Electric Two and Three Wheelers

Global Emerging Market Overview

UNEP Global Electric
Mobility Programme

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This document is a deliverable under the Global Working Group on Electric Two and Three Wheelers, funded by the Global Environmental Facility (GEF) and part of the United Nations Environment Programme's (UNEP) Global Electric Mobility Programme. Together with partners, UNEP's Global Electric Mobility Program is supporting the shift to electric vehicles (including two and three-wheelers, cars and buses and freight vehicles) in over 60 low and middle-income countries (LMICs) around the world. Under this program, more than US$ 130 million in grants are used to develop national e-mobility strategies and roadmaps; implement e-mobility policy frameworks; explore business models and financing schemes and build local capacity through training programs and EV pilots. To ensure the sustainability of electric mobility, the program is explicitly targeting the integration of renewable power for EV charging and has started to work on used electric vehicles, battery end-of-life and circularity in LMICs. Integration of electric mobility with public mass transport and active mobility will be key to reduce growth of energy use, greenhouse gas emissions and air pollution in LMICs.

Website: https://www.unep.org/explore-topics/transport/what-we-do/global-electric-mobility-programme

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Executive Summary

There are an estimated 570 million two and three-wheelers on the road in Africa, Asia and Latin America. As of today, most of these two and three-wheelers are still using internal combustion engines (ICE) and petroleum fuels. They are consuming between 15% and 20% of all liquid petroleum fuels used for transport in non-OECD countries every year.[i] Shifting these vehicles to electric has the potential to mitigate between 500 and 600 MtCO2eq every year[ii]. With rapidly growing two and three-wheeler markets especially in Africa and Latin America, this mitigation potential continues to grow.

This report provides an overview of electric two and three-wheelers in terms of the variety of vehicle types, their technical specifications and respective charging technologies in three regions: Africa, Asia and Latin America. It proposes a classification of vehicles depending on their use cases (i.e. personal use or passenger or freight transport), the number of wheels, frame structures, and how common they are in each region. Based on this classification, the authors collected information on eight hundred electric two and three-wheeler (2&3W) models and analyzed the predominance of different characteristics, including motor power, motor type, charging technologies, use cases, battery types, battery capacity, physical size, and retail price.

Following the global overview, the report provides insights for each region in terms of electric two- and three-wheeler presence, vehicle usage, charging infrastructure, industry structure, and market evolution. It also provides insights in terms of the obstacles to large-scale deployment of these vehicles and their supporting infrastructure including charging stations and swappable battery networks.

While there is great variety in models, the domination of manufacturing in Asia and common use cases in different world regions has led to similarities across the markets. Low manufacturing costs and specialization in lithium-ion battery production has given an edge to export markets in China especially, though manufacturing capacity is now increasing rapidly in Vietnam and Indonesia. Models originating from China are often rebranded, slightly altered and retailed across regions.

There are an estimated 27 million 2&3W in Africa as of 2020, corresponding to an estimated annual market value of US$ 4.8 billion – of which less than 1% are electric. Two-wheelers encompass the majority of these vehicles. A belt of motorcycle-taxis stretches between Dar es Salaam, Tanzania to the outskirts of Dakar, Senegal. North Africa and West Africa have many more users of two-wheelers, primarily scooters but also motorcycles, for

[i] Based on IEA 2022, World Energy Balances (database) and own calculations

[ii] Based on 2020 average grid emission factors for Africa, Latin America and Asia from EMBER (https://ember-climate.org/data/data-tools/data-explorer/). This value does not include GHG emissions from battery production.

individual mobility needs. Passenger three-wheelers are primarily used on the coast of East Africa and more scattered across West Africa, while cargo three-wheelers can be found working as logistic intermediaries in dense urban areas, as well as in rural areas for transport of agricultural products all over the continent. The providers of electric two and three-wheeler have chosen to either focus on simple retail of Asian products, particularly lead-acid scooters or experimental forms of three-wheelers such as trimotos; or to build turnkey solutions mainly using battery swapping solutions. In the case of the latter, young startups – often with a mix of venture capital and grant funding – have adapted vehicles and built battery swapping infrastructure to address the intensive daily usage faced by current ICE models. Countries with strong startup ecosystems such as Kenya have been breeding grounds for these companies, while retailers have quietly entered less well-advertised markets such as Senegal, Zimbabwe, and Tanzania. As ICE 2&3W remain cheaper to purchase than electric 2&3W in most cases, and upfront investment remains the key decision factor despite much lower total cost of ownership, there is still a need for financial incentives to establish an equal playing field. While large scale EV subsidy schemes as provided in European and some Asian markets are most often not an option for African countries, import and value added tax exemptions have been a key tool to lower the cost of these vehicles.

In Asia, the number of 2&3W is estimated around 490 million as of 2019, representing an annual market value of US$ 126 billion, and of which approximately 7% were electric. Asia is generally recognized as the most 2&3W dominant region and the most advanced in the transition to electric 2&3Ws. The transition began over a decade ago, when electric two-wheelers, which were often pedal assisted, were financially promoted in big cities in China as a countermeasure against air pollution. This set the foundation for the industry's local, regional, and even global growth. Over time, the industry has evolved with improved quality, capacity and particularly affordability. The Taiwanese market for electric 2&3Ws has grown significantly due to demand to travel through congested traffic and governmental support resulting in an innovative and widespread battery swapping mechanism that has become a global flagbearer. Increasing use of electric two and three-wheelers in Vietnam and India respectively, followed by a growing market in Thailand, the Philippines and Indonesia, means that Asia is likely to continue dominating the global market for electric 2&3Ws for the foreseeable future. While electric three-wheelers have limited market share in China, Thailand, and the Philippines, lead-acid varieties are very popular in India. With strong government policy and financial incentive to move to lithium-ion models, India could spearhead the electric three-wheelers market with production and export to South Asia, Southeast Asia, and markets further afield.

In Latin America, available data suggests there were an estimated 50 to 60 million 2&3W as of 2022, with an estimated annual market value of about US$ 16 billion, of which less than 1% were electric. The electric two and three-wheeler industry follows trends in Asia in terms of typologies and deployment since most vehicles come from either China or India. These electric 2&3Ws are used for similar reasons as their ICE versions: ease of navigating in dense traffic, a lack of adequate public transport, better access to job opportunities, and direct income generation through provision of informal public transport services. However, there are limitations for large-scale adoption of electric 2&3 wheelers including higher vehicle prices, lack of good charging and swapping networks, the need for better road infrastructure, range anxiety, uncertainty over regulations and a lack of sufficient financial incentives. The region has several industry associations that promote electric vehicles (EVs), though not specifically for electric two and three-wheelers. The fact that industry leaders are the same as for ICE vehicles makes progress slower since the latter still generate greater profits than their electric counterparts. The lack of disaggregated data on two and three-wheeler sales and fleet size make it difficult to estimate the size of the E2&3W market in the region.

Across all regions one similarity is obvious: the success of electric two and three-wheelers will depend on the actual materialization of economic benefits to those who use them – for daily commute, for commercial passenger transport, or for the delivery of goods. The potential is huge: while fueling an ICE motorcycle to drive 100 kilometers with unsubsidized petrol costs about US$ 4.50[iii], the same 100 kilometers using an electric motorcycle now costs about US$ 0.80 to 3 in electricity, depending on whether the vehicle is charged at home or "refueled" using a public charging or a swapping station. The cost difference – between US$ 1.5 and 3.7, together with the frequency at which it occurs (i.e. on a daily basis for a motorcycle taxi or over the course of several days for individual use), will determine the time it needs to cover for the higher upfront price of the vehicle. In case of intensive use, fuel cost savings alone can make up the price difference in under 12 months' time. In most high mileage use cases the business case is already there.

All it needs now is to invest capital at scale while developing the enabling policy and regulatory framework to ensure that the transition to electric 2&3Ws is safe, just and environmentally sustainable.

This report is a product of the Global Electric Two and Three Wheeler Working Group under UNEP's Global Electric Mobility Program.

[iii] Assuming a petrol price of US$ 1.50 per liter and price of electricity of US$ 20ct / kWh for home charging, and vehicle efficiency of 33.3 km per liter for an ICE motorcycle and 25 km per kWh for an electric motorcycle.

Introduction

Methodology

This report presents an effort to understand the characteristics, uptake and overall market of electric two- and three- wheelers in Africa, Asia and Latin America. The study includes the collection of data on electric two- and three-wheeler models in the three regions, a review of the status of the market, projections for region-wide growth until 2040, and recommendations to accelerate the transition towards electric two- and three-wheeler in low- and middle-income countries (LMICs).

The process for developing this report began with the compilation of existing electric two- and three-wheeler models and their charging technology in each of the target regions through interviews with distributors, visits in the field, and internet searches. Details were collected on more than **forty data points** (listed in the appendix), including but not limited to motor power, battery capacity, battery chemistry, certified range, top speed, charger capacity, and physical size. Companies' willingness to share specific data varied widely, posing a challenge and requiring the team to critically assess the data provided. The collected vehicle model and charging technology data was compiled in a database and an online dashboard.

Next, to complement the database, interviews were held with key stakeholders in each region to gain a better understanding of the markets. Electric two- and three-wheeler retailers, manufacturers, and investors were all interviewed, as well as regional and association bodies involved in the e-mobility sector. Interviews touched on market evolution and the general characteristics of these models, their current and future uptake, as well as recommendations for policy and industry.

Finally, the project team used the gathered information to develop this report by meeting periodically to review results, analyze findings, and discuss recommendations.

Projections methodology

To project the growth of electric and ICE 2&3W in each region, we used the UNEP E-Mobility Calculator. The UNEP E-Mobility Calculator (EMC) uses the following set of data to project EV and ICE 2&3W stock and sales:

- Historic regional statistics on a) electric 2&3W sales and stock; b) ICE 2&3W sales and stock.
- Gross Domestic Product (GDP) on a regional level.
- Population of the region.

The Calculator also uses assumptions about the average lifespan of vehicles and 2&3W purchase elasticity, assuming that the growth of the 2&3W stock slows after populations reach milestones of $10,000, $20,000, and $30,000 GDP per capita respectively. This elasticity was assumed to remain the same across all regions, but vehicle lifespans vary and are clarified in each section.

Database

The Global E2&3W Database, linked here, includes over 800 models of vehicles fitting our definition (below). It is filterable by over forty variables with information provided by retailers and manufacturers. It is also possible to download the entirety of the database. The dashboard, linked here, allows users to visualize data from the database.

Definitions

This report focuses on sit-down, motor-powered vehicles, excluding stand-up scooters (also known as kick scooters) and pedal-assist e-bicycles. Often described as micromobility, stand-up scooters and e-bicycles have been a major part of the story of the expansion of electric two-wheeled vehicles, particularly in the Global North and middle-income economies like China. The main differences between micromobility and two- and three-wheelers is that the former are smaller, lighter, and generally have lower emissions than the latter on a vehicle-kilometer basis[iv]. These vehicles tend to be either for personal use or for deliveries, but only very rarely for commercial passenger trips with an operator. They are also used in short-term rental programs and in shared fleet systems in many cities and have gained a negative reputation for their disruptive nature, as they are often spread all over sidewalks, blocking pedestrian access. In the case of stand-up scooters, they also have questionable environmental impacts as they have short lifespans, and users have often transitioned from walking trips to electric scooters.[1]

For the purpose of this report, electric two-wheelers and electric three-wheelers (commonly abbreviated as E2&3W, or electric 2&3W) are electric vehicles (EVs) with either two or three wheels, designed for personal mobility, transport of passengers or goods, and propelled by electric motor(s) and lithium-ion batteries exclusively. This means that the following vehicles are excluded from the database and not the focus of this report:

- Pedal-assist electric bicycles and electric kick scooters. While these are a fundamental part of mobility, the typical uses of these vehicles are significantly different from larger electric two- and three- wheelers.
- All lead-acid battery based electric vehicles. These are present in all three regions, but there is a general transition away from these battery chemistries due to their inefficiency and environmental impacts.

[iv] To use some of the standard definitions of micromobility (ITDP's definition and that of SAE), those vehicles are: human-powered or (partially or totally) electric; privately owned or shared; have a curb weight ≤ 500 lb (227 kg), have a top speed ≤ 30 mph (48 km/h).

Global market overview

ICE 2&3W Evolution

Electric two- and three-wheelers are primarily built to replace the pre-existing ICE 2&3W market, and therefore it is helpful to understand the current ICE vehicle market and its segmentation. ICE vehicles are typically classified by their engine size in cubic centimeters (cc). However, each market has slightly different cutoff points for classifying vehicle sizes. In European markets, it is common to set a 150 cc engine as the cutoff for small engine two-wheelers, while in Latin America the cutoff is usually at 125 cc and Asia is somewhere in between 125-150 cc, both in terms of market classification and taxation levels. In African markets, the East African Community (EAC) and the Economic Community of West African States (ECOWAS) both set the first tariff class at 0-50 cc and the second up to 250 cc.[2]

Amongst ICE two- and three-wheelers, there has been an evolution from highly polluting and less efficient two-stroke engines to four-stroke engines. Two-stroke engines are lighter and cheaper at sale, but burn petrol less efficiently, releasing more harmful PM2.5 and black carbon. Bans in cities in India have been proven to reduce the presence of these air pollutants,[3] but have been difficult to pass in countries like Kenya, where they have been listed to be phased out but with little definitive plan.[4]

In some markets - particularly in Asia and countries with significant natural gas reserves such as Tanzania - there have been concerted efforts to encourage three-wheelers to **use compressed natural gas (CNG), liquified petroleum gas (LPG), or both**. CNG and LPG are both recognized as having lower life cycle CO2 emissions than petrol engines, though only by around 10-30%.[5] However, they require accommodating infrastructures and have lower densities than petrol, creating inconvenience for drivers and obstacles to widespread adoption.

Emissions standards on their own can drive up the price of vehicles by requiring more expensive parts or more intensively maintained parts. In India, for example, the requirement of fuel injection systems instead of carburetors under Bharat Stage 6 emissions standards drove up the price of vehicles by around $50-100.[6] Low-income markets without emissions standards can use lower-cost two- and three-wheelers - but apart from the obvious negative impacts on local air quality, this also means that they remain below the cost of electric vehicles. Introducing emissions standards would thus force ICE two- and three-wheelers to compete with electric vehicles more directly on price point.

On a positive note, the affordability of two- and three-wheelers has given a boost to mobility and economic development of many low- and middle-income countries, reducing travel times at costs much cheaper than personal cars.

There are three primary use cases for two and three wheelers: personal use, commercial passenger transportation, and commercial deliveries. Use case is a reasonable measure of vehicle types within regions, but is complicated when comparing across the globe, as standards of performance can be subjective and there may be different expectations for loadbearing capabilities. While there are also sport vehicles, particularly motorcycles for recreational use, this report is interested primarily in personal and commercial uses.

In the two- and three-wheeler category, the smaller engine models are mainly listed as mopeds or scooters, and larger engine two-wheelers are listed as motorcycles. The Boxer Bajaj, for example, is a cruiser motorcycle with 100, 125, and 150 cc models, which vary in popularity – the 100 & 125 cc models are very common in Uganda, while 150 cc models have become more common in Kenya, though they are both used primarily as motorcycle-taxis and carry similar loads.

Scooters

Figure 1. A classic Vespa ICE scooter in Tangiers, Morocco. Photo credit: Tom Courtright

Scooters are defined in this report as two-wheelers with a fully step-through frame with floorboards for feet placement. Common brands include Vespa, Piaggio, Haojue, Yamaha, and Honda[v]. ICE scooters can be anywhere from 50-300 cc engines (roughly 1.5-10 kW) and usually have automatic transmissions. Vehicle chassis have not changed significantly since the 1960s. They are most common as personal transportation in East and Southern Asia, Latin America, and in parts of West and North Africa. Scooters are also used for delivery trips, often with a carrier box attached. In many Asian markets, they are also used to carry passengers as a commercial service.

Motorcycles

Figure 2. A typical ICE motorcycle in Kampala, Uganda. Photo credit: Katumba Badru / Lubyanza.

ICE motorcycles can be broken down into several categories, but for the sake of this report the key categories are cruiser motorcycles, sportbikes, and underbone motorcycles. Cruiser motorcycles are the most common model, particularly in Africa; they have a fuel tank in front of the driver, seating for the driver and passenger, and typically also have a metal handle or rig in the far back for attaching items for delivery or a cargo container. Sportbikes, on the other hand, are usually higher-powered and for use in leisure activities with comfortable seating for only the driver, while

[v] In certain cases, the term "Vespa" is used as a stand-in for all scooters.

underbone motorcycles are a lower-power variety that resemble something of a hybrid scooter / motorcycle.

Over the past 30 years, ICE motorcycles have become common across Africa, Latin America and Asia, but distribution remains highly unequal and they are still a rare sighting in countries such as Botswana, Chile, and Bhutan. In Latin America, adoption has been higher in areas of warmer weather.[7] In Africa, adoption is defined by the main use case of commercial motorcycle-taxi services, which have spread organically from multiple origin points – particularly in Uganda and Nigeria – and have been more quickly adopted in high-density and low-income countries.[8] In rural areas they are appreciated for their robustness and flexibility, as they are able to traverse heavily potholed streets, steep mountain paths, and muddy roads that are inaccessible to four-wheeled vehicles. In urban areas they have the upper hand in congested areas, where they are the only motorized transport mode that can consistently navigate through traffic jams and get passengers to their destination on time. They are also used as delivery vehicles, including app-based deliveries in urban settings and shop restocking in rural areas. A more niche use case that will not be explored in-depth in this report is the usage of higher-powered motorcycles for leisure or personal transport by higher-income consumers. In general, however, they are a vehicle which allows their owners and users to have greater access to jobs and to other services, and in Latin America, Asia and Africa are a form of employment themselves - as motorcycle-taxis.[9]

Underbone motorcycles fill the specifications gap between scooters and motorcycles. The KTM Power K and the Haojue Lucky, for example, are underbone models widely used for both personal and commercial passenger transport in West African markets, and both have a 110 cc engine for their standard model with the possibility of a 125 cc engine. In Southeast Asian markets like Indonesia and Thailand they are widely used for both personal mobility and commercial passenger transport. Despite the popularity of ICE underbones – the Honda Cub is the highest-selling vehicle of all time - there were less than 10 electric underbone models uncovered in this survey of the industry, and as a result they were labelled as motorcycles as they have overlapping engine sizes and use cases.[10]

Box 1. A note on vehicle typologies

While attempting to categorize vehicles across the Global South - that is, across **85%** of the world's population - we found that the typology related to two- and three-wheeled vehicles is not globally harmonized, and that terminology can vary depend on factors such as usage, form factor, or engine power. The differences between mopeds and scooters in many English-speaking countries, for example, is not necessarily understood by laypeople, and sometimes brand names like Vespa are used as stand-ins for vehicle types.

There are models which challenge the assumptions and descriptions set forth in this report: for example, contrary to general trends and understanding of the market, there are the occasional high-powered scooters with motors over 3 kW, and low-powered motorcycles with 1 kW motors.

Regardless, these are mostly outliers and there is a need to clarify terminology for the sake of comparison. We have focused more on vehicle form factor than specifications, as in many cases form factor can play a larger role in defining use case. We clarify vehicle types in this report in Table 1.

Cargo three-wheelers

Figure 3. An ICE cargo three-wheeler, with open truckbed, in Bogota, Colombia. Credit: Carlos Felipe Pardo.

For ICE three-wheelers, there are two key types: cargo three-wheelers and passenger three-wheelers. Cargo three-wheelers take on a variety of appearances, but all have one wheel in the front and two in the back and are used primarily to carry goods. They usually have small open truck beds or encased cargo boxes in the back. They can have closed or open cabins and can share much of their front chassis with a regular motorcycle. They can have singular driver seating or bench seating, and passengers can also be carried in the truck bed – though this is often illegal.

Cargo three-wheelers go by many names, including guta (Tanzania), torito (Chile), or cargo tuktuk (general). Cargo three-wheelers are often used to move intermediary goods such as market products or construction materials downtown or moving goods from distribution centers to retail outlets. Enclosed cargo box three-wheelers are often owned by fleet owners and specific companies moving company goods, as compared to truck bed three-wheelers which are often for-hire vehicles.

Passenger Three-Wheelers

Passenger three-wheelers generally have covering for passenger benches carrying three to six passengers (though more may climb aboard, regardless of local regulations). Benches can face one another front to back, or side to side, and can even be placed in cargo truck bed three-wheelers to convert them to passenger tuktuks. Older designs evolved from human- and horse-drawn buggies or rickshaws that were more exposed, but these have been slowly phasing out in many regions.

Passenger tuktuks serve multiple purposes. They can provide door-to-door service similar to motorcycle-taxis or carry multiple passengers on arterial routes, picking up and dropping off in the same manner as a minibus but with more potential for route deviation for specific passengers. In contexts such as Tanzania where there are motorcycle-taxis, passenger tuktuks and minibuses, tuktuks play an intermediary role and can compete with motorcycle-taxis on price and minibuses on convenience.

Figure 4. Tuktuk in Moshi, Tanzania. Photo credit: Tom Courtright.

Passenger three-wheelers are often known as tuktuks or auto-rickshaws, though they have a multiplicity of names, including cocotaxi (Cuba), bicitaxi (several Latin American countries), bajaji (Tanzania), or sam-lor (Thailand). Throughout this report, the terms three-wheeler and tuktuk will be used interchangeably for both cargo and passenger vehicles. Thus, a combination of physical appearance, motor power, and use case was used to classify the electric three-wheeler models found across these markets.

Table 1. Table of ICE vehicle typologies. Own elaboration.

Wheels	2W	2W	2W	2W	3W	3W	3W
Vehicle Type	**Scooter**	*Subtype: Moped*	*Subtype: Underbone*	**Motorcycle**	**Passenger tuktuk**	**Cargo tuktuk**	*Subtype: Cargo box tuktuk*
Common brands	Honda, Vespa, Yamaha	Honda, Piaggio	KTM, Honda	Bajaj, TVS, Hero, Haojue, Yamaha	TVS, Bajaj, Piaggio, Mahindra	Piaggio, KingLion, Dayun	Mahindra, Piaggio
Personal use	**Personal Use**				**Very limited personal use**		
Passenger transport	**Very Limited Passenger Transport**		**Passenger Transport**			**Very Limited Passenger Transport**	
Delivery use	**Delivery Use**				**Very Limited Delivery Use**	**Delivery Use**	
Geography	West Africa, most of Asia	West Africa, most of Asia	West Africa, Southeast Asia	Most of Africa, Latin America	Coastal East Africa, Northern littoral West Africa, South and Southeast Asia, Andean Latin America	All regions	All regions
Urban / Rural	Primarily urban	Primarily urban	Urban & rural	Urban & rural	Urban & rural	Urban & rural	Primarily urban
Description	Step through frame with a medium engine (50-250 cc)	Step through frame with a smaller engine size (~50 cc). Similar frame to Scooter, often smaller overall.	Semi-step through frame with a small engine (49-150 cc)	Medium engine (100-250 cc). No step through frame.	Typically, a 3+1 seater, less commonly, a 6+1 seater.	A tuktuk with a basic open truck bed	A tuktuk inclusive of a large cargo box

Electric 2&3W Evolution

Electric two- and three-wheeler models designed to replace their ICE predecessors in Global South markets have often been lower-powered than their ICE equivalents, as Asian manufacturers have instead focused on affordability and fit for low-speed, low-weight urban uses. Since most customers expect similar performance at a similar price when switching over, the introduction of electric two- and three-wheelers has been slow.

The opportunity to play with form factors has also led to the introduction of trimotos, which are three-wheeled, open-air, single-passenger vehicles. Trimotos are typically personal use vehicles that provide more balance than two wheelers and can have either two wheels in front or in the back. In some cases, they have also been used as a means of transportation by people with disabilities. Overall, however, they are quite rare in almost all markets.

Electric motorcycles typically have the highest nominal motor power of all e-two-wheelers as they are the workhorse of rural and urban Africa as commercial passenger and cargo transport.[vi] Personal scooters, on the other hand, are often the first choice of urbanites in rapidly developing, dense cities, particularly in Asia, and low-powered vehicles are sufficient for this use case.

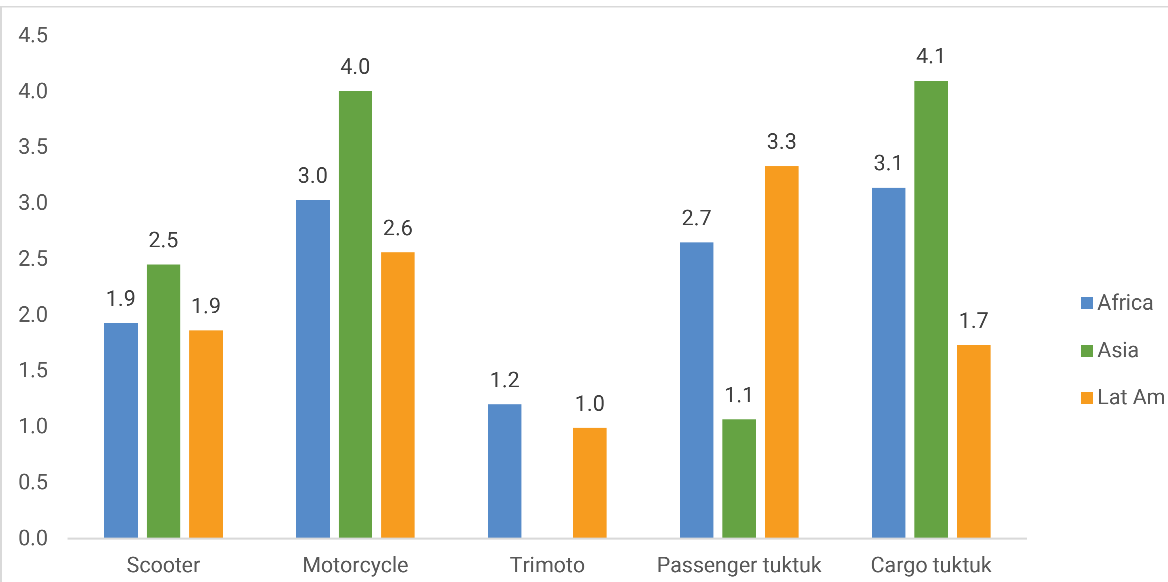


Figure 5. Motor power by region & vehicle type

In India three-wheelers are known as rickshaws and have a longstanding role in cities, and they have been some of the first vehicles to electrify, though E3W are split into two vehicle classes. E-rickshaws are differentiated from electric autorickshaws by speed and motor capacity, as e-rickshaws maximum net power is capped at 2 kW and speed at 25 kmph.[11] E-rickshaws are therefore primarily using lower-cost lead-acid batteries, while electric autorickshaws typically use higher-performance lithium-ion batteries. E-rickshaws, which have seen higher initial sales due to their low costs, are used mostly for commercial

[vi] Nominal power is discussed in full in the text box on terminology.

passenger transport, while electric autorickshaws are used for both passenger transport and delivery.[vii] Electric delivery autorickshaws have seen significant demand from last-mile delivery companies looking to decarbonize their logistics such as Flipkart and Amazon.[12] Dropping battery costs, topographically difficult cities and more intensive usage have also led to increasing numbers of electric autorickshaws with motors rated at a nominal 5 kW or more.

Personal Use

Scooters and mopeds

Figure 6. The Grab / KYMCO electric scooter. Credit: Tom Courtright.

Figure 7. The eWaka Beba electric moped in Nairobi, Kenya. Photo credit: eWaka Mobility Ltd.

Often used in flatter topography, electric scooters have an average power of 2.2 kW. As they are mainly built for personal commutes, the average electric scooter model has a claimed range of 82 km with a 2.2 kWh battery pack, but their actual range varies from 30 km to 200 km.

Mopeds, which have a more stripped-down frame, are less common than scooters, and are in the scooter category for the purposes of this report. There have been several electric moped models introduced to African, Asia and Latin American markets, primarily off-the-shelf Chinese imports with lead-acid batteries. Those with lead-acid batteries remained outside the scope of this study.

[vii] In India, vehicles for passenger carriage and goods carriage are slotted under the L5M and L5N vehicle categories respectively.

Box 2. Lead Acid batteries

The rise of electric two- and three-wheelers in Asia has been partly driven by low-cost, low-quality lead-acid batteries. Estimates of their market share in the e-rickshaw (3W) industry in India range from 55% to 98%, while an expert at a top 5 motorcycle manufacturer estimated over 70% of the two-wheeler market in Asia was using lead-acid batteries.

Lead-acid batteries' primary advantages are their relative upfront affordability, costing less than half the price of lithium-ion batteries. They also have a strong recycling industry for their post-use life, though the recycling process itself is often artisanal and damaging for the environment and human health. Thus, lead-acid batteries have had significant sales in low to middle income economies in Asia where upfront purchase of vehicles is the norm, and where lithium-ion versions are less competitive. More recently, they are also entering African markets. In Tanzania, there are now estimated to be over 10,000 lead-acid scooters on the road despite no formal government support or publicized investments, while similar models are increasingly available in Senegal and Zimbabwe.

However, lead-acid batteries have less usable capacity, 3-7 times lower volumetric and weight specific energy density, slower charging, and shorter lifespans than lithium ion. These feed into higher recycling needs and environmental impacts. They can only be safely and consistently discharged around 50% compared to around 90% for lithium-ion batteries. Most damningly, lead-acid battery recycling in Bangladesh has been linked to the country having one of the highest childhood blood lead levels globally.

Lead-acid batteries have not faced restrictive regulatory action in most major economies, with governments instead favoring lithium ion through incentives. The subsidies for EVs in India under the FAME-I framework, for example, initially provided subsidies regardless of battery chemistry. However, FAME II, which came in 2018, only provides subsidies to advanced battery chemistries - excluding lead-acid batteries.,

Ultimately, lithium-ion and other advanced chemistries such as sodium-ion will likely need innovative financing mechanisms to lower costs and break through to the lower income end of the market.

Commercial Passenger Use

Motorcycles

Figure 8. An electric motorcycle, manufactured by TailG. Photo credit: Tom Courtright.

Globally, the most common motorcycle subtype is cruiser motorcycles, which are built for comfort and regular use and have engines up to 150 cc or 5 kW nominal rated motors (see Box 3 on terminology for further discussion). Higher-powered sportbikes are built for speed and leisure and are targeted by certain manufacturers for their higher profit margins. They are mainly sold in the Global North and have only a niche market in the regions addressed in this report. Their electric versions follow the same overall setup, and there is very little variation across regions.[viii]

Electric motor types (hub and mid-drive)

There are two basic types of electric motor for electric two- and three-wheelers: hub motors, where the motor is physically integrated into the wheel, and mid-drive motors, where the motor runs a chain or a belt to a gear on the wheels or an axle. Hub motors are widely used on scooters, while three wheelers almost exclusively use mid-drive motors as they are spinning axles. Electric motorcycles available today are a mix of hub and mid-drive motors. Nearly all ICE vehicles use mid-drive motors, as the engine drives gears which run chains or belts to the wheel. Hub and mid-drive motors represent several tradeoffs between vehicle feel, torque, cost, and maintenance.

[viii] However, there are a handful of artisanal electric motorcycles with significant variation, such as extra-long chassis or other non-standard features.

Table 2. Advantages and disadvantages of hub motor and mid-drive motor types.

Type	Advantages	Disadvantages
Hub motor 	Lower upfront cost Physically lighter Directly applies torque	Shifts center of gravity towards the back of the vehicle Breakdown often requires wholesale replacement. More directly dependent on voltage for performance Increases the non-suspended weight
Mid-drive motor 	More closely replicate feel of an ICE vehicle with center of gravity in center Usage of gears can allow for greater efficiency of lower voltage systems Longer lifetime	Higher initial cost Require maintenance and occasional replacement of chain or belt

Box 3. ICE Engines vs Electric Motors

As electric vehicles enter the mainstream, terminology around fundamental parts including motors and engines can confuse readers. While engines are more typically referred to on ICE vehicles, and motors on EVs, the terms are interchangeable in common parlance.

Drivetrains are the groups of component parts that deliver energy conversion from the engine or motor to the propelled parts, either an axel or a wheel. In an ICE drivetrain, there is an ICE engine, gearbox, and several component parts including starter motor, battery and fuel tank. An EV drivetrain, in contrast, is much simpler, with only an electric motor and a battery.

These differences make EVs simpler to assemble and require much less maintenance. Electric motors do not require lubrication, unlike ICE vehicles. They also do not require regular carburetor tuning and have fewer parts that require replacement with regular use such as piston rings, gear boxes, and starter engines.

In addition, petrol engines and electric motors deliver power differently. Internal combustion engines – which turn a gear to turn the wheels – are usually not able to operate below 500 revolutions per minute (RPM) or above 6,000 RPM, while comparable electric motors can usually operate from 1 to 20,000 RPM. As power is a function of torque and speed, ICE engines must compensate for their limitations by using gears to turn speed into torque in low gears and then shifting into high speed and lower torque in higher gears. EVs, by comparison, are able to deliver much quicker instantaneous torque and speed and are able to maintain torque more consistently with higher power delivered to the motor, eliminating the need for a transmission system.

Comparing ICE and EV power is also complicated by the fact that international combustion engine measures are effectively maximum capacities, while for electric motors the nominal capacity is more commonly described, rather than the maximum. The nominal capacity of an electric motorcycle is a power rating – measured in kilowatts (kW) – that the motor can theoretically run at indefinitely without overheating or other issues. For example, a 150 cc engine is comparable to a motor with 8.5 kW peak power, yet the electric motor is more often referred to by its nominal power, of around 5 kW.

Underbone

Figure 9. ICE underbone motorcycle, in Ziguinchor, Senegal, popularly known as jakartas. Photo credit: James Courtright.

Underbone motorcycles physically resemble a hybrid of a scooter and a motorcycle, with a partial step through frame. Underbones provide advantages over scooters in having larger wheel rims, which provide more stability on gravel and pitted roads. They are used for both personal and commercial passenger transportation in West Africa, Latin America and Southeast Asia.

Common brands include Honda, KTM, and Yamaha. The engine ranges from 49-124 cc (2.7 – 7 kW peak power), in keeping with the hybrid design, though newer models are often on the higher end. This category also includes the best-selling motorized two-wheeler of all time: the Honda Cub.

Electric underbones

Despite underbones' popularity as ICE models in certain markets, there are very few electric underbone motorcycle models being produced at scale. However, there are more electric models available in Southeast Asia, which may appear in the African market in the years to come. The average electric underbone has a 2 kW motor and 1.9 kWh battery capacity, and the majority use hub motors.

Figure 10. EV underbone motorcycle in Cotonou, Benin. Photo credit: Olou JP Koucoi.

Passenger three-wheelers

The most common design for passenger three-wheelers is for a single central frontal wheel and two in the back, with front-wheel steering. A drivers bench in the front can provide for an additional one or two passengers, while there are typically one or two three-seater backbenches. In India, both ICE and e-rickshaws are usually open air with two backbenches. Latin American versions tend to follow the design of vehicles sold in India and Asia in general, while in Africa they are a mix of the auto-rickshaw style and single-bench versions.

Figure 11. Single-bench electric three-wheeler in Dar es Salaam, Tanzania. Photo credit: Tom Courtright.

The ICE varieties such as the popular TVS King or Bajaj Re have engines between 200-250 cc (equivalent to 11-14 kW peak power), while their electric counterparts are typically 2-8 kW peak power. Batteries are typically around 5-8 kWh, delivering a similar stated range to motorcycles of 80-110 km. While it's not possible to directly compare the engine size of an ICE vehicle and the power of an EV, drivers' experience and speed capabilities demonstrate that electric three-wheelers are often lower powered than their ICE counterparts. The difference stems from the need for larger batteries which would make the vehicle expensive in comparison to the ICE version.

Higher-powered motors need larger batteries because higher power demand on a smaller battery can diminish the lifespan of the battery. This is known as the **C-rate** and is calculated as energy (kWh) over time (hours). If a battery is being depleted (or charged) at faster than 1C – representing complete charge or discharge over an hour – it can cause long-term damage to the battery. An LFP battery, for example, being charged and discharged at 1C can reach over 3,500 cycles before the depth of discharge reaches 80% - but at 4C, it can only manage around 1,000 cycles.[13] In order for batteries to last, batteries must be matched to the motor power – thus driving up the cost of vehicles with higher motor powers.

Figure 12. Electric Bicycle taxis in Bogotá at a mass transit station. Photo credit: Carlos F Pardo.

This also explains the market segmentation that can be found between what are known as electric rickshaws and electric auto-rickshaws (categorized in India as L5, and commonly called electric tuktuks elsewhere). While the policy specification in India is around motor power – electric rickshaws motors are no more than 2 kW – the connection to battery size as mentioned above means that electric rickshaws tend to have lead acid batteries, while L5 tuktuks usually have lithium-ion batteries. Electric rickshaws were one of the earlier mass adoption electric vehicles, taking off in India and Bangladesh around a decade ago, but their slow speeds (typically under 25 km/h), and considerable waste and human health damage from lead-acid batteries (see Box 2 on lead-acid batteries) have garnered significant opposition to them. They are operated primarily in dense urban areas with slow speeds, minimal environmental regulation, and relatively smaller payloads. As they are typically lead-acid vehicles, this report does not focus on e-rickshaws.

In terms of transportation services, passenger tuktuks occupy a flexible ground from a commercial door-to-door ride-hailing service to a route-based service, sometimes serving both on the same trips. While the ride-hailing trips can be more expensive for a single passenger than a motorcycle-taxi, shared route service is typically cheaper. In many cases, especially low-traffic areas, they have been edging out both motorcycle-taxis and minibuses.[ix] ICE tuktuks can cost around US$ 3,000-3,500 in Dar es Salaam, Tanzania, where they are one of the dominant forms of transportation. In Latin America, the service is provided by vehicles equivalent to these but also in the form of electrified or motorized "bike taxis" (rickshaws) which are more prevalent in small cities and towns (see Figure 12).

Cargo three-wheelers

There are a wide variety of cargo tuktuks, but they are all three-wheeled vehicles that are built for not more than 2 passengers seated next to the driver with a cargo compartment that is either open-air or a closed box. Delivery tuktuks engines and specifications are typically in the same range as passenger tuktuks, being around 200-250 cc.

Open air truck bed tuktuks are quite common in cities' trading entrepots, used for all manner of items including agricultural and hardware goods in Africa, Latin America and Asia (especially India) alike. Occasionally they are fixed with benches and turned into passenger vehicles, especially with the addition of a basic roofing structure.

Figure 13. Sinoray electric cargo three-wheeler in Dar es Salaam, Tanzania. Photo credit: Jacqueline Ssenyagwa.

Cargo box tuktuks are often branded fleets that do deliveries and local logistics can also be refrigerated for moving produce. In this, they represent a strong opportunity for supporting electrification, as large logistics companies can provide sizable purchase orders that can get manufacturers off the ground and bring down the cost market-wide.

[ix] Author's observations and interviews in Moshi, Tanzania.


Figure 14. The Trimoto Electrica, by Kayen Corps. Photo courtesy of Kayen Corps.

Trimoto (and emerging designs)

An emerging model of electric three-wheelers that was found during the course of this study is the trimoto. This is a three-wheeler built for personal usage, sometimes with space for one passenger riding pillion. In Morocco, they have been observed being favored by persons with disabilities for their stability.[14] Form factor varies significantly: some have two wheels in the front and one in the back, and others have two back wheels and one in the front. Many have the batteries integrated into the floor of the vehicles and could be described as a three-wheeled version of a scooter.

In Asia, Yamaha introduced the Tricity model in Thailand and Japan in 2014, and later in other countries including Australia and New Zealand.[15] However, the model was later discontinued as it was not as successful as Yamaha hoped for due to lack of interest.[16]

In addition to trimotos, **electric sidecar models** have also been found in Egypt and China. These vehicles consist of a one-wheeled sidecar attached side-by-side to a motorcycle. These models similarly have an unclear use case and seem to be something of a gimmick, as ICE sidecars have gone out of style globally due to their high road safety risks, with the notable exception of Manila in the Philippines.[17]

These models point to the evolution of vehicle designs as the electric two- and three-wheeler market consolidates and expands. It has become more difficult to classify some vehicles into one category, as their size, power, number of wheels and passengers vary greatly. As happens with the early development of a market, it may well be that the years following the publication of this report will see several new form factors enter and leave the market until a few standard models remain and government regulations catch up with private sector initiatives.

Current charging technologies

Ensuring electric two- and three-wheelers have sufficient charge is typically done either by charging or swapping the batteries. Charging the vehicle's battery while in-vehicle is known simply as charging and can happen anywhere with the appropriate infrastructure, which for electric two- and three-wheelers is often just a standard socket. Battery swapping is done by charging additional batteries, usually held at stations throughout a city or at a charging hub, which are then swapped for depleted or used batteries. Lithium-ion batteries can burn particularly hot, and fires that start when charging in private residences can therefore be a serious risk. This risk is reduced through company-controlled battery swapping stations or safety standards for vehicles and charging infrastructure.

Charging options

Globally, there have been two broad approaches to charging infrastructure for E2&3W: plug in charging and battery swapping. In Asia and Africa both models are found, though networks and deployment are significantly more advanced in Asia. In the case of Latin America, the overwhelming majority of charging is done at home and there is virtually no battery swapping despite some in the industry being interested in developing such schemes. Charging style tends to depend on the use case and the region - while in Africa the early commercial vehicles are using a higher proportion of battery swapping, this same technology is used by personal owners in Asia and is almost non-existent in Latin America.

Battery considerations

There are currently a mix of nickel manganese cobalt (NMC) and lithium-ion phosphate (LFP) batteries deployed in the mostly nascent battery swap systems across Asia, Africa, and Latin America. One of the key characteristics of NMC batteries is that they are more energy-dense, meaning smaller, lighter, and therefore can carry more energy than larger, heavier LFP batteries. However, NMC batteries are more susceptible to fires, require cobalt - a mineral linked to significant human rights violations and which has seen price spikes in recent years with heightened demand and concentrated supply - and have shorter lifespans.

Unsurprisingly, cargo tuktuks were found to have the largest battery capacities on average, as the average maximum load is rated at 461 kg, compared to 290 kg for passenger tuktuks or 163 kg for motorcycles. Average motorcycle battery capacity in Asia is high largely due to several high-end models on the market, particularly from the manufacturers Zero Motorcycles and Energica. When these two manufacturers are removed, average battery capacity in motorcycles in Asia drops to 3.5 kWh, similar to the 3.4 kWh in Africa though higher than the 2.5 kWh in Latin America.

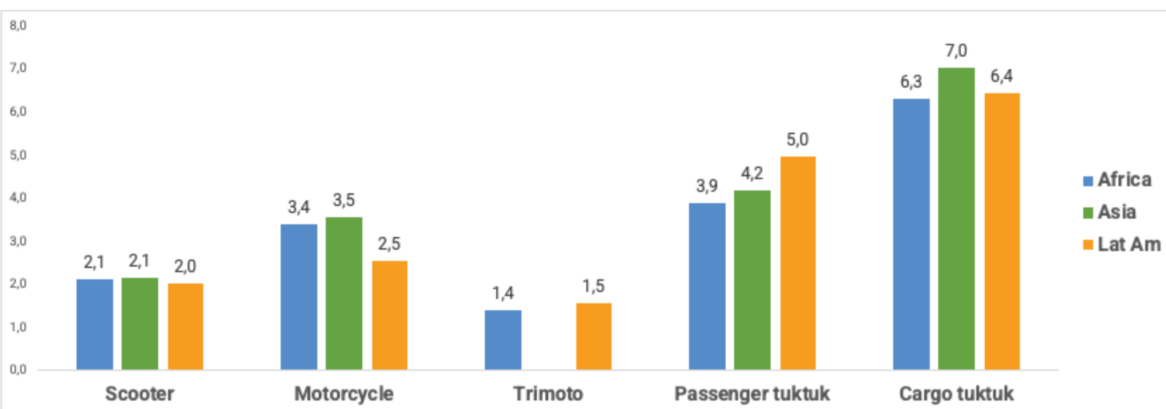


Figure 15. Battery capacity by vehicle type, in kWh; Energica and Zero Motorcycles removed.

The ability to drive longer distances with smaller batteries, referred to as **vehicle efficiency**, is critical to solving user range anxiety without price increases and high energy needs from larger batteries. However, vehicle efficiency depends on a wide range of characteristics, including weight, controller, motor type, and voltage, as well as driving behavior, most importantly speed and acceleration. Importantly, vehicle weight, including battery and loads, has an inverse relationship to vehicle efficiency, as scooters - the smallest vehicles with the lightest vehicle weights and loads – have the highest efficiencies, while passenger and cargo tuktuks have the lowest vehicle efficiencies.

Specifications provided for this report to assess efficiency are largely based on lab testing, meaning new vehicles in near-perfect test conditions, and they are part of marketing material. This often creates a disconnect between the claimed or certified ranges and those experienced by those using the vehicles on the ground where hills and heavier loads can have a significant impact on efficiency. Three electric motorcycle providers in African markets, for example, noted their vehicles were able to cover 22-30 km per kWh, which is significantly lower than the average of 36 km per kWh as claimed by manufacturers.[18] Similarly, an electric passenger tuktuk provider in East Africa receives around 14 km per kWh in real-world conditions, around half of what is claimed by manufacturers.[19]

Table 3. Minimum, average and maximum claimed range by vehicle type.

Vehicle Type	MIN of Certified Range (km) (complete battery capacity)	AVERAGE of Certified Range (km) (complete battery capacity)	MAX of Certified Range (km) (complete battery capacity)	AVERAGE of Efficiency (km / kWh, calculated)
Cargo tuktuks	40	89	200	14.6
Motorcycle	30	100	420	36.2
Passenger tuktuk	35	75	145	29.6
Scooter	30	81	200	45.9
Trimoto	45	71	200	45.3

With the advent of electric vehicles comes a requirement for new energy infrastructure. Charging EV batteries can theoretically be done anywhere there is access to electricity: be it a generator at home, grid electricity at the office, or a solar powered rural charging hub. The main constraints are time, cost, reliability and a preference to slow-charge in order to extend battery lifecycle.

The convenience or inconvenience this presents to users creates a dilemma for the market as larger batteries can carry users farther with fewer stops for recharging, but at a higher cost. In addition, there are upper limits to the size of potential batteries that can be used on two- and three-wheeler vehicles, as they are heavy and bulky – notably lower-density LFP battery chemistries more than higher-density NMC batteries.

Faster charging stations for e2&3W which could charge up to 7 kW can cost around $800 and require a sufficiently stable electricity source but could help solve the issues presented by short range vehicles.[20] These stations could be public or private. With electricity access expanding significantly globally (with some notable exceptions in rural parts of Africa), the ability to charge at home or at an overnight parking location means the key question becomes how far the user travels on a typical day, and this is a result of the use case. Personal use travel of around 30-40 km per day on two-wheelers can typically fit comfortably within the range of most electric two-wheelers, making daily at-home overnight charging viable. Commercial users of two- and three-wheelers on the other hand often travel 100 or more kilometers a day, which is just outside of the range of most vehicles found in our review – and which could possibly be solved with chargers in the 3-7 kW range or with battery swapping.

Plug in charging

Dedicated charging infrastructure for electric two- and three-wheeled vehicles remains rudimentary in most settings. For home-charging, the most common model is currently simple wall chargers at home. These are often charged at around 500 W to 1 kW using the chargers provided with the vehicle at sale. Companies such as Bolt.Earth in India are providing basic chargers in the range of $45 that can allow universal socket connections charging up to 3.3 kW.[21]

Technically, any two- or three-wheeler with the appropriate input can be charged at faster charging stations which can charge at 7 kW (single phase) up to 22 kW (three phase), which would allow the average two-wheeler to charge in twenty minutes. However, charging stations are primarily targeted at four-wheeled vehicles and do not have the necessary plugs for two- and three-wheelers (or, in the case of Latin America, are not even legally allowed to charge two- and three-wheelers because of lack of homologation of the chargers).

It is the charger – consisting of a cable and a voltage regulator – which converts the vehicle's battery voltage (usually 48V or 72V) to socket voltage (220-240V in most markets, 110V in the Americas). Wall sockets designed for e2&3W can therefore handle any charger as long as the outlet voltage matches, but the chargers themselves are typically designed to work with the specific battery models and are usually not interoperable.

While most of the vehicles found in this study have removable batteries, allowing users to carry the battery closer to an outlet, others have a fixed battery and require an outdoor outlet. In addition, there are fifteen socket & plug types globally which have limited interoperability). This requires manufacturing chargers for specific markets. Additionally, to roll out public charge points, manufacturers must align with local sockets. If public chargers are to include the charging cable, then much more harmonization is needed regarding voltage and communication between battery and charger – as the charger voltage must match the vehicle voltage.

Plug-in charging faces two major obstacles: cost and timing. Plug-in charging generally requires the price of the battery to be included in the cost of the vehicle, which can add 80% or more to the price of the vehicle. The higher end is for the case of vehicles requiring larger-than-average batteries, due to either larger motors, higher intensity usage, or high range demands. In addition, plug-in charging can take anywhere from two to five hours on average for a full charge. When the range is shorter than daily driving demand, drivers may need to charge during the day – yet there is little public charging infrastructure for E2&3W and it is often inconvenient to carry a battery (or two) into a place of work to charge. Overnight plug-in charging can allow for slower charging, which is better for battery lifespan. However, this only works if the vehicle range is sufficient for the user's daily travel needs and if stable grid electricity is available as no solar energy will be available at night.

Plug-in Charging Networks and Pricing

While public charging systems for E2&3W are nascent and relatively rare, the evolution of charging stations in Europe and the US for the passenger car market over the past decade is instructive. As electric passenger cars entered the market in Europe, several charging networks arose. They often provided customer cards which could unlock chargers on their networks and bill the customers afterwards. However, initially the networks were not interoperable despite using similar hardware, and drivers were limited to their specific subscribed networks. Recognizing the inefficiencies and limitations this created – as charging stations were both costly and few – several private sector-led interchanges arose which allowed drivers to roam and use other companies' chargers. In October 2022 the EU mandated the adoption of roaming technologies to allow users to access any plug-compatible EV charging stations.[22]

In Africa, plug-in charging stations are few, with several countries yet to establish any formal EV charging networks, and expansion rather than interoperability is the focus of discussion currently. In Latin America, public charging for electric two- and three-wheelers is also not widespread (and in some cases not allowed by regulations as these are not approved yet). In Asia, charging station availability for three-wheelers is growing, particularly in India, but there are yet to be any major initiatives for ensuring EV roaming. As most E2&3W are using standard wall sockets rather than specialized high-powered chargers such as CHAdeMO or CCS and are mostly charged privately rather than at public charging networks, there is little demand yet for standardization. However, if public charging networks for e2&3W do take off, the harmonization of charging standards and payment modes should not wait until the network expands but tackled early on to avoid inefficiencies.

Battery swapping

Battery swapping is an alternative charging system by which discharged batteries are removed from the vehicle and swapped with full batteries that have been charged externally. At swap stations, extra batteries can be charged and stored either in cabinets, on shelves, or even on the floor of a shop. Battery swap networks can consist of dozens or hundreds of swap stations around a city or in a rural solar powered charging hub. It was first introduced at scale in Taiwan by Gogoro, who provides the service primarily for personal use scooters, and is now being piloted in all three study regions.

Figure 16. Battery swapping module. Courtesy of Smobery.com

Battery swapping is typically deployed to solve several interrelated issues. The first is charging time - a full charge of an average electric two-wheeler from a universal slow charge socket can take around two to five hours, while a battery swap usually takes two to three minutes, akin to the experience at a fuel station. Additionally, in most battery swap systems ownership over the battery is retained by the swap operator or vehicle retailer, reducing the upfront cost of the vehicle. This also means that the vehicle owner need never worry about an expensive battery replacement, as the swap company is responsible for ensuring charged and working batteries are always at their disposal - which may also extend battery lifetime and ease reuse and recycling efforts as batteries remain under the control of the company. Finally, battery swapping means there is no need for home charging, which may not be possible if electricity access is limited, interrupted or dangerous if illicit electricity connections are used.

Table 4. Differences between fixed and battery swapping models.

Characteristic	Fixed / plug-in charging	Swapping
Motorcycle ownership	Driver or vehicle owner	Driver or vehicle owner
Battery ownership	Driver or vehicle owner	Swapping company
Charging operations	Driver or owner charges at home, at public chargers, or using commercial fleet infrastructure	Driver swaps battery at swap stations, battery is charged at station or elsewhere by swapping provider
Charging payment	Driver can pay for electricity at home or at public charger (typically plus margin), or fleet owner can handle it	Drivers can pay per swap, or for a subscription service for a set number or limitless swaps per day / week / month
Charging / swapping duration	Typically, 2 – 5 hours with a standard charger	2 – 5 minutes for a swap

Battery failure risk ownership	Driver or vehicle owner. Charging at home can increase the risk of damage	Swapping company
Electricity access	Driver must have stable electricity access at home or at charging stations	Swapping company must ensure reasonable electricity access so that full batteries are always available
Other risks	Driver or vehicle owner must finance the motorcycle with the battery	Driver remains reliant on a swap company's services, including the risk of service stoppage

Box 4. Understanding the Battery Swap Business Model

Currently, the cost of the battery can be around 40% of the price tag of an e-motorcycle, pricing the motorcycles out of the range of the average motorcycle-taxi rider. By selling the e-motorcycle without the battery, the price of an electric vehicle can match the ICE equivalent – but it leaves the swap company having to amortize the cost of the battery. This means that the cost of battery swapping is usually much higher than simply the cost of electricity, as it must include the cost of the battery, battery cabinets or storage, and any other operational costs plus a profit margin for the company. For now, however, battery swapping systems are competing primarily with the price of petrol and remain around 20-50% cheaper per range provided. In Uganda, for example, a local electric motorcycle startup charges $1.37 for a complete swap of a 2.1 kWh battery that can take a user around 60 km, while a comparative amount of fuel would cost a user $2.20.

Pricing strategies can vary, including paying per state-of-charge (SOC), per km, subscription, or a flat rate per swap. In general, the former has proved more popular in low-income countries, with subscriptions more popular in high-income countries like Taiwan and Israel. Additionally, mobile money payments are often preferred due to both their traceability and avoiding the need for change, which is often an issue in many African markets.

Companies maintain and track the batteries in their system, replacing them when they degrade and turning them off if customers default on their loans. Vehicle asset financiers have expressed interest in financing these vehicles, in order to get a foothold in a new sector, attracted by the prospects of cleaning their carbon footprint, meeting stakeholder pressure and having better traceability on leased assets.

With swap networks up and running in Accra, Lome, Cotonou, Kampala, Nairobi, and Kigali, the main constraint on the growth of this model seems to be supply of batteries and the capitals.

Battery swapping systems for electric two- and three-wheelers range from ad hoc swapping stations with batteries lined up on the floor to ensuite battery cabinets, designed in conjunction with the batteries for frictionless charging and a minimal footprint. They can be staffed or offer self-swapping services. In principle, they are a very useful solution to the issue of range anxiety with electric two- and three-wheeler adoption, but the massive capital cost of excess battery capacity, long amortization periods, and a lack of interoperability - that is, standardization of batteries and plugs across brands - remain challenges for widespread adoption.

Provided the battery is easily removable and a charger of adequate length is available, it is usually technically feasible for vehicles to use both charging and swapping. The deployment of dual capability systems is largely due to business model - whether the cost of the vehicle's battery is bundled in with the vehicle cost, or whether it is instead amortized with the battery swap cost over time. There are a wide variety of ways to charge for battery swapping services, such as a flat fee access pass allowing a certain number of swaps over a specific duration, a rental cost per battery usage duration, a charge based on the energy used in the swapped-out battery, or others.

Chargers provided by the manufacturer are typically used with internet-connected devices for tracking charging and battery health. For this study, we defined swappability as whether the battery was a) easily removable, and b) could be charged externally.

There are several key risks in the battery swapping business model, some of which originate from the need to balance battery stock and availability for customers. Deploying battery swap stations requires the company to provide a high number of batteries - an expensive asset - which can take up a lot of a company's resources and create financial risk. Faster charging can help ensure battery availability, but can shorten the lifespan of the battery, meaning slower charging is best in order to reduce capital costs. To reduce this investment without increasing the risk of a station not having a fully charged battery ready for a customer, swap stations and battery state of charge (SoC) must be closely monitored for system optimization. In addition, a stable power supply with limited outages or back up energy storage is required to ensure system continuity and availability for customers, which can be done by adding solar panels to the charging station. Additionally, lithium-ion batteries are at highest risk of fire when they are charging, so having several batteries charging together requires strong safety measures.

A key question remains over battery ownership: if the swap company owns the batteries, they can ensure there are always quality batteries available for the drivers, and also prevent the drivers from charging their batteries elsewhere in unsafe conditions. If the driver owns the battery, they can do as they like with them, though it may affect guarantees or other protections offered by the retailer as well as impact the ease of collecting and using them in second-life applications or for recycling. In Thailand, for example, an initiative to demonstrate battery-swapping with customer-owned batteries has run into a significant issue where customers with newer electric-two wheelers are unwilling to trade out their own batteries. This is because they see the swap as for the worse, as they trade out their own batteries for what may be subpar batteries from customers with older electric-two wheelers.

Box 5. Standardization Efforts

To address issues related to standardization of batteries and a more successful deployment of battery swapping, in September 2021, several major internal combustion engine two-wheeler manufacturers, including Honda, Yamaha, Piaggio and KTM, have established the Swappable Batteries Motorcycle Consortium (SBMC) aiming to develop common technical specifications of swappable battery systems. However, they have done little to no consulting in low- and middle-income markets so far and do not include many of the major manufacturers that serve them. Therefore, there is a serious risk they will develop a standard that will not be made to fit these markets.

Shelves

Shelf-based battery swapping typically includes chargers bought from vehicle suppliers. Smaller stations can use regular grid connections, though local legislation may dictate their tariffs. The installation of a smart meter is often required to make use of lower EV specific tariffs that are being offered in several countries today. There is usually a staff member on hand from the battery owner company to remove and replace the motorcycles battery.

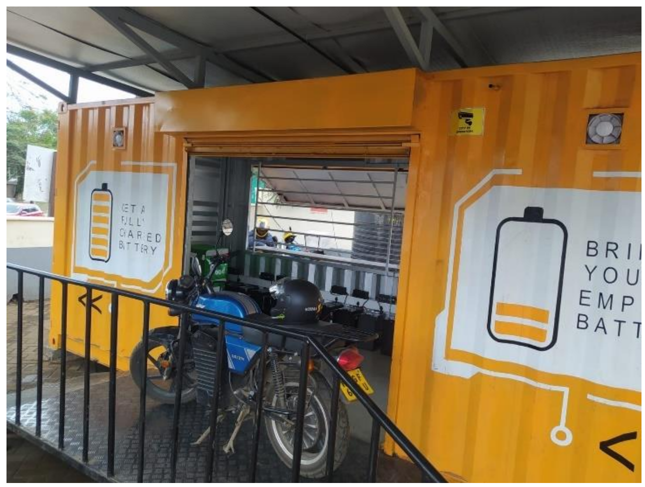


Figure 17. Containerized battery swapping station run by Stima Mobility in Nairobi, Kenya. Photo credit: Tom

Figure 18. An automated battery swapping cabinet by Arc Ride in Nairobi, Kenya. Photo credit: Tom Courtright.

Cabinets

Cabinets can be as simple as lockers with spaces for charging cables, or they can be custom plugless sockets. Plugless sockets require more research and development but are used by Gogoro and Kymco amongst others. Battery cabinets can be operated by staff, but are usually automated to be self-service with the help of a mobile app.

Payment technologies and automation

To register battery swaps, QR codes can be used to identify riders and/or their vehicles as well as the batteries being swapped. Many battery swapping companies still have rudimentary technologies for tracing swaps but are planning for automated systems akin to global market leader Gogoro. This would allow for a rider to unlock a swap with a payment, without the need for any on-hand swapper.

There are multiple means to charge customers for their battery swapping usage, and in some cases payment systems can represent an obstacle to adoption. When purchasing fuel, ICE vehicle users often pay a rounded amount in cash - say, $2 in local currency - and receive whatever that is worth in the current value of petrol, which may be around 1.75 liters. However, this is not possible when paying for the energy that a battery swap represents. This is because the energy provided in a battery swap is that of the presumably fully charged battery minus the charge left in the used battery. This can be measured as state of charge (SoC), ampere-hours (Ah), or kilowatt-hours (kWh), and to a customer is typically described simply as battery percentage. A customer is unlikely to try to go to the swap station when their battery is at a specific SoC, and in some cases battery swap stations may not have a 100% charged battery, so a customer cannot usually choose exactly the energy difference they will pay for. This translates to the payment: say a user has 50 Ghanaian cedis and the kWh difference is valued at 57.5 cedis, one would need to always keep change at the station, and automation would not be possible with most current technologies. Digital or mobile payments are therefore a requirement in most circumstances to pay for battery swaps on a per state-of-charge or per energy unit basis.

Box 6. The social and environmental costs of lithium-ion batteries

While replacing fossil fuel energy sources mitigates the widespread harms from their exploration, extraction, transportation, and consumption, lithium-ion batteries also rely on the extraction of minerals - chief amongst them, lithium and cobalt - which have their own social, environmental, and economic costs.

Lithium, used in most of the dominant EV battery chemistries on the market today, requires large amounts of water for extraction and can have serious impacts on local hydrospheres. A well-documented case of social consequences of lithium extraction is that of Chile in its Atacama region. The extraction of this metal (in the case of Chile, through the evaporation of brines found beneath salt flats) has generated negative consequences in the livelihoods of the local population given that it reduces the availability of freshwater in the region and, more broadly, threatens the existence of entire indigenous communities and ecosystems.

Cobalt, used in NMC but not LFP batteries, is linked to labor rights issues, particularly in the DRC, which holds around two-thirds of global supply. Artisanal mines in the region have been linked to poor labor conditions and human rights abuses. However, this criticism itself has been refuted by mineral and conflict experts who point out that artisanal mines often provide higher-than-average wages, and that industrialized and formalized mines do not necessarily lead to higher local incomes.

Therefore, significant efforts are required to reduce the need for virgin raw materials. First, this can be done through a circular economy approach and high rates of recycling of material in the battery industry. Secondly, the usage of some raw materials in the battery design can be reduced (for example LFP batteries do not require cobalt, and sodium-ion batteries require neither cobalt nor lithium). Finally, right battery and vehicle sizing according to actual use profiles and the promotion of vehicle sharing, public and non-motorized transport can help reduce demand for resources.

Apart from specific payments, battery swap networks can either A) charge a flat rate for every swap at a rounded amount, or B) charge a flat rate for a certain number of swaps (unlimited is also possible) over a certain time period. However, customers may view these options differently depending particularly on their financial circumstances, cultural preferences and use cases. Option A may be seen as “cheating” customers, as a swap that delivers 50% of battery capacity and one that delivers 95% of battery capacity are the same price. It can also encourage thrifty users - such as commercial users - to try to maximize value for money by running the battery as low as possible before swapping. This in turn may lead to more stranded users and strain on the battery and overall system. Option B can similarly encourage maximization of usage by those for whom driving is earning.

There are other issues that may slow the adoption of battery swap stations apart from those around payments. In the case of Latin America several stakeholders identified very persistent hacking and tampering with the digital components of batteries and charging equipment. Hacking and tampering with high-voltage, capital-intensive systems carry risks related to safety and major financial loss. These risks have reduced the interest of the private sector in having large-scale deployments of these technologies in Latin America, though they could be hedged against with contracts that repossess or cutoff drivers who attempt to hack their batteries.[23]

Battery Characteristics

Battery Chemistries

In most cases, retailers and distributors did not openly advertise the chemistry of the battery the vehicle was using. As NMC batteries have been historically dominant, in many cases "Li-On" has been shorthand for NMC.[24] However, it was unclear in which cases this was true during our survey.

Nonetheless, the differences between NMC and LFP are real and significant and warrant a short discussion. As shown in the table, NMC batteries are typically lighter, smaller, have fewer lifecycles, require rarer minerals, and are more fire prone. However, these specific qualities vary strongly depending on other factors, such as quality of manufacturing, accompanying battery management system, and intensity and characteristics of charging and discharging.

Sodium-ion is an upcoming battery chemistry that has very recently gained attention and uptake. While it is not yet widely deployed, the first sodium-ion EV models are now planned for release in China later this year.[25] Sodium-ion batteries' downside is their low energy density - around 160 Wh / kg - but there are major gains in affordability, as raw sodium costs around 1-3% of its lithium counterpart and mineral requirements.[26] This could have a major impact for the low-income countries in our study, where affordability and battery cost remain a major issue. At least one e3W importer in Africa plans to switch to sodium-ion batteries within the year.

Table 5. Key characteristics of four major electric vehicle battery chemistries.

	Nickel manganese cobalt (NMC)	Lithium iron phosphate (LFP)	Sodium-ion (Na-ion)	Lithium nickel-cobalt-aluminum oxide (NCA)
Est. global market share for e2&3W [27]	60% of Li-On	30% of Li-On	<5%	8% of Li-On
Lifecycles [x] [28]	2,000+	3,000+	~1,500	2,000 +
Raw material availability	Constraints on cobalt	Iron & phosphate	Sodium and iron very widely	Nickel widely available;

[x] Battery cycle life is a description of the number of full charge and recharge cycles before a battery can only reach 80% depth of discharge. It is heavily dependent on the speed of charge and discharge: a battery charged or discharged at an average rate of 1C (roughly a full charge or discharge over an hour) can achieve nearly four times as many cycle lives as a battery charged or discharged at an average of 4C.

	Nickel manganese cobalt (NMC)	Lithium iron phosphate (LFP)	Sodium-ion (Na-ion)	Lithium nickel-cobalt-aluminum oxide (NCA)
		widely available	available	cobalt constrained
Cost (factory gate)[xi] [29]	$164 / kWh	$133 / kWh	$90-126 / kWh	$106 - $183 / kwh
Energy density (cell level) [30]	140-200 Wh / kg	90-140 Wh / kg	75-160 Wh / kg	200-250 Wh / kg
Thermal runaway threshold [31]	210 C	270 C	Unspecified; higher than Li-On	150 C

Battery Voltages

Batteries used in two-wheeler battery swaps are typically sized from 2 kWh to around 3.5 kWh, allowing two-wheelers to move around 60-100 km between swaps on a single-battery system. Dual battery motorcycles allow vehicles to double their range, though typically only one battery can be used at once, meaning it does not help reduce the C-rate, which would improve battery lifespan.

To build a battery, cells are stacked in series which build up the voltage and are almost always run at a multiple of 12 volts (though small variations means the maximum voltage listed is often a couple volts off of the nominal voltage). High voltage systems - legislated in the EU as above 60V - carry higher risk of serious injury or death in case of exposure. However, lower voltages require higher current to deliver comparable power, yet higher currents have higher thermal wastage and are generally less energy efficient. Additionally, higher voltage systems are better able to deliver torque for steep hills and rapid acceleration. There is thus a sweet spot of 48V-72V in which 95% of electric two- and three-wheelers fall globally. Regionally, lower voltages are more common in Asia, where adoption of lower powered, affordable models fit for personal use has been fastest.

[xi] This cost reflects the average price of a battery pack at the factory gate. The majority of OEMs have large, long term supply contracts with battery manufacturers. Smaller companies and startups have to pay significantly higher prices at the factory gate. Adding shipping, insurance, and taxes increases the cost even further, so that a battery pack bought for $200 at the factory gate in China by a small EV company can balloon to $400 once shipping, insurance, and taxes are taken into account.

Table 6. Distribution (%) of battery voltages in each region (motorcycles and scooter only)

Battery Voltage (Nominalized)	Africa	Asia	Latin America
12		0.35%	0.34%
36			0.68%
48	14.06%	13.78%	16.61%
60	20.31%	40.28%	30.85%
72	65.63%	44.52%	48.47%
84			1.02%
96		1.06%	2.03%
Grand Total	**100.00%**	**100.00%**	**100.00%**

Chargers are typically built customized to the EV battery they will be charging, meaning that a charger built for a 48V battery cannot be reliably used to charge a 60V or 72V battery. This has implications for both swap networks and charging solutions. For swap networks, this creates potential challenges down the line for interoperability, as a set of swap stations outfitted with chargers working with a certain voltage cannot charge those of a different nominal voltage without changing the chargers, which can cost around $100 apiece. For charging networks, it means that publicly provided chargers similarly must be built to battery specification. However, if the user carries their own charger, it is possible to simply provide internet-connected outlets that could be used by all voltages.

Brand Power and Industry Growth

Industry stakeholders and experts agree that typically it is a handful of major brands in each country that push the EV market and its regulation, and that smaller brands lack the financial “muscle” to achieve significant changes in the sector (in terms of pushing for policies or deploying swappable battery networks).

Interestingly, many distributors of electric two- and three-wheelers are also distributors (and sometimes have assembly plants) of ICE vehicles. This makes it difficult for them to promote their electric vehicles too effectively, as the profit margins of their ICE vehicles are much greater and users still prefer these despite their higher operating costs compared to electric vehicles. In most cases, ICE 2&3W still outsell their electric counterparts by several orders of magnitude (in Colombia, for instance, there were 400 times more ICE motorcycles sold in 2022 compared to electric).

Regional landscapes

Africa

Two- and three-wheeler presence & usage in the region

ICE two- and three-wheelers in Africa have exploded in popularity over the past thirty years, coming to serve as personal transportation, commercial passenger taxis, delivery vehicles, and even small-format arterial services. Their presence and usage vary significantly across the continent, depending on local economic strength, economic structure, regulatory regimes, and residents' preferences.

These vehicles' rise is attributed primarily to the continuing failure of public transport services to adequately serve both urban and rural users.[32] Post-independence public bus services in Africa, which had been struggling through the economic downturn of the 1970s, were discontinued during structural adjustment reforms in the 1980s and 1990s which shrunk the role of the state in many African countries.[33]

Africa has a wide range of two- and three-wheeled vehicles plying rural paths and busy downtowns, moving people and goods, and driving the local economy. The most common applications are motorcycle-taxis, personal scooters, and delivery tricycles, but they vary significantly in price, usage, durability, and locally manufactured content.

Two-wheelers

Table 7. Two-wheeler types and use cases in Africa.

<table>
<tr><th>Scooters</th><th>Underbone</th><th>Motorcycles</th></tr>
<tr><td colspan="2">Personal Use</td><td></td></tr>
<tr><td></td><td colspan="2">Commercial Passengers</td></tr>
<tr><td>Deliveries</td><td></td><td>Deliveries</td></tr>
</table>

In many cities across Africa, motorized two-wheelers have come to be the predominant mode of transport. In Mali and Burkina Faso, two- and three-wheelers account for over 80% of the fleet.[34] Going by dozens of local names (see Figure 20), motorcycle-taxis provide significant services in urban and rural areas, plying every route imaginable - save that of long-haul. Geographically, there is something of a motorcycle-taxi belt, extending from Dar es Salaam to Dakar, and excluding both Southern and North Africa.

Underbone motorcycles, included here under the motorcycle segment, are used for both personal and commercial means. Known popularly as jakartas in Senegal and Mali due to their origins in Indonesia, they are often 110 cc engines.[35] While underbone motorcycles are still a common sight in many West and North African countries, they have largely disappeared in East Africa and seem to have never made a dent in the Southern African region.

Electric Two-Wheelers

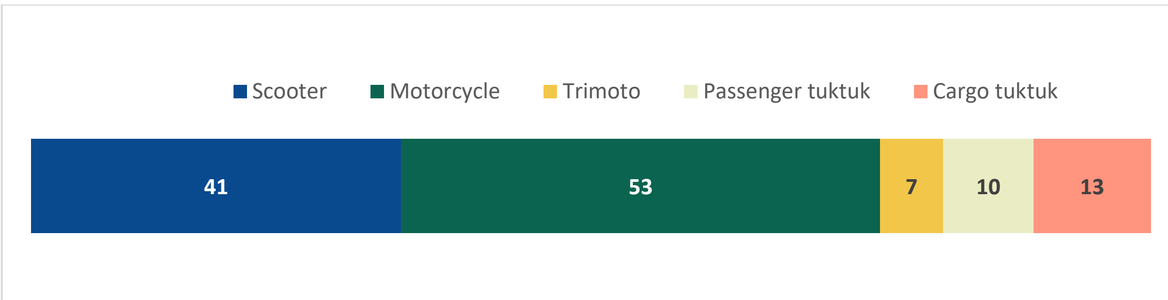


Figure 19. Number of available electric vehicle models by vehicle segment.

Electric motorcycles and scooters have been the most popular EV choice for retailers in Africa, making up 75% of available electric 2&3W models, yet total uptake remains low. A lack of financing for e-motorcycle importers and limited charging and swapping infrastructure has held back deployment. Overall, there are likely less than 20,000 electric motorcycles deployed in Africa, or less than 0.5% of the entire motorcycle fleet on the continent - but growth is accelerating. As of early September 2023, Spiro (previously M-Auto) had distributed an estimated 10,000 e-scooters and e-motorcycles in West African markets and recently entered two East African markets. One of the first electric motorcycle companies on the continent - Ampersand - has over 1,000 e-motorcycles on the road in Rwanda and Kenya with uptake after 4 years of slower growth now accelerating.

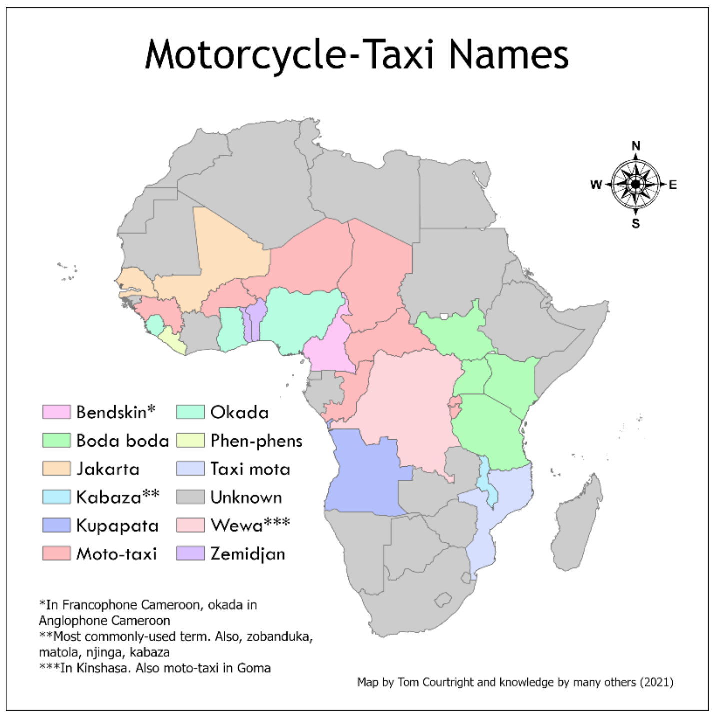


Figure 20. Popular names for motorcycle-taxis across Africa. Credit: Tom Courtright and others.

Scooters and underbones

Scooters in Africa are almost exclusively found in West and North Africa for personal use. Well-known electric scooter models from Yadea, for example, can be found in Egypt and Morocco in both lead-acid and lithium-ion varieties. Similar to elsewhere, most scooters are low-powered vehicles, with a median 1.5 kW motor.

There have also been attempts to utilize electric scooters for deliveries. In Dar es Salaam, Tanzania, a delivery company called Piki has used lead-acid scooters and female drivers to do deliveries in a limited area.[36] While management reports this as largely successful, the geographic limits and the need for annual battery replacement raise serious questions about the usage of lead-acid batteries, and they are seeking to move to Li-On motorcycles. A similar attempt at deploying scooters for delivery service in Nairobi was made but struggled to scale.

Despite the preponderance of the ICE version in West Africa, there have been very few electric underbone models in Africa. Potential explanations for this gap in the market could be the focus on models built primarily for commercial passenger use,[37] or that an equivalent personal underbone model would require higher speeds and motor sizes, which would be outpriced by ICE models.[38]

Three-wheelers

Three wheelers also go by many different local names, including bajaji in Tanzania, yellow-yellow in Ghana, and keke napep in Nigeria. They are more commonly found in coastal East Africa and in Sahelian West Africa. Generally, they tend to be more present in cities and towns with flatter landscapes, partly due to their low ground clearance making them less fit for dirt roads and because of their relatively small engines (around 200cc) and heavy payloads.[39] Tuktuks provide two common types of passenger service in African cities: on-demand door-to-door and shared arterial routes. The most common ICE models, such as TVS King and Bajaj RE, have one passenger bench designed to seat three, and a driver bench that often accommodates an extra passenger - despite legislation against this practice. In some places, they have come to challenge minibuses.[40] In some cities such as Dar es Salaam there have been attempts at pushing out motorcycle-taxis in favor of tuktuks. This is largely due to tuktuks being perceived as safer than motorcycles.

Box 7. Investment landscape in Africa

With most of the world's two- and three-wheeler manufacturing taking place in Asia, Africa is often seen as an afterthought for global players. Lower incomes, low industrial bases, high shipping costs, and import duties create a perception of Africa as a low margins market, requiring healthy volumes to make market entry profitable. Thus, with higher production costs for EVs, a major Indian manufacturer described a concern that margins on EV sales in Africa would be squeezed even lower.

The current retailers of e2&3W in Africa have been primarily either simple importers with little interest in after-sales, or startups developing brands and entire ecosystems including swap or charge stations. These startups have raised over $100 million from mainly foreign investors, with over $50 million in Kenya alone.

EV startups in Africa have thus focused on the motorcycle-taxi market and face significant scaling challenges as they simultaneously adapt vehicles to African markets, develop battery swap stations, program apps to run their payments and IOT, and finance their assets.

Electric Three-Wheelers

Electric three-wheelers remain a rarity in Africa, especially with lithium-ion batteries. This survey only found thirteen electric passenger tuktuk and electric cargo tuktuk models in Africa, though there are very likely more models being sold in offline marketplaces as was the case with electric two-wheeler models. The electric three-wheelers are being used for essentially the same use cases of commercial passenger and delivery services as their ICE competitors. While cargo tuktuks tend to have the largest batteries on average at over 6 kWh, passenger tuktuks so far have had more modest battery pack sizes (Figure 21). This mirrors what is seen in other regions, including the need for cargo tuktuks to carry heavy weights while being uncertain of charging infrastructure.

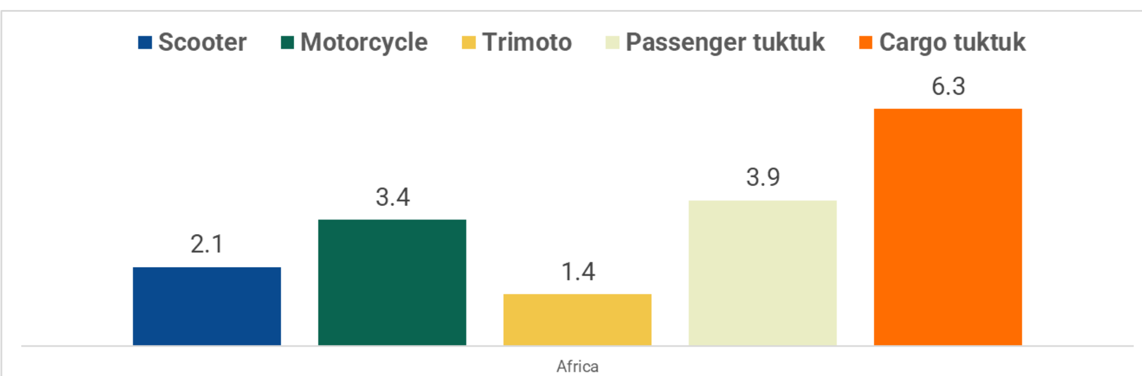


Figure 21. Average battery capacity (kWh) in Africa by vehicle segment.

There are at least three causes of the relative underinvestment in electric 3W in Africa. The first is that they are capital-intensive, costing around three to four times the price of an electric motorcycle.[41] Due to weight limitations, space and size requirements, they are less fitting for battery swapping, which both increases their upfront cost to costumers and the inconvenience of slow charging.[42] In addition, the last-mile delivery service companies that are the key customer segment for cargo 3W companies in Asia are relatively young in Africa, and much of the last-mile delivery services are already carried out by motorcycles.[43] Finally, passenger 3W do not command as wide a geographic spread as motorcycles, as they are concentrated along the east coast of Africa and in coastal West Africa.

Trimoto

Trimoto models do not seem to be widespread in Africa, but at least seven models are being sold by companies in Nigeria and South Africa. They are the only vehicle that does not seem to have an identifiable mass-produced ICE equivalent.

Trimotos do not have a clear mainstream use case and tend to be very low powered (Figure 22). Trimotos singular seat makes them driver-only vehicles and unfit for commercial passenger usage, while their wide back end means they do not have the maneuverability of two-wheelers. Instead, they may fill a niche use case of providing support for disabled and elderly people.[44]

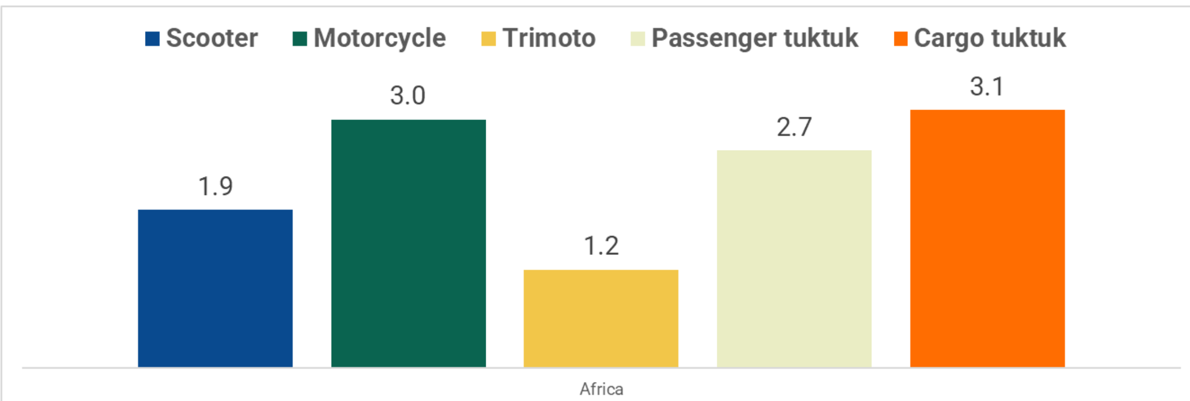


Figure 22. Average motor rated power (kW) in Africa by vehicle type.

Charging & swapping infrastructure

Fundamentally, charging and swapping infrastructure in Africa remains quite scarce and under-developed. Charging stations in many countries have been primarily built for electric 4W, which largely do not serve the two and three wheeler vehicle segments. In Kenya, the leading charging infrastructure network (i.e. excluding battery swapping networks) is still providing charging for free - though their connectors are primarily fit for cars - in order to encourage uptake. However, there are a variety of technical and business model innovations that are being tested out on the continent, chief amongst these being a variety of battery swap models with different payment schemes.

Swapping

Battery swapping in Africa has been primarily used by early-stage companies deploying two-wheelers for commercial purposes. As a result, there are a wide variety of swap station types being tested, including ad hoc shelving, retrofitted shipping containers, and mass-market battery cabinets. While two-thirds of retailers did not explicitly list whether their models can be swappable, more than 90% of those who did have swappable batteries. There were a wide variety of reasons that have favored battery swapping in Africa, including:

- **Lower income customers** who cannot afford to pay a premium for an EV. Battery swapping usually removes the cost of the battery from the vehicle, keeping the vehicle at the same price point as the ICE equivalent.
- Motorcycles and tuktuks are **primarily commercial use vehicles**, which need to maximize uptime. By charging extra batteries while the driver continues to work, battery swapping can replicate the experience of ICE vehicles by significantly reducing time spent refilling the vehicle with energy.
- Africa has some of the **lowest and most unequal rates of electrification** globally, limiting access and grid stability at homes outside of major downtown areas. Furthermore, many electricity connections in urban areas are informal connections that may be improperly installed, creating additional fire risks when charging electric vehicles.

East Africa has largely led the way on battery swapping networks, with Zembo (Uganda), Ampersand (Rwanda), and Arc Ride, Stima Mobility, Ecobodaa, and Roam (all Kenya) all rolling out motorcycle battery swap networks. In West Africa, Spiro (formerly M-Auto) has reportedly deployed over one hundred battery swap cabinets in Togo and Benin. However, these companies are all startups with limited funding who have faced significant capital constraints so that as of June 2023, only Spiro had over 380 active swap stations while the second-largest swap network was Arc Ride with over 70 swap stations.

A note on interoperability

Battery swapping still has several major obstacles to overcome and is viewed by some as a barrier to an accelerated adoption of electric 2&3W in Africa. This is because battery swapping requires heavy capital expenditure and is typically being deployed by ecosystem-building companies that are running several concurrent business arms, including importing, retailing, financing, maintaining, and providing swaps.

Currently, most battery swap networks in Africa have few swap stations. No companies have been found in the research for this report to be sharing batteries or swap stations, meaning every company is setting up their own swap network. When swap stations are few and far in between, riders must travel further in their search for a swap station which increases energy needs, range anxiety, and general inconvenience for users, limiting uptake. While these inefficiencies are highly likely to decrease as swap networks become denser and partnerships may arise between companies to share battery swap stations, it is unclear to what extent companies will be able to optimize battery swapping locations, battery availability, battery size and lifespan and thus reduce capital expenditure.

As noted in Figure 22 the largest batteries are often found in cargo tuktuks, followed far behind by motorcycles and passenger tuktuks. Cargo tuktuks larger battery capacity is likely related to their usage of plug-in charging at small shops or homes and the need to carry heavier loads than scooters or motorcycles.

A landscape of vehicles

The electric 2&3W industry varies across Africa, with more direct retailing in the higher income economies of South Africa and Northern Africa and a focus on lease-to-own sales for motorcycles and tuktuks across most of sub-Saharan Africa.

Industry structure

There are two main approaches in the electric 2&3W industries in Africa, between essentially pure retailers and ecosystem builders. The latter are companies who have raised funding publicly and gained significant media coverage in attempting to bring something innovative to the market mainly in cooperation with Asian manufacturers.

For vehicles aimed at the large motorcycle-taxi market, off-the-shelf Asian products are often unable to meet the specific combination of durability, range, power, and price point. Companies in Africa serving this market must therefore test several models and get more involved in the manufacturing and assembly by finding the right design and parts. This is especially true for the batteries to be used in battery swapping, where lifespan, safety, and price point are all critical to a sustainable business model.

The vast majority of two- and three-wheeler vehicles in Africa are manufactured in Asia. This is true of both ICE and EV versions. Under the classic ICE distribution models, Asian manufacturers would partner with country-level distributing partners to retail their products on the ground. Exclusivity has been the norm with Japanese and Indian brands, but not with Chinese brands, who are usually willing to sell to multiple competitors in an export market.[45]

This means that Chinese manufacturers such as TailG or Kaining are known to provide e-motorcycles to importers, who then rebrand the motorcycles. Ecosystem builder companies who seek to build their own brand, like most of the startups in East Africa, take umbrage with this model for two follow-on reasons. The first is that when the manufacturers are unwilling to consider an exclusive deal, the retailer essentially loses their uniqueness, as anyone else in the market can sell the same product. The potential solution - that the retailer has specific changes requested for themselves alone - often falls through, as the exporter may then include those changes or improvements to competition, again undermining the importer's unique value. Ecosystem builders therefore focus on the component parts of their offering, such as the battery swapping stations, business models, and software.

Battery chemistry

In Africa, as was the case elsewhere, most retailers and distributors did not reveal their battery chemistries beyond lithium-ion. While NMC batteries have been dominant over the past decade, the two largest E2W fleets in Africa as of December 2023 (Spiro & Ampersand) were both using LFP batteries. Interviews with OEMs and several startups painted a trend shifting towards LFP batteries, due to their higher safety standards, lower costs, and avoidance of cobalt. However, companies like Mobile Power in Sierra Leone, which use NMC-based batteries, were less enthusiastic about the transition to LFP, and expressed a belief that NMC's higher energy density made them a better fit for the motorcycle battery swap model. The impact of energy density also affects form factor. Higher-density NMC batteries can be a better fit for motorcycles using mid-drive motors, due to space requirements.

Battery voltages

Compared to Asia and Latin America, Africa has a much higher proportion of 72 volt solutions - 66%, compared to less than 50% in the other two regions (Table 6). This can be explained by use case, as electric two- and three-wheelers in Africa tend to be used intensively in topographically difficult landscapes, and thus require higher-power solutions. Higher voltages provide higher torque to the motors, critical for steeper terrain and for heavier loads.

Price data availability

The business model of either retail or lease-to-own sales had an impact on companies sharing data. Those selling via lease-to-own - primarily targeting the motorcycle-taxi market - often avoided sharing their retail prices or cost of goods. Direct retailers, however, who tend to be servicing the higher-end retail market were more willing to share the retail price, dragging the average motorcycle cost significantly higher. For example, two electric motorcycle companies in Uganda provide their motorcycles at a cost of 65,000 UGX ($17.36) and 86,000 UGX ($23.83) / week for two years ($1,805 or $2,478 altogether), which is in the same range as ICE models, though notably the battery is not included in these offers as the same companies provides battery swap services to their respective models.

Industry Associations

As the E2&3W industry in Africa is young, industry associations remain nascent. Industry associations such as the Uganda Electric Mobility Association or Electric Mobility Association of Kenya are not limited to E2&3W alone but are open to all electric vehicle companies. In countries with younger ecosystems still such as Zambia, Ghana and Nigeria, non-industry bodies like the Zambia Electric Mobility and Innovation Alliance have pushed for supportive policy for electric vehicles. On the continent-wide scale, the Africa E-Mobility Alliance (AfEMA) provides research, data and advocacy tools for the transition to e-mobility and hosts the annual Africa E-Mobility Week.

The growth of the African electric two-and three-wheeler market

Across much of Africa, there is a need for lower cost vehicle options to account for lower-income customers, high import taxes, and long distance shipping, as the local manufacturing base in most countries is not sufficiently advanced to compete with Asian manufacturers. In addition, two- and three-wheelers are commonly used for commercial passenger and delivery services on roads that are often not paved and in poor condition, therefore creating demand for robust, quality vehicles. This combination means that the supply of electric two- and three-wheelers in Africa has been hobbled by a lack of domestic industries which would focus on serving the African market. At the same time, lower margins on electric models mean that Asian manufacturers have been slow to adapt their vehicles to African conditions as the market is small in comparison to domestic Asian demand from better-off customers.

Delays in Asian OEMs deployment in Africa

While the transition to electric vehicles has created space for new manufacturers to enter the market, it remains notable that the major providers of ICE 2&3W in Africa - such as Bajaj, TVS, and Haojue - have not yet brought their electric products to market. There seem to be multiple reasons for this:

- The Asian market has been focused on scooter models rather than motorcycles, which are more common in Africa.
- Domestic distributors for Indian OEMs have significant revenue streams from sales of ICE vehicle spares, which are reduced on electric models.
- Asian OEMs view the African export market as being a low-margins market, which makes it costly to bring EVs to market where margins are lower than for ICE vehicles and there is a well-known dearth of EV infrastructure.
- There are also no purchase subsidies in Africa as there are in Asian markets, making Asian markets comparatively more profitable for manufacturers.

One major ride-hailing company interested in transitioning to electric vehicles noted that the lack of manufacturers who can provide electric motorcycles at scale was preventing the company from engaging with the industry. This being said, at least one major Indian OEM plans to enter Uganda by the end of 2024 and begin bringing in 5,000 e-motorcycles per month - but this would only be around 1% of what is needed across the continent.[xii] Still, this could significantly accelerate the deployment of e-mobility in Africa.

Market projection of ICE & electric 2&3W

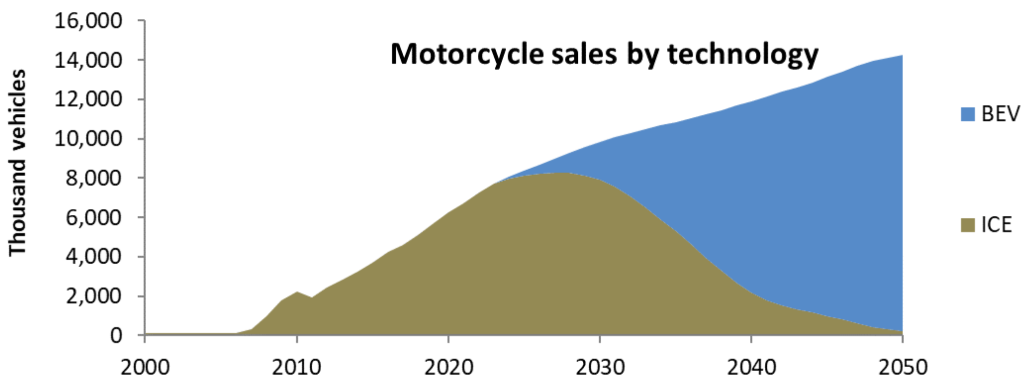
There is little reliable data on ICE 2&3W, and even less on EVs, as some countries are not distinguishing EV imports or are mislabeling them – such as in Tanzania, where most E2W are registered as bicycles. There are many factors that will determine the growth of 2&3W in Africa and the share between ICE and, including but not limited to:

- Supply chain developments, especially for lithium batteries.
- Development and deployment of more affordable battery alternatives, such as sodium ion.
- Uptake in other regions particularly Asia.
- Global and local incentives for EVs.
- Tightening regulations on ICE vehicles in supplier and consumption countries.

[xii] Calculated from the estimate of 20 million motorcycles and an average lifespan of 5 years, implying 4 million imports a year.

- Informal transport regulation, which could either be legitimate and encourage or crack down on and significantly discourage the growth of motorcycle-taxis and tuktuks.
- Local EV charging infrastructural development.
- Changes in electricity access and reliability.
- Local economic growth.
- Development of national EV policies and regulations

For input to the UNEP E-Mobility Calculator, an average lifespan of five years was used. This was the shortest of all regions and is primarily based on the dominance of motorcycle-taxis, which make up a larger share of the fleet than in other regions and are intensively used.



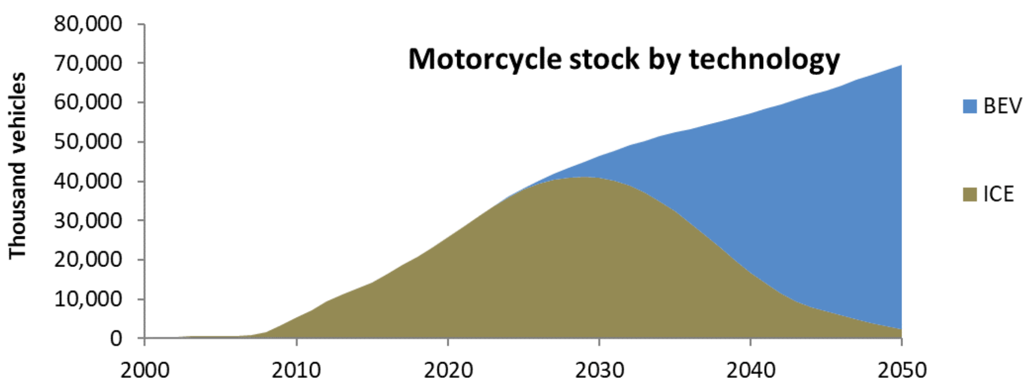


Figure 23. Projection of electric two-wheelers (a) sales and (b) stock in Africa.

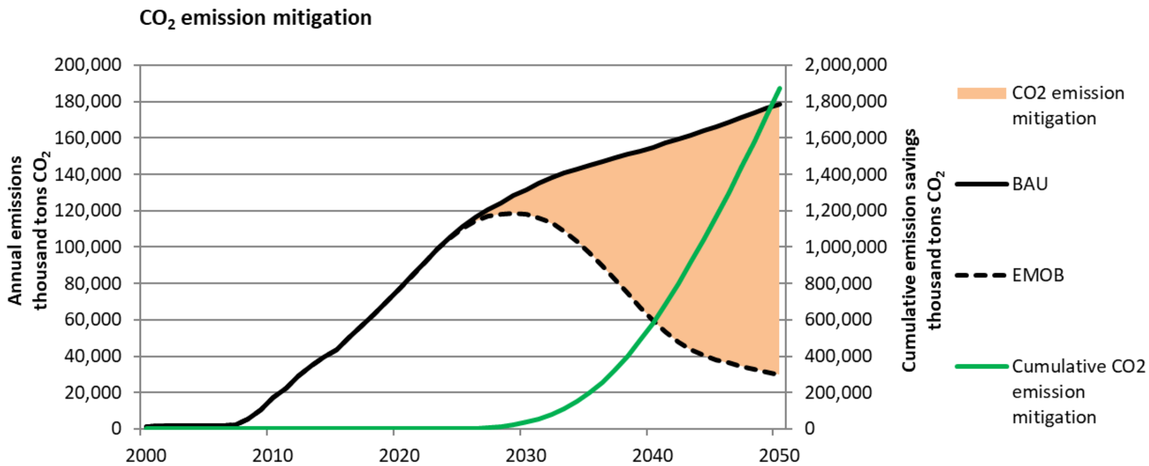


Figure 24. Differences in CO2 emissions in "ICE (BAU) vs E-mobility" scenarios, plus cumulative CO2 emission mitigation for Africa.

An EV share of 71% of the 2&3W stock in 2040 in Africa will be mitigating 95 million tons of CO2 annually. However, this relatively late dominance will result in wasted lives and economic losses from local air pollution, increasing CO2 emissions, lost foreign exchange, and higher daily transportation expenditure for African citizens. It is also a missed opportunity to establish local vehicle manufacturing bases and thereby create new green jobs. Once ICE usage is fundamentally uneconomic, sales of EVs will skyrocket, but it will take several years to phase out the ICE vehicles already in the market. Generally, urban areas are likely to more quickly adopt e-mobility due to better electricity access, higher density of charging and swapping networks, and greater ability to pay, but local contexts and government support can play a large part in this potential inequality. National adoption rates are likely to be accelerated if countries adopt holistic EV strategies including import tax exemptions for electric two- and three-wheelers as has been done in Togo and Rwanda.

The key unknown that will determine this path is the adoption of two-wheeler for personal mobility. If the usage of scooters and motorcycles for personal transportation - not just commercial motorcycle-taxis - is more widely adopted across African countries, this will point to **many more vehicles purchased** (both ICE and EV), and a potentially **slower phaseout of ICE vehicles** as personal vehicles have longer lifetimes and lower energy costs due to lower use than commercial passenger vehicles.

Asia

Two- and three-wheeler presence & usage in the region

Two-wheelers

Asia has long been the engine of the world's two- and three-wheelers growth, both ICE and electric, accounting for over half of global two-wheeler sales and being the primary manufacturing base for electric two- and three-wheelers. As Asia is composed of many middle-income countries with mostly low- to medium-income households living in congested cities, two-wheelers are a popular transportation vehicle as it is perceived as more reliable than public transport at an affordable price. As shown in Figure 25, the top five countries globally for motorcycle production and demand are all in Asia: namely China, India, Indonesia, Vietnam and Thailand. Indeed, between 83-87% of households in Thailand, Vietnam, Indonesia and Malaysia own at least one two-wheeler.[46] In the two countries with the largest two-wheeler populations, China and India, the figures per household are lower but still significant, with 60% and 47% respectively of households reporting having a two-wheeler. The impact of Covid-19 decreased demand and production of two-wheelers in 2020 but the market has bounced back in 2021 due to new demand, particularly from food and parcel delivery.

While countries like Indonesia have significant numbers of motorcycle-taxis, others including China and India are primarily personal use markets. Whole families often travel on a single two-wheeler in Asia. Two-wheelers are used as an effective means of transport for both passengers and deliveries in traffic jam conditions with door-to-door service to destinations that are difficult to reach by four-wheeler. While three-wheelers can be found in much of the region, they are not as popular as they are less flexible than two-wheelers in their ability to move between cars in the traffic.

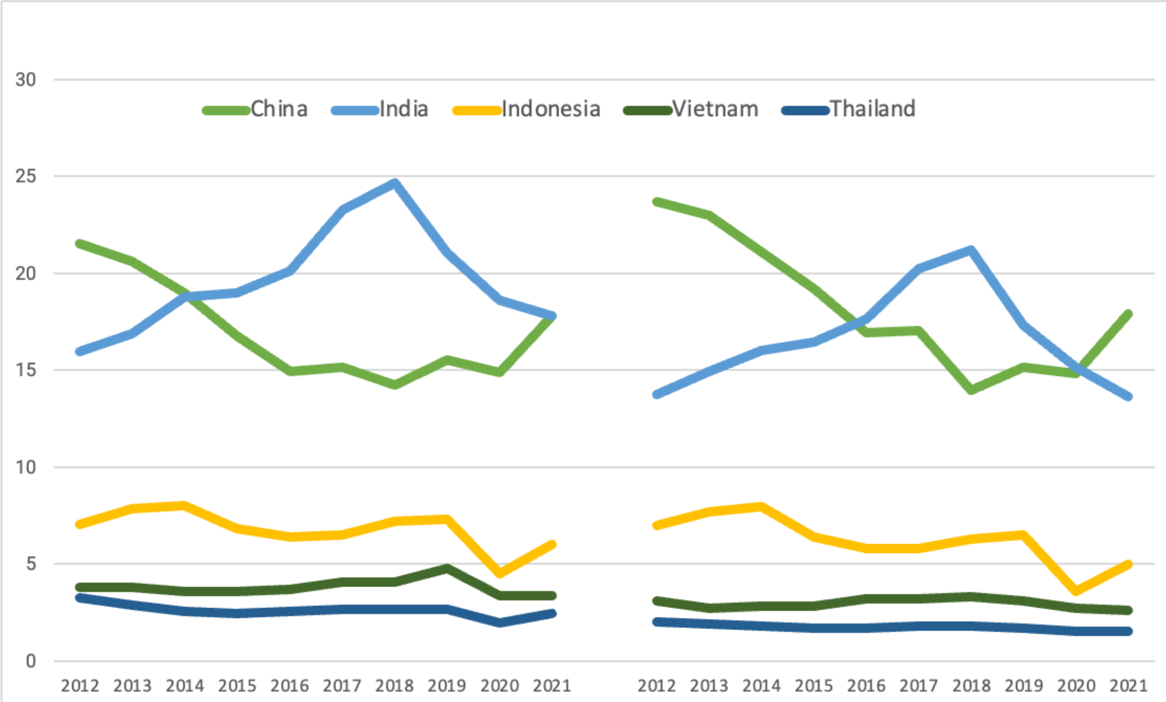


Figure 25. Top 5 countries in motorcycle production (left) and demand (right) in million units. Source of data: Marklines.

The switch over to electric two-wheelers was initially propelled by pollution controls in China over a decade ago, where owners of ICE two-wheelers were required to pay extra or wait to get a permit to ride it in two large cities, Beijing and Shanghai. This restriction boosted the young electric two-wheeler industry in China. Early models of electric two-wheelers used lead-acid batteries as Li-on batteries were still costly. With decreasing Li-on battery costs, many electric two-wheeler manufacturers have shifted over to Li-on while some low-price lead acid models are still sold.

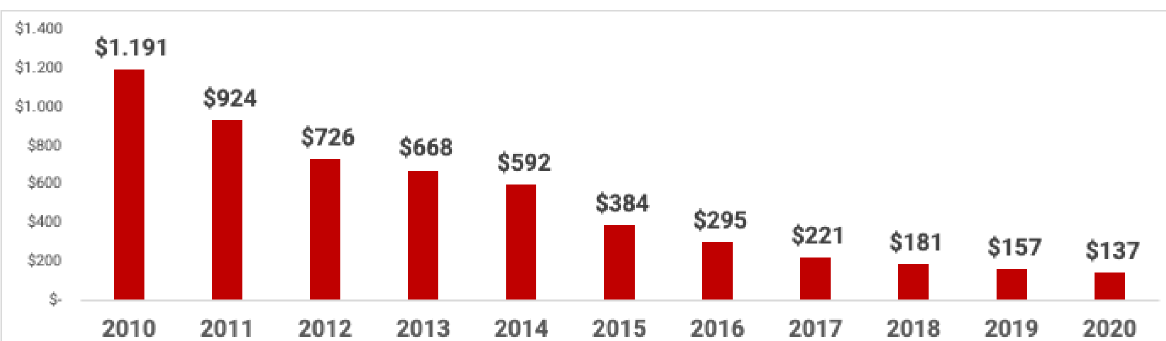


Figure 26. The cost of lithium-ion battery packs per kWh. Source: BloombergNEF.

There has been a steadily increasing share of electric two-wheeler sales in China, peaking at 55% in 2021 before a nearly 10% drop in 2022 due to supply chain shortages of battery materials and integrated circuits during the Covid-19 pandemic and post-pandemic economic turmoil.[47] Another rising market for electric two-wheeler is Vietnam, with electric two-wheelers holding 10% market share of in 2021 and led by local E2W companies Vinfast and Pega.[48]

Three-wheelers

Typical uses of three-wheelers in Asia have included transporting two to four passengers, carrying shopping goods, and moving large home appliances like refrigerators or flat-screen TVs. Efforts to reduce pollution in large cities have included bans on delivery trucks, which in turn have also helped make three-wheelers popular for last-mile deliveries.[49] Asia, especially India, China and Vietnam, has dominated the global electric three-wheeler fleet. India has the largest fleet and share of electric three-wheelers, with more than half (55%) of 2022 3W registration being electric - though a significant number in India and Bangladesh use lead-acid batteries.[50]

Despite a drop in E3W sales during the height of the Covid-19 pandemic in India, E3W sales sprang back to the previous level due to strong government policy, a generous subsidy scheme for lithium-ion electric vehicles, and the rollout of battery-as-a-service (BaaS) business model for both cargo and passenger services.[51] However, a significant amount of the e3W in India are still lead-acid, estimated about 50% in 2021.[52] For China, only a small fleet of electric three-wheelers existed prior to 2018 due to unclear government policy and regulations despite huge demand for cities' last-mile delivery. After clear policy and regulation on electric three-wheelers was issued in 2018, the market has picked up to show continuous sales of 200,000-300,000 units per year, reaching approximately 20% of the three-wheeler market in China.[53]

Box 8. Battery-as-a-Service (BaaS)

Similar to Mobility-as-a-Service (MaaS) business models such as ride-hailing services, Battery-as-a-Service (BaaS) is an innovative business model to provide battery swapping for 2&3W users. This relieves users of having to own and care for a battery, which is the most expensive part of an EV. In addition to reducing the need for high capital investment for switching from ICE to E2W, BaaS relieves the E2W owner of the burden of battery handling and maintenance. The BaaS model has allowed Asia to get to a leading position in switching from ICE 2W to E2W, especially for commercial riders with daily long-distance usage. Swapping cabinets with algorithmic control to optimize battery usage also help prolong battery lifetime which has environmental and economic benefits.

Our survey of e2&3W models in Asia shows that scooter models dominate the market, followed far behind by motorcycles, as shown in Figure 27. In the electric three-wheeler category, there are double the number of models of passenger tuktuk as cargo tuktuks.

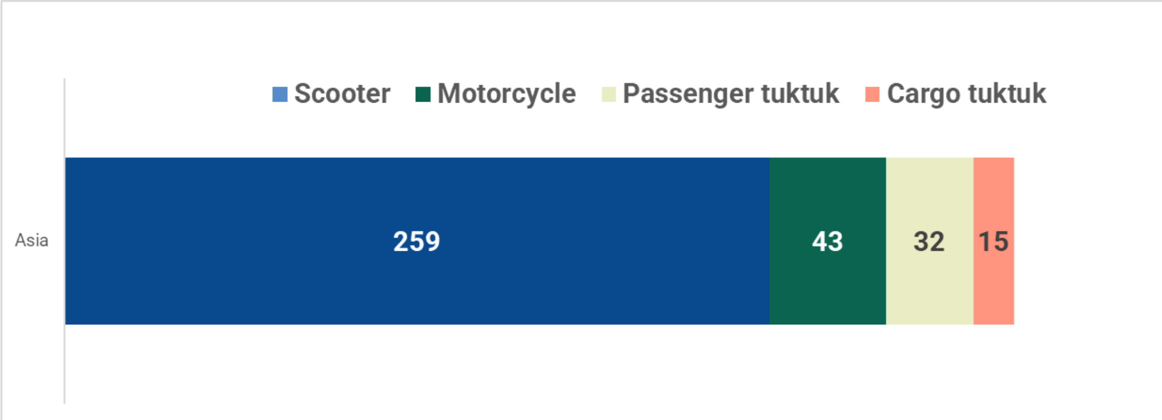


Figure 27. Vehicle types in Asia (number of models in database)

Charging & swapping infrastructure

To address the barrier for electric vehicle uptake of longer charging time, Taiwanese electric two-wheeler company, Gogoro, built a flag bearing battery swapping model on a subscription basis. With over 22,000 battery swapping stations available 24-hours a day, users of electric two-wheelers feel little difference from switching over from ICE two-wheelers.[54] In addition, Gogoro has partnered with several vehicle makers to ensure their battery works with other brands, reducing dependence on Gogoro vehicle sales and expanding their customer base by serving other manufacturers models. Gogoro's success is usually ascribed to a combination of being an early mover and developing a battery that was technologically advanced, fit for market and could work with other manufacturer's scooters.[55]

Battery swapping is also becoming popular in other Asian countries. In November 2020, the Ministry of Energy and Mineral Resources of Indonesia launched a battery swapping station in Jakarta, in a joint effort with private companies including ride hailing company Grab, E2W manufacturer Kymco and battery swapping providers Ezyfast & Oyika. In October 2022, an electric motorcycle charging infrastructure roadmap for Indonesia was developed by the Asian Development Bank with a policy target of E2W being over 50% of 2W sales by 2030.[56] Battery swapping is also being explored in India for both E2W and E3W.[57] In Thailand, battery swapping is offered for E2W by national oil companies, e.g. Swap & Go (owned by oil and gas company PTT Group) and Winnonie (owned by oil and gas company Bangchak), as well as the electricity state enterprise (Electricity Generating Authority of Thailand, EGAT). The battery swapping model can help attract more riders to switch from ICE 2W with by lowering E2Ws upfront cost, which, could help achieve Thailand's policy target of 30% of locally manufactured vehicles being EVs.[58]

Also in Thailand, a national research project led by the National Energy Technology Center (ENTEC), in partnership with local E2W manufacturers, local battery manufacturers and local battery swapping operator, aims to improve the common swappable battery standard TISI-3316 (2021).[59] In addition, the Electric Vehicle Association of Thailand (EVAT) has been trying to establish a 'Charging Consortium' to improve interoperability of various charging providers for electric two-wheelers, as well as exploring an 'EV roaming' platform with other electric vehicle associations in ASEAN.[60]

From Figure 28, the average battery capacity (kWh) of cargo tuktuks was 1.7 times larger than passenger tuktuks, similar to patterns in Latin America and Africa. Electric two-wheelers in Asia also have comparable average battery capacities to Africa, and around 30% larger than Latin America. However, premium e-two-wheelers have much larger battery capacity in Asia, and this is likely to continue with increasing incomes in the region.[61] In terms of swapping capabilities, a little under half of electric two-wheelers models are explicitly swappable while most were not specified. For those countries with widespread swapping like China and Taiwan, the models' catalog typically indicates whether they are swappable, whereas for other countries with low levels of swapping stations, the model catalogs may not explicitly spell out swapping features. Today, almost all electric two-wheelers architecture in Asia allow batteries to be taken out easily for repair or swapping, while this remains more difficult for electric three-wheelers due to weight and design.[62] Hence, whether electric two-wheelers can swap the battery often depends more on supporting swapping station infrastructure rather than vehicle type.

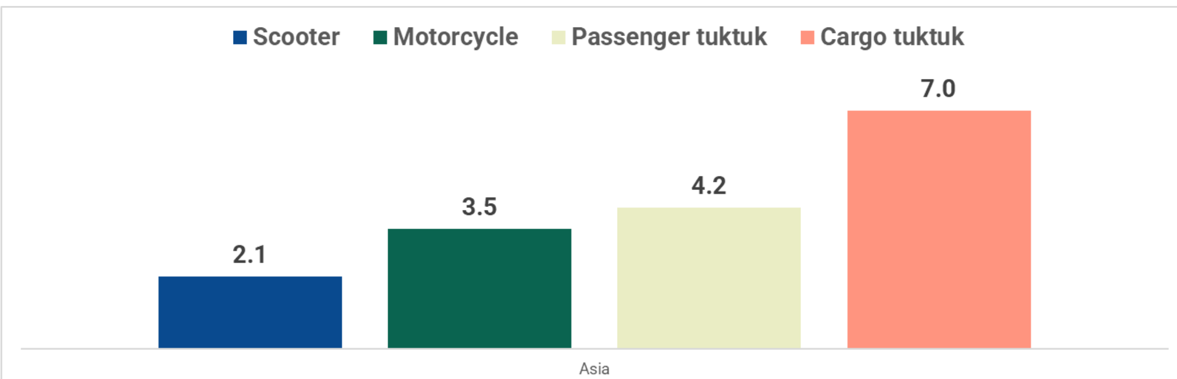


Figure 28. Average battery capacity (kWh) in Asia by vehicle type.

The landscape of vehicles

Two-wheelers in Asia are a widely used vehicle for low to middle class families for personal trips. Recent consumer preferences for larger and high-performance ICE two-wheelers have attracted manufacturers to provide higher motor power for both electric motorcycles and scooters (as shown in Figure 29). The segment of electric two-wheelers with 4 - 7 kW motors is expected to grow in the market.[63] As for electric three-wheelers, the Indian market is growing rapidly partly due to the national Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (FAME-II) scheme, which provided a subsidy based on battery capacity and was up to 40% of the total vehicle cost, though this has reduced to 15% as the program winds down.[64]

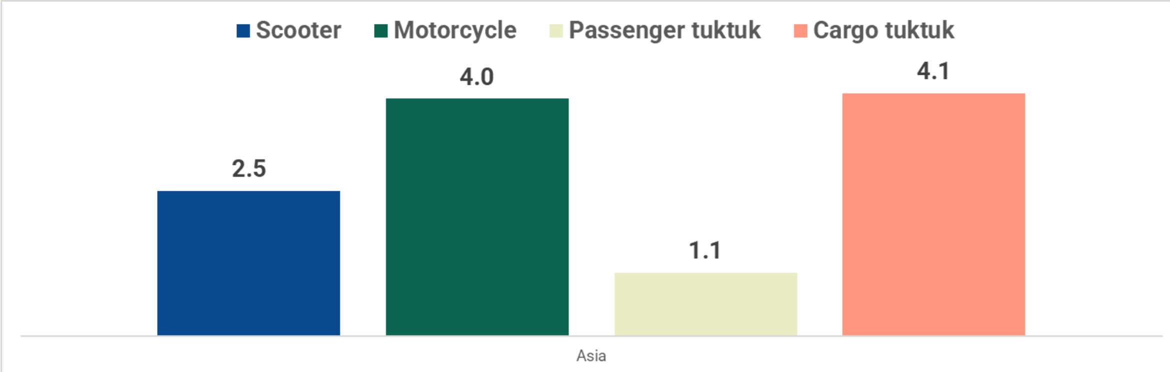


Figure 29. Motor rated power (average kW) in Asia by vehicle type.

Industry structure

Most electric two- and three-wheelers available in Asia are manufactured in the region, benefiting from an existing ICE vehicle industry, simpler registration and wide access to a large customer base. However, there are a few large, high-performance and high-cost electric motorcycles from Europe that are also available in Asia. Industry data was obtained from various industrial organizations, such as the following:

- China Chamber of Commerce for Motorcycle: CCCMP
- Vietnam Association of Motorcycle Manufacturers: VAMM
- Society of Indian Automobile Manufacturers: SIAM
- Taiwan Transportation Vehicle Manufacturers Association: TTVMA
- Asosiasi Industri Sepeda Motor Indonesia: AISI
- Thai Automotive Industry Association: TAIA

The consolidation of an electric two-and three-wheeler market

Figure 30 shows electric motorcycles have the longest claimed range of 107 km, excluding premium motorcycle models, whereas passenger tuktuks and scooters have an average range of 72 and 89 km respectively. This makes them a good fit for passenger transport with short-range use but may require a top-up charging or swapping station in order to satisfy more intense commercial usage.

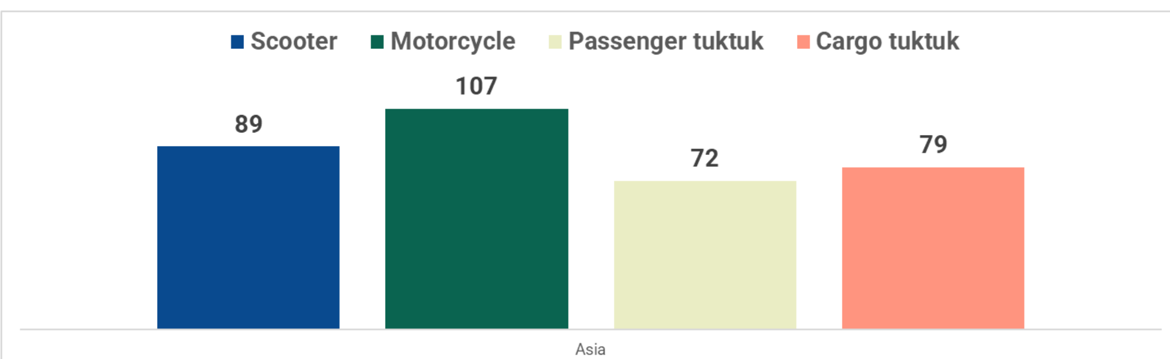


Figure 30. Claimed range in km in Asia.

Market projection of ICE & electric 2&3W

As China has been leading the production and sale of ICE two-wheelers followed by electric two-wheelers for the past two decades, its current market has become saturated over the past decade whereas other markets such as Vietnam and India show higher growth rates .[65] From a sales peak of 30 million electric two-wheelers in 2016, the Chinese market for electric two-wheelers declined in anticipation of a new national technical standard in 2019, which only promotes electric two-wheelers with Li-on batteries. In 2020, more than 100 OEMs in China manufactured 33.9 million electric two-wheelers with 95.1% being sold domestically. A few OEMs dominate the scene: more than half of the market belongs to Yadea, Aima, Tailg, Luyuan and Xinri.[66]

The Indian market shows strong growth in electric two-wheelers coming from favorable government policy making the total cost of ownership similar to their ICE counterparts. Currently, small electric scooters dominate the market but there are an increasing number of more powerful models from two big brands, Ola and Ather.

In Southeast Asia, Vietnam has the highest growth for electric two-wheelers, while Thailand and Indonesia markets will grow in the near future due to the recent rollout of government subsidies. In Vietnam, local brands like VinFast, Datbike, Arevo and Pega, as well as foreign brands, such as Yadea, Dibao, and Niu are the main players. The use of battery swapping has been introduced in Thailand and Indonesia to overcome the higher upfront cost of e-motorcycles. Figure 31 shows the projections for electric two-wheelers in the region.

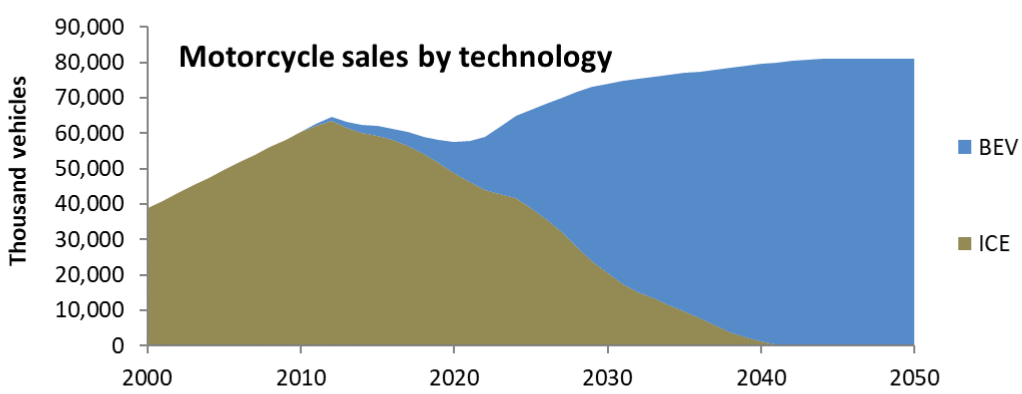
In Indonesia, the market for ICE 2w has been growing at 5.9% annually since 2015 with over 125 million units in the country in 2022. They are used for both personal and commercial uses (ride-hailing and delivery). Since the Presidential Regulation No. 55 of 2019 regarding the *Acceleration of Battery Electric Vehicle Programs for Road Transportation,* which serves as the EV roadmap, many fiscal policy interventions have been issued to reduce various taxes, such as Goods and Services Tax, vehicle tax, ownership transfer fee and Value Added Tax for local content > 40%. According to the Asosiasi Industri Sepeda Motor Indonesia (AISI), E2W have been increasing significantly since 2020 with 32,000 units registered as of the end of 2022 from both foreign (Kymco) and local (Gesit & Viar) brands.[67] Gesit is the first electric scooter manufactured in Indonesia, produced by PT Wijaya Karya Manufaktur (WIMA), a joint venture between PT Wijaya Karya Industri & Construction (WIKON) and PT Gesits Technologies Indonesia (GTI).[68] Recent policy includes a $458 subsidy for electric two-wheelers containing at least 40% local content, with the aim of selling 200,000 new E2W by the end of 2023.[69]

In Vietnam, the ICE two-wheeler market has been dominated by Japanese manufacturers Honda and Yamaha, who held market shares of 71.8% and 15.8% respectively in 2020. However, sales in Vietnam have been declining during the Covid-19 pandemic and as the country reaches saturation of 2W ownership.[70] On the other hand, Vietnam's E2W market has been dominated by local manufacturers VinFast, Pega and Anbico, who benefit from governmental support for local industry. This has helped Vietnam grow to become the world's second largest E2W market after China, shifting from importing electric two-wheelers from leading E2W manufacturers in China, Japan and Korea to local manufacturing and export.[71] Although VinFast has been a leader in providing both public charging infrastructure and battery swapping in collaboration with state-run PV Oil, the leading petroleum company in Vietnam, both public networks are still limited as E2W users mainly charge at home. With an annual production capacity of over 1 million E2W in the country, Vietnam can become a hub of E2W production for export to other ASEAN countries.

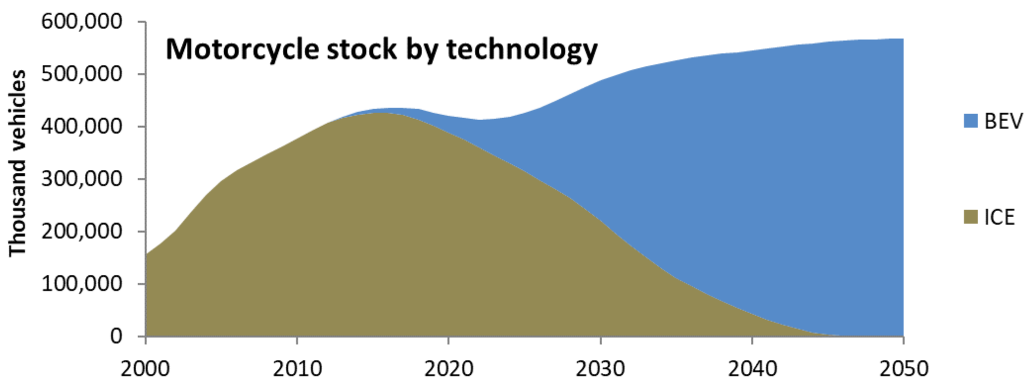
In Thailand, the E2W market started to pick up in 2022 with a governmental subsidy of 18,000 THB (US$ 517) per unit if locally assembled. On the other hand, E3W sales have been limited as safety concerns – same as those that have plagued the ICE 3W sector in Thailand – have led to the restriction of 3W registration. There is increasing use of E2W in the commercial sector, both as passenger taxi and for delivery.[72]

Given the recent development of electric two-wheeler industries in the major Asian economies of China, India, Indonesia, Vietnam and Thailand, these countries are expected to continue to dominate the market for the near future. Regional market projections for electric two-wheelers show a shift from a saturating market in China to emerging markets in India and Southeast Asia. We therefore assume electric two-wheelers across the region to reach 100% sales market share by 2040.

To project the baseline of two-wheeler sales in Asia from the historical record (2012-2021) in the top five economies mentioned prior, we assumed that they represent 70% of vehicle sales in Asia.[73] We used the UNEP E-Mobility Calculator and plugged in population and economic growth data for Asia, as well as historical sales of electric two-wheelers in the region, assuming an average seven-year lifespan.[74] With an already large population of electric two-wheelers in Asia, the gradual increase of electric two-wheeler sales will reach 100% around 2040 and overall sales for two-wheelers will plateau at around 70 million. The stock of electric two-wheelers is expected to follow shape with a gradual increase.



(a)



(b)

Figure 31. Projection of electric two-wheelers (a) sales and (b) stock in Asia.

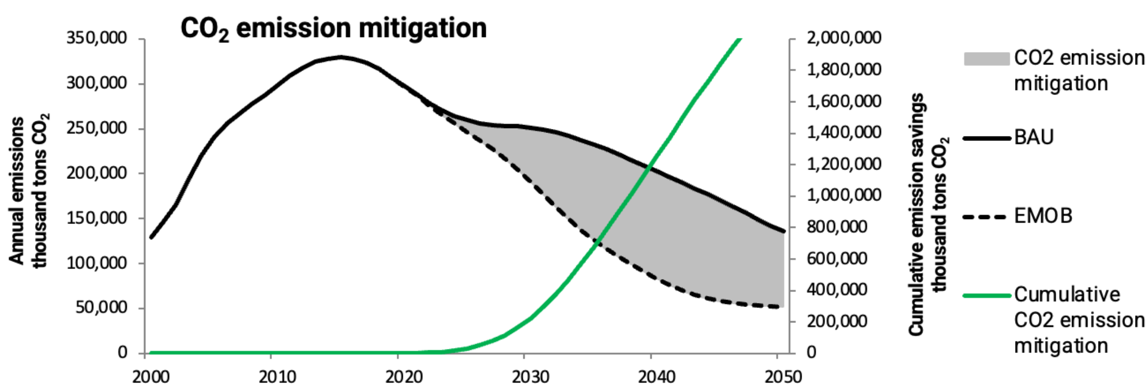


Figure 32. Differences in CO2 emissions in "ICE (BAU) vs E-mobility" scenarios, plus cumulative CO2 emission mitigation for Asia.

Latin America & Caribbean

Two- and three-wheeler presence in the region

Latin America is a region where ICE two- and three-wheelers growth has been quite recent after slow uptake during a large part of the twentieth century. Starting in Brazil in the late 1990s, two- and three-wheelers have since grown rapidly in cities across the region.[75] This was partly the result of the construction of several manufacturing plants in the region, which substantially reduced the cost of these vehicles and, consequently, increased uptake.[76] As described by several authors,[77] public transport has suffered considerably from the passenger loss of these systems and road safety has become a major public health concern. However, the increased availability of two- and three- wheelers at affordable prices has meant that lower income populations can have greater mobility and improved access to jobs in areas underserved by public transport.[78]

In the case of electric two- and three-wheelers, the market is predominantly composed of Asia-manufactured vehicles, and uptake has not yet been substantial as per discussions with distributors and shops. Electric two- and three-wheelers seem to be part of a niche market, still too expensive to enter mass market. In Colombia, where importation and purchase of electric vehicles has been strongly promoted, prices of electric two- and three-wheelers have come close to their ICE counterparts. However, range anxiety continues to be a major concern for consumers, and is often cited as one of the key factors in preventing the purchase of electric vehicles, including motorcycles.[79] Range anxiety is exacerbated by a lack of charging or battery swapping systems, which would allow users to take the occasional longer trip (as they might with an ICE vehicle) without a larger-than-average and therefore costly battery. While there is no network of battery swapping system in the region, some brands have begun to conduct battery swap pilots in Mexico, Brazil and Colombia. Charging networks are not widespread either in the region.

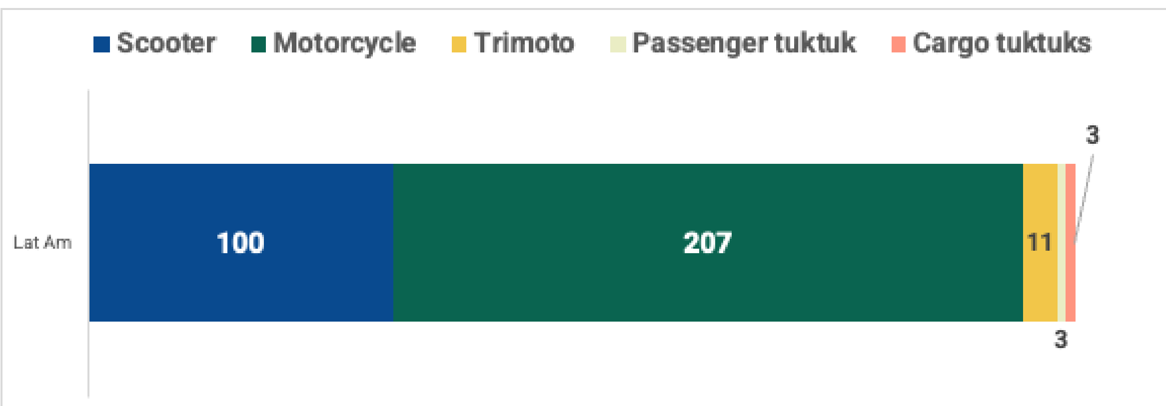


Figure 33. EV vehicle types in Latin America.

Use cases of two- and three-wheelers and uptake of electric versions

In general, two- and three- wheelers in Latin America are used for personal trips for individuals or families, deliveries and small freight, and to a lesser extent as a public transport mode (in smaller cities, this is more popular). Historically, motorcycles have generally been more common in small cities and towns, where public transport service is infrequent and unreliable and lower income populations have used them as their main travel mode. Today, however, the presence of passenger, delivery, and commercial passenger motorcycles have all increased in larger cities where congestion is greater and demand for home delivery has risen.

In many cases, electric two-wheelers are being used by people who have “fled” public transport because of concerns over crowding, inconvenience, unreliability, or safety.[80] Industry stakeholders indicate that most electric two-wheelers are purchased by low-to-middle income citizens. This is particularly true for lead-acid models, which remain in distribution throughout the region. This could also be due to the effective promotion of electric motorcycles as being cheaper to own, operate and maintain to those who are purchasing a vehicle for the first time.

Several public entities in Costa Rica,[81] Argentina,[82] Salvador,[83] and Chile[84] purchased small fleets of electric motorbikes (or cargo tuktuks, in the case of Costa Rica’s postal service)[85] between 2021 and 2022 for government services including traffic police, health and postal services.

Charging & swapping infrastructure

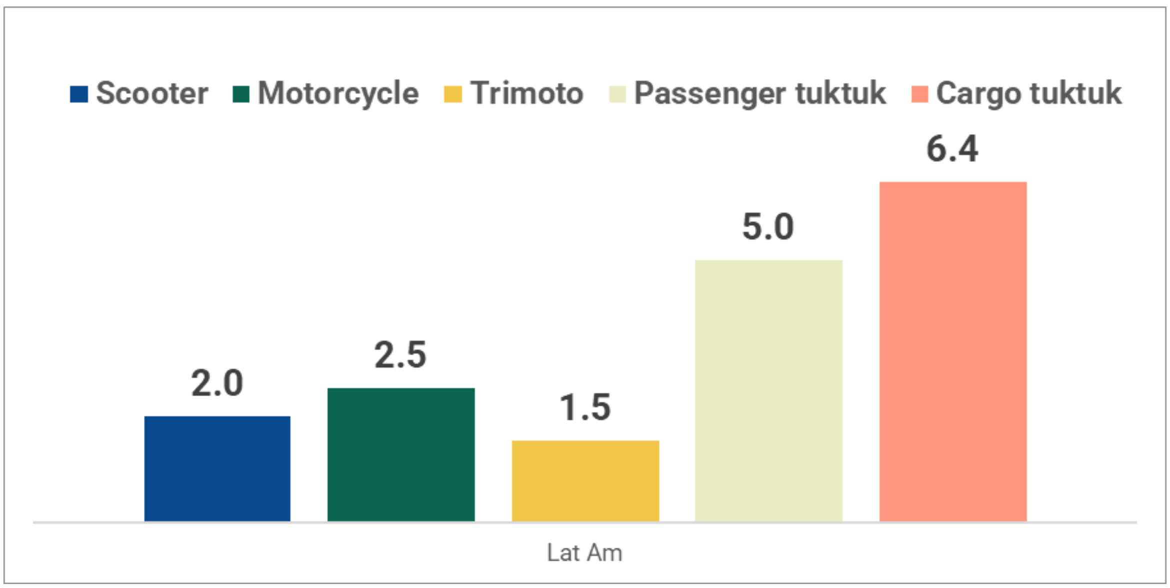


Figure 34. Average battery capacity (kWh) in Latin America by vehicle type.

Latin America does not yet have significant charging infrastructure for electric two- and three-wheelers, and charging is predominantly done at home with regular sockets. With respect to battery swapping, even though most E2&3W have swappable batteries and batteries for scooters and motorcycles have an average capacity of 2 and 3 kWh respectively, several obstacles exist in deploying large-scale swapping networks. The first of these is the lack of proper regulation for electric two- and three-wheeler charging, as existing regulations only cover electric four-wheeler charging infrastructure which makes it cumbersome (and sometimes illegal) to build E2W charging stations.

With regards to battery swapping networks, these are almost non-existent in the region though there have been pilot deployments in Brazil (led by food delivery services in Sao Paulo) and in Colombia (in Medellín by Auteco and AKT, distributors of Niu and Supersoco), as well as in Mexico.[86] However, the lack of standardization of battery characteristics has made it difficult to develop a suitable large-scale network that does not depend on specific brands. The atomization of the market – several brands working with an individual aim to gain market share, and little cooperation between them – has also been described as a reason for not having a massive deployment of battery swapping networks. However, companies such as Vammo and Leoparda Electrica have begun to experiment with a Gogoro-like model since 2021.[87]

Another challenge facing charging infrastructure is the lack of standardization of charging plugs, which increases the complexity and cost of deploying charging stations at scale. Finally, a risk-averse culture that doesn't motivate the industry to launch large-scale endeavors of charging networks (which have a high capital cost) and a large proportion of unbanked customers slow down the deployment of charging or battery swapping stations.

To address the challenge of higher upfront costs, battery leasing is being tested to increase availability of batteries without requiring direct purchase, which industry stakeholders and experts agree can increase vehicle uptake by bringing the cost of EVs closer in line with ICE vehicles. Some experts in the region argue that a stronger case can be made for a "business-to-business" deployment of swappable systems, where large companies own swapping stations in their buildings for company staff. This could help tackle both upfront costs and the lack of infrastructure. In the case of intensive vehicle usage by corporates such as delivery companies, outfitting private buildings with charging stations, which don't require complex permitting processes and can be deployed more quickly than public stations, could be another boost to charging infrastructure.

A landscape of vehicles

Industry structure

Given the recentness of the introduction of electric 2&3Ws in Latin America, there is little systematized information available, as governments in the region have not always clearly defined these vehicle types in tax categories or vehicle registration data. This has made it difficult to assess the size and characteristics of the market and its ongoing evolution. For instance, Asomove, an electric mobility association in Costa Rica, has not been able to produce analysis for these vehicles given the lack of differentiated sales and other important data by the government. Data surrounding electric cars is much better, as vehicle categories are well defined in legislation and import regulations in most of the countries surveyed – though in some countries, such as Bolivia, there are still no available official registration or importation records of electric vehicle models specifically.

China is the major manufacturer of E2&3W in LAC, and these imported E2&3W are sold through local distributors. The main role of the existing private sector players in the region is to assemble, distribute and market the vehicles, while design and production of component parts are done abroad.

While there are some European and American models such as Starker, Segway and Niu, their higher cost makes them less competitive. Oftentimes, Asian brand and model names are rather fluid in that the same vehicle can appear with two or three different brand or model names when sold in a different country. This may mean that other more generic brands have a larger market share but with an array of names.

In some cases, stakeholders have created country-wide associations that promote electric mobility policies and uptake which, though not exclusively related to two- and three-wheelers, advocate for their increasingly important role. Their work entails gathering information and statistics, lobbying for better regulation, and aligning the interests of industry members, as well as organizing events, fairs and campaigns to raise awareness. However, their work in advocating for the 2&3W subsector is made more difficult by a lack of reliable statistics.[88] These associations have also begun to be represented in motorcycle-themed events and fairs. Such is the case of the "Feria de Dos Ruedas" two-wheeler event in Colombia which has progressively included electric models in their exhibits.[89]

The extraction of critical minerals such as lithium has also helped push for the development of local EV industry. This has led Bolivia, which has significant lithium reserves, to create a nascent battery assembly industry, while some vehicle factories are starting to manufacture electric motorcycles.[90] Mexico has also started to develop their own electric vehicle industries, seeking to combine the exploitation of lithium with a pre-existing ICE auto industry.[91]

The consolidation of an electric two-and three-wheeler market

Figure 35 presents the average range in kilometers according to vehicle type, while Figure 36 presents the rated power of each vehicle model, as per the data collection exercise done in this study. Manufacturers provide vehicles with average ranges from 60 to 85 km, with trimotos having the shortest average range and motorcycles the longest.

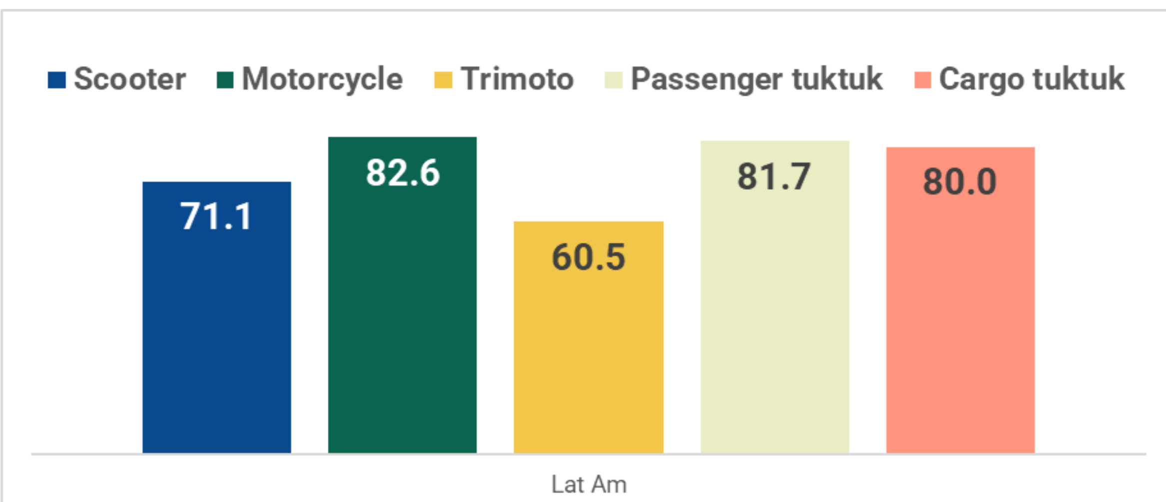


Figure 35. Average range in kilometer vs vehicle type.

Box 9. Micromobility in Latin America

Though they are not included in the associated catalogue, it is relevant to mention that smaller electric micromobility vehicles have had considerable success in the region. This is despite the generally poor condition of streets, but due to the high density of cities in the region and the related short trip distances; with some exceptions such as Sao Paulo and Mexico City where trip distances are often much greater than 20 kms. From discussions with distributors, electric kick-scooters enjoy greater popularity when compared to their larger counterparts, due to lower costs, the inexistence of ICE equivalents and the very lax / inexistent regulation related to small electric vehicles in general. These small vehicles are generally allowed to circulate anywhere, either because regulators don't perceive a problem in their use, or because there is a lack of progress in updating regulation. However, these are only seen in large urban areas with higher quality roads, where the low ground clearance of micromobility is less of an issue. Origin-destination surveys have just begun to include these smaller vehicles, so data is not widely available on their mode share in daily trips.

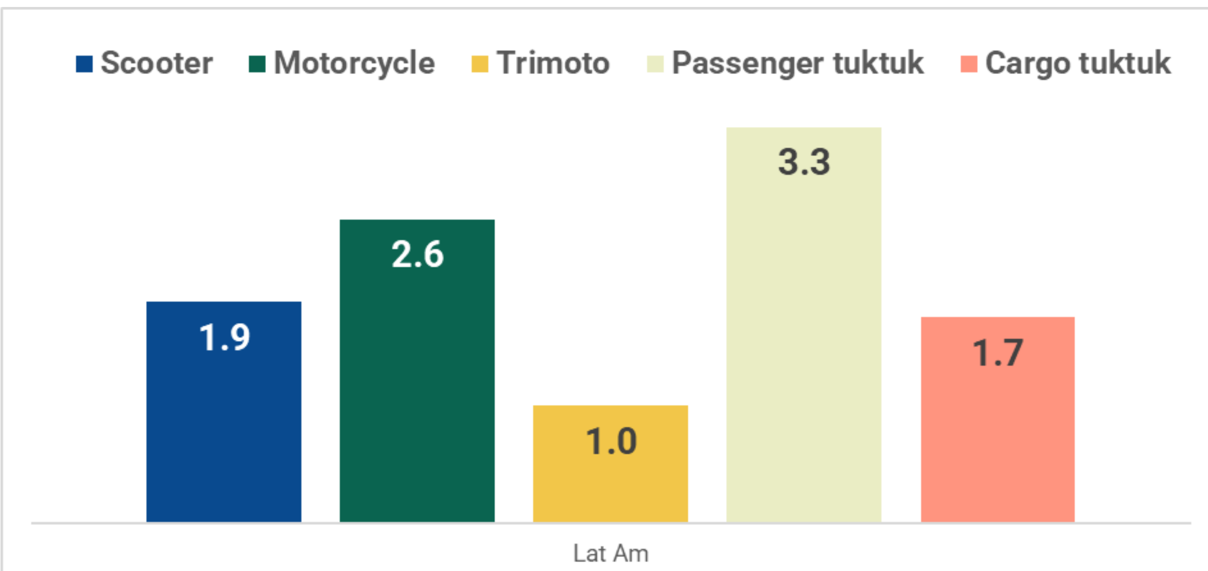


Figure 36. Motor power & vehicle types in Latin America.

Stakeholders interviewed for this project have indicated that the following issues could substantially increase the electric two- and three-wheeler market in the region:

- **Reductions in levies and fees assigned to the purchase of electric two- and three-wheeler vehicles**. This and other regulatory stimuli can help to lower the comparative costs of electric vehicles.

- **Offering tax incentives.** Currently only electric cars enjoy well-defined tax reductions and purchase incentives. An example is Bolivia, which has removed the import tax and reduced the specific consumption tax on electric passenger cars, ordered the National Energy Company to build out charging stations, and set a goal of 10% growth rate in EV sales for public transport by 2030.[92] Governments throughout the region should ensure these benefits are also extended to E2&3W to support their growth.

- **At the local level, clarifying allowed uses, circulation and non-fiscal incentives related to the daily operations of E2&3W.** Doing this would help increase investor and consumer trust in the sector, improve road safety, and reduce conflict over road use. This holds especially true for the lower-powered versions that are not allowed on cycling infrastructure but can become unsafe when operating in large avenues due to their smaller size and slower speeds.

- **More stringent emissions standards for ICE vehicles.** By creating financial disincentives for ICE vehicles, the government can push the market in the direction of adopting E2&3W.

- **National level regulations**. Regulation that applies to electric motorbikes is generally included in a "electric mobility law" or similar national-level instruments. However, in the e-mobility laws of Argentina, Colombia, and Ecuador there is no specific mention or incentive for two- and three-wheelers, as most are specifically aimed at automobiles or buses.[93] The exceptions are Panama, Paraguay, and Guatemala.[94] In the case of Peru, very stringent regulations for two- and three- wheelers were sanctioned in 2022, which required mopeds to have a specific insurance scheme – but the scheme was not yet on offer by insurance companies, creating uncertainty for E2&3W companies and users alike.[95]

- Improved **infrastructure** conditions for two- and three-wheelers. These, including special lanes for smaller electric vehicles similar to cycling infrastructure but for a wider range of vehicles could increase uptake by improving safety and visibility.

- More **charging / swapping infrastructure** for electric two- and three-wheelers. While some initiatives exist in this regard, they are small and purely private sector driven. In some cases, the lack of standardization makes it difficult for public charging stations to be deployed effectively and en masse, as the usage of different plugs can result in redundant infrastructure.

The E2&3W uptake in the region is unequally distributed. Some countries have a much stronger presence and uptake of electric two- and three-wheelers[xiii] (notably Costa Rica, Colombia, Mexico and Brazil) while others lag behind in their introduction and presence

[xiii] Most discussions and references around this topic refer to electric two-wheelers specifically. Electric three-wheelers in Latin America are more of an outlier.

(Chile, Salvador, Guatemala). In Guatemala only 122 electric motorcycles were sold in 2022, while Costa Rica sold 1,077, Colombia sold 2,688 in that year[96] and Argentina sold 1,929 in 2022.[97]

Market projection of ICE & Electric 2&3W in Latin America

The vehicle data that is available is usually aggregated for all electric vehicles. Only a few countries have recently started to disaggregate two- and three-wheelers. Hence, the projection relied heavily on known historical values of ICE motorcycles, and the scarce data available on fleet and sales of electric two- and three-wheelers in some Latin American countries.

This projection used UNEP's Electric Mobility Calculator, and an average lifespan of seven years was assumed for two- and three-wheelers.

Results of projection

The following figures present the results of the projection prepared for Latin America.

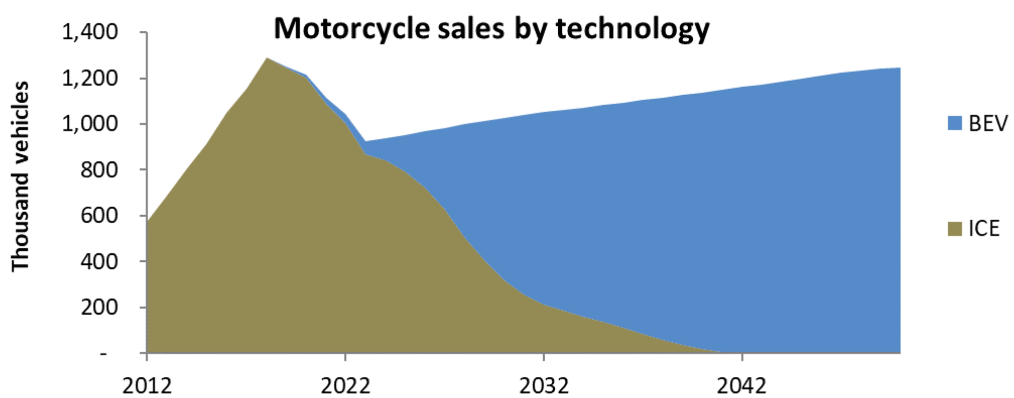


Figure 37. Projected evolution of ICE and electric two-and three- wheeler sales.

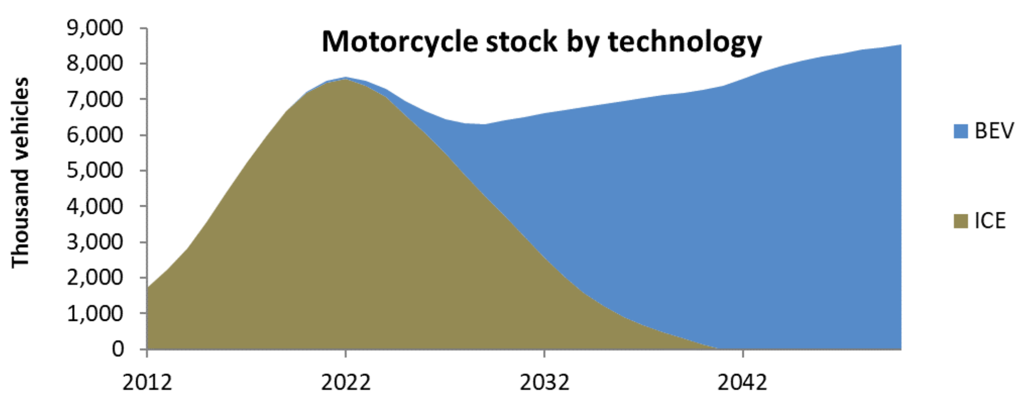


Figure 38. Projected evolution of ICE and electric two-and three- wheeler stock.

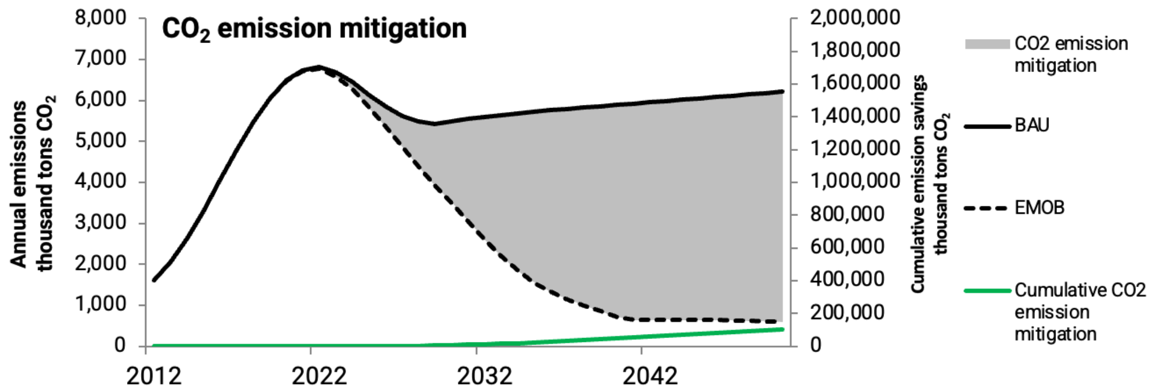


Figure 39. Differences in CO2 emissions in "ICE (BAU) vs E-mobility" scenarios, plus cumulative CO2 emission mitigation for Latin America.

The result of the projection is that electric two- and three- wheelers will progressively replace the ICE fleet. This assumes that the costs of battery capacity and vehicle autonomy will continue to decrease as production, new technologies, and new battery chemistries are scaled up. This would bring electric motorcycles to cost parity with ICE versions and provide long-term savings for users due to lower operational costs. These cost savings from transitioning from fossil fuels to electricity as well as savings on maintenance are then expected to drive uptake in Latin America. The shift to electric vehicles will also deliver significant societal benefits in lower energy consumption, CO2, and NOx emissions and improved air quality.

Questions remain around the mode shift towards electric two- and three-wheelers from public transport and larger personal vehicles, and whether this would influence overall sustainability of the transport sector. This is likely to be determined by the growth and improvement in public transport services, as well as travel-demand management measures applied in dense cities and the region's economic development.

Potential improvements and reflection

If more data at the user and shop/distributor level on existing stock, annual sales by country, vehicle specifications, profile of owners, and operator use in terms of kilometers ridden and charging behavior were available, a future version of the report could respond to the following questions:

- Whether the changes in fleet size of electric two- and three-wheelers result from mode shift from public transport or other modes.
- How improvements in taxes, levies, and regulations associated with electric mobility increase the fleet, and the duration of these effects.
- How the build out of charging and battery swapping infrastructure impacts uptake of electric two- and three-wheelers.

An ideal scenario would be one where the mode shift results primarily from ICE two- and three- wheelers and cars and not from public transport or non-motorized transport. There are two major levers in this discussion: the role and eagerness of the private sector, and decisive policy action.

The private sector, composed of an industry of distributors, dealers, fleet owners, and charging / swapping station operators, has a significant role in enabling the uptake of electric two- and three-wheelers. Interviews with industry stakeholders have indicated that interest in this uptake is mild from large distributors, given their role in manufacturing ICE vehicles which currently provide greater profit margins. Improvements in comparative costs of electric and ICE two- and three-wheelers happening now will surely increase the interest of these stakeholders and generate a tipping point moment where electric two- and three-wheelers become more lucrative. This in turn would increase sales and change the proportion of electric vs ICE two- and three-wheelers in line with the projections above.

Latin America may continue to have a hesitant approach towards electrifying transportation. This has held true for issues such as mass transit implementation, transit-oriented development, bikeway development and other topics.[xiv] In all of these, critical mass has taken more than twenty years to flourish. However, mass adoption of E2&3W is likely to be driven by the private sector which tends to move faster than governments.

Finally, policies towards these vehicles should direct citizens and users towards adoption as complements to public transport, as a supporting vehicle for local logistics, and as a replacement of ICE motorcycles. Electric two- and three- wheelers could help transform polluting fleets into cleaner ones and increase access to jobs and opportunities. However, governments should be wary of a mass adoption that cannibalizes public transport and worsens road safety as has been the case with the ICE counterparts.[98] While this document describes the factors that could increase sales of electric two- and wheelers, delivering environmental and social benefits, it's clear that it should not be to the detriment of public transport, walking and cycling.

[xiv] Several cities in Latin America are now well-known for their deployment of large-scale BRT systems. However, these took years (if not decades) to be deployed en masse (the first being in 1974 in Curitiba, the second in 1990 in Quito, and the actual large-scale uptake since 2000 in Bogotá). The same can be said of bikeways (first large-scale network in Bogotá in 2000 which was only truly scaled up after 2010 in the rest of the region). In some cases, such as public bicycle systems, there is little progress in large-scale deployments while in Europe, US and Asia the deployments have been quicker.

Appendix A: Acknowledgements / Interviews

UNEP spoke to a wide range of experts in the field, including EV and ICE manufacturers, retailers, financiers, and users, as well as policymakers, investors, and researchers.

In a few limited cases the name of the organization was not open to the public and we have instead listed their general affiliation.

Africa

Olou Koucoi, Co-Founder, Zed Motors (Benin)

Niko Kadjaia, Co-Founder & CEO, Tri (Tanzania)

Gaurav Uppal, CEO, One Electric (India)

Jayant Gupta, CEO, Grevol (India)

Anonymous, Top 5 Motorcycle OEM (India)

John Msingo, Chief Revenue Officer, EVChaja (Kenya)

Dominique Nkurunziza, Chief Marketing Officer, Spiro (Benin)

Toukam Ngoufanke, Principal, Persistent (Kenya)

Emile Fulcheri, CTO & Co-Founder, Stima (Kenya)

Fredrick Mushi, Director of Operations & Business Development, Ekoglobe (Tanzania)

Christopher Maara, Founder and CEO, Kiri EV (Kenya)

Warren Ondanje, Managing Director, Africa E-Mobility Alliance (Kenya)

Daniel Dreher, Co-Founder, Zembo (Uganda)

Brahim Lazrak, Director General, Multitrade (Morocco)

Jules Raoul Yimtchi, Strategy and Development Director, Docker (Morocco)

General support and discussion: Jesse Forrester, Brady Grimes, Paschal Giki, Emilie Martin, Kim Chepkoit

Asia

Motorcycle and electric motorcycle companies who are members of Electric Vehicle Association of Thailand (EVAT).

Latin America

Valeria Morales at Andemos (Colombia)

Oliverio García, President at Andemos (Colombia)

Jose Ignacio Latorre, BU Manager at Smoberry (Spain)

Luis Martínez, CEO at Liebrenaranja (Colombia)

Juan Arango, CEO at Mandarina bike (Mexico)

Juan Domaniczky, CEO Movilidad eléctrica (Paraguay)

Felipe Mantilla at Niu

David García at AKT

Evelyn Rodríguez at Evelyn Motors (Costa Rica)

Jill Dominguez at Century (Peru)

Vefase (Venezuela)

Pablo Rodriguez at 2050 ambiental (Colombia)

Simón Machado at Lola

Juan Carlos Restrepo Goez at Auteco (Colombia)

Mariano Luis Jimenez at AAVEA (Argentina)

Silvia Rojas at Asomove (Costa Rica)

Carlos Soruco, CEO at Quantum (Bolivia)

General support in compiling information and systematizing data: Carolina Fernández, Santiago Tulcan, Karen González, Juan Pablo Toca Salazar, Juliana Escobar, Jonathan Roldan, Joaquín Andrés Franco Gantiva, Sebastián Rozo, Felipe Becerra, Sofía Segura, Ana Puentes.

Appendix B: Data Points in Database

This work included the development of a database of all models found in the three regions with details of each. Below is a list of the data points included in that database, and the database is available in https://bit.ly/UNEP-23W-database . A dashboard presenting details of the report is available in https://bit.ly/unep-e23w-visualizer .

You can contribute to the database or help improve the dashboard. If you have an interest in this, please follow the instructions given in the database's "about" tab.

1. Manufacturer
2. Distributer
3. Model Name
4. Information Source
5. Country Available (Name)
6. Country Available (ISO Alpha-3)
7. Additional Countries Available
8. Vehicle Type
9. Subtype
10. Country of Manufacturing
11. Motor (Rated Power) kW
12. Peak Power (if listed)
13. Motor Placement (2W)
14. Efficiency (km / kWh)
15. Rated Max Load (kg)
16. Vehicle Curb Weight (kg)
17. Top Speed (km/h)
18. Driving Modes
19. Certified Range (complete battery capacity)
20. Local Road Tested Range (km)
21. Battery Chemistry
22. Battery Voltage (Nominal)
23. Battery Ah
24. Battery kWh
25. Battery #s
26. Total Battery Capacity (kWh)
27. Charger Included (Y/N)
28. Charger Watts
29. Charger Voltage
30. Charger Amperage
31. Charger Type
32. Charging / Swapping Capable
33. Climbing capacity (degrees)
34. Length (mm)
35. Width (mm)
36. Height (mm)
37. Wheel Base (mm)
38. Ground Clearance (mm)
39. Retail Price (local currency) (no sales / registration taxes)
40. Currency Name of Retail Price
41. Retail Price (no sales / registration taxes)

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