ACCELERATING LOW-CARBON PATHWAYS THROUGH E-MOBILITY

PERSPECTIVES FROM DEVELOPING ECONOMIES

Alexandra Pamela Chiang and Jürg M. Grütter

NO. 84

March 2023

ADB SUSTAINABLE DEVELOPMENT WORKING PAPER SERIES

ASIAN DEVELOPMENT BANK

ADB Sustainable Development Working Paper Series

Accelerating Low-Carbon Pathways through E-Mobility: Perspectives from Developing Economies

Alexandra Pamela Chiang and Jürg M. Grütter

No. 84 | March 2023

Alexandra Pamela Chiang is senior transport specialist, Transport Sector Group, under the Sustainable Development and Climate Change Department at the Asian Development Bank.

Jürg M. Grütter is an independent consultant and the chief executive officer of Grütter Consulting.

ASIAN DEVELOPMENT BANK

Creative Commons Attribution 3.0 IGO license (CC BY 3.0 IGO)

© 2023 Asian Development Bank

6 ADB Avenue, Mandaluyong City, 1550 Metro Manila, Philippines
Tel +63 2 8632 4444; Fax +63 2 8636 2444
www.adb.org

Some rights reserved. Published in 2023.

ISSN 2789-0619 (print); 2789-0627 (electronic)
Publication Stock No. WPS230066-2
DOI: http://dx.doi.org/10.22617/WPS230066-2

The views expressed in this publication are those of the authors and do not necessarily reflect the views and policies of the Asian Development Bank (ADB) or its Board of Governors or the governments they represent.

ADB does not guarantee the accuracy of the data included in this publication and accepts no responsibility for any consequence of their use. The mention of specific companies or products of manufacturers does not imply that they are endorsed or recommended by ADB in preference to others of a similar nature that are not mentioned.

By making any designation of or reference to a particular territory or geographic area, or by using the term “country” in this document, ADB does not intend to make any judgments as to the legal or other status of any territory or area.

This work is available under the Creative Commons Attribution 3.0 IGO license (CC BY 3.0 IGO) https://creativecommons.org/licenses/by/3.0/igo/. By using the content of this publication, you agree to be bound by the terms of this license. For attribution, translations, adaptations, and permissions, please read the provisions and terms of use at https://www.adb.org/terms-use#openaccess.

This CC license does not apply to non-ADB copyright materials in this publication. If the material is attributed to another source, please contact the copyright owner or publisher of that source for permission to reproduce it. ADB cannot be held liable for any claims that arise as a result of your use of the material.

Please contact pubsmarketing@adb.org if you have questions or comments with respect to content, or if you wish to obtain copyright permission for your intended use that does not fall within these terms, or for permission to use the ADB logo.

The ADB Sustainable Development Working Paper Series presents data, information, and/or findings from ongoing research and studies to encourage exchange of ideas and elicit comment and feedback about development issues in Asia and the Pacific. Since papers in this series are intended for quick and easy dissemination, the content may or may not be fully edited and may later be modified for final publication.

Corrigenda to ADB publications may be found at http://www.adb.org/publications/corrigenda.

Notes:
In this publication, “$” refers to United States dollars.
ADB recognizes “Kyrgyzstan” as the Kyrgyz Republic.

CONTENTS

TABLES, FIGURES, AND BOX

TABLES

FIGURES

BOX

ACKNOWLEDGMENTS

This publication was commissioned by the Asian Development Bank (ADB) under the regional technical assistance (TA) for TA 9420: Implementation of Sustainable Transport for All. The TA was cofinanced by the Government of Japan, through the High-Level Technology Fund; the Republic of Korea, through the Republic of Korea e-Asia and Knowledge Partnership Fund; and the United Kingdom, through the Urban Climate Change Resilience Trust Fund under the Urban Financing Partnership Facility. ADB wishes to acknowledge the valuable inputs and contributions of all stakeholders that contributed to this piece.

Jurg Grütter (chief executive officer of Grütter Consulting) prepared the publication, with inputs and under the overall guidance of Alexandra Pamela Chiang (senior transport specialist, Transport Sector Group, Sustainable Development and Climate Change Department [SDCC]) and Ki-Joon Kim (principal transport specialist, SDCC). Jamie Leather (chief, Transport Sector Group, SDCC) provided support and direction while preparing the publication, and Diane Hernandez-Louis (transport officer, SDCC) and Franzella PinkyVillanueva (associate operations analyst) provided TA administration support. Mariel Gabriel (knowledge management consultant) managed the production process.

ABBREVIATIONS

ADB – Asian Development Bank
CAPEX – capital expenditure
EV – electric vehicle
GHG – greenhouse gas
ICCT – International Council on Clean Transportation
IEA – International Energy Agency
IPCC – Intergovernmental Panel on Climate Change
kg – kilogram
$kgCO_2$ – kilogram of carbon dioxide
km – kilometer
kw – kilowatt
kWh – kilowatt-hour
NO_X – nitric oxide
OPEX – operational expenditure
$PM_{2.5}$ – particulate matter 2.5
PRC – People’s Republic of China
TCO – total cost of ownership

I. BACKGROUND AND CONTEXT

The transport sector is one of the main contributors to greenhouse gas (GHG) emissions—approximately one-quarter of all energy related GHG emissions come from this sector (IPCC, 2022)—and emissions continue growing. Urgent concerns over climate change and air pollution demand transitions away from fossil fuels. The Intergovernmental Panel on Climate Change (IPCC) estimates that without interventions, transport emissions could increase by 16%-50% by 2050, with high growth expected particularly in developing countries in Africa and Asia (IPCC, 2022). A separate forecast by The International Council on Clean Transportation (ICCT) expects that under a business-as-usual scenario, transport GHG emissions will increase much more, by 75% by 2055 (ICCT, 2020). The figure below provides annual projections from the International Energy Agency (IEA), indicating the GHG emissions profile up to 2050, even with the current stated policies in place to reduce GHG emissions from the transport sector.

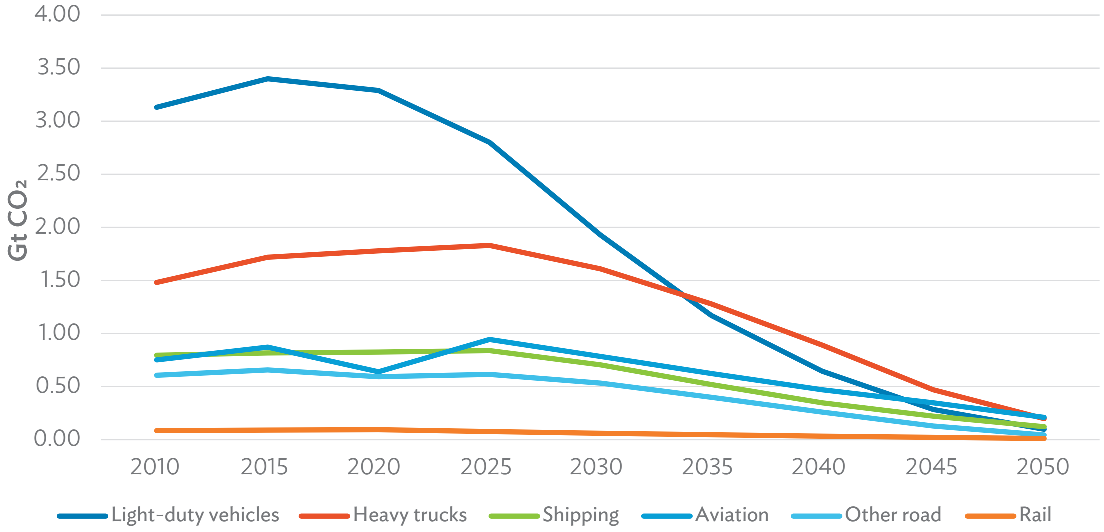
Figure 1: Projected Global CO_2 Transport Emissions under the Stated Policy Scenario by 2050

CO_2 = carbon dioxide, $GtCO_2$ = gigaton of CO_2.

Source: IEA, 2021a.

The projected with policy scenario above—which already contains significant GHG reductions compared to a business-as-usual development—contrasts sharply with a net zero pathway as shown in the following figure.

Figure 2: Projected Global CO_2 Transport Emissions per Mode with a Net Zero Emission Target by 2050



CO_2 = carbon dioxide, $GtCO_2$ = gigaton of CO_2.

Source: IEA, 2021a.

While an increasing number of countries have formulated overall net-zero GHG targets, net-zero or zero GHG road maps specifically for the transport sector are (still) less common. Based on a desk review of existing road maps, a common feature can be observed: while measures such as fuel efficiency, mode shift, and traffic avoidance are listed, many such road maps rely on zero-emission vehicles dominated by electric vehicles for road transport and alternate fuels for shipping and aviation to achieve zero emissions.[1] On the former, fuel cell electric vehicles are often relied on as complementary technology for heavy duty vehicles. The dominant importance of zero-emission vehicles is also reflected in the following key events:

(i) During the COP26 in Glasgow in 2021, a declaration was made to accelerate transitions toward zero emission cars and vans (note that this is represented by light-duty vehicles in the figure above), targeting 100% of global sales of new cars and vans are zero emission vehicles by 2040.[2] The declaration was signed by 39 governments, multiple cities and regional governments, automotive manufacturers, fleet owners and operators, and others. COP27 reinforced global interest and commitment across developed and developing economies to accelerate global transition toward zero-emission vehicles.

(ii) The G7 meeting in 2022 recognized that electrification of road transportation is pivotal to decarbonization.[3]

(iii) The IPCC AR 6 Working Group III Report states that in general, electrification tends to play the key role in land-based transport decarbonization. The decarbonization potential is however strongly dependent on the decarbonization of the power sector.

---

[1] European Commission. A European Green Deal: Striving to be the first climate-neutral continent.

[2] Government of the United Kingdom. COP26 declaration on accelerating the transition to 100% zero emission cars and vans.

[3] Government of Germany, Federal Ministry of Economy and Climate Protection. 2022. G7 Climate, Energy and Environment Ministers' Communiqué. Final declaration point 78.

(iv) The IEA report on *Net Zero by 2050* (IEA, 2021a) clearly states that electrification is the main option to reduce GHG emissions from road and rail modes (p. 138).

(v) The Global Climate Action of the United Nations calls for a complete electrification of railways and light-duty vehicles, calling for a combination of electrification and zero-emission fuels for heavy-duty vehicles and zero-emission fuels for shipping and aviation to achieve a decarbonized transport sector by 2050 (UNFCCC, 2021). This requires that 100% of light-duty vehicles sold in 2040 are zero emission.

(vi) The International Council on Clean Transportation (ICCT) states that electric vehicles (EVs) are the single most important technology for decarbonizing the transport sector (ICCT, 2020).

Rapid technological advancements in the EV industry are creating more efficient and sustainable modes of mobility. Encouraged by this promise, governments around the world are looking closely at this technology to resolve their dependence on fossil fuels in transport.

In this context, this paper explores the current trends and state of technological development relevant to uptake of electric vehicles in Asia and the Pacific. It discusses opportunities to further support members of the Asian Development Bank (ADB) in transitioning toward their low-carbon pathways through electrification of transport modes.

II. OVERVIEW OF DEVELOPMENTS IN E-MOBILITY

A. Trends

This chapter reviews trends in electric vehicle deployment for a range of transport modes, including passenger cars, electric 2- and 3-wheeler vehicles, electric light commercial vehicles and trucks, electric buses, and electric vessels. The opportunities, barriers, and challenges in these modes are explored in turn.

1. Passenger Cars

The sales of full electric and plug-in hybrid cars have soared over the last 5 years. By 2021, there were about 16.5 million electric cars[4] on the worlds' roads (IEA, 2022). In 2021, 9% of global car sales were electric vehicles, and 85% of these were in the People's Republic of China (PRC) and Europe. However, EVs as a percentage of total car stock has risen much slower due to vehicle replacement rates. Norway currently leads with the highest percentage of battery electric car sales with nearly 80% as of June 2022,[5] even though the electric car stock as of June 2022 was only 18%.[6] This shows that it will take time to achieve the desired environmental impacts, since this is dependent on total number of vehicles in use, and not just the number of new EVs in use. Early actions to increase EV penetration levels will also help to enable the desired outcomes to be achieved sooner.

More than 1.8 million publicly accessible chargers are operating worldwide with an average of 10 EVs per charger and 2.4 kilowatts (kW) per EV (IEA, 2022). The share of fast chargers (defined by IEA as chargers > 22 kW) as percentage of all chargers varies widely (Figure 3). Within the study, the median

---

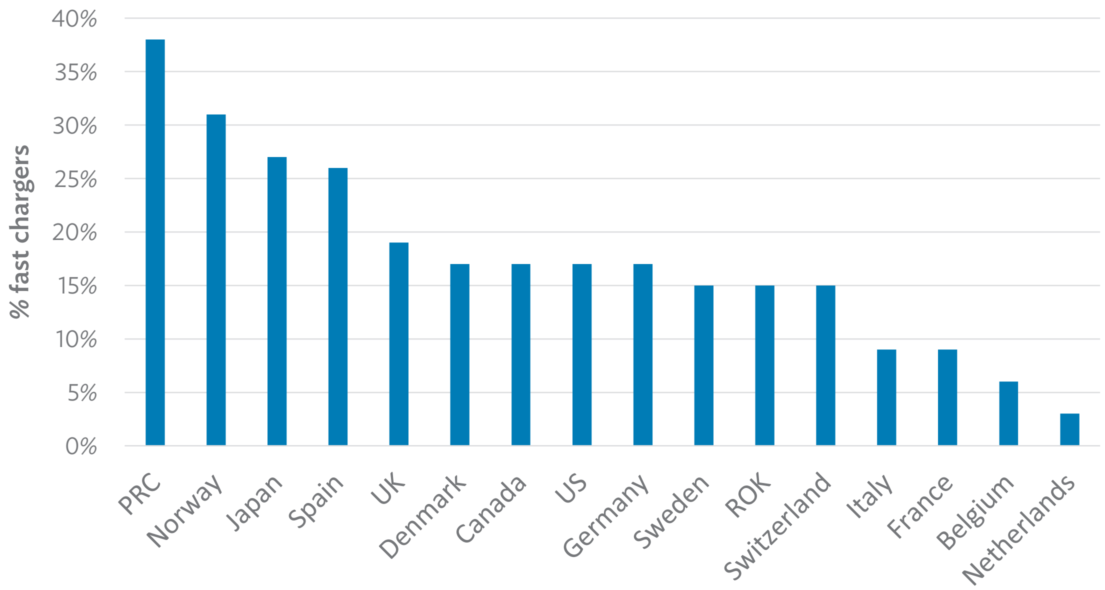
[4] This includes battery electric cars and plug-in hybrid electric cars with the majority being battery electric vehicles.

[5] Including plug-in hybrid cars at 24%

[6] Norwegian Electric Vehicle Association. Electric vehicle statistics (accessed 1 September 2022).

value of fast chargers as a percentage of all public chargers is 17% whereas the individual country value ranges from 3% in the Netherlands (which also has a large share of plug-in electric hybrid vehicles) to 38% in the PRC.

Figure 3: Fast Chargers (> 22 kW) of all Public Chargers in 2020



kW = kilowatt, PRC = People's Republic of China, ROK = Republic of Korea, UK = United Kingdom, US = United States.

Source: International Energy Agency. Global EV Data Explorer.

Of all public chargers worldwide, 83% are concentrated in five countries: the PRC, the United States, the Netherlands, the Republic of Korea, and France, in decreasing order. The relation between numbers of electric cars and available public chargers varies widely, from 2 EVs per public charger in the Republic of Korea, to 20 units per charger in Norway. The median value for number of EVs per charger is 6 (Table 1). For fast chargers, the values range from 11 EVs per fast charger in the PRC, to 89 EVs per fast charger in the Netherlands, with a median value of 45 EVs per fast charger.

Table 1: Chargers per Battery Electric Car 2020

Country	BEVs per All Chargers	BEVs per Fast Charger	Share of Fast Chargers
Belgium	4	67	6%
Canada	10	56	17%
PRC	4	11	38%
Denmark	10	57	17%
France	6	70	9%
Germany	7	44	17%
Italy	4	45	9%
Japan	5	17	27%
ROK	2	12	15%

Continued on next page

Table 1: continued

Country	BEVs per All Chargers	BEVs per Fast Charger	Share of Fast Chargers
Netherlands	3	89	3%
Norway	20	64	31%
Spain	6	21	26%
Sweden	5	35	15%
Switzerland	7	47	15%
United States	12	68	17%
UK	6	33	19%
Median	**6**	**45**	**17%**

BEV = battery electric vehicle, PRC = People's Republic of China, ROK = Republic of Korea, UK = United Kingdom.

Source: International Energy Agency. Global EV Data Explorer.

There is no obvious or fixed relationship between number and type of chargers versus the uptake of EVs. Therefore, it is critical to consider each unique context when developing a charging system strategy.

2. Electric Two-and Three-Wheelers

The PRC dominates the electric two-wheeler market by annual sales (estimated at 9.5 million registrations in 2021 out of a global total of 10 million) (IEA, 2022). Regulations not allowing gasoline motorcycles to ply the streets of most cities in the PRC and modest prices have resulted in strong uptake in EVs. Other high-volume markets are in Viet Nam and India. Two- and three-wheelers are technically quite straightforward to decarbonize, due to their lower weight, shorter range, and the higher efficiency of electric motors. However, in the absence of either high financial subsidies or regulations, customers will prefer to purchase gasoline motorcycles, which have more power and speed than their same-cost electric equivalents. E-motorcycles of comparable performance and perceived value cost 2 to 3 times more than a gasoline unit. While the limited driving range and the absence of charging infrastructure is a deterrent, it is not the core issue with uptake of e-motorcycles. This is clearly shown for example in Taipei,China, which has established a very dense battery swapping network without e-motorcycles increasing their market share beyond 10%–15% and still requiring massive subsidies. The core reason customers prefer gasoline units is also the "the need for speed," and higher-powered e-motorcycles with comparable speed to standard gasoline motorcycles are far more expensive.

Hence, the promotion of e-motorcycles to date has had limited success, although at first glance e-motorcycles seem to be comparable in purchase cost and have lower operational costs. India, Indonesia, and Viet Nam (together with the PRC, the world's largest motorcycle market) have achieved modest sales of e-motorcycles, with the market mostly taken up by low-powered electric-scooters (e-scooters) used primarily by students, as these can be driven without a license. Such e-scooters often replace bicycles or public transport trips. The market share of e-motorcycles in these economies is marginal, although India for example has significantly subsidized e-motorcycles (TERI, 2019). In Taipei,China, massive subsidies in battery swapping stations and subsidies of up to $1,200 per motorcycle have resulted in a stagnating market share of 10% of e-motorcycles. The only success case for widespread adoption of electric two-wheelers is the PRC where gasoline units have been replaced with electric ones due to restricting operations of gasoline motorcycles in most cities (Grütter Consulting, 2021).

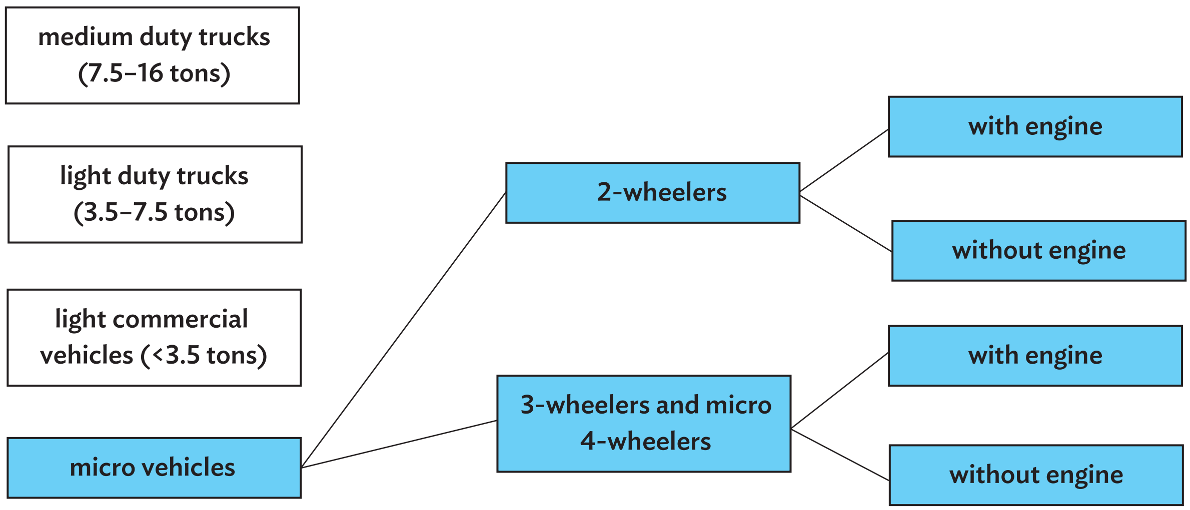
3. Electric Light Commercial Vehicles and Trucks

Electric light commercial vehicles are approaching cost parity with gasoline units for lifetime cost and vehicle sales have increased strongly in the last few years, reaching a market share of new vehicle sales of 2% by 2021 (IEA, 2022). Next to the PRC, France, Germany, and the United Kingdom are the countries with the largest numbers of electric light commercial vehicles.

Last-mile delivery services in many cities of the world are growing annually at high double-digit rates. Urban freight is thus quickly becoming one of the major if not the largest source of transport-related air pollution and GHGs in cities. For example, in Hanoi, emissions from last-mile delivery service vehicles in 2030 are expected to be 30%–50% of total transport emissions, although the vehicle share is less than 15% (Grütter Consulting, 2020a).

Urban freight is characterized by transient loads with high-power peaks for acceleration with low loads in slow and gridlocked traffic. Daily distances driven are much lower than for long-haul trucks, with frequent stops in between. Such vehicles also have a much lower payload. The market can be segregated in four categories of vehicles from medium-sized trucks to micro-vehicles with or without engine (Figure 4).

Figure 4: Major Urban Freight Vehicle Categories



Source: Grütter Consulting.

EVs are available for all vehicle sizes. Micro-vehicles are by far the largest vehicle segment for last-mile delivery services.

Full electric heavy duty long-haul trucks are still at the piloting stage. Problems are associated with range, required battery load, and required fast-charging capabilities at truck stops. Hydrogen powered trucks might be an alternative for heavy-duty long-haul trucks and have picked up in the last few years, with Switzerland, for example, introducing 1,500 34- to 40-ton hydrogen trucks over the next years. The business model is based on operators paying a leasing fee per kilometer to cover vehicle, energy, and maintenance costs.[7]

---

[7] H2 Energy.

4. Electric Buses

About 700,000 battery electric buses operated worldwide in 2021, of which 95% were deployed in the PRC (IEA, 2022). E-buses in the PRC represent around 20% of the total bus fleet, with many cities intending to transition to 100% electric bus fleets within the next few years. This target has already been met by Shenzhen in 2018 with more than 16,000 e-buses operating in the city.

In comparison, far less battery electric buses are operating outside of the PRC, although the trend is changing, with many cities now interested in deployment of electric buses to tackle climate change and air pollution. For example, India initiated the Faster Adoption and Manufacturing of (Hybrid and) Electric Vehicles program to stimulate the demand and the supply side of e-buses. The government has sanctioned 5,600 electric buses in 64 cities under the program's second phase.[8] By mid 2022, Latin America had about 2,100 electric buses operating (plus more than 1,000 trolleybuses),[9] of which the largest fleets in Bogota, Colombia, with 1,050 e-buses and Santiago de Chile with around 850 units. Moscow, Russian Federation operated about 1,000 electric buses at the end of 2021, and is now only purchasing electric buses.[10] In Europe battery electric buses have clearly passed compressed natural gas units as top choice for alternative fueled buses. More than 7,600 battery electric buses were operating mid 2022 in Europe, next to electric trolleybuses.[11] The Middle East and Africa are also getting poised for electric bus assembly or manufacturing, with Egypt closing deals to locally manufacture e-buses,[12] while Qatar ordered 1,100 e-buses for the FIFA World cup 2022.[13]

To identify the optimal e-bus type, the ecosystem within which e-buses move has to be assessed. This requires optimization of the e-bus technology jointly with the charging infrastructure and the required grid and potential bus depot upgrades. The e-bus ecosystem is influenced by a range of factors such as operating conditions, climatic conditions, routes, policies, business models, and finance structures (Figure 5).

---

[8] This includes 400 inter-city units, with the rest being urban buses. Union Internationale des Transports Publics (International Association of Public Transport). UITP in India.

[9] For more information and tracking of e-bus deployment, see E-Bus Radar. Electric buses in Latin America (accessed 1 September 2022).

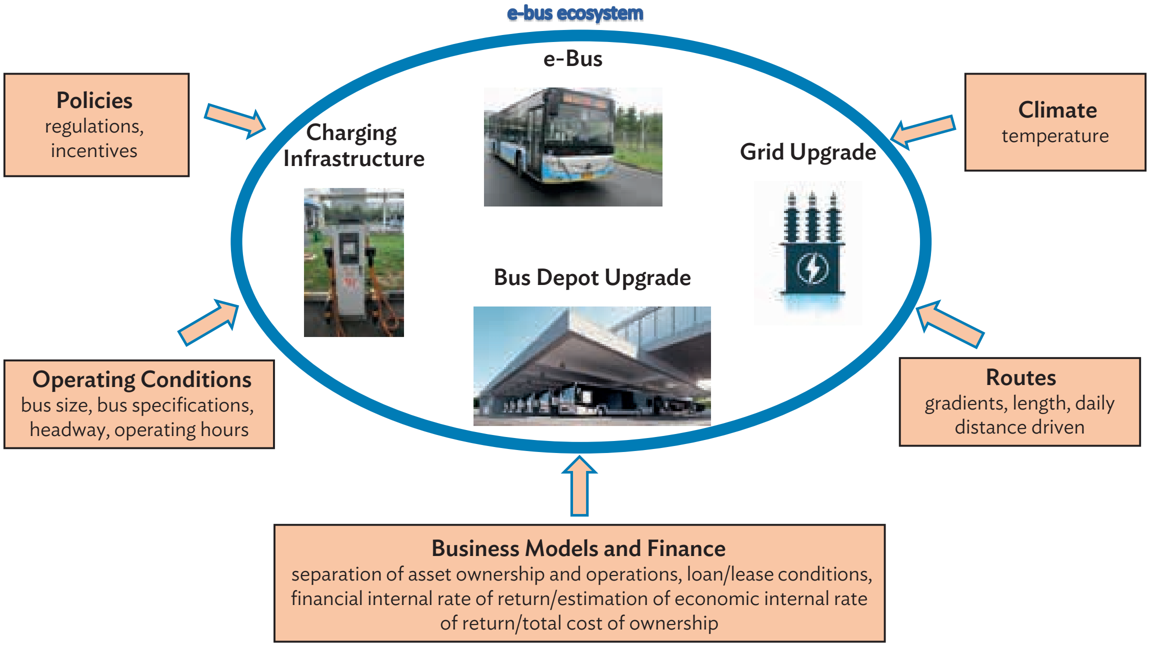
[10] *Green Car Congress*. 2021. Starting this year, Moscow will only buy electric buses. 2 July.

[11] European Commission. European Alternative Fuels Observatory (accessed 1 September 2022).

[12] *Sustainable Bus.* 2020. Foton to begin electric bus production in Egypt in November. 24 February.

[13] *The Peninsula Qatar*. 2021. 1,100 electric buses to ferry FIFA World Cup 2022 fans. 25 April.

Figure 5: e-Bus Ecosystem and Influencing Factors



Source: Grütter Consulting.

Basic e-bus technology types are (i) overnight/slow or depot-charged buses; (ii) fast-charged buses charged once or twice (if required) during the day for 10–30 minutes during off-peak periods, e.g., at the bus depot or close to route endings; (iii) opportunity-charged buses with charging at the end of the route for 5–15 minutes; (iv) ultra-fast charging at bus stops during 10–20 seconds while passengers board and de-board the bus; (v) trolleybuses including hybrid trolleybuses; and (vi) battery swap buses. For specific charging technologies, specific batteries are required. Batteries used for slow-charging cannot be used for fast or ultra-fast charging (but the reverse is possible). Energy densities and costs also vary between battery technologies. Therefore, optimization needs to be made of the e-bus system, considering operational conditions, technical requirements of the bus operator, the grid situation, investment costs of the bus, charging system, depot upgrades, and grid adjustments. Table 2 summarizes core advantages and disadvantages of e-bus systems.

Table 2: Comparison of e-Bus Systems

E-bus system	Advantages	Disadvantages	Optimal applications
Slow-charged BEB	Simple to operate, proven technology, low electricity cost	Large battery set, high bus weight and cost, range limitations, high operational risks, potentially high power demand at depot	Buses up to 12 meters running on shorter routes
Fast-charged plug-in BEB	Proven technology, range flexibility, moderate battery size and bus weight/cost	Requires recharging during the day, additional space for chargers required	Buses up to 18 meters on any standard routes
End-of-route opportunity charged BEB	Range flexibility, moderate battery size and bus weight/cost	Requires sufficient time at end of route, buses can only be used on equipped routes, power outages can affect the system	Buses of any size on routes with headways > 6 minutes for 18 meter buses (> 4 minutes for 12-meter units)

Continued on next page

Table 2: continued

E-bus system	Advantages	Disadvantages	Optimal applications
Ultra-fast charged BEB	Range flexibility, small battery, low bus weight, low risk, high system redundancy	Buses can only be used on equipped routes, high infrastructure costs, new technology	18–28 meter buses on bus rapid transit routes with short headways
Battery swap BEB	Range flexibility, moderate battery size and bus weight/cost	Requires re-charging during the day, very high system costs, lock-in with certain bus models and manufacturers	System not recommended due to minus points
(Hybrid) trolleybus	Range flexibility, small battery size and low bus weight,	Very high infrastructure cost, limited flexibility, potentially high electricity costs, power outages can affect the system	System only recommended in cities with a relatively new trolleybus infrastructure already in place

BEB = battery electric bus, e-bus = electric bus.

Source: Grütter Consulting.

5. Electric Vessels

The global electric vessel market is projected to triple from $5.2 billion (2019) to > 15 billion by 2030.[14] Norway is the world's leader in electric mobility and plays a leading role in electric vessels.[15] The Norwegian Parliament in 2015 passed regulation requiring low- and zero-emission solutions for all cruise ships and ferries in the Norwegian world heritage fjords as soon as technically possible and no later than 2026. This will make the fjords the world's first zero emission zone at sea. It has also led to an electric revolution in the Norwegian fjords, as more than 60 electric ferries will be seaborne within the next few years.[16]

Amsterdam decreed in 2013 that all recreational boats in the city center should be emission free by 2025 and in the entire city by 2030 in order to reduce pollution and GHG emissions.[17] The transition among commercial vessels is well under way, with 75% of the 550 vessels on the city's water qualifying as emissions free (footnote 17). The city is also working with contractors to have 100 boat charging stations installed by the end of 2021, as well as a floating charging station expected to help with grid balancing.[18]

Meanwhile in Bangkok, Energy Absolute and partners, with cofinancing from ADB, have deployed around 30 electric high-speed vessels for 200–250 passengers. These cruise at 16 knots on the canals of the city. The trip distance is 30 kilometers (km) with four 300 kW fast chargers at each end for 15 minutes during boarding and de-boarding of passengers. The vessels' battery capacity is 800 kilowatt-hours (kWh) and the engine rated power is 2 x 90 kW. Bangkok already has eight smaller electric vessels running on secondary canals. These are 12 meter boats for 30–40 passengers running on a 5-km route.

Electric propulsion is used for different sizes of vessels and with different charging technologies (slow overnight charging or fast charging; battery technologies for slow and fast charging are different). The major advantage of full electric vessels is low noise levels and zero direct emissions. The major limitations are power and range, and limited shore-side electric facilities making charging complicated. Cost-effective applications are primarily achievable in small to medium-sized vessels, at slow speed,

---

[14] Markets and Markets. Electric Ship Market.

[15] Norway is the world's seventh largest shipping nation measured by number of vessels, the ninth largest by gross registered tonnage, and was the fifth largest by fleet value in 2017.

[16] M. Launes. 2018. Norwegian parliament adopts zero-emission regulations in the fjords. *Maritime Cleantech*. 3 May.

[17] T. Sterling. 2020. Amsterdam's boats go electric ahead of 2025 diesel ban. *Reuters*. 3 March.

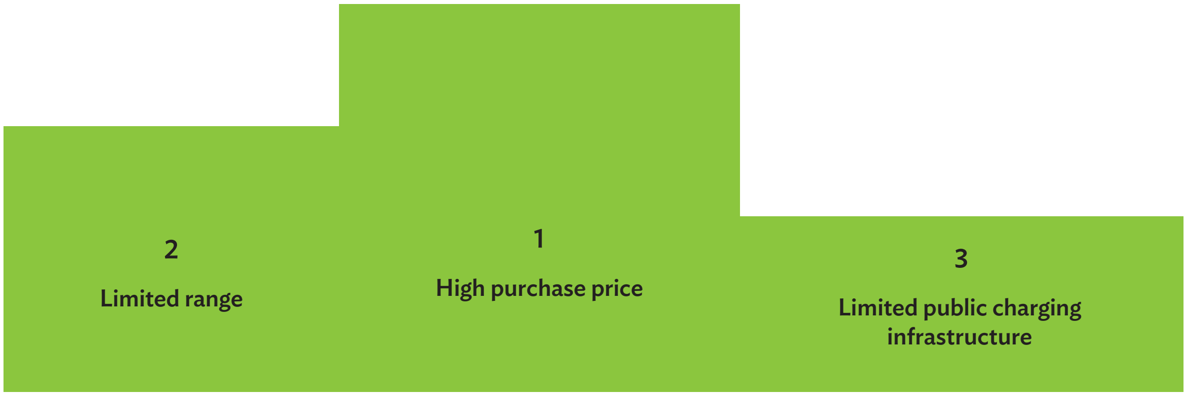
[18] J. Butler. 2020. New Amsterdam floating battery terminal for electric boats. *Plugboats*. 8 March.

such as for tourism and for environmentally sensitive areas. The common denominator for successful battery use is to operate the vessels close to shore.

B. Policies and Regulations

Policies to support e-mobility have been introduced around the world to motivate people to purchase electric vehicles. Multiple surveys have assessed attitudes toward electric passenger cars. The three major barriers that often arise are the high purchase cost of EVs, limited driving range, and lack of charging infrastructure (Figure 6).

Figure 6: Major Perceived Disadvantages of Electric Passenger Cars



Source: Grütter Consulting based on (Lebeu, 2013), (Dow, 2019), (Broadbent, 2019), (Gaton, 2019), (McKinsey, 2016), (Hertzke, 2016) , (UK Department for Transport, 2016), (UBS Evidence Lab, 2018); similar results were confirmed in an Asian Development Bank survey in the Kyrgyz Republic (Grütter Consulting, 2020b).

Other important considerations are long charging times, lack of home charging, lack of reliability of EVs, limited electric vehicle models or types, and lack of information. Table 3 shows policy options available for directly tackling the barriers.

Table 3: Barriers and Possible Policies to Facilitate Electric Vehicle Adoption

Barrier	Potential Policies to Address These Barriers
High purchase cost	Subsidize purchase of EVs, reduce tax rates on EVs, foster leasing/rental systems for EVs
Limited range	Provide information on EV charging to reduce range anxiety, establish dense high-powered fast-charging network which reduces the potential problem of a short range
Limited public charging infrastructure	Subsidize establishment of charging infrastructure, provide incentives for private operators of chargers, create a clear legal framework for the operation of chargers, waive power/demand charge at least initially for public chargers, provide low electricity price for companies with public chargers (thereby making the business model to establish public chargers attractive), prioritize investments on grid networks to enable public fast chargers

Continued on next page

Table 3: continued

Barrier	Potential Policies to Address These Barriers
Long charging times	Provide incentives for fast and ultra-fast chargers, no power/demand charge at least initially for fast chargers, prioritize investments on grid networks to enable ultra-fast public chargers
Lack of reliability of EVs	Publish results on EV testing, inform the public on possible issues with used EVs; require a state-of-health report and require a minimum level for the import of used EVs to ensure a sufficient remaining battery life span
Limited electric vehicle models	Inform the public about available EVs worldwide, as often local vehicle dealers do not want to import EVs due to lower profit margins on EVs and less after-sales services (spare parts and maintenance)
Lack of information	Conduct information campaign on benefits of EVs

EV = electric vehicle.

Source: Grütter Consulting.

Table 4 shows policies adopted by countries leading the EV revolution, including the PRC with the highest absolute number of vehicles and the three countries with the highest share of EVs (Norway, the Netherlands, and Iceland).

Table 4: Policies of Countries with High Impact on EV Sales

Country	Major Policies to Promote Electric Passenger Cars
People's Republic of China	Central and local government incentives exist, e.g., upfront cash subsidies for cars, subsidies for charging infrastructure, waiving of vehicle tax. Nonfinancial incentives basically from cities, e.g., preferential treatment of EVs when travel restrictions apply or less or no restriction on issuing license plates for EVs, while for a fossil fuel car a bidding process or a lottery system is applied with an extremely low chance of being awarded a license plate.
Norway	Official target is to sell only EVs by 2025; registration tax including VAT (25%) exemption also on leased vehicles. Monetary incentives amount to on average $25,000 per EV (Lorentzen, 2017), no annual road tax, local incentives such as waivers on toll roads or ferries, free parking, use of bus lanes, etc.[a]
Netherlands	No tax on EV car acquisition and annual car registration fee. Drivers of leased electric and hybrid cars are exempted from taxation on private use of lease car (20% of value of new car for fossil fuel units). Subsidy of public charger installations: official target is that no new fossil cars are sold after 2030.
Iceland	Exemption from import excise duties for EVs (while for fossil fuel cars these may amount to 65% of the car's value). VAT exemption for EVs. Grants for public fast-charging stations. Reykjavik offers free public charging as well as free parking for EVs. Low electricity price combined with high fossil fuel prices create a positive environment. Iceland is also one of the most urbanized countries in the world, with a maximum of 500 kilometers to cross the country east to west making range anxiety less of an issue.

[a] With increasing share of EVs various incentives for EVs will be phased out.

Sources: Foc-Penner (2019); European Automobile Manufacturers' Association (2019); Government of the Netherlands' policy on eco-friendly transport fuels; Wappelhorst and Tietge (2018).

The experience of policies in Norway to foster EVs has been summarized in the phrases "cheap to buy," "cheap to use," and "easy charging access" (Lorentzen, 2017).

C. Driving Forces

The major driving forces for government to promote e-mobility are as follows:

Improving air quality. Many cities worldwide suffer serious air pollution, causing health problems, degradation of quality of life, diminished attractiveness of the city, loss of productivity, and economic costs. EVs have zero combustion emissions. They still have, equal to their fossil counterparts, non-combustion emissions resulting from tire and brake pad abrasion as well as from re-suspension of particles. Nevertheless, EVs will still result in a significant impact on improving air quality in cities.

Reducing the carbon footprint of transport. EVs reduce GHG emissions, even in electric grids largely dominated by fossil fuels (see the following section). The transport sector has a growing share of GHG emissions and electric vehicles present an option to tackle this problem. Even with a cradle-to-grave perspective, EVs have lower overall GHG emissions than fossil fuel units in the overwhelming majority of contexts. Intelligent charging technologies can also avoid charging EVs during peak production periods and can for example take up wind or hydropower, produced also at night.

Reducing noise pollution. This is a strong argument for electric motorcycles (e-motorcycles) and for electric urban delivery vehicles especially, which could then also operate during the night without disturbing residents. This again can increase the productivity of urban freight companies as they can operate outside normal business hours and use their assets better. Quieter transport modes (e.g., e-ferries) are also beneficial for tourism.

Reduced energy usage. EVs are far more energy efficient, using around 3 times less energy than their fossil fuel counterparts. This reduces energy bills.

Less dependency on fossil fuel imports and external price shocks. Fossil fuel prices are extremely volatile. This creates constantly changing transport tariffs or subsidy levels. Many countries have a large national potential to increase renewable energy generation while having to import fossil fuels. Electrifying the transport sector reduces the political and economic dependency on volatile and politically sensitive fossil fuel markets and reduces the drain on foreign exchange.

Industrial policy. Economies that include or component manufacturers will have to adjust to the new vehicle technology, which will phase out fossil fuel vehicles. Creating a domestic market for EVs and favorable conditions for EV and battery manufacturers can strengthen the domestic industry and maintain or create new jobs.

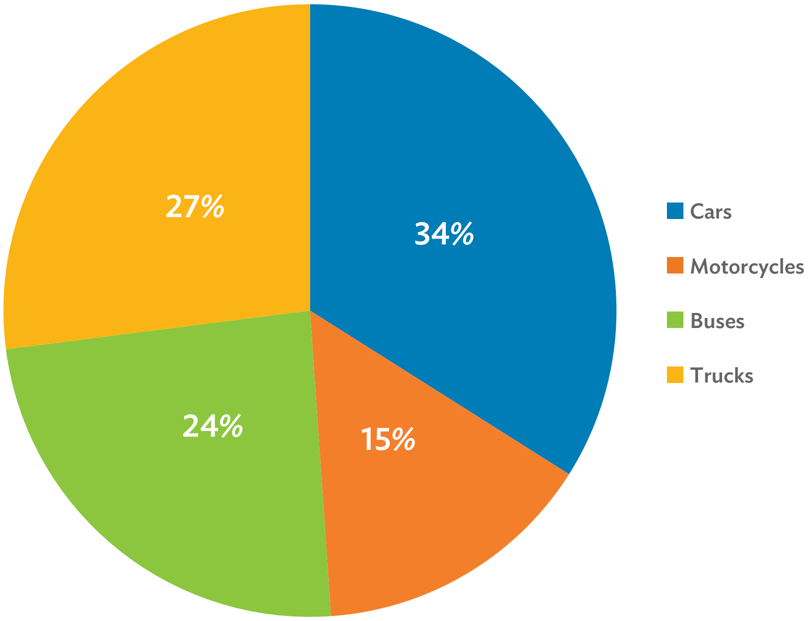
III. CHALLENGES IN TRANSITIONING TO E-MOBILITY

This chapter provides high-level comparison of the different socioeconomic indicators across the select cities. Parameters assessed in this summary are related to (i) air pollution and the share of transport in particle and nitrous oxide (NOx) emissions, which indicates potential impact of EVs on improving air quality in the respective cities; (ii) GHG emissions and the carbon factor of the electricity grid as well as life-cycle GHG emissions of EVs versus conventional fossil vehicles per vehicle category, which indicates GHG reduction potential of EVs with the current electricity production mix; and (iii) financial viability looking at the total cost of ownership and influencing parameters for the different jurisdictions and cities.

A. Air Pollution

Air pollution, especially of particulate matter of less than 2.5 micrometers in diameter ($PM_{2.5}$) and NOx, is a major problem in many cities in Asia. The transport sector is a major source of pollutants in urban areas. While updated vehicle emission standards and cleaner fuels could gradually mitigate this problem, EVs potentially offer zero tailpipe emissions and can thus play an important role in reducing urban air pollution and related health problems. Figures 7 and 8 show average share per vehicle category of $PM_{2.5}$ and NO_X emissions in observed cities. Commercial urban vehicles (buses, taxis, and urban trucks) contribute toward up to 50%–70% of pollutants, although the number of cars and motorcycles is far larger. This is mainly because the latter modes are powered by gasoline engines and are used at a much lower mileage. At the same time, electrification of buses is technically and financially feasible and can already be readily deployed to deliver significant reduction in GHG emissions and improvement in air quality. If the cities involved would pursue an electrification strategy as proposed by the IEA of 30% of sales of new vehicles being electric by 2030, transportation related emissions of local pollutants could be reduced by about 15% by 2030.[19]

Figure 7: Average Share of $PM_{2.5}$ Transport Emissions in Selected Cities Observed in 2019



$PM_{2.5}$ = particulate matter of less than 2.5 micrometers in diameter.

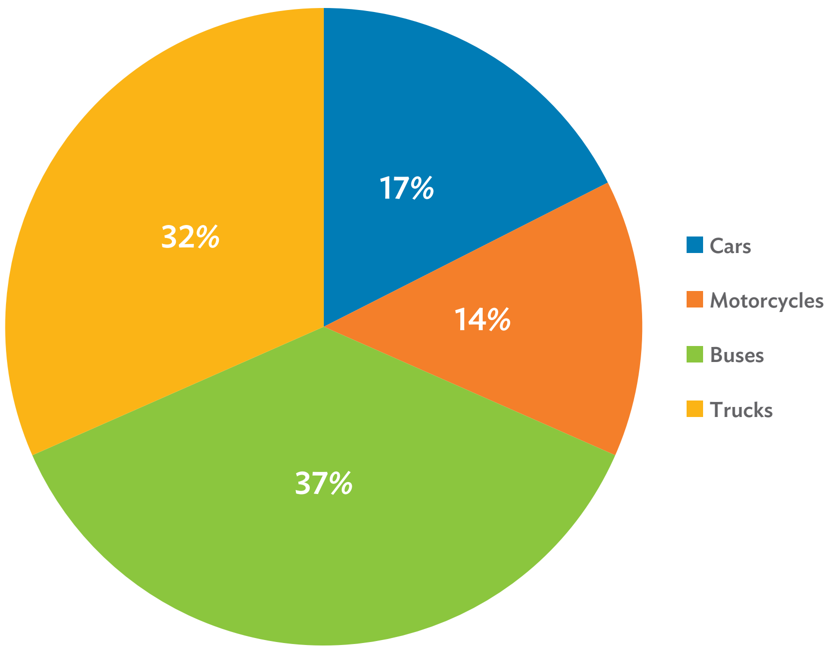
Note: Based on modelling for the cities of Baku, Bangkok, Bishkek, Dhaka, Dushanbe, George Town, Hai Phong, Ho Chi Minh, Hue, Jakarta, Kathmandu, Krabi, Langkawi, Makassar, Malacca, Manila, Phuket, Suva, Tbilisi, Ulaanbaatar, Vientiane, Yangon, and Yerevan.

Source: Grütter Consulting.

---

[19] It takes considerable time to achieve large impacts, due to low vehicle turnover rates.

Figure 8: Average Share of NO_X Transport Emissions in Cities Observed, 2019



NO_X = nitrous oxide.

Note: Based on modelling realized for the cities of Baku, Bangkok, Bishkek, Dhaka, Dushanbe, George Town, Hai Phong, Ho Chi Minh, Hue, Jakarta, Kathmandu, Krabi, Langkawi, Makassar, Malacca, Manila Phuket, Suva, Tbilisi, Ulaanbaatar, Vientiane, Yangon. and Yerevan.

Source: Grütter Consulting.

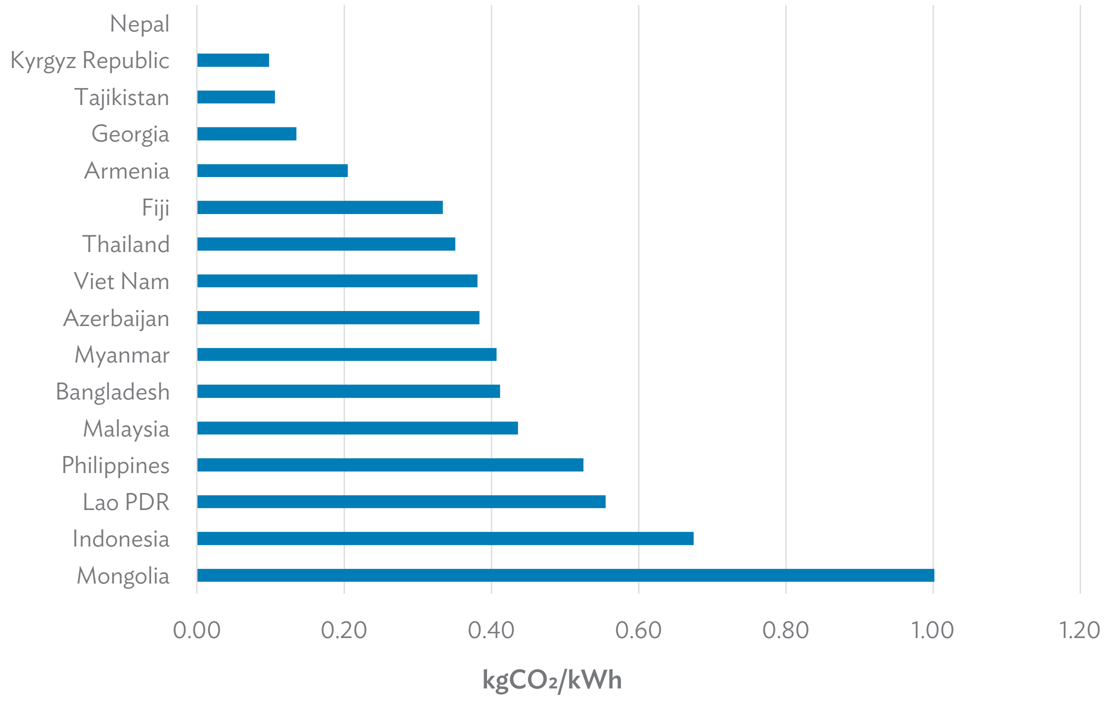
B. Greenhouse Gas Emissions

Under a business-as-usual scenario it is expected that transportation-related GHG emissions will grow in the observed cities by on average 60% from 2019 to 2030. For cities such as Dhaka, Ho Chi Minh, Hai Phong, Hue, Manila, Vientiane, Yangon, or Dushanbe, a doubling of GHG transport emissions could be expected. In other cities, slower growth of vehicle numbers is expected. With a strategy of having 30% of new car sales electric by 2030, GHG emissions of the transport sector in the analyzed cities would be on average 10% lower. On the other hand, it is crucial to note that the indirect GHG emissions of EVs depends on the carbon factor of the electricity grid. Figure 9 shows the 2021 carbon grid factors for involved countries. The average carbon grid factor of included countries is 0.38 kilograms of carbon dioxide ($kgCO_2$) per kWh, which is identical to the world average.[20]

---

[20] IFI Dataset of Default Grid Factor Version 3.2., 2022

Figure 9: Carbon Grid Factors 2019
($kgCO_2/kWh$)



$kgCO_2/kWh$ = kilograms of carbon dioxide per kilowatt-hour, Lao PDR = Lao People's Democratic Republic.

Note: Combined margin grid emission factor for electricity consumption 2022 based on IFI Dataset of Default Grid Factor Version 3.2., 2022.

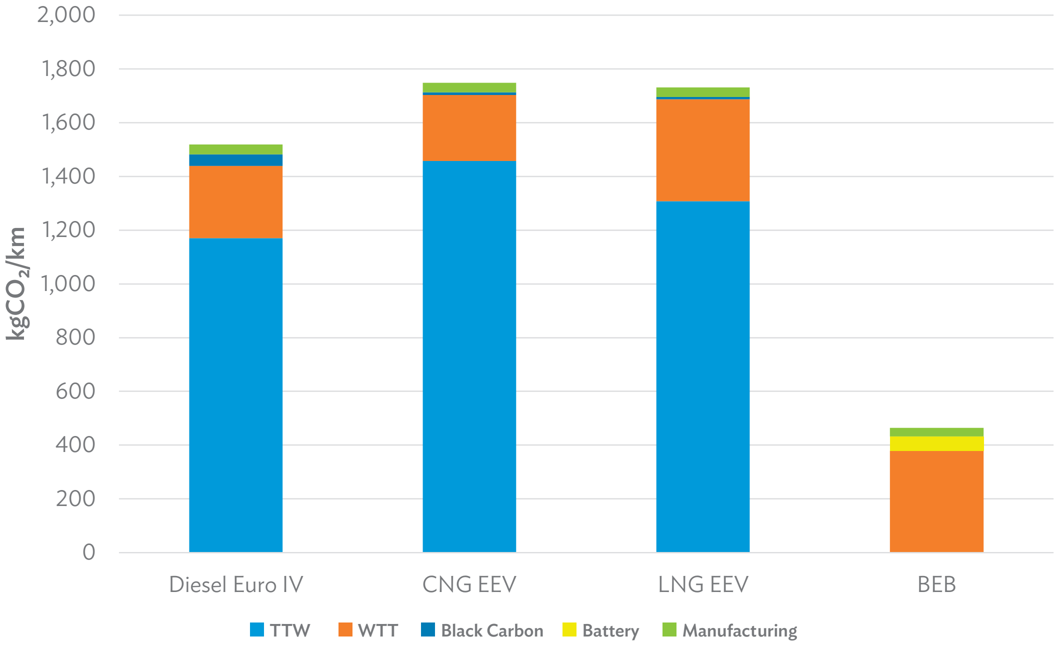
Source: Grütter Consulting.

Figures 10 and 11 compare the life cycle GHG emissions of electric buses and taxis with baseline (new) fossil fuel units for the average grid factor of involved countries.

On average, accounting for life cycle emissions, battery electric buses reduce GHG emissions in observed countries by 70%. Even with the highest grid factor of all involved countries, such as Mongolia with 1.00 $kgCO_2/kWh$, e-buses could still reduce GHG emissions by 30%.

On average, accounting for life cycle emissions, e-taxis reduce GHG emissions in observed countries by 50%. Even with the highest grid factor of all involved countries, such as Mongolia with 1.00 $kgCO_2/kWh$, e-taxis still reduce GHG emissions on a well-to-wheel base and have comparable emissions on a life cycle base.

Figure 10: Life Cycle Greenhouse Gas Emissions of Fossil Fuel and Electric 12-Meter Standard Urban Bus

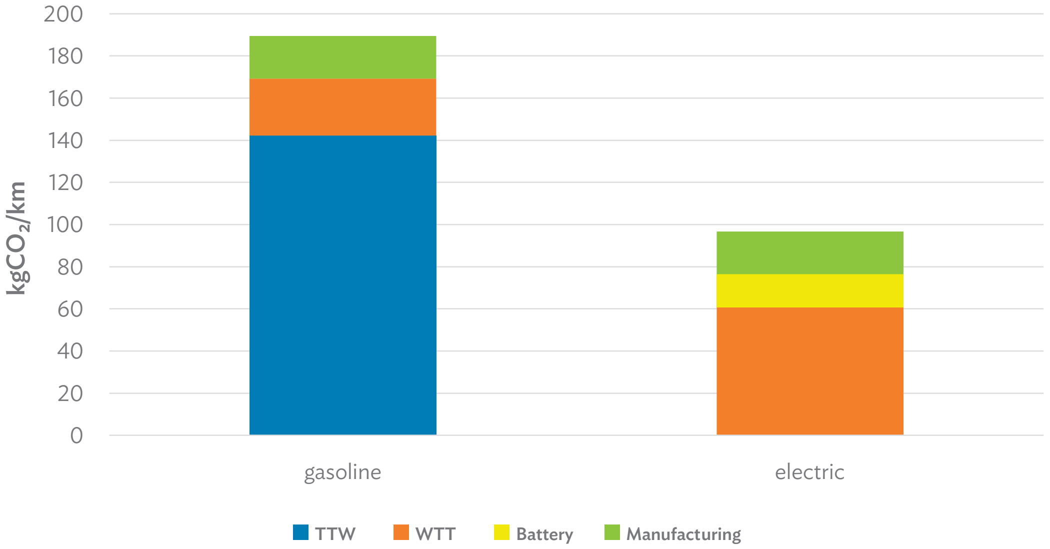


BEB = battery electric bus, CNG = compressed natural gas, EEV = enhanced environmentally friendly vehicle, $kgCO_2/km$ = kilograms of carbon dioxide per kilometer, LNG = liquefied natural gas, TTW = tank to wheel, WTT = well to tank.

Note: Includes for CNG and LNG buses direct and indirect methane emissions.

Source: Grütter Consulting.

Figure 11: Life Cycle Greenhouse Gas Emissions for Fossil Fuel and Electric Taxis



GHG = greenhouse gas, $kgCO_2/km$ = kilograms of carbon dioxide per kilometer, TTW = tank to wheel, WTT = well to tank.

Source: Grütter Consulting.

C. Total Cost of Ownership of Electric Vehicles

In some cities, the total cost of ownership (TCO) of electric vehicles is lower than for fossil fuel vehicles, while in others the cost is higher. The relative profitability of EVs depends to a large extent on relative energy prices, especially fossil fuel prices. This is due to the high energy efficiency of EVs; the electricity price influences the relative profitability of EVs less than the fossil fuel price. In cities such as Kathmandu, Tbilisi, and Yerevan, EVs are especially profitable as fossil fuel prices are relatively high and electricity prices low.

However, EVs are also profitable in cities such as Bangkok, Krabi, or Phuket, even if electricity prices are relatively high, as fossil fuel prices are also high. In locations with relatively low fossil fuel prices, however, promoting EVs would be challenging as this would either require very low electricity prices, such as in Bishkek, or implementation of financial incentives to be financially attractive for the consumer.

The calculation of TCOs depends on a range of assumptions, methodologies (for example, constant real costs versus nominal costs) and a variety of parameters. They also depend on the types of systems being analyzed (for example, many e-bus analyses only include overnight-charged buses). Core assumptions which influence the TCO values are listed as follows.

Capital expenditure. The capital expenditure (CAPEX) of buses, charging infrastructure, bus depot upgrades, and grid connections; battery replacement, if required, should also be included as a CAPEX component for the future.[21]

Additional fleet of e-buses. If required, these could resulting in additional CAPEX as well as operational expenditure (OPEX) in the form of additional drivers, insurance, finance, and management costs.

Lifespan of buses. E-buses have less vibration and moving parts and can thus have a life span 20% longer than fossil fuel units.[22] However, the largest e-bus suppliers are from the PRC and the average usage of buses (not only e-buses) in that country is 8 years, with less than 500,000 km, i.e., much less than in other countries (ADB, 2018). Standard PRC e-buses may thus have a limited lifespan, and bus specifications need to ensure that buses can comply with the life span proposed.

Distance driven. E-buses have lower OPEX than fossil fuel units. The higher the distance driven, the more profitable e-buses will be. On the other hand, due to range issues and battery size, e-buses are often used on shorter routes, thus reducing their advantage. In the PRC, for example, e-buses run on average only 50% of the annual mileage of fossil fuel buses, although the gap is decreasing. This not only influences OPEX savings, but also requires purchase of additional buses (ADB, 2018).

Lifespan of batteries and battery replacement costs. Most battery and e-bus suppliers today guarantee 8 years battery life span with 80% state of charge. In Europe, many bus operators today calculate that no battery replacement during the 12–15 year life span of the bus will be required. The cost of replacement batteries—if at all required—depends on the size of the battery pack, the battery type, and the estimated reduction of battery costs. Adjustments of the battery management system may also be required.

Energy prices. Electricity prices for medium tension consumers generally include a power and a consumption charge, which can vary depending on time of usage. Different e-bus technologies can thus

---

[21] Fossil fuel prices already include these components; grid adjustments up to substations normally need to be paid by the system owner for medium-tension connections; bus depot upgrades can include paving bus depots, charger installation including protection roofs, as well as additional space requirements in the depot due to usage of e-buses.

[22] Based on the experience of Swiss operators with e-buses, for example, which circulate for 20 years, while compressed natural gas and diesel buses are operated for 12–15 years; but bus lifespan is also linked to the battery lifespan, e.g., replacing the battery one time during usage.

have different electricity costs. Also, within the same system, the way buses are charged will influence the electricity bill.

Constant or changing real energy prices. Projections of real fossil fuel prices are notoriously difficult and depend on price setting mechanisms in the particular context. Electricity prices, depending on the fossil production share, might be linked to fossil fuel price development. One aspect frequently disregarded in TCOs with increasing fossil fuel prices is that passenger tariffs or service rates charged by bus operators are in general linked to fossil fuel price development, i.e., while costs and TCOs may increase for fossil buses with increasing fuel prices, this does not necessarily affect the profitability rate of fossil bus operators and is thus not necessarily an advantage of e-bus operators.

Maintenance costs. Maintenance costs are generally assumed to be 20%–50% lower for e-buses in most TCO calculations, based on e-bus manufacturer claims or on experiences of bus operators (ADB, 2018). In theory, the maintenance costs of battery electric buses should be well below diesel buses because e-buses have fewer moving parts. However, in practice there are components which increase the maintenance cost of battery electric buses. This includes, for example, the demand for technically qualified and skilled personnel, more expensive spare parts (secondary spare parts are not readily available in the market), and longer delivery times for spare parts, which result in longer down times. Operators of large fleets of battery electric buses have also noted a 20% lower mileage of tires compared to diesel buses, due to the increased weight of a battery electric bus.[23] However, brake maintenance costs are lower for BEBs, and oil and filter changes are not needed. Large BEB operators still experience more failures than diesel units. In the medium term, maintenance costs should be lower than for diesel buses. However, practical long-term experience is still mixed, as various PRC cities show (only PRC cities have practical long-term experience with e-buses). Only few cities in the PRC (e.g., Guangzhou) have sufficiently long records to compare year-by-year repair and maintenance costs of e-buses with conventional units. Results have shown that e-buses have equal or up to 20% higher tire costs (due to the higher weight of overnight charged battery electric buses and sharper acceleration and deacceleration), lower overall maintenance cost, and higher repair parts costs (due primarily to a lack of a secondary spare parts market). Lower overall maintenance costs are primarily due to less maintenance staff required (ADB, 2018). This will only materialize in the medium term and in cases where a large fleet is being deployed. Thus, assumptions in this area need to be critically reviewed as more data becomes available over time.

Other costs. Insurance costs only have a minor influence. Other major costs of bus operators, such as drivers, ticketing, management, and overhead costs, are the same as for fossil buses and do not influence differential costs between electric and fossil buses, as long as no additional fleet is required due to operating e-buses.

The cost of e-bus systems is expected to decrease by around 30% by 2030, driven largely by decreasing battery prices and increasing market competition. However, the e-bus ecosystem includes not just the buses, but also the charging infrastructure, grid connection, as well as bus depot upgrades to operate the new system. Total system investment costs per bus unit are thus still expected to be significantly higher than for fossil fuel units by 2030. The low OPEX, however, make e-buses increasingly attractive for private investors, even without support policies. This is becoming apparent from the increasing uptake of e-buses observed in the market.

TCOs can therefore vary widely between locations, between e-bus systems, and between assumptions made. While TCOs are important, they are only one of many considerations which will influence the purchase decision. TCOs are built on forecast savings, with medium- to long-term payback periods,

---

[23] Such as in Tianjin, where 1,350 battery electric buses of 12 meters in length have been running since 2013.

while transit authorities and transport operators have immediate needs, limited capital, and budgets. The purchase of e-buses also involves the following considerations:

High capital expenditure. The total e-bus system will require an up-front investment that is 2 to 3 times higher than purchasing fossil fuel buses.[24] This higher upfront cost may be recovered with lower OPEX (as reflected by the TCOs). For traditional bus operators, this potentially results in higher debt load, which leads to higher guarantees demanded by lenders. E-buses, due to insecure re-sale value, are not necessarily accepted by financial institutions at the same guarantee level; charging infrastructure and bus depot infrastructure are, in large part, sunk costs.[25] The larger upfront CAPEX investment is an additional financial burden to borrowing entities, and may pose risks and impact on their financial sustainability.

Low profitability of the incremental investment for e-buses. The TCO of an e-bus may be higher than for a fossil bus, but the incremental investment is only recovered over a long period and the financial internal rate of return of the incremental investment is low and potentially lower than of alternative investments, as expressed in the weighted average capital cost.

Technological risks. The risks of the new technology are not adequately reflected in the TCO. Loan payments for e-buses are well known; however, savings are based on assumptions concerning electricity usage, the future development of diesel prices, maintenance costs, and on bus performance, including bus availability rates. High up front investments of e-buses are thus a fact, while savings over the lifetime are a possibility and not a given. Risks include those related to (i) technology performance (e.g., actual electricity consumption influenced strongly by heating and cooling, which can result in operational problems as electricity consumption will influence the bus range); (ii) risks related to the life span of equipment (including bus, batteries, and charging equipment); (iii) risks related to a change of bus providers (major e-bus providers from the PRC are not common bus providers in many jurisdictions); (iv) risks related to maintenance and repair costs, including costs of spare parts; (v) risks related to bus availability rates; and (vi) operational risks due to reduced flexibility (e.g., buses cannot be used on all routes and at all times).

The core business of a bus operator is the transport of passengers, and switching technologies could pose a perceived threat to the profitability of the core business itself. This may occur, for example, if routes cannot be served identically with the e-bus option. Therefore, while TCOs may paint a picture favorable for e-buses, bus operators are unlikely to invest in such units if involved risks, uncertainties, and financial burdens are not cushioned and/or compensated.

IV. OPPORTUNITIES TO ACCELERATE E-MOBILITY IN THE REGION

Interest in EVs is gaining traction in many cities. Various governments have also established initial incentives for EVs, based primarily on tax incentives. The focus in most locations, however, is on private electric cars and, eventually, motorcycles. Cities need to establish charging infrastructure to enable greater uptake of these vehicles. However, in the short term, the largest and quickest impact

---

[24] This includes the e-bus, charging infrastructure, grid connection, and bus depot upgrade: see section 3.5. for incremental cost components.

[25] Grütter Consulting. 2021. *Benchmark Report on Commercial Electric Vehicles*. Table 6. Report produced as Annex 23 for GCF Funding Proposal of ADB.

can be achieved through electrification of commercial electric vehicles, especially buses, where TCO has achieved price parity with their fossil fuel equivalents in many cases. In terms of technology, this segment is also ripe for use with some localized upgrades and interventions; massive electrical grid upgrades are often not required. This is because the charging system can be accommodated relatively easily at bus depots or along bus routes. Replacing fossil fuel with electric buses also increases the attractiveness of public transport while having an important positive impact on air pollution. Apart from land-based modes, electric vessels for public transport are also becoming viable, as demonstrated by the vessels recently deployed in Bangkok by Energy Absolute with ADB cofinancing.

A. Electric Buses

Only a few cities or jurisdictions have explicit EV targets, although many are willing to promote EVs. Cities can most easily influence the electrification of urban public transport buses. This is also the area where the largest environmental and health impact can be achieved and where price parity is close. Cities either own and manage a public transport fleet or give concessions to route operators and can thus directly influence the usage of electric buses. However, it is important to ensure that public transport tariffs are not increased due to the purchase of e-buses, as these could erode the benefits of e-bus deployment. Financial instruments such as temporary subsidies can be applied to help operators cushion any incremental costs arising initially. This can include subsidies for charging infrastructure, concessional loans for the purchase of e-buses, or a reduction of electricity costs, just to name a few. Table 5 highlights some of the significant incentives and support systems that have been implemented to scale up e-bus deployment.

Table 5: Incentives for e-Bus Purchase

Country	Incentive
People's Republic of China	100% of incremental bus cost subsidized; chargers and grid connection up to 100% subsidized; electricity price initial 3–5 years subsidized; decreasing rates since program start in 2009
India	80%–100% of incremental bus cost subsidized in Faster Adoption and Manufacturing of (Hybrid and) Electric Vehicles (FAME)-II; chargers subsidized. FAME I 2015–2019 had 20 percentage points higher subsidy levels compared to FAME II
Germany	80% of the total incremental cost of e-buses and 40% of all other costs for charging infrastructure, grid connection, bus depot upgrades, plus 100% of training costs (for drivers or maintenance staff) and 100% of costs for the establishment of new maintenance centers subsidized.
Switzerland	80%–100% of incremental costs of buses and 100% of charging infrastructure and grid connection costs subsidized
United Kingdom	75% of incremental bus and charging infrastructure costs subsidized; under Phase I (2016–2019) 90% of incremental costs were financed
Poland	100% of incremental cost of entire e-bus system subsidized
United States	90% of incremental cost of entire e-bus system subsidized
Colombia	100% of incremental capital expenditure (CAPEX) of entire e-bus system was paid in Medellin and Phase I in Bogota. 100% of incremental total lifetime cost of e-bus system (CAPEX plus operational expenditure) subsidized Phase III in Bogota (16% incremental cost compared to fossil units)
Chile	100% of incremental cost of entire e-bus system for Phase I (200 buses) subsidized with monthly instalments for 10 years; phase II longer concession periods for e-buses compared to conventional units (+40%) and additional points in tenders

Source: Grütter Consulting. 2021. *Benchmark Report on Commercial Electric Vehicles*. Table 6. Report produced as Annex 23 for GCF Funding Proposal of ADB.

Countries thus consistently subsidized 80%–100% of the entire e-bus system incremental cost for the initial phase. However, it is interesting that countries decreased their subsidy rates significantly within a few years. The importance of significant up front investment subsidies—independent of TCOs—to kick-start deployment of e-buses is thus clear. It also shows that once a large fleet is established, subsidies can be reduced gradually and even be eliminated within 5–10 years, due to more competitive prices of e-buses and the experience of mass operation of e-buses.

Cities and governments may also choose to directly purchase e-buses and lease them to operators. ADB is structuring loans in various countries in Asia and the Pacific for the purchase of e-buses.

Some of the problems identified can be resolved with alternative business models, others with government policies. The economic and environmental benefits of e-buses are basically of a global nature (lower GHG emissions) and at city level (reduced air pollution). Incremental costs are born by the investor, while environmental benefits are public goods or externalities. This also justifies the usage of public money or financial incentives to compensate investors for risks and incremental costs when purchasing e-buses. Business models proposed for e-buses are structured around bulk purchase and splitting asset ownership and operation. Unbundling ownership and operation can also include the provision of power, chargers, and bus depots. Leasing by fleet owners can be limited to the vehicle or include maintenance and energy. Leasing can effectively reduce the barrier of up front investment for the public transport operator. Various models are being implemented, comprising different types of leasing, participating leasing entities, or components being leased. Typical delivery models that could be followed for e-bus projects include (i) public sector-led, e.g., by the municipality which purchases and owns the vehicles and leases them to operators; (ii) private sector-led, e.g., an asset company which purchases and leases the vehicles to operators; and (iii) public transport operator-led, which is the traditional model, where the public transport operators also own the vehicles.

B. Electric Taxis and Last-Mile Delivery

Another opportunity for cities is in the promotion of electric last-mile delivery vehicles and in electric taxis. While these vehicle categories are mostly owned by private operators, the city can use access restriction policies, licensing policies, charging infrastructure policies, or financial incentives to foster EV use.

However, high mileage and high driver-to-taxi ratios mean that taxis only have a limited down time. Charging electric taxis at home is thus not feasible, as home connections will not be sufficient for fast-charging the battery.[26] Therefore, taxis will need public fast-charging infrastructure capable of re-charging the taxi during driver breaks with durations up to 30 minutes. This will require 100–150 kW fast-chargers and batteries capable of receiving such charging.[27]

Currently, it is clear that public charging infrastructure is inadequate, particularly at such power levels, as it is also not targeted toward taxis, but at private passenger cars, which require much less range. Most cities have focused on regular-speed charging when traveling within urban areas, while fast charging is more applied to inter-urban sites, e.g., on highways. Hence, the charging requirements and demands of private cars and of taxis clearly do not match.

---

[26] The Nissan Leaf, with the larger battery set (62 kWh) and assuming remaining 20% state of charge, can be charged at home with an AC 6.6 kW charger at maximum. It will thus, for a full charge, need around 9 hours (even if a 22 kW charger is installed, the AC charging is limited to single phase 6.6 kW). Some models, such as the new Nissan Ariya, allow AC charging up to 11 kW; still, home charging will require 5 or more hours for full charging. Level 3 or DC fast chargers are very expensive and home grid connections will not support such chargers.

[27] Based on 2–3 charges of 20–30 minutes per 24 hours; this is also considered the new standard for fast chargers.

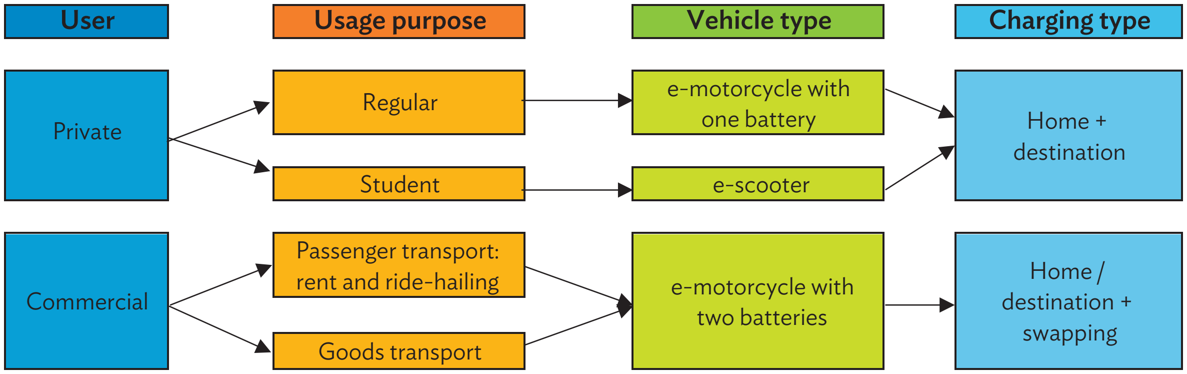
Establishing a dense network of high-powered chargers in urban areas can be costly, not just in terms of infrastructure investment, but also in terms of land requirements and grid upgrades that will be needed. Sites for taxi charging may not match well with sites used for private charging, as the latter is typically located in urban areas at malls, restaurants, and dwelling points of private residents. Taxis require fast-charging points at typical resting and waiting areas. Furthermore, taxi drivers would prefer chargers to be conveniently located (without needing to drive long distances to access it) and that are not blocked by private users. Catering to these concerns, around 50% of fast-chargers in London are dedicated to taxis (Major of London, 2019).

Therefore, to ensure its successful implementation, e-taxis need to be given priority at EV fast-charging stations, and the EV fast-charging network should be designed to ensure convenient access for taxi drivers. Often, the issue of reliance on home charging is overlooked. While home charging is more suitable for private uses, given the long driving ranges, charging of e-taxis using the same home chargers will take far too long, as capacity of home chargers is limited.

C. E-Motorcycles

Based on earlier analyses, the most promising policy to promote uptake of e-motorcyles is to restrict usage of fossil fuel motorcycles and to restrict (or even halt) issuance of registration permits for fossil fuel units. Financial incentives have proven ineffective with e-motorcycles, as fossil fuel units are very economical to purchase and maintain, with e-motorcycles having limited benefits. E-motorcycle systems can be analyzed based on user category (private or commercial) and usage (Figure 12). This results in different two-wheeler types and charging systems relative to user and usage purpose.

Figure 12: Relationships Among E-Motorcycle Users, Usage Purpose, Type, and Charging System



Source: Grütter Consulting.

Private users can be categorized into regular or standard electric two-wheeler users and students. Regular owners use their vehicle for daily trips to work, shopping, visiting friends, or other activities. Students contribute towards an important share of motorcycle users. Low-powered and low-speed e-scooters are popular among students, as they do not require a license. In practice, many students have replaced bicycles, ride-hailing services, or public transport with low-powered e-scooters. Private e-motorcycles will generally prefer home and destination charging. Battery swapping is not a necessity for private users nor a big advantage, except for long-distance rides. Charging facilities at work or school (so-called "destination chargers") are critical to reduce the range anxiety issues of private clients.

Commercial users can be categorized into ride-hailing services for passengers, rental services, and in goods transport. On average, commercial users drive 80–100 km per day. Commercial clients would therefore purchase e-motorcycles with two batteries. For commercial users, whose daily mileage is higher, battery swapping becomes advantageous as it reduces downtime needed for charging.

The batteries of e-motorcycles cannot receive a high-powered charge and therefore require a minimum charging time of 1–2 hours, which is far too long for commercial applications. In such cases, battery swapping is an ideal option for commercial users as it addresses the concern on limited range and long charging times of home and destination charging.

Box: Examples on Promoting Uptake of e-Motorcycles

Taipei,China has been subsidizing e-motorcycles since 1996. Since 2013, the subsidy level has been $240 for electric scooters and up to $1,200 for e-motorcycles, with a slight decline since 2020. Swapping-cum-charging stations are also subsidized with up to 50% of construction costs and free publicly accessible land. Battery swap sites are placed every 500 meters in urban Taipei,China. They turn up every 2–5 kilometers in rural areas. Nonfinancial incentives include exclusive parking spaces, preferential parking fees, and prohibition for two-stroke engines in certain areas. The large subsidies had a positive impact on e-motorcycles sales, but have not resulted in a paradigm shift. The market share of e-motorcycles sales grew from 3% in 2017 to 15% in 2019, but dropped back to 10% in 2020, the loss coming at the same time as subsidy levels were decreased.

In **the PRC,** without massive subsidies, electric two-wheelers dominate the market with more than 200 million units (the majority of which are deemed to be electric scooters). Nearly every major PRC city has banned gasoline motorcycles. Thus, the driver of the electric two-wheeler boom in the PRC has been the local motorcycle bans.

Viet Nam, as of 2014, had around 43 million registered motorcycles. The electric two-wheeler market peaked in 2016 and then dropped again, basically due to the frustration of users with the low quality of vehicles. The majority of units in Viet Nam are low powered e-scooters used mainly by students, again, as they do not require a license for these units and have a lower purchase cost.

In 2017, some 55,000 electric two-wheelers were sold in **India,** about 10% e-motorcycles and the rest low-powered e-scooters, which do not require a driving license or helmet, and not classified as motor vehicles under the Central Motor Vehicle Rule. The federal government's 2019 Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (FAME) policy offered a subsidy of up to $400 per electric two-wheeler. This was intended to encourage faster adoption of e-scooters and motorcycles, but only 26,000 e-motorcycles with speeds above 45 kilometers per hour were sold in 2020, while the total market sold 20 million units. E-motorcycles therefore have a very marginal market share in India and subsidies have not succeeded in changing this situation.

Source: ADB.

To date, promotion of e-motorcycles has achieved limited success in many contexts, although at first glance e-motorcycles appear to be comparable in purchase cost. This is also despite the lower operational costs as compared to fossil fuel units. India and Viet Nam have only achieved very limited sales of e-motorcycles with the market only taking up low-powered electric scooters used primarily by students (TERI, 2019). In Taipei,China, the market share of e-motorcycles has stagnated at 10% despite massive subsidies in swapping stations and vehicles. The only success case for widespread adoption of electric two-wheelers has been in the PRC, where gasoline units have been replaced with electric units due to bans imposed on gasoline motorcycles in most cities. In the absence of either high financial subsidies or regulations, for the same price point, customers will prefer to purchase gasoline motorcycles which have more power and speed than their electric equivalents. While the limited driving range and the absence of charging infrastructure is an argument, it is not the core issue with e-motorcycles. This is clearly shown for example in Taipei,China, which has established a very dense swapping network without e-motorcycles increasing their market share beyond 10%–15% and still requiring massive subsidies. This suggests that the reason could be behavioral in nature, and that is the motorcycle user's "need for speed."

The lessons concerning promotion of electric two-wheeled motorcycles are thus clear. Without government intervention, the market for electric two-wheelers in the next few years will focus on low-powered e-scooters, which do not primarily replace gasoline motorcycles, but rather bicycles and public transport. Financial incentives need to be very high to persuade customers to choose e-motorcycles. Regulations limiting the sale and usage of gasoline-powered motorcycles have been proven to be most effective in promoting uptake of electric units.

D. Electric Cars

National governments can play an important role in promoting electric passenger cars. This can be done through, for example, fiscal/tax incentives favoring electric over fossil fuel cars. In developed cities such as those in Europe, nonfiscal/tax incentives also play a role in incentivizing EVs. This includes, for example, providing city access and parking incentives for EVs. In the case of most cities in Asia and the Pacific, such nonfiscal options are expected to be limited. For example, they do not tend to have a strong parking policy nor do they restrict city access to cars.

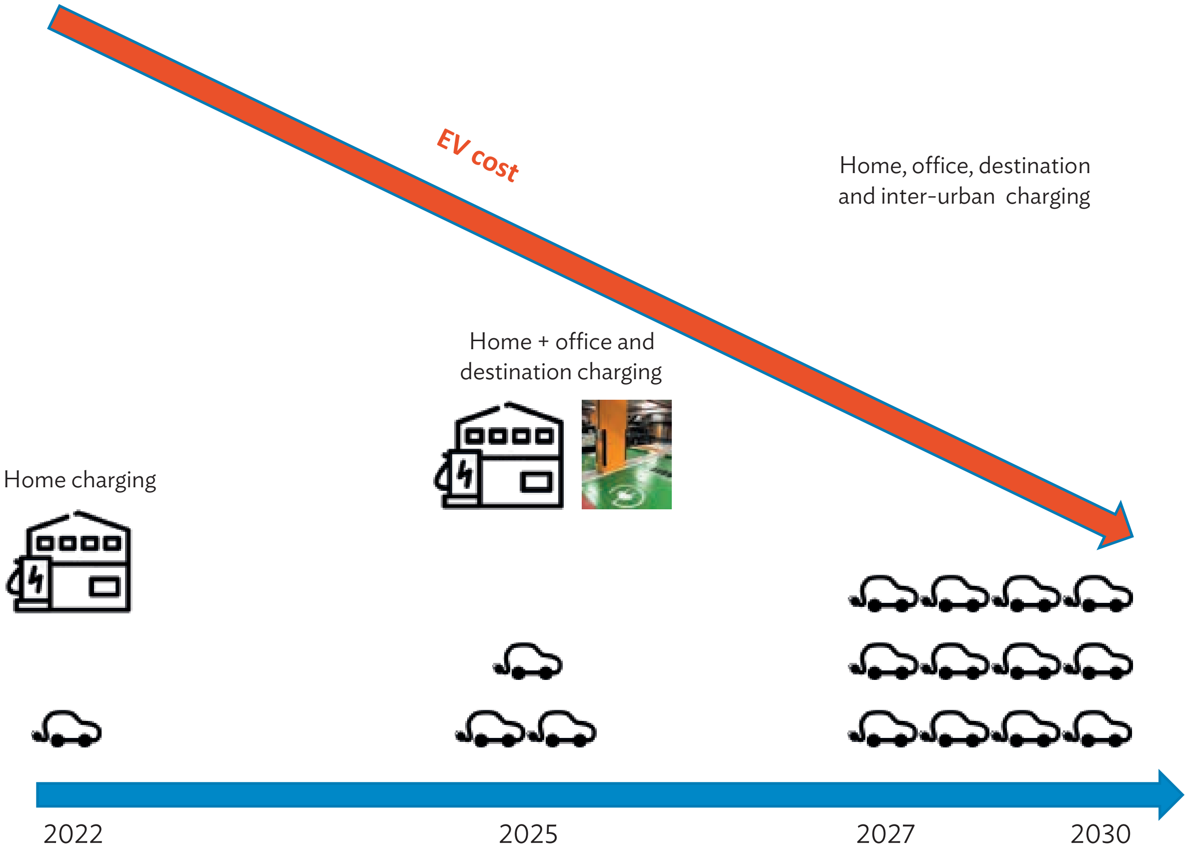
Electric car deployment can be described in three phases: (i) limited EV uptake through early adopters basically using home charging and operating in urban surroundings; (ii) increased market uptake due to the decreasing cost of EVs, with vehicles being used primarily in urban settings, with home charging blended with charging at the workplace or destination charging; and (iii) EVs become common and are cost competitive.

The speed of transition from phase 1 to phase 2 and then phase 3 depends on national (incentive) policies and the (external) market development of EVs. This development is therefore not uniform between jurisdictions. The charging infrastructure can be matched with the EV market maturation. In the first phase with early adopters, EVs often represent second vehicles and are basically used in urban areas. Home charging is the predominant method and very limited demand for other forms of charging exist. In the second phase of a transition period the local market for EVs expands. This also increases demand for public chargers. In this phase, the home charging infrastructure can be expanded with destination and work charging sites, i.e., public or semi-public intermediate power chargers. In a third, EV market phase, EVs become popular and increasing demand for away-from-home charging infrastructure exists, including demand for high-powered inter-urban fast chargers (Figure 13).

Various charging metrics are used around the world to determine the number of required public chargers:

(i) Chargers per km on highways or national roads. This is primarily used to determine the inter-urban minimum charging network. For example, Costa Rica established that a charger needs to be installed on main national roads every 80 km and on secondary national roads every 120 km.
(ii) Public chargers per square kilometer as fixed, e.g., by the State of Baden Württemberg in Germany.
(iii) Chargers per quantity of EVs, e.g., the indicative target of 1 public charger per 10 EVs was set by the European Union Alternative Fuel Infrastructure Directive.

Figure 13: Phases of Electric Vehicle Market Maturation and Related Charging Infrastructure



EV = electric vehicle.

Source: Grütter Consulting.

E. Electric Vessels

Electric vessels are of increasing interest, especially small units. A large number of vessels are used across Asia for river and short-haul marine transport, as well as fishing boats. Boat size ranges from small units for 6–8 passengers to larger ferries for up to 300 passengers. Fossil fuel-powered boats not only create high emissions, water pollution, and fuel usage, but also a lot of noise—a problem not only for the ship operator, but also for the public in general and the environment, especially in sensitive areas. Electric vessels are increasingly entering the market, i.e., technical solutions are becoming viable. ADB has for this reason launched a pilot project on electric vessels in Thailand, with outreach in other countries, and is assessing loans for larger electric ferries.

V. WAY FORWARD

It is hoped that this publication can help decision makers envisage their future of mobility by presenting the environmental and economic implications of e-mobility for their cities.

The transition to e-mobility from the internal combustion engine vehicle is gathering momentum globally. Many central and local governments are declaring low or zero-emission vehicle policies. Many have implemented electric vehicle strategies and are planning to develop the electric vehicle industry. Automobile companies are implementing or planning production of non-fossil fuel vehicles, consumers are responding as EV models become available and economical, and international institutions are allocating substantial funding to e-mobility. This momentum is gathering pace amid climate change and recognition of e-mobility as the most direct, effective, and economic option for reducing GHG emissions in transport.

Most cities will have an interest in e-buses and EVs that promise large reductions in emissions. Yet, many may not be aware of the suitability of e-bus technologies for different local contexts, including hybrid trolleybuses, slow and fast-charge battery electric buses, and other charged electric bus options. Different technological options also exist for charging systems, which have different impact and demands from local grids. It is therefore critical that technical, operational, and financial aspects of e-bus systems need to be considered and optimized based on each project's specific needs.

Last-mile delivery vehicles is another area of growing importance, particularly as e-commerce becomes a growing trend. Such modes tend to have significant private sector interest, particularly private companies active in logistics and interested in reducing their carbon footprints. Last-mile connectivity services can use e-motorcycles, e-pedicabs, electric bikes, and e-scooters. City services such as vehicles deployed for utility services—such as waste collection and cleaning—can also be electrified.

As technology advances, a new era of e-mobility is emerging and shifting away from over a century of internal combustion technology. Clearly, this transition is positive for the environment, but it is also disruptive in many ways. It disrupts fossil fuel consumption and traditional automobile manufacturing and services. Such traditional business models and jobs need to evolve and transition to a future that shall "Leave No One Behind," which is the central promise of the 2030 Agenda for Sustainable Development and its Sustainable Development Goals.

On the other hand, the transition will also boost demand for renewable energy, new supply chains for producing electric vehicles, electric charging, and for financing and business models. A well-orchestrated transition can minimize the economic and social cost of this transition. With the creation of this new economy and new jobs, it will also be important to reskill individuals from the old economy to ensure a just transition.

REFERENCES

Asian Development Bank. 2018. *Low-Carbon Buses in the People's Republic of China.* Manila.

Broadbent G. H. et.al. 2019. An Analysis of Consumer Incentives in Support of Electric Vehicle Uptake: An Australian Case Study, *World Electric Vehicle Journal 2019.* 10 (11).

Dow J. 2019. Survey says consumers avoid electric cars due to three myths: range, price, charging, https://electrek.co/2019/08/20/survey-consumers-avoid-evs-myths-range-price-charging/

Fox-Penner P. et.al. eds. 2019. Melting the Ice

Gaton B. 2019. What do consumers need to make the switch to an electric car? *The Driven.* 23 April. https://thedriven.io/2019/04/23/what-do-consumers-need-to-make-the-switch-to-an-electric-car/

Grütter Consulting. 2020a. *Last-Mile Delivery Services and Potential Impact of their Electrification in Viet Nam.* Report prepared for ADB.

———. 2020b. *Report Market Survey EVs Kyrgyzstan.* Report prepared for ADB.

———. 2021. *E-motorcycles Charging Infrastructure Roadmap for Indonesia.* Report prepared for ADB.

Hertzke P. et.al. 2016. Electric vehicle market. https://www.mckinsey.com/industries/automotive-and-assembly/our-insights/dynamics-in-the-global-electric-vehicle-market

International Council on Clean Transportation. 2020. *Vision 2050: A strategy to decarbonize the global transport sector by mid-century.*

International Energy Agency. 2021. *Global EV Outlook 2021.*

———. 2021a. *Net Zero by 2050.*

———. 2022. *Global EV Outlook 2022.*

Intergovernmental Panel on Climate Change. 2022. *Climate Change 2022: WG III contribution to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.*

Lebeu K. et.al. 2013. Consumer attitudes towards battery electric vehicles: A large-scale survey, *International Journal of Electric and Hybrid Vehicles.* 5(1): 28–41.

Lorentzen E. et.al. 2017. Charging infrastructure experiences in Norway – the worlds most advanced EV market; in EVS30 Symposium

Major of London. 2019. *London electric vehicle infrastructure delivery plan.*

McKinsey Sustainable Mobility Initiative. 2016. Electrified Vehicle Consumer Surveys

UBS Evidence Lab. 2017. UBS Evidence Lab Electric Car teardown – Disruption Ahead

UK Department for Transport. 2016. Public attitudes towards electric vehicles: 2016 report (revised)

The Energy and Resources Institute. 2019. Faster Adoption of Electric Vehicles in India: Perspective of Consumers and Industry.

United Nations Framework Convention on Climate Change. 2021. *Climate Action Pathway Transport.*

Accelerating Low-Carbon Pathways through E-Mobility

Perspectives from Developing Economies

With the transport sector being one of the main contributors to greenhouse gas emissions, and with critical concerns over climate change and air pollution, transitioning away from fossil fuels has become increasingly pressing. Electric vehicles (EVs) have emerged as an important lever to decarbonize transport. As more efficient and sustainable modes of mobility are seen in the EV industry, this study explores the current trends and technological developments relevant to the uptake of EVs in Asia and the Pacific. The paper also discusses opportunities to further support the Asian Development Bank's regional members in transitioning toward low-carbon pathways via the electrification of transport.

About the Asian Development Bank

ADB is committed to achieving a prosperous, inclusive, resilient, and sustainable Asia and the Pacific, while sustaining its efforts to eradicate extreme poverty. Established in 1966, it is owned by 68 members —49 from the region. Its main instruments for helping its developing member countries are policy dialogue, loans, equity investments, guarantees, grants, and technical assistance.

ASIAN DEVELOPMENT BANK
6 ADB Avenue, Mandaluyong City
1550 Metro Manila, Philippines
www.adb.org