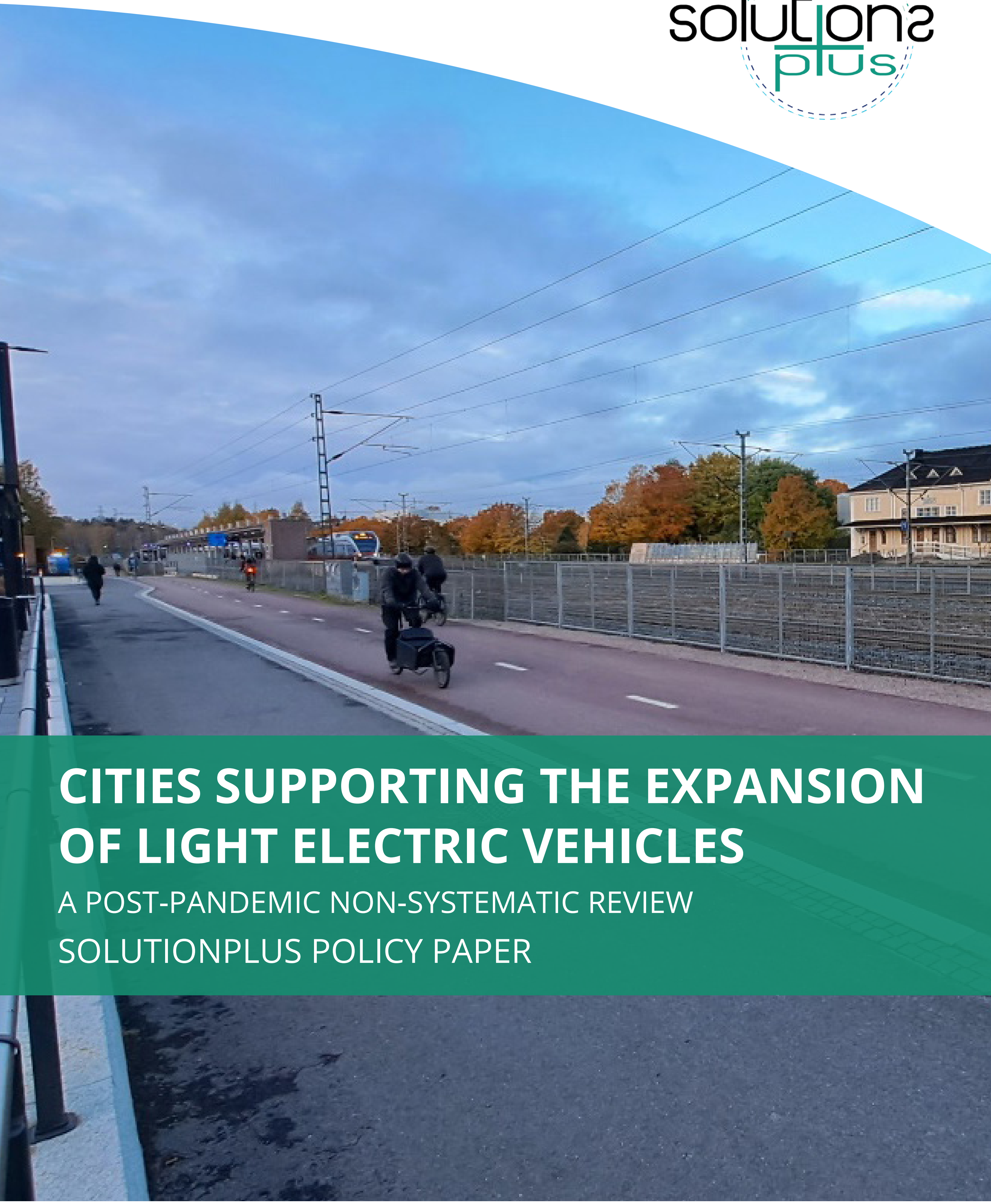

CITIES SUPPORTING THE EXPANSION OF LIGHT ELECTRIC VEHICLES

A POST-PANDEMIC NON-SYSTEMATIC REVIEW

SOLUTIONPLUS POLICY PAPER

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TITLE

Cities supporting the expansion of light electric vehicles : A post-pandemic non-systematic review

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EXECUTIVE SUMMARY

The human transport system evolves constantly, but also currently a great path-dependencies. Currently the system based on privately owned, heavy, internal combustion engine vehicles is both likely to continue expanding and challenged by the appearance of light electric vehicles. To avoid the superficial improvement that a transition towards heavy electric vehicles would bring about, policies supporting light electric vehicles are needed.

To achieve any relevant impact, these policies need to be directed towards the fundamental mechanisms at work in each city or location. Given the urgency to address the unsustainability crisis, especially in relation to the reduction of carbon emissions, lengthy processes of data collection and analysis should be avoided, in favor of workable compromises with stakeholders to lower the barriers to the individual-level adoption of light electric vehicles, and to support system-level opportunities.

An increase of mobility with light electric vehicles (LEVs) will have the envisioned sustainability benefits when it substitutes other modes of transport that are more energy and material intensive, and/or when it increases the fair accessibility to activities that support human well-being (i.e., when it reduces social inequalities).

Policy recommendations:

1. The users of light electric vehicles need to be supported with appropriate space: separate cycling routes that are safe, preferential access routes to zero-emission central areas to give a clear public message of support, integration with public transport through appropriate parking at the stations and on-board possibilities. At the metropolitan scale, regional routes for LEVs can support both work commuters and tourists.

2. To support the expansion of LEVs, its policies need to be aligned with the concept of mobility justice. The human experience of mobility is affected by differential power relations built around social issues of gender, race, and class, as well as global issues of resource extractivism and the displacement of emissions and waste. Policies supporting LEVs need to take into consideration how they may affect these issues, to ameliorate, instead of reproducing, existing inequalities.

3. The user experience of light electric mobility revolves around the vehicles themselves. For this reason, policies are required to easy the access to experiencing them, and to improving the experience of owning and replacing LEVs. Community programs to try e-bikes, followed by economic incentives to acquire them, can bring in new users. The role of public bike systems is also central to making LEVs better known: they should be electrified as soon as possible, together with the rest of the public transport fleet. Finally, the convenient experience of electric cars should be included in a new narrative of electric mobility, but heavy and big electric cars (e.g., SUVs) should be disincentive through taxes and banning them from central areas.

CONTENTS

Purpose	1,100
Coordination	3,500-4,000
SOLUTIONSplus partners	VTT
Contributors	Carlos Lamuela Orta, Eetu Wallius
Reviewers	

1 INTRODUCTION

Like most phenomena in life, human mobility has evolved with patterns of rise and decline: historic waves in the invention, adoption, peak and decline in use of different transport modes (Raulo et al., 2023). Electric micromobility might already be changing global urban mobility. At the same time, the transport system has great inertia and path-dependencies, and it is likely that most new technologies fail to survive and expand among competing entities. In any case, regardless of what is the real current trend, there is a reason to support the extension of electric micromobility. Automobility is pervasive as a system (Urry, 2004), but although cars have positive social impacts in the form of increased accessibility, liveability and safety, there is an equally systemic need to reduce the material, energy, and carbon-emissions footprint of human mobility. As the electrification process continues, we will see global city streets with more electric vehicles and less internal combustion engine (ICE) cars and buses. Furthermore, small vehicles and micromobility take up less space than conventional cars. Light electric vehicles (LEVs) or electric micromobility have thus a double efficiency benefit during their life cycle: from decreased emissions and from decreased space use. It is with the explicit goal of guiding policy makers in their support of such scenarios that this policy report should be read.

There are different definitions for LEVs and micromobility, but we take a very general acceptation to include any electric vehicle lighter than a fully-sized electric car: electrically pedal-assisted bicycles (EPACs), speed pedelecs, electric MTB, electric mopeds, electric motorcycles, electric cargo bikes, electric tricycles, electric recumbent cycles, electric velomobiles, electric trailers, electric folding cycles, electric self-balancing vehicles, electric scooters, and monowheels —even electric quadricycles of the EU L6 category (i.e., light electric cars). All these vehicles offer greater accessibility to valuable activities, thanks to increased range and speed when compared to active mobility (walking and cycling). In some cases and for some users, they also offer a level of comfort and convenience that surpasses that of public transport (specially buses) and of private cars (specially in dense urban environments with appropriate design features to support micromobility).

With an increasing variety of formats, from e-scooters to micro electric cars, LEVs have raised interest because of their theoretical potential to support more diverse user groups and applications. For example, in Europe both users and non-users perceive LEVs positively for environmental reasons, travel comfort and increased accessibility (Mesimäki & Lehtonen, 2023) — although they are also considered relatively less safe and practical (ibid.). The conventional wisdom is that the three key obstacles to the expansion of electric vehicles are battery range anxiety, lack of recharging stations, and high upfront costs (World Economic Forum, 2022). In addition to costs, the transport system and the overall cultural context, personal characteristics from age and gender to education and income level also influence the choice of ELVs as a transportation mode. Yet despite barriers, a large electrification of transport is indeed a very plausible process. Electric mobility, including the electrification of previously active mobility like cycling, is well aligned with the overall socio-technological evolution of human mobility that results in more energy and material use per capita, less physical effort, and longer distances travelled per capita. In this sense, the rise of light electric vehicles could have a clear benefit (reduced carbon emissions) or result in other problems related to wider sustainability, but it would not be a disruptive turn of events in the long-term evolution of mobility.

Both individual choice and policy discussions respond to technological evolution.

Technology evolves through selective forces (e.g., competing for resources and attention, not all inventions survive to become applied innovations). But in opposition to biological evolution, the branches representing the diversity of technologies can rejoin and there is a feedback loop from successful innovation to earlier stages of research and invention in the process (van den Bergh, 2018, chapter 10). Some innovations require adjustments of the production system to become successful at scale; for example, electric cars with limited range might require a network of charging stations (ibid. p. 295). At the same time, behaviour and policy are also evolutionary processes that respond to randomness in the creation of variation and to selective pressures affecting replication. In this regard, it is worth considering how will electric micromobility expand: will its evolution respond mostly to market and individual behaviour dynamics (e.g., as a chaotic expansion of products, use, and waste), or will it be mostly determined by the evolution of policy (e.g., as collective support and regulation). Probably it will be a combination of the two mechanisms, but in any case policy is urgently required to avoid the most chaotic and negative future scenarios.

Despite data uncertainties, it seems clear that as of 2023 electric bicycles worldwide vastly outnumber electric cars, thanks to a large Chinese market with around 300 million e-bikes (Sun et al., 2023, quoting IEA data). But whereas in general there is no policy support for infrastructure specifically for electric micromobility, the policy momentum is high for electric car policy. For example, the European Union has put an end to the sales of combustion engine cars for 2035, and the replacement of the current stock is expected to be completed by 2050. In the long term, all personal mobility vehicles are likely to be electric. But future scenarios have very different consequences, even if they all share the electrification of most vehicles (see e.g., Kiviluoto et al., 2022, with future scenarios for Finland).

The question then for the second half of the XXI century is to a large extend that of light vs. heavy vehicles. What will be the percentages in the global vehicle stock for electric micromobility (from e-scooters to e-bikes), other light electric vehicles (tricycles and quadricycles) and for large electric vehicles (e.g., SUVs and minivans). Unfortunately, the current trend is the continuous growth of sales for large electric cars,[1] but social learning, collective action and policy can play an important role in offering alternative evolutionary paths.

1.1. THE EXPANSION AND DOMINANCE OF LIGHT ELECTRIC VEHICLES AS A PLAUSIBLE EVOLUTION OF TECHNOLOGIES FOR HUMAN MOBILITY?

Humanity has developed different technologies to move. The weight and the propulsion type of a vehicle are two important features among the many variables that get reconfigured in this technological evolution. In fact, these features were already present in the early times of the motorized vehicles and played an important role in the process that replaced horses and carriages. Before the introduction of the Ford Model T, the American vehicle market was composed of two categories: open, light-weight vehicles with a rear engine called "horseless carriages" or "runabouts" (e.g., the 1901 Oldsmobile Curved Dash); and heavier, closed vehicles that did not directly resembled horse carriages, but had a more powerful engine in the front, called "touring cars" (Standage, 2021, p. 72). Due to its versability it was the latter category of heavier vehicles that went on to expand and define the car market, despite being more expensive. Henry Ford

1 Paradoxically, this recent development was the unintended consequence of policies requiring more safety and emission efficiency from cars. The cap on emissions by vehicle weight pushed technical innovation (including illegal innovation, in the emission measure schemes later discovered as the "diesel-gate"), but its implementation as a weight-related maximum emission level also favoured commercially the larger cars that offered more features for a given price.

was the one to succeed in combining the performance of the heavier category with the affordability of the lighter category —a combination allowed by the use of vanadium steel (ibid.)

Image 1: "In My Merry Oldsmobile" sheet music featuring an Oldsmobile Curved Dash automobile, 1905, Wikipedia. Light vehicles competed with heavier versions already in the early phases of the evolution of automobility.

The other feature (energy source) was present even before the turning point between light and heavy. During the development of the automobile in Europe there were electric options. Following the first ever car ride by Bertha Benz in Germany, there were early races in France organized to test which was the better design that included participant vehicles powered by electricity and steam vehicles —as well as petrol combustion engines, which proved to be the most practical and reliable. For example, in the 1895 Paris-Bordeaux race there were two electric cars, but neither could complete the route (Standage, 2021, p. 61). In any case, up to 40% of the few existing cars where electric in late XIX North American cities, before declining because of then low-range batteries and high price when compared to the affordable oil-engine Ford Model T[2]. As with mobility in general (Uteng & Cresswell, 2016), gender also played a role here: reportedly these original electric cars where marketed specifically for women, because they were silent, clean and easy to operate when compared to oil engines that had to be cranked[3].

In sum, a variety of technology features has been available before, but the evolution of transport technologies has not yet resulted in the dominance of light and electric vehicles. The first dominant wave was light cars with combustion engines, then

2 See Daniel Sperling and Gil Tal: "The surprisingly long history of electric cars", TED-Ed https://www.youtube.com/watch?v=-EG6rqA2vvA

3 See an electric model that did not need cranking at Fully charged show: "Why Electric Cars Failed 100 Years Ago" https://www.youtube.com/watch?v=Xzk6acQO-KQ

gradually cars got heavier, and more recently cars got electrified. In addition to available technology, the rapid expansion of any given mode of transport is determined by economic and demographic factors (see Marquet & Miralles-Guasch, 2016, about the rise of motorcycles in Barcelona 2004-2012, up to represent one in four vehicles). On the contrary, the current emerging trend is the increasing offer of electric and heavy vehicles with a very good performance in all aspects affecting user experience and consumer status: from speed to carrying capacity to safety. It is in fact the comparatively lower safety offered by light electric vehicles that might be one of their main barriers preventing larger adoption[4].

1.2. LOWERING BARRIERS, SUPPORTING OPPORTUNITIES

It is important to discern between authentic barriers and opportunities, and those that are manufactured to appear as such because of other interests. For example, in the case of barriers to cycling (a main category for LEVs), lack of data is often represented as a barrier for policy. But research in most cities in the world, which have clearly car-centric policies, suggest there is more than enough knowledge about the state of cycling to inform policies to support it —what is missing is the political will to act, not more detailed data analyses (Nello-Deakin, 2020). Furthermore, insisting on the need for more data collection, data-based models, or data-driven applications, that is, insisting on the value of further datafication before policy can be designed and implemented can be used to postpone action through the tool of socially constructing ignorance or doubt (Nikolaeva, 2024).

Conversely, some "opportunities" in the mobility field are indeed efficient ways for capital investments to extract value from urban life and supported by public actors (e.g., see Moisio & Rossi, 2023, with a case-study of the delivery start-up Wolt in Finland), but do not constitute a feasible path towards less carbon intensive or more just mobility. Equally important is to consider how some barriers and opportunities are interconnected in feedback loops. For example, battery range anxiety is often mentioned as a barrier. Its solution through the construction of charging infrastructure could indirectly also solve the barrier of cost, if more recharging points result in the acceptance of lighter vehicles with smaller batteries and less range —but in turn this scenario would decrease the incentive of range anxiety to the policy of building more charging points.

1.3. VEHICLE OWNERSHIP VS. MOBILITY-AS-A-SERVICE AND SHARED ELECTRIC MOBILITY

Ownership and replacement of constantly evolving products has been a fundamental part of industrial development since the mid XX century. "Dynamic obsolescence", market segmentation, and yearly redesigns of a product's aesthetics appearance were a management innovation that appeared precisely in the car industry, introduced by the director of General Motors, Alfred P. Sloan. The GM cars (in fact, a collection of different brands) became status-symbols where consumers could express themselves in picking the color and aesthetics and "upgrade" as often as they could afford (and consumer finance played an important role here). In comparison, the previous management paradigm of Henry Ford's Model T was one of static ownership, where the car was before anything a practical, affordable to run product with a design that did not change for a long time—it was available only in black (Standage, 2021, chapter 5, 'You are what you drive').

4 The issue of raising the safety standards in light electric cars of the L6 or L7 category has been approached, for example, in REFLECTIVE —an EU project led by VTT, see: https://www.reflective-h2020.eu/concept-b/

And yet in the 2020s the discussion has been around Mobility-as-a-Service schemes, where consumers pay to access a vehicle, or mobility more generally, instead of owning a car. And argument for the feasibility of this fundamental change has been that currently it has been the smart phone, not the car, that has served as a constantly evolving product for consumers to show their aspirations and economic status (Standage, 2021, p. 87). Design obsolescence was introduced by Sloan around a hundred years ago, but its relevance only increased since the introduction of the iPhone in 2007 —and its implications for sustainability and consumer behavior remain a difficult act of "balancing creativity and longevity" (Alzaydi, 2024).

In this regard, there are several aspects of ownership and obsolescence that will affect the expansion, and the impacts, of light electric vehicles. In comparison to ICE vehicles , light electric vehicles provide a flexible means of mobility mainly due to the lack of regulation that would restrict their use. At the same time, in comparison to active means of mobility, light electric vehicles are convenient and fast, thus making them appealing to a wide audience. Consequently, light electric vehicles are well-suited for Mobility-as-a-Service schemes that have emerged in many parts of the world simultaneously with their broader expansion. In many areas, such schemes have even led the charge in the widespread adoption of light electric mobility.

But importantly here, research suggest that ownership modes have different sustainability impacts. For example for the case of e-scooters, privately owned ones make longer trips and are more likely to replace car trips than shared ones, which are more frequently combined with public transport (Oostendorp & Hardinghaus, 2023); and manufacturing accounts for more than 70% of their environmental impacts, so that intensifying the use rate of shared ones could reduce their impacts by at least 50% (Reis et al., 2023). Thus, policy guidelines for product longevity should be developed for the specific needs of light electric vehicles —for example about modular design (where individual components can be replaced without discarding the whole product) and recycling programs (Alzaydi, 2024).

2 METHOD AND APPROACH

This literature review of previously published reviews took place in February 2024 using Google scholar. It followed a non-systematic approach with the keywords: "Review" AND ("e-bike" or "electric bike" or "e-scooter" or "electric scooter" or "e-mopped" or "electric mopped" or "electric motorcycle" or "electric micromobility"). The most recent reviews were analyzed first, using a snow-balling process by which each considered article offered links to other relevant articles for this article's goal of providing policy recommendations. This snow-balling process was continued going back in the time of publication, with a time limit on January 2020 (included), which we take as the symbolic date for the COVID pandemic period. We have thus considered reviews published between January 2020 and January 2024.

For example, about e-bikes, Zhou et al. (2023) offer a systematic review of e-bike research in the last 50 years; Gu et al. (2021) offer an empirical review of recent two-wheeled mobility evolution dynamics in China; Bigazzi & Wong (2020) compile results from 24 published studies about the modal substitution of e-bikes. Whereas about e-scooters, Dias et al. (2021) review the literature in relation to pre/post pandemic changes in mobility in European cities, with a case study in Portugal; Wang et al. (2023) review findings about what modes e-scooters displace —relying on grey literature, as they argue that there are still few peer-reviewed studies of e-scooters modal shift.

In relation to public transport, Oeschger et al. (2020) published the first review of micromobility and public transport integration, based on 48 articles (in the shared micromobility category, the majority of the reviewed articles are about Chinese cities, in the privately owned category the majority are from the Global North). About autonomous vehicles, Narayanan et al. (2020) review the literature about their foreseeable impacts, which include the undesirable but likely increase in overall mobility, congestion, and inequality, and propose a suitable policy framework to respond to these challenges.

In addition, general books about the evolution of technology have been consulted, in particular those touching about the past and possible future of mobility (Banister, 2005; Sperling & Gordon, 2010; Sheller, 2018; van den Bergh, 2018; Standage, 2021).

3 FINDINGS

The benefits of increasing trips made with LEVs depend crucially on what traffic mode they substitute —if the substitute any. If LEVs represent instead a net increase in mobility, their benefit should come from increased accessibility to valued activities that have an impact on well-being (see Ferdman, 2021).

In the following subsections we present findings for the main LEV categories.

3.1 ELECTRIC BICYCLES (E-BIKES, PEDELECS)

Electric bicycles have raised in prominence during the past 20 years due to improvements in motor and battery technology coupled with an overall "cycling renaissance" that links to increased concern for the negative impacts of transport and ambitious goals to reduce emissions (for a review of research questions, see Bourne et al., 2022). The general lack of political support for concrete cycling policies, despite enough evidence of what would work (Nello-Deakin, 2020) has led to researchers calling for "integrated, research-based cycling policy" (Anaya-Boig, 2022).

Modal shift of e-bikes

The literature suggests that only around a third of new e-bike and electric micromobility trips come from car trips, although this percentage might reach different peaks in different locations and phases of their expansion. In China, in 2006-2010 the percentage of e-bikes that substituted car or taxi trips increased from 12% to 25% (or 1 in 4 e-bike trips), whereas the percentage that substituted bus trips remained around 50% (Cherry et al., 2016).

SWOT analysis of e-bikes

Strengths (promoting factors, best practices):

- E-bikes are on average 50% faster than mechanical bicycles (Schleinitz et al., 2017); therefore, with appropriate infrastructure they can offer regional commuting that is still competitive time-wise when compared to public transport or congested car roads.
- In highly auto-dependent contexts, personal (owned) e-scooters and e-bikes reduce transport emissions compared to the transport modes they replace (Reck et al., 2022, with data from the USA context).

Weaknesses (limiting factors, bad practices):

- The number and location of charging stations for e-bikes can become a limiting factor (Zhou et al., 2023); in some locations the safety of these charging points is also a limiting factor (e.g., the risk of batteries or e-bikes being stolen).
- E-bike accidents are a major concern in contexts with lots of trips, such as China (Zhou et al., 2023), although in the case of accident there aren't relevant differences in the type of injuries when compared to conventional cycling (Verstappen et al., 2021).
- In the context of high income countries in cold climate areas, the main barrier reported by users and would-be users are poor weather and road maintenance conditions (Simsekoglu & Klöckner, 2019).

Opportunities:

- Previous experience with e-bikes positively affects the intention to buy one (Simsekoglu & Klöckner, 2019); interventions offering free access to the experience of owning an electric bike improve self-classification as a regular cyclist (Bjørnarå et al., 2019).
- Successful experiences can scale up in other regions if there is a successful mechanism for international transfers in cycling policy (e.g., the case of Russia, see Bidordinova, 2021).
- Further support may come from the expansion of solar and photovoltaic technology for diversified charging infrastructure, not only associated with stations of shared e-bikes (Zhou et al., 2023).
- New data sources (Willberg et al., 2021) and data analysis methods for cycling studies are an opportunity to better characterize the current situation and the impacts of policy in cities.

Threats:

- In a context without appropriate legislation or data-gathering[5], the majority of light electric vehicles may remain unregistered, which makes it difficult to evaluate the evolution of modal share; the threat is that the rise in e-bikes goes unnoticed by official statistics. Another threat is narrow understanding of e-bikes as a modal share percentage, when instead the modal shift they make possible has systemic, life-course, and life-style elements (see Rérat et al., 2024).
- With growth in e-bike adoption, increasing accidents of e-bike users is a risk, specially of vulnerable users such as online shopping delivery (i.e., "riders" or "couriers") (Zhou et al., 2023).

5 As is the case in ASEAN countries, according to Gitano-Brigs et al., Policy Guidelines for Electric 2- & 3-wheelers for South-east Asia. SOLUTIONSplus project, e-mobility toolbox, available at: https://emobility.tools/tool/4f5e0698-f913-4738-8850-3d5d2c505070 The e-Mobility Toolbox is a joint product of the EU Horizon 2020-supported SOLUTIONSplus project led by the Urban Electric Mobility Initiative and the Global Electric Mobility Programme to Support Countries with the Shift to Electric Mobility led by the United Nations Environment Programme.

- There is a safety risk in the potential growth of indoor e-bike charging (Zhou et al., 2023); or in outdoor parking in locations with high temperatures and solar radiation.
- In contexts that are adverse to the experience of cycling, or with a strong cultural appreciation of the car as a status symbol, e-bike ownership can be part of the pathway towards motorization (Sun et al., 2023), with a later modal shift happening from e-bikes to cars (Ling et al., 2015).
- The environmental impacts created by e-bikes has not yet received attention in the research literature (Zhou et al., 2023); these include issues from resource extraction for the materials in the batteries, to the disposal of waste along the process until the final recycling or disposal of the bike.

3.2 E-SCOOTERS (TROTTINETTE ÉLECTRIQUE)

E-scooters are electric-powered stand-up two-wheel vehicles that are mainly designed for short distance transport within urban settings. E-scooters usually have smaller wheels compared to e-bikes, therefore requiring smoother surfaces to be used while making them more sensitive to infrastructure deficits. E-scooters can be privately owned, but dockless services are currently more common. This commercial version is likely to have more environmental impacts than the active and public transport trips it replaces, because the scooters’ short life span and nigh-time recollection done by diesel vans raise their life cycle emissions by travelled distance / person (Hollingsworth et al., 2019). For the USA context, shared electric-scooters increase emissions, while owned electric-scooters reduce emissions compared to the transport mode they replace (Reck et al., 2022).

The e-scooter short-term rent services that first emerged in 2017 in the US and expanded quickly to most big cities across the globe, usually without any planning (Dias et al., 2021) . These services provide access to scooters, usually around city centres, which the users can locate and deploy using a mobile app and ride them to their destination from where the next user can pick the e-scooter. During the last few years, E-scooters have transformed cityscapes with many new entrants in the market. Their proliferation has not been without problems, raising concerns related to social and environmental sustainability, including the life-cycle environmental impacts, safety, and the use of public space (Lipovsky, 2021). In response, many cities have posed restrictions on their use to alleviate the problems and concerns associated with these devices (e.g., night restrictions, see Pakarinen et al., 2023). Although the initial proposition of the e-scooter service providers was to contribute to sustainable urban mobility by replacing trips previously made by car, there exists a growing body of research suggesting that in most cities they mainly replace active modes and the public transport (Wang et al., 2023). In addition, dockless e-scooters rely on a user base that is disproportionally local, young, male, with relatively higher education (ibid., data from USA).

Modal shift of e-scooters

There is mixed evidence regarding the modal substitution of e-scooters, and research suggests that shared and private scooters differ in which modes they substitute, with private e-scooters replacing more car trips than shared ones (Oostendorp & Hardinghaus, 2023), although users of e-scooters are in general highly multi-modal and more likely to own an e-bike and a car (Kazemzadeh & Sprei, 2024). In general, shared e-scooters mainly replace walking (Wang et al., 2023), but in Europe they have been shown to also replace public transport trips (Wang et al., 2023), while in heavily car-dependent contexts like the USA they also replace car, ride-hailing and taxi trips (ibid.).

There is, however, little evidence of what are the conditions that influence mode substitution in the case of e-scooters. One possible explanation for the substitution of walking and public transport is that shared e-scooter services are mainly limited to central areas that are characterized by public transport and pedestrian facilities, causing them to compete with sustainable modes in speed and convenience rather than replacing private cars (Krauss et al., 2024).

SWOT analysis of E-scooters

Strengths (promoting factors, best practices):

- E-scooters are perceived as useful, reliable, and enjoyable (Javadinasr et al., 2022).
- E-scooters are in general cheaper to acquire than e-bikes.
- Privately owned e-scooters are easier to carry on public transport vehicles than e-bikes, as it is easier to enable sufficient capacity onboard. This allows using privately owned e-scooters for both first- and last mile mobility (Oeschger et al., 2020).

Weaknesses (limiting factors, bad practices):

- Despite their potential to support multi-modal trips, many cities have prohibited e-scooters within public transport, allegedly due to concerns over battery safety. Furthermore, the fact that shared e-scooter services are available mainly in areas with good transport offerings but may be prohibited from these public transport trips causes them to compete with public transport.
- Shared e-scooters tend to cause a large number of accidents, due to neglecting of traffic rules, and riding intoxicated (Vasara et al., 2022, with data from Helsinki, Finland).
- E-scooters are also a public health concern (Nisson et al., 2020) and their users are perceived as more risky drivers than users of e-bikes (Useche et al., 2022). Another public health weakness is related to the problem of sedentary lifestyles, as e-scooters do not imply physical activity like e-bikes, and offer very few, if any, health benefits in this regard, therefore having a net negative public health impacts when replacing active modes (Bozzi & Aguilera, 2021).
- Shared e-scooters are redistributed using ICE-vehicles, which leads to increased environmental impacts and traffic (Reis et al., 2023).
- Shared e-scooter services use public space in an uncontrolled manner as they lack dedicated infrastructure for parking and riding (Bozzi & Aguilera, 2021).
- Shared e-scooters are mainly used on trips that would have been otherwise been made using active modes or public transport (Wang et al., 2023).
- Shared e-scooters have a short lifespan and are targets for vandalism (Bozzi & Aguilera, 2021; Reis et al., 2023).
- E-scooters are limited to certain groups of users due to requiring certain physical capabilities or attitudes toward risk; shared e-scooters are mostly used by male, young and highly educated (Bozzi & Aguilera, 2021).
- Shared e-scooters have gathered negative media coverage, and divisive public opinions which can be difficult to reconcile (Wallgren et al., 2023).
- E-scooters are more sensitive to infrastructure than e-bikes (Ma et al., 2021), which could cause safety issues, limit their operational environment and necessitate infrastructure investments

Opportunities:

- Scooters do not require any physical effort and thus removes an entry barrier to use LEVs for some groups of users.

- Shared scooters may provide a wide alternative to cars if the spread to car-dependent areas with limited public transport services; currently shared mobility users are more likely to live in central areas with more public transport and population density (Mouratidis, 2022).
- The tendering of service providers to allow only a limited number of services in a city ("The Oslo model"), based on qualitative safety, sustainability, and accessibility criteria is an opportunity to avoid 'wild west' chaotic situations (Attard & Balbontin, 2024).

Threats:

- E-scooter can make destinations more attractive to both tourists and locals and thus have negative impacts through net increases of mobility (e.g., more airplane travelling, more energy and material throughput)
- Shared e-scooter services privatize user mobility data and enable algorithmic procedures for population management; without an "institutionalization of mobility data as a public good" shared electric mobility will not necessarily promote sustainable mobility (Creutzig, 2021).
- The expansion of shared scooters may continue to litter public space, unless better models for parking control and usage are enforced.
- If negative impacts and perceptions of electric scooters continue, more cities may ban them all together (e.g., like Paris and Barcelona).

3.3 ELECTRIC CARGO-BIKES AND TRAILERS

The use of electric cargo-bikes is increasing in cities with a supportive cycling infrastructure and where their purchase is affordable (e.g., in the Nordic Countries). Electric cargo-bikes offer the advantage of carrying several kids, so they replace mostly car trips when the purpose is not commuting but leisure or shopping trips (Carracedo & Mostofi, 2022). However, concerns about safety in the absence of dedicated cycling infrastructure limits their uptake (ibid.). Their expansion has been further limited because their perception includes negative images of cost, as they are relatively more expensive than conventional e-bikes, and of usability, as they are considered cumbersome by unexperienced would-be users[6] (Heinrich et al., 2016).

A majority of published studies about electrically assisted cargo bikes has focused on their potential for logistics (for a literature review see Sheth et al., 2019), especially in the context of European cities (e.g. see Nürnberg, 2019). The financial viability of delivery by electric cargo-bikes requires dense urban areas served by local logistic hubs (about microhubs see Katsela et al., 2022), where parcels arrive by light commercial vehicles and are further delivered by bike (Robichet et al., 2022, with data from Paris), and could have an investment return period of less than two years (Leite Nascimento et al., 2020, for the context in Brazil).

6 Another aspect limiting usability seems to be bike designs that do not take all body sizes and abilities into account. For example, interviews during the solutions+ project revealed that women in Latin America felt that the cargo bikes deployed in the project where uncomfortable to manoeuvre for their body size and arm strength.

SWOT analysis of cargo bikes

Strengths (promoting factors, best practices):

- Can transport heavy loads or several children.
- Much cheaper compared to a car or a van, requires smaller parking space.
- Can use both car roads and bike paths.

Weaknesses (limiting factors, bad practices):

- More expensive than a regular e-bike; low production volume prevents economies of scale.
- For their use in logistics, the risk of theft of the cargo is a weakness in some locations—product design issues would need to be solved with contextual awareness of their use.

Opportunities:

- If they are made attractive to parents (e.g., by deploying supportive infrastructure), they have the potential to allow families to avoid car-dependence (Thomas, 2022).
- Potential to grow quickly if adopted by large companies in the urban logistics sector (see Schliwa et al., 2015).
- In Europe, regulation limiting the use of conventional vehicles is correlated with higher purchases of electric cargo-bikes (Narayanan et al., 2022).

Threats:

- Unregulated expansion, or unskilled delivery drivers, could result in accidents with pedestrians, especially in dense urban areas like pedestrianized city centers, and lead to negative public opinion or regulatory backlash[7].
- Ownership of an electric cargo-bike correlates with decreased active mobility and public transport trips are reduced, making the public health and collective transport systems impacts of electric cargo-bikes uncertain (Carracedo & Mostofi, 2022). It is therefore key to avoid situations where e-bikes do not replace car or van trips.

3.4 LIGHT ELECTRIC CARS (L6 AND L7 CATEGORIES)

In general, a narrow policy focus on the electrification of private vehicles (i.e., electric automobility) is not sustainable. On the contrary, it is likely to be conducive to an increase of social injustice in human mobility that does not solve fundamental problems, like microparticle pollution and road deaths. Given the current fossil-prevalent energy grid mix, electrifying automobility simply shifts emissions from urban to rural areas, becoming a form of structural violence against the environment and human communities (Hosseini & Stefaniec, 2023). From a policy perspective, this structural violence takes the form of an "space for exception" (ibid., after Ong, 2006) where the transition to electric vehicles is supported and perceived as sustainable only because negative environmental impacts and increasing inequalities are kept outside this "electric vehicle bubble". The shielding effect of the bubble allows electric cars drivers to signal themselves as pro-environmental agents without changing their behavior (ibid.)

7 This is an opinion from the interviews that we carried out with stakeholders in Quito, Ecuador, for the SOLUTIONSplus project.

This is the case for conventional electric cars, but micro electric cars do not simply substitute combustion engines. Electric quadricycles in the L6 and L7 categories also imply a change in behavior and the acceptance of a new, much lighter and smaller vehicle concept. If concerns and behavior barriers are overcome (e.g., travelling in pairs, or with less cargo), with the addition of electric quadricycles LEVs could in theory substitute a relevant percentage of automobility (in the case of Germany, an estimate 75% of trips and 50% of emissions, see Gebhardt et al., 2023). In addition, electric quadricycles have smaller batteries and lighter bodies than conventional electric cars and are thus, again theoretically, more efficient. Despite these benefits, the adoption of L6 and L7 electric quadricycles is hindered because of consumers' concerns about their lack of safety and relatively high price (Ewert et al., 2021).

SWOT analysis of light electric cars

Strengths (promoting factors, best practices):

- Smaller batteries and in general lighter material footprint when compared to conventional electric cars.
- Protection from the weather, when compared to e-bikes and e-scooters.
- Weaknesses (limiting factors, bad practices):
- Perceived lack of safety when compared to cars.
- Relatively expensive for their cargo capacity.
- In some regions L6 and L7 vehicles cannot use inter-urban roads or highways, so they are limited to intra-urban routes.

Opportunities:

- Synergies with other forms of electric micromobility may lead to LEV-only routes, a policy that could overcome the traditional bicycles vs. cars polarization.
- Tax benefits and preferent spatial access may be focused on electric quadricycles once conventional electric cars reach a critical mass where they don't require additional support (e.g., the case of Norway).

Threats:

- The expansion of micro electric cars may further reduce active mobility in urban areas.
- Incentives to electric car might exacerbate social polarization if they are perceived as unjust or benefitting only the wealthiest groups in a given context.

4 CONCLUSION: POLICY RECOMMENDATIONS

As we have briefly presented, the factors supporting or limiting the growth of light electric vehicles depend to a large extent on their specific geographical location and socio-economic context. Despite LEVs representing the same technology and global resource flows, their sustainability impacts also depend on their specific use case. In this regard, there is a fundamental limitation to the general policy recommendations that can be made to support electric micromobility, boost its benefits, and avoid the more detrimental consequences.

Yet because most studies derive their conclusions from specific case studies, they recommend different pathways towards the goal of increasing the modal share of light electric vehicles. But without an appropriate decontextualization and theorization of the mechanisms at play, these recommendations are very limited in their applicability. Furthermore, carbon tunnel vision affects the policy landscape, which becomes overtly focused on greenhouse emissions, and thus favours (heavy) electric car futures and single-minded policies in their support (Sun et al., 2023).

Because of these contextual limitations, wide evaluation frameworks and mixed policy packages are more likely to succeed than simple best practices about “silver bullet” solutions. And despite these limitations, each context has positive elements (strengths and opportunities) that can be boosted, while negative elements (weaknesses and threats) could be mitigated. Context-specific regulations are needed to leverage these policy-packages that can be designed from the lessons learned in different contexts.

In addition, to guide such policy analysis and design we should aim to understand the evolutionary causes driving the technological and cultural processes. In evolutionary studies of innovation and policy, understanding only proximal causes —how things work— is not enough; instead we need to understand also ultimate causes —why things exist (van den Bergh, 2018). To do so and design effective policies for complex socio-economic problems, we need to get better at “collecting many distinct, mutually consistent insights to reach unequivocal ultimate explanations” (ibid., p. 7).

While it is outside the scope of this policy paper to present detailed analyses of different causes, we recommend this causal-historic evolution method to be applied locally, to understand why light electric mobility (or lack of thereof) has come to be this way in your context. In addition to this methodological recommendation, below we present the most important general policy recommendations classified by thematic categories.

Policy Dimension 1: spatial factors

Light electric vehicles still need to find their place in cities. On one hand, electrification increases speed and subsequently increases spatial access; on the other hand, the users of these vehicles are more vulnerable because of LEVs reduced size and weight. In general, we know from cycling research that users of lighter vehicles need to be physically separated from car traffic because psychological safety is a key factor for their positive experience. In addition, offering preferential access (for example, through more direct routes) further amplifies the increased accessibility offered by LEVs and active mobility modes, while giving a clear message to society about the incentives for electrifying mobility.

LEVs usually compete for space and users with public transport or pedestrians (e.g., as it has been the case for e-scooters). The problem is precisely that because of a market logic that benefits from density, these shared mobility options are usually not deployed in less dense, car-dependent areas far from the city centres. Besides trying to maximize trips per scooter, but it also further deepens inequality in access to travel options. Yet regional commute from car-dependent areas can be supported a combination of dedicated infrastructure and light electric vehicles. An example is the concept of "cycling highways" in the Nordic Countries, which could be generalized into "LEV-highways" (separate routes only for active and electric micromobility vehicles).

Finally, a significant barrier is the lack of integration between public transport and policies for supporting light electric mobility. Infrastructure to support this integration can be as simple as convenient parking facilities at public transport stations, or as complex as an integrated strategy to support both modes through synergies. In practical terms, segregated and continuous cycling infrastructure to reach public transport stations is the first step towards a multimodal system, and this can be further supported with convenient access to public transport vehicles with private micro vehicle —that is, taking your e-bike or e-scooter with you on the train or metro, instead of parking it at the station (Oeschger et al., 2020).

POLICY	EXAMPLES
Protect with appropriate infrastructure	Separated bike lanes, regional LEV-highways.
Give access priority to electric micromobility	Zero-emission pedestrianized zones.
Target both car-dependent and transit-dependent urban areas	Low-traffic neighbourhoods that filter car traffic but allow direct public transport and LEV traffic; support non-car-users in car-dependent areas.
Integrate with public transport	Access network, parking facilities, integrate micro LEVs onboard public transport.

Table 1: spatial dimensions of policy to support light electric vehicles

Policy Dimension 2: mobility justice factors

The growth of electric and digitized micromobility creates new working habits and labour relations which have unequal impacts on different groups. For example, the safety impacts of e-scooters are very different on the people working remotely from home and ordering food deliveries and on the couriers working for a delivery platform and using light electric vehicles to move. Furthermore, the most vulnerable user groups are likely to be left complete aside of these processes, to never experience the use of electric light vehicles and only witness their negative impacts on their lives.

In most contexts, gender is the main category affecting unequal mobility justice. In many other contexts, racial discrimination is also central for understanding mobility injustices. For example, in a city in the Nordic Countries electric scooters might be very imbalanced by gender, with few women using them, whereas electric bikes might be close to gender parity; at the same time young immigrants or racialized locals might prefer e-scooters to public transport but be completely missing along bike lanes[8]. If half of participating groups in transport are, or feel, excluded from the desired transition towards electrified and lighter modes of transport, growth and substitution of prevailing modes are unlikely to happen. In this sense, women and racialized citizens need to be central considerations and participants in policies for light electric vehicles.

The expansion of LEVs will thus only be successful if it both benefits from and supports justice in human mobility. Mobility Justice (Sheller, 2018) is a multi-scalar concept that refers to all embodied or global power relations that are both maintained with unequal mobility arrangements and maintaining the status quo of injustice. As an opposition to mobility injustice, the mobility justice project proposes "mobilizing commoning as a relational practice of heterogenous coming together in negotiated political alliance" (ibid., p. 171). In other words, mobility justice is a political process that goes towards a common and fair global mobility, in the opposite direction of political politization, exploitation, and global extractivism.

POLICY	EXAMPLES
Integrate a gender perspective	Understand how policy affects the experience of women when using, or not using, LEVs; include women in policy (and product) design;
Consider racial discrimination	Understand the experience of racialized citizens and support them in accessing LEVs.
Support underserved communities	Understand how LEVs affect underserved communities; design policies to increase their access to LEVs and shared mobility services.
Consider multi-scale effects	Consider aspects of infrastructural (in)justice, also outside the city (e.g., who is affected by LEVs' materials' extraction / waste cycles)

Table 2: justice dimensions of policy to support light electric vehicles

Policy Dimension 3: vehicle and technology factors

Allowing access to the experience of using a new type of vehicle could be key to promoting LEVs. For example, a pilot where parents of small kids had access to different types of e-bikes has been found to change their attitudes (Bjørnarå et al., 2019). Although we recognize that cost is a very important obstacle, perhaps once the benefits of owning and moving in one are experience in first person the willingness to pay of potential users increases. Another important policy to scale up the experience of electrically assisted mobility is the implementation of public bike systems that deploy electric bikes. Likewise, cross-sectoral collaborations outside the transport policy context can make use of electric bikes for their own policy objectives (especially public health, in relation to sedentary lifestyles).

Once the number of LEV owners starts to grow, it is equally important to retain them as active users. Repairment of electric bicycles and scooters is already a bottle neck in some contexts, because of lack of qualified mechanics. A local ecosystem that has the

8 This example is from observations in Helsinki, see Lamuela Orta: Gender and electrification in a Nordic "cycling highway" morning commute. (forthcoming)

production of LEVs (or at least assembly from imported parts) can better support also the growth of repairment professionals and companies. One such ecosystem where the product can close its full lifecycle, from design to disposal and recycling, might lead to more ownership and less sharing (which would be beneficial for the case of the environmental impacts of e-scooters). Local incentives can also support ownership of LEVs that fall in between the micro scale (scooters and bicycles) and the full-sized electric car. City governments usually cannot implement tax incentives, to support these electric quadricycles or small electric cars, but they can use spatial incentives to disincentivize bit electric SUVs.

Finally, it should be noted that conventional wisdom is that the lack of charging infrastructure is, or will be, a bottleneck for the uptake of electric and plug-in-hybrid vehicles. However, these comment ignore the fact that infrastructural conditions vary greatly among countries, and that public chargers will only be necessary in contexts with dense urban populations without the possibility of charging at home (Funke et al., 2019). For this reason, the issue of charging is outside the scope of this policy recommendation (but see another SOLUTIONS+ project publication by A. Fadel da Costa dealing with this theme).

POLICY	EXAMPLES
Offer free access to the experiences of different e-bikes	E-bike use as a benefit for parents of kindergarten children, or as doctors' prescription to sedentary patients.
Support a local ecosystem for building and repairing LEVs	To extend the lifecycle of LEVs, cities can establish education programs for mechanics, or support the reconversion of outdated factories to host local assembly of LEVs.
Electrify public city bike services	Implement an e-bike sharing system, or substitute existing city bike service of mechanical bikes
Renovate public transport towards light and electric vehicles	Design a system of on-demand electric vans that can complement the heavy-electric network of train or metro.
Incentivize light electric cars, disincentive electric SUVs	Exemptions from road tolls and parking fees, preferent access; smaller parking spaces in best location.

Table 3: vehicle and technology dimensions of policy to support light electric vehicles

5 CONCLUSION

With the right policies in place, light electric vehicles can contribute to a better future of urban mobility. A future with better air quality, less traffic accidents, and less local carbon emissions. If policy steers the growth of LEVs towards mobility justice, this future could be one where access to valuable activities is distributed equally, where democratic participation is supported by a common mobility system, and where both access inequalities and average kilometres-travelled are decreased.

Public policies are a part of culture, and as we have mentioned above, technology and culture co-evolve. The current goal for cities that want to see a growth of Light electric vehicles is to understand what policies can, in their specific context, on one hand leverage electric micromobility technologies, and on the other accelerate the peak and dismiss of mobility based on fossil fuels. Policy is not all-powerful, but technological development is not deterministic either. Cities can make a difference with their policy decisions.

There is a need for specific regulations that address the unique needs of each location. At the same time, although some policies have proven their positive impacts, they remain difficult to implement everywhere because they challenge the status quo of car mobility. For this reason, besides studying its specific situation, the next three steps for any city that wants to promote Light Electric Vehicle would be to:

1. Build more protected routes for bicycles. Cycling infrastructure can also be used by other LEVS besides e-bikes. Furthermore, accelerate the construction of protected routes for LEVs. This policy program does not need to be overtly expensive, as tactical urbanism design principles use temporary elements, such as road barriers and planters, that are already in use in cities.

2. Electrify and lighten public transport. This needs not be as sophisticated as on-demand, self-driving electric vans, but means simply to start by growing the city public bike system with more electric bikes.

3. Incentivize small cars. Regardless of the degree of electrification of the car fleet, lighter vehicles need to be supported now and in the future. The idea of big bars, such as SUVs, needs to be associated with outdated, ugly mobility. Cities can disincentivize big cars through urban design measures that gain back space to re-green its streets.

While there is no magic solution to promote the rise of light electric vehicle, there are policies such as these ones that are affordable across the very different cities that participated in the solutions+ project. The urgency and challenge for cities is to overcome past divisions and to start to build political coalitions for a shared mobility justice future around light and electric vehicles for all.

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