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FOR A BETTER URBAN FUTURE

INTEGRATION IS KEY:

THE ROLE OF ELECTRIC MOBILITY FOR LOW-CARBON AND SUSTAINABLE CITIES

Urban Pathways

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FOREWORD

We live in a rapidly urbanising world, and cities provide many opportunities for unprecedented socioeconomic development and innovation. At the same time, the demand for resources to meet the needs and aspirations of this increasing urban population is growing, a development often dependent on the increasing use of fossil fuels. Greenhouse gas emissions from the transportation sector are growing faster than any other energy-end use sector. Conventionally fuelled vehicles are also a major source of urban air pollution. Meeting the mobility needs of citizens while reducing emissions and air pollution from the transport sector therefore requires urban planners and policymakers to shift their focus from planning for personal cars to planning for low-carbon mobility by promoting public transport, shared mobility and improved walking and cycling infrastructure and facilities. Simultaneously, a shift towards renewable energy is also pivotal to reducing the sector's reliance on fossil fuels. Guided by the New Urban Agenda, cities must align their transport, climate, energy and urban development plans to achieve both the Sustainable Development Goals and the Paris Agreement goals.

Electric mobility solutions should be part of a new culture of integrated mobility planning, focussing on high quality public transport services, well integrated with shared mobility options, walking and cycling. For cities to fully benefit from the transition to electric mobility, these efforts need to be implemented in the overall context of better and more compact urban planning with a focus on accessibility and urban liveability. This will require close collaboration between public and private actors in which governments can bring forward enabling regulatory frameworks and provide incentives to encourage the uptake of electric mobility.

This report, "Integration is key: the role of electric mobility for low-carbon and sustainable cities", is meant as guidance for cities, providing recommendations and principles to implement electric mobility strategies. It is my hope that policymakers, city planners, engineers, and entrepreneurs alike will find this guidance useful in their continued efforts to foster a more sustainable urban future.

Raf Tuts

Director, Global Solutions Division

UN-Habitat

Executive Summary

Key highlights

- The use of electric vehicles is rising in many cities around the world, underpinned by the urgent need to reduce levels of air and noise pollution, and tackle the ever-growing energy-related greenhouse gas (GHG) emissions from conventionally fuelled vehicles. The Intergovernmental Panel on Climate Change (IPCC) recognises electrification of short-distance vehicles as a powerful means for reducing emissions. The strong increase of renewable energy sources in electricity generation, observed over the past decade and expected to further grow, maximises the climate benefits of electric mobility. Chapter 1

- Transport electrification can simultaneously contribute to sustainable urban mobility by enhancing vehicle energy efficiency and supporting the shift towards public transport and active mobility. Electric mobility expands the mobility options in our cities, with a range of lightweight, new electric vehicles including electric bicycles and kick e-scooters which can act as a catalyst for behavioural change. Proactively integrating these small electric vehicles as feeders into mass transit can promote the shift from private cars and bolster the role of public transport as the backbone of the urban mobility system. In addition, electrification can also catalyse investments in clean public transport and new bus fleets, which, in turn, can raise the attractivity of public transport through modern and more silent vehicles. Chapter 1

- The right accompanying policies need to be developed and adopted at national and local levels, supporting the electrification of public and shared vehicle fleets as the most cost-effective options among electrification strategies, and increasing the share of renewable energy sources in electricity generation. Ensuring that the deployment of electric vehicles and infrastructure fits within a sustainable urban mobility paradigm is crucial to reap the benefits of this transition. Many publications focus on electric private passenger cars. These, however, do not address issues of congestion and unfair distribution of urban space. Electric vehicles are in fact more diverse, ranging from lightweight two- and three-wheelers such as electric bicycles, cargo bikes, scooters, mopeds and tuk-tuks (private, shared or commercial forms), to electric light duty vehicles, and electric heavy-duty trucks and buses.

- Electric mobility should be guided by a set of ten core principles: Chapter 2
  - ↗ Integrate electric mobility in the context of improved urban planning and in a balanced "Avoid-Shift-Improve" framework
  - ↗ Prioritize people and public transport over private cars
  - ↗ Plan and design to accommodate a rich mix of electric mobility options integrating active and high-capacity modes of transport
  - ↗ Identify opportunities for multimodal transit hubs through the strategic location of electric mobility charging infrastructure
  - ↗ Design an integrated transport policy approach seeking synergies between national and local measures
  - ↗ Build cross-cutting institutional cooperation
  - ↗ Engage with all relevant stakeholders across multiple sectors, strengthen public-private partnerships, and create co-ownership of the transition
  - ↗ Promote equity and inclusion in the deployment of electric mobility
  - ↗ Increase the share of renewable energy sources and move towards a zero-emission future
  - ↗ Provide adequate access to information on electric mobility to users.

- Rolling-out electric mobility is not without challenges: policymakers and stakeholders are frequently confronted with four types of challenges: Chapter 3
  - o financial and investment barriers,
  - o policy, regulatory and institutional barriers,
  - o technical challenges,
  - o behaviour and knowledge concerns.

- To tackle these challenges, cities can gain experience from other cities which have already designed and rolled-out electric mobility programmes. Policies can support the uptake of integrated electric mobility via measures addressing four dimensions: planning and infrastructure measures, fiscal measures, institutional and regulatory instruments, as well as communication campaigns. It is recommended to follow a Sustainable Urban Mobility Planning (SUMP) approach to implement electric mobility at the local level. National measures can also support the deployment of electric mobility at city level. Sections 3.1 and 3.2

- Innovative business models are paramount to facilitate the transition to electric mobility, reaping the benefits of lower running costs while addressing higher upfront investment costs. Shared systems and innovative procurement models for electric buses are presented in this publication. Section 3.10

- Electric mobility can improve urban logistics, for instance via electric cargo bikes. Section 3.11

- The entire lifecycle of batteries should be considered, adopting a circular economy approach, making use of "reuse, repurpose and recycle" opportunities, and avoiding environmental and health hazards in the recycling of batteries. The second life use of electric vehicle batteries as energy storage systems can facilitate the integration of variable renewable energy sources into electric grids. Sections 3.15, 3.16

Disclaimer

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Abbreviations

A-S-I	Avoid-Shift-Improve
BEV	Battery Electric Vehicle
BC	Black Carbon
BRT	Bus Rapid Transit
CNG	Compressed natural gas
CO_2	Carbon dioxide
COP	Convention of the Parties
EoL	End of Life
EPAC	Electronically Power Assisted Cycles
EU	European Union
EV	Electric Vehicle
GDP	Gross domestic product
GHG	Greenhouse Gas
ICE	Internal Combustion Engine
IEA	International Energy Agency
ILO	International Labour Organization
IPCC	Intergovernmental Panel on Climate Change
ITDP	Institute for Transportation and Development Policy
NDC	Nationally Determined Contribution
NGO	Non-Governmental Organisation
NO_x	Nitrogen oxide
NPE	(German) National Platform for Electric Mobility
OEM	Original Equipment Manufacturer
PLDV	Passenger light-duty vehicles
PM	Particle Matter
PTO	Public Transport Operator
PPP	Public-private partnership
PV	Photovoltaic (solar energy)
R&D	Research & Development
SDGs	Sustainable Development Goals
SME	Small and Medium Enterprise
SO_2	Sulphur dioxide
SUMP	Sustainable Urban Mobility Plan
TRL	Technology Readiness Levels
TUMI	Transformative Urban Mobility Initiative
UEMI	Urban Electric Mobility Initiative
UITP	International Association of Public Transport
UNECE	United Nations Economic Commission for Europe
VAT	Value Added Tax
WHO	Word Health Organization
WRI	World Resources Institute
V2G	Vehicle to grid

Introduction

Electric mobility is on the rise in many cities across the globe, underpinned by the urgent need to reduce critical levels of urban air pollution, greenhouse gas emissions, and noise pollution. Electrification of road transport vehicles was recognised as a powerful low-carbon transport strategy by the Intergovernmental Panel on Climate Change and the 2015 Paris Declaration on Electro-Mobility and Climate Change launched at the climate summit COP-21. A total of 54 Nationally Determined Contributions (NDCs) under the Paris Agreement on climate change and Long-Term Strategies have included measures promoting electric mobility so far, by countries located both in the Global North and South (TraCS and SLOCAT, 2021). Further to these environmental benefits, electric mobility has numerous economic and social multipliers. These include the opportunity to promote a more sustainable urban mobility stimulated by the renewal of public transport fleets and the introduction of innovative mobility options such as e-bikes, a new industry market and job opportunity, as well as the opportunity to proactively support gender-inclusive mobility.

Recognising these opportunities, an increasing number of countries have enacted national and urban policies in recent years to support the roll-out of a variety of electric mobility options. Electric fleets range from lightweight two- and three-wheelers such as electric bikes, cargo bikes, scooters, mopeds, tuk-tuks – provider under private, shared or commercial forms -, over electric light duty vehicles including passenger cars and light commercial vehicles, to electric heavy-duty buses and trucks. In this global movement, cities can act as natural champions to foster a transition towards electric mobility. Cities are incubators of innovation, concentrating economic activities and the creativity of people. These strengths, coupled with the shorter distances between destinations and higher population and residential densities that characterise cities, place them in a unique position to complement national programmes and steer electric mobility in the most sustainable direction.

As a disruptive technology that deeply impacts a broad range of stakeholders, market dynamics, urban planning and public policies, electric mobility is, however, not without challenges for cities. Urban policymakers are confronted with critical questions: how can electric mobility strategies best be implemented, and adoption barriers tackled? Which policies and principles can steer electric mobility in the most sustainable way? How can communities and relevant stakeholders be engaged in electric mobility processes? Which innovative business models can help overcome higher investment costs?

Answering these questions requires an in-depth and context-specific knowledge of electric mobility characteristics, supporting policies and planning needs. Recognising the need for this transition, UN-Habitat, at the UN Climate Summit in September 2014 in New York, launched the Urban Electric Mobility Initiative (UEMI). The UEMI aims to support the phasing out of conventionally fuelled vehicles in cities and the integration of electric mobility into a wider concept of sustainable urban transport.

To this end, this publication aims to provide city managers, urban planners and other stakeholders with an overview of key aspects of electric mobility and an outline of the core principles that can guide them in developing their strategies to increase its uptake. Ensuring that the deployment of electric vehicles and infrastructure fits within a sustainable urban mobility paradigm is crucial to reap the benefits of this technological transition. While electric mobility entails direct sustainability gains, the extent to which benefits can be maximised depends on accompanying public policies, support of stakeholders, and financing. It is important to recognise that electric mobility is not a silver bullet per se, but rather a strategy for generating multiple benefits under an overall sustainable urban mobility paradigm.

This publication tackles a broad thematic and geographic scope, reflecting the diversity of electric vehicles in countries at different stages of economic development. It encompasses all urban transport modes, considering that one cannot understand the benefits and complexity of electric mobility without considering the diversity of vehicles involved. While many publications focus on electric passenger cars, these do not address issues of congestion, nor the unfair distribution of urban space. The publication further assesses the situation of low, middle and high-income countries, as it is critical to represent the realities of electric modes in different settings. Finally, it also provides an entry point to urban electric mobility and refers to further guidance tools and reading materials for cities intending to delve deeper into the topic.

The report is built around three core chapters. The first chapter elaborates on the potential and characteristics of electric mobility in cities. The second chapter lists key principles that should serve to structure a sustainable roll-out of urban electric mobility. The third and final chapter dives deeper into the multiple facets of electric mobility in cities, addressing planning and policy instruments, implications on the environment, economy, neighbourhoods, innovation and resources.


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CHAPTER 1:

THE NEED FOR ELECTRIC MOBILITY IN CITIES

1.1 Why do we need urban electric mobility?

Fossil fuel-based vehicles are among the most rapidly growing sources of airborne pollution and present a major public health risk, particularly in regions with sharply increasing motorization. The transport sector is currently responsible for approximately one quarter of worldwide GHG emissions (24% of direct CO2 emissions in 2018 according to the IEA, 2020a), and transport-related emissions are growing more rapidly than any other sector (IPCC, Sims et al., 2014). Globally, urban public spaces are dominated by vehicles with fossil fuel-driven internal combustion engines, as oil-derived fuels account for 95 % of energy consumption in transport (EEA, 2020). These vehicles emit GHG and saturate the air with toxic pollutants such as nitrogen oxides, sulphur oxides, particles, carbon monoxide and hydrocarbon. Black carbon, which comprises a substantial portion of small particulates, is an important climate forcer, contributing significantly to short-term global warming.

This cocktail of pollutants and particles is a direct cause of acute and chronic illnesses, including strokes, heart disease, lung cancer, chronic obstructive pulmonary diseases, diabetes, high blood pressures, and respiratory infections such as pneumonia (WHO, 2018). In addition, it is becoming clearer that polluted air increases mortality rates from pandemic outbreaks. A recent study demonstrated a significant association between air pollution over many years with an increase in mortality from a COVID-19 infection (Wu et al., 2020). This has also been found in other diseases caused by a coronavirus such as the Severe Acute Respiratory Syndrome (SARS) (Harvard University T.H. Chan School of Public Health, 2021).

It is therefore crucial to move away from fossil fuel-based mobility which severely impacts public health and contributes to global warming.

Electric mobility, or e-mobility, can play a significant role in the decarbonisation of the transport sector and the reduction of air pollution. Many e-mobility solutions are readily available, several of which are already cost-effective and can deliver wider socio-economic benefits, making the prioritisation of these solutions pivotal for mobility-related policy decisions. This was recognised by the Paris Declaration on Electro-Mobility and Climate Change launched at the 2015 Paris climate summit COP-21, aiming for a 20% share of all global road transport vehicles to be powered by plug-in electricity by 2030, as well as the Action towards Climate friendly Transport (ACT) initiative launched at the 2019 UN Climate Summit. Moreover, in 2018, the Intergovernmental Panel on Climate Change (IPCC) recommended to accelerate the uptake of climate mitigation solutions, among which the electrification of transport, which it recognized as a powerful measure for short-distance urban vehicles. The global fleet of fossil-fuel passenger vehicles would need to be replaced by electric vehicles, electric bikes and electric transit by 2035-2050 in order to stay below the target limit of a 1.5°C increase in earth surface temperatures (IPCC, 2018).

Cities are the essential levers to achieve decarbonization targets: they provide critical densities of goods and people, stimulate socioeconomic interactions and networks and are therefore vital centres for trade, innovation, communication and culture. According to UN-Habitat, within 30 years from now, two-thirds of the world's population will live in urban areas. 90% of urban growth will occur in less economically developed regions, such as East Asia, South Asia and Sub-Saharan Africa (UN-Habitat, 2020). Currently, cities account for 60% to 80% of worldwide energy consumption and generate as much as 70% of human induced GHG emissions, primarily through the consumption of fossil fuels for energy supply and transportation. In order to achieve the Sustainable Development Goals (SDGs), the Paris Agreement goals and the New Urban Agenda, as well as deliver on UN Habitat's mission to ensure "a better quality of life for all in an urbanizing world", cities need to shift towards more sustainable urban development, renewable energy systems and low-carbon transport modes. According to a comprehensive assessment by the IPCC (2018), cities need to cut emissions to avoid the catastrophic effects of a changing climate, most notably by decreasing the use of fossil fuels and increasing renewable energy sources. Cities have an opportunity to reduce carbon emissions and air pollution by using synergies between the different sectors of urban development: urban planning, urban energy, transport and waste resource management.

As an effective low-carbon strategy, electric mobility improves urban air quality by reducing local pollutants including particle matter, nitrogen oxide, and sulphur dioxide, reduces fossil fuel consumption, and helps mitigate climate change, all the more as the share of renewable energies in the electricity generation mix increases. It also significantly reduces ambient noise, improving the quality of life in cities. In addition to these environmental benefits, electric mobility can also steer local economic development, improve intermodality, bring in innovative vehicles catering to mobility needs of urban dwellers, and reshape existing infrastructure and planning conditions, especially in developing contexts. Figure 1 depicts the gains and opportunities electric mobility offers. Several of these benefits that can be reaped from e-mobility depend on the way it is implemented. Hence, there is a pressing need to adopt the right accompanying policies, following key principles highlighted in this document (Chapter 2) and corresponding strategies, challenges and solutions (Chapter 3). Some benefits are direct ones (for instance the improvement of air quality and urban noise), while others will depend on enabling public policies and stakeholder mobilization (for instance neighbourhood involvement, impact on transport providers). Accompanying policies including the decarbonisation of electricity generation, are essential.

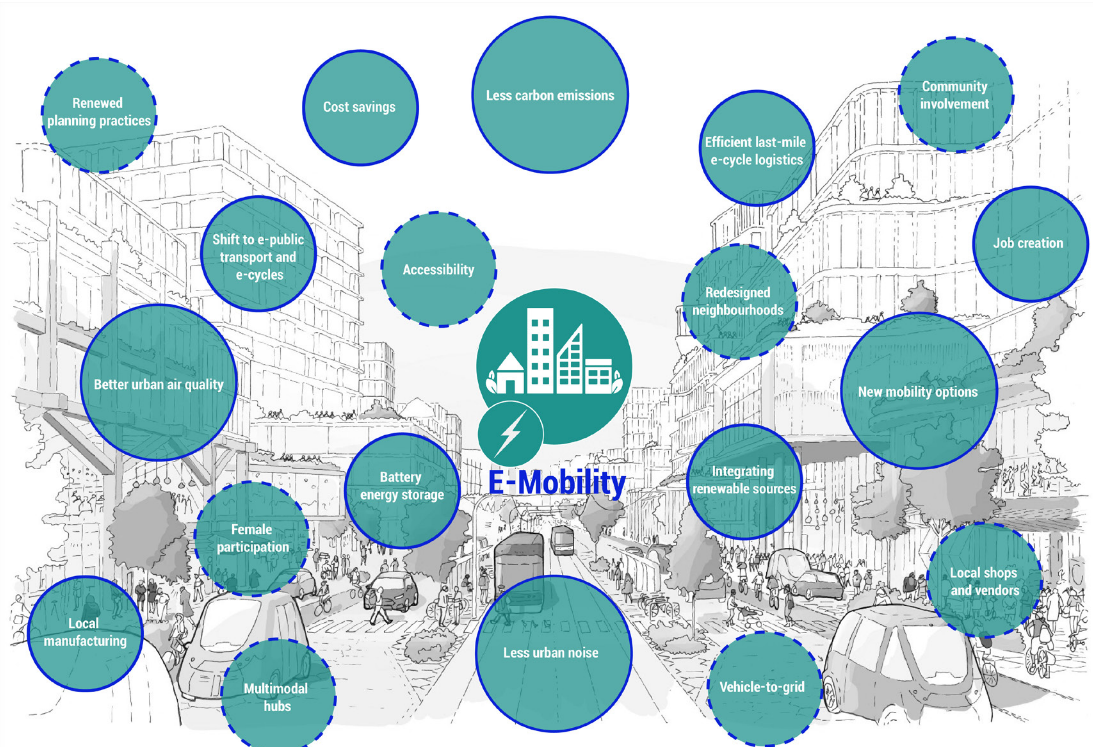


Figure 1: Gains and opportunities leveraged by electric mobility

Box 1: Emission reduction potentials of electric bicycles

A 5% increase in trips made by e-bikes and other electric micromobility options, replacing car trips, would reduce CO_2 emissions from the urban transport sector by 7% by 2030. This represents more than 134 million cars off the road (ITDP, 2019). This analysis does not only apply to passenger trips, but also to urban deliveries that have a growing carbon footprint in many cities. Electric bicycles and cargobikes have shown proven results in reducing GHG emissions (see section 3.14 on urban logistics).

Box 2: Employment opportunities

The promotion of green transport will generate employment opportunities to diversify and safeguard jobs. Doubling investment in public transport by 2030 is estimated to enable the creation of at least 2.5 million additional jobs in the transport sector worldwide, and up to at least 5 million jobs when considering the wider impact on other economic sectors (UNECE and ILO, 2020). Introducing a target of half of all manufactured vehicles to be fully electric would add a net total of almost 10 million jobs to worldwide employment across all sectors (ibid).

1.2 Electric mobility within Sustainable Urban Mobility

UN-Habitat advocates for a people-centred approach to mobility planning and decision making. Electric mobility must be framed within the New Urban Agenda, which encourages cities to promote access to safe, age and gender responsive, affordable, accessible and sustainable urban mobility and land and sea transport systems for all. The integration of transport and mobility plans into comprehensive urban and territorial plans and the promotion of a wide range of transport and mobility options enables meaningful participation in social and economic activities in cities and human settlements. Transport development is not a standalone process, and is closely linked with urban development and land use. While supporting the uptake of all types of electric vehicles is vital for the transition to low-carbon transport technology, efforts to do so should not be carried out at the expense of investments in public transport, walking and cycling infrastructure investments.

Electric mobility needs to be implemented in the overall context of better and more compact urban planning and in a balanced Avoid-Shift-Improve scenario, with a particular focus on accessibility and urban liveability. Achieving low-carbon transport and fostering sustainable urban development includes the avoidance or reduction of motorised journeys through compact urban design, shifts to public transport and non-motorized transport (primarily walking and cycling), the uptake of improved vehicle and engine performance technologies including low-carbon fuels, investments in related infrastructure, and structural changes to the built environment (Figure 2).

Electric mobility is primarily an "Improve" strategy, enhancing vehicle energy efficiency. In addition, electric mobility can also contribute to the "Shift" pillar through two mechanisms:

1. In relation to the "Shift pillar", electric mobility expands mobility options in our cities, which can have two major impacts: challenge the status quo and improve last-mile connectivity to public transport. A range of small, lightweight and low-speed new electric devices, including electric bicycles (e-bikes) and kick or e-scooters, can act as a catalyst for behavioural changes, triggering individual decisions to move away from the use of private cars. Electric assistance can increase comfort of travel and is particularly useful in hilly cities, when transporting goods or ferrying children on a cargo-bike, or to cover longer distances in cities with lower density. As such, e-bikes can also tap into new user groups who may previously not have felt comfortable using a pedal bicycle. These new options can therefore act as a "point of entry" to sustainable urban mobility and modal shift (ITDP, 2019). In addition, strategically locating charging points for small electric vehicles - ideally shared - at multimodal hubs incentivizes connection to mass transit and promotes the integration of the transport system.

2. Also in relation to the "Shift pillar", electric mobility can catalyse investments in clean public transport, stimulating bus fleet renewal, which will make public transport more attractive through modern and more silent vehicles. The electrification of public and shared vehicles fleets is the more cost-effective option, since these vehicles tend to drive longer distances and serve a substantially higher number of people. The transition to bus electrification needs to be undertaken in a well-considered manner, as it requires rethinking the system on multiple levels along the public mobility chain including operations, charging infrastructure, costs – especially upfront investment costs - , maintenance, procurement options, as well as training (see Box 1 information on electric buses in sections 3.1, 3.6 and 3.10). Thoroughly designing the transition and looking at the local characteristics and needs of the public

transport system is crucial to maintain and improve the quality of services while transitioning: a public transport fleet might well be zero-emission; yet, if it is perceived to be unsafe, irregular or too costly, it will not be attractive to urban dwellers.

A sustainable transition should also integrate the "Avoid" dimension of the paradigm (see Chapter II on the principles to deploy electric mobility).

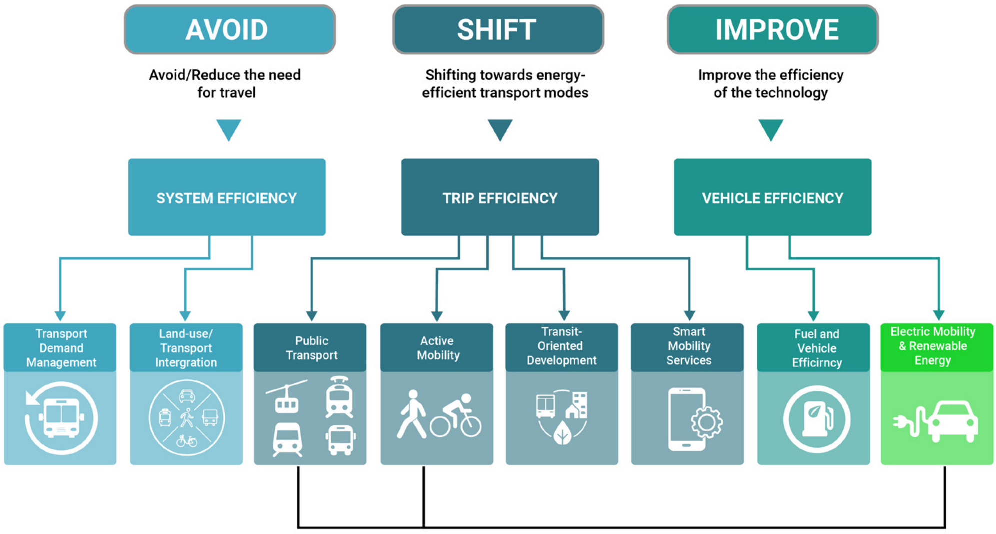


Figure 2: Avoid-Shift-Improve paradigm (UN-Habitat)

Meeting the targets of the Paris Declaration on Electro-Mobility

To meet the targets of the Paris Declaration on Electro-Mobility of a 20% stock share of passenger vehicles (cars, SUVs and other passenger light-duty vehicles, buses and motorized 2 wheelers) to be powered by electricity by 2030, a substantial transition has to take place. In particular, reaching the electrification target of 150 million plug-in passenger light-duty vehicles (PLDVs) by 2030 (9% of total PLDV stock) may be challenging, as the need is much greater than today's global stock levels of around 10 million electric cars (IEA, 2021).

One way to lower these requirements while preserving the percentage stock targets, is to consider an alternative future where urban travel is reoriented toward mass transit and active transport, primarily walking and cycling, with less car travel. The 'Three Revolutions' or '3R' scenario of ITDP and UC Davis (Fulton et al., 2017) centres around electrification, automation and sharing, while encouraging increased public transport performance and better infrastructure for walking and cycling. This scenario would allow to dramatically reduce the number of vehicles on the world's roads and, in particular, of private car travel in 2050 compared to a business-as-usual scenario. In this High Shift scenario, the changes in numbers of electric vehicles needed (with no changes in their percentage targets) can be easily calculated. As shown in Figure 3 and Figure 4, in the High Shift scenario, the total stock of personal vehicles and required stock of plug-in electric vehicles drops significantly. Figure X shows the change just in electric vehicles that preserves the 20% stock target: 2&3 wheeler plug- in requirements drop from 350 to 300 million; PLDV plug-in requirements drop from 150 million to 100 million. Bus numbers rise somewhat, since there are more buses in the High Shift scenario. Thus, the High Shift scenario would provide a similar level of mobility and allow a relaxation of plug-in vehicle numbers while still hitting the percentage targets. And since the modal shift itself cuts CO2 emissions significantly, it results in an overall greater level of CO2 reduction than achieved by the electrification in the Base scenario.

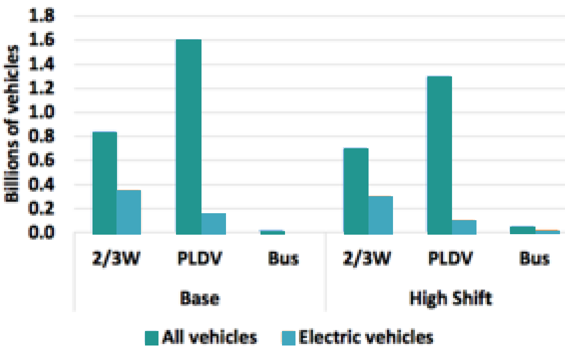


Figure 3. Base and High Shift scenario comparison of all vehicle and e-vehicle stocks in 2030 (UEMI, 2017)

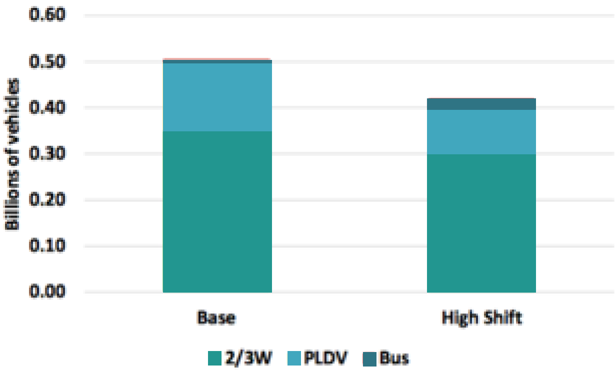
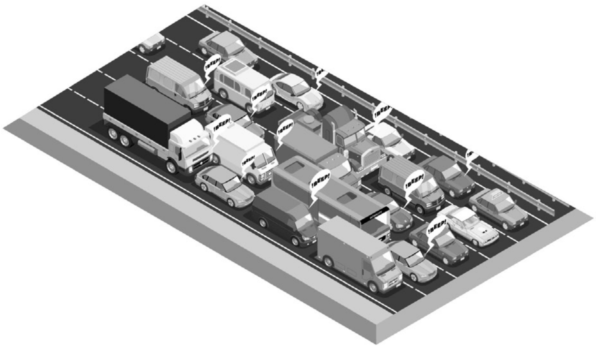


Figure 4. E-vehicle stocks in the Base and High Shift scenarios for 2030 (UEMI, 2017)

Moving away from the status quo and choosing sustainable pathways

For too long, most cities have prioritized the private motorised vehicle, directing funds and policies towards the expansion of the road network. Unfortunately, these developments engender a vicious circle. Expanding roads leads to urban sprawl, stimulating the use of cars and increasing congestion which, in turn, is often seen as a call for further infrastructure development. This has resulted in a range of unintended adverse environmental, social and economic consequences of urban sprawl, severe congestion, air and noise pollution. Given the emergency and severity of climate change and air pollution, cities urgently need to embrace a sustainable mobility pathway by moving away from the priority given to private cars towards a sustainable and integrated transport system with accessible, affordable and clean public transport at its heart, and compact urban planning. This is particularly important in the context of electric mobility, as the replacement of private fossil fuel-driven cars with private electric cars will not solve current issues of congestion, inefficient and inequitable land use, and poor road safety.



CURRENT SITUATION

SITUATION WITH ELECTIC CARS

Current Situation

With electric Cars

Hence, choosing the right pathway to sustainable and clean urban mobility is critical. This will be particularly important for cities in low- and middle-income countries, of which many still have high shares of sustainable modes of transport, including walking and collective transport, but are facing soaring private motorisation rates. In order to meet the mobility needs of citizens while reducing emissions from the transport sector, these cities may benefit from the experience of other cities that have implemented sustainability mobility measures. A wide range of measures has been trialled and implemented, covering transit-oriented development, improvements to public transport, promotion of active mobility, congestion pricing or parking regulations, shared mobility, and innovative business models. The UN-Habitat Global Report on 'Planning and design for sustainable urban mobility' (2013) and the joint UN-Habitat and ITDP publication entitled 'Streets for walking and cycling' (2018) provide key insights into these sustainable pathways.

Figure 5 shows different mobility patterns, and how developing cities can leapfrog to a low-carbon pathway with a limited modal share of motorized private vehicles through the aforementioned measures, avoiding the rise of the cars (lowest curves in the figure).

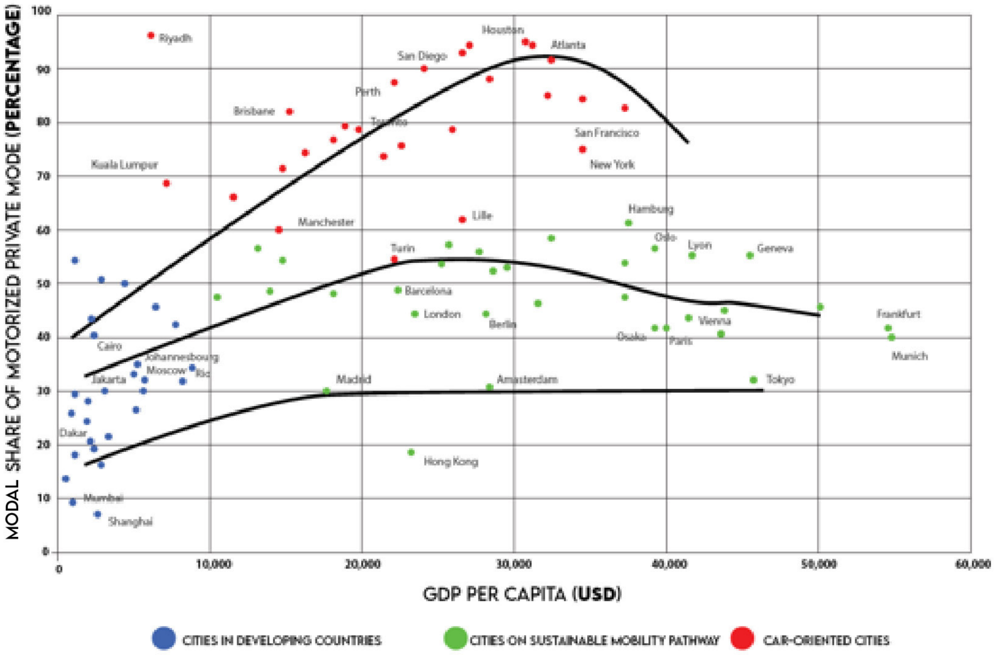


Figure 5: Choosing a sustainable mobility pathway (Teoh, 2016)

By promoting e-mobility, local governments can act as key drivers to reduce emissions and air pollution, noise and stress, while improving public health and accessibility. Yet, e-mobility on its own is not sufficient to transition to a more sustainable and low-carbon city: if cities lack compactness, proximity, mixed use, social integration and a resilient and well-connected transport network, e-mobility solutions will not achieve their full potential. As the morphology of a city plays a role in determining its sustainability, integrated urban and transport planning is a precondition for the development and provision of alternative and low-carbon mobility options.

There is compelling evidence for the inverse correlation between urban compactness and CO_2 emissions per capita. Less fragmented and more compact cities emit less CO_2 from the passenger transportation sector than cities with lower population densities (Figure 6).

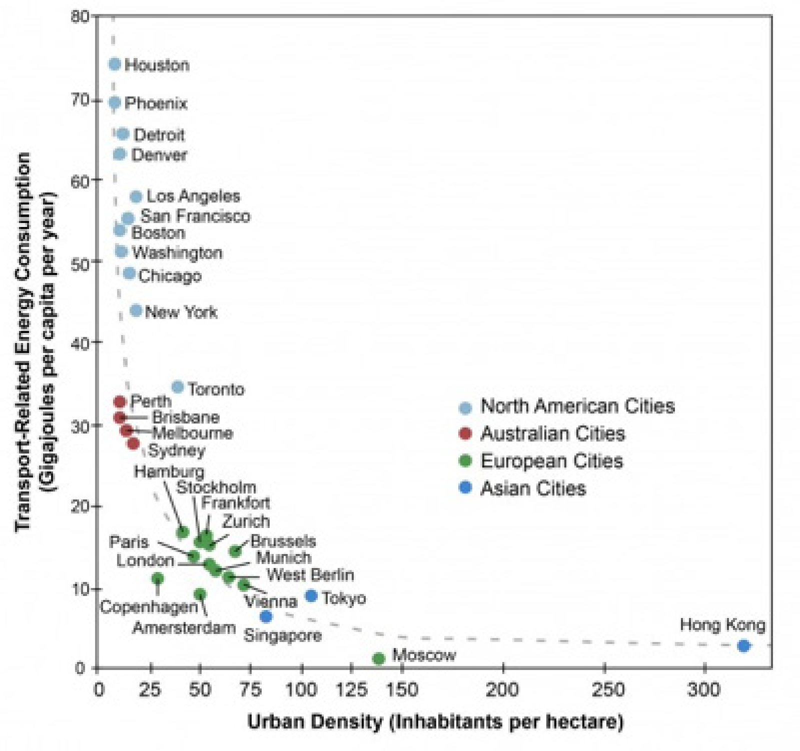


Figure 6: Center for Sustainable Systems, University of Michigan, 2019. Pub. No. CSS09-06. (Adapted from UNEP (2008) "Kick the Habit: A UN Guide to Carbon Neutrality.")

E-mobility systems can be more easily and impactfully implemented in more compact cities, as they are optimal for shorter distances and urban intermodality, combining different types of e-solutions to reach the final destination. In this sense, the electrification of public transport and shared mobility options including micromobility is a critical decarbonization pathway for urban city centres.

Key takeaways:

- ↗ Electric mobility should be envisaged through the lens of the Sustainable Development Goal 11.2, namely to "provide access to safe, affordable, accessible and sustainable transport systems for all, improving road safety, notably by expanding public transport, with special attention to the needs of those in vulnerable situations, women, children, persons with disabilities and older persons" by 2030.
- ↗ Electric mobility is key to decarbonize the transport sector and cannot be envisaged without improved urban planning or integration with measures shifting transport towards improved public transport and active mobility.

1.3. Integrating a diversity of electric vehicles in cities

Cities are increasingly active in the support of transport electrification. Chinese cities such as Shenzhen have been pioneers in implementing ambitious electric mobility policies; an increasing number of cities including London, Amsterdam, Stockholm, Tokyo, Victoria, Oslo, Paris, San Francisco, Barcelona, Delhi and Quito have already designed policy frameworks to stimulate transitions to electric mobility (see sections 3.1 and 3.2 on planning and policies).

It is essential to understand that, in order to establish a successful e-mobility system, different e-mobility solutions need to be integrated into one coordinated system. These solutions encompass electric commuter trains, electric buses and shuttles, cable cars, a wide range of electric two- and three-wheelers including electric bicycles, e-cargo bikes, e-scooters, as well as electric taxis and shared cars, and electric urban delivery trucks – all supported by an infrastructure of public and private charging or swapping points, integrated ticketing, and digital platforms. E-mobility initiatives should not be deployed in a fragmented and unimodal manner, creating issues of lacking coordination and interoperability.

Figure 7 illustrates the great diversity of electric vehicles, operational modalities and the different parameters to build an integrated system.

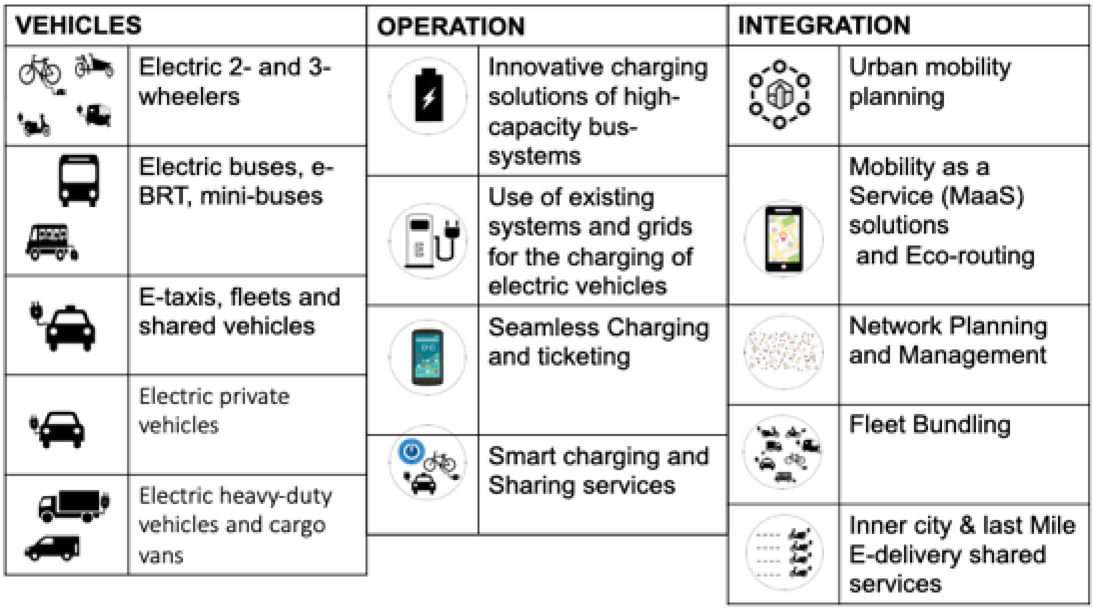


Figure 7: Key pillars of electric mobility in SolutionsPlus: vehicles, operation and integration (UEMI, 2020)

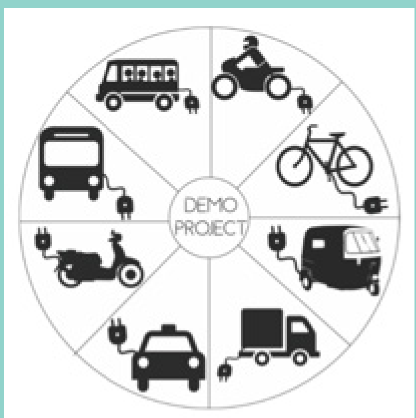
Box 3: The SOLUTIONSplus Project

Accelerating transformational change towards sustainable urban mobility through innovative and integrated electric mobility solutions

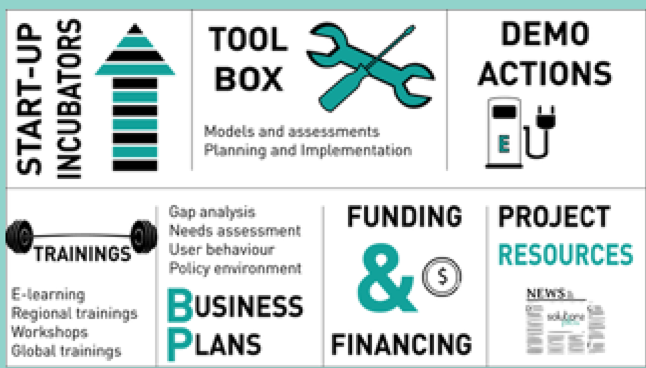
SOLUTIONSplus brings together highly committed cities, industry, research, implementing organisations and finance partners and establishes a global platform for shared, public and commercial e-mobility solutions to kick start the transition towards low-carbon urban mobility. To deliver this objective the project will boost the availability of electric vehicles, foster the efficiency of operations and support the integration of different types of e-mobility in large urban areas and addressing user needs and local conditions in Europe, Asia, Africa and Latin America. The project encompasses city level demonstrations to test different types of innovative and integrated e-mobility solutions, complemented by a comprehensive toolbox, capacity development and replication activities.

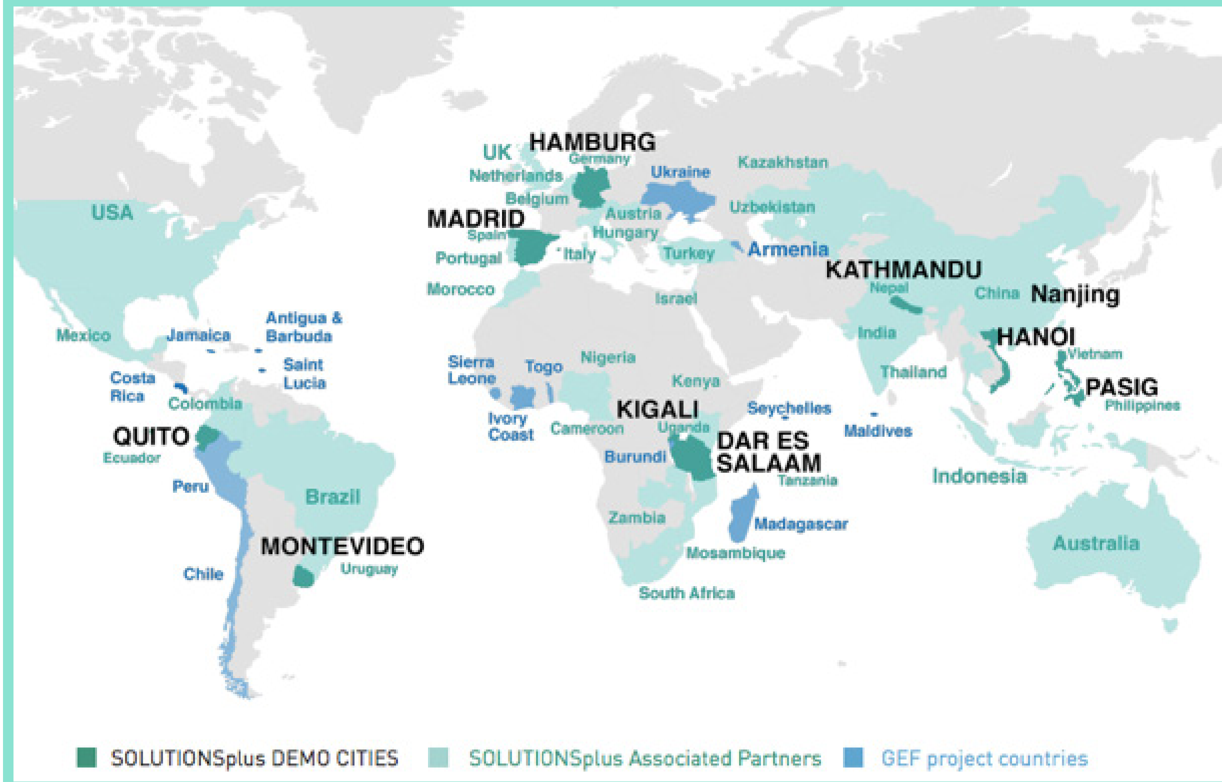
Demonstration actions have been launched in Hanoi (Vietnam), Pasig (Philippines), Lalitpur/Kathmandu (Nepal), Kigali (Rwanda), Dar es Salaam (Tanzania), Quito (Ecuador), Montevideo (Uruguay), Madrid (Spain), Nanjing (China) and Hamburg (Germany), testing a variety of electric vehicles adapted to local needs as shown at the bottom left. Regional and international replication are integrated in the project to reach out to a larger number of cities and countries.

Overview of the solutions tested in the SOLUTIONSplus cities



Overview of the support modalities embedded in the project





This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 875041.

More on: http://www.solutionsplus.eu/

CHAPTER 2:

PLANNING PRINCIPLES FOR URBAN ELECTRIC MOBILITY

Safe, affordable, accessible and sustainable transport systems with public transport as the backbone are key to achieving liveable, pollution-free and resilient cities, where all people, including those in vulnerable situations, women, children, persons with disabilities and older persons, are able to move independently.

Electric mobility is increasingly being promoted in cities around the world - and brings with it many opportunities if designed and implemented well. The following principles are key to support and guide urban policymakers and planners in their quest for effective electric mobility solutions, allowing them to achieve their intended sustainability aims across climate, air quality, urban development, economic, institutional and policy dimensions.

2.1 Integrate electric mobility in the context of improved and more compact urban planning and in a balanced Avoid-Shift-Improve framework

Electric mobility should be implemented in the overall context of better and more compact urban planning and in a balanced Avoid-Shift-Improve (A-S-I) framework. This means that the hierarchy of the A-S-I approach should be taken into account, starting with the creation of more accessible and compact urban development (Avoid) that facilitates e-mobility, followed by the shift to public transport (improved and electric) under stable funding frameworks for infrastructures and services, active mobility and shared mobility (Shift), to then, finally, complement these efforts by promoting technological advancements (Improve).

Such technological advancements are necessary but not sufficient on their own: the replacement of private fossil fuel cars with private electric cars, for instance, does not solve problems of urban sprawl, unfair land use, and poor road safety. On the other hand, incentivizing electrification of public transportation and shared vehicle fleets (taxis, rideshare) as well as subsidising the purchase of personal e-bikes and integrating e-bikes into existing bike-share systems does improve overall urban liveability.

Box 4: The boom of e-bikes

Pedal assisted electric bicycles[1] are increasingly gaining popularity, entering cities as a new mobility option. E-bikes sales rose impressively over the last couple of years, especially in European countries, where 3,332,000 units were sold in 2019 against only 98,000 in 2006 (Scherer, 2021). In addition, the number of e-bikes sold in the European Union is much higher compared to battery electric cars and hybrid cars (Figure 8). In 2018, pedelec sales made up 17% of EU bicycle sales on average (Scherer, 2021). In individual countries, this share lies considerably higher: e-bikes made up 23.5% of total bicycle sales in Germany in 2018 and more than the half in the Netherlands (Cooper et al., 2020).

This rise was boosted by the Covid pandemic, driven by the need for physical distancing which spurred active mobility, especially as pop-up bicycle lanes emerged. Over 350 cities, from Paris to Bogotá, made space for walking and cycling (Johanson, 2020). The pace at which non-motorised transport facilities such as cycle lanes are implemented was accelerated, contributing to population health by stimulating active commuting. Supported by these evolutions, e-bikes sales further rose and reached new markets. In the United States, conventional bicycle sales increased by 46% in the January-October 2020 period, compared to the same period in 2019, while e-bike sales grew by 140% (Furchgott, 2021). This increase is forecasted to continue in the future, especially if challenges of affordability and unclarity over the regulatory framework applying to these vehicles, that persists in some countries, are tackled (see Section 3.3). Deploying electric bicycles in a shared fleet is another option that municipalities can explore. The logistics sector is a further area where cycles can play a crucial role: replacing trucks by electric cargobikes for urban logistics is a promising solution in order to reduce emissions and alleviate congestion caused by deliveries (see further details in Section 3.11).

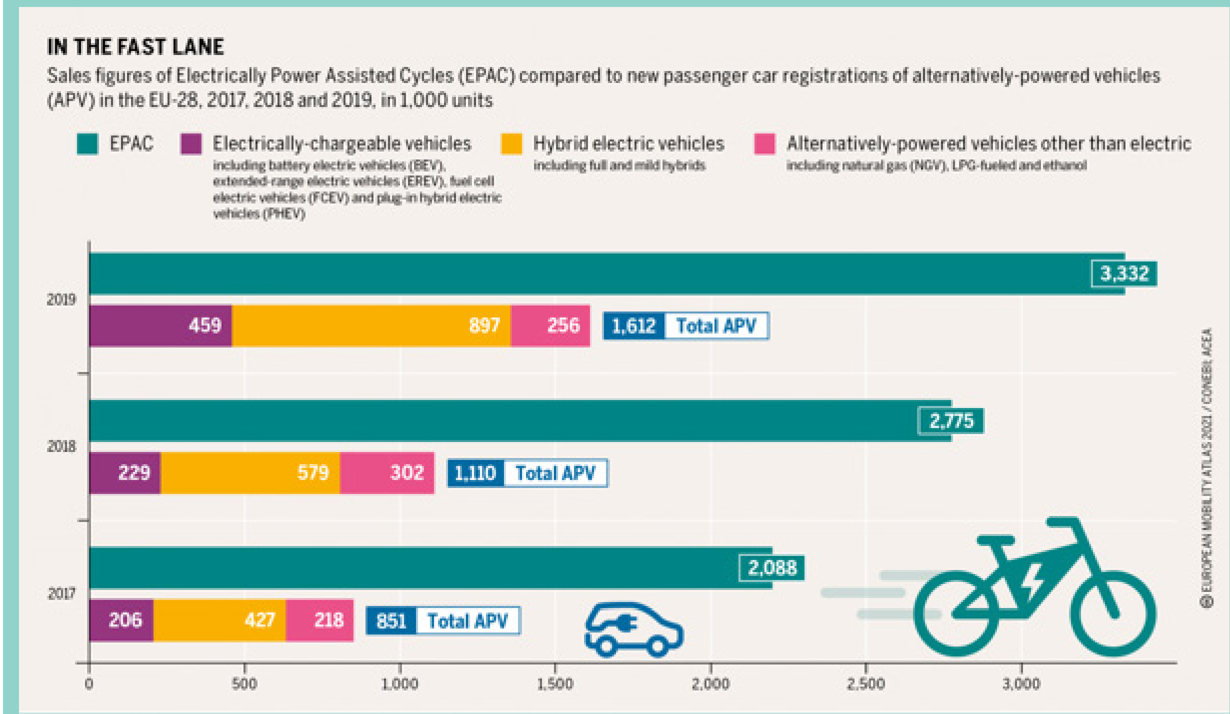


Figure 8. In the fast lane: sales figures of Electrically Power Assister Cycles (EPAC) (Heinrich-Böll-Stiftung European Union, 2021, CC-BY-SA 4.0)

1 Also referred to as Electronically Power Assisted Cycles (EPAC), or pedelecs. When using the terminology of "e-bikes", this box addresses this type of pedal electric bicycles, not the scooter-style e-bikes without pedals.

How can e-bikes contribute to a desirable modal shift? A recent study reviewing existing research on the use of pedal electric bicycles, mostly conducted in Europe and North America, found out that the use of personal e-bikes is linked with a reduced use of private fully motorised means (Bourne et al, 2020). Various studies have shown that e-bikes have replaced short car trips ranging from 20% to 86% (ibid). The degree to which e-bikes replace other transport modes significantly vary across locations. For instance, they substituted 38% of car trips among survey participants in Antwerp (Belgium), 49% in Rome (Italy), and 25% in Barcelona (Spain) (Castro et al., 2019). Yet, e-bikes may also be an important substitute to conventional bicycles, public transport or, to a lesser extent, walking. In a study across seven European cities, Castro et al. (2019) found out that e-bikes exclusively substituted 25% private motorized vehicle trips (car or motorbike), 23% conventional bicycle trips, and 15% public transport trips on average. These differences in terms of modal shift are likely to depend on the mode of travel that was dominant prior to the acquisition of the e-bike. In addition, policymakers can influence the outcome by designing policies constraining the use of conventional cars and motorcycles in cities (for instance, congestion pricing, parking demand management, low emission zones), which will support the shit towards public transport and active mobility, which includes e-bikes (Astegiano et al., 2019). Supporting conventional and electric bicycles via high-quality cycling infrastructure is vital to support the uptake of active mobility.

Figure 9. "I replace a car", a logistics project implemented in Germany (DLR, 2012)

2.2 Prioritize people and public transport over private cars

The mobility of people, and not vehicles, should be at the centre of transportation planning and decision-making for e-mobility. This is achieved through a fair allocation of the urban space among various modes of mobility and the establishment of an efficient and reliable transport system where public transport forms the backbone, integrated with walking and cycling and other shared mobility options, while discouraging the use of private cars and low-occupancy vehicles.

2.3 Plan and design to accommodate a rich mix of electric mobility options integrating active and high-capacity modes of transport

Planning must cater for a range of environmentally friendly choices, prioritizing active mobility, public transport and shared mobility options. Promoting intermodality between these modes - and combining the strengths and offset the weaknesses of each mode - is key, especially between a dense, well-connected and direct network of walking and cycling routes to high quality public transport. Fare integration between public transport and feeder modes is an important modality increasing the attractiveness of public transportation. To assist the commuters to smoothly interchange between modes, intermodal journey planners and Mobility-as-a-Service (MaaS) apps can be introduced to plan and schedule trips in an integrated manner oriented to the commuting needs of clients.

Box 5: Electric Buses

While electrified public transport modes such as metros, tramways or trolleybuses have existed in many cities for a long time, a recent trend is the expansion of electric bus fleets worldwide. The shift to electric buses is paramount, as urban buses have been predominantly powered by diesel engines, accounting for approximately 25% of the black carbon (BC) emitted in cities (Climate & Clean Air Coalition, 2020). The BC in diesel exhaust poses a significant health risk and has been listed as a known human carcinogen by the World Health Organisation (WHO). Electric buses are essential to reduce noise, air and GHG pollution in cities, while catering for a significant share of the mobility needs of urban dwellers.

At the end of 2018, there were 460,000 e-buses worldwide according to the International Energy Agency (2019). China dominates the sector both in terms of manufacturing and vehicle registration, with figures two orders of magnitude higher than other countries and regions (Figure 10, recent deceleration due to decreasing subsidies). Nonetheless, recently, electric bus fleets have been expanding in other parts of the world as well: registrations doubled in Europe and India between 2018 and 2019. In India, the policy scheme Fame II supported this uptake. In Europe, buses with e-mobility elements are expected to increase from a current 10-12% of the bus market to circa 40% in 2025 (World Bank and UITP, 2018). In addition, urban electric fleets have been growing in the United States, while in South America strong markets exist in Chile, Argentina, Brazil, Colombia and Ecuador. National and urban supporting policies are critical to foster the uptake of electric mobility.

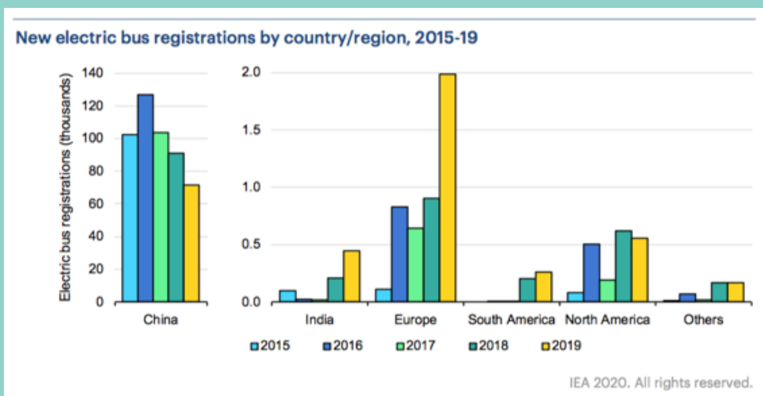


Figure 10. New electric bus registrations by country/region, 2015-2019 (IEA, 2020b)

Cities can lay out the path towards ambitious or even full electrification of their bus fleets. This is already the case in the Chinese cities of Shenzhen and Dalian, while cities such as Los Angeles, Seattle, Copenhagen, Amsterdam, Guangzhou and Nanjing have started the procurement and operation of e-buses and set a target of a full transition of their fleets by 2030 or earlier (C40, 2019).

Santiago de Chile currently has a fleet of circa 400 battery-electric buses in operation- the largest e-bus fleet outside China- and targets full electrification by 2035. Rolling out this e-bus fleet enabled the reduction of GHG emissions, a substantial reduction of operational costs compared to conventional buses, while showing higher transport users' satisfaction (ZEBRA, 2020). The reliability of e-bus operations is equal to or higher than that of diesel buses (ibid). Innovative partnerships and leasing models with electric utilities can help tackle challenges of initial investment.

Public authorities are critical for creating the financing and incentive frameworks for electric bus uptake in urban and suburban areas. Section 3.10 of this booklet delves deeper into the procurement of and business models for electric buses, showing how innovative financing and organizational schemes can alleviate the barrier of higher upfront investment costs.

2.4 Identify opportunities for multimodal transit hubs through the strategic location of electric mobility charging infrastructure

Rolling-out electric mobility requires the deployment of an adequate public charging infrastructure, which is one of the main challenges to the uptake of e-mobility in cities. This requires knowledge of electricity generation capacity, transport demand, land availability and e-mobility uptake projections.

The question of where to locate this infrastructure offers the opportunity to rethink transportation infrastructure. Cities should support the creation of intermodal transit hubs enabling seamless connectivity between mass transit and feeder services, as these increase the attractiveness of public transport. Transit hubs can act as suitable locations for the charging of different electric mobility vehicles, including e-buses, e-taxis, and electric two- and three-wheelers, especially when provided on a shared or taxi basis. Transit hubs could also be suitable places for battery swapping stations, enabling exchange of depleted batteries in a few minutes, particularly where shared, time-sensitive mobility providers are operating (see section 3.6. Charging). Besides being a place for vehicle public charging, these hubs could service as attractive places with diverse functions, activities and uses. Offering the opportunity to engage in other activities such as shopping or cultural events, while vehicles are charging, would enhance the attractiveness of electric mobility.

Figures 11 and 12 show potential scenarios of multimodal hubs in different contexts and with different vehicles, where exchanges between public, private and commercial (taxi) modes are facilitated and with an integration of electric mobility in the urban realm. Adequate space is provided for public transport, with reserved street lane and BRT stations, as well as bike lanes and bike racks; surrounding non-motorised transport infrastructure is improved, with a focus on safe walkways. Solar panels capture solar energy to supply charging stations suited to a variety of electric vehicles, on top of the electric grid. Spaces for social and economic activities, such as markets, are integrated within the mobility systems to increase attractivity of public transport and space.

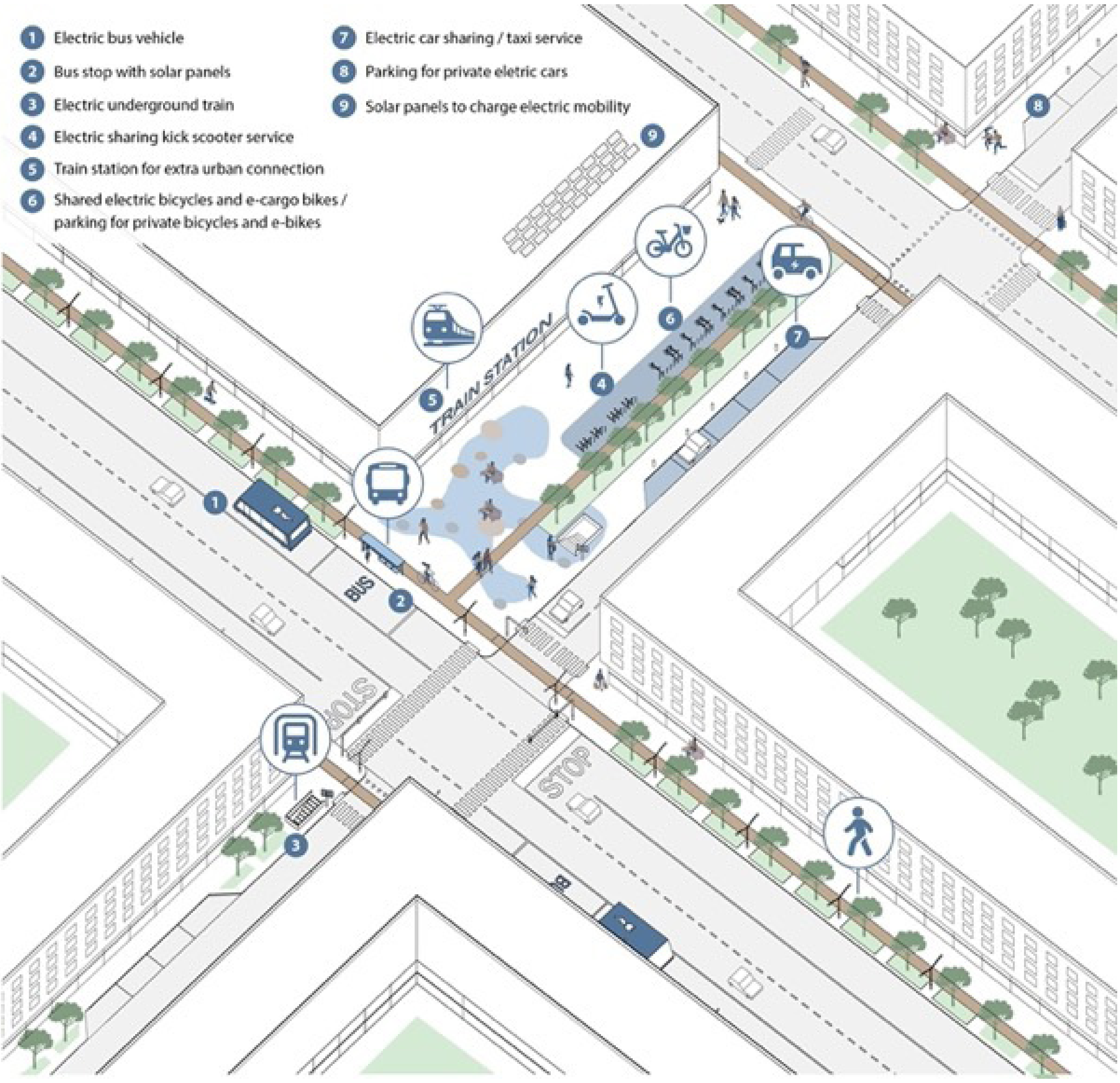


Fig. 11 Multimodal hub, Example 1 – Integration of railways, underground electric buses, electric kick scooters, shared electric bikes, electric car taxis (UN-Habitat)

Fig. 12 Multimodal hub, Example 2 – Integration of electric Bus Rapid Transit (BRT) services, bicycles and e-bike parking, electric tuk-tuks and motorcycles with improved pedestrian infrastructure (UN-Habitat)

2.5 Design an integrated transport policy approach seeking synergies between national and local measures

All available mitigation options are required to bring the transport sector on a 2° Celsius stabilisation pathway, including vehicle fuel efficiency, modal choice and compact urban design among others, in line with the Avoid-Shift-Improve framework (Lah, 2015). Efforts should cover all transport modes and require the involvement of national as well as local levels of government. As the uptake of low-carbon transport solutions has been lagging behind its potential, due to the existence of numerous hurdles among which the initial-cost barrier (see the introduction of Chapter 3 on typical barriers), a vital element for transport decarbonisation is to design an integrated policy package. This multi-modal, multi-level sustainable transport package should tackle all elements of the Avoid-Shift-Improve paradigm and seek alignment and complementarity between national and local policies. Integrating national and local policies is critical to streamline decisions and ensure consistency in measures targeting sustainable mobility. Figure 13 shows the critical interlinkages between systemic pillars as well as between local and national measures by highlighting some of the key interventions at the local and national level addressing system efficiency, trip efficiency and vehicle efficiency.

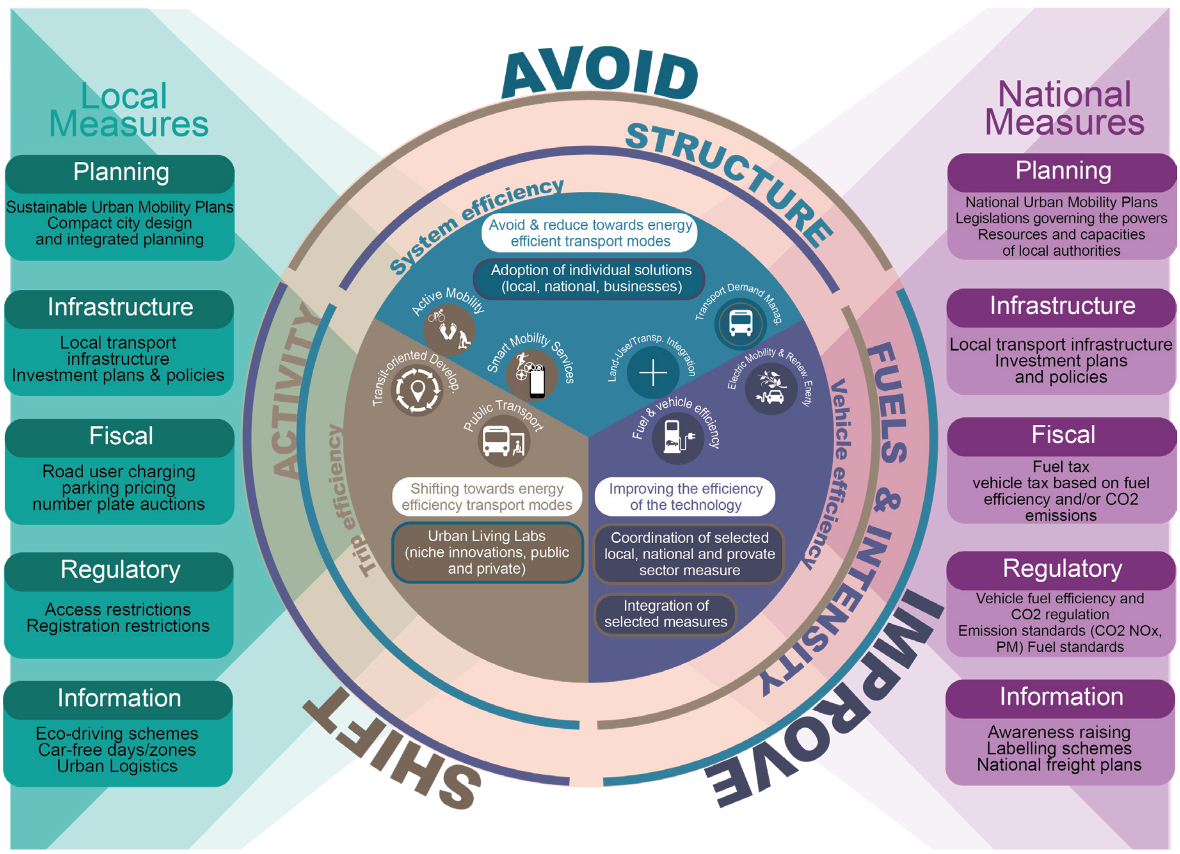


Figure 13: Key measures in a comprehensive mobility transition strategy (UEMI 2020)

Table 1 gives a non-exhaustive overview of possible measures of both national and local measures, which are further detailed in Sections 3.1 and 3.2 on policies targeting electric mobility.

Table 1: Elements of a multi-modal, multi-level sustainable transport package and their complementarity (Lah, 2019)

National Measures	Complementarity of measures	Local Measures
Planning • National Urban Mobility Plans • Legislations governing the powers, resources and capacities of local authorities	Objectives of national and local plans are in line and contribute to common goals • Compact and policy-centric planning enables short trips and increases access	• Sustainable Urban Mobility Plans • Compact city design and integrated planning
Infrastructure • National transport infrastructure investment plans and policies	• National and local transport infrastructure projects are following an integrated planning approach and contribute to the same objectives	• Local transport infrastructure investment plans and policies
Fiscal • Fuel tax • Vehicle tax based on fuel efficiency and/or CO_2 emissions	• Fuel tax encourages more efficient use of vehicles, which helps minimising rebound effects • Complementary measures at the local level help managing travel demand and can generate funds that can be re-distributed to fund low-carbon transport modes	• Road User Charging, parking pricing, number plate auctions • Provision of public transport, walking and cycling infrastructure and services
Regulatory • Vehicle fuel efficiency and CO_2 regulation • Emission standards (CO, NOx, PM) • Fuel standards	• Vehicle standards and regulations ensure the supply of efficient vehicles together with local regulations and access restrictions help steering consumer behaviour	• Access restrictions • Registration restrictions
Awareness and information • Awareness raising • Labelling schemes • National freight plans	• Consistent messaging can help influencing choices and mobility behaviour of individuals and businesses	• Eco-driving schemes • Car-fee days / zones • Urban logistics

2.6 Build cross-cutting institutional cooperation

Similar to other sustainable transport policies, the development and implementation of an e-mobility strategy requires an integrated approach with cooperation and consultation between the different levels of government and relevant authorities.

This integrated planning needs to be carried out at two levels. At a horizontal level, coordination across different governmental institutions is crucial to ensure that targets and policies are aligned. Electric mobility impacts a broad range of sectors, namely transport, energy, industry, finance, environment, urban development, education and research. At a vertical level, alignment of strategies developed by national, regional and local authorities is similarly critical to ensure consistency. National governments have to bring forward enabling policies, regulatory frameworks and modulate fiscal instruments in order to facilitate a transition to e-mobility on the local level, for instance through fuel, import, VAT and electricity duties and charges. Sections 3.1. and 3.2. of this document detail policies which can be implemented at different levels and planning processes.

2.7 Engage with all relevant stakeholders across multiple sectors, strengthen public-private partnerships and create co-ownership of the transition

E-mobility is characterised by a particularly extensive range of stakeholders from the transport, energy, environment, urban development, industry and health sectors. To implement successful e-mobility programmes, participation in the design of e-mobility solutions must be encouraged and stimulated with a systemic approach among transport operators, grid operators and energy producers, utility companies, original equipment manufacturers (OEM), urban residents, businesses, shops, academia, mechanics, and other stakeholders who may be directly or indirectly involved in or impacted by a transition to e-mobility. As situations vary depending on local contexts and transport modes involved, an ad-hoc mapping of relevant stakeholders is a prerequisite to any e-mobility policy. Different sectors should understand e-mobility as a contributing element to their policy objectives, such as air pollution, climate strategies or local economic development. In more advanced e-mobility programs, governments are finding a role in supporting industry innovation, targeting both emissions policy and industrial policy with the specific aim of creating jobs and developing domestic industry.

Participatory planning makes public acceptance and support more likely and thus minimises risks for policymakers. Government needs to bring forward enabling regulatory frameworks and provide incentives to the private sector to engage in electric mobility. Citizens and stakeholders can not only contribute to the design of policies, but also implement policies: they will be the ones (co-)owning electric mobility assets (i.e. vehicles and charging infrastructures) and/or using (shared) electric mobility services.

Box 6: Two illustrations of multi-stakeholder e-mobility cooperation

AT THE CITY LEVEL: THE LIVE PLATFORM IN BARCELONA, SPAIN

The uptake of electric vehicles in Barcelona has been possible thanks to actions and incentives promoted at both governmental and local levels. Subsidies and funding opportunities facilitate the uptake of electric vehicles in Spain, such as the MOVELE Plan for cars, PIVE 8 Plan for efficient cars and the PIMA Air Plan for electric commercial vehicles and electric bikes. In Barcelona more specifically, benefits for e-vehicle drivers include free or discounted parking spaces at regulated areas, and free circulation on high occupancy vehicle lanes managed by the city. Another strategy adopted is the usage of social media to inform or promote the benefits of e-vehicles to the citizens. The platform LIVE (Logistics for the Implementation of the Electric Vehicle) coordinates policies and supports projects to promote e-mobility as well as new start-ups in the field of e-mobility. The platform is led by Barcelona City Council, the AMB (the public administration of the metropolitan area of Barcelona), and the Government of Catalonia, and is open to all private entities with an interest in e-mobility.

More examples: http://www.uemi.net/toolkit.html

AT THE NATIONAL LEVEL: THE GERMAN NATIONAL PLATFORM FOR ELECTRIC MOBILITY (NPE)

The NPE was founded in 2010 by the German Federal Government as an advisory council tasked with monitoring the process of e-mobility development and developing recommendations to achieve the objectives of the National Development Plan for Electric Mobility. As dialogue between different sectors and stakeholders is critical for the success of e-mobility, the Platform gathers 150 representatives from industry, science, public institutions, trade unions and trade associations, looking at economic, social and environmental potentials of electric mobility. The NPE is supported by the Federal Government's Joint Agency for Electric Mobility (GGEMO). One of the working groups is specifically dedicated to urban planning and intermodality.

More information: http://nationale-plattform-elektromobilitaet.de/en/

Box 7: Working with innovators to promote electric mobility: un-habitat's experience

UN-Habitat's experience of supporting a "mobility accelerator" at the University of Nairobi C4DLab in Kenya, led to the idea of challenging local innovator communities to come up with e-mobility solutions in collaboration with city authorities. A competitive selection process was run in 2021 by UN-Habitat, which resulted in 21 proposals tackling various electric vehicle types from different cities, including Hanoi (Vietnam), Pasig City (Philippines), Kathmandu (Nepal), Dar es Salaam (Tanzania), Kigali (Rwanda), Quito (Ecuador) and Montevideo (Uruguay).

This experience shows that cities can similarly adapt their standard procurement process to "procure" and "co-develop" innovative e-mobility solutions with the entrepreneurial community. Based on UN-Habitat's experience, cities can consider the following steps to collaborate with the start-up community:

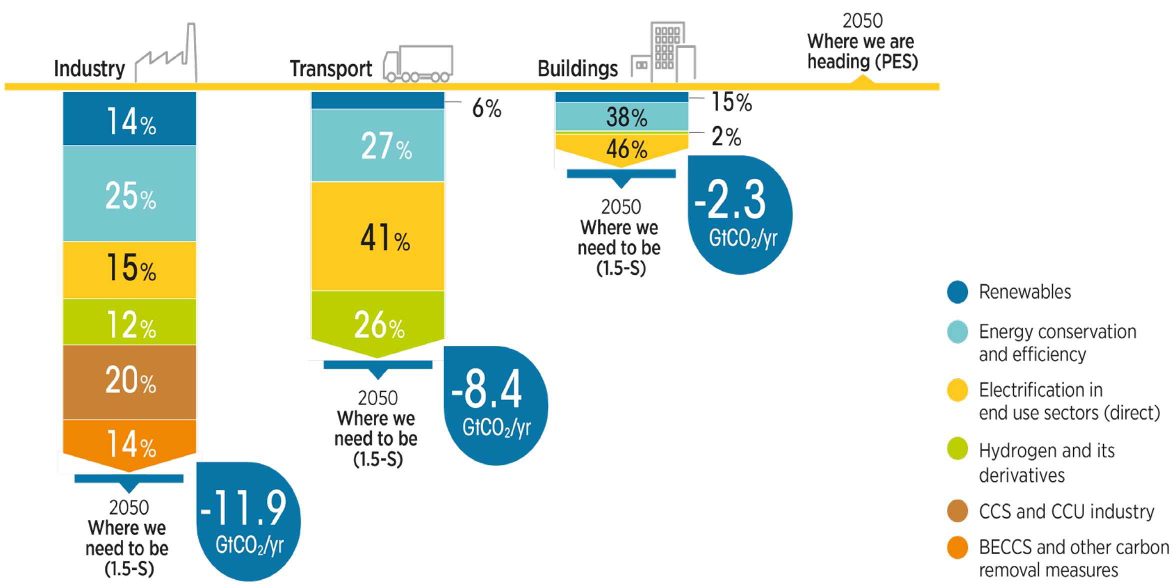
- engage with national, local universities and technical institutions to establish "start-up/ mobility accelerators",
- carry out a market assessment of what is available. Cities can run a process or competition asking the start-up communities to present their innovative ideas and conduct a city-industry meet,
- frame more detailed specifications and invite competitive bids from the market for broadly defined solutions, for instance a bike-sharing or a freight delivery system,
- launch a call for proposals and compare bids based on objective criteria such as passenger or freight kilometres offered by the e-mobility solution,
- frame contracts and make payments to the successful start-up based on performance criteria.

2.8. Promote equity and inclusion in the deployment of electric mobility

Equitable and inclusive e-mobility solutions that meet the needs of diverse users must be promoted, with particular attention to people with disabilities, women, the elderly and children. Physical, financial and digital access to electric mobility should be ensured by carefully designing these options. For e-mobility planning and implementation to be inclusive and socially sustainable, the benefits and costs of transport and travel services (mobility) and the spatial organisation of facilities and services (geographic accessibility) should be equally and equitably distributed across the urban society (Grieco, 2015). An increase in the adoption of e-mobility should not amplify existing inequities and inequalities in accessibility. Shared systems offering lightweight electric vehicles such as e-bikes, are one strategy to address the affordability issue of electric vehicles, possibly including discounts for low-income users.

In developing contexts, paratransit and semi-formal transport operators should be involved in the design and implementation of e-mobility projects. As charging infrastructure will need to be deployed, e-mobility allows to rethink approaches to paratransit waiting and parking spaces that may be neglected in urban planning. In addition, the question of the total cost of ownership of electric mobility is critical: while electric vehicles are more expensive to purchase (higher upfront investment costs), they also have lower operational and maintenance costs, depending on local parameters such as fuel and electricity costs. Business models that remove the risk of the transition for transport providers should be encouraged and supported: one possible scheme is leasing or renting out batteries or vehicles to the driver or operator, instead of selling them (see section 3.10 on innovative business models). Such schemes are key to facilitate the transition and possibly translate the electric vehicles' lower running costs into increased drivers' earnings.

Furthermore, e-mobility projects can be used as an opportunity to proactively promote and strengthen the role of women. Some e-mobility initiatives already include a stronger women involvement as drivers and entrepreneurs, for instance the Safa Tempos in Nepal, or the Mobility for Africa start-up in Zimbabwe. Gender-sensitive policy design and implementation are essential for the successful transition to a low-emission transport sector. Programs should explore options and work with policymakers to integrate gender considerations into e-mobility, aiming to increase the participation of women in various segments of the transport value chain.



Source: IRENA, 2021

Figure 14: Emission reduction from the electrified transport sector in 2050

Box 8: Safa Tempos: Women-led electric three-wheelers in Nepal

In the 1990s, a fleet of electric tuk-tuks emerged in the Kathmandu valley, following the ban of diesel-powered three-wheelers. A successful example of public transport electric vehicles, these tuk-tuks - continuously operational since 1996 - use a system of battery swapping, travelling 100-120 km per day with 2 sets of lead-acid batteries. Remarkably, women drove the development of these vehicles named 'Safa Tempos', both as entrepreneurs and drivers. At the start of the project, a group of seven women purchased and ran vehicles. Today, 210 women own and operate their own Safa Tempo business, with more than half of drivers also being female (UITP, ESMAP and World Bank, 2020).

Within the SOLUTIONSplus programme, which supports innovative and integrated electric mobility solutions worldwide funded under the European Union's Horizon 2020 programme, the Safa Tempos system will be modernized, introducing fast charging and switching to lithium-ion batteries

Source: UNEP (2020)

Box 9: E-mobility for all: Equity and Inclusion

There are several linkages between electric mobility and equity. Firstly, the reduction of air pollution enabled by electric mobility can have a socially beneficial and environmental justice impact: emissions from the transportation sector have historically disproportionately impacted low-income communities, often residing closer to pollution sources while possessing fewer private vehicles (Mitchell and Dorling, 2003). Secondly, it is critical for cities to place equity and affordability at the center of electric mobility deployment programs to ensure that these are rolled-out in an inclusive way.

In the United States, Forth, a non-profit trade association founded in 2011 with over 180 members, is advancing the use of smart transportation to move people and goods in a more efficient, cleaner, and equitable way. Forth recognizes that past transportation policy has often reinforced inequality and prioritizes bringing clean transportation options to historically underserved communities. Sample work includes:

- community-based needs assessments to design electric mobility projects fitted to their needs, through partnerships with trusted community-based organizations and leaders focusing on capacity building, funding, and reinforcement of the expertise of community-based organization staff to engage on mobility issues,
- an electric carsharing program in a low-income neighborhood,
- a shared electric bike program,
- a project demonstrating how electric vehicles can strengthen senior services and save money for community-based organizations in low-income communities,
- an assessment of city practices that center equity in electric mobility programs, and a program that brings environmental and equity groups together.

Learn more at forthmobility.org/about/equity

Carsharing pilot in California (Forth, 2020)

2.9 Promote the use of renewable energy sources and move towards a zero-emission future

A clean energy mix is a precondition for a successful transition towards a zero-emission future. Rapidly reducing the carbon intensity of power generation by increasing the share of renewable energies is paramount to maximise climate and air quality benefits of electric mobility.

Over the past decade, renewable energy cost reductions coupled with innovation and enabling policies, have paved the way for the growing capacity additions and investments, which have been driving the process of global energy transformation (IRENA, 2020a). Since 2009, the global installed renewable power generation capacity has doubled, largely driven by variable renewable energy sources such as solar photovoltaics (PV) and wind power (IRENA, 2020b). By 2018, more than a quarter of the total electricity generation was from renewable energy sources. Thanks to continued decline of their costs, the share of renewable electricity in the total generation is expected to increase to 90% by 2050 as part of global measures to limit the global temperature rise below 1.5 °C (IRENA, 2021).

Countries across the globe are picking on the development of renewable electricity generation and are also accelerating the deployment, which benefit the transition of other sectors. Germany provides an inspiring example: the share of renewables has contributed to approximately 56% of the total net electricity generation for the public power supply in the first half of 2020 in the country – the new record representing nearly a tripling in share comparing to that of 19% about one decade ago – thus providing the potential to decarbonise other sectors, such as the transport sector (Fraunhofer ISE, 2020; Eriksen, 2020). In 2020, global EVs sales, with 3.2 million units, accounts for 4.2% of the global total, representing a 43% increase from 2019, even in a difficult situation affected by the COVID-19 pandemic crisis. To some extent, this is attributable to the 24% drop in cost of battery packs and cells for EVs over 2018-2020 (IRENA, 2021).

The rapid increase in shares of EVs in the total car sales will eventually change the global landscape of transport sector, which will also be steadily integrated with the power sector on a pathway toward a decarbonised sector. By 2030, electric vehicles could reduce GHG emissions by two-thirds compared with conventional vehicles in a scenario with higher penetration of renewables, versus a 50% reduction in a less ambitious scenario (IEA, 2020b). IRENA's World Energy Transitions Outlook projected that the stock of electric cars would reach 380 million over the same time period, representing a 38-fold increase from today's level, and by 2050 reach 1,780 million, in addition to 28 million electric trucks. Electric vehicles would meet more than 80% of the total road transportation demand by 2050, while avoiding the emission of 3.4 $GtCO_2$ annually as shown in Figure 14 (IRENA, 2021).

The transition to e-mobility is part of the overall energy transition strategy to achieve the net-zero target by 2050, which will work only if electricity for charging EVs is generated from renewable and other emission-free energy sources. In return, EVs with smart charging could contribute significantly to enhance the grid flexibility that would be needed in accommodating high shares of variable renewable energy sources such as solar PV and wind (IRENA, 2019) (see Section 3.14 on Vehicle-to-Grid). This requires a concerted cross-sectoral planning process to ensure system integration and inter-operationality among different sectors at various levels including the national, regional and city levels. Wherever applicable, renewable-based decentralised energy systems that can be deployed locally in and around cities should be given priority. This would not only minimize the transmission losses but more importantly create local economic activities and job opportunities, while at the same time enhancing climate resilience when systems are coupled with an array of supporting technologies including smart charging with EVs, intelligent energy management systems and other sector-coupling devices (IRENA, 2020c).

2.10 Provide adequate access to information on electric mobility to users

The lack of information and awareness are frequent barriers hindering the uptake of e-mobility, since consumers, policymakers and vehicle manufacturers are often not fully aware of the environmental and economic benefits related to electric mobility.

The access to and use of e-mobility options can be facilitated by providing users with regular and accurate information on the benefits of e-mobility, locations of charging and battery swapping stations, and the availability of shared mobility options, among others. Alongside communication events or workshops, MaaS applications and other digital platforms are convenient tools to inform and communicate with citizens. To avoid the exclusion of low-income population groups which may not have access to smartphones or bank accounts frequently required to use shared systems, alternative modalities to provide information and rent vehicles– for instance, cash payment options - can be additionally provided, alongside reduced tariffs (ITDP, 2019).

Communication about the benefits of e-mobility should go hand in hand with raising public awareness on air pollution - including via local measurements of air quality - and its health impacts. Measurements will also support the identification of the critical modes to be electrified with priority.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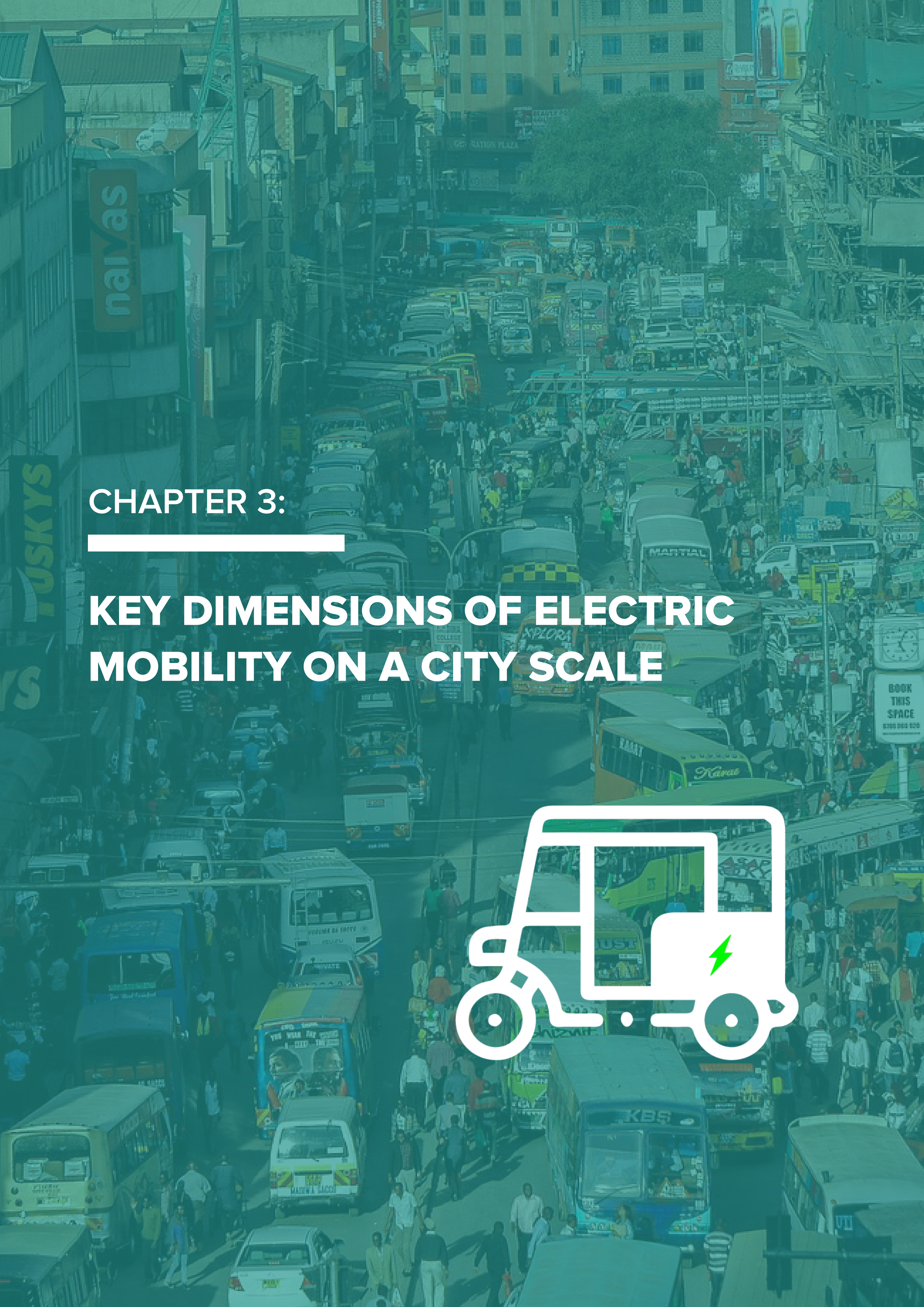
CHAPTER 3:

KEY DIMENSIONS OF ELECTRIC MOBILITY ON A CITY SCALE



Electric mobility is an opportunity to reshape the city, as it introduces new mobility options, requires planning the introduction of charging infrastructure points, and prompts innovative approaches to promote the use of electric vehicles. Successfully transitioning to sustainable electric mobility implies strengthening cooperation between policymakers, urban planners, mobility, energy and industry players, transport users and urban communities, as well as aligning policies.

An increasing number of cities across the world have integrated or are considering integrating electric mobility within their transport, energy and urban planning strategies. This undertaking may appear challenging given the extent of dimensions deeply impacted by electric mobility. Hence, this chapter aims to attract the attention of urban public authorities and stakeholders to key dimensions to consider when implementing electric mobility.

Transitioning to electric mobility means overcoming a number of barriers relating to policy, regulatory and institutional, technical, financial, as well as behavioural and knowledge aspects, summarized below in figure 15. One of the most pressing obstacles to the widespread market penetration of energy efficient products is the investment barrier. Various studies indicate that GHG reduction measures in transport have quite favourable abatement costs but need higher capital intensity than many measures in other sectors (Lah, 2015). Even though over the lifetime of a vehicle, these investments lead to considerable economy-wide benefits, they may not create sufficient payback rates for consumers ultimately responsible for vehicle purchasing decisions, who often do not take into consideration cost-savings from fuel efficiency beyond 2-3 years.

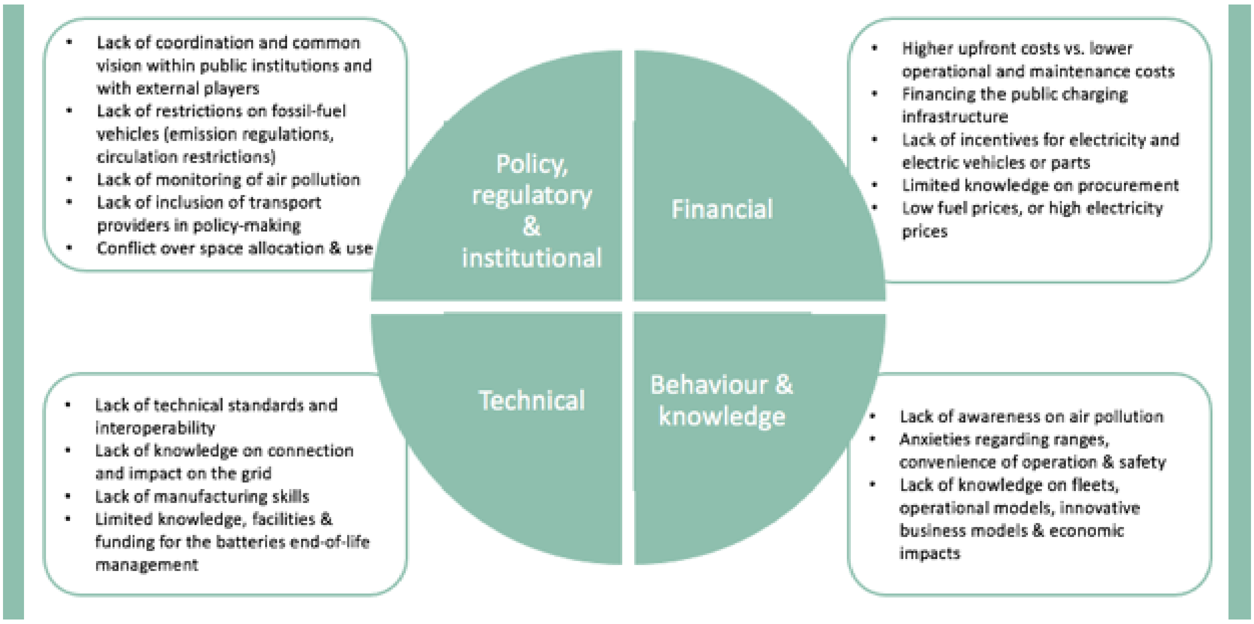


Figure 15: Overview of some key barriers hindering the development of electric mobility

Similar challenges to the uptake of electric mobility may be found across locations; however, a thorough assessment of local challenges and needs, transport characteristics and business models should be undertaken before adopting any policies. This chapter thus describes common challenges faced when designing and rolling-out e-mobility solutions, and provides some answers.

Box 10: Tools and platforms to support cities in implementing e-mobility

The Action Platform Urban Electric Mobility Initiative (UEMI) was launched by UN-Habitat and the SOLUTIONS project in 2014. To contribute significantly to the goal of decreasing urban CO_2 emissions globally, the UEMI aims to phase out conventionally fuelled vehicles in cities and integrate e-mobility into a wider concept of sustainable urban transport. The UEMI secretariat develops partnerships with local authorities, industry, SMEs, knowledge and network partners (over 150 partners), and currently implements the EU-funded project SOLUTIONSplus project. piloting innovative and integrated urban e-mobility solutions worldwide.

TUMIVolt forms the e-mobility branch of the Transformative Urban Mobility Initiative (TUMI) (https://www.transformative-mobility.org/campaigns/tumivolt). Through webinars, conferences and pilot projects, TUMIVolt supports cities in the Global South in introducing integrated electromobility solutions. In addition, TUMIVolt intends to prepare over 500 cities to procure 100.000 e-buses by 2025. TUMIVolt also actively supports the development of policy recommendations on the international and local levels by leading the e-mobility workstream of Sustainable Mobility for All (SUM4ALL).

Action towards Climate-friendly Transport (ACT) coalition

The Action towards Climate-friendly Transport (ACT) coalition was launched at the UN Climate Summit 2019. It aims to catalyse transport as an enabler of sustainable development in line with the 2030 Agenda for Sustainable Development and the Paris Agreement, by connecting innovative approaches with integrated long-term planning, accelerating the deployment of electric buses in cities around the world.

INTEGRATED POLICIES TO MAINSTREAM ELECTRIC MOBILITY

3.1 Urban planning and management tools at local level

As more cities realise the advantages that clean mobility can bring to sustainable urban development in areas such as local economic development, integrated transport, social integration and urban health, there is a need to ensure that e-mobility is included as part of urban visions, plans and strategies.

Cities can make use of five types of interlinked policy instruments to facilitate the uptake of e-mobility and steer it in the most sustainable direction: planning, infrastructure, fiscal, institutional and communication. The table below identifies the most relevant urban planning instruments to achieve the integration and implementation of e-mobility in cities (table 2). It also provides a non-comprehensive list of tools utilized to roll out e-mobility in cities in a coherent and organized manner, taking advantage of the existing planning and legal frameworks. Urban planning and urban planning instruments such as mobility plans, land use plans, local area plans, and development contracts are being utilized as the main means to achieve this integration, as well as to manage the different e-mobility initiatives expanding the mobility alternatives in our cities from the public perspective.

Table 2. Local policy instruments to favour the uptake of e-mobility

City Scale	
Planning and infrastructure	
Sustainable Urban Mobility Plan (SUMP)	In order to integrate e-mobility in sustainable urban mobility planning (SUMP), a number of issues and specificities need to be tackled, including cooperation with a broad network of stakeholders, the procurement of new fleets by public authorities and transport operators, the deployment of charging infrastructure, intermodality and multimodality, adapted parking regulations, management of regulations and benefits for electric vehicle users, possible establishments of low-emission zones and neighbourhoods (Polis and Rupprecht Consult, 2019). E-mobility must be considered in its many forms and dimensions, including public transport, urban freight, shared mobility, private mobility, micro-mobility and active mobility (e.g. electric bikes or scooters). The practical steps to undertake the integration of e-mobility in SUMP planning, with a focus on infrastructure deployment, are detailed in Box X below. Example: electric mobility can be a distinct chapter of a SUMP or a separate strategy following the SUMP steps, for instance Barcelona's Electric Mobility Strategy referring to the SUMP.
Land use plans (regional, municipal, local)	Land use plans provide a shared vision for the future of cities, and help to guide the type of future activities that can take place in different areas. In order for e-mobility to become a reality, land use plans need to guide the city's or neighbourhood's vision in a direction that allows for e-mobility to be operational. Compactness, proximity, density, mixed-use, public transport and networks of public spaces are cornerstones of a functional mobility and e-mobility network and, as such, need to be core components of land use plans. Moreover, these plans should determine the equitable and efficient allocation of urban space for mobility infrastructure, parking lots and eventual charging facilities for e-mobility. The land use plan represents the strategic opportunity to include broader mobility and specific e-mobility strategies and initiatives, ensuring their detailed roll-out.
Development contracts	Development contracts are flexible urban planning instruments. Given its flexibility, the contract makes it possible for the municipality and the developer or investor to agree on providing parking spaces for e-vehicles, creating charging infrastructure in new developments or buildings, and even providing mobility management and e-car-sharing schemes in new residential areas. Additional building rights and support for real estate developments that include electric vehicles' charging stations are further options to consider. In general, contractual agreements and legal frameworks specifying responsibilities of the various stakeholders, for instance during a SUMP process (Box 11) can help increase transparency and business confidence, facilitating a transition.

Fiscal	
Financial incentives for e-mobility	Cities can make use of a variety of tools to provide financial incentives, for instance tax rebates or exemptions (e.g. exemption from road pricing charges or tolls), lower or zero parking fees for electric vehicles, lower electricity charges, subsidies for individual purchase of electric vehicles, grants and loans, scrappage schemes. To address the issue of high capital expenditure of electric vehicles and reap the benefits of lower running costs, financial support should be identified to facilitate innovative business models, for both vehicles and charging infrastructure (see section 3.10). Public procurement is a further significant instrument for municipalities to ease e-mobility uptake, by directly purchasing electric vehicles for their own fleet or requiring external contractors to introduce EVs (public transport, municipal fleets, waste collection vehicles etc.). Bringing actors together for the joint procurement of EVs also enables information sharing, streamline processes and possibly bring prices down, as implemented in Stockholm (EVUE, 2012). With regards to electric buses, the International Union of Public Transport (UITP) provides guidance on tendering and renewal processes, via reference documents such as the Bus Tender Structure Report (TSD version 3.1), a toolkit to support e-bus procurement in the specific case of India (UITP, 2020) or the Bus Fleet Renewal Checklist (UITP, 2020). Financing the shift towards cleaner vehicles can be done through national or local public funds or mixed funding models including joint ventures and public-private partnerships (PPPs). This may also be encouraged by a feebate system, introducing taxes for polluting vehicles whose revenues are then used to financially support EVs (IIT Madras (CBEEV) and WRI India, 2019).
Incentives for modal integration of EVs	Integrated fare and ticketing between public transport and electric first and last mile options, such as shared electric bicycles and electric kick scooters, can facilitate seamless connectivity (e.g. integration of multiple electric mobility options via a single card in La Rochelle, France)
Institutional and regulatory	
Vehicle access to central areas and low emission zones, parking management	An additional way to promote the use, convenience and early adoption of e-mobility is to incentivize the use of EVs by providing special parking or access permits to EVs, for instance in low emission zones (see dedicated box), as well as access to publicly accessible charging stations. Such permits should be temporary, or the low-emission zone standards become stricter over time, in order not to result in a congestion scenario once many people have switched to EVs.
Parking statutes and requirements for charging infrastructure for E-vehicles	Parking statutes are related to both urban planning and urban management. Independent or as part of urban plans, they define the maximum and minimum parking requirements for vehicles in specific areas of the city. Requirements for charging infrastructure for EVs should be included in the statutes as a mechanism to develop the e-mobility infrastructure in the city in a coordinated manner and merging the efforts of public and private entities (see dedicated box).
Cooperation	Beyond the necessary collaboration across institutional boundaries, building partnership with innovative companies (e.g. sharing or leasing models) is a proven instrument to test pilot projects which can be upscaled later.

Communication	
Stakeholder engagement, nego-tiations, PPPs and alliances and citizen consultations as ways to promote e-mobility, awareness raising	E-mobility adoption depends both on technical aspects as well as a mindset shift. This is a change that can only be achieved by working in collaboration with a broad range of actors from public, private sector, academia, NGOs and citizens organizations to promote the use and adoption of E-mobility. The SUMP process (see Box X) recognises the importance of involving urban residents in e-mobility policies, key to learning about users' needs and create a sense of ownership. The establishment of low emission neighbourhoods can also offer the opportunity for stakeholder outreach, such as in London (ICCT, 2020a).
Awareness raising	Alongside stakeholder engagement, e-mobility deployment can usefully lean on awareness-raising with regards to air pollution and its health impacts, e.g. through local air quality measurement campaigns. In addition, public aware-ness campaigns can help alleviate anxieties with regards to reliability and range of EVs.

Box 11: Planning electric mobility: Practical steps to undertake in a SUMP logic

The Sustainable Urban Mobility Planning cycle includes four phases, starting at preparation and analysis, over strategy development and the planning of measures, to implementation and monitoring (Polis and Rupprecht Consult, 2019). E-mobility can be integrated within a SUMP (e.g. a chapter of a SUMP), however, as e-mobility is relevant to all phases of a SUMP and has a particularly broad range of aspects to be considered, it may be valuable to address it through a dedicated strategy document that will complement a SUMP, or through a SUMP annex (e.g. Barcelona Electric Mobility Strategy referring to the SUMP).

Table 3. *Details of the steps of a SUMP and how they relate to specific e-mobility activities, as well as the principles for e-mobility developed above (Polis and Rupprecht Consult, 2019).*

	Steps	Sub-steps and implications for e-mobility
Preparation & analysis	01 Set up working structures	1.1. Evaluate capacities and resources: identification of entities and skills lacking in the mobility team to tackle e-mobility 1.2. Create inter-departmental core team: Principle 2.6 to cooperate across institutional boundaries 1.3. Ensure political and institutional ownership, incl. discussions over public or private ownership of charging infrastructure 1.4. Plan stakeholder and citizen involvement: key step to learn about user needs and preferences, as well as create a sense of ownership for e-mobility projects; requiring preliminary ad-hoc mapping of locally relevant stakeholders: Principle 2.7 on broad engagement with stakeholder and 2.8. on equity and inclusion
	02 Determine planning framework	2.1. Assess planning requirements and define geographic scope ("functional urban areas"), incl. identification of regulatory barriers, for instance for the deployment of charging infrastructure in public space 2.2. Link with other planning processes, with a focus on energy requirements, grid characteristics and impacts 2.3. Agree on timeline and work plan 2.4. Consider getting external support
	03 Analyse mobility situation	3.1. Identify information sources and cooperate with data owners 3.2. Analyse problems and opportunities (all modes) For both sub-steps, e-mobility should lean on a preliminary assessment of air pollution levels (How severe is the issue? Which modes should be electrified in priority?). In addition, the baseline assessment should include an analysis of mobility patterns, of existing or intended private and public EV and charging infrastructure initiatives, and of the housing stock (impact on charging options).
	⇨ Milestone: analysis of problems and opportunities concluded	

Strategy development	04 Build and jointly assess scenarios	4.1. Develop scenarios of potential futures, considering integration of e-mobility within a mobility ecosystem (e.g. e-mobility as potential leverage to improve transport modes) Principle 2.1. on Avoid-Shift-Improve and 2.3. on planning for a rich mix of e-mobility options 4.2. Discuss scenarios with citizens and stakeholders, e.g. extent of electrification and prioritization of transport modes Principle 2.8. on equity and inclusion
	05 Develop vision and strategy with stakeholders	5.1. Co-create common vision with citizens and stakeholders, e.g. charging options and locations, in a transparent decision-making process ensuring accessible information (e.g.: map of planned charging sites) as well as interoperability Principle 2.4. Identify locations and promote multimodal hubs and 2.8. on equity and inclusion 5.2. Agree on objectives addressing key problems and all modes
	06 Set targets and indicators	6.1. Identify indicators for all objectives 6.2. Agree on measurable targets, for implementation and impacts
	⇨ Milestone: Vision, objectives and targets agreed	

Measure planning	07 Select measure packages with stakeholders	7.1. Create and assess a long list of measures with stakeholders, including on vehicles and infrastructure procurement, policies regarding parking and vehicle access restriction (e.g. low-emission zone), infrastructure deployment (location, operation), etc. 7.2. Define packages of integrated measure 7.3. Plan and measure monitoring and evaluation
	08 Agree actions and responsibilities	8.1. Describe all actions 8.2. Identify costs, funding sources and assess financial capacities 8.3. Agree priorities, responsibilities and timeline, including on data management and interoperability 8.4. Ensure wide political and public support
	09 Prepare for adoption and financing	9.1. Develop financial plans and agree on cost sharing 9.2. Finalise and assure quality of a “Sustainable Urban Mobility plan document”
	⇨ Milestone: SUMP adopted	

Implementation & monitoring	10 Manage implementation	10.1. Coordinate implementation and actions 10.2. Procure goods and services for vehicles (e.g. public transport, waste collection, carsharing), infrastructure deployment (required for these vehicles, as well as public stations), applications
	11 Monitor, adapt and communicate	11.1. Monitor progress and adapt via preliminarily identified indicators 11.2. Inform and engage citizens and stakeholders (communication campaigns, accessible information tools, feedback mechanisms, possible design of branding via a local e-mobility logo), contact person within the administration Principles 2.8. on equity and inclusion and 10 on adequate access to information on electric mobility to users
	12 Review and learn lessons	12.1. Analyse successes and failures 12.2. Share results and lessons learned 12.3. Consider new challenges and solutions
	⇨ Milestone: Measure implementation evaluated	

Box 12: Low emission zones

Restricting access to certain areas of a city, normally the city centre, can have a direct effect on local air quality noise pollutions and traffic safety in this area. The effect on greenhouse gas emissions depends on the design and complexity of the scheme and the provision and integration of modal alternatives. Access restrictions schemes are applied in many cities in Europe in different forms and generally aim to restrict access to city districts or specific traffic hotspots in the city (Cervero, 2004). The main objectives are to reduce congestion and pressures on parking spaces, improve safety, reduce noise and harmful emissions. Basic access restriction schemes are easy to adopt, but require enforcement efforts to operate in the intended way (Santos, 2008). There are different types of access restriction schemes, including those that control access at specific points (e.g. when crossing a bridge), cordons or areas (e.g. around a specific location), which may differentiate further between different types of vehicles or times of the day. While these schemes can be very effective in managing congestion, noise and air pollution, they may have unintended consequences, e.g. by banning higher polluting, but potentially more fuel efficient diesel cars from entering the city, which may induce travel by redirecting to longer routes or encourage the shift to a less efficient petrol powered car. Hence, access restrictions should be implemented in combination with other measures that minimise trade-offs.

Box 13: Urban road rolls, congestion charges

One very effective option to improve traffic flows and reduce overall travel demand by avoiding and shifting traffic to more sustainable transport modes is congestion charging, which is an urban road pricing scheme for peak hours (Börjesson et al. 2012; Liu et al. 2009). Congestion charging lies at the intersection of traffic management and travel demand management, as information gained from real-time traffic information systems could be used to improve the pricing mechanisms of congestion charging by introducing real-time variable pricing systems, which can encourage more efficient travel behaviour. Congestion charging systems have been operating in Singapore for several decades and were implemented more recently in London and Stockholm. As early as 1975, the road pricing was implemented in Singapore to manage the choked streets of the rapidly growing city. First, an Area License System was established, which required a permit to enter Singapore's central area (B.W., 1990). The city entry charge boosted public transport patronage almost immediately after its introduction and led to a 45% reduction in traffic, road site accidents decreased by 25% and average travel speeds increased from about 20 km/h to over 30 km/h (Lah 2015b). The system resulted in a public transport share of over 60% in daily traffic, an increase of nearly 20% (SOLUTIONS 2016). The success of the system in improving infrastructure capacity, safety and air quality and reducing travel demand, fuel use and greenhouse gas emissions inspired the congestion charge systems in London and Stockholm and provided the basis for several feasibility studies for similar schemes for cities around the world (Prud'homme & Bocarejo 2005).

Good practice: Despite being a mid-sized city, Gothenburg in Sweden decided to introduce a congestion charging system in January 2013, which has already shown to be effective in reducing traffic by over 10% during the charging hours and a similar increase in public transport ridership. The case of Gothenburg shows that these types of schemes are not only applicable for large cities, such as London and Singapore, but also for mid-sized cites. The congestion tax applies when drivers enter or exit the congestion tax area and varies depending on the time of the day, from 0 during the night, on weekends and holiday to 22 SEK (around 2.30 Euro).

More examples: http://urbanaccessregulations.eu

Box 14: Parking Management

Similar to road user charging, parking management and pricing can help discourage the use of a privately-owned car and raise revenue to fund public transport, walking and cycling infrastructure and improve public spaces. Parking management schemes reduce the number of cars entering the city, which can reduce congestion and can encourage the use of public and non-motorised transport. The parking pricing structure and the level of enforcement are important aspects to consider. A structured fee that differentiates between different zones of a city or times depending on the demand is one aspect that needs strong enforcement to be meaningful. Coordination of parking pricing and zoning among relevant municipal authorities is another vital aspect. Parking management can be a powerful tool for local authorities to manage car use and to raise revenue (Litman, 2006). Parking management also includes time restrictions and a control of the number of available parking spaces. Parking time restriction for non-residents, e.g., to two hours, is a proven tool to reduce commuting by car without affecting accessibility to urban shops. In fact, in many cases, shops and other local businesses become more accessible when public space is freed up by a reduced number of parking spots.

Good practice: The city of Bologna introduces a differentiated parking fee system that is based on the environmental characteristics of vehicles. The wider parking management strategy includes an extension of on-street parking payment areas in the city centre from 30,500 to 45,000 spaces, and an extension of the time frame during which parking fees apply beyond 20:00. Specific high demand areas are planned to be extended and paid parking permissions for residents for the second car per family are also foreseen.

More examples: http://civitas.eu/content/pricing-and-monitoring-policies-parking

3.2 National policies supporting low-carbon urban mobility

As highlighted in Principle 2.5, “Design an integrated transport policy approach seeking synergies between national and local measures”, vertical cooperation between national, subnational and local levels of public institutions, as well as alignment of public policies, is a vital prerequisite to foster the uptake of electric mobility and ensure its development under sound conditions. In addition, horizontal, cross-cutting cooperation must be organised, as transitioning to electric mobility requires the involvement of transport, energy, environmental and industry stakeholders.

National authorities have a crucial role to play by setting targets for the penetration of electric vehicles, legal and financial incentives, as well as technical standards, with a specific focus on interoperability. A combination of fuel pricing and removal of fossil fuel subsidies, as well as differentiated vehicle and emission taxation, can help boost energy efficiency in the transport sector - and steer the purchase and deployment of electric vehicles. These measures, together with the provision of modal choices and compact city design, support the shift towards a more energy-efficient transport system. Table 4 displays a non-exhaustive list of policies which may be taken at national level, having an impact on the urban implementation of e-mobility.

Table 4. ***National policy examples that support the uptake of e-mobility at the city scale***

Sector	Policy Example
General framework (standards, fiscal instruments)	Vehicle fuel efficiency standards, aiming to safeguard a supply of efficient vehicles and to curb the level of fuel consumption throughout the vehicle fleet, providing certainty to manufacturers in order for them to invest in new technologies
	Fuel taxes and excise duty rates, which ought to be set at a level that internalises external costs (e.g. from GHG emissions), impacting travel demand, vehicle technologies, fleet fuel consumptions and CO2 emissions
	Differentiated vehicle taxation, based on fuel efficiency and/or CO2 emissions, in order to guide consumer demand (e.g. vehicle registration, purchase taxes, and/or feebate schemes). For instance, circulation taxes, a typically yearly charge, can be calculated according to cars' fuel economy (CO_2 emissions, engine size or power-to-weight ratio). Higher taxes can be placed on the purchase of less efficient vehicles, and feebate schemes can enable rebates for higher efficient vehicles.
Electric Vehicle	National targets for EV penetration with a corresponding timeline
	Technical standards covering aspects of safety, operation, test procedures and performance of different EVs (see below for charging standards) Clarifications of rules on the use of EVs (e.g. for light electric vehicles: maximum speeds, driving age, use of helmets, circulation, parking)
	National framework enabling financial incentives (e.g. direct subsidies, loans and grants, tax breaks on purchase and insurance, reduced VAT, exemption of registration charges or annual circulation tax, company car tax exemptions etc.)
	Support for local manufacturing of parts including batteries; decrease of import tariffs for EVs and parts (balance to be found between both measures)
	National framework allowing low-emission zones; registration charges and bans for petrol/diesel cars in inner city areas; planned progressive phase-out of fossil-fuel vehicles; requirement of only new electric ride-hailing vehicles etc.
	Support the introduction of new e-buses or retrofit of conventional vehicles with an electric powertrain, for instance through PPPs, financing pilots, co-investing in the charging infrastructure
	Subsidies for electric two- and three-wheelers, support of innovative rental or leasing models
	Foster research and development and promote enabling regulations for innovative shared electric mobility modes, such as cable cars and electric taxis
	Funding to support the uptake of e-bicycles and e-cargo bikes
Battery	National government invest in private tech sectors to develop local battery supply chains; development of EV clusters
	Government-led R&D centre to deliver innovations to support battery industrialisation
	Support vehicle-to-grid innovation where electric vehicles are used to supply electricity to the grid at times of high energy demand
	Support and facilitate battery end-of-life management by encouraging repurposing EV batteries into a second life (energy storage) and refurbishing old electronics into new EV batteries; national Extended Producer Responsibility policy to increase collection rates

EV Charging Infrastructure	Establish uniform charging and payment standards, including rules on socket standards and minimum requirements for public charging stations
	Clarification of responsibilities and obligations to provide connection, as well as the procedure for connection
	Amendment of construction laws/building code to integrate charging infrastructure in new developments
	Provide funding for the establishment of public charging hubs (possible swapping) in key strategic, community, or urban locations
	Support the charging infrastructure uptake by providing taxation exemptions for charging services, e.g. lower electricity tariffs for EV charging/swapping stations; clarifying the regulatory framework applicable to charging stations
Innovation	Drive competitions and open calls, collaborate with private sectors and academia to deliver the most state-of-the-art solutions
	Provide an Open Innovation Platform to enable local and foreign companies and research organizations to develop and test various mobility technologies
	Set up a Global Innovation Centre to undertake research and develop work in the areas of mobility and energy management solutions

Box 15: National Urban Mobility Policy (NUMP)

The complexity of urban transportation requires a strong policy framework from the national level that supports integrated urban design, enables the shift to low-carbon modes and fosters the take-up of low-carbon vehicle technologies. While this creates challenges for appropriate policy design, it also creates opportunities for co-benefits between climate policy and other objectives, such as safety, air quality and energy security. The interplay of various policy objectives calls for coalitions among key local and national political actors and a National Urban Mobility Policy (NUMP) can provide a framework and process for this (Lah 2018).

A coherent National Urban Mobility Policy (NUMP) that links national and local policy and investment flows is a vital element in a common strategy to decarbonise the transport sector. NUMPs aim at policy coherence and the exploitation of synergies among different policy fields on the national level (vertical integration) and at facilitating the uptake of high-quality Sustainable Urban Mobility Plans (SUMPs) in cities and regions (horizontal integration, enabling cities).. A NUMP identifies the linkages between local and national policies, sets up coordination mechanisms between institutions in charge of delivering on urban mobility policy and planning, establishes funding and financing mechanisms that embrace the concept of subsidiarity, but also ensures that local actions meet national climate and sustainable development objectives. Elaborating and adopting a NUMP is a consensus building process that defines system boundaries (i.e. relevant policy fields and actors), derives and ranks policy objectives, responsibilities and resources, identifies policy measures and establishes a review and evaluation process.

3.3 New urban mobility options through e-mobility

Reshaping mobility options

Electric mobility provides an opportunity to reshape user patterns and sustainable mobility opportunities through the introduction of new and innovative vehicle types, such as electric bicycles or standing e-scooters, possibly acting as a catalyst to replace car trips. Studies have shown that owners of e-bikes reduce private car trips more than other user groups, are more prone to switch to non-motorised transport and increase their distances cycled for daily travel (Fyhri and Sundfør, 2020).

In addition, these services can provide first and last-mile connectivity and reinforce the backbone role of public transport. Innovative electric vehicles can also address the needs of delivery businesses that are increasingly contributing to transport emissions in cities (further information in Section 3.10).

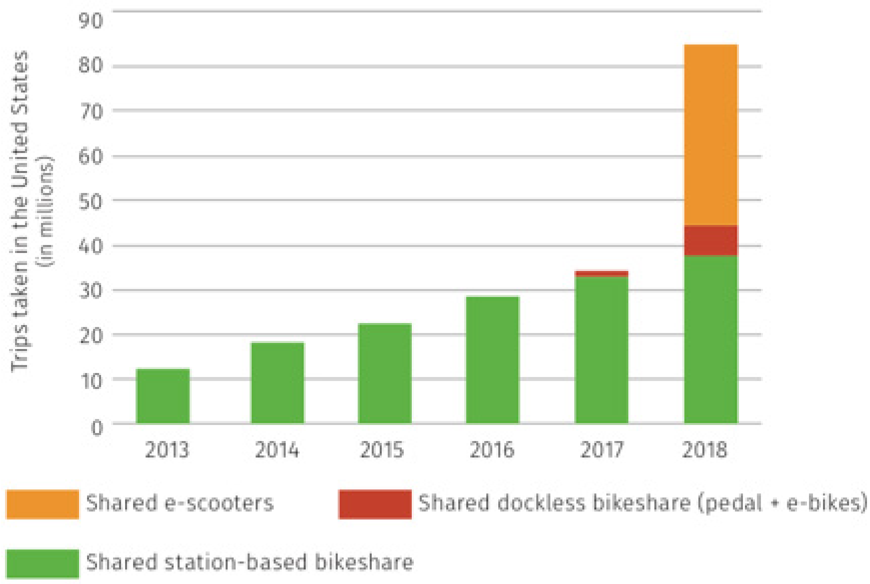
Yet, a set of barriers still hinders the development of electric bicycles. Affordability is one aspect, as upfront and charging costs can be a significant hurdle for low-income groups, as well as in low- and middle-income countries (ITDP, 2019). Shared systems (see below) may offer an alternative option. Yet, they also need to be available outside high-income neighbourhoods where dockless e-bikes tend to be concentrated. Another barrier concerns national regulatory frameworks, as e-bikes are sometimes assimilated to motor vehicles, necessitating registration, license or insurance. These administrative barriers may discourage potential users and obstruct mass adoption. Another caveat is that countries do not always properly consider e-bikes when talking about electric mobility, hence not including incentives such as reduced import taxes for bicycles.

Finally, a safe cycling infrastructure is a critical dimension to consider in order to reduce crashes and injury. In the past, failures to develop this infrastructure have prevented a mass uptake of active mobility at times where cycling was gaining popularity, for instance in the 1970s in the United States (Furchgott, 2021; Sisson, 2017).

Shared vehicles

E-vehicle sharing services, which emerged in major cities in the early 2000s and have grown worldwide over the past decade, allow members to borrow electric scooters, e-bikes, electric mopeds or electric cars on a short-term basis and can reduce the effects of climate change while increasing access to jobs, resources, and raising overall quality of life. The economics of electric vehicles, with higher investment costs but lower operational and maintenance costs, favour sharing vehicles. Within a sharing system, the user gets access to an EV without having to bear the high purchase costs. Sharing electric schemes are on the rise: Figure X shows the growth of passenger trips undertaken by using shared systems (e-scooters, e-bikes, conventional bikes) in the US between 2013 and 2018.

Alongside the rise of privately owned e-bikes, mentioned earlier in the publication, shared systems including electric bicycles are growing as well, though at a slowly pace. According to ITDP (2019), less than 60 of over 1,600 publicly financed bikeshare schemes across the world offer at least 100 e-bikes, and less than half of those are full e-bike systems. The impact of electric bikeshare systems, as well as patterns of modal shift induced by bikeshare systems, have been less researched than privately owned e-bikes (Bourne et al., 2020).



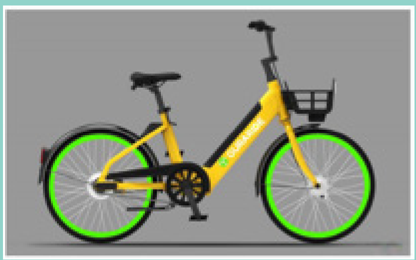
Expansion of passenger trips using shared transport modes (ITDP, 2019)

Box 16: Examples of shared e-bikes systems

The competitive selection process run by UN-Habitat (see Section 2.7) saw the selection of 21 proposals, including shared schemes including electric bicycles.

(VN Explorer, 2020)

Hanoi and Hoi An, Vietnam: the Vietnamese company QIQ Vietnam has deployed a public shared electric bike system in Ecopark, Hung Yen, a township in the vicinity of Hanoi (6 docking stations, 40 electric bikes), and in Hoi An (100 electric bikes and 225 mechanical bikes distributed in 15 parking stations). Booking of e-bikes is possible through the QIQ app. Following the UN selection process, QIQ will further deploy a shared e-mobility system consisting of e-bikes and e-scooters, connected to the Bus Rapid Transit system. The solution is being developed in partnership with the University of Transport Technology, Vietnam and the Hanoi City authorities.



(Gura Ride, 2020)

Kigali, Rwanda: Gura Ride is a green e-mobility ride-share transport system company based in Rwanda, aiming to reduce carbon emission, improve air quality, and ease congestion by developing alternative means of green transportation. Services offered include shared bicycles, electric scooters and electric bikes, available in a single app to enable users to choose their ride preference. The deployment of dock stations is concentrated in the vicinity of bus stops in order to facilitate seamless first and last mile connectivity for transport users.

Moreover, in Quito, Ecuador, a consortium of organisations led by PLURENFOKE CIA LTDA (PLURAL), will encourage the adoption of electric mobility in the Historic Center of Quito (HCQ) through the development and deployment of electric bike-vehicles with the Mobility Secretariat of the Municipality of Quito.

Box 17: Lightweight electric vehicles in China

In a context fraught with dangerously high urban pollution levels and ultra-congested streets, cities like Beijing and Shanghai lead the way to reduce automotive transportation and make the switch to emission-free solutions. In the 1990s and 2000s, several Chinese cities enacted bans or restrictions on gasoline-powered motorcycles, fuelling the surge of private electric bikes through a mix of bicycle-style and scooter-style e-bikes. A modal shift was observed in Kunming, with 25% of e-bike riders stating to have replaced their car trips by this mode (Fishman and Cherry, 2015). E-bike sales grew faster than other types of personal transport vehicles.

In parallel to this e-mobility evolution, conventional docked bike-sharing municipal programs were launched in Hangzhou in 2008, in an effort to alleviate mobility issues. Numerous other cities within China, including Beijing, Shanghai, Wenzhou, Kunming and Guangzhou, have since set up public bike-sharing programs. The roll-out of shared electric bicycles and kick scooters often faces concerns with regard to road safety and urban management such as the use of sidewalks by vehicles (WRI, 2020). Yet, the demand for the coverage of longer distances using shared electric means has grown in the wake of the Covid-19 pandemic (Ma Wenyan, 2020). To address these safety concerns of electric micromobility, ITDP (2019) recommends designing safe, inclusive on-street infrastructure such as cycle lanes, and offering public safe-riding courses in partnership with civil groups, schools and operators.

Box 18: Another type of innovation: cable cars

The use of cable car technology as a means of urban public transport has been recently initiated. An energy-efficient electric motor propels the aerial rope to which the cabins are attached. The electric drive limits noise pollution and ensures the absence of local emissions such as nitrogen oxides (NOx) or particulates, securing its low environmental impact. Cable cars can thereby contribute to the decarbonization of the urban transport sector.

Cable car installations have a small physical footprint. This allows for implementation in a densely built urban environments, and preserves open and green spaces, a valuable asset in cities. Cable cars can serve areas that are difficult to reach with conventional means of transport. They can complement and be conveniently integrated in existing transport networks or may act as the backbone of a transport network. A coordination of schedules is not necessary, as cabins are in continuous movement which reduces or even eliminates waiting times and smoothens modal interchanges. Several cities worldwide have introduced cable cars as components of their public transport networks, including London, Bogotá, La Paz and Mexico City.

Example: Mi Teleférico (which translates as "my cable car") in La Paz, Bolivia, is the world´s largest cable car network. It consists of 10 cable car lines with an overall length exceeding 30 kilometres. Up to 68,000 people can be carried per hour, and the system is used by some 300,000 people per day. Commuters use this public transport system to get to work, to reach places for education or healthcare and for going shopping or other leisure-time activities.

Before the cable car construction, the roads between El Alto and La Paz and in the centre of both cities were congested with cars, minibuses, buses, taxis. This caused the daily commute times to increase significantly. The situation required a change and the introduction of a sustainable mobility solution for all. Seven years after its introduction in 2014, the cable car has made a considerable positive socioeconomic and environmental change.

Furthermore, the cable car's carbon emissions were carefully examined. Based on a Functional Unit which considered all mobility requirements for a route connecting El Alto with La Paz the Life Cycle Assessment confirmed that the cable car is the most eco-friendly mobility solution (Nieman et al. 2020).

3.4 E-mobility and neighbourhoods

With increasing urban populations alongside the need to adapt to sustainable transport strategies, there is bound to be a shift in the way neighbourhoods are operationalised. The uptake of electric mobility is changing neighbourhoods through new vehicles and devices, as well as charging infrastructure. The demand for infrastructure will vary from one area to another based on the demand and speed of uptake of electric vehicles. Including e-mobility considerations at the granular level of the neighbourhood will give policymakers a clear perspective of the actual mobility demand in a particular neighbourhood. This will enable them to better respond to people's needs and at the same time promote the acceptance of e-mobility interventions by local citizens. Involving neighbourhood actors (e.g. residents, communities, businesses) is a significant aspect to consider when planning electric charging infrastructure deployment, such as in the London Low Emission Zone's stakeholder outreach programmes (ICCT, 2020a).

Specific attention should be given to the seamless integration of electric mobility and related infrastructure in the neighbourhood fabric at the local level. Charging infrastructure, both public and private, requires space, which can cause conflict with other uses of the public space. Problematic situations have sometimes been observed in European cities with cables found running across the pavement between the EV owner's residence and a parking spot, for overnight charging purposes and in the absence of off-street parking. This creates physical obstacles reducing the inclusivity and walkability of streets, while posing risks for pedestrians to. In addition, there is a risk of privatisation of car parking spots for electric vehicles. Hence, regulation enabling the shift to electric mobility should also ensure the continued accessibility of streets for all, and especially those with mobility challenges (e.g. wheelchairs, strollers). Municipalities have a key role to prevent such situations, clarify the regulatory framework, preserve walkability and possibly support innovations such as installation of chargers in lamp posts, or via pavement channels not constituting obstacles.

On a broader city level, equity of distribution between neighbourhoods is a further topic to address. Dockless systems entail a risk of concentrating devices and charging infrastructure in wealthy neighbourhoods with high demand. This concentration of demand and supply entails a possible inequitable distribution. Cities may therefore require providers to ensure minimal levels of services in areas with lower demand (ITPD, 2019).

Pictures: Diversity of modes and integration in neighbourhoods (from top to down and left to right, Jelbi app and stations for shared electric seated scooters, e-kick scooters and bikes in Berlin (Germany), electric car-sharing service in Singapore, e-bikes in Amsterdam within the eHUB project)

3.5 E-mobility, health and public spaces

Transportation represented 23% of energy-related CO_2 emissions in 2010 (IPCC, 2014), and significantly contributes to air, and noise pollution which have direct and cumulative adverse human health effects. According to the WHO (2014), annually, there are 7 million premature deaths due to air pollution. On the contrary, electric vehicles do not produce exhaust emissions, and can therefore be considered as environmentally and human-health friendly. As electric vehicles substitute fossil fuel vehicles, nitrogen oxide (NO_x), particular matter (PM) and sulfur dioxide (SO_2) emissions are reduced, and urban air quality is improved.

In addition, electric vehicles produce significantly less sound. This decreases the amount of ambient noise in cities even during peak hours of circulation of these vehicles on the streets. Alongside noise reduction, electric vehicles can also improve rider and driver comfort, thereby reducing stress levels. A study done by LEVC (2018) revealed that electric vehicles not only cut drivers' fuel costs and help improve air quality, but also reduced stress behind the wheel. Monitoring brain activity of drivers of both electric and diesel taxis revealed that drivers of the new electric taxi were found to be more focused and calmer compared to the diesel ones. The concerns about the quiet nature of electric vehicles, potentially posing danger to other road users, in particular pedestrians, are gradually being resolved through the integration of acoustic vehicle alerting systems (European Commission, 2019).

A further benefit lies in the potential to maintain some levels of physical activity through the use of pedal-assisted e-bikes, allowing elderly or physically impaired persons to remain mobile, and reduce risks of cardiovascular illness (Weiss et al, 2015).

The reduction of air and noise pollution will create more welcoming public spaces and improve overall urban liveability, especially for those groups most exposed and vulnerable to their effects, such as the elderly, women and children. Public spaces also play a vital role in the social development of people, from small neighbourhoods to large cities, and give meaning to communities and urban landscapes. They provide a platform where people can interact, or simply be present in and part of the urban space. Public spaces are particularly valuable when they are part of an urban environmental network combining eco-compatible activities (primarily walking, running and cycling) with the natural landscape and habitats.

A multiplicity of multi-functional public spaces including charging infrastructure can be envisaged, based on the needs and the active engagement of local communities, as shown in Figure 16.

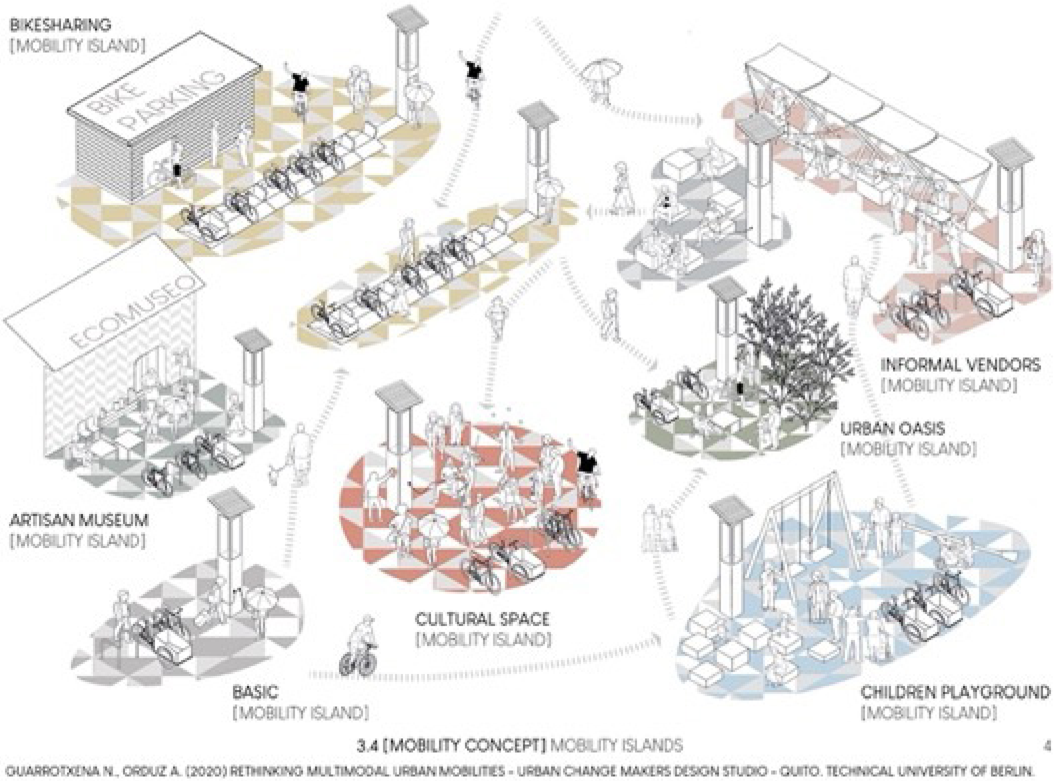


Fig 16. Diversity of possible spaces emerging in the wake of e-mobility deployment (Guarrotxena and Orduz, 2020)

Bicycle charging facilities installed near a playground for children can allow parents to charge their bicycles while staying at the playground.

Figure 17. E-Mobility and Public Space

Figure 17 depicts how charging infrastructure can be integrated into the neighbourhood layout in connection with local shops, while taking the opportunity to work on improving public space through additional greenery or seating areas.

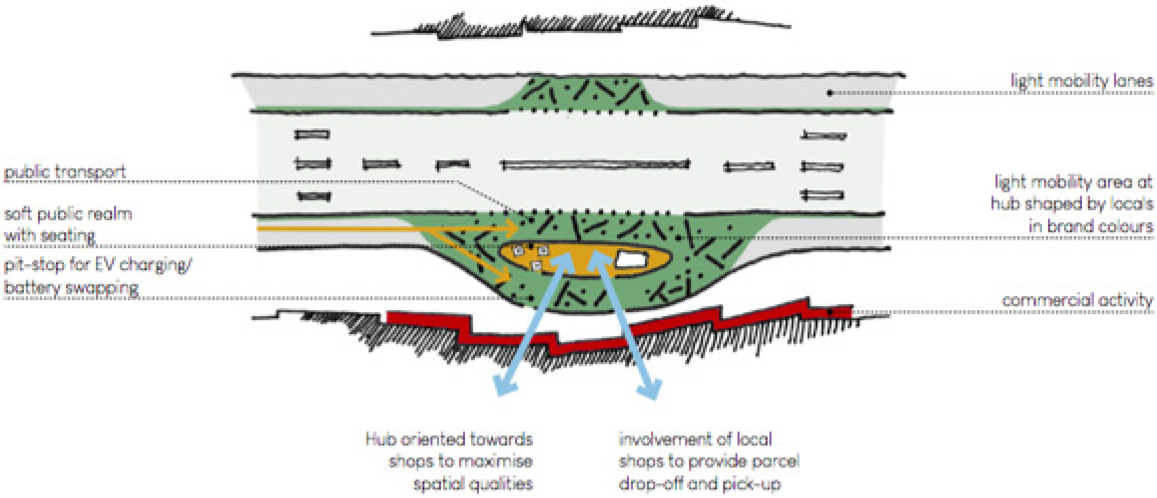


Fig 18. Proposal for charging infrastructure deployment in Pasig, Philippines (Lees and Rony, 2020)

Crucially, decisions on the use of public space should undergo a transparent process informing and involving residents. In contexts of scarce space, the deployment of charging and parking points for electric vehicles may have the capacity to trigger tensions if not well-designed, and if residents are not consulted about whether they support this infrastructure deployment. The involvement of citizens in planning e-mobility charging options and strategies is therefore key to ensure acceptability (see section 3.1. on involvement within Sustainable Urban Mobility Plans).

3.6 Urban Charging Systems

All electric vehicle batteries need recharging, and this requires deploying a charging infrastructure and consequent investments, either publicly funded by governments or by private investments (e.g. at non-residential buildings), as well as stability of the electric grid.

Charging may be undertaken at a wide range of private or public locations, such as the home, transit stations, parking lots (workplace, residential buildings, retail centers, eateries, highway exits etc.), lampposts, curb sides, fuel stations, bus depots, electric utility facilities among others. Public charging is particularly useful for those without home charging capacity, depending on the vehicle type and living conditions (for instance, light-duty vehicles for an urban population living in apartment buildings), or in the absence of stable electricity in residential areas in several low- and middle-income countries. In tropical regions with good sunshine, combining it with rooftop solar energy (photovoltaic panels) is emerging as an interesting opportunity.

Charging will also vary from one city to another depending on context-specific needs and conditions, such as the dominant vehicle type, the battery size and type, the operational model and the access of urban population to electricity. To identify relevant charging infrastructure options, cities must consider at least the following variables: housing stock, modal split and commuting patterns, dominant e-mobility technologies, typical driving ranges, opportunities for decentralised options such as solar energy. There is thus no 'one-size-fits-all' charging solution with one corresponding type of infrastructure.

Two main systems to recharge batteries exist: charging or swapping them. Battery charging can be slow to maximally preserve the battery capacity (for instance at night), fast when needing timely recharging during the day, or ultra-fast. Swapping is based on the exchange of a depleted battery for a charged one, requiring only a few minutes. This can be done manually or mechanically, depending on the battery size (IIT Madras and WRI India, 2019). Swapping has been less widely spread because of challenges related to investment costs, standardisation, and the required amount of batteries. Nonetheless, it is gaining traction in some contexts with intensive use, for instance for two-and three-wheelers used as commercial (taxi) vehicles. Business models where batteries are owned by energy operators and rented out to drivers or owners of vehicles, as is the case with LPG gas cylinders in many countries, are already successful in India. This addresses the issue of the high vehicle upfront cost and is particularly relevant for taxis and ride-hailing services requiring frequent charging.

For electric buses, batteries can be charged at the depot overnight (slow charging), during the day with so-called opportunity charging (en route with pantographs or inductive charging, or at the end station) or a combination of both. Further options are available, such as continuous charging inductive via overhead wire (trolleybus), or swapping (ADB, 2019).

Choosing between different types of chargers does not only have an impact on the duration of the vehicle immobilisation and the use of space, but also on costs of e-mobility systems and battery lifespan. All options must therefore be carefully assessed to identify solutions optimally adapted to the operational, financial and technical local conditions, especially for buses.

Investing in public charging is instrumental to increase customer confidence by reducing range anxiety and to drive the uptake of electric vehicles (ICCT, 2020a). It presents, however, a significant financial and technical challenge for public authorities having limited financial resources. Financing options include public funding, taxes levied on household consumers justified by the environmental improvements benefitting all, and extra service fees for owners of electric vehicles (ADB, 2019). Other pathways include partnering with the private sector to expand the charging infrastructure or including requirements for charging to be included in new buildings. Partners can include local businesses whose sales may be boosted as customers come for charging, and electric utilities. For instance, electric utilities in Mumbai have been interested in installing charging stations in their facilities to increase business opportunities. The costs of charging stations have substantially decreased in recent years. For instance, Amsterdam witnessed a fall of 83% of costs for curb side charging since 2009 (ICCT, 2017). However, setting up charging stations involves costs of installation, management and maintenance, as well as possible land acquisition costs. Furthermore, in cities with weak grid, investment in upgrading grids may be necessary to support rapid chargers. Project financing may be difficult for developers due to use and volume risk, as it is often the case in infrastructure projects. Models used in telecommunication and road infrastructure projects could provide for inspiration.

Identifying where to locate priority charging points is a complex mapping process that should rely on the assessment of multiple criteria, ideally in a consultation process with energy and mobility stakeholders, residents, and possibly businesses. In Stockholm, a participatory mapping exercise brought together city authorities, the grid operator, the municipal planning department and local businesses. Depending on the size of the area, participatory processes and modelling can be either alternative or complementary to each other. In India, three approaches were identified: a local knowledge stakeholder approach for small or medium areas, a modelling approach for larger areas, and a hybrid approach (NRDC, GERMI and ASCI, 2020). Methodologies to assess optimal localisation can rely on supporting indicators, including operational driving patterns (user behaviours), user needs, points of interest and activity, length of stay at these places, the electricity grid network and capacity, parking areas, and space limitations, hence using different methods (Funke et al., 2015; Gkatzoflias et al., 2016).

In addition, a ratio of a number of public chargers needed per electric vehicle can be set, based on the expected growth of electric vehicles and access to home charging. For instance, in countries with important access to charging in residential or office buildings (e.g., California), fewer public chargers will be required. This differs for cities with limited private parking, such as the Netherlands, requiring then more public chargers (lower ratio of electric vehicles per charging point). It is key to monitor the growth in electric vehicles, to avoid potential mismatch between demand for charging services and availability of chargers. The type of charging (low, rapid, ultra-fast, swapping) can also vary substantially across cities, depending on needs and vehicles. This variability can be seen in the selected top 25 electric vehicle capitals in 2019 in figure 19 (ICCT, 2020b).

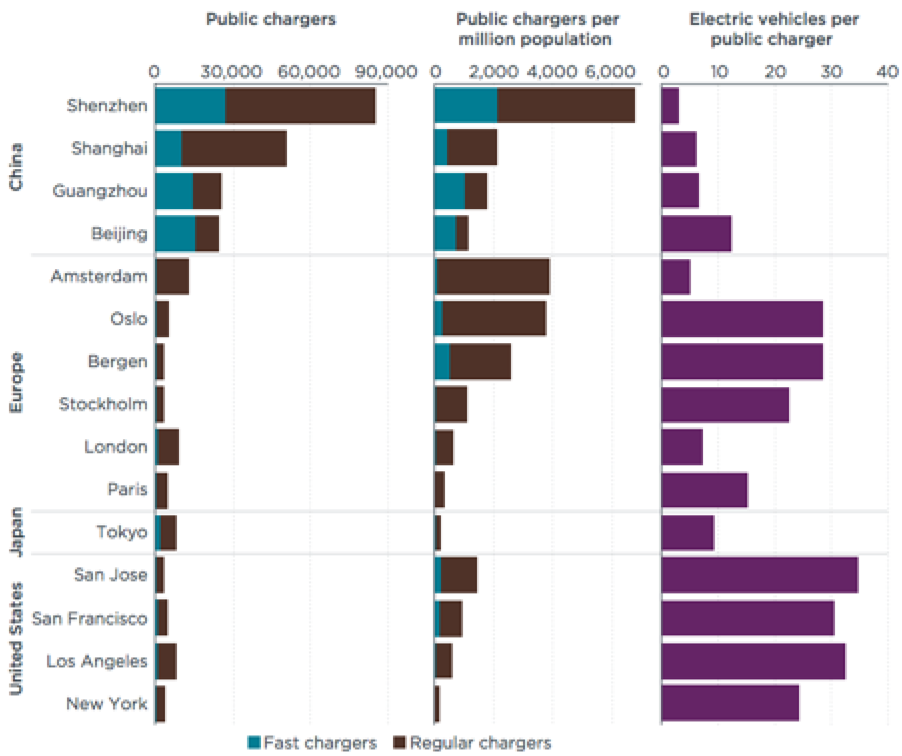


Figure 19. Public charging infrastructure deployment in selected electric vehicle capitals in 2019 (ICCT, 2020b)

Finally, clarifying the legal requirements applying to charging infrastructure and adopting technical standards for this infrastructure is paramount to build trust in stakeholders and users, as well as facilitate its uptake. For instance, in 2018, the legal framework was adapted in India to clarify that setting up charging stations does not require a license under the 2003 Electricity Act (IIT Madras (CBEEV) and WRI India, 2019). Interoperability is a further key aspect to facilitate uptake, to possibly mutualise costs between operators and to increase convenience and confidence in the system.

Figure 20. Electric three-wheeler at a battery swapping facility in Chandigarh, India (Ranjan, 2020)

Box 19: Urban Charging Systems: The case of the united kingdom

In 2018, the government of the United Kingdom published the Road to Zero strategy, which set out a comprehensive package of support to reach the objective for all new cars and vans to be effectively zero-emission by 2040 (HM Government, 2018). In the strategy, the government set out its intention for all new homes to be EV ready, and committed to consult on requirements for every new home and residential building with an associated car parking space to have charging points, where appropriate. The government also proposed requiring every residential building undergoing major renovation with more than 10 car parking spaces to have cable routes for electric vehicle charging points in every car parking space. For new non-residential buildings, the government has proposed any major renovation with more than 10 car parking spaces to have one charging point and cable routes for an electric vehicle charging point for one in five spaces. The government has also proposed a requirement of at least one charging point in existing non-residential buildings with more than 20 car parking spaces, applicable from 2025.

To ensure that such strategies do not result in induced demand, they should be embedded in a broader city parking policy that includes the reduction of parking spaces to shift to more sustainable transport modes, or the transformation of car parking into bicycle parking spots or lanes.

3.7 Multimodal e-mobility hubs

To support modal shift toward public transport, cities should use the opportunity of e-mobility projects and consequent deployment of a charging infrastructure to strengthen multimodality and intermodality (Knese, 2015). Intermodal hubs provide a focal point in the transportation network that integrates different modes of transportation, multimodal supportive infrastructure, and placemaking strategies. Interconnection is at the heart of a multimodal electric mobility hub. For it to function successfully, it must consider the charging and parking needs of a variety of electric two-, three- and four- wheelers (shared or not) to be integrated into an electrically powered mass transit system such as electric buses.

Mobility hubs incorporate a diversity of public spaces, ranging from plazas, parks, courtyards, and landscaped seating areas that are visible and accessible from the street and transit station. In addition, the hub would need to interact with placemaking functions, such as attractive walkability and public spaces that invite staying while providing opportunities for leisure, enjoyment or shopping during e-vehicle charging time. The hub can also be a suitable location for charging or swapping stations, connected to grids and possibly using roofs on the hub for solar panels providing energy for the adjacent e-vehicle charging facilities. Such roofs also provide shade, an increasingly important component in a context of climate change and urban heat island effects. In addition, work should be undertaken to improve non-motorized transport facilities (cycle lanes, safe walkways) to ensure seamless connectivity. Repair shops for bicycles could also be situated in the vicinity to further support connectivity between mass transit and cycling.

Figure 21. Improving public space, cycling and walking infrastructure while deploying electric mobility hubs as proposed in Quito, Ecuador (Guarrotxena and Orduz, 2020)

Innovative vehicles and a multimodal hub in Quito (Ecuador)

A multimodal e-mobility hub will be created in the historic centre of Quito, Ecuador, supported by the EU-funded electric mobility programme SOLUTIONSplus. Through the introduction of several diverse innovative electric vehicles, the project will support converting the historic centre into a low-emission zone. Shared e-bikes, passenger e-tuk-tuks, e-cargo bikes, e-quadricycles and even e-delivery vans for last-mile deliveries, well-adapted to the commercial and touristic character of this area and narrow streets, will improve connectivity with mass transit services. In addition, the already existing Direct Current-grid infrastructure of the trolleybus and the subway systems in the area will be used to create multimodal charging points.

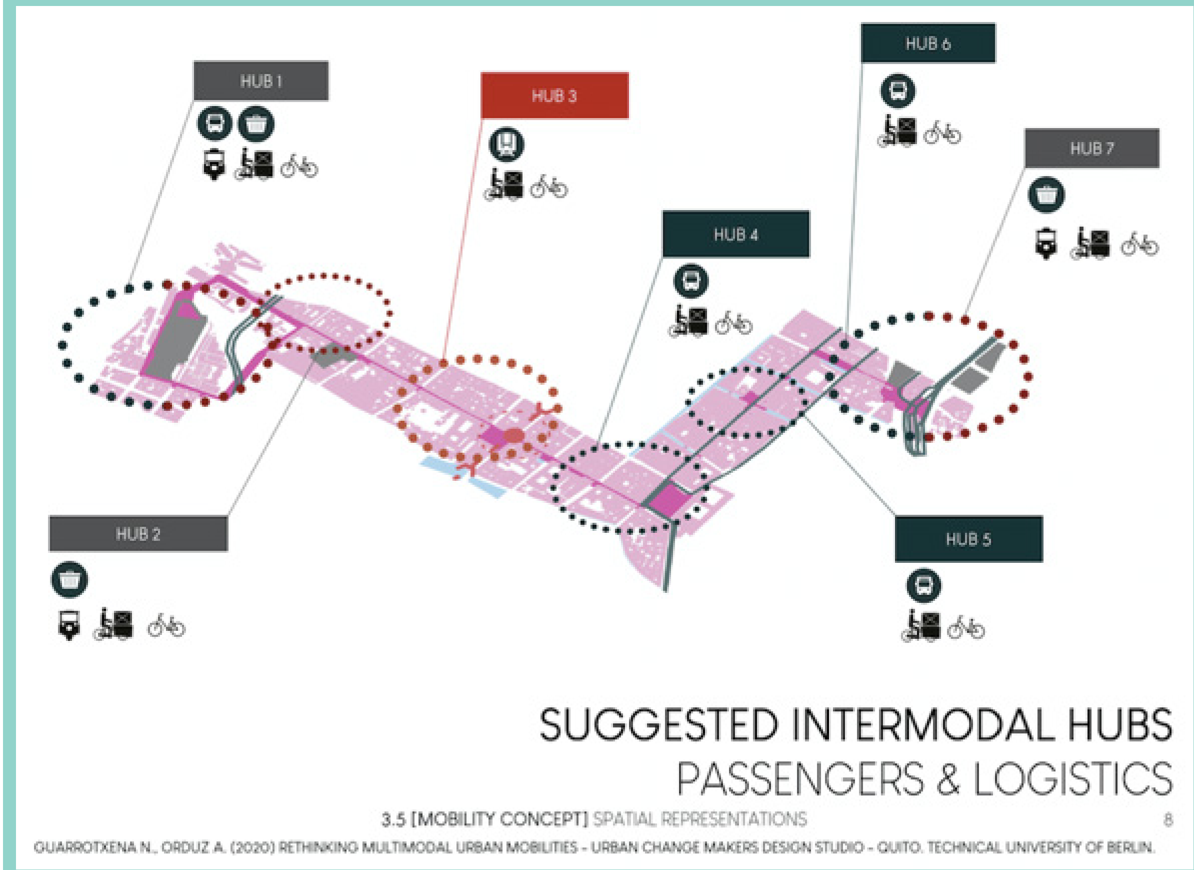


Figure 22– Diversity of electric vehicles offered at various multimodal hubs – SOLUTIONSplus (Guarrotxena and Orduz, 2020)

Figures 22 and 23 further show how, far from being an isolated endeavour, such hubs should be planned and act in an integrated manner, building a network of multimodal hubs facilitating seamless connectivity organised around electric vehicles and active mobility.

Figure 23 - Illustration of a network of multimodal hubs

3.8 Resilience and e-mobility

Resilience is capacity of a system to function efficiently in spite of external changes or stresses that destabilize it. In a transport system, resilience centres around the ability of the system to recover from shock while adapting and transforming its structure to accommodate change and uncertainties. Integrating electric mobility into the transportation system introduces disruptions that can ultimately enhance the resilience of the transport network and its capacity to adapt to change.

Information and communication technologies in conjunction with e-mobility systems can provide a powerful platform for the integration of systems and modes to achieve flexibility, redundancy and responsiveness – some of the essential qualities of resilience. A resilient, integrated mobility system will in turn provide users with a seamless, reliable, efficient, and multimodal service in case of an emergency. Resilience also includes considerations regarding climate change adaptation, including careful selection of charging infrastructure locations away from risk areas, or provision of shade via solar roof panels. Working on improving the resilience of electricity generation systems in the context of more frequent extreme weather events is a further prerequisite to ensure continuity of electric mobility.

Box 20: Resilience, E-mobility and COVID-19

The COVID-19 global pandemic has significantly affected urban mobility with the implementation of lockdowns and restrictions on public transport in different regions and countries. Many motorised trips have been transferred to active modes, primarily cycling and walking, during lockdown phases. Physical distancing will likely persist to some degree for some time, possibly contributing to an increase in the use of micromobility options such as bicycles, electric bicycles, electrical skateboards or standing electric scooters. In the long term, the need for personal vehicles may reduce with an increase in remote working and increased pressure on governments to invest in clean transport modes. According to N.P.D. Group, a marketing research company, in March 2020, sales of commuter and fitness bikes increased by 66 percent, leisure bikes sales jumped 121 percent, children's bikes went up 59 percent and electric bikes rose 85 percent compared to the previous month in the United States (Goldbaum, 2020).

Example case: electric rickshaws as an efficient adaptation method against COVID-19

Responding to the Covid-19 outbreak, several mobility-based adaptation examples have been observed worldwide over the last few months. The evolution of the E-Rickshaw project launched by the city of Singra (Bangladesh) in 2018 is one of these encouraging examples. Originally, the 12 electric rickshaws, financially and technically supported by the Transformative Urban Mobility Initiative (TUMI), were meant to improve the public transport system in the region. In addition, they provided better access to emergency health services to citizens since two e-rickshaws were designed as ambulance vehicles offering door-to-door emergency services.

Following the imposition of a national lockdown in March 2020 to combat the spread of the novel coronavirus, public transportation, restaurants and shops were suspended. People were instructed to only leave their homes for daily basic needs or in case of emergencies. The municipality of Singra decided then to use the e-rickshaw fleet to start a "home delivery system" for its low and middle-income citizens. The city launched two helpline numbers, where delivery requests for essential goods can be entered. The requested products are then purchased and delivered to the doorstep of the families by the TUMI vehicles. Daily consumables including vegetables, dried food, fish and meat, besides beverages and medicines, have been delivered with this service. In addition, the e-rickshaws have been used to collect samples for COVID-19 tests and the emergency health services have been expanded to rural areas. Thanks to the reliable fleet of electric rickshaws, the municipality was able to quickly react to the new reality created by the health crisis.

©Singra municipality

3.9 E-Mobility and economic development

Among the economic effects of e-mobility is the potential to develop a national manufacturing of e-vehicles as well as the employment of staff for electric, shared mobility services. Electrification bears the promise of employment opportunities linked with new companies, electric technical skills, charging and exchanging batteries at swapping stations. To ensure acceptability of this transition, particularly in the Global South, the introduction of e-mobility in cities would envision an opportunity to upgrade current maintenance and repair skills to higher-value activities. Therefore, it is key to integrate professional training components in electric mobility projects and policies. Capacity building on electric mobility can go well beyond the adoption of new (imported) vehicles: it can include the development of fit-for-purpose vehicles and services that maximise local value generation.

3.10 Costs and innovative business models

Lifecycle costs for operating electric vehicles are close to, or in some cases lower than, internal combustion engines vehicles (Fulton et al. 2017). Figures 24 and 25 show estimated cost per passenger kilometre for a range of electric modes and technologies in OECD-Europe and India. The importance of different factors (for instance, drivers and fuel cost) differs by region. For example, the low labour cost of the bus drivers, along with higher average load factors in India and other developing economies makes public transport modes even more cost effective than in industrialised (OECD) countries. But in both cases, costs of electric vehicles are close to competitive on a life-cycle basis, and this will only improve over time as battery costs continue to drop.

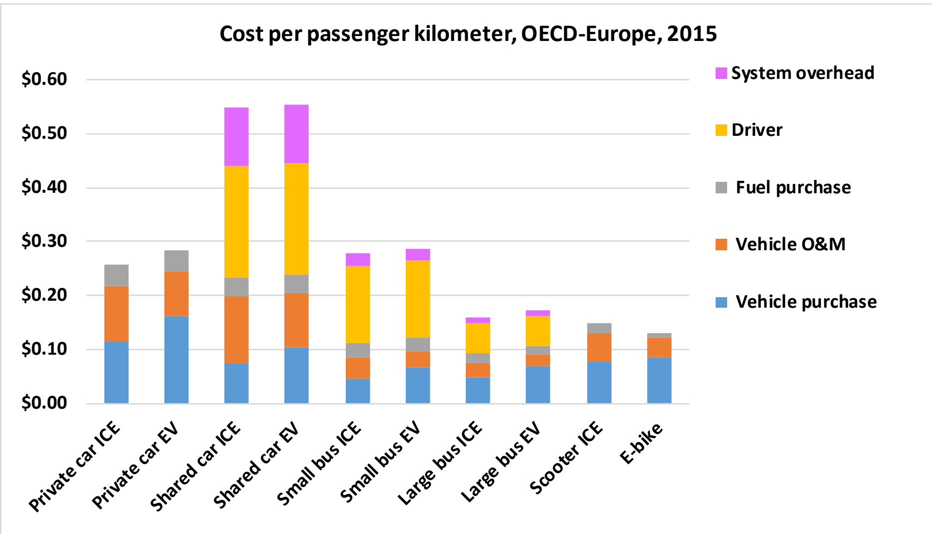


Figure 24 Costs per passenger kilometre in Europe, Fulton et al., 2017

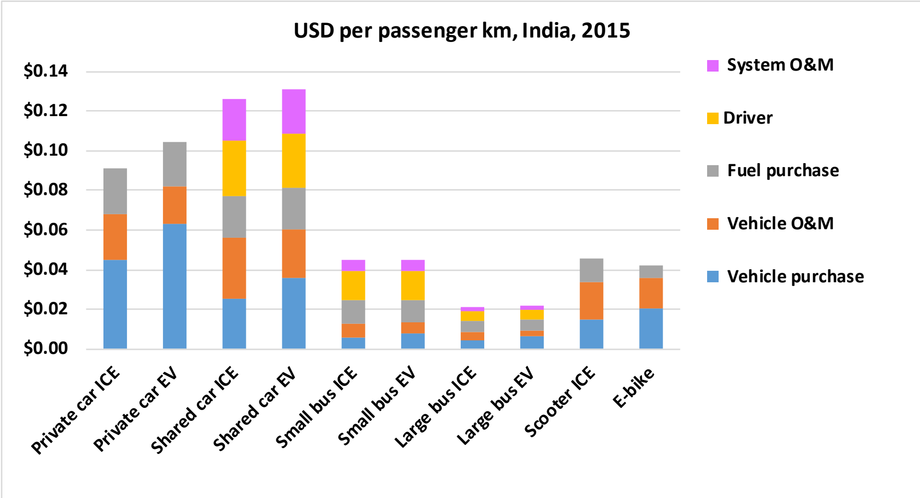


Figure 25 Costs per passenger kilometre in Asia, Fulton et al., 2017

Yet, the uptake of e-mobility faces two main cost hurdles: the higher upfront investment cost of vehicles, and the classical 'chicken-and-egg' dilemma – put simply, difficulties to switch to electric vehicles in the absence of charging infrastructure and vice versa. Therefore, innovative financing and business models are required to address these issues and reduce the risk of switching to e-mobility, both for the vehicles and the charging infrastructure segments. Such innovative models enable to reap the advantages of e-mobility, such as lower running costs enabling savings. Solutions will vary according to local characteristics, and there is no one-size-fits-all. A baseline assessment is useful in this regard, for instance when following a SUMP process (section 3.1). Solutions may involve transformation processes of manufacturers into mobility suppliers (e.g. battery rentals), or the involvement in mobility of 'non-usual' players such as energy stakeholders (EVUE, 2012).

With regards to vehicles, a variety of options exists, ranging from classical purchase, over rental or leasing of vehicles and/or batteries, to shared options - the case of bus procurement being specific and separately analysed in the box below. Subsidies combined with commercial loans can help reduce the cost gap between conventional vehicles and electric vehicles, with interest subsidies further reducing capital costs (IIT Madras (CBEEV) and WRI India, 2019).

Rental and leasing options, instead of purchasing, have proven useful to reduce upfront costs as well. These strategies may cover both vehicles as well as batteries alone. The latter case is especially interesting when coupled with a swapping system whereby batteries remain in the ownership of the mobility or energy company. Modality for the fees to use the battery can also vary, for instance with a pay-as-you-go model – currently used in the electricity sector, mainly for solar energy – or through a monthly or daily fee in a subscription model. Designing models lowering upfront costs and de-risking the transition is particularly vital for paratransit and informal feeder modes in the Global South. Such models are gaining traction in contexts like India or East Africa for electric two- and three-wheelers.

When it comes to reenergizing infrastructure, two policy instruments may support its deployment. On the one hand, subsidies or preferential treatments can be awarded to private companies deploying charging or swapping points. On the other, public funding can act as a starting point for the establishment of charging facilities.

Innovative business models for e-mobility promotion can be addressed by public transport companies as well. Well-integrated, new electric mobility solutions may improve last-mile connectivity and ultimately increase public transport ridership. For instance, the public transport company Hochbahn Hamburg is involved in several initiatives providing first- and last-mile solutions. With support of the SOLUTIONSplus program, Hochbahn will develop an e-scooter sharing system conceived (50 e-scooters co-funded by the project and the city), which will aim to test an incentive and pricing scheme that complements the public transport system and coverage, rather than competing with it (SOLUTIONSplus, 2020). In addition, Hochbahn and the mobility company MOIA developed a ride pooling project, operational since 2019, structured around electric shuttles of six seats, which can be booked on demand on the Hochbahn 'switchh' platform.

Financing electric bus adoption

Electric buses have a higher upfront investment cost than diesel buses. Depending on the region, the purchase price of an e-bus could be two to three times higher than the price of a diesel bus (IFC, 2020). However, the total cost of ownership (TCO), which includes maintenance and energy costs, levels the field significantly. E-buses also reach equal or even lower breakdown rates than internal combustion engine (ICE) buses (IEA, 2020b). The extent of operational gains will depend on local characteristics such as fuel and electricity prices. These particularities have led to the appearance of new business models and financial mechanisms that involve new stakeholders in the ownership and operations of e-bus fleets for public transport. These models aim at making the uptake of electric buses more affordable, less risky and scalable. Business models and contractual relationships must be designed in such a way that they reap the benefits of lower operational costs and facilitate the transition, for instance through leasing mechanisms (vehicles or chargers).

The key models being used to fund and finance the electrification of public transport in cities include:

1. **Operator Procurement Model**
   The commonly selected procurement model is characterised by the purchase of the e-buses and the corresponding charging infrastructure directly by the Public Transport Operator (PTO), which could be public or private. Thus, in this model, both the ownership and the operations remain in the hands of the PTO. This is usually made possible with public funding support to overcome the barrier of upfront capital costs, such as purchase subsidies provided at national or local level, targeting both vehicles (buses) or chargers. The purchase of electric buses could also be financed by debt, for instance through concessional, market loans, or green bonds (GIZ 2019; WRI 2019c).

   This model can be applied in both Net Cost Contracts (NCC), where the PTO collects and keeps its own fare revenue, and Gross Cost Contracts (GCC), in which the government receives the fare revenue and pays the PTO. Choosing the contract type depends on a series of parameters including previous bus operation mode, funding availability, costs and earning or technology (UITP's, 2020 for the Indian support scheme FAME II). In the race for public transport electrification, many cities are moving towards GCCs with vehicle suppliers. GCCs creates incentives for a high-quality public transport service, since the government's payments to the PTO are based on a formula heavily weighted on a fee per kilometer of service provided (ITDP, 2020).

   Examples: Medellín (Colombia), 69 e-buses purchased by the public PTO with municipal resources; Montevideo (Uruguay), 30 buses purchased by the private PTOs with a subsidy covering the difference between diesel and electric buses

2. **Leasing Model**
   Leasing is a business model, which is becoming more and more popular in fleet renewal processes, as the investment risk is divided among various parties. In the case of leasing, the ownership of buses (or their components) or charging infrastructure is separated from the operation. A third-party company, for instance utility companies, battery manufacturers or OEMs, purchases the e-buses, the batteries or the charging equipment and leases them to the PTOs. The PTOs will then have to pay a monthly fixed amount, which will depend on the terms defined in the leasing contract (GIZ 2019; WRI 2019c).

Examples: Santiago (Chile) with the utility company leasing the buses; Bogotá (Colombia) with a third party leasing the buses and the utility company providing the charging infrastructure. Case of battery leasing: São Paulo (Brazil).

3. **Pay-as-you-Save (PAYS)**

   PAYS is a business model developed by Clean Energy Works by which the PTO acquires the chassis of the buses and the utility company purchases the corresponding batteries and charging equipment. The investment costs are recovered over time through a fixed tariff charged on the electricity bill agreed beforehand in the terms of the contract service (GIZ, 2019).

   Example: no example in the mobility sector yet, but significant potential to be transferred from the energy sector where it has been successfully operating.

It is worth noting that a comparison of several municipal electric bus fleets shows a high heterogeneity of solutions opted for in terms of financial support, responsibility for buses and chargers, types of contracts, and nature of charging infrastructure solutions (IEA, 2020b). Hence, there is again no one-size-fits-all strategy to be followed, and the presented models could also complement each other. Assessing local specificities when designing an e-buses model is a prerequisite.

Finally, financial mechanisms and incentives are not the only tool to promote the electrification of public transport. For instance, Santiago (Chile) implemented non-fiscal incentives in the form of longer contracts awarded (14 years for operation of e-buses versus 10 for conventional buses). These alternatives should be accounted for.

Useful resources:

IEA (2020b). E-bus case studies

IFC (2020). E-Bus Economics: Fuzzy Math?

ITDP (2020). Quick guide to bus sector modernisation

WRI (2019a). Barriers to Adopting Electric Buses; WRI (2019b). How to Enable Electric Bus Adoption in Cities Worldwide

WRI (2019c). Financing Electric and Hybrid-Electric Buses: 10 Questions City Decision-Makers should ask

GIZ (2019). Financial Mechanisms for Electric Bus Adoption

ICCT (2020c). Next stop for zero emission buses: Latin America

C40 (2019). How to shift your bus fleet to zero emission by procuring only electric buses

UITP (2020). Bus fleet renewal checklist; UITP (2020) Toolkit to support e-bus procurement under FAME II

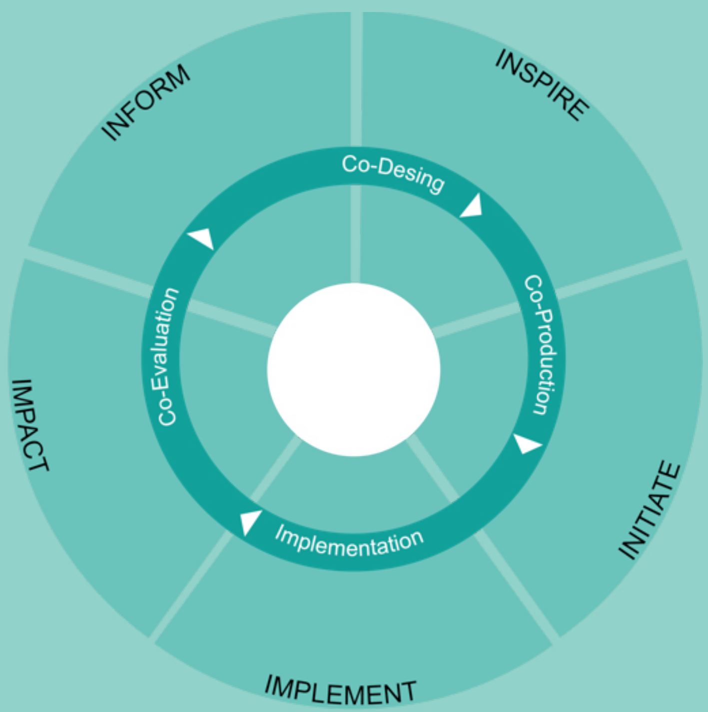
UITP (2020). Bus fleet renewal checklist; UITP (2020) Toolkit to support e-bus procurement under FAME II

Testing e-mobility solutions in urban Living Lab

To enable transformative change towards sustainable urban mobility, it is vital to go beyond a mere technical perspective on vehicle technologies and take a systemic approach.

Testing innovative urban e-mobility solutions at different Technology Readiness Levels (TRL) and in different environments can enable replication and can contribute to a supportive political, legal, economic and fiscal landscape. The Living Lab concept addresses the innovation of electric mobility as a component of an intermodal concept that assists in the wider transition towards sustainable urban mobility.

An integral part of effective Living Lab approach is the facilitation of close cooperation between local, regional and national decision-makers, operators, industry and businesses to develop innovative e-mobility solutions that not only fit into the local context, but also are scalable and replicable. The Living Lab approach considers mobility as a socio-technical system that consists of technologies, regulations, institutional settings, the economic system, interests, influence and governance structures, behavioural patterns, and social norms. It considers that e-mobility should be integrated with existing transport services and networks in the frame of sustainable urban mobility planning tailored to the specific local economic, technological, social, political and environmental context.



Testing electric mobility solutions in urban Living Labs can help ensuring that vehicles and services are fit-for-purpose, create buy-in from key actors and stakeholders. This co-development process can be structured along five pillars:

Inform: Boost capabilities, provide tools to plan, assess and implement

Inspire: Foster the take-up by inspiring through peer-to-peer exchange

Initiate: Strengthen collaboration by initiating partnerships

Implement: Create reference models by implementing demonstration actions

Impact: Scale-up, replicate and transfer innovations (Lah 2018).

The transition to sustainable mobility has the potential to unlock trillions of dollars in cost-savings or more sustainable travel patterns, along with substantial co-benefits that help transforming cities into more liveable, environmentally friendly and economically efficient centres. Electric mobility in all forms can play an important role in this. However, this potential can only be utilized if e-mobility solutions are integrated into a broader transition strategy. Isolated interventions or technology shifts can have unintended consequences, positive and negative as they rarely only affect one objective. Testing the interplay of innovations in a controlled operating environment of an urban Living Lab can provide vital evidence for scaled-up transformative projects and can help providing a basis for coalitions of among key actors.

Testing the potential for co-benefits in a Living Lab may help identifying suitable packages of measures that fosters synergies and reduces risks and trade-offs. This provides a basis for coalitions that can align different actors and stakeholders. These packages can then be integrated into the wider frameworks of Sustainable Urban Mobility Plans (SUMPs) and National Urban Mobility Programmes (NUMPs).

3.11 E-Mobility and city logistics

Around the world, e-mobility options have proven to be suitable for urban freight and city logistics in terms of trip pattern and daily mileage. However, they remain an under-utilized solution. To date, urban freight is mostly conducted by conventional trucks and other large delivery vehicles. These are not only dangerous for pedestrians and cyclists, but also contribute to traffic jams by monopolising street space during on- and off-loading, blocking sidewalks or cycle lanes. One solution is to move away from these conventionally fuelled vehicles, replacing them with electric vehicles. For instance, the delivery company DHL is using electric delivery vans (DHL, 2021). Innovative four-wheelers are another option, such as the low cost, multi-purpose, smart electric quadricycles that the SOLUTIONSplus project will test in Pasig (Philippines), in cooperation with PHLPost and Pasig City.

This transition can ideally be accompanied by a shift toward smaller, space efficient vehicles, since urban delivery vehicles should be adapted to better suit the density of urban space. The replacement of inefficient and dangerous trucks in inner-city areas with electric two- and three-wheelers for delivery is among the most promising solutions. This shift does not only improve safety, but also cuts noise, lowers emission and pollution levels and frees up valuable public space. Electric bicycles have illustrated the potential to become a preferred 'last-mile' vehicle, particularly in high density and congested areas.

Box 21: Last mile goods delivery: the revolution of bicycle logistics

Electric bicycles (e-bikes), cargo bikes or innovative three-wheelers are increasingly used for last-mile deliveries (letters, small parcels, food delivery, bulkier boxes, or even waste collection) and represent a significant opportunity to transform urban logistics. These vehicles do not only allow to reduce the quantities of pollutants emitted in cities, contributing to tackling climate change and air pollution. They also permit a much more efficient use of urban space than delivery trucks, beating congestion especially in the presence of cycle lanes, improve safety, and can reduce delivery costs (Nocerino et al, 2016, ITDP, 2019). Electric two- and three-wheelers prove particularly efficient in dense urban areas with short delivery rounds. Besides being a sustainable mode of delivery, they also provide income opportunities to low-income earners while contributing to an active and healthy lifestyle.

For these reasons, more and more traditional transport companies, delivery companies and postal services have started resorting to e-bikes and e-cargo bikes for the urban last-mile deliveries. The potential for a shift from cars and trucks to e-bikes is massive. It has been estimated that e-cargo bikes could replace 85% of logistic trips undertaken by car couriers in cities (DLR, 2012), and that more one quarter of all goods, and half of light goods could be delivered with bicycles in Europe (Choubassi et al, 2016). Several European companies active in postal and delivery services, such as La Poste in France or DHL Express, have already introduced innovative electric two- and three-wheelers, including cargobikes (ITDP, 2019). In the centre of New York City, e-cargo bikes could substitute 40% of truck trips used for logistics (ibid). Significant developments are not exclusively bound to Europe and the US: the SOLUTIONSplus programme will test e-cargo bikes for urban delivery transport services in Quito, Ecuador.

Figure 26: E-cargo bike prototype to be tested in Quito (Ecuador)

Cities can play an enabling role in this transition in many ways, such as including cycle logistics in local planning, identifying support mechanisms such as subsidies, procuring e-bikes, supporting urban logistic centres, or building awareness around e-bikes (Fištrek and Rzewnicki, 2015). Pilot tests can overcome companies' initial reluctance to adapt their processes and fears regarding performance and range. Furthermore, using e-bicycles as cargo vehicles is particularly encouraged when combined with policies that restrict motor vehicle access to specific areas of a city, such as downtown or commercial districts, limit speeds, or with the extension of dedicated bike lanes.

Benefits of e-bikes and e-cargo bikes in a nutshell:

- Reduction of GHG emissions, which is critical as cities face a rise of commercial delivery services and consequent increasing emissions,
- More efficient use of urban space tackling current inefficiencies of distribution systems where trucks block streets when double-parking,
- Economic savings linked with lower running costs than conventionally fuelled vehicles,
- Faster and more agile than trucks and vans, especially when they benefit from cycle lanes, and having less difficulties finding parking places,
- Improving urban liveability with silent vehicles.

E-MOBILITY AS A DRIVER OF URBAN INNOVATION

3.12 E-Mobility as a Service (MaaS)

Mobility as a Service (MaaS) is the integration of various forms of transport services into a single mobility service accessible on demand. This involves integration of many different transportation modes into a seamless and convenient app. In addition to mode discovery and trip planning, it also includes the idea of one payment system across these modes. An effective MaaS will offer a viable alternative to private car ownership and usage. Every journey can be covered by the use of multimodal transportation, be it taxi, public transport or bike sharing. The MaaS model can be used to increase the adoption of EVs by the public by shifting away from individual vehicle ownership and optimizing the utilization of EVs as a service. By replacing individual ownership of vehicles with shared EVs, this combination will facilitate the use of EVs, as shared vehicles do not face the issue of upfront investment cost faced with individual vehicle purchase. In addition, EV sharing services can be connected to other eco-friendly modes of mobility, such as public transport, walking and cycling.

Toolkit: The UITP 2019 Mobility as a Service Report provides an overview on the topic by explaining what MaaS is, how it works and who are the different stakeholders involved, their roles and expectations. https://cms.uitp.org/wp/wp-content/uploads/2020/07/Report_MaaS_final.pdf

3.13 E-Mobility and Data

Big data refers to extremely large data sets that may be analysed computationally to reveal patterns, trends, and associations, especially relating to human behaviour and interactions. EVs (shared, public fleets, commercial fleets) and infrastructure can be fitted with computer chips and sensors that will collect data that can be used to improve the development of e-mobility vehicles and charging systems as well as improve the adoption of e-mobility. The data can also help to provide information for forecasting and on adaptability of the system to policymakers for policy and planning purposes. The availability of data can support both spatial and statistical analysis of the e-mobility system. Common spatial applications of the data collected include mapping suitable locations for constructing charging stations, with close proximity to the highest population.

Critically, cities can also use electric kick scooter and bike-share data in order to improve integration with transit, understand trip patterns to site infrastructure, and manage private operators. A possible further use of data relates to safety metrics, in contexts where vehicles contribute to a large proportion of road safety accidents (e.g. motorcycle taxis in sub-Saharan Africa).

3.14 Vehicle-to-grid (V2G)

Vehicle-to-grid technology is a system enabling the energy stored in an EV battery to be fed back into the electric grid when the vehicle is parked. Relying on bidirectional charging, this technology could enable recharging EV batteries at times of low demand, and export energy back to the grid at high demand in order to level demand peaks. In addition, V2G could enable EV batteries to store energy produced from variable renewable energy sources such as wind or solar. These ways, V2G could help both regulate more efficiently the electricity network and contribute to energy decarbonization.

While V2G technologies are still mostly in the research phase, and the impacts on the batteries' lifespan and its economic feasibility still in question, several pilot projects are ongoing to investigate their potential. In London, the Bus2Grid project is a trial to redistribute energy generated by buses not in use at Northumberland Park (Mehmet, 2020). The initial phase will make use of the batteries of 28 double decker buses, to feed back over 1MW of energy to the electric grid. The pilot is implemented by a consortium led by the utility infrastructure company SSE Enterprise in partnership with BYD, the UK Power Networks, the University of Leeds, Transport for London, the UK bus manufacturer Alexander Dennis and the bus operator Go-Ahead London.

3.15 E-mobility Resource and Waste Management

Battery resourcing and supply chain

The technology underlying rechargeable batteries for electric vehicles is evolving rapidly. Whereas a mere decade ago lead-acid batteries were still the unrivalled type, lithium-ion batteries emerged as a long-lasting and viable alternative for commercial vehicle use in the last ten years (Gaines, 2014). Research is ongoing, assessing potentials of new technologies and components such as solid-state batteries. E-mobility can only be fully and truly environmentally, socially and economically sustainable if sustainability principles are accounted for and respected from the initial stages of the supply chain of these primary units powering the electrification drive in transportation.

With the increased attention for the crucial role batteries can play in meeting both the SDGs and the Paris Climate Agreement goals, a growing body of work has scrutinised the conditions in which their raw materials are resourced and transformed into batteries to be used in vehicles (Olivetti et al., 2017). In light of its vision to create a sustainable battery value chain in 2030, the World Economic Forum (WEF) stresses the need to guarantee a transparent resourcing and production process which ensures safe working conditions and minimises the environmental impact resulting from the mining of raw materials (WEF, 2019). From a socioeconomic point of view, specific attention should be paid to adherence to international practices and norms enabling sustainable and profitable business models, and the elimination of child and forced labour. Moreover, the highly uneven geographic distribution of raw materials, creating monopolies and sometimes located in conflict-affected areas, calls for an effort to ensure environmental and labour standards are upheld at all times (WEF, 2019). The WEF therefore incites companies in the value chain, international regulators and labour, civil society and international organisations to verify compliance with internationally accepted social and environmental practices, along with a rigorous monitoring and evaluation framework based on best practices (EBA, 2021). This call is being acted upon. Since its launch in 2017, the European Union's 'European Battery Alliance', for instance, attempts to ensure all Europeans benefit from safer traffic, cleaner vehicles and more sustainable technological solutions. Their 18 priority action points identified to reach this aim include the need to secure access to sustainably produced battery raw materials at reasonable cost (EBA, 2021).

Similarly, the often-hidden GHG emissions that accompany the extraction of raw materials and manufacturing of batteries should be recognised and limited through a focus on using renewable energy in this production process (Beaudet et al., 2020). While the research on and development of lithium-ion batteries has flourished in recent years, leading to ever-increasing efficiency and lifecycle duration, the finite and geographically clustered supply of battery components, cobalt in particular, should be kept in mind (WEF, 2019).

Battery repurposing, refurbishing and recycling

Electric mobility must be framed from the start within a circular economy approach. Cities are encouraged to promote sustainable models that extend the productive life of lithium-ion batteries (repair, refurbish and/or repurpose) and recycle them, as depicted in figure 27. Innovative models have emerged over the last years, driven by increasing demand for battery components. Lithium-ion batteries offer greater perspectives owing to their longer lifespan, capacity and energy density compared to lead-acid batteries, combined with decreasing prices.

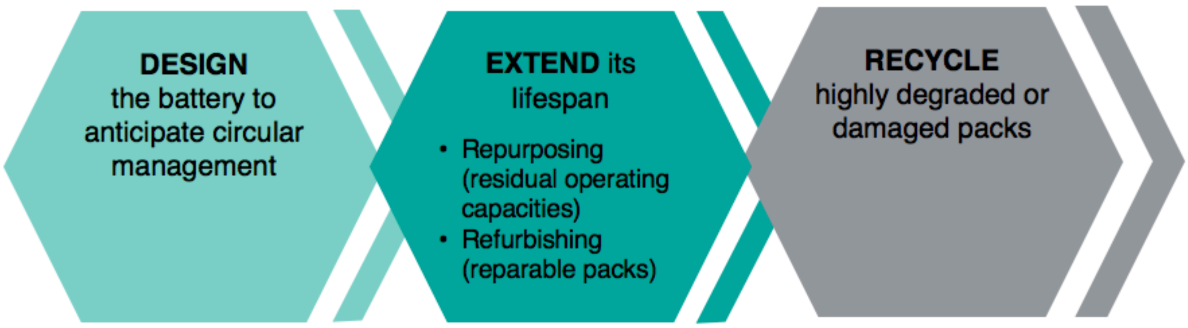
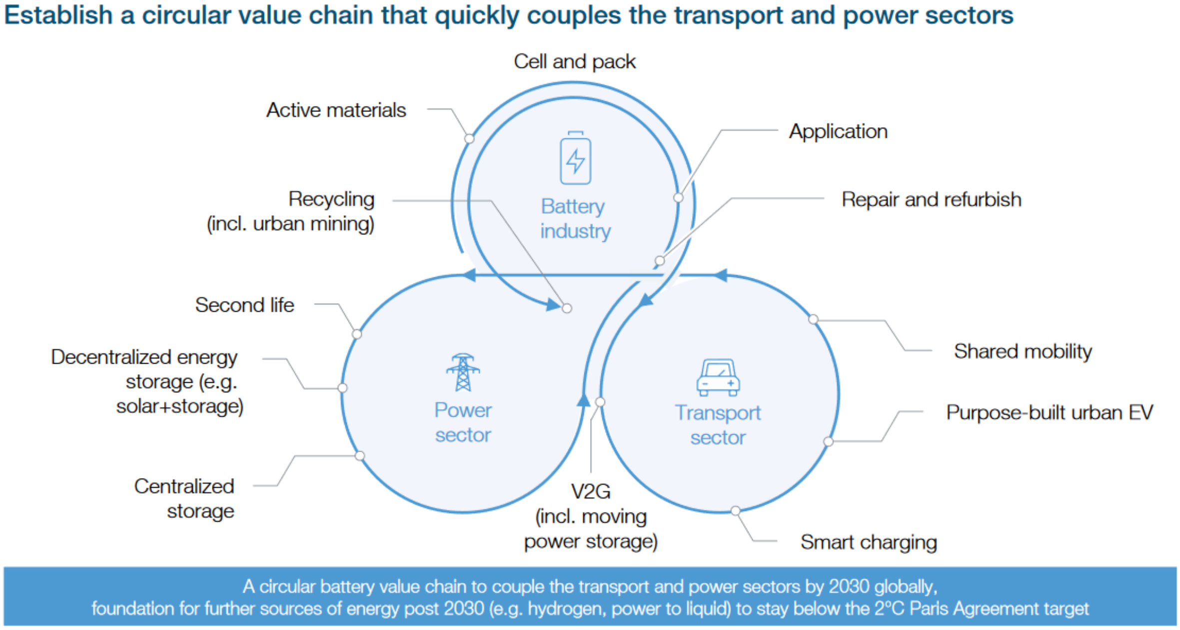


Figure 27. Main steps to ensure a sustainable end-of-life management of lithium-ion batteries (SOLUTIONSplus fact-sheets: Marchiori Silva, 2020; Martin, 2020; Carriquiry, 2020)

Batteries can have a so-called 'second life'. After a certain number of charge and discharge cycles, batteries whose remaining capacity is insufficient to fulfil mobility purposes, having lost circa 20 to 30% of their initial capacity, may be collected to be repurposed in stationary energy storage systems, making use of their 70-80% residual capacity. These provide critical support for smart systems allowing more efficient grid management, integration of renewable energies into the grid, and back-up power, as well as decentralized energy access as depicted in figure 28 (Pagliaro and Meneguzzo, 2019; World Economic Forum and Global Battery Alliance, 2019). Repairing and refurbishing faulty batteries is another innovative practice consisting of the identification and removal of faulty cells, to be further used in EVs or other applications.



Source: World Economic Forum, Global Battery Alliance; McKinsey and SYSTEMIQ analysis

Finally, recycling materials should be undertaken in a controlled and safe manner, leaning on a sound and transparent regulatory framework. This phase is crucial to avoid toxic components polluting the environment, as well as to recover valuable components.

In addition, traceability is a key dimension to ensure proper management of the batteries' end-of-life (EoL). Cities can support initiatives based on battery leasing models where mobility or energy leasing companies remain owner of the batteries. Indeed, retaining ownership eases the traceability of the battery pool, as well as data collection on the performance of the battery, and consequently facilitates the end-of-life management. Countries may also legally require manufacturers to organize the end-of-life management of batteries, encourage information sharing in a transparent manner, and exchange best practices. In addition, business models should be designed to disincentivize the discharge of batteries below the 80% threshold to maximally preserve battery capacity.

Durability of vehicles is a further criterion of sustainability. When designing new electric vehicles or retrofitting existing vehicles, manufacturers are encouraged to plan a sufficiently long prototype phase to ensure that vehicles are adapted to local conditions, terrains and typical loads.

3.16 Managing existing fossil vehicle fleet and retrofitting vehicles

As countries around the world continue to promote the uptake of electric vehicles, a number of strategies have been adopted for the management of existing fossil fuel vehicles in the global fleet. One of these strategies has been the gradual phasing out of fossil-powered vehicles, particularly in developed countries. This has led to a 'dumping effect' whereby these conventional vehicles are sold at competitive prices to developing countries that are yet to make the transition to cleaner mobility. While this is a temporary solution, it has not been without controversy, especially as some vehicles arriving in developing countries have their catalytic converters and other key components helping to reduce harmful emissions removed. This, in turn, becomes counterproductive to the fight against climate change, as these vehicles are still in circulation and in some cases pollute more following tampering at the point of export. It is therefore important for both exporting and importing countries to establish standardized vehicle emission testing and labelling to ensure that used fossil fuel-powered vehicles are in top notch condition.

Retrofitting vehicles, the converting of existing fossil fuel vehicles with an electric drivetrain, is a promising, already-operational strategy to increase EV adoption. In order to meet the IPCC recommended 1.5°C global temperature rise limit and to decarbonize the existing car fleet, it is imperative to accelerate the conversion and/or retrofit existing fossil fuel vehicles into hybrid or fully electric vehicles to be powered by electricity from renewable energy sources.

In line with the principles of a circular economy and the waste management hierarchy, aged fossil vehicles that are no longer roadworthy can be scrapped, recycled and used in the manufacturing of new vehicles. It is important to note that most parts of internal combustion engine vehicles are recyclable. This innovative option becomes all the more important as new fleets are increasingly electric, and the challenge of how to handle old internal combustion engines is raised. Companies like Opibus in Kenya and BharatMobi in India are successfully retrofitting vehicles. Such schemes have the key benefits of making use of the existing hardware and possibly extending the vehicle's lifespan, as electric vehicles have a much smaller number of parts.

CHAPTER 4:

OUTLOOK

The global electric vehicle fleet operating in cities has expanded significantly over the last decade, underpinned by technological advances and national and local policies. This trend is expected to continue at even faster rates, especially in light of worsening climate change, air pollution and congestion of rapidly growing urban environments. This toxic combination poses unprecedented challenges to ensure sustainable, safe and efficient mobility in a rapidly urbanising world. It has become apparent that an approach of mobility issues focussing on expanding road space for individual, fuel-based cars, is not an option anymore. There is simply no space for these cars – and the urban climate is already choked. Urgent action is needed, which also presents unique opportunities to lever the potential of innovations in electric mobility, engage all relevant stakeholders, design adequate, accessible and integrated transport systems and inclusive policy frameworks. Cities of the future must reduce overall demand for private vehicles, and electrify the remaining vehicle fleets, structured around the backbone of public transport complemented by feeder services to ensure a better quality of life for their citizens.

A wide variety of pivotal issues will determine the pace and direction of the development towards global electric mobility, ranging from technological innovations, over financial incentives, to enabling policy frameworks. Incorporating these interrelated components into a multidimensional strategy, will be central to its success. Peer-to-peer exchange and capacity building on the local level within and between cities, who will play a leading role in driving this development, will be critical in confronting the associated challenges while bolstering the possibilities electric mobility presents. Technological considerations of vehicles, batteries and optimal patterns for charging infrastructure for private and public transport are but one core element to meeting the needs for future sustainable mobility system. Most importantly, this needs to be complemented by the integration of transport modes ensuring last-mile connectivity, and the design and implementation of adequate regulatory frameworks developed with all stakeholders, balancing social inclusion, affordability and data protection.

Cities should invest in the development of policies supporting sustainable transport, aiming to ensure that public transport and active mobility make up the majority of completed trips. The remaining journeys that need to be completed by a private or shared vehicle, including first- and last-mile options, should be electric. Without this focus on sustainable, integrated urban mobility, policies supporting widespread public charging and parking incentives will only result in the replacement of conventional cars with electric ones. This does not solve the severe issues cities currently face.

Hence, adopting this integrated approach, transport electrification has the potential to significantly contribute to a more sustainable urban mobility, and to the objectives of the Paris Agreement and the New Urban Agenda.

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