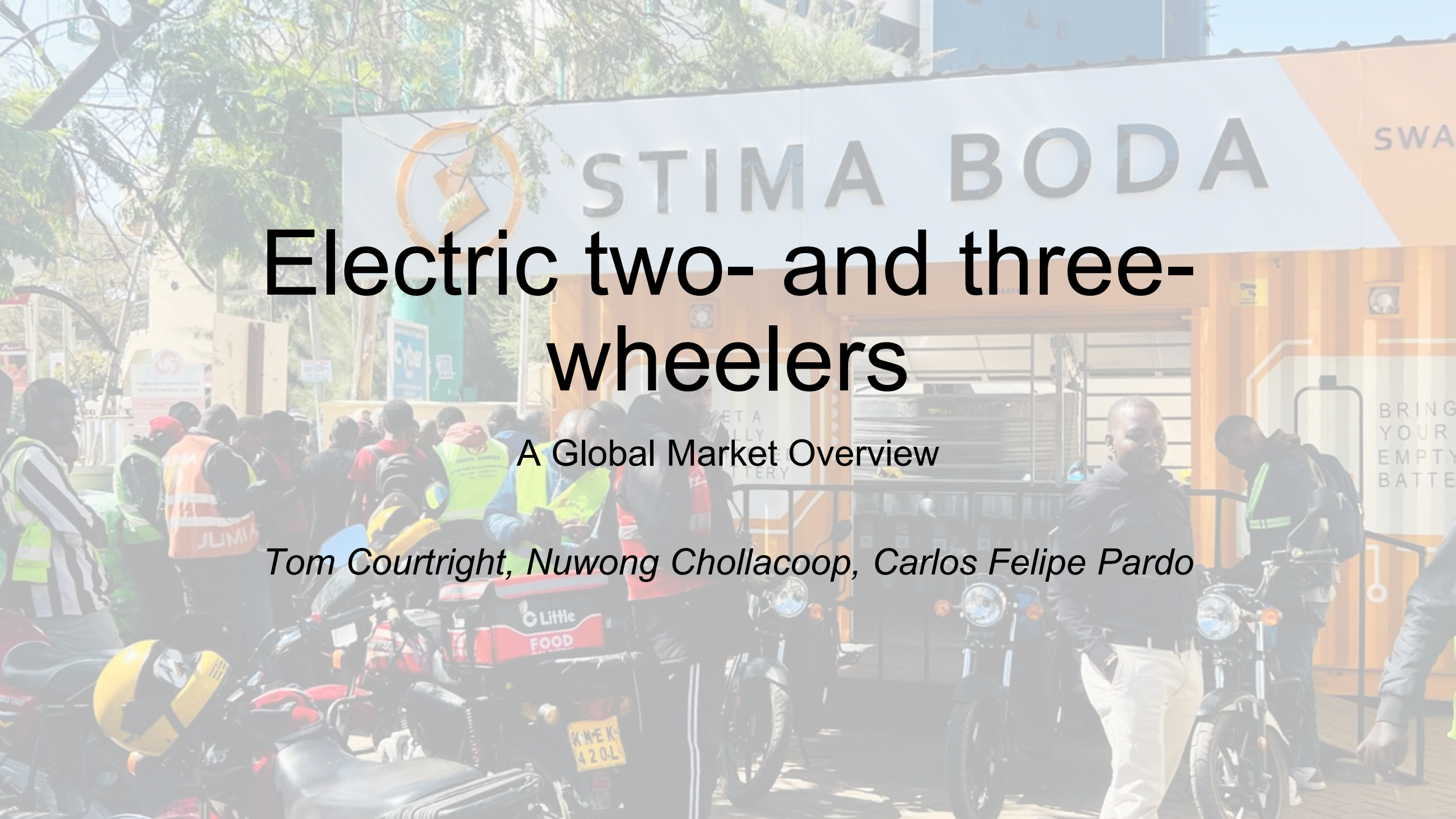


Electric two- and three-wheelers

A Global Market Overview

Tom Courtright, Nuwong Chollacoop, Carlos Felipe Pardo

Background

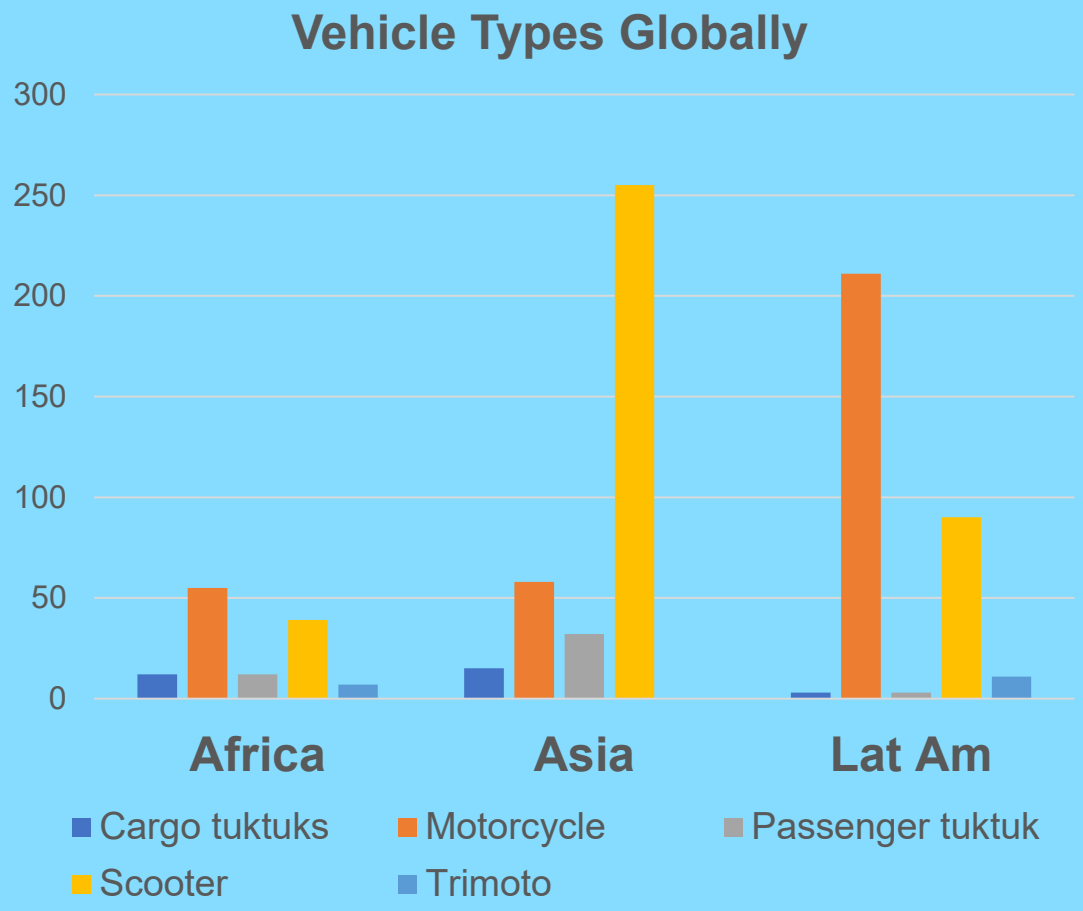
- This report set out to understand the characteristics, uptake and overall market of electric two- and three- wheelers in Africa, Asia and Latin America
- This work is part of the United Nations Environment Programme's (UNEP) Global Electric Mobility Programme

Methodology & Definitions

- Project team compiled database of existing electric two- and three-wheeler models in each of the target regions on 40+ specifications.
- Interviews were held with key stakeholders, including retailers, manufacturers, and investors, as well as regional and association bodies involved in the e-mobility sector.

ICE 2&3W Types

- 850+ models of e2&3W
- The domination of manufacturing in Asia – China in particular – and some similar usages has led to similarities across the markets.
- Models are often rebranded or slightly altered across regions.



Scooters – Use Cases

- Commonly used as personal transportation, but also for commercial passenger and delivery trips.
- Found in East and Southern Asia as well as Latin America, as well as in Francophone and North Africa.
- In Asian markets, scooters are used for a wide variety of cases, from personal use to cargo delivery.

Scooters - Specifications

Internal Combustion Engine

- Two-wheelers with a fully step-through frame with floorboards for feet placement.
- Piaggio, Haojue, Yamaha, and Honda are common brands.
- 50-300 cc engines, but usually under 125 cc and usually have automatic transmissions.

Electric

- Typically lower-powered, with 1-3 kW motors
- Dominated by East Asian market, with lead-acid versions increasingly exported elsewhere

ICE motorcycles – use cases

- Commonly used for commercial passenger and delivery trips, smaller role in personal transport particularly by high-income users
- Motorcycles are widely used in Africa and to a lesser extent Latin America for commercial passenger and delivery trips

Motorcycles – Specifications

Internal Combustion Engine

- ICE motorcycles have their fuel tank between the seat and the handlebars, footrests on the side
- Common, low-cost models are usually 100-150 cc engines
- Fuel tanks usually capable of 300+ km
- Typically heavier than scooters

Electric

- Similar physical shape
- Nominal motor power between 1-5 kW
- Batteries averaging 3.4 kWh, claimed range around 85 km

Passenger 3W – Use Case

- Known as tuktuks or auto-rickshaws, passenger 3W are almost exclusively used for commercial passenger transport
- They can carry 3-6 passengers, depending on their design and local regulations
- Provide both arterial and door-to-door services

Passenger 3W - Specifications

Internal Combustion Engine

- Evolved from buggies or rickshaws, pulled by people or horses
- One or two benches behind a driver, typically covered
- Between 150-250 cc engines

Electric

- Generally underpowered, with an average of 1.6 kW motors
- There are essentially two classes of E3W
  - E-rickshaws: lower cost, lead-acid batteries with under 2 kW
  - Electric autorickshaws: higher cost, li-on batteries, 2-8 kW

ICE Cargo 3W – Use Cases

- Cargo 3W come in several shapes and sizes but are generally used to move goods, either from warehouse to smaller shop or small shop to home.
- They can also be used for informal passenger transport or converted for passengers.

Cargo 3W – Specifications

Internal Combustion Engine

- Cargo 3W are often flatbeds with seating for a driver plus one, but can also be enclosed cargo boxes or even refrigerated.
- Similar in power and capabilities to passenger 3W

Electric

- Also on average underpowered, with an average of 3.1 kW motors
- Have made some inroads in dense downtowns for short-distance cargo deliveries, but primarily lead-acid

Trimoto

- A variety of designs with three wheels but only 1+1 seat
- Can have two wheels in front, or in back
- Primarily personal use; mostly higher-income users, and some for disabled users

Battery Types

	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	60% of Li-On	30% of Li-On	<5%	8% of Li-On
Lifecycles	2,000+	3,000+	~1,500	2,000 +
Raw material availability	Constraints on cobalt	Iron & phosphate widely available	Sodium and iron very widely available	Nickel widely available; cobalt constrained
Cost (factory gate)	$164 / kWh	$133 / kWh	$90-126 / kWh	$106 - $183 / kWh
Energy density (cell level)	140-200 Wh / kg	90-140 Wh / kg	75-160 Wh / kg	200-250 Wh / kg
Thermal runaway threshold	210 C	270 C	Unspecified; higher than Li-On	150 C

Charging Infra

Charging

- Charging vehicles while the battery is in-vehicle is known as either plug-in charging or simply charging
- Can be done from standard sockets or from charging stations (public or private)

Swapping

- Battery swapping consists of removing depleted battery and swapping it for charged battery
- Done at swap stations, which can be cabinets or dedicated shops

Africa – E2&3W Charging & Swapping

	Fixed / plug-in charging	Swapping
Vehicle 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 fleet infrastructure	Driver swaps battery at swap stations
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
Charge / swap 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	Requires 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

Charging Infra - Use Case

Charging

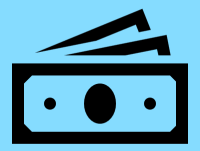
- Better for lower daily mileage vehicles, such as personal vehicles
- Higher CAPEX

Swapping

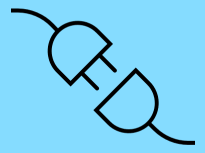
- Better fit for higher daily mileage vehicles, such as commercial passenger and deliveries
- Can also work for higher-income places with little charging infrastructure (i.e. Taiwan)
- Higher OPEX

Battery Swapping

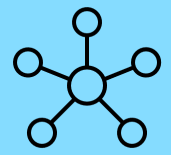
Geography: Commonplace in East Asia for personal and less so in SE Asia and Africa for commercial



Payments: Can pay via subscription, flat rate, or SoC. SoC most closely reflects fuel payment habits; subscription more convenient, but often more costly.



Maintenance: Swap cost depends heavily on battery lifespan, which depends in turn on C-rate



BSN density: Higher network density is needed with smaller batteries, but is costly. Swap cabinets can lower costs, but also reduce jobs.

Swapping Infra

Shopfront

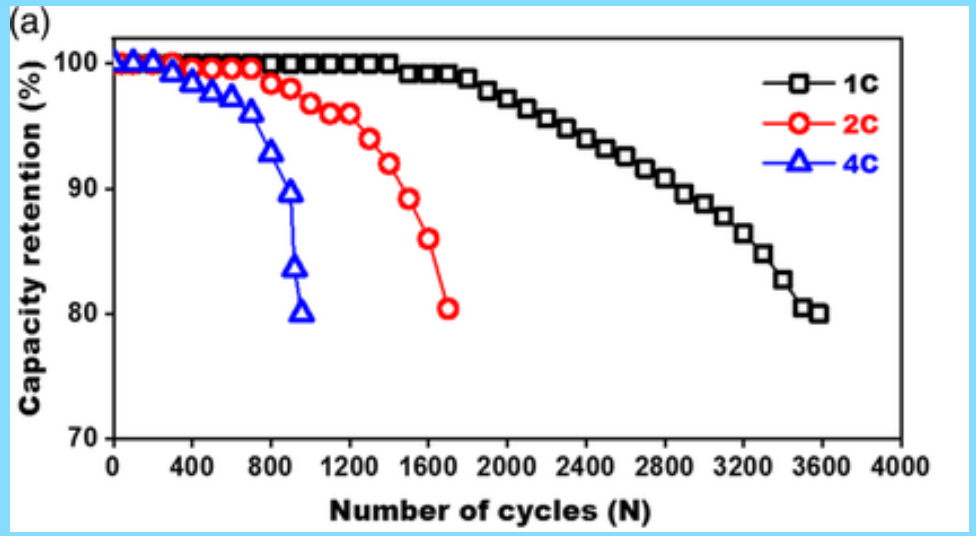
- Largely ad hoc set up
- Requires additional costs (rent, labor)
- Much more oversight

Cabinets

- Lower-cost rollout
- Makes more sense for smaller batteries
- Less jobs, less oversight

Battery Swap Model (Cont.)

- The cost of the swap includes: electricity, battery, infrastructure
- Short lifespan leads to higher costs (can be 3x cost of electricity)
- Lifespan / cycle lifes depends on several things, but mostly C-Rate
- C-rate in turn is dependent on a) usage, and b) charging



Motor Types

	Advantages	Disadvantages
Hub motor 	• Lower initial 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 life-time	• Higher initial cost • Chain or belt to maintain

Swap Pilot Models

Grab / Kymco

- Grab has bought the vehicles from Kymco, owns them
- Grab Drivers pay daily or weekly
- Kymco's subsidiary Innox provides battery swap cabinets
- Batteries are swapped at no extra cost

Ampersand

- Third party financier buys motorcycles and leases them to users
- At end of lease, user owns e-motorcycle
- Users pay for battery swaps pro-rated to SoC (e.g. 100 KSh for 50%, 200 KSh for 100%)

Current State – Latin America

ICE 2&3W

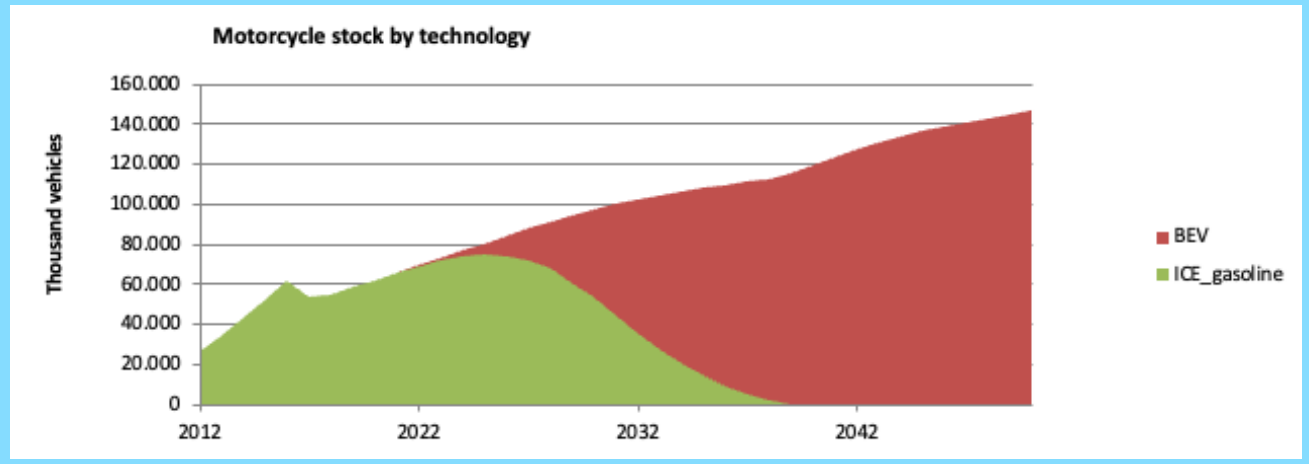
- Around **62 million** 2&3W across Latin America
- Personal motorcycle usage mostly high-income
- Moto-taxis in Brazil, spreading elsewhere
- Deliveries across high-income cities

Transition to E2&3W

- Only a handful of battery swap pilots
- Some artisanal conversions & retrofitting
- Less focus overall on E2&3W than Africa & Asia

Projections – Latin America

- The transition will be dependent on cost of E2&3W and the rollout of infrastructure (charging or swapping).
- Regulations and incentives are minimal and scattershot



Current State – Asia

ICE 2&3W

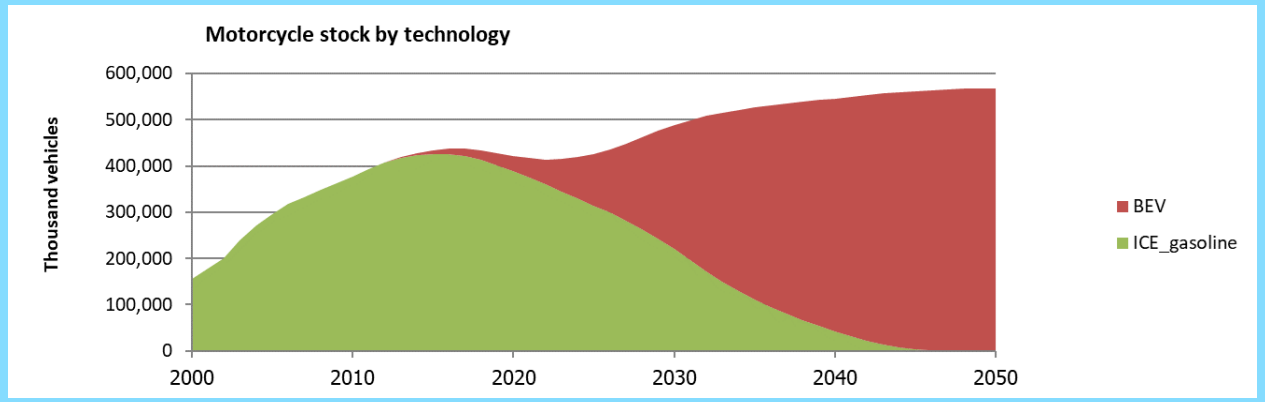
- Already has the majority of the worlds 2&3W – **490 million**
- High personal usage throughout
- Commercial passenger usage in several SE Asian countries
- Delivery usage increasing everywhere

Transition to E2&3W

- E2&3W first pushed in China with regulations over 10 years ago
- Battery swapping first pioneered by Gogoro in Taiwan

Projections – Asia

- 2&3W expected level off with continued economic growth
- China, India, Indonesia, Thailand and Vietnam market leaders
- Indonesia accelerating with subsidies and local manufacturing



Current State – Africa

ICE 2&3W

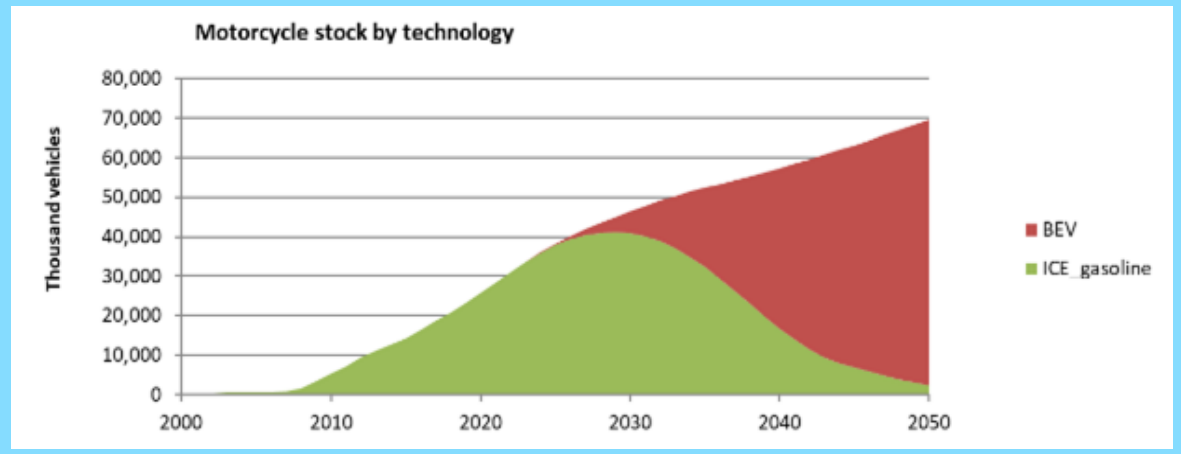
- An estimated the **27 million** 2&3W
- Personal 2W in North Africa, Francophone Africa
- Moto-taxis in the boda belt from Dar es Salaam to Dakar
- Informal delivery across the continent

Transition to E2&3W

- Less than 1% of 2&3W
- 60+ startups
- In process of adapting Asian products for African market
- There are lead-acid 2&3W for personal use arriving in several countries

Projections – Africa

- The transition to E2&3W is expected to be led by commercial 2W and battery swapping
- Policies that can reduce cost of vehicles through tax incentives are critical
- Will be a significant added demand on the grid




GrabElectric