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

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Abstract

This paper develops a new conceptualization of the diffusion of innovation in transitions. Current transitions literature tends to emphasize the rigidity of socio-technical systems and regimes. We therefore draw on "assemblage thinking", particularly as it has been developed in human geography, to develop insights in diffusion during transitions. This perspective draws our attention to the instabilities and agency potential in the world. It helps conceptualize the political and geographical dimensions of transitions. We illustrate our perspective with a case study in the field of automobility, often characterized as a highly stable field, but currently changing with the ascent 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, the users of electric vehicles.

1. Introduction

Sustainability transitions are large-scale, systemic transformations that address grand societal challenges. They involve technical and social innovations, such as solar panels or car-sharing. Increasingly, these innovations are diffusing in a variety of geographical contexts around the globe. The diffusion process in transitions is much more complex than that of discrete products (Geels et al. 2018, Lyytinen & Damgaard, 2000). It also consists of changes in user behaviours, infrastructures and institutions. It does not conform well to traditional innovation diffusion models. Diffusion in transitions tends to be slow and show high geographical variation. Given the urgency attributed to societal challenges such as climate change, the temporal pace and geographical reach of diffusion in transitions have become a new topic of debate (Geels & Johnson, 2018; Sovacool & Geels, 2016). This raises the questions as to how geographical processes of diffusion in transition processes occur and what the role of specific actor groups is herein.

In literature on sustainability transitions, attention is shifting from emergence towards diffusion of innovations (Geels et al. 2018; Geels & Johnson, 2018, Loorbach et al., 2017). Rooted in innovation studies and environmental governance, the sustainability transition perspective is concerned with radical changes in complex systems fulfilling a societal function, such as energy or mobility. Importantly, in these sectors regimes exist, dominant configurations creating path-dependency and lock-in. Regimes emerge out of the co-evolution of socio-technical elements over time, and consist for example of vested interests of companies, but also of routines on the side of users. Think of how the coal regime is stabilized by powerful corporate actors, but also by our daily thirst for cheap energy.

Sustainable innovations rely on outside pressures to break out of their niches into the regime, and spur a transition i.e. a shift from one dynamic equilibrium to another. In the burgeoning transitions field, elements of this main model have been refined in ever more detail: mechanisms of niche protection (Smith and Raven, 2012), power play by regime actors (Smink et al. 2015; Geels et al. 2014) and growth mechanisms of the innovation (Bergek et al, 2015; Dewald & Truffer, 2011),with the emphasis gradually shifting to later stages of niche growth. Driven by observations of actually diffusing innovations, recent studies describe an "acceleration phase" in transitions and identify diffusion mechanisms (Geels & Johnson, 2018), as well as the role of certain actors in acceleration (Hyssalo et al. 2018).

Foremostly, from a transition perspective, we should see diffusion as a dual process, that entails both a certain degree of deconstruction of the existing regime, as well as the built-up of a socio-technical system around the innovation (Geels et al. 2018; Geels et al, 2017). To grasp the complexity of diffusion in transitions Geels & Johnson (2018) propose using multiple existing diffusion models, that vary in importance depending on the diffusion stage. Naber et al. (2017) develop a typology of different patterns with which sustainable innovations scale up. They remind us that diffusion is not limited to simply growing a sustainable experiment, but can also entail replication in different places, or preparing the ground for institutional change. Hyysalo et al. (2018) show that diffusion in transitions also involves changes to the innovation during diffusion. In their study, these adaptations are made by a group of users connected via an internet forum. Aforementioned studies still relatively heavily draw on existing transition frameworks and apply them to the diffusion phase. This enables them to build on a wealth of identified mechanisms and other insights obtained during the emergence phase of transitions. It also presents some challenges. There is already debate about the extent to which transition studies are more inclined to explain stability than the politics of change (Gillard et al. 2016; Fünfschilling & Truffer, 2016;Geels et al. 2011). Such debates will become more prominent in the diffusion phase, in which large-scale changes are occurring (Geels et al. 2018). Then there is the debate concerning the geography of transitions, which has led to valuable insights in how place-specificity matters for transitions. It has also been shown how relations across scales could influence innovation development, though the geographical dimension is often added only as an extra layer to existing transition models (Hansen & Coenen, 2015). We therefore think that there is also room for new conceptualizations of diffusion in transitions.

We draw on recent developments in the field of human geography, specifically assemblage thinking, to conceptualize innovation diffusion. Within geography, there is a long history of thinking about innovation diffusion. Hägerstrand (1968) and other scholars of the quantitative revolution started modeling innovation diffusion as a spatial process, with agents more likely to adopt after other proximate agents adopted as well (van der Horst, 2011). Influenced by Actor Network Theory (ANT) (Latour, 1990), which emerged from studying innovation development and diffusion, geography took a "relational turn" in the 90s. The implications of a relational perspective on innovation diffusion are currently best illustrated in the field of policy mobilities (Peck, 2011; McCann, 2011). 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 (Affolderbach & Schulz, 2016; Sengers & Raven, 2015). As another relational perspective, assemblage thinking is applied to analyze complex, changing constellations of social and material elements, such as cities (Dovey, 2012; Mcfarlane, 2011) or social movements (Mcfarlane, 2009). Assemblage thinking is rooted in the work of Deleuze & Guatuari (1987), has been adapted and transformed into a more coherent framework by Delanda (2016; 2006), and is applied in different variations across geography (Anderson et al. 2012). Although not yet specifically for diffusion, it has also been connected to transition studies. Haarstad & Wanvik (2016) take 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 a transition perspective, with its focus on regimes, would have it.

In this paper we elaborate on the contributions assemblage thinking can make to understand diffusion in transitions. Assemblage thinking points out the transformative potential in the world (Gillard et al, 2016; Dewsbury, 2011). It invites us to understand existing socio-technical systems or regimes differently. Instead of stable systems, assemblages are temporary stabilizations, that are reconfiguring as a result of their part's relations with other assemblages. Parts have a relative freedom to leave their assemblages and join others. Distinct political processes drive change in more established structures. As the core of our framework, we see diffusion as the process by which an increasing number of assemblage parts shifts from an established assemblage to a new one. What do we hope to see clearer by adopting an assemblage perspective? First, assemblage thinking points out instabilities and emphasizes a latent agency to change, which is also present in more mundane actors. Accordingly, it is instructive in analyzing change patterns in diffusion. These foci do 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, particularly in a world in which the innovations in transitions are actually diffusing. Second, assemblage thinking enables us to see diffusion as a political process. Third, an assemblage perspective can address the geographical dimension of transitions, without ending up in binary thinking about the influence of local or global factors in diffusion. It allows us to adopt a geographical perspective that focuses on the connections between the local and global and how these are produced (Mcfarlane, 2009).

To illustrate our assemblage perspective we provide a case study in the field of automobility, often characterized as a highly stable field, but currently changing with the ascent 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, the users of electric vehicles. We have studied an online community of electric vehicle users and analyzed mainly its Dutch part, using a method that has been coined "netnography" (Kozinets, 2002).

This paper is structured as follows. Section 2 provides background for the case study and methods. Section 3 presents an assemblage perspective on diffusion in transitions. In section 4 the illustrative framework is presented. Section 5 discusses and concludes.

2 Case background and methodology

Our assemblage perspective on diffusion in transitions will be illustrated with a case study of the Dutch part of an online community of Electric Vehicle (EV) users. The transition central in this study is that from fossil fuel cars to electric vehicles. It fits our criteria of a large-scale transformation, involving changes in user practices, markets, infrastructures and institutions. It has also been analyzed 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 has started to leave the emerging phase, and at least in certain countries is experiencing accelerated adoption (IEA, 2016). The assemblage central in our study is an online community of electric vehicle users. 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 community has fuzzy boundaries and is active on other platforms as well, both online and off-line. In our assemblage perspective, we will follow relevant connections of the EV user community with this wider EV assemblage (as well as some other assemblages). As a geographical focus, we consider EV users from the Netherlands. Many issues in the diffusion of EV are related to socio-spatial factors at the national level, such as subsidies and charging point standards (Bakker et al, 2015; Sierzchula et al., 2014). Also much of the discussion on the internet forum we study takes place between users of the same nationality. It therefore makes sense to focus on a sub-community from a particular nation. The Netherlands is a frontrunner country in EV adoption. The Dutch community is also one of the most active on the internet forum we study. Consistent with our assemblage perspective, we will also follow the Dutch users in their interactions with users from different countries.

The empirical material for the illustrative case study is collected from a) a so-called netnography of the Dutch part of Tesla Motors Club internet forum, b) 13 interviews with users active in the online EV community c) scientific literature and reports about the development of EV in The Netherlands and beyond. In the internet etnography or netnography, 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 your EV abroad or EV insurance). These threads are sometimes short with only a view replies to the thread starter, but can also go on for years and consist of hundreds of pages. It should be noted that messages in the threads are annotated with date and location (mostly city-level) of the poster. This is very useful in investigating the role of the online community in the diffusion of EVs through space and time. 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 and threads (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 online community (see (Meelen et al., 2017) for a more elaborate description of the case and methodology). 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

online community users were held that lasted around one hour. Interview candidates were selected partly based on posts identified in the previous stage of the research. The sample was taken as to obtain a high diversity in forum members. In terms of experience (number of posts) in the online community, from "lurker" to people with thousands of posts, as well as in terms of role fulfilled in the community (e.g. a user that also sells charge points, a user that is a "critical" voice in the community, 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 to provide more context to the case, scientific studies, sector reports and other documents about EVs were consulted throughout the research process. It is important to note here that transition to EV in The Netherlands is very well documented. To give an illustration, among various EV newsletters, the semi-governmental Netherlands Enterprise Agency (Dutch: RVO), sends around a detailed report concerning the adoption of all different types of EVs and charging points every month, which irregularly also includes specialized reports e.g. on user charging behaviour.

3. Diffusion in transitions

3.1 A different world

Based on the work of Deleuze & Guatarri (1987), Delanda (2006) has developed a theory of assemblages to model complex entities such as social networks and cities. Largely following Haarstad & Warvik (2016), we do not argue for a total adoption of Delanda's framework by transition scholars, but we do think assemblage thinking can offer relevant insights for the study of diffusion. At the very basic assemblages are constellations of human and non-human elements (Müller & Schurr, 2016; Anderson et al. 2012; Anderson & McFarlane, 2011) and can in that sense be compared to socio-technical systems. However, there are also some aspects on which assemblage thinking deviates from current approaches to socio-technical systems. Assemblages are entities without essence. They are inherently instable and composed of heterogeneous elements that only form a symbiosis for some time (Haarstad & Warvik, 2016; Delanda, 2016). Assemblages are characterized by relations of exteriority (Delanda, 2016 p. 10). This means that parts of the assemblage have a certain autonomy, as they also have relations with other assemblages. Parts of an assemblage can also be detached and plugged into another assemblage where they have different relations. There is a difference between the properties and capacities of parts and assemblages. The capacities of assemblages are dependent on a part's properties, but also on its interaction with other entities. However stable they might appear, assemblages therefore have *emergent capacities* for change, as their parts are related to assemblages that are more susceptible to change. The current assemblage is only one actualization of its possible forms, the others remaining virtual as potentials that are not (yet) actualized (Dittmer, 2014).

Assemblages are engaged in continuous processes of territorialization and deterritorialization (Haarstad & Wanvik, 2016; Delanda, 2006 p. 12). Territorializing (stabilizing) processes sharpen the borders of the assemblage and increase its internal homogeneity, as deterritoralization (destabilizing) processes do the reverse. Some components of the same assemblage can be working to stabilize it, whereas others contribute to its destabilization. By drawing on different capacities, even one component can be both

territorializing and deterritorializing. Change in assemblage thinking occurs through the entry of new elements and the actualization of untapped capacities of parts and wholes. Change patterns are complex (Anderson et al. 2012; Bennett, 2005). Change can affect only one particular element, as well as different elements at different times (Delanda, 2006). Additionally, *assemblage converter*s are well placed elements that can either bring transformative change or enduring stability (Haarstad & Wanvik, 2016). Think for example of the Fukushima incident for nuclear energy.

The characteristics of assemblages also have implications for the politics driving change (Gillard, 2016; Purcell, 2013; van Wazemael, 2008). As the current assemblage is only one of its possible actualizations, politics is a creative process of exploring and experimenting with alternative configurations. Given the complex change patterns, this is an open-ended process and likely to fail. Importantly, given the relational character of assemblages, transformative change will only occur if connections are created between different actors that pursue change as well as between them and the status quo.

Finally, assemblage thinking can help us address the geography of socio-technical constellations. Geographical study of transitions risks ending up in debates about binaries such as the influence of local/global or network/territoriality on transitions. Assemblage thinking attempts to move beyond these dichotomies and provide different accounts of spatiality (Davies, 2012, Mcfarlane,2009). Mcfarlane (2009) introduces the concept of "translocal assemblage" and uses it to analyze a social movement. Translocal assemblages are composites of place-based movements that exchange ideas, practices and resources across sites. The sites in the translocal assemblage are not merely nodes as in the oft-used the network metaphor. Instead, their history is important and their capacity is not only tied to the rest of the assemblage. For example, Mcfarlane (2009) mentions that the local affiliation of a housing movement in Mumbai acts in a certain way to distinguish itself from more leftwing movements in the city. The influence of this relation of exteriority then also carries over to the rest of the social movement. As we will see, these relationships also work the other way around, as translocal assemblages affects cities or villages. Accordingly, the translocal assemblages are not only some resultant spatial category, but refer to doing and events. They require labour to be maintained, can be more or less stable over time, and also reassemble in a different form.

3.2 Diffusion patterns

Having described how we can use assemblage thinking to model socio-technical constellations, let us now continue to use it to conceptualize geographical diffusion processes in transitions more specifically.

3.2.1 Transversal politics

The perspective employed here questions the hegemony of powerful assemblages, by showing that they are contingent, that they do necessarily have to be this way, that there are certain ways out (Müller, 2015). One of these ways out, which have also been taken up in political theory, are transversal lines. These are lines for escaping the status quo that cut through established identities. In the process of diffusion, resistance might be expected from

powerful actors in highly territorialized assemblages. For diffusion to occur then new connections are to be formed in order to escape the status quo. This is a political project in the form of an open-ended and creative process (Gillard et al. 2016; Scott-Cato & Hillier , 2010). Drawing on Raunig's (2002) notion of "transversal multitudes" we describe a politics of transversal lines for diffusion in transitions to occur.

First, any new assemblage wanting to challenge an existing hegemonic assemblage has to be *transsectoral i.e.* it has to cut across social fields. A movement that is based solely in fanatic environmental circles will not make it. The transversal lines connect the aspirations in each of the fields and link their activities. This should however, not lead to a unified conforming apparatus that covers up contradictions. Instead, it is most effective as a *"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). Second, a *molecular* organization structure is needed. The question here is how the creativity of the masses can be unleashed in order to foster sustainable innovation, without resulting in (self)-destruction. The search for alternatives also carries a destructive element, with people losing themselves in fanaticism and new dogmas (Deleuze & Parnet, 1987, p. 138). New organization and communication mediums are needed flexible enough to host the temporary transversal linkages that cut across existing structures. The mediums should also be able to become more rigid, if circumstances demand it. Specifically, they should allow for acknowledging individual differences between assemblage parts, while also facilitating a sense of community. Third, *new modes of subjectivation* are needed. To escape the status quo a coming together is needed of a variety of knowledge and experiences residing in different individuals, lay people and experts. The assemblage here is not to be represented in existing structures, but should be able to speak for itself (cf. van Wezemael, 2008). Fourth, for diffusion in transition to occur any new assemblage that wants to challenge existing hegemonic assemblages has to be translocal, for transitions are not limited to one country or other geographical entity.

3.2.2. Parts changing assemblage

Having established political drivers for diffusion in transitions to occur, let us now delve deeper into the processes of diffusion. Assemblage parts have a certain autonomy, they can detach and become part of different assemblages. Accordingly, the main diffusion process in transitions are parts changing assemblage. When we observe an assemblage what we see is only a certain actualization of the assemblage part. There can be many others. Assemblage parts have unexercised capacities that can produce highly different outcomes if they are being connected to other assemblages (Haarstad & Wanvik, 2017; Delanda, 2006). Delanda (2016, p.73) gives the example of a knife. It can be a simple tool as it is part of the "kitchen assemblage". However, when it is part of the "army assemblage" it becomes a lethal weapon. As another example we could remove the cycle in a bicycle-body assemblage, place it in a gallery, and it becomes an art object, part of a bicycle-gallery assemblage (Colebrook, 2001). Coming towards the topic of transitions, Haarstad & Wanvik (2016) give various illustrations of this process in the disassembly of fossil fuel assemblages. In Stavanger, Norway, because of technical developments in the off-shore field, old ship wharfs became superfluous, but

then they became re-used as spaces for sustainable urban living. This process of parts changing from the old assemblage to new one, can be used to model the process of diffusion in transitions. Diffusion is then the process in which an increasing number of assemblage parts switches from the old assemblage to a new one. All elements of the socio-technical assemblage can switch, be they users, producers, use practices, infrastructures or values. Following Haarstad & Wanvik (2016), *Assemblage converters* are well-placed elements that speed up this diffusion process, or delay it considerably (or even reverse it).

3.2.3 Productive assemblages

In the process of diffusion, the assemblage also develops a logic of its own. Assemblages are productive and creative entities. They produce connections and through these connections create. Paraphrasing Benett (2005, p. 446) their collective agency can be described as the distinctive efficacy of a working whole made up various socio-technical elements. Importantly, each of the assemblage parts has an "energetic pulse" that is somewhat "off" with that of the rest of the assemblage, making it an open-ended entity (Benett, 2005). The assemblages seek expansion by forming new connections. Hence, they become diffusion motors, that try to make more and more parts join the new assemblage (Purcell, 2013). The assemblages obtain a collective form of agency that is more than the sum of that of their parts. However, also in the process of diffusion, each of the parts works slightly in its own way, pursuing its own wishes (Müller & Schurr, 2016). Never a totalizing system emerges, there is always instability, parts that detach, a productive but provisional sympathy.

3.2.4. Geography

Assemblages are conceptualized in this study as "translocal" (Mcfarlane, 2009). In the process of diffusion it is the topological i.e. network (or in our terminology assemblage) distance rather than the metric distance that matters (Müller, 2015). *Relations of exteriority* imply that the sites in the assemblage are more than nodes in the diffusion network (Mcfarlane, 2009). An innovation that is developed in a certain place, carries the history of that place in in it in some way. During the process of diffusion the innovation travels to other places. These places can transform the innovation. The innovation then mutates one the move (Peck, 2011). The innovation can also reshape the place where it arrives (Murphy, 2015). Which of the processes dominates depends on the *territorialization (stabilization)* of the socio-technical assemblage as well as that of the local assemblage in which it arrives. Finally, the diffusion assemblage has a spatial structure that is constantly produced and changing. For this it uses all kinds of communication mediums, from face-to-face contacts to television advertisements to internet forums.

3.2.5. Change does not stop here

Deleuze & Guattari (1987, chapter 8) talk about how the lives of people are constructed from different lines. There is rigid lines structuring lives, such as work-transportation-leisure. These are not necessarily bad. There is also more supple *deterritorializing* lines people follow in their lives, such as a secret love affair. Once people have followed such a line, they may well return to their normal lives. But on the other hand, now they have seen that difference is possible, "everything has changed" (Deleuze & Guattari, 1987, p.231) and a "line of flight"

has emerged that is even broader than the particular topic on which it emerged. In diffusion processes in transitions, it is such discovery of difference by the parts of the assemblage, that leads to the adoption of more sustainable innovations. Once people have discovered that there is a way out, they also apply this notion of difference in broader contexts. This does not mean that people will start living completely sustainable right away, as they are still heavily bound by existing structures. Yet each adoption slightly weakens the current non-sustainable modes of living (cf. Purcell, 2013).

4. Case study

4.1 A different world

Let us illustrate this perspective with the online community of electric vehicle users we have studied. This is an internet forum with a heterogenous community of mainly Tesla users, but also aspiring Tesla users, other EV users, and EV enthusiasts. It is a complex socio-material constellation of people, their EVs, charging points, practices, norms and values. It is a vibrant community. People share knowledge, go on roadtrips 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 community borrows each other plugs when they need to charge abroad, and lobby politicians and organizations for the creation of more charge points. Constant processes of *territorialization (stabilizing)* and *deterritorialization (destabilizing)* occur. There is an increased bonding as members get to know each better online, and also start organizing real-word events such as an EV-rally. On the other hand the community is continuously deterritorialized, most notably by the influx of many new members. These constantly open new forum threads in which they ask basic questions about EV. At some points this even threatens to tear the community apart altogether. From the community then a website is launched where beginning users can find answers to their questions.

The online EV community is also part of a larger EV assemblage, that includes EV manufacturers, other users, EVs, charging infrastructure and policy makers. The online EV assemblage is also tied by *relations of exteriority* to many other assemblages. Its active members are also members of other clubs, inhabitants of cities, maybe even parts of the fossil fuel car assemblage, users of communication technologies. Regarding the latter, changes in this assemblage, i.e. the rise of the smartphone, leads to an increase of app conversations threatening the existence of the online community in its current form of an internet forum. In this way ripples of change proceed through assemblages. Regarding the fossil fuel car assemblage, it is obviously highly *territorialized*, as can be seen in our daily commute habits or the presence of fuel station infrastructure. However, it is also always has *emergent capacities* for change. Haarstad & Warvik (2016) give some illustrations of its inherent instability. The car users are also part of other assemblages, such as the labour market or urban assemblages. Development in these assemblages, e.g. the flexibilization of jobs and the construction of bicycle lanes contributes to a declining popularity of the gasoline car among the young. *Assemblage converters* like the "Dieselgate scandal" of Volkswagen (Boretti, 2017) can even lead to rapid disassembly.

In terms of its geography, the online EV community is best described as a translocal assemblage. The studied forum is composed of multiple regional subforums. In these forums people discuss EV-related topics related to a specific locality. So in the Dutch forum we studied, there are discussions about local social factors such as policies for charging or EV subsidies. Also local natural factors are discussed: what happens to the range of your EV in the windy, relatively cold Dutch climate? However, in various forum threads people from all kinds of places are active and exchange ideas. Their locations are not merely network nodes, they matter. For, example the Dutch Tesla users start an international action to make the Tesla S compatible with fast-charging as it possible with the Dutch (and wider North-Western-European) electricity grid. The geographical structure of the online community is also changing and being produced. At first, most discussion takes places in the international sections of the forums, with some threads dedicated to a certain locality. With the influx of new users geographical reassembling takes place, and much discussion shifts from the international forums towards local (in this case mostly national-level) sub forums.

4.2 Diffusion patterns

4.2.1. Transversal politics

We described political factors that foster diffusion. Firstly, for achieving transformative change, the assemblage needs to be transsectoral, i.e. cut across social fields. In our interviews with people that 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 that bought a Tesla after his dad bought one after he rented a hybrid car. The former Apple retailer lured by the design and software-focus of the Tesla. The self-employed part-time installer of solar panels and heat pumps, very much interested in sustainability. Also in the wider online EV community we can observe a very rough one third split between car, technology and sustainability enthusiasts. Together they form a symbiosis for some time:

"*I also thought the user group was very fun and diverse, because there were petrolheads 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" (Int,3)*

In terms of organizational structure the internet forum is very close to the ideal of a *molecular* structure that is able to unleash the creativity of the masses, while also retaining some form of community. The forum is accessible for everyone. Any person can contribute by opening a new thread or reacting to an existing one. It unleashes creativity, from people starting their own charging point company, to people encouraging each other to go provide a critical voice at policy meetings about hydrogen (an EV competitor), because they hate it so much. And still, with the influx of many new users during diffusion discussions become longer and unreadable, leading some users to search for other forms mediums of communication and organization. Nevertheless, the online EV community becomes a knowledge sharing collective, not reducible anymore to any of its parts. For example, in a topic on charging users work out their own do-it-your self solutions for connecting their EV. Users post

description of their solutions, an EV driver that also happens to be an electric engineer comments on the safety of the construction, others users react, and so on. A user refers to the community as their *"collective brain"(Int1).* Finally, the online EV community is translocal as users from many countries and regions join discussions. It is only later in the diffusion process, that many national subforums are created. Discussions become more extensively coloured by the respective countries of origin of the participants. This limits the potential for transclocal action to a certain extent.

4.2.2. Parts changing assemblage

Users that are part of the EV assemblage, were likely part of the fossil fuel car assemblage before. They might even still be part of both assemblages. The important point here is that these users have capacities, which they might very well have not been aware of, that are only actualized now they are part of the EV assemblage. Let us illustrate with a quote of a self-proclaimed petrol head user: "*I also note that I feel less urgency to drive fast on the left lane. Cruising at 100 and listening to the fantastic audio is much more relaxing. (Is this me saying this??)"*. There is no complete overthrow of the old assemblage, many parts just continue functioning in the new assemblage (albeit in slightly different ways). This applies also to gasoline stations that have recently started installing EV fast-chargers in The Netherlands[1]. Making use of their locations near highways, they now take up a role in the EV assemblage. In this process of parts changing assemblage, *assemblage converters*, such as the "Dieselgate scandal" of Volkswagen (Boretti, 2017), trigger many fossil fuel assemblage parts to switch at the same time, and to actualize new capacities, as they become part of the EV assemblage.

4.2.3. Productive assemblages

The online EV community becomes a productive assemblage. It seeks expansion. The user community lobbies governments and organizations for more charging points. An E-rally is organized through the internet forum with more than hundred electric cars, increasing their visibility. 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 enthousiast develops a detailed overview of the environmental benefits of EVs, enabling the community 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. He is rewarded by Tesla for this. Increasingly, his own project gets more out of sync with the rest of the community. Some community members believe he is only pursuing his own desires, interested in the rewards of Tesla, instead of in fostering the cause of EVs. Again, the assemblage is not a coherent totality. Still, 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? In the online EV community 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

[1] https://www.shell.nl/motorists/onze-tankstations/shell-installeert-snelladers-voor-elektrische-autos.html

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. With these specific cars they are productive parts of the EV diffusion assemblage, but they are also, maybe more firmly, part of a fossil fuel assemblage that moves in a very different direction.

4.2.4 Geography

We conceptualized the assemblage in diffusion as translocal. An innovation carries the history of a place where it develops, transforms during diffusion, and can transform the places where it arrives. The geographical form of the assemblage is constantly changing and being produced. Let us illustrate these points with a concrete example. In (Northern) Europe residential areas are supplied with 3-phase electricity connections, whereas in the United States they are only connected to one-phase, but with a higher number of Amperes. The first Tesla, the Tesla Roadster sportscar, was equipped with a charger customized for the US electricity system. However, as there was no 3-phase charging possibility, charging in Europe could take very long (up to 24 hours). When rumours emerged that the a new EV model, the Tesla Model S would not support charging compatible with the European 3-phase electricity system, online community users took action. The internet forum tread was started by a Dutch Tesla user. American users from both coasts joined in and lengthy discussions followed in which participants discussed the electricity networks in the various countries. In these discussions there emerged no smoothly working system, as there were often disagreements between the users from different localities. *"I don't give a rip about three-phase"* (f2). Nevertheless, a collective letter was sent to Tesla, endorsed by users located in multiple places, asking Tesla to make its car more compatible with European electricity systems. In the same internet forum thread, the vice-president of Tesla then confirmed it would. The connections made by the Dutch user with other international users as well as Tesla show how scale is produced in the assemblage during diffusion.

4.2.5 Change does not stop here

In the online EV community there is many discussion on various sustainable energy solutions. Now people have an EV, they get also 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 e.g. solar panels. A session is organized where a user who installs heat pumps tells about their potential. A forum user recounts the discovered difference in the world: "*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?"* (INT6). A former petrolhead 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."* (INT2). Again, it is not that anything is possible, not that every other sustainable alternative now codiffuses rapidly, people are part of many different assemblages that also constrain. Yet the discovery of difference leads people 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" (INT2) .

5.Discussion

Socio-technical transitions towards sustainability have entered a new phase, now that sustainable innovations are actually diffusing. Current theoretical frameworks for analyzing transitions still tend to emphasize stability, in the form of rigid regimes or coherent systems. We therefore explored an assemblage perspective to understand diffusion in transition. This perspective draws our attention to the instabilities and agency potential in the world. By applying insights from assemblage thinking, political factors were identified fostering diffusing in transitions. It was then shown how diffusion can be conceptualized as an increasing number of assemblage parts switching from an established socio-technical assemblage to a new one. The assemblage around the innovation develops a logic of its own, and its productivity and creativity further diffusion. Yet it does not become a coherent totality, there is always frictions and parts escaping. Diffusion is seen as a translocal process. An innovation carries the history of a place where it develops, transforms during diffusion, and can transform the places where it arrives. Finally, the diffusion of the sustainable innovation drives the innovation of other sustainable innovations as well. This perspective on diffusion was illustrated with a case study of an online community of electric vehicle users. We explored the agency potential in diffusion of these users, a relatively mundane group of actors.

Let us now compare this assemblage perspective to existing approaches to sustainability transitions. To begin with, there are many commonalities between assemblage thinking and approaches such as the Multi-Level Perspective (MLP) or Technological Innovation Systems (TIS). They share their focus on heterogenous socio-technical constellations as the main unit of analysis in transitions. The perspectives are all somewhere middle way between a purely relational perspective on diffusion (such as ANT), and a perspective stressing individual entities (such as Rogers (2000)). Obviously there are also some differences. An assemblage perspective puts more focus on instabilities and agency potential. This most notably conflicts with the "regime" notion of the MLP. It should be noted that an assemblage perspective does not deny the existence of highly established structures. Yet there are always (small) processes of stabilization and destabilization ongoing. Additionally, the connections between assemblages make ripples of change proceed through various assemblages. People are part of multiple assemblages that both enable and constrain. This provides them with a relative autonomy to act in a variety of ways in relation to different assemblages. For diffusion in transitions, this implies that assemblage parts can switch more easily and that there is likely no full-scale overthrow of an existing regime. As compared to many TIS analyses, in an assemblage perspective it is stressed that there is no coherent and smoothly running system needed. Instead, the assemblage is a provisional yet productive sympathy of actors that each have different interests. Even stronger, frictions are needed for diffusion to occur.

There is a growing debate surrounding the political dimensions of transitions (Geels et al. 2018; Avelino et al. 2016). What our assemblage perspective could add here is a focus on a politics that emerges outside existing structures, and concentrates on forging relations between different groups. It is a creative and open-ended politics, based on temporary coalitions. The question is whether such experimental politics actually resorts in larger changes at the macro-level. At least, from our case study we can see that it also has a role to play in the diffusion phase of transitions. Finally, we have adopted a translocal perspective to assemblages that focuses on the connections between the local and the global and how these are produced. This has allowed us to see how the electric vehicle innovation transformed in the diffusion process, partly because of connections made between geographically dispersed users. Such an approach has many similarities with the emerging work on policy mobilities connected to transitions (Affolderbach & Schulz, 2016; Sengers & Raven, 2015).

Assemblage thinking is often referred to as a "cousin" of ANT (Actor Network Theory), because of their common focus on relations and material objects (Briassoulis ,2017; Müller, 2016). However, it is worthwhile outlining some differences between ANT and the assemblage perspective employed here. First, our assemblage perspective recognizes differences between human and non-human elements, whereas ANT often treats the two as completely symmetric. Humans possess reflexivity and pursue certain interests. Second, in contrast to ANT, actors are not fully determined by their network position. Instead, in assemblage thinking they are relatively autonomous. Third, more than ANT, the assemblage thinking employed here stresses the process of assembling.

Obviously there are also limitations to the perspective employed here. First, being developed as a philosophical set of ideas, assemblage thinking provides only few concepts for concrete application in empirical work (Muller, 2016). Assemblage studies can therefore become rather descriptive. We have tried to counter this by providing various concepts and relating them directly to specific empirical examples. We have also tried to employ our perspective to explain why diffusion in the case of electric vehicles is occurring. 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. We do not claim in any way to cover all the richness and complexity of assemblage thinking as it is developed in the works of Deleuze & Guattari, most notably throughout Deleuze & Guattari (1987). Our assemblage perspective is mainly connected to the works of Haarstad & Wanvik (2016) and Delanda (2016,2006) with some more elaborations of the political and geographical dimensions. Even then, in exploring contributions assemblage thinking can make for diffusion in transitions, it was unavoidable to do some concessions and highlight particular points. We do not provide an extensive discussion of the virtual, i.e. the not yet actualized possible configurations of assemblages. Delanda (2006) visualizes these in a possibility space, which can be used to discover tendencies, as not all possibilities are equally likely to occur. There is much overlap here between assemblage and complexity thinking (Dittmer, 2014). Given the growing number of studies taking a complexity perspective to innovation (e.g. Frenken et al, 2014), this is a fruitful field for further research, for example for the

identification of assemblage converters. Third, our case of a well-connected online community 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 explored the contributions an assemblage perspective can make to the study of diffusion in transitions. In a case study, the perspective allowed us to investigate various processes by which an online community of electric vehicle users participated in diffusion. We hope that this work stimulates the debate regarding stability and change in transitions, now that sustainable innovations have actually started scaling up.

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