Novel or normal? Electric vehicles and the dialectic transition of Nordic automobility

Article (Accepted Version)

Kester, Johannes, Sovacool, Benjamin K, Zarazua de Rubens, Gerardo and Noel, Lance (2020) Novel or normal? Electric vehicles and the dialectic transition of Nordic automobility. *Energy Research and Social Science*, 69. a101642. ISSN 2214-6296

This version is available from Sussex Research Online: <http://sro.sussex.ac.uk/id/eprint/91641/>

This document is made available in accordance with publisher policies and may differ from the published version or from the version of record. If you wish to cite this item you are advised to consult the publisher's version. Please see the URL above for details on accessing the published version.

Copyright and reuse:

Sussex Research Online is a digital repository of the research output of the University.

Copyright and all moral rights to the version of the paper presented here belong to the individual author(s) and/or other copyright owners. To the extent reasonable and practicable, the material made available in SRO has been checked for eligibility before being made available.

Copies of full text items generally can be reproduced, displayed or performed and given to third parties in any format or medium for personal research or study, educational, or not-for-profit purposes without prior permission or charge, provided that the authors, title and full bibliographic details are credited, a hyperlink and/or URL is given for the original metadata page and the content is not changed in any way.

Novel or normal? Electric vehicles and the dialectic transition of Nordic automobility

Abstract: Over the last decade or more, the automobility literature has sought to observe and affect the dynamic tenacity of passenger vehicles. This paper takes up a recent call to actually study how private electric vehicles (EVs) are changing automobility. For this, it identifies four qualitative categories of automobility: general vehicle use, the car in daily life, vehicle symbolism and the effects of electrification. We study how these categories are affected by electric vehicles based on original data we gathered during a large empirical research project in the five Nordic countries, consisting of 227 expert interviews, 8 focus groups and 4,322 randomized survey respondents. We find a paradoxical relationship between EVs and automobility. Some aspects embed and strengthen car-based mobility and the current automobility regime, as EVs essentially offer a substitution technology. In other contexts, however, EVs challenge, threaten, and open up questions about automobility and germinate an awareness that it cannot continue as is. We conclude by arguing that the moment transport policy acknowledges this dualism and smartly links up to other developments in transport, like automation and connectivity, policy efforts can be designed to minimize drawbacks and emphasize strengths.

Keywords: Electric Vehicles (EVs); Automobility; Dialectics; Transition; Electric Mobility

1 Introduction

Road-transport is in need of a transformation away from internal combustion engines and fossil fuels towards alternative power trains, technologies and organizations of motorized mobility for a variety of reasons, core among them the challenge to lower carbon and pollutant emissions [1,2]. Over the last decade and more, a particularly relevant development has been the electrification of light private and commercial vehicles as evidenced by the low but steadily growing share of electric vehicles (EVs) in the global fleet and the various countries showcasing vehicle market shares of EVs well in the double digits [3]. However, road-based personal motorized transport is more than just a shift in engine technology or fuel supply. It is part of a system of automobility [4]: a “self-perpetuating system ... of actors, materials, technologies, policies and practices that make up and reinforce private vehicle usage [5].” Building on earlier theoretical contributions [6–9] that hypothesize about the extent and ways that an electrification of transport, in particular EVs, is changing this system of automobility, this paper asks whether EVs tediously reinforce the system of automobility or seek to radically reform it?

So far, evidence in favour of either a conservatism or radicalism of automobility due to EV deployment remains mixed. On the one hand, scholars note that EVs, by replacing internal combustion engines with electric drivetrains, require an entirely new set of suppliers, assembly processes, and technicians. The alteration of manufacturing processes and creation of new production lines is said to be transformative as it would require considerable intellectual and human capital [10]. Similarly, Mitchell et al. [11] call EVs nothing short of “transformative” and “revolutionary” for their potential effects on mobility patterns following their driving characteristics and lower variable costs. Turton and

Moura [12] in turn add that if EVs are placed in a vehicle-to-grid configuration the transformative potential of EVs multiplies, as the usage of an EV's batteries as a storage service for electricity grid purposes represents "a paradigm shift in how the energy and mobility markets are related." More recently, and writing in *Science*, Crabtree [13] professes that "electric vehicles are poised to transform nearly every aspect of transportation, including fuel, carbon emissions, costs, repairs, and driving habits ... The questions are not if, but how far, electrification will go."

Other scholars however note that there is little that is radical about EVs and that they merely embed automobility as we know it. This stream of scholarship notes that EVs merely encourage private and individual driving [14], thus resulting in much of the same negative impacts on sustainability, traffic, inactive lifestyles, and space use as conventional cars [15,16]. The negative environmental impacts of electric mobility, following increased mileage (rebound effects) [17], may be especially acute when EVs are bought not as a substitute but adopted as an additional second or third car [18,19]. Michalek et al. [20] similarly caution that extending the range of EVs to increase their appeal to a larger share of adopters will involve trade-offs, including higher greenhouse gas emissions and environmental impacts that result from the larger battery packs which require more resources to produce and because of their increased weight, spend additional energy to propel the vehicle forward.

In contrast to the primarily theoretical work above, this paper draws on a large empirical research project that studied the challenges and benefits of electric mobility and vehicle-to-grid (the use of EV batteries as a storage solution for electricity grid load balancing) in Iceland, Norway, Sweden, Finland and Denmark (the Nordics). Together with insights from the transition literature [21,22], more general policy-oriented analyses on EVs [23–25], and the literature that takes the car as performative, symbolic and functional of a private and individually owned mode of transport [14,26,27], this empirical orientation opens up EV research to a broader reflection beyond (1) its climate and sustainability aspects and (2) discussions that present EVs in terms of a substitution on simple costs and technical aspects only [5]. Additionally, the paper touches on the extent to which EVs are complementary with other innovations around automobility (like automation, car-sharing, battery storage and renewable energy), and it questions the temporality of transitions more broadly. Probing these complexities offers an empirically useful snapshot of the current state of affairs of automobility and its future prospects as it is present in the Nordic countries around the winter of 2016-2017.

The article proceeds as follows. First, section 2 identifies and summarizes eleven core elements that make up the regime of automobility based on an interdisciplinary review of the literature. Next, section 3 offers a brief overview of the Nordic EV landscape and the three methods. In turn, section 4 discusses our findings across each of these eleven elements in four subsections on overall vehicle use, urbanization and commuting, status and identity, and the effects of electrification. The conclusion summarizes and reflects.

2 Automobility and transitions

The concept of automobility reflects the whole sociotechnical system, politics, practices, emotions and other sociocultural dimensions around car-based transportation. Following its material-discursive [28] constellation, automobility reproduces itself through existing road infrastructure and urban landscapes, historically enabled longer travel distances and a sociocultural and individualized bonding with the vehicles that goes far beyond commodification and transportation [4]. Geels visualizes automobility as a sociotechnical system of competing transport regimes per Figure 1. Described as a pinnacle of modernity [29], automobility shapes the innovations in Figure 1 via landscapes and build environments, systems of governance, autonomous mobile subjects, and perceptions of nature, space and time. And based on the individualized “liberal” cocooned freedom of car use [30], it actively mediates the daily work-live routines and experiences of all those directly or indirectly involved with automobility [4,31–35]. Below, this section summarizes some of the important elements of automobility, and then reflects on the transition of the automobility regime with the broader automobility and transition literature.

Figure 1: Automobility innovations as part of a socio-material or sociotechnical system with multiple transport regimes

Source: Geels [36]

First, from the interdisciplinary literature on automobility we identify four broad categories and eleven distinct elements [5,7,8,37]. For example, Sheller [7] focuses on the cultural aspect of automobility at niche, regime and landscape levels by looking at anecdotal trends in the practices, networks and discourses around private car use through a 3x3 table. With the help of the literature on frames and framing, Sovacool [8] and Sovacool and Axsen [5] in turn offer a functionalist approach that depicts a range of elements where EVs could shift the automobility regime. Specifically, they draw on Axsen and Kurani's [37] four categories that depict how vehicles simultaneously have functional and symbolic effects on both a private (costs vs. status) and societal (climate effects vs. market signals) level – primarily because studies have found that consumers do not always behave according to functional and rational logics of cost or time minimization [38,39]. Table 1 summarizes these elements and offers a brief description of their positive or negative consequences on automobility. These elements will be analysed later in the paper based on the methods described in section 3.

Table 1: Automobility elements potentially affected by EVs

	Elements	Reforming Automobility	Reinforcing Automobility
Vehicle use	Vehicle uptake	EVs substitute ICEVs and scooters	EVs increase car-based mobility by drawing people away from active and public modes of transport
	Intermodality/seamless transfers	EVs used more in intermodal (active and public transport) systems and in combination with measures to discourage car use	EVs encourage excessive driving and are bought as second or third (luxury) cars
	Cocooning/fortressing	EVs increase the use of car sharing/ride sharing schemes	EVs increase the preference for private, single-occupancy driving practices
Car in daily life	(Sub)urbanization	EVs are a wakeup call to address private vehicle use if alternatives are available – public transport, shared services etc.	EVs, through their cheaper variable costs, enable longer distances, thus supporting urban sprawl. They also compete with public transport and shared services.
	Work-life balance (connectivity, automation, mobile offices).	EVs allow for more family time as commutes are part of office hours	Office hours are extended to commutes and travel time.
Symbolism of vehicle	Expression of gender	EVs and EV marketing break with gender distinctions through alternative design, comfort and ease of operations.	EVs and EV marketing reinforce stereotypical car images of masculinity (large, sporty, pickup trucks) or femininity (small, quiet, early generation EVs),
	Expression of identity	EVs and EV marketing point to new stereotypes around responsible and sustainable car use.	EVs and EV marketing reinforce stereotypical car discourses of joy and notions of freedom.
	Expression of class/wealth	EVs break with class distinctions, as low variable costs enable more mobility for all.	EVs reinforce class/wealth distinctions as high capital costs imply that only rich can afford them and their benefits
Environmental effects of electrification	Environmental stewardship	Through their use EVs signal a need for more efficient low-carbon propellants, alternative modes of transport, less mobility and spur pro-environmental behaviour in other sectors	The lower emissions lead to rebound effects: more miles travelled, heavier vehicles, more private vehicles. Esp. relevant if the ecosystem around EVs fails to materialize, e.g. no battery recycling, only dump charging, non-renewable electricity, etc.
	Oil independence	EVs minimize and signal lower oil/gas consumption, which reduces	The reduction in demand for oil reduces the oil price, which makes fuelling

		dependency among households and non-oil producers on oil companies and oil producing countries.	conventional vehicles cheaper. It also reduces investments and limits production to a smaller group of oil producing countries (those with low variable costs), thereby, counterintuitively increasing dependence on a smaller group of countries.
	Economic effects (Employment, competitiveness, growth and innovation)	Designed and promoted by sustainable firms with a focus on innovation and entrepreneurship	Co-opted and marginalized by transnational conglomerates with little desire for social change.

Sources: [5,7,8,37].

Even though table 1 is not meant to be comprehensive, it already highlights the importance of proper governance beyond technology and finances for a favourable use and development of EVs. Without proper policies, research across transport studies, geography, and policy notes how electric mobility can potentially displace large amounts of carbon from passenger vehicles and even fleets, but also run the risk of further embedding motorized, private automobility and increase vehicle miles travelled. For example, Graham-Rowe et al. [19] noted that because adopters perceived their EVs to be more “environmentally-friendly,” they drove them 1.64 times further than cars they did not see as “eco-cars.” Some plug-in hybrid electric vehicle (PHEV) drivers even attempted to recharge their vehicles not by plugging in at home or at work, but by running the internal combustion engine and then using the re-generative braking system to “charge” their vehicle—“thereby negating the carbon savings” [19]. Similar EV rebound effects have been found in Austria [40] and Sweden [41]. Modelling of EV driving behaviour in South Korea further underscores this paradox [42]: EVs are more technically efficient than conventional cars, meaning they have great carbon abatement potential, but if/when adopters increase their annual mileage, overall emissions for transport can actually increase. This underscores that EVs can entrench automobility.

Furthermore, the autopoietic (the self-reproducing and self-sustaining) nature of automobility works viciously. Graves-Brown argued, already in 1997, that increased private car use, especially its speed and seamlessness, alienates drivers from experiencing the local effects of driving which includes scrap sites, landfills, exhausts, vibrations and noise [43]. Similarly, Figure 2 exhibits two proud Americans with their recently purchased trucks and sports utility vehicles—bought despite the advice from an environmental conscious family member because of their “safety” and because the drivers liked to be “high up and protected”. While anecdotal, it (re)confirms Campbell’s [44] argument about the impossible relationship between ever bigger vehicles and a desire for safety in the USA; vehicles that last at least a decade and will be driven in single occupancy most of their lifetimes. These rebounds, contradictions and vicious self-sustaining processes lead some authors, like Beckmann [31], to argue that most transport policy-level reflections too “often merely lead to a reproduction of traditional ‘auto-scapes’.” Part of this stems from the material, discursive and cultural elements that

re-preform the core elements of the automobility regime. On both landscape and regime level, for example, the system locks itself in through constructed infrastructure, traffic rules and regulations, expertise (in terms of professional knowledge and beliefs), travel routines, cultural values around enjoyment, status and freedom, and incumbent industries.

Figure 2: Two Proud Owners of Toyota Trucks in Ohio, January 2019

Source: Authors

The robustness of the automobility regime does not imply that the system is static however [4]. Geels et al. [45] describe automobility for example as “dynamically stable”; as constantly changing but primarily “within the bounds of the existing regime.” A core reason for its constant dynamic stabilization, is the “inherent fragility” of the self-reproduction of the automobility regime [46]. Over the years numerous scholars have questioned the system for its harmful effects and concerns around congestion, traffic accidents, fossil fuel dependency, CO₂ and particle emissions, resource use (tyres, steel, chemicals), land use and social isolation [4,34,43,47,48]. A set of effects, that together have led Böhm et al [49] to conclude that automobility is an inherent contradiction and cannot continue at all. A sentiment shared by those who study this dynamically stable regime precisely in the hope to ‘crack it open’ [7,34,48].

In this respect, Urry [4] highlighted the potential of new technological and organizational innovations, like new fuel systems, new materials, smart-card technology [nowadays evolved into mobility-as-a-service (MaaS)], increasing levels of shared car ownership, connected vehicles, and transport policies that no longer prioritize car-solutions. More recently, Urry [48] shared four different

future automobility scenarios, including Fast Mobility (increasing horizontal and vertical mobility, hydrogen, automation), Digital City (non-physical meetings, smart environments, connected-cars), Liveable City (green, EVs, minimization of cars, shared cars), and Fortress City (elite segregation, offshoring, shortages). While impressive in breath and scope, Reese [34] convincingly shows for the USA that, on a more abstract discursive level, only three different automobility futures are imagined. A future wherein automobility is “reinvented” [11] and accelerated through many small scale primarily technical changes (clean and autonomous). A second future wherein automobility is reversed and reduced to more historic levels (smart cities, more active/public transport, car reduction policies). And a third future wherein society is too late and has to adapt to fuel shortages and climate change (with measures resembling the second future). Electric mobility seems to fit Reese’s category of ‘reinvention’ and thus points to an acceleration of existing automobility practices. In other words, a situation where new technology is co-opted and integrated into a political economic regime so that it can continue its individual, private and space consuming form of mobility [50]. It is a “greening of cars”, emphasis on the latter [51].

Whether one sees dynamic stability, consistency or change depends on the observer’s relative position (scale and scope), temporality and understanding of radicalness. In terms of scope, the empirical chapters in Geels et al. [22] for example offer conclusions about the transformative effect of EVs that go both ways. Some chapters show that infrastructure and traffic management are changing and transforming automobility on a system level, just as that EVs are close to breaking through on a niche level [6]. Other chapters however argue that these are not truly changing automobility. For example, Sheller [7] argues that a true change of automobility will most likely come from developments on a landscape level outside automobility, including developments that change urban environments and a driver’s interaction with their car as well as developments that offer alternative forms of seamless transport. Bottom-up or top-down and regional perspectives are thus important when making claims about system change, stability and closures.

Temporality is another aspect to transformations [52–55]. Ultimately, as Graves-Brown [43] quotes McLuhan [56], “the car as a vehicle ... will go the way of the horse. ... Its future does not belong in the area of transportation.” The near-term expectations behind Reese’s future visions above thus contrast with other imagined endings of the car as a mode of transport. Interestingly, while there is quite some attention in automobility to the effects of the speed and acceleration of the vehicle on “spatial mobility”, less attention is spent on the rate of change of automobility itself rather than the argument that the change is not fast or radical enough [45,46,48]. This ignores that time is often used within debates as an argument itself. For example, when people agree on electric mobility, but differ about the rate of change needed to get to a certain level of deployment. The conclusion that EVs offer

a radical shift is thus itself a political and performative argument [57], just as when one claims that the shift is incremental.

Lastly, radicalness not only refers to the relative scope and impact of change but here also refers to either a transition *of* the automobility regime by diminishing the importance of private autonomous vehicles or a transformation *within* the automobility regime through a “politics of reform” (Böhm et al p24), e.g. congestion charging, shifts in drivetrains, traffic regulations, taxation and so on. The recent uptake of EVs in private car-based transport (as well as e-bikes and scooters) seems to fit the latter. Of course, that is not to say that EVs do not potentially enact huge changes to dealerships, car production, fuelling industry and local infrastructure. Nor does it include the broader developments behind EVs, like smart charging, connected vehicles, shared EV fleets, etc., that potentially open up to a transformation of automobility itself.

3 Research Methods

Given the extensiveness of the automobility literature and our research question on the transformative effect(s) of EVs on Nordic automobility, we draw on the data gathered for a multi-method empirical project on electric mobility and vehicle-to-grid in the five Nordic countries [25,58–63]. This project utilized three different methods and consisted of 227 expert interviews with 257 respondents, eight focus groups with 61 participants and a survey with 4,322 randomized respondents, each briefly described below. At a high level, each method was meant to collect data at a different “level” or from a different “stakeholder group,” the idea being that all three methods used together would lead to a higher degree of triangulation between methods but also a more comprehensive outlook and synthetic analysis. The expert interviews were intended to tap into elites with a great deal of expert knowledge about the topic; the focus groups to solicit a non-representative sample of public input through a group dynamic oriented towards consensus and open deliberation; the survey to solicit data from a representative sample with an instrument oriented towards private views and closed deliberation.

The Nordic countries offer a relevant comparative case study to test the influence of EVs on automobility globally. In 2017, both Norway and Iceland had world-leading sales shares of Pluggable Electric Vehicles (PEVs) – both newly sold Battery Electric Vehicles (BEVs) and Plugin Hybrid Electric Vehicles (PHEVs) – of respectively 39.25% and 11.7%. This drops to 6.27% in Sweden, 2.57% in Finland, and 0.56% in Denmark [64]. The Nordics are thus witness to a variety in EV adoption levels, despite relatively similar climates and geographies (with Denmark arguably the most suitable for EVs in that perspective), comparable political systems, and a shared concern for alternative transport technology due to relatively clean electricity generation. These different adoption rates can be linked to national differences in political agreement about EV incentives, different car taxation systems, and the specific

structures of the incentives resulting from local conditions and priorities [25]. Denmark in this respect is a prime example of constantly changing EV support policies, including a phase-out of tax exemptions late 2015 that was later reversed again. Norway and Iceland both share extensive purchase tax and value added tax exemptions plus additional incentives for BEVs, PHEVs and hydrogen vehicles. Sweden, as the only car-producer, recently activated a dynamic bonus-malus system, which should offer a budgetary neutral and long-term stable option for all alternative fuel vehicles. And while Finland's incentives are comparatively low and late, they do seem to work given growing sales shares.

3.1 Expert interviews

As part of this larger project, we conducted 227 semi-structured interviews with professionals working directly or indirectly on electric mobility and vehicle-to-grid across the five Nordic countries while visiting 17 cities from late September 2016 until May 2017 (Table 2). Professionals were contacted beforehand based on sector, and later during fieldwork via snowballing questions, with researchers aiming to gain access to senior staff (CEO's, professors or lead researchers, heads of department, spokespersons, project managers, senior consultants, etc.) across several sectors related to electric mobility. These sectors included local, regional and national government ministries, agencies, and departments; regulatory authorities and bodies; universities and research institutes; electricity industry players; automobile manufacturers and dealerships; private sector companies working on charging equipment, transport software, alternative transport technologies (incl. competing technologies), and electricity and fuel traders; as well as industry groups and civil society organizations. Questions were asked about the major energy and transport challenges, about the benefits of EVs as well as their challenges, about potential suggestions to speed up the EV transition, and about vehicle-to-grid (its benefits, challenges and potential incentives). The interviews lasted between 25-90 minutes and were conducted in person or by phone if personal meetings were impossible.

Table 2: Overview of Nordic expert interviews

	Interviews (n=227)	Respondents (n=257)	% of Respondents
Country			
Iceland (Sept-Oct 2016)	29	36	14.0%
Sweden (Nov-Dec 2016)	42	44	17.1%
Denmark (Jan-Mar 2017)	45	53	20.6%
Finland (Mar 2017)	50	57	22.2%
Norway (Apr-May 2017)	61	67	26.1%
Gender			
Male	160	207	80.5%
Female	40	50	19.5%
Groups	27		
Expertise			
Transport or Logistics	73	81	31.5%

Energy or Electricity System	63	75	29.2%
Funding or Investment	10	12	4.7%
Environment or Climate Change	12	16	6.2%
Fuel Consumption and Technology	22	23	8.9%
Other	13	14	5.4%
EVs and Charging Technology	34	36	14.0%
Sector			
Commercial	68	70	27.2%
Public	37	46	17.9%
Semi-Public	40	51	19.8%
Research	37	39	15.2%
Non-Profit and Media	12	13	5.1%
Lobby	23	25	9.7%
Consultancy	10	10	3.9%

3.2 Public Focus groups

In addition to the expert interviews, we conducted 8 focus groups with 61 members of the public gathered with the aim to discuss EVs with people not directly involved with EV transition policies, sale processes or direct ownership. The participants in Table 3 were recruited either through local university connections, personal contacts and broad advertisement or through local psychology labs with subsequent recruitment through the email lists of those labs. The only requirement for participation was that the participants were over 18 and living permanently in the region of the particular focus group. Moreover, car ownership was deliberately not a requirement to open up to discussions about the role of cars in society. Candidates were offered around 20 euros and a light meal with refreshments. In general, the groups lasted between 1.5 and 2 hours and consisted of 5 to 10 and ideally 6 to 8 participants. The candidates knew the topic beforehand and were given a brief introduction into the workings of the focus group, and halfway in about V2G, but not about EVs. Overall, the groups were tilted towards participants living in urban/semi urban regions and towards (advanced) students and young professionals. Gender was relatively equal, but age ranged from 19 to 61, with the majority in their late twenties and early thirties. Most of them had a driver's license but few owned a car, although many could borrow one from family or friends. In some of the focus groups in Denmark, Sweden and Norway participants had experience with an EV and shared this with the group.

Table 3: Overview of focus groups

Classifications	Participants (n=61)	% of Participants
G1: Iceland [Mixed Gender] (Oct 2016)	5	8,2%
G2: Sweden [Mixed Gender] (Nov 2016)	6	9,8%
G3: Denmark [Mixed Gender] (Feb 2017)	10	16,4%
G4: Finland 1 [Mixed Gender] (Mar 2017)	9	14,8%
G5: Finland 2 [Mixed Gender] (Mar 2017)	7	11,5%
G6: Denmark [Male] (Jun 2017)	7	11,5%
G7: Denmark [Female] (Jun 2017)	8	13,1%
G8: Norway [Mixed Gender] (Sept 2017)	9	14,8%
Female	32	52,5%
Driver's license	50	81,9%

Currently own or have access to a car	29	47,5%
EV Experience (as driver or passenger)	8	13,1%
Own an EV	0	0,0%

After collection of the interview and focus group data, each interview and focus group was fully transcribed and then coded inductively, statement by statement, on its relevant topics by one individual in NVIVO. The inductively derived codes were subsequently collated in larger themes (e.g. the theme EV challenges included codes on battery life, battery production, battery recycling, etc.). As both methods were conducted under full anonymity, we report individual quotes and statements by either expert respondent number [e.g., R1] or focus group number [e.g., F1F reads Finland 1, Female], yet frequencies are reported on an interview or focus group level.

3.3 Five national surveys

To collect data on the demographics of electric mobility we relied on a structured online questionnaire consisting of three parts with 44 questions (including a choice experiment, which is excluded here). The first part asked about the vehicle background and existing mobility patterns of respondents, namely how often they drive or use other forms of transport, how far, how much they are willing to pay for a new car, etc. The second part asked respondents what they valued most (or least) when they considered future purchases and forms of private automobility, such as acceleration, size, safety, etc. as well as some questions specifically about EVs (like charging, range, battery life, and so on), asking them to rate these features on a five-point Likert type scale ranging from very unimportant to very important. The final part of the survey asked respondents for basic demographic information such as age, gender, education, and occupation as well as more sensitive questions about income, political affiliation, and environmental values (among others).

After excluding surveys that were incomplete (we allowed respondents to skip a small number of questions), the survey was completed by 4,322 randomized adult respondents from across the Nordic region in an online survey facilitated through survey hosting firm Qualtrics. Table 4 offers an overview of the demographic distribution of the final respondents. While these demographics show predictable distributions, it should be noted that our EV owning subsample is actually larger than the average EV ownership share in the Nordic car fleet at the time of the survey.

Table 4: Overview of Nordic survey respondents

Gender		Urbanization*		Car ownership	
Male	49.3%	Rural	20.4%	No	25.2%
Female	49.2%	Suburban	45.7%	Yes	74.8%
Other / PNTA	1.5%	Urban	33.9%	<i>n</i>	4320
<i>n</i>	4321	<i>n</i>	4318		
Age		Country		Daily km by car	
<25	18.2%	Denmark	22.0%	Not regularly	29.1%

25-34	18.0%	Finland	22.3%	< 20 km	29.4%
35-44	18.1%	Iceland	11.5%	20-50 km	27.1%
45-54	19.2%	Norway	22.2%	50-80 km	7.9%
55-64	15.6%	Sweden	22.0%	80-100 km	3.1%
65>	10.9%	<i>n</i>	4322	> 100 km	3.5%
<i>n</i>	4318			<i>n</i>	4322
EV driving experience		EV ownership			
Don't know / not sure	4.1%	No	93.3%		
No	77.0%	Yes, but sold	2.8%		
Yes	18.9%	Yes	3.9%		
<i>n</i>	4320	<i>n</i>	4322		

Note: * The level of urbanization reflects the self-identification of respondents based one of the survey's questions.

4 Results

This section presents the results, divided across the core elements discussed in section 2. Section 4.1 details actual EV use and its relationships to other modes of traffic. Section 4.2 touches on daily life, routine commutes and the built environment, while section 4.3 discusses the symbolic value of cars. The last section analyses our data on the economic, environmental and fuel dependency effects of EVs.

4.1 Vehicle use, intermodality and cocooning

In terms of whether EVs increase private car use in relation to other modes of transport and in contrast to earlier expectations [65], our evidence (based on self-reported knowledge) finds that a larger share of EV owners drives further on a daily basis than non-EV drivers (Figure 3). This intuitively originates from the cheaper variable costs per kilometre of EVs as well as their relatively higher capital expenditure requiring a higher mileage to pay off. However, those able to buy new EVs should not be compared to the general vehicle population but to those who buy new ICEVs; buyers who are often employed, have a family, earn above average and generally drive more than other car owners. Figenbaum [66] explicates this point for Norway when he shows that new BEVs and new conventional vehicles have a similar yearly total travel and only slightly different travel patterns on longer distances. Furthermore, the literature [66,67] and 42 interviews highlights that most EVs in the Nordic countries were bought as the second car in multi-car households, although some of our experts remarked that those EVs, while smaller, should actually be counted as the first car as they see most use and most yearly kilometres. On the other hand, even with the relative predictable and low price elasticity of fuel costs, income to fuel demand, and income to travel demand [68,69], the low variable costs of driving an EV could spur an increase in vehicle miles travelled when EV adoption spreads to lower income groups.

Figure 3: Self-stated average daily distance driven by percentage of EV and ICEV owners (n=3132)

Note: This figure excludes survey respondents who skipped the question on vehicle ownership or who stated not to own a vehicle.

While the interviews and focus groups lack specific views on whether EVs, motorized two-wheelers or modes of active and public transport reduce vehicle use, this seems not the case as participants generally shared the assumption that EVs principally substitute ICEVs. In the focus groups for example, participants remarked across 6 groups how an *“electric car is still a car (Fin2_F)”* while discussing the importance of cars in society, which some depicted as a necessity *“once you get outside the city centre (Fin2_M)”* and others saw as a status symbol, a tool, a convenience or mediated by on ones’ family and living situation. Among experts, personal transport demand by consumers was similarly taken for granted, with only a small number (8.37% of interviews) explicating that societies are over-reliant on cars. That said, while demand was taken for granted it was also seen to be in need of active mitigation through public transport, car minimalizing policies, and so on. *“A car is a car (R84)”* or as R62 reflected: *“Sometimes you hear people say that ‘well it’s not a problem with cars, because we will just make them electric and we can keep on driving them as we always have’. - No actually, you can’t! [In cities] it’s just not possible, space wise, to ... have people drive personal vehicles, even if they are electric.”* Measures to this point included environmental zones (10.1% of the interviews), parking or toll road disincentives, and investments in public and active modes of transport. Interesting is the Norwegian long-term vision to have EV drivers pay toll in the near future, above public transport levels, but always below ICEV levels [R198, R201, R235; ,66]. Implicit behind statements like these is that EVs substitute ICEVs and hence compete with other modes of transport, but not that people trade other modes of transport for EVs.

Besides measures that discourage car use and increase public and active modes of transport, we also came across arguments for better interconnections between different modes of transport.

Although the notion of *intermodality*, the technical term that describes such interconnections, only explicitly came up once (R126), there was some attention to Mobility as a Service (7.93% of the interviews with 24% in Finland). Furthermore, a large number of experts discussed active modes of transport like biking or walking (16.74% of the interviews with 28.57% in Sweden) and public transport (38.77%) and directly or indirectly reinforced the need that these should be integrated and connected. The focus group participants confirm a similar need, as public transport was their number one transport challenge (in terms of costs, availability and time expenditure) and mentioned in seven of the eight groups by a total of 56.34% of the participants. In short, while current EV purchases and use could be perceived as increasing personal transport through second cars and “rich man’s” expensive EVs, the actual use seems to be on par with conventional vehicles.

Next, given that EVs are often sold as a personal automobile (ignoring both electrification of public and freight transport), this implies a similar cocooning and fortressing as ICEVs, perhaps even a strengthening of it. For example, during the focus groups the absence of engine noise was an oft-discussed point, but in the Icelandic group this was partly discussed in terms of a further privatization of the vehicle when participants wondered what would happen if drivers could add their own sound to their vehicle, *“just like a continuous ringtone for the car (Ice1_M).”* Similarly, experts and focus group participants in Sweden discussed an electric bus line in Gothenburg. This bus was appreciated, partly for its drivetrain and lack of vibration, but mainly because it offered free Wi-Fi and phone recharging possibilities and thus facilitated a further retreat in their private bubble (R54, R63, Swe_F). Anecdotes like these are only indicative of course, but they link up to the increasing connected nature of EVs and other new vehicles where *“you would likely spend more time in your car (R122).”*

On the other hand, connectivity also implies remote or wireless access to cars, which is a core feature for shared cars (R167). Shared ownership of vehicles, shared use of private vehicles, and especially commercially owned shared fleets, were discussed by both experts in 18.94% of the interviews [especially in Denmark (33.33%) and among transportation experts (35.62%)] and in 6 out of 8 focus groups to decrease the number of vehicles in urban and suburban environments. While this excludes ride hailing services (as these were deemed illegal by various Nordic countries at various times, see [70]), shared use of vehicles thus resonated among parts of the focus group participants and experts, partly due to cost savings and technological advances that increase accessibility and convenience [9]. It should be noted that our urban-oriented focus group participants with their low preference for ownership - some actively and solely used shared vehicles – are not representative of the larger Nordic population. Until broad public acceptance, private transport remains central to many of the Nordic trips, and with increased integration of online services will continue to cocoon drivers and passengers in their ever connected and mobile private worlds.

4.2 Daily habits and routines: urbanization and commuting

Acknowledging that EVs, for now, primarily substitute drivetrains instead of a shift in modes of transport or the number of vehicles, implies a rather similar infrastructure and build environment as conventional vehicles. Changes do occur, mostly visible around (re)charging infrastructure and the replacement of fuel stations. The expert interviews and actual fieldwork visits indicate that the effects of these infrastructure changes on public build environments are strongly mediated by local decision-making. For example, on-street charging is highly prevalent and visible in Oslo and many other Norwegian cities (R198) whereas Stockholm (Sweden) directs its public charging investments towards underground parking structures (R40). Charging in Aarhus (Denmark), was almost always outside, making it somewhat inconvenient if drivers had to recharge during the rain, wind, or snow (See Figure 4). Moving to more rural environments in Sweden and Norway, experts reflected on the surprising popularity of EVs in certain local areas by pointing out that every household has a grid connection, and thus the opportunity to charge an EV, while low rural population density was increasingly reducing the viability and number of fuel stations (R37, R40, R51, R74, R217).

Figure 4: On-street public charging for EVs in Aarhus, Denmark, 2016

Source: Authors

Beyond direct infrastructure effects, the lack of local exhausts implies that electric mobility has the potential to change transportation inside buildings and other enclosed spaces (like mines). For example, R155 stated that work from his research institute showed that lower ventilation costs already make electric mobility cost effective in commercial mining activity and harbours. In Gothenburg (Sweden), we observed an experiment that mixed indoor and outdoor driving, with a popular electric bus route that stops inside a building with a coffee area next to it (Swe_2; R38; “ElectriCity Media,” 2014). The possibilities go further as a reduced need for ventilation ultimately could lead to construction of buildings above road infrastructure in densely urban environments and extend tunnel length (Fin_2). In such a scenario, political influence would shift from petrol to electricity providers, but as automobility would be further “hidden” from public view it would be even more entrenched.

While changes like these transform our urban environments, the mode shifts away from automobility are primarily initiated by urban policies that regulate parking and access to inner-cities (like toll-roads), both for residents and commuters from surrounding regions. Electric mobility itself does not affect that. Similarly, in terms of what Sovacool and Axsen call ‘mobile offices’, we confirm that EVs maintain, if not strengthen current practices. Interesting in this respect is that while this was not discussed during our interviews or focus groups, and only automation will increase time spend on office work in the vehicle while driving, there are numerous stories of early EV drivers who use the time it takes to charge their EV during their commute or on their way to customers, not just for food or rest, but also for emails and other work related activities. Yet, in the focus groups the counter argument was made: that charging time challenges automobility, as participants remarked that it will probably drive up the costs for companies and customers *“because I’m getting paid for my time spent travelling (Den3_F)”* to and from customers. Then again, Den_1 discussed how an EV’s charging time could be used to enforce breaks and periods of rest for (truck) drivers, simultaneously adapting and entrenching automobility.

Lastly, experts (21.15%, 40% in Denmark) and focus group participants (6 out of 8 groups) touched on automated vehicles. Focus group participants remarked for example that automation and EVs do not form a self-evident relationship, but that it could be synergetic (Ice, Den_1, Fin_1). This constituted a repeated insight among experts (R82, R84) as well, who expected it to be cheaper than current options for consumers who rely on personalized public/shared transport (taxis). Although car producers recently have started advertising with it [72], office work was not discussed explicitly in our meetings (R209). Both experts and focus group participants did discuss being able to get home drunk, or the expected increased mobility of sight impaired persons (Ice) and children (R122) [73]. Among experts, automation was further supported for its potential to reduce the number of vehicles and increase the capacity of existing roads, but only if automation is organized smartly and through shared vehicles so that unnecessary individual trips can be minimized (R88, R98, R102, R112, R131). The fear

however was that the number of empty trips would increase [74] as would the acceptance of people “to spend more time in the car” due to increased on-line connectivity (R122).

R96 hence surmised that “*the nicest scenario would be a shared electric automated future for cars.*” In short, instead of weakening automobility, EVs without shared or shared autonomous functions are seen to reinforce the practice, materiality and rules and regulations behind automobility even further [9,73–75].

4.3 Vehicle status and driver identity

Cars are intrinsically connected to emotion (R62) and sentiment mediates rational cost calculations and usage identifications [35,39,76]. Sovacool and Axsen [5] approach this by arguing that the car is a private symbolic expression of gender and/or class. Sheller [7] touches on it as well in her cultural framework that focusses on landscape level discourses like the joy of driving and freedom. In this section we touch on three aspects: gender, identity and class.

First, in terms of gender, EVs have the potential to break with traditional gender ascriptions to cars. Discussions about big, fast and loud masculine vehicles versus the small, quiet and cheap feminine vehicles were popular during the focus groups (partly due to the single-gender groups in Denmark), but gender also returned in the survey and in the expert interviews. On the one hand, experts confirmed what the survey showed, namely that current EV owners are primarily male. Interestingly, the survey provided indications that this male-dominated market, which the literature explains by innovator’s and early adopters’ technological and environmental interest combined with higher incomes [37,77], is not self-evident as EVs correlate to driving preferences of women and other groups in society even though women indeed profess a lower interest in EVs [78]. Furthermore, many early EVs are smaller vehicles, which has led some experts to break with traditional male dominated, even sexist [61] depictions of power, speed, and luxury to explain the new ‘first-car use’ of bourgeois households in the Nordics. As R49 explained: “*in a traditional bourgeois household, the man is driving the big car [and] the woman maybe works half time and has the small car. Now it is shifting around. The man has the small car to get to work every day, the battery car, the woman has to drive the kids to football practice and to school and so on and needs a bigger car for that.*” Among the focus groups this tension returned as well with participants sketching typical male car stereotypes (“*Viking men*” in Iceland) and then questioning them either in practice [whether those marketing gendered stereotypes are really true (Den_1, Den_3)] and in principle [with statements that real men care about silence and the environment (Den_1, Den_2)]. The expression of gender is thus reinforced, but it is showing serious cracks compared to traditional gender patterns following alternative designs, comfort and ease of operations of EVs.

Second, in terms of identity, the above discussed 'gender neutral' environmental focus opens up to an identity of environmentally responsible car use. This is another increasingly ascribed identity that is put forward *in addition* to existing notions of freedom, joy of driving, "needs", and so on. It is additional, because EVs still capture the freedom of a car and potentially reinforce it further as they reduce feelings of guilt normally attached to the pollution that results from driving (R146). In fact, building on what experts called the "EV smile" (R39, R40, R105), EVs are (and should be) increasingly sold based on their ease and joy of driving [25]. In other words, EVs reinforce traditional automobility expressions of freedom and joy through both their driving experience and their environmental entitlement – although the latter introduces a new expression of identity around responsible vehicle use.

Lastly, cars represent a high capital expenditure for consumers and therefore often are an expression of both class and wealth. As new and relative expensive vehicles, EVs only reinforce this aspect. Specifically, the class argument goes one of two ways: class distinctions decrease as companies offer small EVs with cheaper variable costs or they are reinforced as companies mainly offer large and expensive EVs with long range. Given the early state of EV markets and the popularity of one luxury all-EV brand, class was a regular argument during the interviews (14,1%) when experts discussed how some consumers see EVs as a "*rich man's toy*" (R21). This framing was less of a topic in the focus groups (2 out of 8), although price certainly was a shared challenge across all of them. Important to note is that this class aspect seems less a discussion about automobility as it is a discussion about EV incentives. These incentives, due to their structure and set-up often favour more expensive vehicles [25], raise questions from an energy and mobility justice perspective (distribution of public funds) or from an efficiency perspective (cheaper ways to gain CO₂ reductions). At the same time, experts argued that the incentives are actually effective because they enable a larger group of people to buy EVs, not just the rich (R79, R201) and because they help drive down costs on the long term (R59). In sum, EVs offer similar expressions of class and wealth as ICEVs, although much depends on the actual EV models and their battery size.

4.4 Environmental effects of electrification

The last three elements of automobility detail the environmental, economic and fuel effects of EVs.

In terms of environmental effects, experts highlighted emission reductions locally and globally as well as their energy efficiency as the first and foremost benefit of EVs. Focus group participants similarly saw this as the first and foremost benefit of EVs and in their discussions touched on both local particle emissions and more global CO₂ emissions reductions, especially in combination with the transition in energy generation (mentioned in 4 out of 8). Simultaneously, some participants doubted

the environmental effects of battery production (5 out of 8 groups) and the actual emission reductions of EVs, especially with fossil fuel based electricity generation (4 out of 8 groups). Others also discussed the export of fossil-fuel (and older) cars out of the Nordic region as they are displaced by cleaner, newer EVs. Next, our survey confirms a positive relationship between stated importance of sustainability values and interest in EVs among non-EV owners ($r(4032) = .286, p < .01$). Lastly, among our experts, battery recycling was considered a challenge as well, but only mentioned in 4.4% of the interviews and thus far behind more immediate issues like price, range, and charging infrastructure. Simultaneously, 24.2% of the experts highlighted the link with more sustainable electricity generation. The electricity generation and recycling indicate that well-to-wheel effects are important.

Fuel reduction and oil independence were listed as important benefits to EVs in 5 out of 8 focus groups, primarily in Iceland, Denmark and Finland, but in terms of time spent was a little discussed topic. Among experts, fuel reduction and oil independence arguments came up in 10.1% of the interviews, especially in Iceland where 38% of the interviews linked oil imports to concerns about their currency and exchange rate. We therefore agree with R75 who argued that experts and public authorities should use this more to justify and fund EV incentives. On a more strategic fleet transition level, experts wondered how the fuel and car markets will develop overtime, as lower demand will most likely reduce fuel prices, making it cheaper to keep and drive conventional cars. On the other hand, discussions about decreasing gas stations in the north of Sweden point to a more virtuous circle pushing electrification forward. Few experts discussed the long-term development of the car fleet, beyond full support for electrification partly achieved via diminishing urban access rights and increasing emission requirements [23]. That said, even with full focus and investment in EVs (R48, R52, R106, R138), some experts discussed biofuel blending as a way to counter the emissions of those conventional vehicles that will be sold in the coming decades (and remain operational for a decade or more). In general, biofuels were discussed in 45.81% of the interviews, either in terms of an incumbent industry, a blending/transition fuel, or a heavy transport fuel alternative, particularly in Sweden (64.29%), Finland (58%) and Norway (39.34%). In short, while EVs definitely reduce fuel consumption and dependency, it is as of yet unclear how the fuel markets will develop – especially as oil and gas are used for industry purposes as well.

Lastly, EV deployment has effects on employment, competitiveness, growth and innovation. In terms of technologies, the focus groups made links to coupling EVs with renewable electricity generation and battery storage (in line with our focus on V2G) as well as with shared and automated vehicles. Incumbent industries were touched on in 4 of the 8 focus groups with participants pointing to a desire to be free from OPEC, oil companies and car companies. Employment was not a topic mentioned among the focus groups, but recent studies indicate that increased employment in the re-charging industry vs the refuelling sector might be a core benefit of electric mobility [79] while losses

are expected at the vehicle maintenance side [80]. Among experts, incumbents were also discussed, more in terms of competing technologies like hydrogen and biofuels, and the position of the biofuel industries in Finland and Sweden (R37, R51) or the role of local car and truck producers in Sweden (R49, R51, R56, R59). In both cases, local employment opportunities played an important role in EV incentive discussions (R60), although not without acknowledging the expected losses in relation to vehicle maintenance. Besides incumbents, unambitious politicians were depicted as a source of resistance, especially in Denmark (35.6% of the interviews) and Finland (14%). Interestingly, the few incumbent fossil fuel or biofuel companies we spoke to primarily advertised themselves as energy traders: dealing in petrol, biofuels, electricity and other products (insurances, phones, etc.), wherever they saw a market. Of course, this still implies a certain conservatism and reactivism, and does not compare to the proactive positions that other full EV producers, renewable energy generators or electricity storage systems developers take. Yet it also highlights that (some of) those pre-existing industries are moving and that EVs are co-opted into existing systems. Whether this is a positive development depends on the observer's desired speed of the transition and the rate of change of the supply chains within legal, technological and wider economic bounds (outside direct investment decisions).

In short, the environmental, fuel and economic effects of EVs are both reinforcing and challenging automobility. They reinforce automobility through guilt free driving and potential price competition from oversupplied ICEVs and fuel. Automobility is also reproduced through competing interests, political priorities and a certain level of reactivism within society among established industries and institutions. And automobility is challenged through alternative infrastructure and the growing public awareness of environmental effects of personal car use. These contradictions and earlier insights highlight that EVs offer a transformation of personal car-based transport, but not of automobility. The latter only transitions in conjunction with developments in shared and automated driving and external measures aimed to limit car ownership and use.

5 Discussion and Conclusion

Automobility is a dynamically performed set of practices with a broad material and discursive underpinning. It depicts an entrenched mobility regime, but because of its constant re-performative use is also open to change. Our empirical data confirms earlier conclusions that most change over the last decades involved the co-option and integration of new elements into the system of automobility – thus furthering overall car use. Yet, we also find empirical indications that emerging external influences in automation, connectivity and urban space use, do in fact question the self-reproducing nature of automobility. Rephrased, EVs, on their own and without external transitional

developments, represent a substitution of combustion engines with electric drivetrains and as merely reproduce the normality of automobility.

Still, as Table 5 summarizes, EVs highlight complicated trade-offs when put into the context of reforming or reinforcing automobility. Some effects on Nordic automobility are mostly positive: such as complementing intermodality, challenging gender roles, or the generation of beneficial employment and innovation effects. Some effects are mostly negative, such as increased car usage, or the societal embeddedness of intensive driving practices and norms. A great many are mixed, such as the effects of EVs and charging infrastructure on urbanization and suburbanization, or their impact on oil dependence. This reminds us that EVs need to be put in the context of, or even blanketed by, strong policy mixes to capture those aspects that challenge automobility—if that is indeed the goal of Nordic policy—and avoid those that entrench it.

Table 5: Summary of effects of Nordic EVs on automobility

	Elements	Effects on Nordic automobility	Results and explanation*
Vehicle use	Car use	Negative	- EV adopters drive further on a daily basis (but similar km/day to other new car buyers) --- EVs bought primarily as a second car (replacement or additionally) --- EVs contribute to congestion/traffic jams and the need for parking spaces and roads + EVs substitute for some ICEVs
	Intermodality/seamless transfers	Positive	++ EVs complement and increasingly are used with intermodal modes of transport such as taxis, buses or trains
	Cocooning/fortressing	Mostly negative	--- Absence of engine noise strengthens performance and luxury aspects of cars +/- Can facilitate digital connectivity that encourages car sharing or vehicle-to-grid, but also ease long term inactivity and reinforce cocooning
Car in daily life	(Sub)urbanization	Mixed	+/- Charging infrastructure is resource intensive but can also alleviate range anxiety +/- Electrification is not limited to automobility alone and opens up to alternative space use (indoors)
	Work-life balance (connected, automation, mobile offices).	Mixed	+/- Can strengthen cars as “indoor offices” which may displace commuting but can also reinforce cocooning +/- Could be synergistic towards automated mobility
Symbolism of vehicle	Expression of gender	Positive	++ EVs are challenging norms about masculinity and femininity around cars
	Expression of identity	Mostly negative	++ Strengthens climate consciousness - Reduces feelings of guilt for driving -- Can reinforce notions of freedom and joy of driving
	Expression of class/wealth	Mixed	+ Smaller, more affordable and mass market vehicles can reach a wider range of consumers - Larger, less affordable luxury items will only exacerbate wealth inequality

Effects of electrification	Environmental stewardship	Mostly positive	+++ Reductions in carbon dioxide and greenhouse gas emissions + Reductions in local ambient/particulate air pollution -- Environmental impacts associated with manufacturing and batteries
	Oil independence	Mixed	+++ EVs come to substitute for fossil fuels and therefore promote oil independence - EVs could depress oil prices, making conventional transport more affordable
	Economic effects (Employment, competitiveness, growth and innovation)	Mostly positive	++ Can promote linkages to other sectors (electricity, battery storage, mobility as a service, automation) ++ Promotion of new markets (energy services, energy trading) ++ Enhancement of local employment around EVs, EV re-charging -- Loss of maintenance, sales and revenues at automotive dealerships and fuel traders

Source: Authors. *Note: + indicates a recognized positive effect by our experts, focus group participants and survey findings that challenges automobility, - indicates a negative effect that embeds automobility. The number of marks reflects the degree to which we conclude they do so: one mark indicates a slight effect, two marks a moderate effect, three marks a strong effect.

For instance, it is primarily in the co-deployment and development of EVs with automation and increased connectivity that EVs challenge automobility itself. Additionally, automobility is challenged by measures around usage and access, like those that limit car use in urban environments. Given this, future transport research and policy should take into account future market developments and turnover rates in the car fleet and fuel industry. Attention needs to be paid to vehicle marketing, with target groups beyond the well-off suburbanites and with a focus on more rational car purchase decisions: not a car for a few days a year (that long distance holiday or family visit), but a car for most days of the year (commute to work, visit local family, shopping) [81]. There is clear urgency to focus both research and policy support on shared (most likely automated) EV fleets, further electrification and a reduction in private transport. Regarding the latter, our paper finds that increased connectivity is not something we should embrace automatically: the moment commuting becomes a joyful/useful event, it is no longer a barrier that people want to circumvent. Studies have found a relatively stable “acceptable” commuting time, but connectivity and automation might disrupt this which would counter a reduction of vehicle miles. Similarly, alternative enclosed road environments might sound amazing, but only as long as this is in conjunction with a reduction in private transport.

In laying out these findings, our study points to various other future research directions. For instance, we have treated all aspects of EVs as the same for our study, grouping together PHEVs and BEVs, grouping together countries, and grouping together different makes and models, from the more luxurious and higher priced Teslas and BMWs to the more mass market produced Volkswagens and Renaults. It could very well be that particular types, national contexts, and models reinforce, or reform,

automobility in different ways. Furthermore, attenuated analysis on these aspects would be useful. Same with exploring the extent to which EVs are interoperable with, or compete with, emerging innovations such as ridesharing, automated mobility, micro-mobility (electric skateboards, scooters, bikes, etc.) and other forms of electric mobility. Do EVs harmonize with these innovations, or threaten them?

Basically, research and policy are both in need of a longer term vision that focusses fully on the elements that keep ‘the cracks’ in automobility open [14,82], presuming at least they want to challenge and subvert it. For example, through a transport carbon tax or by promoting EVs, but only to the extent that they do not compete with public transport or more active modes of cycling and walking. To offer national level guidance on car free and conventional car free zones. Or to regulate the opening of transport companies’ databases through standardized application programming interfaces to enable intermodal Mobility-as-a-Service functionality by third-parties. Such efforts would also need to include attention to the distributional justice discussions behind the policy incentives for electric mobility [16,83]. In other words, to have a transport vision that acknowledges that (1) private mobility for all is not possible (even if socially desirable) and (2) that a mobility for the rich is undesirable (even if costs are the primary impediment). No matter how we get there, transport may be in need of drastic, more transformative changes to practices and technologies. Unfortunately, at present automobility is only marginally affected by electrification because it is shifting the goal posts while only organizing a marginal changeover of the players. It may very well be time to envision how the game of automobility itself is designed, played, and evaluated.

6 References

- [1] R. Schaeffer, R. Sims, J. Corfee-Morlot, F. Creutzig, X. Cruz-Nunez, D. Dimitriu, M. D’Agosto, Transport, in: Working Group III Contribution to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Climate Change 2014: Mitigation of Climate Change, Chapter 8, Cambridge University Press, Geneva, 2014.
- [2] IRENA, Global Energy Transformation: A Roadmap to 2050, International Renewable Energy Agency, Abu Dhabi, 2018.
- [3] IEA, Global EV Outlook 2019: Scaling-up the transition to electric mobility, OECD/International Energy Agency, 2019. <https://doi.org/10.1787/35fb60bd-en>.
- [4] J. Urry, The “System” of Automobility, *Theory, Culture & Society*. 21 (2004) 25–39. <https://doi.org/10.1177/0263276404046059>.
- [5] B.K. Sovacool, J. Axsen, Functional, symbolic and societal frames for automobility: Implications for sustainability transitions, *Transportation Research Part A: Policy and Practice*. 118 (2018) 730–746. <https://doi.org/10.1016/j.tra.2018.10.008>.
- [6] R.J. Orsato, M. Dijk, R. Kemp, M. Yarime, The electrification of automobility: The bumpy ride of electric vehicles toward regime transition, in: F.W. Geels, R. Kemp, G. Dudley, G. Lyons (Eds.), *Automobility in Transition?: A Socio-Technical Analysis of Sustainable Transport*, Routledge, New York & London, 2012: pp. 205–228.
- [7] M. Sheller, The Emergence of New Cultures of Mobility: Stability, Openings and Prospects, in: F.W. Geels, R. Kemp, G. Dudley, G. Lyons (Eds.), *Automobility in Transition: A Socio-Technical Analysis of Sustainable Transport*, Routledge, New York, 2012: pp. 180–202.

- [8] B.K. Sovacool, Experts, theories, and electric mobility transitions: Toward an integrated conceptual framework for the adoption of electric vehicles, *Energy Research & Social Science*. 27 (2017) 78–95. <https://doi.org/10.1016/j.erss.2017.02.014>.
- [9] F. Sprei, Disrupting mobility, *Energy Research & Social Science*. 37 (2018) 238–242. <https://doi.org/10.1016/j.erss.2017.10.029>.
- [10] B.K. Sovacool, L. Noel, R.J. Orsato, Stretching, embeddedness, and scripts in a sociotechnical transition: Explaining the failure of electric mobility at Better Place (2007–2013), *Technological Forecasting and Social Change*. 123 (2017) 24–34. <https://doi.org/10.1016/j.techfore.2017.05.037>.
- [11] W.J. Mitchell, C.E. Borroni-Bird, L.D. Burns, *Reinventing the Automobile: Personal Urban Mobility for the 21st Century*, The MIT Press, Cambridge, Mass, 2010.
- [12] H. Turton, F. Moura, Vehicle-to-grid systems for sustainable development: An integrated energy analysis, *Technological Forecasting and Social Change*. 75 (2008) 1091–1108. <https://doi.org/10.1016/j.techfore.2007.11.013>.
- [13] G. Crabtree, The coming electric vehicle transformation, *Science*. 366 (2019) 422–424. <https://doi.org/10.1126/science.aax0704>.
- [14] F. Friis, An alternative explanation of the persistent low EV-uptake: The need for interventions in current norms of mobility demand, *Journal of Transport Geography*. 83 (2020) 102635. <https://doi.org/10.1016/j.jtrangeo.2020.102635>.
- [15] L. Kanger, F.W. Geels, B. Sovacool, J. Schot, Technological diffusion as a process of societal embedding: Lessons from historical automobile transitions for future electric mobility, *Transportation Research Part D: Transport and Environment*. In press (2018). <https://doi.org/10.1016/j.trd.2018.11.012>.
- [16] J. Henderson, EVs Are Not the Answer: A Mobility Justice Critique of Electric Vehicle Transitions, *Annals of the American Association of Geographers*. 0 (2020) 1–18. <https://doi.org/10.1080/24694452.2020.1744422>.
- [17] B. Nykvist, M. Nilsson, The EV paradox – A multilevel study of why Stockholm is not a leader in electric vehicles, *Environmental Innovation and Societal Transitions*. 14 (2015) 26–44. <https://doi.org/10.1016/j.eist.2014.06.003>.
- [18] D. Addison, M. Al-Chalabi, C.A. Elwell, M. Evans, N. Salmond, R. Sauders, *Open Roads, Anxious Drivers: A Technology and Policy Assessment for Long Range Electric Vehicles in the UK.*, Energy Policy Project, London, 2010.
- [19] E. Graham-Rowe, B. Gardner, C. Abraham, S. Skippon, H. Dittmar, R. Hutchins, J. Stannard, Mainstream consumers driving plug-in battery-electric and plug-in hybrid electric cars: A qualitative analysis of responses and evaluations, *Transportation Research Part A: Policy and Practice*. 46 (2012) 140–153. <https://doi.org/10.1016/j.tra.2011.09.008>.
- [20] J.J. Michalek, M. Chester, P. Jaramillo, C. Samaras, C.-S.N. Shiao, L.B. Lave, Valuation of plug-in vehicle life-cycle air emissions and oil displacement benefits, *PNAS*. 108 (2011) 16554–16558. <https://doi.org/10.1073/pnas.1104473108>.
- [21] N. Berkeley, D. Bailey, A. Jones, D. Jarvis, Assessing the transition towards Battery Electric Vehicles: A Multi-Level Perspective on drivers of, and barriers to, take up, *Transportation Research Part A: Policy and Practice*. 106 (2017) 320–332. <https://doi.org/10.1016/j.tra.2017.10.004>.
- [22] F.W. Geels, ed., *Automobility in transition?: a socio-technical analysis of sustainable transport*, Routledge, New York, 2012.
- [23] L. Fridstrøm, From innovation to penetration: Calculating the energy transition time lag for motor vehicles, *Energy Policy*. 108 (2017) 487–502. <https://doi.org/10.1016/j.enpol.2017.06.026>.
- [24] S. Hardman, A. Chandan, G. Tal, T. Turrentine, The effectiveness of financial purchase incentives for battery electric vehicles – A review of the evidence, *Renewable and Sustainable Energy Reviews*. 80 (2017) 1100–1111. <https://doi.org/10.1016/j.rser.2017.05.255>.

- [25] J. Kester, L. Noel, G. Zarazua de Rubens, B.K. Sovacool, Policy mechanisms to accelerate electric vehicle adoption: A qualitative review from the Nordic region, *Renewable and Sustainable Energy Reviews*. 94 (2018) 719–731. <https://doi.org/10.1016/j.rser.2018.05.067>.
- [26] M. Sheller, J. Urry, The New Mobilities Paradigm, *Environ Plan A*. 38 (2006) 207–226. <https://doi.org/10.1068/a37268>.
- [27] N. Spurling, A. McMeekin, Interventions in practices: Sustainable mobility policies in England, in: *Social Practices, Intervention and Sustainability: Beyond Behaviour Change*, Routledge, London, 2014.
- [28] K. Barad, Posthumanist performativity: Toward an understanding of how matter comes to matter, *Signs*. 28 (2003) 801–831.
- [29] S.C. Rajan, Automobility and the liberal disposition, *The Sociological Review*. 54 (2006) 113–129. <https://doi.org/10.1111/j.1467-954X.2006.00640.x>.
- [30] D. Lupton, Monsters in metal cocoons: “Road rage” and cyborg bodies, *Body & Society*. 5 (1999) 57–72.
- [31] J. Beckmann, Automobility—A Social Problem and Theoretical Concept, *Environ Plan D*. 19 (2001) 593–607. <https://doi.org/10.1068/d222t>.
- [32] J. Faulconbridge, A. Hui, Traces of a Mobile Field: Ten Years of Mobilities Research, *Mobilities*. 11 (2016) 1–14. <https://doi.org/10.1080/17450101.2015.1103534>.
- [33] M. Featherstone, Automobilities: An Introduction, *Theory, Culture & Society*. 21 (2004) 1–24. <https://doi.org/10.1177/0263276404046058>.
- [34] K.G. Reese, Accelerate, Reverse, or Find the Off Ramp? Future Automobility in the Fragmented American Imagination, *Mobilities*. 11 (2016) 152–170. <https://doi.org/10.1080/17450101.2015.1097037>.
- [35] M. Sheller, Automotive Emotions: Feeling the Car, *Theory, Culture & Society*. 21 (2004) 221–242. <https://doi.org/10.1177/0263276404046068>.
- [36] F.W. Geels, Low-carbon transition via system reconfiguration? A socio-technical whole system analysis of passenger mobility in Great Britain (1990–2016), *Energy Research & Social Science*. 46 (2018) 86–102. <https://doi.org/10.1016/j.erss.2018.07.008>.
- [37] J. Axsen, K.S. Kurani, Social Influence, Consumer Behavior, and Low-Carbon Energy Transitions, *Annual Review of Environment and Resources*. 37 (2012) 311–340. <https://doi.org/10.1146/annurev-environ-062111-145049>.
- [38] J.L. Kent, Still Feeling the Car – The Role of Comfort in Sustaining Private Car Use, *Mobilities*. 10 (2015) 726–747. <https://doi.org/10.1080/17450101.2014.944400>.
- [39] L. Steg, Car use: lust and must. Instrumental, symbolic and affective motives for car use, *Transportation Research Part A: Policy and Practice*. 39 (2005) 147–162. <https://doi.org/10.1016/j.tra.2004.07.001>.
- [40] S. Seebauer, The psychology of rebound effects: Explaining energy efficiency rebound behaviours with electric vehicles and building insulation in Austria, *Energy Research & Social Science*. 46 (2018) 311–320. <https://doi.org/10.1016/j.erss.2018.08.006>.
- [41] J.H.M. Langbroek, J.P. Franklin, Y.O. Susilo, How would you change your travel patterns if you used an electric vehicle? A stated adaptation approach, *Travel Behaviour and Society*. 13 (2018) 144–154. <https://doi.org/10.1016/j.tbs.2018.08.001>.
- [42] M. Hamamoto, An empirical study on the behavior of hybrid-electric vehicle purchasers, *Energy Policy*. 125 (2019) 286–292. <https://doi.org/10.1016/j.enpol.2018.10.042>.
- [43] P. Graves-Brown, From Highway to Superhighway: The Sustainability, Symbolism and Situated Practices of Car Culture, *Social Analysis: The International Journal of Social and Cultural Practice*. 41 (1997) 64–75.
- [44] D. Campbell, The biopolitics of security: Oil, empire, and the sports utility vehicle, *American Quarterly*. 57 (2005) 943–972. <https://doi.org/10.1353/aq.2005.0041>.
- [45] F.W. Geels, G. Dudley, R. Kemp, Findings, conclusions and assessments of sustainability transitions in automobility, in: F.W. Geels, R. Kemp, G. Dudley, G. Lyons (Eds.), *Automobility in*

- Transition? A Socio-Technical Analysis of Sustainable Transport, Routledge, London and New York, 2012: pp. 335–374.
- [46] S. Böhm, C. Jones, C. Land, M. Paterson, Introduction: Impossibilities of automobility, in: S. Böhm, C. Jones, C. Land, M. Paterson (Eds.), *Against Automobility*, Blackwell Publishers/Sociological Review, Malden, Mass, 2006: pp. 3–16.
 - [47] M.J. Cohen, A Social Problems Framework for the Critical Appraisal of Automobility and Sustainable Systems Innovation, *Mobilities*. 1 (2006) 23–38.
<https://doi.org/10.1080/17450100500489106>.
 - [48] J. Urry, *What is the Future?*, Paperback Octavo edition, Polity Press, Cambridge, UK ; Malden, MA, 2016.
 - [49] S. Böhm, C. Jones, C. Land, M. Paterson, eds., *Against Automobility*, Blackwell Publishers/Sociological Review, Malden, Mass, 2006.
 - [50] J. Kester, Governing electric vehicles: mobilizing electricity to secure automobility, *Mobilities*. 13 (2018) 200–215. <https://doi.org/10.1080/17450101.2017.1408984>.
 - [51] P. Wells, P. Nieuwenhuis, R.J. Orsato, The nature and causes of inertia in the automotive industry: regime stability and non-change, in: F.W. Geels, R. Kemp, G. Dudley, G. Lyons (Eds.), *Automobility in Transition? A Socio-Technical Analysis of Sustainable Transport*, Routledge, New York and London, 2012: pp. 123–139.
 - [52] A. Grubler, C. Wilson, G. Nemet, Apples, oranges, and consistent comparisons of the temporal dynamics of energy transitions, *Energy Research & Social Science*. 22 (2016) 18–25.
<https://doi.org/10.1016/j.erss.2016.08.015>.
 - [53] F. Kern, K.S. Rogge, The pace of governed energy transitions: Agency, international dynamics and the global Paris agreement accelerating decarbonisation processes?, *Energy Research & Social Science*. 22 (2016) 13–17. <https://doi.org/10.1016/j.erss.2016.08.016>.
 - [54] B.K. Sovacool, How long will it take? Conceptualizing the temporal dynamics of energy transitions, *Energy Research & Social Science*. 13 (2016) 202–215.
<https://doi.org/10.1016/j.erss.2015.12.020>.
 - [55] B.K. Sovacool, F.W. Geels, Further reflections on the temporality of energy transitions: A response to critics, *Energy Research & Social Science*. 22 (2016) 232–237.
<https://doi.org/10.1016/j.erss.2016.08.013>.
 - [56] M. McLuhan, *Understanding media: The extensions of man*, McGraw-Hill, London and New York, 1964. <https://designopendata.files.wordpress.com/2014/05/understanding-media-mcluhan.pdf> (accessed November 20, 2018).
 - [57] H. van Lente, Navigating foresight in a sea of expectations: lessons from the sociology of expectations, *Technology Analysis & Strategic Management*. 24 (2012) 769–782.
<https://doi.org/10.1080/09537325.2012.715478>.
 - [58] J. Kester, L. Noel, G. Zarazua de Rubens, B.K. Sovacool, Promoting Vehicle to Grid (V2G) in the Nordic region: Expert advice on policy mechanisms for accelerated diffusion, *Energy Policy*. 116 (2018) 422–432. <https://doi.org/10.1016/j.enpol.2018.02.024>.
 - [59] L. Noel, G. Zarazua de Rubens, B.K. Sovacool, J. Kester, Fear and loathing of electric vehicles: The reactionary rhetoric of range anxiety, *Energy Research & Social Science*. 48 (2019) 96–107.
<https://doi.org/10.1016/j.erss.2018.10.001>.
 - [60] L. Noel, G. Zarazua de Rubens, J. Kester, B.K. Sovacool, Beyond emissions and economics: Rethinking the co-benefits of electric vehicles (EVs) and vehicle-to-grid (V2G), *Transport Policy*. 71 (2018) 130–137. <https://doi.org/10.1016/j.tranpol.2018.08.004>.
 - [61] B.K. Sovacool, J. Kester, L. Noel, G.Z. de Rubens, Energy Injustice and Nordic Electric Mobility: Inequality, Elitism, and Externalities in the Electrification of Vehicle-to-Grid (V2G) Transport, *Ecological Economics*. 157 (2019) 205–217. <https://doi.org/10.1016/j.ecolecon.2018.11.013>.
 - [62] B.K. Sovacool, L. Noel, J. Kester, G. Zarazua de Rubens, Reviewing Nordic transport challenges and climate policy priorities: Expert perceptions of decarbonisation in Denmark, Finland, Iceland, Norway, Sweden, *Energy*. 165 (2018) 532–542.
<https://doi.org/10.1016/j.energy.2018.09.110>.

- [63] B.K. Sovacool, J. Kester, G.Z. de Rubens, L. Noel, Expert perceptions of low-carbon transitions: Investigating the challenges of electricity decarbonisation in the Nordic region, *Energy*. 148 (2018) 1162–1172. <https://doi.org/10.1016/j.energy.2018.01.151>.
- [64] IEA, Nordic Energy Research, Nordic EV Outlook 2018: Insights from leaders in electric mobility, International Energy Agency; Clean Energy Ministerial; Electric Vehicles Initiative; Nordic Energy Research, Paris, 2018.
- [65] Z. Liu, Q. Wu, L. Christensen, A. Rautiainen, Y. Xue, Driving pattern analysis of Nordic region based on National Travel Surveys for electric vehicle integration, *Journal of Modern Power Systems and Clean Energy*. 3 (2015) 180–189. <https://doi.org/10.1007/s40565-015-0127-x>.
- [66] E. Figenbaum, Electromobility status in Norway: Mastering long distances - the last hurdle to mass adoption, Institute of Transport Economics (TOI), Oslo, 2018. 978-82-480-2135-3.
- [67] L.-H. Björnsson, S. Karlsson, Electrification of the two-car household: PHEV or BEV?, *Transportation Research Part C: Emerging Technologies*. 85 (2017) 363–376. <https://doi.org/10.1016/j.trc.2017.09.021>.
- [68] R. Hössinger, C. Link, A. Sonntag, J. Stark, Estimating the price elasticity of fuel demand with stated preferences derived from a situational approach, *Transportation Research Part A: Policy and Practice*. 103 (2017) 154–171. <https://doi.org/10.1016/j.tra.2017.06.001>.
- [69] J. Odeck, K. Johansen, Elasticities of fuel and traffic demand and the direct rebound effects: An econometric estimation in the case of Norway, *Transportation Research Part A: Policy and Practice*. 83 (2016) 1–13. <https://doi.org/10.1016/j.tra.2015.10.003>.
- [70] S.M.N. Oppegaard, A. Ilsøe, B. Rolandsson, Uber in the Nordic countries: Challenges and adjustments, (2019) 4.
- [71] ElectriCity Media, ElectriCity. (2014). <https://www.electricitygoteborg.se/en/media> (accessed December 12, 2018).
- [72] Mercedes-Benz, Filestress wordt 'me-time' [Traffic will become 'me-time'], Fd.NI. (2018). <https://fd.nl/advertorial/mercedesnext/1279033/filestress-wordt-me-time> (accessed December 17, 2018).
- [73] C.D. Harper, C.T. Hendrickson, S. Mangones, C. Samaras, Estimating potential increases in travel with autonomous vehicles for the non-driving, elderly and people with travel-restrictive medical conditions, *Transportation Research Part C: Emerging Technologies*. 72 (2016) 1–9. <https://doi.org/10.1016/j.trc.2016.09.003>.
- [74] Z. Wadud, D. MacKenzie, P. Leiby, Help or hindrance? The travel, energy and carbon impacts of highly automated vehicles, *Transportation Research Part A: Policy and Practice*. 86 (2016) 1–18. <https://doi.org/10.1016/j.tra.2015.12.001>.
- [75] D. Milakis, B. van Arem, B. van Wee, Policy and society related implications of automated driving: A review of literature and directions for future research, *Journal of Intelligent Transportation Systems*. 21 (2017) 324–348. <https://doi.org/10.1080/15472450.2017.1291351>.
- [76] N. Bergman, T. Schwanen, B.K. Sovacool, Imagined people, behaviour and future mobility: Insights from visions of electric vehicles and car clubs in the United Kingdom, *Transport Policy*. 59 (2017) 165–173. <https://doi.org/10.1016/j.tranpol.2017.07.016>.
- [77] M. Coffman, P. Bernstein, S. Wee, Electric vehicles revisited: a review of factors that affect adoption, *Transport Reviews*. 37 (2017) 79–93. <https://doi.org/10.1080/01441647.2016.1217282>.
- [78] B.K. Sovacool, J. Kester, L. Noel, G.Z. de Rubens, The demographics of decarbonizing transport: The influence of gender, education, occupation, age, and household size on electric mobility preferences in the Nordic region, *Global Environmental Change*. 52 (2018) 86–100. <https://doi.org/10.1016/j.gloenvcha.2018.06.008>.
- [79] K. Turner, O. Alabi, M. Smith, J. Irvine, P.E. Dodds, Framing policy on low emissions vehicles in terms of economic gains: Might the most straightforward gain be delivered by supply chain activity to support refuelling?, *Energy Policy*. 119 (2018) 528–534. <https://doi.org/10.1016/j.enpol.2018.05.011>.

- [80] P. Holley, 'People are freaking out.' Will electric vehicles doom your neighborhood auto mechanic?, Washington Post. (2017).
<https://www.washingtonpost.com/news/innovations/wp/2017/12/11/people-are-freaking-out-why-electric-vehicles-might-doom-your-neighborhood-auto-mechanic/> (accessed December 17, 2018).
- [81] P. Plötz, N. Jakobsson, F. Sprei, On the distribution of individual daily driving distances, *Transportation Research Part B: Methodological*. 101 (2017) 213–227.
<https://doi.org/10.1016/j.trb.2017.04.008>.
- [82] L. Ingeborgrud, M. Ryghaug, The role of practical, cognitive and symbolic factors in the successful implementation of battery electric vehicles in Norway, *Transportation Research Part A: Policy and Practice*. 130 (2019) 507–516. <https://doi.org/10.1016/j.tra.2019.09.045>.
- [83] B.K. Sovacool, J. Kester, L. Noel, G.Z. de Rubens, Energy Injustice and Nordic Electric Mobility: Inequality, Elitism, and Externalities in the Electrification of Vehicle-to-Grid (V2G) Transport, *Ecological Economics*. 157 (2019) 205–217. <https://doi.org/10.1016/j.ecolecon.2018.11.013>.