Battery Swapping Harmonization in the ASEAN Region

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TITLE

Battery Swapping Harmonization in the ASEAN Region

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Review

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PICTURES

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EXECUTIVE SUMMARY

The The rapid growth of electric two and three-wheelers (E2&3Ws) across the ASEAN region offers a significant opportunity to reduce emissions and improve urban mobility. With more than 10 million new 2&3Ws added each year, ASEAN's E2&3W market is projected to grow by 4.5 times by 2030, reaching full electrification by 2040. Battery swapping has emerged as a critical solution to address the high upfront costs of electric vehicles, which are largely driven by battery expenses. This system allows users to quickly replace depleted batteries with fully charged ones, enhancing the affordability and convenience of E2&3Ws.

However, the current battery swapping landscape in ASEAN is fragmented, with varying technical standards and protocols across the region. Harmonizing these battery swapping systems can accelerate the deployment of electric vehicle infrastructure, reduce technology risks, increase user confidence, and improve access to financing for battery swapping networks.

This policy paper highlights the opportunities and barriers to achieving battery swapping harmonization in ASEAN. Harmonization can significantly reduce investment costs, boost technology cooperation, and increase market stability, but it also presents challenges in terms of standardization, business models, regulatory oversight, and technology selection.

Key policy recommendations include the establishment of a regional task force to oversee the development of harmonized battery swapping standards, the undertaking of a region-wide use case analysis to define modular battery systems, and the initiation of pilot programs across ASEAN to test and refine these systems. Stakeholder engagement, including non-OEM actors such as utilities and fuel retailers, will be essential in creating a robust and flexible regulatory framework that supports the widespread adoption of battery swapping.

Case studies from Indonesia and Thailand demonstrate the progress already made in the region, offering valuable insights for the development of a harmonized battery swapping system. By following a step-by-step approach and promoting collaboration across stakeholders, ASEAN can build a unified battery swapping ecosystem that accelerates the transition to electric mobility, enhances energy resilience, and drives sustainable economic growth.

1. Battery Swapping Harmonization in the ASEAN Region

The ASEAN region has experienced significant growth in the use of electric two and three-wheelers (E2&3Ws), which play a key role in reducing urban emissions and achieving sustainable mobility goals. With over 10 million new two and three-wheelers (2&3Ws) added annually, the region's E2&3W sales are expected to triple by 2026 and increase 4.5 times by 2030. The target is to transition completely to electric two and three-wheelers by 2040. However, challenges around charging infrastructure, affordability, and technical standards remain barriers to widespread adoption.

Battery swapping systems present a viable solution to mitigate the upfront cost of electric vehicles (EVs), which is primarily driven by the cost of batteries, making E2&3Ws more affordable. Harmonizing battery swapping standards across the ASEAN region can accelerate the rollout of EV infrastructure, reduce technology risk, and boost user confidence. Although many technical specifications and battery swapping systems already exist across ASEAN, harmonizing these systems could enable a more streamlined approach to EV adoption and support the region's climate goals.

ASEAN's growing reliance on electric two and three-wheelers offers an opportunity to tackle urban pollution while enhancing mobility. While electric vehicles, including motorcycles and scooters, can offer a cleaner alternative to internal combustion engines (ICE), the upfront cost of batteries remains a major deterrent. Battery swapping—a system where depleted batteries can be replaced instantly at designated stations—can make EVs more affordable and ensure that they are operational as quickly as conventional ICE vehicles.

Battery swapping in ASEAN is currently fragmented, with various manufacturers and countries employing differing standards and protocols. The harmonization of battery swapping systems across the region would not only drive economies of scale but also reduce technology risks, enhance consumer confidence, and increase access to financing for battery swapping infrastructure.

Opportunities of Harmonized Battery Swapping

Harmonizing battery swapping systems offers multiple benefits for the ASEAN region. These include:

1. **Acceleration of EV Infrastructure Rollout:** Harmonization addresses consumer convenience and technology risks, allowing for a rapid expansion of EV infrastructure, particularly in the underserved areas of ASEAN.
2. **Reduced Investment and Increased Financing:** By reducing the technical risks associated with investing in battery swapping infrastructure, harmonization can lower capital costs and attract more financing for both vehicle production and infrastructure development.
3. **Technological Cooperation:** Harmonization requires a high level of cooperation across industries and nations, leading to greater technological conformity and enabling seamless transitions for manufacturers and users alike.
4. **User Confidence and Convenience:** With a unified battery swapping system, users benefit from a more reliable network, alleviating concerns related to battery availability and range anxiety.

5. **Scalability and Flexibility:** Harmonized systems allow for modular designs, enabling the sharing of batteries across various platforms, reducing operational costs and improving system reliability.

Barriers to Harmonization

However, several challenges remain in achieving harmonization:

1. **Technology Selection and Standardization:** Deciding on the most suitable battery technology, voltage levels, form factors, and connectors requires extensive consultation with manufacturers and stakeholders across the region.
2. **Business Models:** Harmonized systems can complicate business models, particularly when balancing the cost-sharing structure between EV manufacturers and battery swapping operators.
3. **Regulatory Oversight:** ASEAN countries must establish strong regulatory frameworks and institutions capable of guiding the development of standardized protocols, resolving disputes, and ensuring that battery systems remain interoperable across the region.
4. **Security and Ownership Issues:** Ensuring the proper handling, security, and ownership tracking of mobile battery assets will require sophisticated monitoring systems and coordination among stakeholders.
5. **Battery Degradation and Maintenance:** Harmonized systems must account for the varying levels of battery degradation across multiple operators, as well as ensuring proper maintenance practices.

Policy Recommendations

The following steps are recommended to support battery swapping harmonization in ASEAN:

1. **Establish Regional Coordination:** A task force under the ASEAN Economic Community Council should be set up to oversee and guide the development of harmonized technical specifications and operational guidelines for battery swapping systems.
2. **Undertake Regional Use Case Mapping:** Conduct a region-wide analysis to define battery capacity, power, and size requirements based on various E2&3W use cases. This would help to develop a modular battery system that can be scaled across the region.
3. **Initiate Pilot Programs:** Launch competitive processes to identify technology options and pilot successful systems across ASEAN member states. The results of these pilots will inform the creation of a harmonized standard for battery swapping.
4. **Promote Stakeholder Engagement:** Involve non-OEM stakeholders, such as utilities, insurance providers, and fuel retailers, early in the process to help guide the development of a battery swapping ecosystem that meets both market and regulatory needs.
5. **Develop a Stepwise Approach to Standards:** Implement a phased approach to developing battery swapping standards, starting with less restrictive elements such as connectors and communication protocols, before moving toward more detailed battery capacity and performance standards.
6. **Enable EV Roaming:** Implement EV roaming systems to ensure interoperability across different battery swapping networks. Roaming hubs should be established to facilitate this, using best practices from other regions, such as Europe.

Case Studies: Indonesia and Thailand

Both Indonesia and Thailand have already made significant progress in developing battery swapping infrastructure. Indonesia's ambitious targets include nearly 1,000 battery swapping stations and a well-defined regulatory framework that is beginning to take shape. In Thailand, the 30@30 policy is working toward positioning the country as the region's EV hub, with significant battery swapping infrastructure already in place.

These case studies provide valuable lessons for other ASEAN countries and offer a foundation for developing regional standards that reflect the diverse needs of the ASEAN market.

Conclusion

The harmonization of battery swapping systems across ASEAN presents a unique opportunity to accelerate EV adoption, reduce operational costs, and enhance technological collaboration. Through a combination of regulatory oversight, stakeholder consultation, and market-driven approaches, ASEAN can create a battery swapping ecosystem that not only meets the region's sustainability goals but also drives economic growth and energy resilience. A step-by-step approach, starting with the establishment of a harmonized battery swapping standard and supported by pilot programs and stakeholder engagement, will be critical to realizing the full potential of electric mobility in the ASEAN region.

Annex I: Technical Policy Training Kit Battery Swapping Harmonization in the ASEAN Region

A detailed training kit attached in the annex provides further insights into the technical specifications, case studies, and stakeholder feedback necessary for the implementation of a harmonized battery swapping system in ASEAN.

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Technical Policy Slide Deck
Battery Swapping Harmonization in the ASEAN Region

June 2024

UNEP Global Electric Mobility Programme

European Commission

Executive summary

E2&3W and battery swapping in ASEAN

- More than 10 million 2&3 wheelers added every year in ASEAN. E2&3W sales in Asia are projected to triple by 2026 and grow by 4.5 times by 2030 to reach 100% E2&3W in 2040. Already, and nine of ten ASEAN member states have targets for EVs or EV supply equipment.
- Battery swapping can make E2&3Ws affordable but comprise complex value chains. Many different battery swapping systems already exist for motorcycles and scooters in ASEAN with a wide range of technical specifications.
- Reduction of battery cost is key. To design E2&3W technical specifications and to optimize modular battery systems, the development of regional wide mission profiles and E2&3W use cases is a prerequisite.
- The need for power, speed and range has many impacts on EV technology. Similarly, standardized battery size and form impacts the vehicle design. Overall, standardized batteries significantly limit individual choices of EV manufacturers and result in vehicle conformity.

Opportunities and barriers of harmonized batter swap systems

- Swapping harmonization accelerates EV charging roll-out through rapidly addressing user convenience and technology risk.
- Swapping harmonization reduced investment cost for both vehicle and swapping network development and access to financing is increased.
- Swapping harmonization requires high level of cooperation and results in technological conformity. Similarly, harmonized swapping systems require complex business models.
- Harmonized swapping systems require an informed, strong and flexible regulator and a robust stakeholder consultation and market-feedback process.
- First steps on e2&3W swapping harmonization has been taken in Indonesia and Thailand. Many similarities between EV charging regulation in the EU and battery swapping harmonization in the ASEAN exist. EV roaming is a prerequisite for swapping market structuring.

Policy recommendations

- Put in place the structures and capacity at ASEAN level to guide the development of a battery swapping standard and formulate a strategy
- Follow a step-approach to harmonize battery swapping systems.
- Undertake an ASEAN wide 2&3 wheeler use case mapping to define battery capacity, power and size based on a modular approach.
- Put in place a competitive process to identify technology options responding to the established battery capacity – power output – size scheme and pilot the successful technologies.
- From pilot to upscaling – from guardrails to standards.
- Involve non-OEM stakeholders which are likely to play a role in battery swapping systems early on.
- Start designing and implementing battery swapping market regulations in parallel and establish the necessary institutions.
- Implement a sub-regional process to enable EV roaming based on agreed protocols and a cross-boarder clearing house structure.

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Abbreviations

Abbreviations

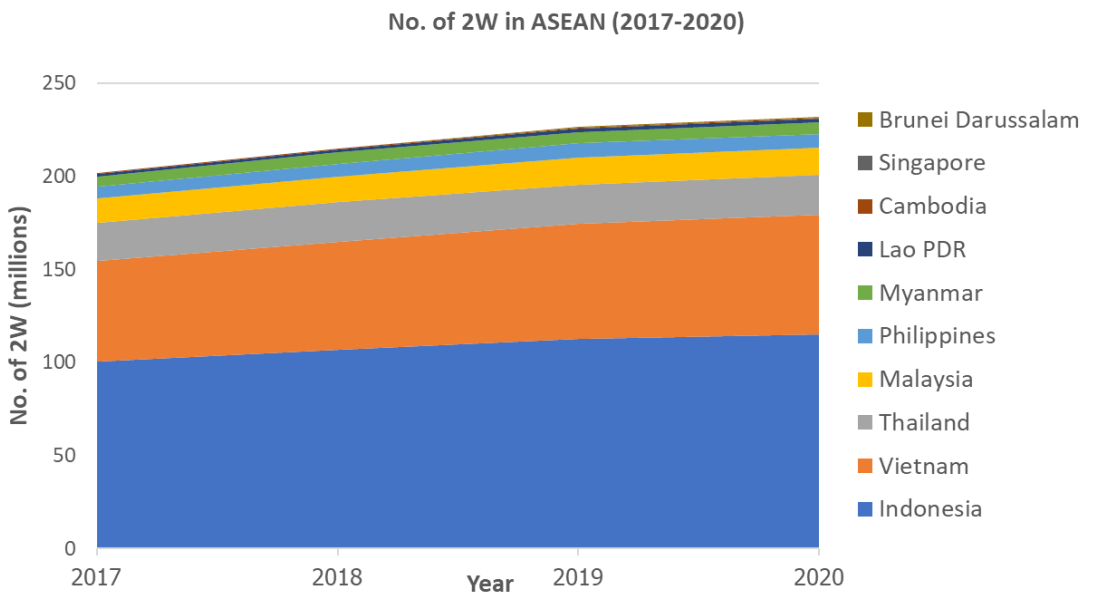
2W = Two-Wheeler
3W = Three-Wheeler
ASEAN = Association of Southeast Asian Nations
BMS = Battery Management System
BSS = Battery Swapping Station
CPOs = Charge point / swapping operators
DC = Direct Current
E2W = Electric Two-Wheeler
E3W = Electric Three-Wheeler
EMSPs = E-mobility service providers
EU = European Union
EV = Electric Vehicle
EVCS = Electric Vehicle Charing Station
ICE = Internal Combustion Engine
Kg = Kilograms
kWh = Kilowatts-Hour
MaaS = Mobility as a Service
MHESI = Ministry of Higher Education, Science, Research and Innovation
mm = millimeters
OEMs = Original Equipment Manufacturers
SEA = Southeast Asian
TOU = Time-of-Use
V = Volts
W = Watts
Wh = Watts-Hour

Electric 2&3 wheelers in ASEAN

2&3 wheeler market in ASEAN

More than 10 million 2&3 wheelers added every year in ASEAN

- 2&3 wheeler market in ASEAN ~230 millions (2020)[1]
  - ✓ Indonesia about 50% market share
  - ✓ Top 5 countries (Indonesia, Vietnam, Thailand, Malaysia and Philippines) over 95% market share
- World ranking
  - ✓ 3 of 5 countries with world highest 2W population are in ASEAN: Indonesia, Vietnam, and Thailand, following leading countries like China and India[2].
  - ✓ Top four in the world with highest household owning 2W are Thailand, Vietnam, Indonesia, and Malaysia with over 80%, exceeding China (60%) and India (47%)[3]



1 https://www.eria.org/uploads/Analysis-of-Future-Mobility-Fuel-Scenarios-Phase-III.pdf & https://data.aseanstats.org/
2 https://www.krungsri.com/en/research/industry/industry-outlook/hi-tech-industries/motorcycles/io/io-motorcycles-20
3 https://www.worldatlas.com/articles/countries-that-ride-motorbikes.html

Status quo of electric 2&3 wheelers in ASEAN

Viet Nam leading the transition with over 1.8 million E2W on the road (2022)[1]

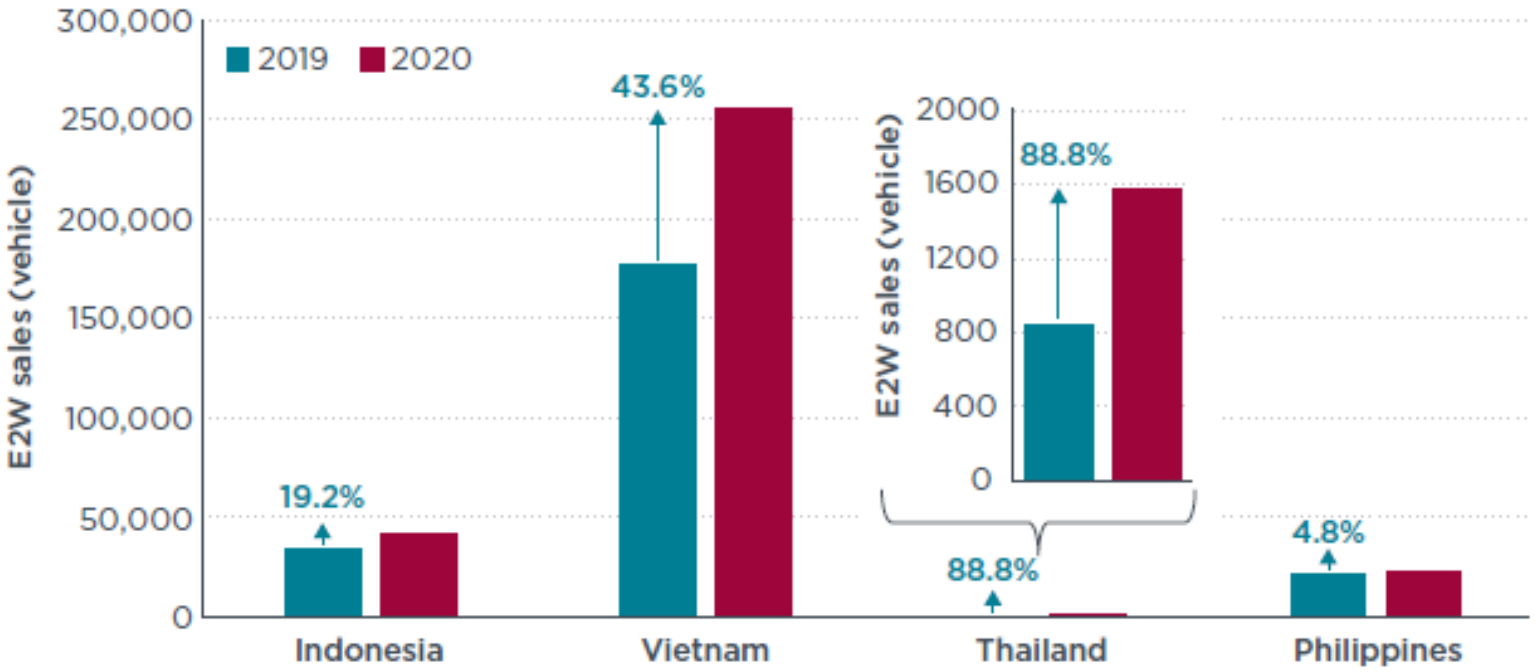


Figure 5. Comparison of E2W sales by country, ASEAN Four nations, 2019 and 2020

- While other countries in ASEAN are just starting, E2W sales already hit 250,000 in Viet Nam in 2020

Graph: https://theicct.org/wp-content/uploads/2022/06/asia-pacificlvsNDC-TIA-23W-market-ASEAN-countries-jun22.pdf

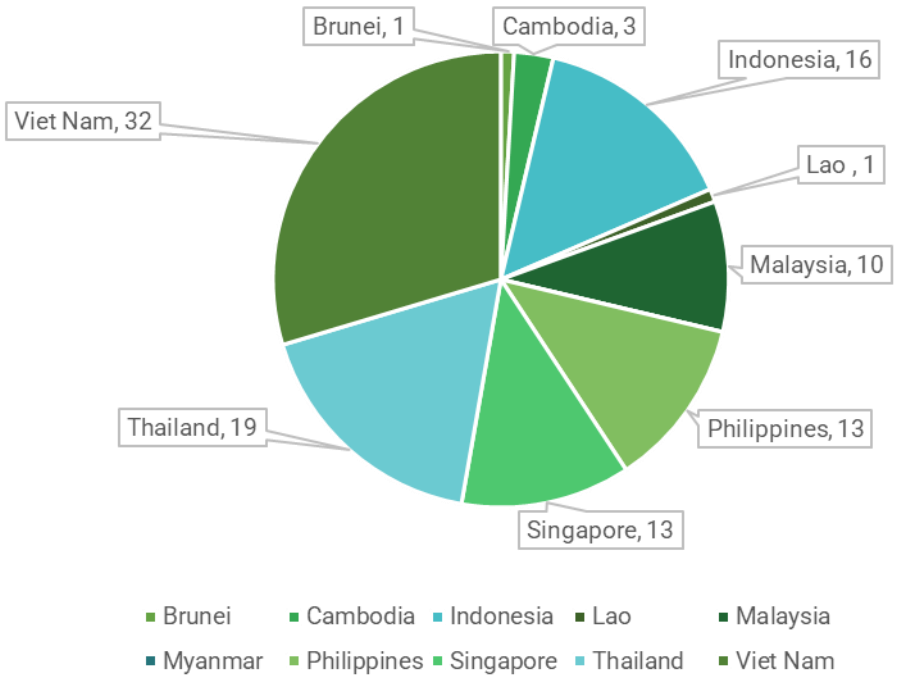
1: ERIA Working Group meeting on "Analysis of Future Mobility Fuel Scenarios Considering the Sustainable Use of Biofuels and Other Alternative Vehicle Fuels in East Asia Summit Countries", 26 April 2023

Status quo of electric 2&3 wheelers in ASEAN

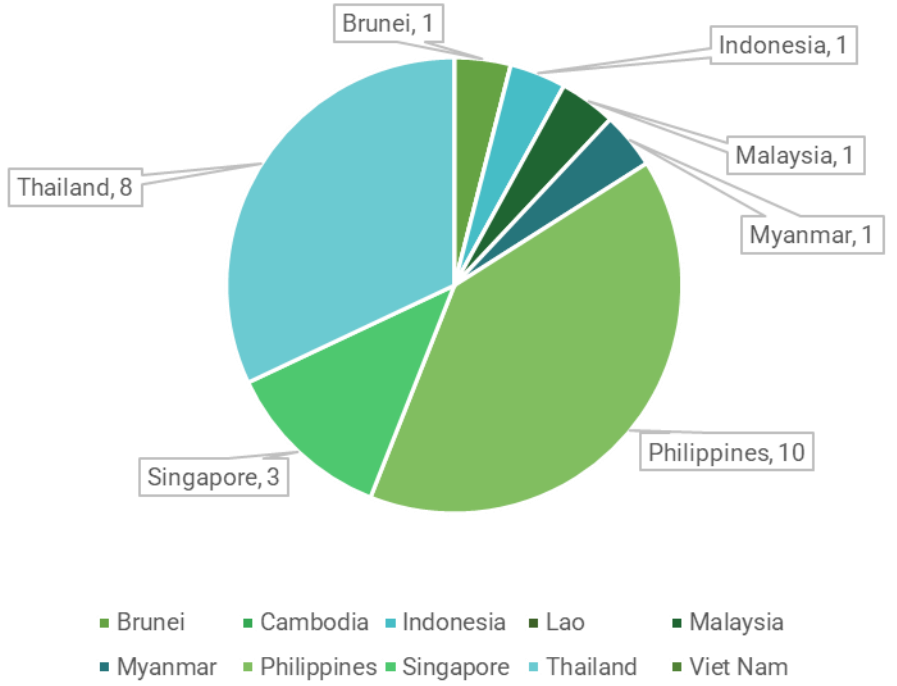
Viet Nam has the most E2W models whereas E3W model choice is highest for Philippines in 2023

- In 2023, about 108 E2W and 25 E3W models were available in ASEAN*
- Most e2&3W manufacturers are from within ASEAN and China

Available E2W models in the market (total of 108 as of 2023)



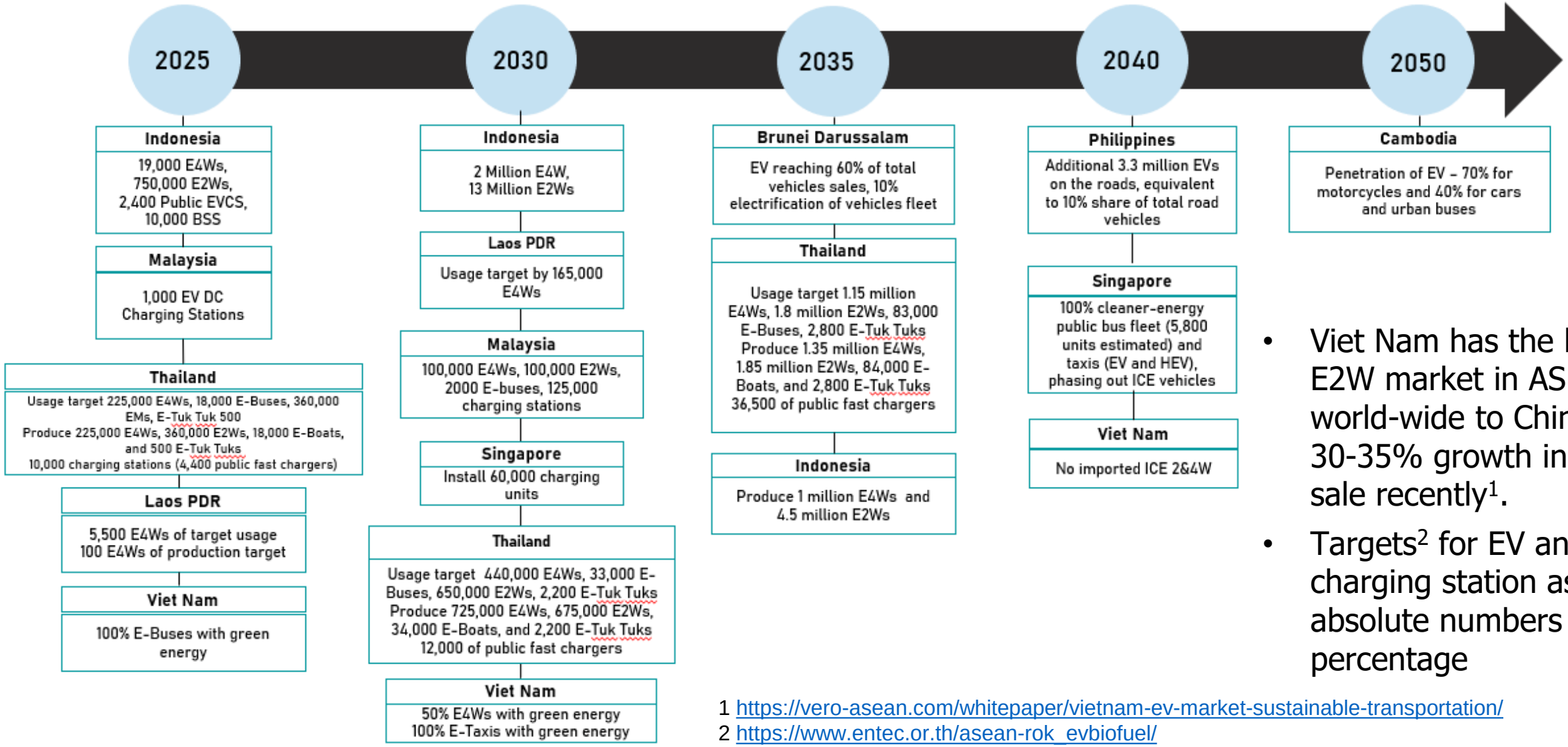
Available E3W models in the market (total of 25 as of 2023)



* https://www.unep.org/resources/report/global-emerging-market-overview-electric-two-and-three-wheelers

Overview of EV targets in ASEAN

9 of 10 ASEAN member states have targets for EVs or EV supply equipment



- Viet Nam has the largest E2W market in ASEAN (2nd world-wide to China) with 30-35% growth in E2W sale recently[1].
- Targets[2] for EV and EV charging station as absolute numbers and percentage

1 https://vero-asean.com/whitepaper/vietnam-ev-market-sustainable-transportation/
2 https://www.entec.or.th/asean-rok_evbiofuel/

EV policy landscape

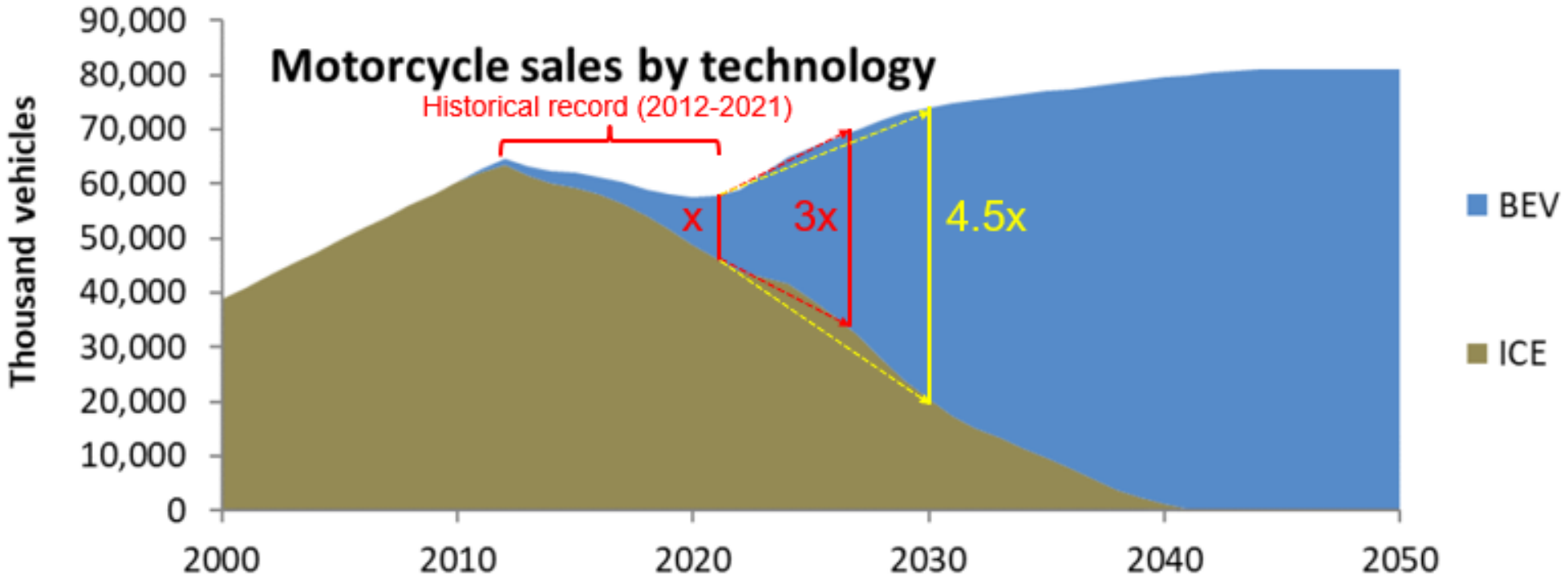
ASEAN countries applying a suite of measures to promote EVs

	Policy/AMS	BRN	KHM	IDN	LAO	MYS	MMR	PHL	SGP	THA	VNM
Electric Vehicle	Exemption/reduction of import duty		✓	✓	✓	✓ (2022)	✓	✓ (2022)		✓ (2022)	
	EV utilization mandate										✓
	Promotion of EV production			✓						✓	
	Corporate tax incentives			✓		✓					
	Permit for foreign nationals to be employed under technology transfer agreements							✓			
	Agreement to lease factory space for assembling plant of electric buses						✓ (2020)				
	Special taxation system applied for manufacturing of environmentally friendly vehicles						✓ (2019)				
	Exemption from mandatory unified vehicular volume reduction programmes, number-coding scheme or other similar schemes							✓ (2022)			
	EV standard including safety			✓						✓	
	Exemption/reduction of excise tax			✓		✓ (2022)		✓ (2022)		✓ (2022)	✓ (2022)
	Exemption of sales tax					✓					
	Registration fee exemption/reduction							✓ (2022)			✓
	Exemption/reduction of road tax for electric vehicle				✓	✓ (2022)			✓	✓	
	Exemption/reduction of vehicle license fee	✓							✓		
	EV income tax relief					✓ (2022)				✓ (2022)	
	Purchase subsidies								✓	✓ (2022)	
	EV waste management			✓						✓	
	Charging station incentives								✓	✓ (2022)	
	EV infrastructure subsidy			✓						✓	
	EV electricity tariff			✓						✓	
	Raising the rapid charging tariff rate										
	Intensive funding to support R&D			✓						✓	

- Fiscal incentives, standards, regulations and purchase subsidies are common
- Indonesia and Thailand already have regulations for EV waste management

E2&3 wheeler market projections

E2&3W sales in Asia to triple by 2026 and 4.5 times by 2030 to reach 100% E2&3W in 2040



- While the 2&3 wheeler market in China is saturated, the overall market is still growing in India and the ASEAN
- With stringent policies, 2&3 wheeler sales are to switch to electric by 2040

https://www.unep.org/resources/report/global-emerging-market-overview-electric-two-and-three-wheelers

Introduction to battery swapping

Why battery swapping?

Battery swapping can make E2&3Ws affordable

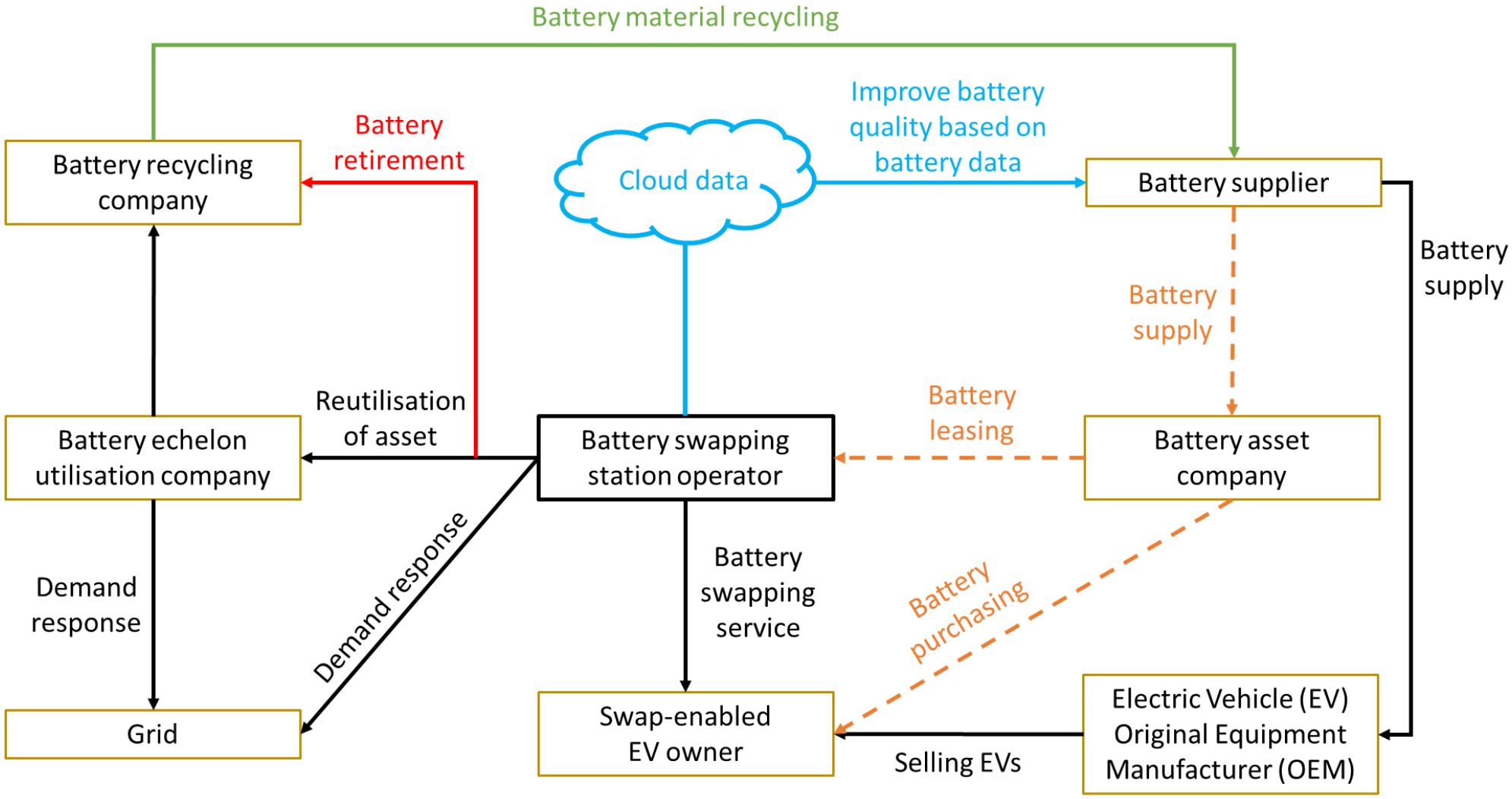
- Higher upfront cost of E2&3Ws vs. lower operating cost
- Usually payback times for an E2&3W are about 9 to 18 months
- 2&3 wheeler market is very price sensitive
- The Battery makes up for 20-45% of the E2&3W purchase price
- By separating the battery from the vehicle, E2&3Ws become purchase cost competitive
- Swapping an empty battery with a fully charged battery against a swapping fee renders E2&3W wheeler charging as fast as ICE (Internal Combustion Engine) vehicle refueling
- Users can reduce overall cost by around 30% based on E2&3Ws and battery swapping systems

However, battery swapping can:

- Severely impact battery technology innovation through the need for standardization
- Become obsolete in case battery cost drop drastically
- Be disrupted by super-fast charging technology in the future

Battery swapping ecosystem

Battery swapping systems comprise complex value chains



https://www.idtechex.com/en/research-report/battery-swapping-for-electric-vehicles-2022-2032-technology-players-and-forecasts/868

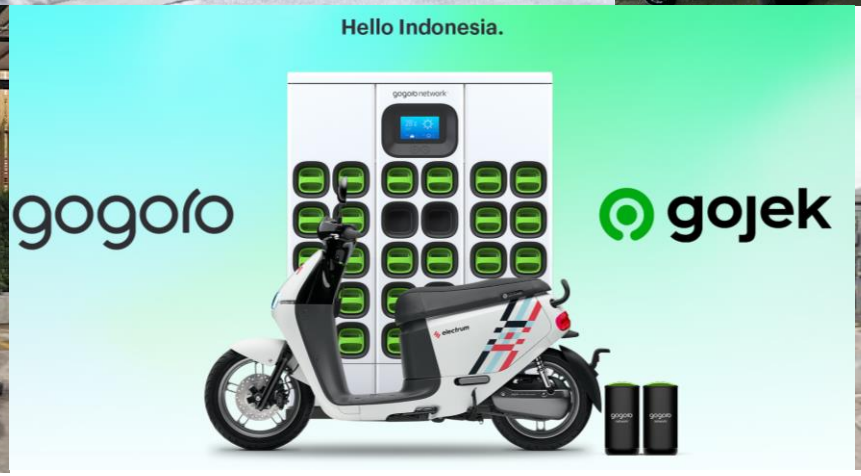
Battery swapping business model

Innovative business models drive battery swapping development

- Very often, companies in the sector are vertically integrated and:
  - ✓ Manufacture and assemble the vehicle
  - ✓ Provide the financing to purchase the vehicle
  - ✓ Operate a mobility as a service (MaaS) app
  - ✓ Provide the battery swapping service
  - ✓ Provide capacity building and insurance cover
- Common platform (size, voltage, connector) swappable batteries with many E2Ws in the system can help reduce operating cost
- Optimal spatial mapping of battery swapping station with rider's driving behaviour is key

Battery swapping technology

Swapping systems already exist for motorcycles and scooters in ASEAN



https://www.entec.or.th/entec-news_50-electric-motorcycles/
https://th.postupnews.com/2022/12/swap-and-go-stallions-group-battery-swapping.html
https://www.gojek.com/news/gojek-and-gogoro-announce-strategic-partnership-to-electrify-two-wheel-transportation-in-indonesia
https://www.gogoro.com/news/g20-2022-indonesia-electrum/
https://en.prnasia.com/releases/apac/heading-towards-net-zero-carbon-swap-energi-indonesia-collaborates-with-bp-akr-fuels-retail-to-accelerate-indonesia-electrical-vehicle-ecosystem-371739.shtml

Battery swapping technology

Electric tuktuks with swappable batteries are emerging outside ASEAN

- E3Ws with swapping technology are available from major manufacturers such as Piaggio or Mahindra in India – Huge learning potential for the ASEAN market
- E3W taxi operators in Thailand explore existing E2W battery swap systems for modular application in E3Ws

https://tqpr.com/onion-mobility-unveils-in-bangkok-battery-swappable-fully-electric-cargo-three-wheeler-to-drive-green-deliveries-in-southeast-asia/

Technical specifications of battery swapping systems

E2&3 wheeler use cases - The need for power, speed and range

Mission profiles are key to design E2&3W technical specifications

- To best capture the market, the rider's behavior needs to be characterized according to:
  - ✓ Driving range per charge → battery capacity
  - ✓ Performance (speed & acceleration) and carriage capacity needed → charge/discharge rate of battery in conjunction with power of the electric motor and performance of the BMS (battery management system)
  - ✓ Physical sizing / connectors → match with E2&3W design and communication channel
  - ✓ Environment → temperature, humidity and water resistance
- Based on this a cluster of use cases should be developed for 2&3wheelers
- Once designed, field tests to confirm applicability are necessary

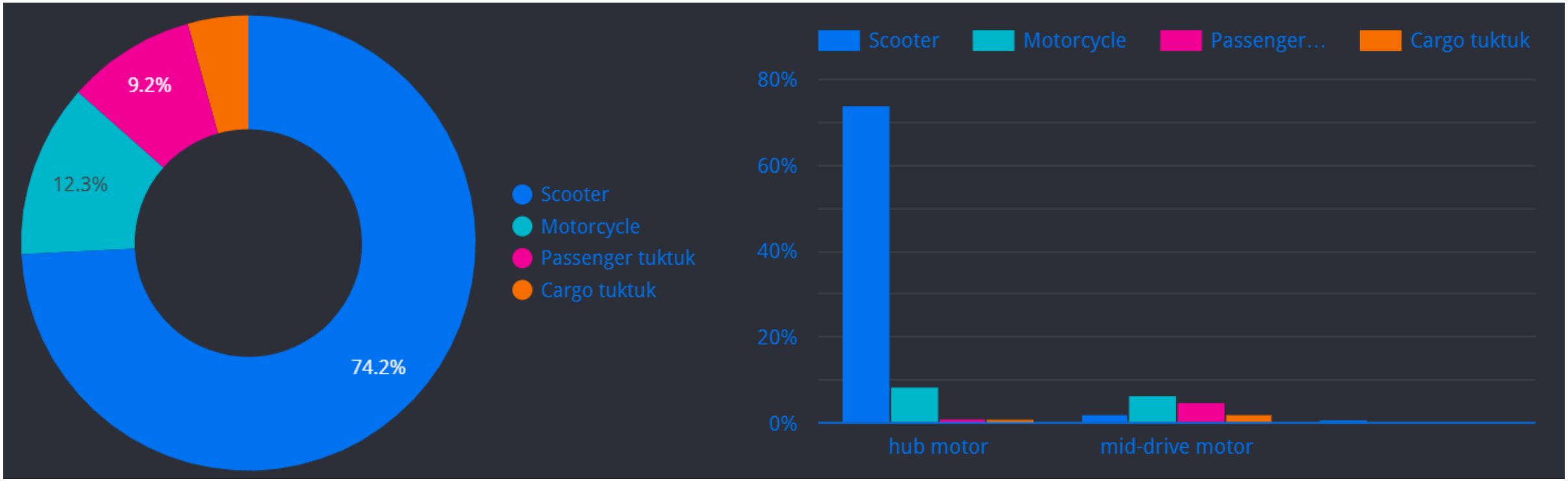
E2&3 wheeler use cases – Impact on EV and battery technology

The need for power, speed and range has many impacts on EV technology

- ✓ Voltage of the vehicle
- ✓ Chemistry of the battery
- ✓ Capacity of the battery (in kWh)
- ✓ Power supply of the battery (peak W)
- ✓ Size, form and weight of the battery (form factor)
- ✓ Battery management system (BMS)
- ✓ Connectivity of the battery (which connector and position)
- ✓ Charging technology

Use case and motor placement in Asia

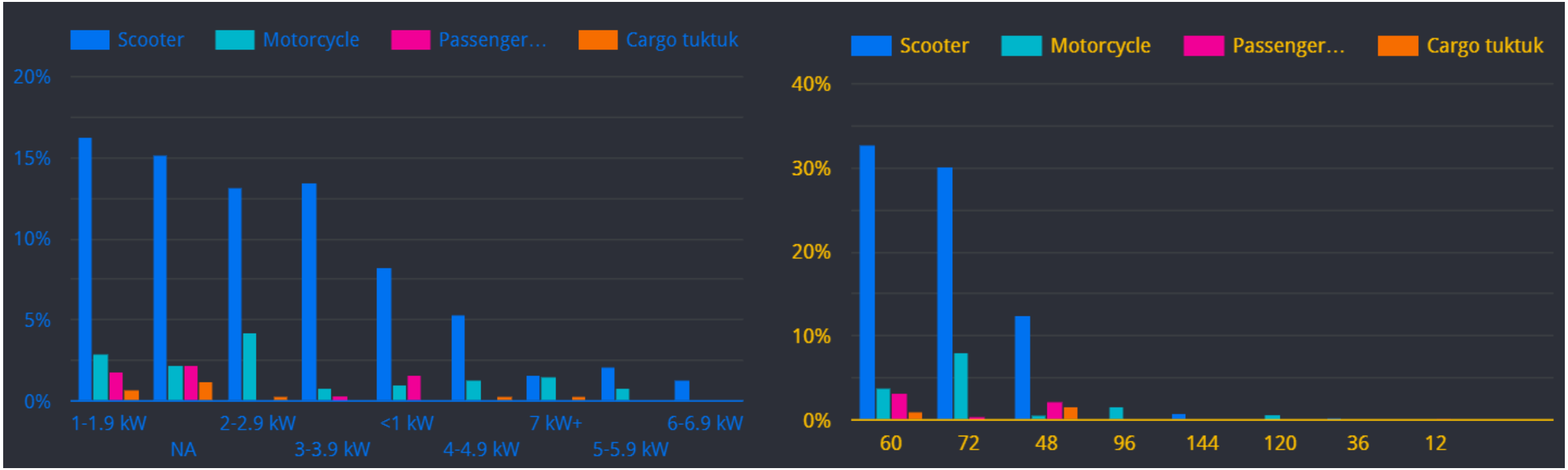
Electric scooters are predominant in the Asian E2W market – and with them the hub motor



https://www.unep.org/resources/report/global-emerging-market-overview-electric-two-and-three-wheelers
https://lookerstudio.google.com/u/0/reporting/a423c16c-f5b4-487e-9922-2ea71eb3ec30/page/7LGmD

Use case, power and voltage in Asia

The lower the need for power, the lower the voltage

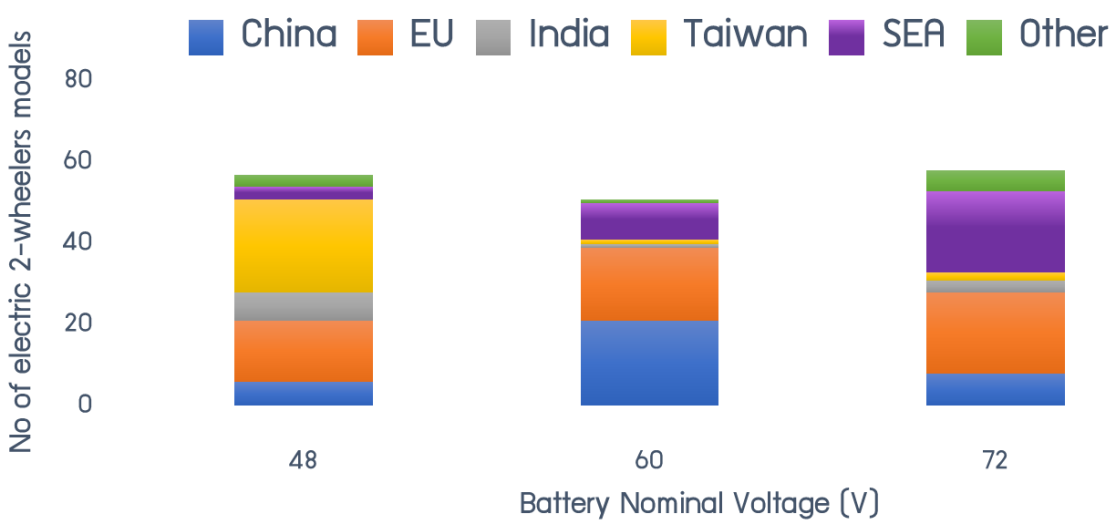


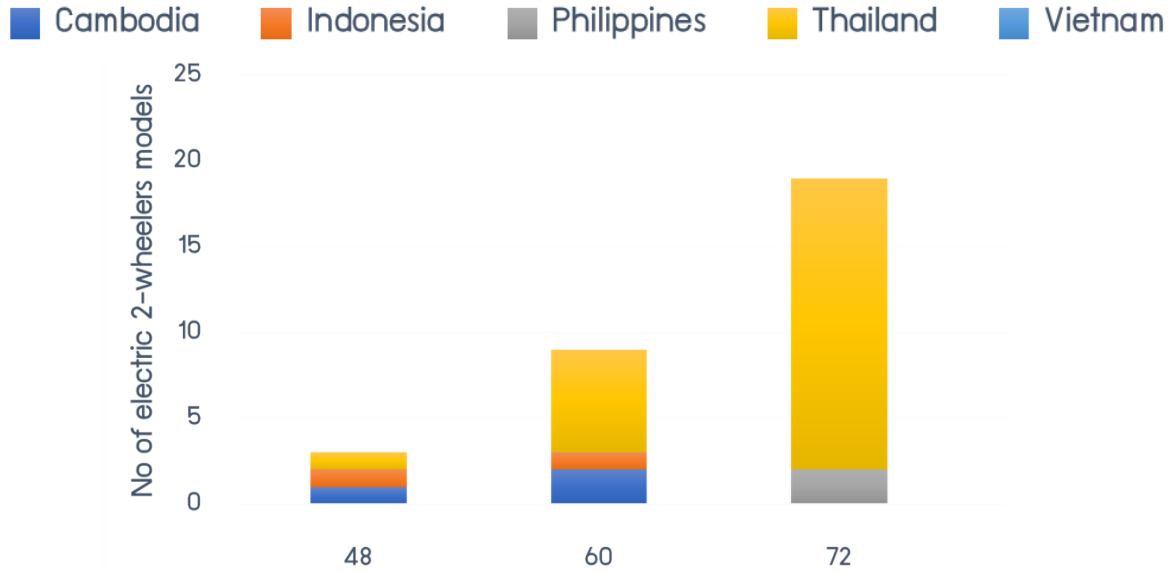
- Compared to e-scooters, e-motorcycles have a higher share of 72V systems

https://www.unep.org/resources/report/global-emerging-market-overview-electric-two-and-three-wheelers
https://lookerstudio.google.com/u/0/reporting/a423c16c-f5b4-487e-9922-2ea71eb3ec30/page/7LGmD

Battery voltage

Low voltage is wide-spread in China, high voltage in Thailand



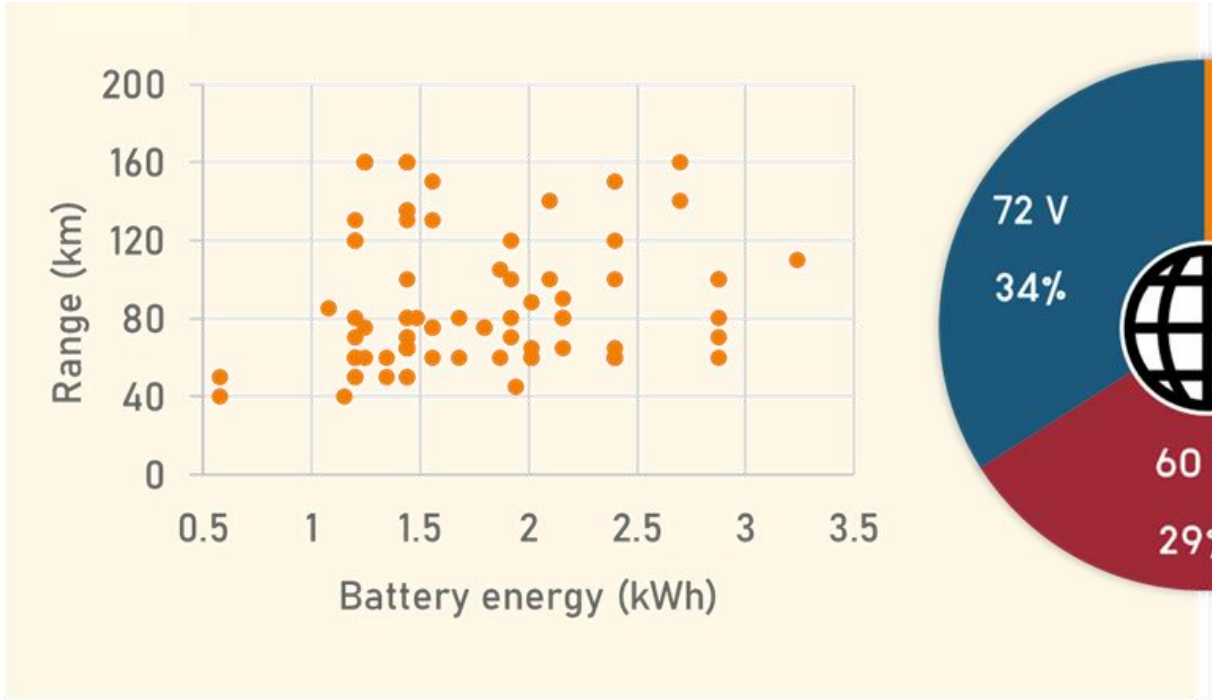


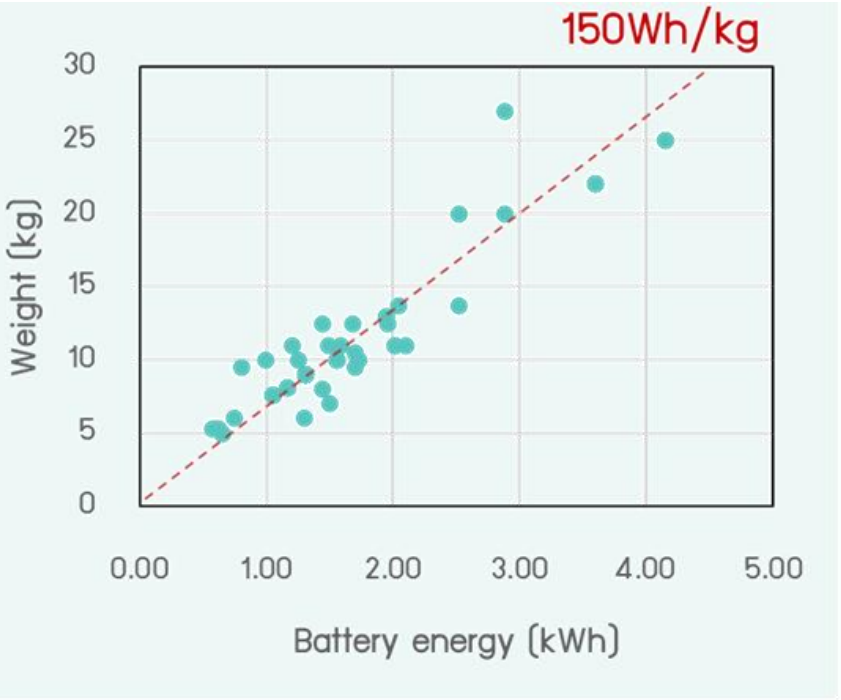
- A survey of existing E2Ws worldwide shows a similar fraction for 3 levels of battery voltage: 48V/60V/72V
- However, there is regional preference:
  - ✓ 48V: Taiwan, EU, Indonesia
  - ✓ 60V: China, EU, Thailand, Vietnam, Indonesia
  - ✓ 72V: Thailand, Philippines

https://batteryswapping.in.th/

Battery capacity, range and weight

Most E2W batteries have capacities of 1 to 2.5 kWh good for 40 to 80 km of range





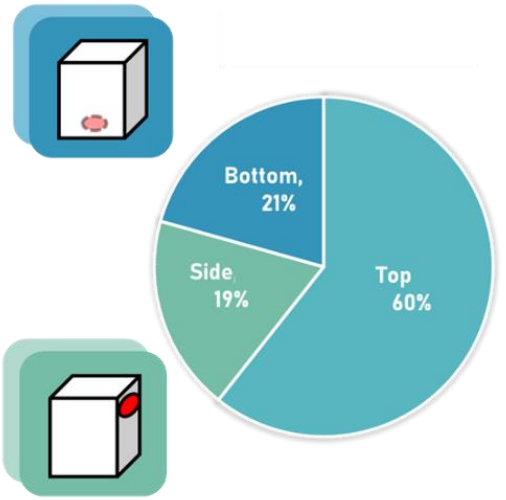
- Available batteries in the world-wide E2W market show an equal fraction for voltage ranges and:
  - ✓ 1-2.5 kWh battery can run for 40-80km
  - ✓ With average of 150Wh/kg, 1-2.5 kWh battery weighs 6.67-16.67kg

https://batteryswapping.in.th/

Formfactor and mounting

Different sizes, capacities and mountings exist for battery swap systems

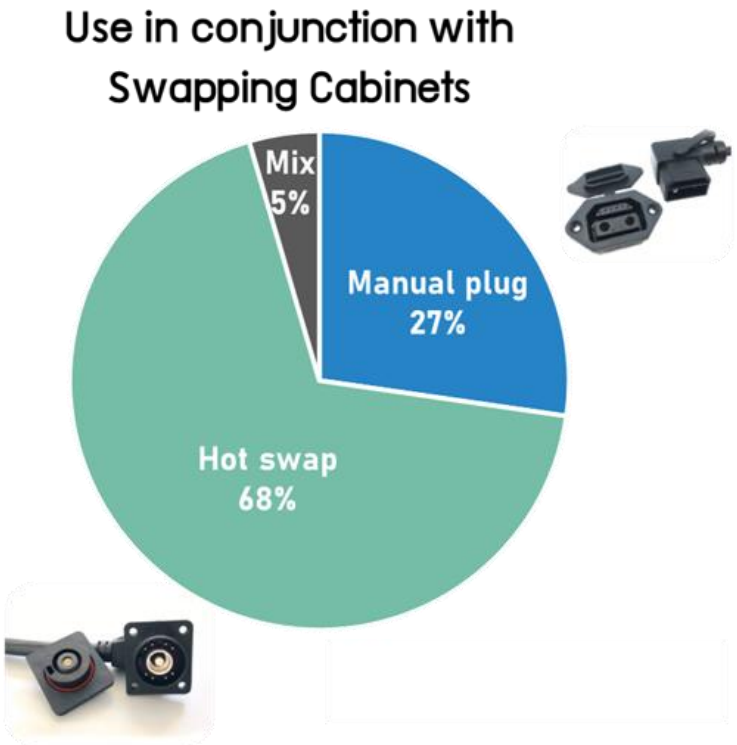
- As for connector characteristics, most connectors are located at the top of swappable batteries with hot swap connection for easy changing of battery
- "Hot swap" refers to the ability to switch a partially charged battery with a fully charged battery without having to power down electric two-wheelers
- All these existing characteristics of swappable batteries for electric two-wheelers must be taken into consideration for drafting a standard



https://batteryswapping.in.th/

Swapping cabinet technology

Battery size and form impacts the vehicle design



- Hot swap is dominant due to ease of swapping without having to power down E2W

https://batteryswapping.in.th/

Optimal battery size for e2&3 wheeler use cases

Reduction of battery cost is key

- Objective: reduce the cost of the E2&3W battery
- Find out exact power, speed and range requirements for various E2&3W applications
  - ✓ Commercial passenger transport (urban / rural)
  - ✓ Freight transport
  - ✓ Individual use
- Determine the optimal battery
  - ✓ Power / range and swapping interval
  - ✓ Chemistry
  - ✓ Capacity
  - ✓ Formfactor
  - ✓ Connectivity

Opportunities and challenges of harmonized battery swapping systems

Opportunities of harmonization

Swapping harmonization accelerates EV charging roll-out

- Accessibility
  - ✓ Totally un-harmonized: 10 swapping companies with 10 swapping stations each results in a swapping network of 10 per system
  - ✓ Totally harmonized: 10 swapping companies with 10 swapping stations each results in a swapping network of 100 interoperable swapping stations
- Market stability
  - ✓ User feels more confidence with harmonized battery swapping platform in case some E2W companies go out of business
  - ✓ Financial institution can finance both sides (battery swapping operators & users) easier knowing E2W and battery assets are widespread compatible

Opportunities of harmonization

User convenience and technology risk are addressed rapidly

- Improved user confidence and reduced range anxiety through high density of swapping stations
- Reduced technology risk through increased conformity of E2&3Ws on offer
- Significantly reduced risk of loss of investment in E2&3Ws in case of swapping operator bankruptcy
- Significantly increased reliability of E2&3W business models
- Improved user satisfaction through clear use-case mapping and streamlined E2&3W segments
- Improved flexibility through modular battery systems allowing for sharing across platforms for E2Ws, E3Ws and other applications
- Improved repairability, service & maintenance and aftermarket business opportunities
- Improved second-life use cases through standardized battery packs e.g. for stationary use for power storage
- Improved safety through less battery variety, better homologation processes and stricter regulation
- Improved vehicle safety through conformity of drivetrain technology

Opportunities of harmonization

Investment cost are reduced and access to financing increased

- Development cost of E2&3W drivetrains can be shared among manufacturers
- Investment costs for swapping network are shared among all companies
- Harmonized swapping systems increase confidence of financiers and reduce capital cost
- Market regulation and interoperability transaction cost are reduced
- Rapid upscaling enables economy of scales and return on investment faster
- Reduced swapping network cost result in lower energy prices for consumers (or higher margins for operators)
- Repair and maintenance can become cost effective
- Cost of battery end-of-life and for re-purposing, re-manufacturing and recycling can be dramatically reduced

Barriers of harmonization

Swapping harmonization requires high level of cooperation and results in technological conformity

- Which approach? Top down (regulatory) vs. Bottom up (market)?
- Which technology to choose in absence of experience?
- How to enable continued technology development?
- How to maintain similar quality of battery for operators with different entry into the platform?
- How to track battery degradation from various operators in the pool?
- How to keep track of mobile asset ownership i.e. batteries owned by various companies in the market?
- How to ensure proper handling of the expensive batteries?
- How to prevent theft?

Barriers of harmonization

Harmonized swapping systems require complex business models

- Cost are shared – and revenues too!
- How to enable viable business cases for EV manufacturers once the vehicles will be very similar for identical use cases as technology options are significantly reduced (voltage / battery system / capacity / size are all fixed)?
- How to structure the swapping market / battery ownership?
- How to develop and harmonize proper pricings plan to reflect user's behaviour?
- How to encourage users with unlimited swap plans to not swap batteries too soon i.e. increasing the number of charging cycles without depleting the battery?
- How to optimize size and location of swapping stations and how allocate prime-spots and secondary spots to market participants?

Barriers of harmonization

Harmonized swapping systems require an informed, strong and flexible regulator and a robust stakeholder consultation and market-feedback process

- Criteria to decide whether swapping is the way to go?
- Who chooses the technology?
- How to structure the process of standardization
- How is feedback between market and regulator provided?
- How to address failure?
- How to enforce battery swapping standards across the region?
- How to regulate benefit sharing between early and new operators?
- How to regulate co-existence of battery swapping and public charging options?

Battery swapping case study: Indonesia

Indonesia – Charging infrastructure regulation

Some EV charging regulation is in place

- Indonesia already has regulations on charging station infrastructure business, technical specifications, safety and standards
- Battery swapping standards can be added to the Regulation of the Minister of Energy and Mineral Resources Indonesia No. 1 2023, Electric Charging Station Infrastructure

Indonesian Vehicle Electrification Policy

Presidential Regulation No. 55 of 2019 regarding the Acceleration of Battery Electric Vehicle Programs for Road Transportation	→	The roadmap of Indonesian Vehicle Electrification
Indonesian Government Regulation No. 74 of 2021	→	Luxury Tax of xEV < ICE
Indonesian Government Regulation No. 8 of 2020	→	Vehicle Tax of xEV < ICE
Jakarta Governor Regulations No. 3 of 2020	→	Ownership Transfer fee of xEV < ICE
Regulation of The Minister of Finance Indonesia No. 38 of 2023, Value Added Tax on EV	→	VAT reduction for Local Content 40%+
Regulation of The Minister of Energy and Mineral Resources Indonesia No. 1 of 2023, Electric Charging Station Infrastructure	→	Related to charging station infrastructure business, specification, safety, and standards
Presidential Decree No. 7 of 2022, The Use of BEV as Operational Service Vehicles for Central Government and Regional Government	→	To accelerate the xEV uses by procuring new xEVs or converting ICEs to xEVs
Governor of Jakarta Reg. No. 88 of 2019, Exemption of BEVs from license plate number based road access limitation (“Ganjil Genap”)	→	Exemption of Battery EVs from license plate number based road access limitation (“Ganjil Genap”)

Monetary Incentives

Non-Monetary Incentive

Indonesia - Charging infrastructure roadmap

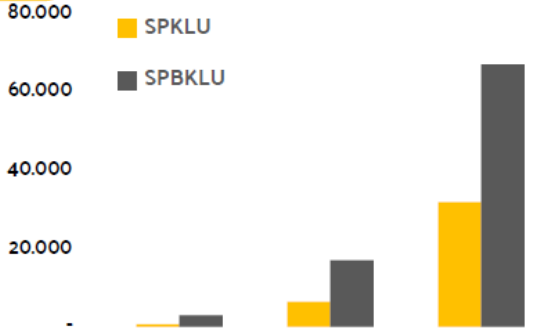
Ambitious national charging and swapping station targets exist

- Higher target for battery swapping stations (SPBKLU) than public charging stations (SPKLU)
- State-owned utility enterprise (PLN) is employed to initiate charging infrastructure investment
- Time-of-Use (TOU) discounted electricity tariff is in place for EV charging infrastructure (22:00-04:00)

INFRASTRUCTURE SUPPORT FOR EV CHARGING STATION

Public Electric Vehicle Charging Station (SPKLU) & Public Electric Vehicle Battery Swap Station (SPBKLU) 2020-2030

SPKLU & SPBKLU Roadmap by GSEN



	Unit	2021	2025	2030
SPKLU	Unit	572	6,318	**31,859**
SPBKLU	Unit	3,000	17,000	**67,000**

CHARGING STATIONS PROVISIONS

- Electricity Supply Business License (IUPTL) and Business Area;
- State owned energy company and/or other business entities;
- Initial assignment for PLN;
- PLN can cooperate with BUMN and/or other business entities.

DG NREEC @2023

Private Electric Installation

EV Charging Station

EV Battery Swap Station

Incentives in the form of Facilitation:

- **Installation cost**; and/or
- **Electricity subscription guarantee**; also
- **Minimum Account Exemption for the first two years**

Discount on electricity tariff for charging BEV battery at 22:00 to 04:00 the following day.

Source: Directorate General of Electricity, MEMR 2023

Indonesia – Charging and swapping station distribution by region

Almost 1,000 swapping stations envisaged

- Challenge: EV charging infrastructure allocation throughout many islands
- As of December 2022, more battery swapping stations exist (SPBKLU) compared to public charging station
- E2W conversion program is supported

EV UNITS AND ITS INFRASTRUCTURE DEVELOPMENT

1. Number of EV (Unit) (status December 2022)

Passenger Car	3 Wheel Vehicle	Motorcycle	Bus	Box Car	Total
9.636	288	28.808	74	6	**38.812**

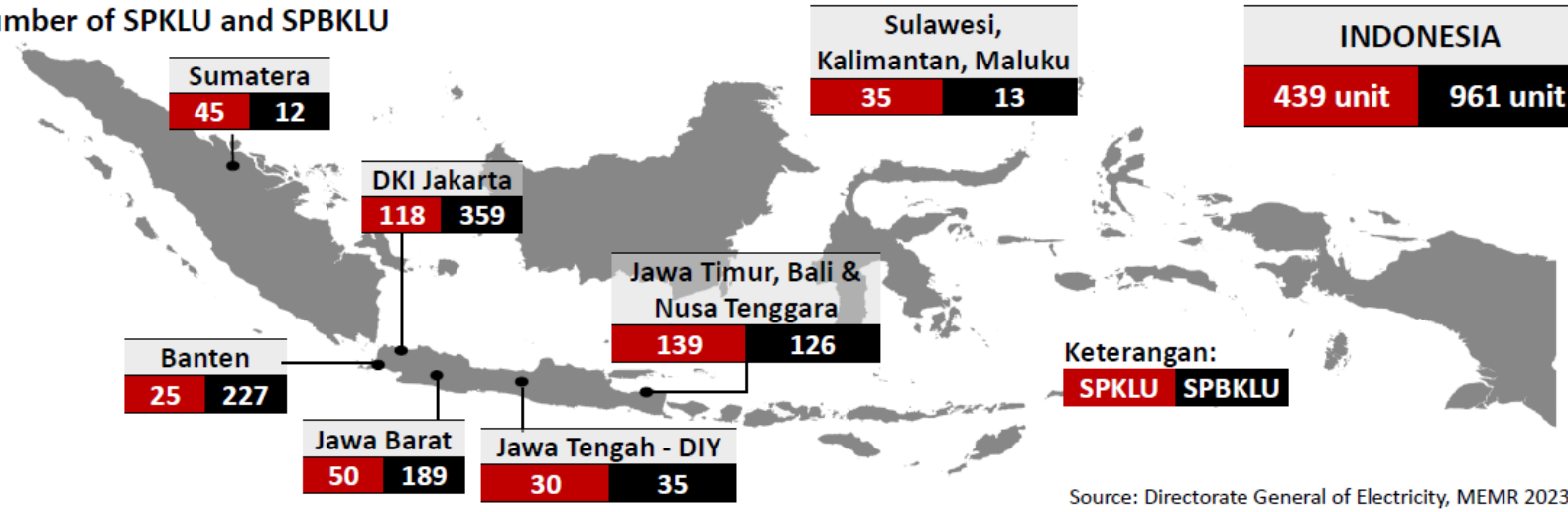
2. Motorcycle Conversion Program Data (unit) (status September 8th 2022)

NUMBER of SPU	TEST RESUME	DRAFT PROCESS	APPROVED	SUT	SRUT
123	109	0	1	108	108

Source: Ministry of Transportation

Information:
- KBLBB = Electric Vehicle
- SUT = Type Test Certificate
- SRUT = Type Test Registration Certificate
- SPKLU = EVCS
- SPBKLU = BSS

3. Number of SPKLU and SPBKLU



Source: Directorate General of Electricity, MEMR 2023

Indonesia – Pertamina swapping system

Indonesia state-own fuel retailer (Pertamina) helps the transition

- 20 swapping stations spread over 13 Pertamina gas stations to serve 600+ E2Ws in South Jakarta and Bali
- Technical partnership with:
  - ✓ Indonesian Gesits and Taiwanese Gogoro E2W manufacturers
  - ✓ Electrum charging infrastructure
  - ✓ Grab and Gojek for ride-hailing services
- Business model: use existing fuel stations as outlet for battery swapping

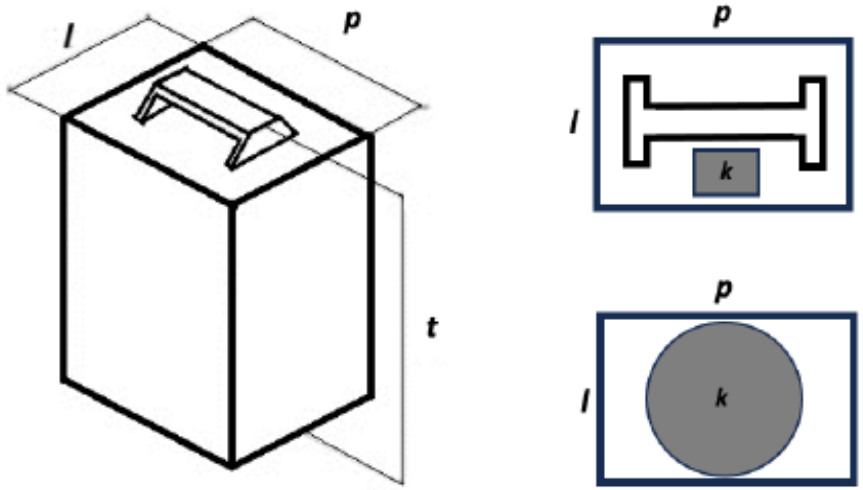
PERTAMINA

Indonesia – Battery regulation: Dimensions, Voltage, Weight, Energy Capacity

Preliminary standard issued on 12 December 2023

- National Standard SNI 8928 (2023) for 'Category L electric motor vehicle battery system — Specification of interchangeable batteries for electric motor vehicles'
  - ✓ Physical dimensions, nominal voltage, maximum weight and minimum energy capacity

Rated voltage (V)	Nominal voltage range (V)	Max mass (kg)	Min energy capacity (Wh)	Maximum size (mm)		
				Long	Wide	Tall
60	55 – 66	13	1,300	220	200	385
72	67 - 78					



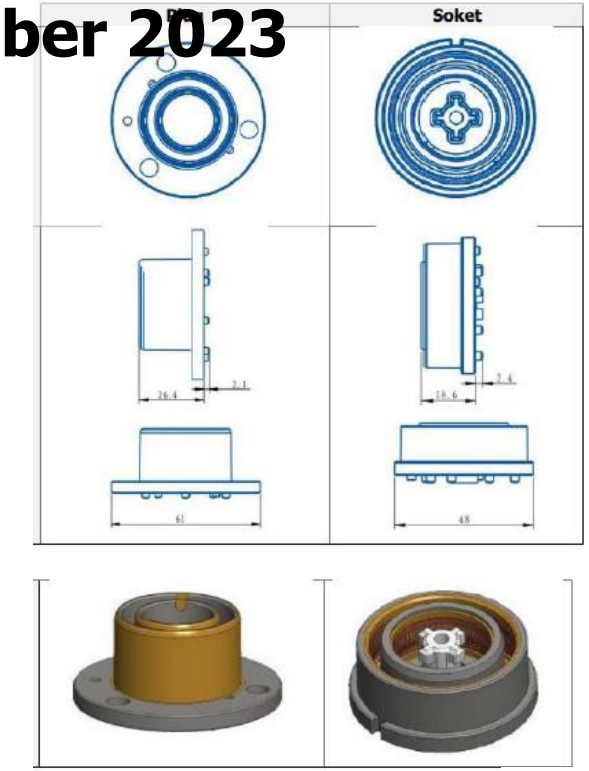
p: battery length;
l: battery width;
t: battery height including battery handle;
k: socket on the battery.

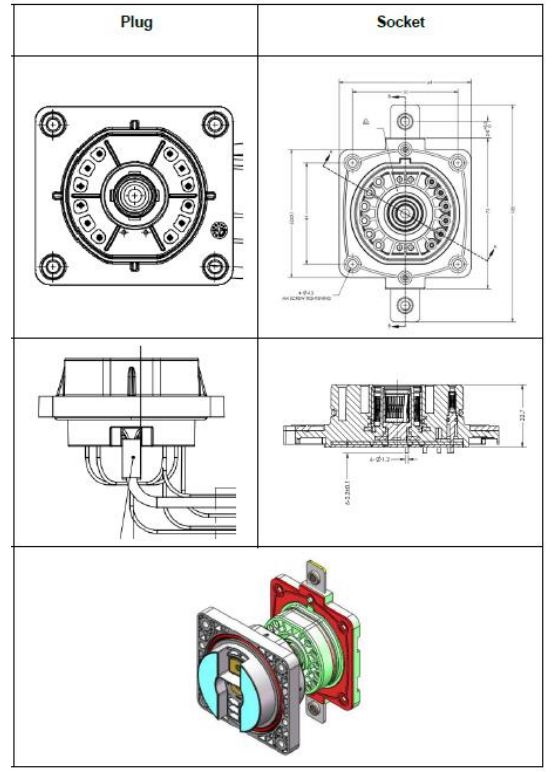
http://sispk.bsn.go.id/SNI/DetailSNI/14690

Indonesia – Battery regulation: Connector

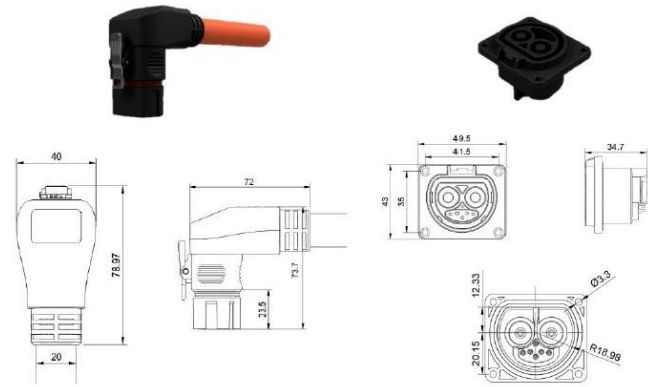
Preliminary standard issued on 12 December 2023

- National Standard SNI 8928 (2023) for 'Category L electric motor vehicle battery system — Specification of interchangeable batteries for electric motor vehicles'
  - ✓ Connector pin location and characteristic with communication protocol





No	Location of connectors on battery	Connector pin	Connector current rating
1	Top	2 DC pins, 6 communications pins	≥ 80 A
2	Bottom	2 DC pins, 12 communications pins	
3	Bottom	2 DC pins, NFC (Near-field communication)	



http://sispk.bsn.go.id/SNI/DetailSNI/14690

Battery swapping case study: Thailand

Project background

Battery swapping can address many of the identified challenges

Targets

- Thailand 30@30 Policy Targets for E2W production of 30% by 2030
- Domestic production target: **675,000** units
- Domestic sales target: **650,000** units
- Swapping station target: **1,450** stations

The Thailand 30@30 Policy aims to position Thailand as the ASEAN EV hub

Challenges

- Long-distance travel demand for serviced motorcycles, such as those used for food and parcel delivery in Thailand
- Current battery specifications in E2Ws require long charging times, disrupting the continuity of service
- The limited battery capacity of many of the current market offerings cannot meet the demand for extended traveling distances, necessitating frequent recharging.

Thailand battery swapping platform

BATT SWAP
Battery Swapping Platform

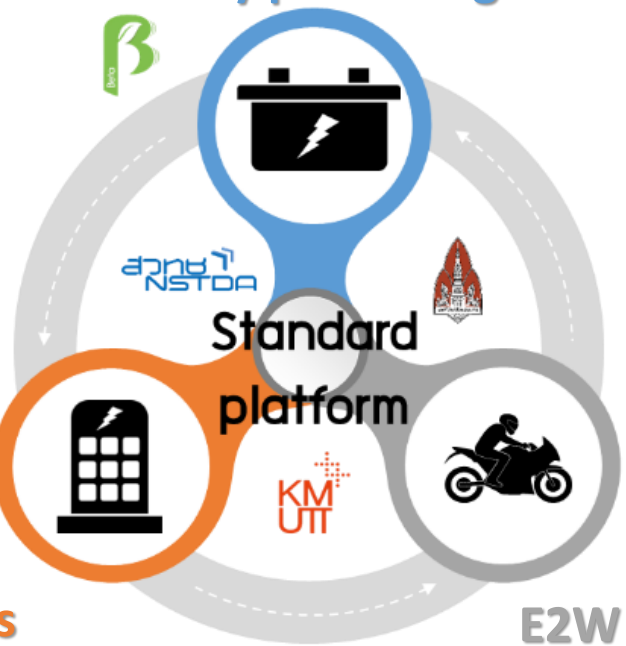
Thailand Battery Swapping Platform

Project Period 2021 - 2023

- A collaborative project between research institute, universities, battery pack producer, E-motorcycle producers and charging service providers
- Target to create standardized battery packs which can be used in various motorcycle providers, and charging operators
- Funded by

PMUC

Ministry of Higher Education, Science, Research and Innovation (MHESI)



- Electrical and Electronics Institute
- Electrical and Electronic Products Testing Center
- Thailand Automotive Institute
- Thailand Industrial Standard Institute

http://www.batteryswapping.in.th

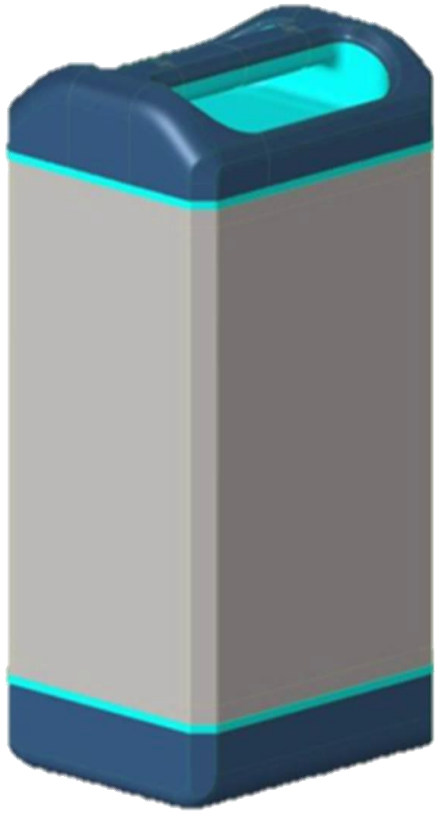
Thailand battery swapping harmonization process

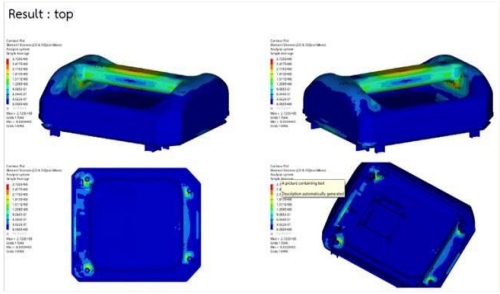
Prototype development

- **Market Analysis** & stakeholder consultation on common battery pack platform, physical battery pack specification (voltage/connector/control/communication)
- **Targeted product specification** formulated and circulated to stakeholders for feedback
- **Battery cells survey** to achieve design parameter
- **Battery cell testing** to ensure battery cell characteristics after procurement
- **Design of battery pack** with E2W manufacturers and battery swapping station
- **Lab & Field testing** to ensure performance and endurance of battery pack design

Thailand battery stack prototype

- Dimensions and weight adjusted to Thai users based on a comprehensive survey
- Voltage and battery characteristics (normal/max charging current, charge/discharge current) designed to respond to user behavior
- Fabricated for field test with data monitoring for continuous improvement





Item	Specification
Overall system	
Dimension W x L x H (mm)	145 x 180 x 340
Total Weight	TBD
Storage temperature	0-35°C
Operating temperature	Charge: 0-45°C, Discharge: -20-60°C
1. Battery packs	
total number of cell	140
number of cell in series	20
number of cell in parallel	7
Cell specifications	HDCNR18650-2600-3.6V 2.6Ah
Connection	2 modules 7P10S in series (7P10S*2)
pack capacity (Ah)	18.2
pack nominal voltage (V)	72
pack minimum voltage (V)	55
pack maximum voltage (V)	84
pack Energy (kWh)	1.31
Normal discharging current (A)	18.2A (1C)
max cont. discharge current (A)	54.6A (3C)
max pulse discharge current (A), 20 seconds	72A (@ 20-100% SOC), 120 A (@40-100%C)
Normal charging current (A)	9.1A (C/2)
Max charging current (A)	18.2A (1C)
total cells weight (kg)	6.44
2. BMS	
Maximum continuous current	Discharge 150A Charge 75A
Connections	1 Centralized system
Cell balancing method	Passive
Cell balancing current	30 +/-5 mA @ cell voltage >3.8V
Cell balancing guarantee voltage	Δ Vcell ≤ 50 mV

https://batteryswapping.in.th/

Case study:
EV charging infrastructure regulations in the EU

EU charging infrastructure policy approach

Many similarities between EV charging regulation in the EU and battery swapping harmonization in the ASEAN exist

- In the EU, a first step was to develop a Trans-European Transport Network (TEN-T) strategy and to set clear targets and milestones for the roll-out of EV charging infrastructure
- The second step was to harmonize the EV charging market was to standardize plugs and sockets used to connect EVs to different types of chargers (Directive 2014/94/EU of the European Parliament and of the Council of 22 October 2014 on the deployment of alternative fuels infrastructure)*
- A third step was to develop structures to harmonize the fragmented, non-interoperable and in-transparent EV charging market*

However, even to date there is still no standardized set of regulations, neither at the national nor at local levels**

Sources: *Ferwerda et al., Advancing E-Roaming in Europe: Towards a Single "Language" for the European Charging Infrastructure, World Electr. Veh. J. 2018
** https://monta.com/uk/blog/what-is-ev-roaming-how-its-developing/

EU seamless travel

EV roaming as a prerequisite for swapping market structuring

- Directive 2014/94/EU on the deployment of alternative fuels infrastructure (AFID) states that:
  - ✓ Charging point operators should offer charging services on an ad hoc basis
  - ✓ Costumers under contract of one charge point operator (i.e., having a subscription) should be allowed to charge at any other operator
- The option to use various battery swapping networks requires roaming between swapping operators
- Roaming implies the following:
  - ✓ A contractual agreement between the operators, either direct (bilateral) or indirect (via a roaming hub or clearing house)
  - ✓ The charging point to be equipped with an internet connection, an RFID card reader or a function for remote activation
  - ✓ Interoperable communication protocols
- EU wide access to charging infrastructure is still based on a series of operating hubs with different levels of development, size and reach, and EV charging provider ensuring access to charging stations across the continent will have to reach agreements with those hubs**

Source: Ferwerda et al., Advancing E-Roaming in Europe: Towards a Single “Language” for the European Charging Infrastructure, World Electr. Veh. J. 2018

Policy recommendations

Policy recommendations I

Put in place the structures and capacity at ASEAN level to guide the development of a battery swapping standard and formulate a strategy

- Take forward the ASEAN Leaders' Declaration on developing an ASEAN regional EV ecosystem adopted at the 42nd ASEAN Summit
- Strengthen ASEAN Economic Community Council to oversee and guide the development of the EV ecosystem
- Establish a taskforce at ASEAN level to develop technical specifications, operational guidelines and business models for the implementation of a harmonized e-2&3 wheeler swapping system
- Develop a strategy and roadmap establishing clear targets and milestones as well as a timeline for the introduction of an ASEAN wide harmonized e-2&3 wheeler battery swapping system
- Design a process or platform for public hearings to get feedback and consensus from stakeholders over time

Policy recommendations II

Follow a step-approach to harmonize battery swapping systems

- Focus on technology standards which have the greatest impact and impose few constraints first and regulate more complex issues as the market evolves
- Start regulating connectors, plugs and communication protocols, which can be used across a wide variety of other technology specifications such as voltage levels, battery chemistries, battery energy capacities and power outputs
- Use data on available product offers in the market and consult with private sector on development of these standards
- Put in place a consultative process with OEMs, national regulators, utilities and EV user associations
- Support development of battery swapping consortia / coalitions to help reduce risk from private sectors

Policy recommendations III

Undertake an ASEAN wide 2&3 wheeler use case mapping to define battery capacity, power and size based on a modular approach

- Compared to vehicle charging regulation, harmonization of swapping technology is more complex as choices have deeper impact on vehicle technology and performance compared to selecting standardized connectors and data exchange protocols
- Start with a regional e2&3 wheeler use case mapping to categorize the demand for vehicle speed, carrying capacity and range across countries in the sub-region
- Based on the use-case mapping, develop a modular battery capacity – power output – battery size scheme
- Use the Thailand and Indonesia case-studies as input for this approach
- Integrate existing initiatives such as the Swappable Batteries Motorcycles Consortium (SBMC, Honda, KTM, Piaggio, Yamaha 2021)

Policy recommendations IV

Put in place a competitive process to identify technology options responding to the established battery capacity – power output – size scheme and pilot the successful technologies

- Combine bottom up (market) and top-down (regulatory) approach
- Based on available systems, initiate a competitive process to receive technology proposals for EV, battery and swapping technology based on modular battery systems to cover the previously identified e-2&3wheeler use cases
- Conduct pilots based on the proposed tender in several countries of ASEAN
- Collect, analyze and disseminate data and organize for an open review process integrating all necessary stakeholders
- Start drafting regulations and standards for agreed elements and disseminate for adoption in ASEAN member countries

Policy recommendations V

From pilot to upscaling – from guardrails to standards

- Develop a guardrails approach for technology standards in parallel to the pilots suggesting preferred technology parameters but not imposing them
- Communicate on best performing battery and swapping technology for E2&3Ws early on and based on current market penetration to send clear signals to the EV industry
- Develop financing schemes targeting the most promising system from the pilots.
- Narrow-down the benchmark approach over an agreed time frame from technology guidelines to standards to allow non-aligned market participants for eventual corrections
- Go-ahead with regular consultations and regularly inform stakeholders about current processes and next steps
- Keep all processes transparent, open and participative
- Introduce descriptive standards for battery capacity, power, size, form factor and connectivity as winning systems crystalize from market
- Review and adapt standards to enable adoption of progress
- Keep the process open for step changes – in case new break-through technologies enter the market.

Policy recommendations VI

Involve non-OEM stakeholders which are likely to play a role in battery swapping systems early on

- Involve power utilities to develop appropriate metering devises and protocols and establish the basis for differentiated prizing of electricity based on peak / off-peak considerations
- Raise awareness amongst policy makers at the highest levels regarding the benefits of e-mobility and the impact of reduced electricity tariff for EV charging
- Involve fuel retailers in the design and development of battery swapping station layout as they will most likely play an important role for battery swapping station location
- Involve insurance companies early on to tackle issues related to the safe coexistence of swapping and fueling stations.
- Develop safety requirements with regards to the siting of swapping stations for both manned and un-manned stations

Policy recommendations VII

Start designing and implementing battery swapping market regulations in parallel and establish the necessary institutions

- Make use of regulations, institutions and business models established in advanced markets such as the EU, North America and China
- Aim for interoperable and transparent payment schemes right from the beginning
- Use open standards principle
- Enable roaming between different battery-swapping providers
- Enforce ad-hoc payment schemes e.g. based on card payment at swapping stations

Policy recommendations VIII

Implement a sub-regional process to enable EV roaming based on agreed protocols and a cross-boarder clearing house structure

- EV roaming is critical as it enables drivers to swap their batteries at different swapping providers using a single card or app
- EV roaming necessitates a common protocol to enable communication between:
  - ✓ Charge point / swapping operators (CPOs) that own and/or operate a charging network
  - ✓ E-mobility service providers (EMSPs) offering network access via an app or charge key
  - ✓ Roaming platforms, which enable roaming agreements between the CPOs and EMSPs
- EV roaming requires a coordinating agency between the different market actors collecting data and overseeing transactions
- Processes for EV roaming should be guided by similar processes in the past, for example mobile networks roaming

Source: https://yocharge.com/faq/the-different-ev-roaming-protocols-ocpi-oicp-ochp-emip/

Conclusions

E2&3W and battery swapping in ASEAN

- More than 10 million 2&3 wheelers added every year in ASEAN. E2&3W sales in Asia are projected to triple by 2026 and grow by 4.5 times by 2030 to reach 100% E2&3W in 2040. Already, and nine of ten ASEAN member states have targets for EVs or EV supply equipment.
- Battery swapping can make E2&3Ws affordable but comprise complex value chains. Many different battery swapping systems already exist for motorcycles and scooters in ASEAN with a wide range of technical specifications.
- Reduction of battery cost is key. To design E2&3W technical specifications and to optimize modular battery systems, the development of regional wide mission profiles and E2&3W use cases is a prerequisite.
- The need for power, speed and range has many impacts on EV technology. Similarly, standardized battery size and form impacts the vehicle design. Overall, standardized batteries significantly limit individual choices of EV manufacturers and result in vehicle conformity.

Opportunities and barriers of harmonized batter swap systems

- Swapping harmonization accelerates EV charging roll-out through rapidly addressing user convenience and technology risk.
- Swapping harmonization reduced investment cost for both vehicle and swapping network development and access to financing is increased.
- Swapping harmonization requires high level of cooperation and results in technological conformity. Similarly, harmonized swapping systems require complex business models.
- Harmonized swapping systems require an informed, strong and flexible regulator and a robust stakeholder consultation and market-feedback process.
- First steps on e2&3W swapping harmonization has been taken in Indonesia and Thailand. Many similarities between EV charging regulation in the EU and battery swapping harmonization in the ASEAN exist. EV roaming is a prerequisite for swapping market structuring.

Policy recommendations

- Put in place the structures and capacity at ASEAN level to guide the development of a battery swapping standard and formulate a strategy
- Follow a step-approach to harmonize battery swapping systems.
- Undertake an ASEAN wide 2&3 wheeler use case mapping to define battery capacity, power and size based on a modular approach.
- Put in place a competitive process to identify technology options responding to the established battery capacity – power output – size scheme and pilot the successful technologies.
- From pilot to upscaling – from guardrails to standards.
- Involve non-OEM stakeholders which are likely to play a role in battery swapping systems early on.
- Start designing and implementing battery swapping market regulations in parallel and establish the necessary institutions.
- Implement a sub-regional process to enable EV roaming based on agreed protocols and a cross-boarder clearing house structure.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