue that assemblage converters, such as policy measures to stimulate EV, are similar to what would be called "landscape factors" in the MLP. In this vain, Van Bree et al. (2010) in their analysis of EV diffusion see environmental regulations for cars as part of the landscape, and out of the sphere of influence of regime actors. An assemblage perspective, on the other hand, would question to which specific elements these policies are related and how these relations have come about. In this case, it would identify a mutual influence between policies and "niche" elements such as users who *en masse* claim EV subsidies leading to their downsizing, or "regime" actors such as car manufacturers trying to influence them. On this view, there is no 'external' factor or event that shapes the EV transition trajectory as a contingent, nearly-impossible-to-steer eventuality. Instead there is a sequence of actions and reactions emerging from, and reconfiguring, assemblages in constant formation.

Obviously, there are also limitations to the perspective employed here. First, an assemblage perspective provides a broad framework for analyzing innovation diffusion that, because it is reluctant to a priori specify rules or patterns, necessarily leaves open many questions for empirical analysis. A particularly salient question of this kind relates to the extent to which the newly emerged assemblages really break with existing ones. In our empirical case, do most elements of the gasoline car assemblage simply carry over to EV? Can this then also strengthen the gasoline assemblage and reduce EV to an add-on? Second, there are many versions of assemblage thinking (Anderson & McFarlane, 2011). This is not necessarily a problem in itself, and one could even argue that the emergence of a more uniform version would go against the very nature of assemblage thinking. Our assemblage perspective is mainly connected to the works of DeLanda (2006, 2016) – and Haarstad and Wanvik (2017) who build directly on DeLanda's version of assemblage theory – with some more elaborations on specific dimensions such as lines of flight. Even then, in exploring the contributions assemblage thinking can make to understanding innovation diffusion in broader transitions processes, we had to make some concessions and highlight particular points. We do not provide an extensive discussion of the virtual, i.e. the not yet actualized configurations of assemblages, which is central to Deleuze's philosophy and can be drawn upon to think about tendencies in particularly complex assemblages (DeLanda, 2006; Lagendijk & Boertjes, 2013; Dittmer, 2014). Third, our case of a well-connected internet forum fits well with an assemblage perspective. More research is needed to see to what extent the assemblage perspective works with off-line communities in diffusion (see e.g. Scott-Cato & Hillier, 2010).

To conclude, we have started to explore the contributions an assemblage perspective can make to the study of innovation diffusion within broader transitions dynamics. In a case study, the perspective allowed us to investigate various processes by which an internet forum of electric vehicle users participated in diffusion. We hope that this work stimulates the debate regarding stability and change in transitions, now that innovations offering the prospect of greater sustainability, such as EVs, have actually started to diffuse.

Chapter 6

Conclusion

6.1 Main findings and contributions

This thesis set out to develop more refined characterizations of users in upscaling as well as to advance our understanding of the contribution users can make to upscaling. Some innovations that are part of those fundamental transformations needed to achieve a sustainable society (viz. sustainability transitions), have recently started to scale. This development brings users to the center of the transitions debate. In the transitions field, a distinction is made between early niche users and mainstream users who follow the regime (Mcmeekin & Southerton, 2012), but not yet much is known of what characterizes users in between. Furthermore, the contributions of users to the initial emergence of innovations is widely recognized, but it is still debated as to what extent users actively participate in the upscaling of innovation. In this thesis, I intend to contribute to these debates by studies on car-sharing and electric vehicle users and by exploring some conceptual and methodological additions to the transitions field. The first two questions of this thesis are as follows:

1. **How can users in the upscaling phase of sustainability transitions be characterized?**
2. **How do users actively contribute to processes of upscaling?**

Chapters Two and Three focus on characterizations of users during upscaling. Chapter Two presents the results of a survey that investigated motivations and socio-demographic characteristics of people who state that they are willing to participate in various forms of the sharing economy. Building on socio-psychological studies concerned with sharing economy adoption (Hamari et al, 2015; Tussyadiah, 2016), but now in a sustainability framework, the chapter analyzes the role of environmental, economic, and social motivations. Accordingly, the influence of multiple motivations in car-sharing adoption could be observed. The importance attached to each of these motivations also differs per social group. Peer-to-peer car-sharing adoption mainly results from a combination of environmental and economic motivations. Motivations vary per social group, as illustrated by findings that lower-income people are more economically motivated, older people more socially driven, and women more environmentally motivated to join the sharing economy.

The geographical heterogeneity in socio-demographic characteristics of the user base is shown in Chapter Three. I also investigate how this variety relates to the upscaling of two forms of car-sharing: business-to-consumer (b2c) car-sharing, in which users rent a locally available car from a car-sharing organization, and peer-to-peer (p2p) car-sharing, in which users rent a car from an individual car owner via a digital platform. Extending recent elaborations of the geography of transitions and the regime concept (Späth & Rohracher, 2012; Fünfschilling & Truffer, 2014), this chapter argues for a spatially heterogeneous conception of the niche, regime and landscape levels of the multilevel perspective. This allows for the inclusion of a geographically heterogeneous user base in the transition analysis, as part of the landscape level. In a statistical analysis, socio-demographic characteristics of the user base are linked to adoption of the two forms of car-sharing. The results demonstrate that the spatial distribution of one innovation variant, business-to-consumer car-sharing, remains limited to geographical niches. Its geographical reach is influenced by the current socio-technical regime of car ownership and characteristics of the user base, such as levels of environmental awareness and education. Peer-to-peer car-sharing, in contrast, emerges in many places irrespective of the characteristics of the user base. Still, specific user characteristics such as environmental awareness relate to higher numbers of peer-to-peer shared cars in a neighbourhood.

Chapter Four presents an internet ethnography of a user community related to the electric vehicle (EV), mainly consisting of Tesla owners. Given the advent of new social media, a considerable part of interactions between users now takes place in the online domain. In terms of user characterization, albeit not socio-demographically heterogeneous, the observed user community is diverse on two axes. First, in terms of "professionality" participants range from people who are only EV users, to "hybrid" users who are EV owners but for example also have a side business selling charging points, to professional actors. Second, there is a large diversity among the users in terms of the knowledge levels regarding EV. In spite of this diversity, a relatively strong sense of community is present. The contribution of forum participants to the upscaling of the EV is assessed, extending recent work that has described involvement of internet communities of geographically dispersed users in innovation (Grabher et al., 2008; Grabher & Ibert, 2013), and specifically upscaling in transitions (Hyysalo el al., 2018). Hereto the study draws on recent transition literature to identify different dimensions of upscaling: system-building, geographical circulation, and reconfiguration of the existing socio-technical regime. I find that the community plays an important and distinctive role in fostering electric vehicle use across these dimensions. Notably, beyond simple knowledge sharing, users contribute to the development of infrastructure and institutions. With regard to geographical circulation, the virtual community facilitates trans-local interactions between users in a variety of geographical contexts, exemplified in actions to increase international standardization of chargers. Members also empower each other to challenge the existing socio-technical regime of fossil fuel cars and perform some regime-adapting activities, for example by establishing and protecting parking places with EV chargers. The virtual community equally acts in an unorganized and ad-hoc manner, in a pattern of "bricolage" and the solutions it proposes are mainly workarounds. Still, by the uncertainty it reduces, the driving practices it tries out and explains, and the empowerment it brings to users, it makes a clear contribution to upscaling.

Chapter Five considers the electric vehicle internet forum as well. In terms of user characterization it reveals how the forum members have different socio-psychological characteristics and motivations to buy an electric vehicle. In that sense, the internet forum is a coming-together of fairly different user groups. There are former "petrol head" car enthusiasts, technology enthusiasts and people who are buying the EV because of environmental concerns. Together they address upscaling barriers the EV encounters in transitions. The chapter contributes in the search for useful new conceptualizations of upscaling in transitions, able to describe the role of users among other actors (STRN, 2017, p. 32; Geels & Johnson, 2018). It explores an assemblage perspective, which invites to understand socio-technical systems or regimes differently as at most temporary stabilizations, without clear boundaries. I describe how users have a relative freedom to join the electric vehicle assemblage and take up new roles there. The user internet forum emerges as a complex constellation of social and material elements. The forum is vibrant, lively and stimulates the creativity of its parts. As an illustration of actions emerging on the forum, users together go on long road-trips throughout Europe to demonstrate the feasibility of the EV alternative and have fun. The forum never becomes a coherent whole, there are always (productive) frictions, constituent elements whose actions and goals are going in directions that are not shared by other elements, and parts that embark on other initiatives that may form other novel assemblages. The discovery of the electric vehicle as a sustainable alternative stimulates the forum users to search for alternatives in other contexts as well.

As a bridge to the next section, let me summarize main findings. The thesis shows that online interactions have empowered users to play active roles in sustainability transitions beyond initial niche experiments. It demonstrates how on a lively internet forum different users in relation with various social and material elements engage in multiple upscaling processes: system-building, geographical circulation and reconfiguration of the socio-technical regime. The variety in the user-base during upscaling in terms of socio-demographic and socio-psychological factors as well as geography is pointed out. Environmental concern is still driving the adoption and use of innovations during upscaling, but among motivations such as costs and performance, for which the expectations are influenced by the technology of the current socio-technical regime.

3. **What implications can be drawn for a more user-centered perspective on upscaling in the sustainability transitions field?**

My engagement with the sustainability transitions literature (Markard et al., 2012; Geels et al., 2017) throughout this thesis can be summarized as: taking a step back (by drawing on the innovation adoption literature), further refinements (by elaborating geographical and upscaling dimensions), going beyond (by taking an assemblage perspective). Historically only limited attention has been paid to users in the transition field, and progress on this issue so far is indicated as "mixed" in the research agenda of the network of transition scholars (McMeekin & Southerton, 2012; STRN, 2017, p. 29). It therefore made sense to start this thesis by looking outside the field and draw on insights of "innovation adoption studies". Initiated decades ago by Rogers (2010), research in this field has extensively linked socio-demographic and socio-psychological factors to innovation adoption, with increasing attention being directed towards sustainable innovations. These studies are useful in providing more refined characterizations of users in up-scaling. The choice to experiment with an assemblage perspective to model users in upscaling in the final part of the thesis, was mainly made to circumvent some of the limitations of the concept of socio-technical regime. This notion is highly useful in explaining relative inertia in socio-technical systems. However, it cannot account for the variety among users (McMeekin & Southerton, 2012). Also, as discussed by Pesch (2015), particularly during upscaling, it becomes problematic that actors, such as users, are seen as only being part of a regime. With this an important part of their agency is obscured, since they are in reality part of many societal and institutional realms, each more or less stable, and are motivated by a variety of influences. Their inclusion in multiple social structures can provide them with opportunities to deviate from the regime and become involved in sustainable innovation. Indeed, in the assemblage perspective in chapter Five, I conceptualize users as part of many social configurations, which are inherently unstable.

Let me assess the overall contribution of this thesis to the field of sustainability transitions. What can and should we do such that the next research agenda of transition researchers will state that the progress regarding users has been "considerable"? This would require at least a more user-centered approach to upscaling. Throughout my thesis run three lines, which could be used as initial building blocks for such an approach.

The first of these is a conceptualization of users as diverse and able to actively contribute to upscaling. Overall the thesis has shown that in terms of user variety it at least makes sense to consider 1) differences between socio-demographic and socio-psychological groups, 2) differences between users in various locations, and 3) combinations of motivations of users. Most notably in Chapter Three on geographical heterogeneity in transitions, I demonstrate how such variety could be accommodated within existing transition frameworks. It should be noted that in spite of the observed variety, also in upscaling environmental awareness is still among the factors driving adoption (see Geels & Johnson, 2018). Yet it often occurs in tandem with motivations such as costs and performance, for which expectations of users are influenced by the existing regime technologies. The thesis has additionally demonstrated that users can contribute actively to innovation beyond initial niche developments. Extending the findings of Hyysaloo et al. (2018), who focus on knowledge development of user internet communities, the analysis in Chapter Four has shown that users in these communities also contribute to the development of institutions and infrastructures. In the framing of Randelli & Rochi (2018), it provides further evidence that users can contribute to all system functions as specified in the TIS framework. This does obviously not imply that all users during upscaling will be highly active contributors to innovation. However, the observation that the innovation-fostering online communities attract a large audience and involve a large diversity of both inexperienced and highly active users make that these new forms of connections between users are an important factor in influencing upscaling.

The second line consists of a further refinement of the concept of socio-technical regime. When dealing with users, the regime concept is certainly valuable, but also does not really specify the heterogeneity and changes that arise in use patterns. I was therefore fortunate to able to draw on some recent further specifications of the regime concept (Fünfschilling & Truffer, 2014; van Welie et al, 2017). These allowed me to follow a line of gradual deconstruction (albeit in a constructive way) of the regime concept throughout the thesis. Chapter Two illustrates how users can be classified in different social groups, which are each driven by a different combination of motivations. Still it seems that innovations that appeal to motivations related to the existing socio-technical regime scale up fastest. Chapter Three adds the geographical heterogeneity of the regime. This geographical heterogeneity at least partly results from a user base that is socially diverse, and unevenly distributed geographically. Chapter Four shows that even the mundane actor group of users, at least when organized in a community, is able to engage in reconfiguration of the regime. Chapter Five then finally sees users as parts of multiple social entities, that are stabilized only to a certain extent, instead of being influenced by one socio-technical regime. By virtue of their connections with fellow users and a variety of other socio-material entities, users engage in the reconfiguration of powerful and established assemblages.

The third line is a methodological approach that is able to strike a balance between breadth and depth. Traditionally, transitions research draws on qualitative, narrative approaches. Data sources are often interviews or historical records. Methods such as interviews can result in very rich in-depth descriptions, but become increasingly unfeasible when the number of users increases during upscaling. Therefore I explored alternatives throughout this thesis. Chapter Two draws on stated preference data. This has the advantage that relatively large groups of users can be reached when an innovation of interest is still early in the upscaling process. Obviously this method has the drawback that it is unclear if the users actually start using the innovation. Chapter Three uses a geographical dataset to trace upscaling among users in an entire country. Here a breadth of cases is achieved that is going beyond conventional case studies in transition, which allows, for example, for mapping a socio-technical regime. The data is obviously less in-depth than that obtained from interviews or historical sources. On the other hand, increasingly detailed spatial datasets are available, and some more crossovers to transition studies are started to be made. For example, Feola & Nunez (2017) use a geospatial dataset and quantitative methods to compare the upscaling of grassroots initiatives in two countries. Finally, the internet forum analysis allowed for both breadth and depth as I could conduct in-depth analyses of user discussions, for a relatively large number of users who are dispersed across many geographical locations. Such internet ethnographies seem a particularly valuable method for studying upscaling in transitions, not only for analyzing an online community as research object as I did, but also for studying the development of wider societal discourses (cf. Paskevicius et al., 2018).

6.2 Reflection

The employment of multiple perspectives provides me with the opportunity to reflect on how the different perspectives shape the view on users in upscaling. The literature concerned with relating socio-demographic and socio-psychological characteristics of users to innovation adoption has received most critique from transitions scholars (Shove, 2010; McMeekin & Southerton, 2012). Most notably this holds the criticism that it can only provide a static account of users with a fixed set of preferences. I employ insights from this literature in Chapter Two, on social groups, and partly in Chapter Three, to construct a geographically heterogeneous regime and landscape. In support of the use of these socio-demographic and socio-psychological and variables, it should be noted that they are widely recognized indicators of user preference. Their inclusion in transition studies can facilitate dialogues with other fields as well as policy-makers. Moreover, their inclusion opens up a large number of (existing) quantitative datasets for transition analysists.

An associated criticism of the use of static socio-demographic and socio-psychological variables could be that I overemphasize the relation between preferences related to the regime, such as cost and performance, and the adoption of sustainable innovations. Indeed, I do not take into account in these studies that such preferences of users might change over time. On the other hand, I still find an influence of environmental motivations in adoption during upscaling. This can be seen as a reflection of a broader societal trend of concern about environmental sustainability. A limitation to "innovation adoption" studies compared to transitions studies is that they are not able to explain upscaling as arising from interactions between actors. On the one hand, such limitations are inherent to the dominant psychological perspective (and to some extent to the use of quantitative methods). On the other hand, the conducted analyses here are still fairly basic. For example, it would be worthwhile to track the environmental identity of participants in user communities over time, taking into account social influences, and investigate influences on upscaling (see Bögel & Upham, 2018).

The case study of the electric vehicle internet forum can be used to compare the common socio-technical systems approach to sustainability transitions (Chapter Four) and the assemblage perspective (Chapter Five). A detailed comparison of the two perspectives is given in chapter Five, here I highlight some main differences. First, the assemblage perspective focuses on the process of assembling. It stresses that "system" elements are only partly determined by a "system" of which they are part and explores how these elements are in relation with many others. "Systems" are always subject to frictions and reconfigurations, and labour is required to hold the system together. In contrast, in a socio-technical perspective the focus is often on delineated systems, in which internal synergies lead to the development of system-specific resources, and the system becomes increasingly structured over time, notably with the development of a socio-technical regime.[23]

A comparison between the case studies in Chapters Four and Five illustrates some of these differences. For example, the systemic perspective stresses synergetic processes of knowledge, infrastructure and institution-building on the forum. The assemblage perspective is more attuned to frictions, between one EVangelist user and the rest, between petrol-heads and environmentalists, and does not see these as negative, but stresses their productive character. As another difference, the socio-technical transition perspective is more skeptical regarding the possibility of changes to the existing socio-technical regime. It recognizes that users can make changes but also argues that much user activity is also geared towards making the innovation "fit and conform" to the existing regime (Smith & Raven, 2012). On the other hand, the assemblage perspective stresses the provisionality of existing assemblages and the possibility for users to change them from within as long as they connect with other assemblages. Both Sovacool & Geels (2016) and Haarstad & Wanvik (2017) here argue that there is also a normative case to make for applying a more change-oriented perspective (such as assemblage thinking). Notions such as "regime" that we use as researchers are not neutral, but inherently political. They risk (unintentionally) consolidating the narratives of actors such as the oil industry, which stress the endurance of our reliance on fossil fuels, also for the decades to come.

Overall, the employed perspectives are largely complementary. They add up to what Geels & Johnson (2018) call a "modular approach" to upscaling in transitions. Each of the perspectives highlights elements that the other leaves out, or addresses more sparsely. The multidisciplinary

[23] These are stylized differences, there are also studies taking an approach more in between, see chapter Five.

approach employed made sense given the variety of complex dynamics characterizing upscaling. I have also not integrated theories into some metatheory of users in upscaling, but rather explored crossovers between the different perspectives and the broad field of sustainability transitions. In some instances overlap between the theories resulted in theoretical triangulation, in which similar findings were obtained in multiple theoretical perspectives. An example are the combinations of motivations driving innovation adoption during upscaling that emerged in the socio-psychological analysis of Chapter Two, and were also observed in the assemblage analysis of electric vehicle users in Chapter Five.

Although they have clearly grown beyond initial niche developments, the innovations of car-sharing and electric vehicles are also still relatively early in the upscaling phase. I defined upscaling in this thesis as the expansion of the innovation and its associated socio-technical system beyond initial niche experimenting. It is currently unclear if the innovations studied here will develop into dominant technologies, and do so in the form they are in now. In general, further research is needed to see if the findings and concepts developed in this thesis also hold for later stages of upscaling. I used the term upscaling phase to indicate a period in the transition that is dominated by different processes than the phase of initial niche experimentation. However, there will always be overlap between processes associated with various phases and a transition should not be seen as a linear process occurring in clearly delineated phases. Most prominently, such is visible in the chapter analyzing electric vehicle diffusion with an assemblage perspective. Here continuous changes throughout transition phases are emphasized, and it is shown that upscaling can also halt or even be reversed.

The two case studies considered, car-sharing and electric vehicles, are both part of the transport sector. It is worthwhile considering to what extent the findings carry over to other sectors relevant for sustainability transitions, such as energy and food. The socio-technical regime in transport centers around fossil-fuel powered, personally owned cars. A difference between transport and other sectors is the existence of various *subaltern regimes,* such as train and bus (Geels, 2012). These are not as dominant as the car regime, but they are relatively stable and have been around for decades. Chapter Two discusses the heterogeneity of the car regime. It can be argued that the existence of subaltern regimes contributes to this heterogeneity, by providing users in certain locations with different transport options. As can be observed from the dominance of the personal car regime in many places, however, it does not seem to be the case that users are in general less attached to the regime in the transport sector compared to other sectors such as energy. When it comes to the active contributions of users, these are also widely documented for sectors such as energy (Dewald & Truffer, 2011; 2012) or food (Randelli & Rochi, 2017). When looking more specifically at virtual user communities in the upscaling phase of transitions, this work can currently only be compared to the study by

Hyysalo et al. (2018) on heat pumps. I find much user activity on physical infrastructure. This could be attributed to the fact that the case studied is part of the transport sector, in which infrastructure is obviously important. On the other hand, user contributions to infrastructure have also been observed in very different settings (see Egyedi and Mehos (2012) for a wealth of examples). Given the number and variety in online communities dealing with sustainable innovations currently scaling up, studies into this phenomenon from other sectors are very welcome.

Finally, the geographical focus of my study was on the Netherlands. There are characteristics of The Netherlands that likely foster user engagement with sustainable innovation in transitions. The Netherlands are a rich welfare state. A large part of the population has a certain income level that allows them to engage with sustainable innovation. Considering active contributions to innovation, hours worked per week are low as compared to other European countries (CBS, 2017), which might provide people with more time to pursue innovation-related activities. The Netherlands also has a rich tradition of "polderen", in which a variety of actors solves problems based on consensus, which could also stimulate user interactions with other actors in transitions. Finally, there is a highly developed internet infrastructure. These characteristics do not imply that the contributions of this study do not hold for other countries. Particularly, for Western European countries differences with The Netherlands on the aforementioned socio-spatial context factors are a matter of degree, and not fundamental. However, it is important to keep these issues in mind when transferring the findings of this study to other countries, particularly outside European welfare states. Fortunately, there is now a large community of scholars exploring differences in transition dynamics in a variety of contexts around the globe (STRN, 2017).

6.3 Two roads ahead

Throughout the chapters of this thesis, multiple specific suggestions for further research are provided (see Sections 2.5, 3.6, 4.5, 5.5). Here I will lay out two broad avenues for further research.

6.3.1 Acceleration of transitions because of online user interactions

The first concerns the extent to which online interactions between users accelerate transitions. The studies of the EV internet forum have shown how online interactions facilitate the increased leverage of user resources in a community of geographically dispersed and heterogeneous users. Additionally, as noted by Hyysalo et al. (2018), the internet forum can help render sustainable technology neutral and more acceptable for a larger group of users. I found that an internet forum can foster sustainability discourses and the adoption of other sustainable innovations. Clearly, the internet forum has empowered users as compared to traditional off-line local communities. Moreover, during my research I encountered various other online or mixed online/off-line communities empowering users, such as (local) Whatsapp groups and Facebook groups. These groups certainly deserve more attention. A telling example of their usefulness is a local Whatsapp group in which EV users coordinate the use of scarce local EV charging spots. Given all these empowerments, I would like to posit the hypothesis that the rise of online interactions between users considerably accelerates transitions.

At least two steps need to be taken to further test this hypothesis. The first is an engagement with the broader literature on digital technologies and social transformations (Christensen, 2011; Dumitricia & Wyatt, 2015). The presumed "Twitter and Facebook Revolutions" in Moldovia, Egypt and Tunesia have engendered considerable debate. *Techno-utopianists*, *techno-dystopianists,* and people in-between have discussed multiple aspects of the rise in online activism. A central question here is whose agendas are ultimately advanced by the rise of digital technologies. Translating some of the addressed issues to the topic of sustainability transitions results in questions to critically scrutinize my hypothesis: what specific notions of sustainability do online users have in mind and where do these come from? To what extent do online users perform actions that other actors such as governments used to do (or should do)? Is the "enemy", for example climate skeptics, equally empowered by online interaction? A second step in testing the hypothesis would then link back these insights to the specific debate regarding the acceleration of sustainability transitions. These transitions are more than other change processes characterized by the involvement of new technologies and often also infrastructure. A robust debate is unfolding regarding the possibility of acceleration, and how it should be measured. In this debate the user figures overwhelmingly as passive consumer and even barrier (Sovacool, 2016; Grubler et al., 2016; Sovacool & Geels, 2016). So a further exploration of an empowered online user base in acceleration would be a worthwhile addition here.

6.3.2 Users in a decentralized economy

Most notably the sharing economy, but also the electric vehicle, are linked to a general decentralization of power structures across society and economy (Koirala, 2016; Martin, 2016). Here the common environmental notion of sustainability transitions as also used in this thesis is increasingly complemented by a conception of transitions that also foregrounds wider issues of social justice and equality. Such discourses have been strongest for the sharing economy. The rise of this phenomenon would empower users to become increasingly independent from governments and large companies, by sharing all kinds of assets, from cars to meals to pets in cooperative communities (Botsman & Rogers, 2011; Agyeman et al., 2013). Such overly positive visions have not (yet) materialized. Instead they have led profit-oriented companies to "sharewash"[24] their activities, to subsequent interventions of academics to the define the sharing economy more properly (Meelen & Frenken, 2015), and to an eventual general backlash against the sharing economy as a "neoliberal nightmare" (Martin, 2016).

Still, there are various relevant questions to be asked. Most notably now that some forms of the sharing economy, such as car-sharing, have started to scale up. There is convincing evidence that car-sharing contributes to sustainability in an environmental sense, but does it also really have positive social effects on users? In chapter Three, we saw the spatially uneven diffusion patterns of car-sharing, reflecting a heterogeneous user base. Although differences in availability are less pronounced for the peer-to-peer car-sharing variant, we can ask ourselves the question: to what extent does an economic model in which users increasingly rely on fellow users reinforce inequalities between social groups? One can imagine, for example, that there is more to share in richer neighbourhoods. Some social groups, such as the elderly, are on average also less proficient in the use of digital platforms, possibly restricting their access to shared resources. Similar questions regarding social consequences can be asked for the electric vehicle, where user communities are empowered by going off-grid, and save the energy collected with solar panels on their homes in an EV (Van der Kam et al, 2018). Such solutions can reinforce social inequalities between neighbourhoods in which people have the wealth to invest in these innovations and subsequently benefit from cheap and environmentally sustainable energy. The combination of EV and solar panels is indeed heavily propagated on the internet forum I studied. So, even the discourses propagated by EVangelists do not always lead to salvation.

[24] Claiming that a service offered consists of sharing, while it does not. Most often this concerns rental services.

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Appendix A

	Shared cars (p2p)	Shared cars (b2c)	Motorization	Population density	Distance to facilities
Shared cars (p2p)	1				
Shared cars (b2c)	0.679	1			
Motorization	-0.497	-0.386	1		
Population density	0.527	0.451	-0.721	1	
Distance to facilities	-0.373	-0.214	0.576	-0.589	1
Environmental awareness	0.457	0.374	-0.178	0.210	-0.220
Household size	-0.380	-0.336	0.493	-0.4916	0.468
Income	-0.058	-0.057	0.455	-0.349	0.246
Highly educated	0.533	0.448	-0.217	0.295	-0.306
Age 25-45	0.481	0.396	-0.627	0.620	-0.413
Western Immigrants	0.334	0.346	-0.332	0.429	-0.408
Municipal policy(p2p)	0.451	0.366	-0.468	0.453	-0.334
Municipal policy(b2c)	0.434	0.323	-0.511	0.529	-0.423
University city	0.438	0.414	-0.500	0.445	-0.308
Population	0.512	0.306	-0.488	0.443	-0.502

	Env. awareness	Household size	Income	Highly educated	Age 25-45
Shared cars(p2p)					
Shared cars(b2c)					
Motorization					
Population density					
Distance to facilities					
Environmental awareness	1				
Household size	-0.412	1			
Income	0.231	0.527	1		
Highly educated	0.763	-0.384	0.383	1	
Age 25-45	0.013	-0.3611	-0.407	0.206	1
Western Immigrants	0.268	-0.588	-0.149	0.413	0.316
Municipal policy(p2p)	0.317	-0.391	-0.159	0.390	0.418
Municipal policy(b2c)	0.307	-0.419	-0.161	0.390	0.454
University city	0.271	-0.440	-0.213	0.386	0.420
Population	0.054	-0.256	-0.186	0.149	0.342

	Immigrant from Western countries	Municipal car-sharing policy (p2p)	Municipal car-sharing policy (b2c)	Uni. city	Population
Shared cars(p2p)					
Shared cars(b2c)					
Motorization					
Population density					
Distance to facilities					
Environmental awareness					
Household size					
Income					
Highly educated					
Age 25-45					
Western Immigrants	1				
Municipal policy(p2p)	0.366	1			
Municipal policy(b2c)	0.387	0.772	1		
University city	0.338	0.472	0.542	1	
Population	0.272	0.255	0.332	0.278	1

Summary

The use of sustainable innovations, such as car-sharing and electric vehicles, has grown considerably is the past years. In the current narrative this growth is mostly seen as the result of the efforts of companies such as Tesla and Snappcar. The role of end-users in the growth of sustainable innovations has received considerably less attention. This thesis tells the story of the users of car-sharing and the electric car. The aim of the thesis is to obtain more insight in the characteristics of users as well as in their active role in the diffusion of innovations.

A large-scale questionnaire, held in Amsterdam, was used to gain insights in motivations for car-sharing. Environmental and financial motivations are important in driving car-sharing. Other forms of the sharing economy are driven by different sets of motivations. The sharing of houses is for example more financially motivated. From a user perspective, one can thus not speak of one sharing economy. This is something to take into account for policy-makers as well. Differences in motivations for sharing economy participation equally exist between socio-demographic groups. For example, people on lower incomes have higher financial motivations, older people have more social motivations and women are more environmentally driven.

Subsequently, the geographical diffusion of two forms of car-sharing in the Netherlands was mapped. This concerned business-to-consumer car-sharing, in which a company owns cars that are located dispersedly over neighbourhoods, and peer-to-peer car-sharing, in which users rent out their own cars via an online platform. The diffusion was linked to socio-demographic and built environment characteristics of neighbourhoods. Business-to-consumer car-sharing is limited to urban areas, with specific groups of users. Peer-to-peer car-sharing appears in all kinds of neighbourhoods. One explanation is its complementarity to the existing mobility system: the underutilized capacity of cars that are already there is put to use.

The active role of users in the diffusion of innovation is studied by means of an analysis of an internet forum of mainly Tesla users. I considered their contribution to different dimensions of upscaling: the built-up of an innovation system, the geographical diffusion of the electric vehicle, and the removal of institutional barriers to growth. The users deliver a unique contribution to each of these dimensions. They share knowledge and practical solutions for the daily use of electric vehicles. They lobby for charging points, and even mingled in international discussions about standardization. The users try to establish a more positive view of electric vehicles in the media and aim to prevent gasoline cars from parking at their charging places. In spite of these contributions, the forum is relatively chaotic and subjective. This makes it hard for policy-makers to utilize the knowledge developed on the forum.

Finally, the role of users in the growth of electric vehicles is considered from an assemblage perspective. This approach goes back to the philosophies of Deleuze and Delanda and describes a world that is constantly changing. The Tesla internet forum is a combination of very different users: environmentalists, car hobbyists and gadget freaks. Exactly the temporary alliances between those different groups contribute to the further diffusion of the electric vehicle.

All in all, the thesis describes the users of sustainable innovations as a heterogenous group with different motivations, that provides an active contribution to the transition towards a more sustainable society.

Samenvatting

De afgelopen jaren groeit het gebruik van duurzame innovaties, zoals autodelen en de elektrische auto. In het huidige discours wordt deze groei vooral gezien als het resultaat van de inspanningen van bedrijven als Tesla en Snappcar. De rol van eindgebruikers in de groei van deze innovaties blijft echter sterk onderbelicht. Deze thesis vertelt het verhaal van de gebruikers van autodelen en de elektrische auto. Het doel van het onderzoek is komen tot meer inzichten in kenmerken van gebruikers en hun actieve rol in de verspreiding van innovaties.

Een grootschalige enquête gehouden in Amsterdam is gebruikt om inzicht te krijgen in motivaties voor autodelen. Milieu- en financiële motivaties zijn belangrijke drijvers van autodelen. Andere vormen van de deeleconomie worden gedreven door andere combinaties van motivaties. Het delen van huizen is bijvoorbeeld meer financieel gemotiveerd. Vanuit gebruikersperspectief kan er dus niet gesproken worden over één deeleconomie, iets waar ook beleidsmakers rekening mee moeten houden. Er zijn eveneens verschillen in motivatie voor participatie in de deeleconomie tussen socio-demografische groepen. Zo hebben mensen met lage inkomens een hogere financiële motivatie, ouderen meer sociale motivaties en zijn vrouwen meer milieugedreven.

De verspreiding van twee vormen van autodelen over Nederland is vervolgens in kaart gebracht. Het gaat hierbij om business-to-consumer autodelen, waarbij een bedrijf auto's bezit die verspreid staan over verschillende wijken, en peer-to-peer autodelen, waarbij gebruikers hun eigen auto's verhuren via een online platform. De diffusie is gelinkt aan socio-demografische en omgevingskenmerken van wijken. Business-to-consumer autodelen blijft beperkt tot stedelijke wijken, met specifieke gebruikersgroepen. Peer-to-peer autodelen verschijnt in alle soorten wijken. Een verklaring is het voortbouwen op het huidige mobiliteitssysteem: men benut de ongebruikte capaciteit van de auto's die er al zijn.

De actieve rol van gebruikers in de verspreiding van innovaties is bekeken door middel van een analyse van een internetforum van voornamelijk Teslagebruikers. Ik bekeek hun bijdrage aan verschillende dimensies van opschalen: het opbouwen van een innovatiesysteem, de geografische verspreiding van de elektrische auto en het wegnemen van institutionele belemmeringen voor groei. De gebruikers leveren een unieke bijdrage aan ieder van deze dimensies. Ze delen volop kennis en praktische oplossingen voor het dagelijks gebruik van elektrische auto's. Ze lobbyen voor laadpunten, en mengden zich zelfs in internationale standaardiseringdiscussies. De gebruikers pogen een positiever beeld neer te zetten van de elektrische auto in de media en proberen te voorkomen dat benzine-auto's op hun laadplekken staan. Ondanks deze bijdragen blijft het internetforum vrij chaotisch en subjectief. Dit maakt het voor beleidsmakers lastig om de op het forum ontwikkelde kennis te benutten.

Tot slot is de rol van gebruikers in de groei van elektrische auto bekeken vanuit een assemblageperspectief. Deze invalshoek gaat terug op de filosofieën van Deleuze en Delanda en schetst een wereld in constante verandering. Het Tesla internetforum is een combinatie van zeer verschillende gebruikers: milieu-idealisten, autoliefhebbers en gadgetfreaks. Juist de tijdelijke verbanden tussen die verschillende groepen zorgen voor verdere verspreiding van de elektrische auto.

Al met al beschrijft de thesis de gebruikers van duurzame innovaties als een heterogene groep met verschillende motivaties, die een actieve bijdrage levert aan de transitie naar een meer duurzame samenleving.

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Toon Meelen

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Curriculum Vitae

Toon Meelen completed a bachelor and master in *Science and Innovation Management* (both cum laude) at the University of Utrecht, The Netherlands. In between he did an exchange in Geography at Sorbonne University in Paris. He also worked for electric vehicle start-up The New Motion. During his PhD, Toon has visited the Transport Studies Unit of the University of Oxford for three months. Toon is currently a research associate (postdoc) at the University of Oxford on the Vehicle-to-Grid Oxford (V2GO) project. In this trial project with electric vans, he looks at the viability of implementing vehicle-to-grid in electric vehicle fleets.

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