

ANALYSIS

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# Capacity and market potential for local production and distribution of electric two-wheelers in Southeast Asia, focused on Thailand, Indonesia and Vietnam

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## Abstract

Although international efforts toward vehicle electrification in Southeast Asia have primarily focused on four-wheeled vehicles, greater emphasis must be directed toward two-wheeled vehicles (2 W). Southeast Asia has the world's highest rate of 2 W penetration, particularly in Thailand, Vietnam, and Indonesia. These vehicles are popular in this region mainly due to the limited public transportation, their agility on narrow roads, and their ability to maneuver through heavy traffic. Additionally, 2Ws provide a flexible and affordable transportation option, significantly enhancing accessibility and last-mile connectivity to existing public transit networks. However, the vast majority of 2Ws in the region still rely on internal combustion engine (ICE), contributing significantly to urban air pollution and greenhouse gas emissions. Considering the significant role of 2Ws in transporting people and goods throughout Southeast Asia, electrifying this sector offers a substantial potential to mitigate climate impact. This paper advocates for collaborative initiatives across digital platforms, financial mechanisms, and supportive government policies to accelerate the adoption of electric 2Ws (E2Ws) by promoting local production, fostering innovative business models, and establishing conducive regulatory frameworks. A robust E2Ws ecosystem, local E2Ws in the region will require increased cooperation among local E2W and charging equipment manufacturers within the global supply chain, ensuring the development and distribution of environmentally sustainable, technologically advanced, and competitively priced products. Furthermore, E2Ws producers must develop and implement various innovative business models, particularly around battery reuse and recycling, developed in partnership with market stakeholders, including digital platform companies with high growth potential. The financial sector can play a crucial role by creating advanced financing solutions to ease consumer access to E2Ws. Lastly, the governments must support this transition through both financial and non-financial policies, including technical standards, offer preferential policies for E2Ws and charging equipment, and facilitating rapid development.

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**Keywords** Electric two-wheelers, Local production, Vehicle manufacturers, Southeast Asia, Thailand, Indonesia and Vietnam

## Introduction

Southeast Asian countries face two pressing challenges: the need to pursue sustained economic growth and the urgent need to address climate change. Economic expansion in the region has led to a rapid increase in purchasing power, driving heightened demand for transportation and fossil-fuel energy consumption. With a population of approximately 600 million, the middle-class households (defined by annual income between \$10,000-\$25,000) is projected to rise from 39 million in 2022 to 68 million by 2030 [1]. Given this potential demand, the transition to electric vehicles (EVs) and the establishment of a domestic EV production industry presents a dual opportunity - not only to decarbonize the transportation sector but also to stimulate industrial and green economic growth enhancing job security.

Historically, Japanese companies have dominated Southeast Asia's internal combustion engine (ICE) vehicle market, holding a 90% share [2]. As the market shifts towards EVs, a new competitive market is emerging, driven by the reorganization of parts production and supply chains. Several Southeast Asian countries are seeking to establish domestic manufacturing hubs in collaboration with EV and battery manufacturers. This initiative is aimed at both enhancing national energy security and positioning the region as a global leader in EV manufacturing. In this ongoing transformation, traditional ICE vehicle manufacturers face difficulties competing the market, while new opportunities for local EV producers are expanding. Notably, approximately 40% of the cost of an EV is attributed to its battery, a component not directly comparable to those found in ICE vehicles. However, EVs typically consist of fewer than ICE vehicles, offering new market opportunities for local manufacturers [3].

The global EV market, however, is currently experiencing significant challenges in the supply of materials, components, and finished vehicles. These disruptions are largely attributed to geopolitical tensions and shortages of electronic components. The supply of essential raw materials for battery production has been delayed by the ongoing conflicts. Key economic blocs such as the United States, China, and Europe are increasingly consolidating supply chains within their borders, posing further challenges to the development of local EV production capabilities in Southeast Asia.

Thailand, Indonesia, and Vietnam have demonstrated notable initiatives to position themselves as regional hubs for EV manufacturing hubs. These countries are forging collaboration between leading global EV and battery

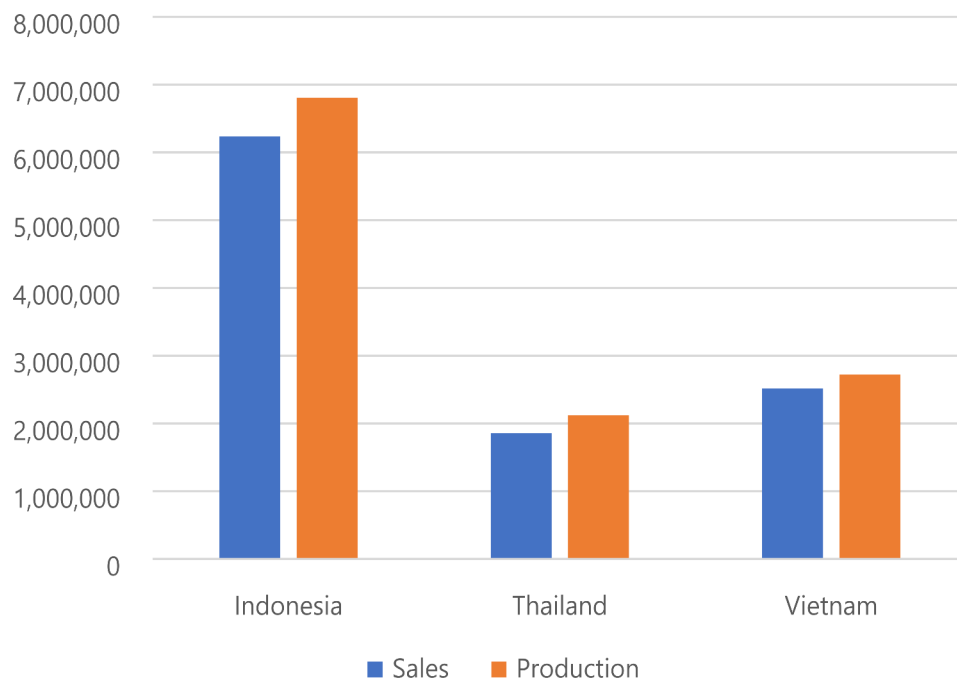
manufacturers with local companies in their respective countries [4], building on their historical prominence as centers of automobile production or as emerging manufacturing countries. However, these efforts primarily target cooperation with global four-wheeler brands. Considering the economic and travel behaviors in Southeast Asia, electric two-wheelers (E2Ws) show significant potential for widespread adoption. For instance, in Indonesia, a popular E2W model is priced approximately half of the country's average annual income, while, a prevalent electric four-wheelers model costs approximately ten times the average annual income [3].

The two-wheelers (2Ws) are a dominant mode of transportation in Southeast Asia, notably due to the limited public transportation network, the high maneuverability of motorcycles on the narrow roads, and ability to navigate through traffic congestion efficiently. They are particularly prevalent in both urban and rural areas due to their lower cost compared to cars and their capacity to enhance first- and last-mile connectivity to public transportation.

Farmer et al. [14] predicts a potential shift from two-wheeled vehicle to four-wheeled vehicles for private use in Asia, driven by rising income, policy initiatives, and the growth of the local automobile industry. Nevertheless, four-wheeled vehicles remain prohibitively expensive for many, suggesting that two-wheelers will continue to serve as the primary mode of transportation in the region. As evidenced by the experiences in China and India, 2Ws are likely to remain integral to urban transport system [15].

In 2022, the global market value of 2 W was valued approximately US\$ 108.58 billion [9], with Southeast Asia having the highest penetration rate of 2Ws. In 2023, Thailand, Vietnam, and Indonesia ranked the highest in household ICE motorcycle ownership in Asia at 87%, 86%, and 85%, respectively [10]. The ICE motorcycle sales in these three countries are also remarkably high, with Indonesia, Vietnam, and Thailand recording 2023 annual sales of approximately 6 million, 2,5 million, and 2 million units, respectively [11]. In addition, these three countries are significant production hubs, manufacturing nearly 12 million of ICE mopeds and motorcycles in 2023 [12]. Figure 1 illustrates the comparison between ICE motorcycle sales and productions in Indonesia, Thailand, and Vietnam.

The International Energy Agency projected that 2 W sector must be fully electrified between 2040 and 2050 in order to respond to the climate crisis [16]. A considerable number of cities in Southeast Asia are experiencing



**Fig. 1** Sales and production of ICE motorcycle and scooter in 2023 (11; 13; 12)

severe air pollution, emphasizing the need for the electrification of transportation. On a positive note, more than 100 million electric 2Ws is projected to be in operating worldwide by 2027 [17], along with the battery capacity expected to reach 228 GWh by 2030 [18].

Recent studies from countries such as India, Nepal, and Vietnam highlight several key factors influencing E2W adoption, including economic benefits, charging infrastructure, and social influences [5–7]. Economic benefits, such as, lower life cycle costs and maintenance costs, play a crucial role in shaping consumer perceptions and attitudes towards E2Ws [6, 7]. However, inadequate charging infrastructure remains a major barrier, discouraging potential users due to concerns about convenience and range [5, 8]. Social factors, such as peer and family recommendations, also positively impact consumer attitudes, indicating the significance of cultural acceptance in accelerating adoption of E2W [7]. Environmental motivations, such reduced emissions, are also factors but tend to be insufficient without supportive government and incentives [5, 6]. Furthermore, research indicates that women are more likely to purchase E2Ws than men, indicating potential demographic targeting opportunities for manufacturers [7]. In summary, the literature suggests that improving charging infrastructure, offering targeted incentives, and disseminating information on the economic and environmental benefits of E2Ws are effective strategies for promoting adoption [5, 7, 8].

This paper examines the current state of local E2W production and distribution infrastructure in the three Southeast Asian countries: Thailand, Indonesia and

Vietnam, with a particular focus on the barriers and implications. Additionally, it provides recommendations from the supply side perspective for establishing a robust E2W ecosystem in the Southeast Asian market, through technological advancements, industrial collaboration and innovation, and supportive national and regional policies. The target audience includes policymakers, government agencies, industry stakeholders, and financial institutions and private investors, all of whom play pivotal roles in addressing the challenges identified in the E2W sector.

### Challenges in local production and distribution of electric 2Ws

This section highlights the challenges related to the production and distribution of E2Ws across Thailand, Indonesia, and Vietnam. As previously stated, these three countries account for the highest number of 2Ws in Southeast Asia and have the potential to become regional hubs for E2W manufacturing. Recognizing the strategic importance of both increasing E2W adoption and establishing themselves as production hubs [13], these countries aim to advance their capabilities in the sector. See Table 1 for an overview of E2W market, targets and policies in Thailand, Indonesia and Vietnam.

#### Challenge 1: competition with ICE 2W and (cheaper) foreign electric 2W brands

Despite 2W sales in Southeast Asia reaching 12.9 million units annually, E2W sales represents only 4% of total 2W [21]. Vietnam leads the E2W market, with an 8.5% market share in 2020 [21], and its E2W sector is expected

**Table 1** Overview of E2W market, targets, and policies in Thailand, Indonesia, and Vietnam

	Thailand	Indonesia	Vietnam
Market share in 2020 (compared to ICE) [19]	0.1%	1.1%	8.5%
Local brand examples [20]	BIZ NEX, DECO, E-Tuk Factory, H SEM, Edison Motors, KAVALLO	Gesits, Electrum, Rakata, Selis, VIAR, Volta	Datbike, DIBAO, VinFast
Production target (21)	650,000 by 2030	3.1 million by 2035	N/A
Incentives examples [21]	Tax exemptions or reductions for consumers and producers, foreign investment restrictions waiver, direct subsidy for consumers	Import tariff exemptions, tax exemptions or reductions for consumers and producers, work visa grant	Tax exemptions or reductions
Industry standardization examples [21]	(TISI): IEC 61980-1:2015, (TISI): IEC TS 62840-1:2016, (TISI): ISO 13063:2012, (TISI): ISO 18243:2020, (TISI): ISO 18246:2015, (TISI): ISO 26262-12:2018, UNR 136	IEC 62660-1:2018, SNI 8613:2018, ISO 13063:2012, SNI 8614-1:2018, ISO 13064-1:2012, ISO/PAS 16,898	QCVN 91, QCVN 90:2019/ BGTVT,TCVN 12773:2020, TCVN 12775:2020, TCVN 12776-1:2020,TCVN 12776-2:2020

to grow to \$22 billion by 2025, with an annual growth rate of 7.3% from 2021 to 2025 [1]. On the other hand, as seen in Table 1, Indonesia and Thailand reported lower E2W market share with only 1.1% and 0.1% penetration, respectively [1]. The limited uptake of E2Ws across the region can be largely attributed to the high initial cost of ownership and the lack of a local production capacity [1]. For instance, the price of lithium-ion (Li-ion) powered e-mopeds and e-motorcycle are approximately three times higher than comparable ICE model [22]. Additional factors contributing to the challenges of E2W adoption includes performance-related issues, such as limited battery range and lower top speeds, difficulties in accessing charging or battery swapping infrastructure compared to widespread petrol stations, and general uncertainty regarding the reliability of new technology.

The emerging E2W market also launches new local key players in these three countries. As summarized in Table 1, the local brands include Gesits, Electrum, and Selis in Indonesia, BIZ NEX and Edison Motors in Thailand, and VinFast, Dibao, and Datbike in Vietnam. Notably, VinFast ceased production of ICE vehicles by the end of 2022, positioning itself as a leading E2W manufacturer in the region. In contrast to Indonesia and Vietnam, Thailand's e-motorcycle market is predominantly dominated by foreign brands such as DECO and H Sem [23]. Based on United Nations Environment Programme (UNEP)'s database [24], the average price of locally produced

e-scooter in Thailand is almost double compared to the imported ones.

A significant challenge in Southeast Asian countries is competition from low cost, lower quality imported motorcycles. In the early 2000s, Chinese manufacturers gained a significant foothold in Vietnam's motorcycle market, capturing 80% of market with competitively priced products. However, these products were eventually rejected by consumers due to poor quality and inadequate after-sales service, leading to the near elimination of Chinese motorcycles from the Vietnamese market within a decade. Ensuring the quality of low-cost imports while building an efficient after-sales service network remains a critical challenge for exporters [25]. To address some countries have implemented policies to keep domestic products competitive. For example, Indonesia has introduced the Domestic Components Level (TKDN) regulation, which requires manufacturers to use a specified percentage of domestic components in their products [26].

#### Challenge 2: limited availability of incentives for local producers and distributors

Indonesia, Vietnam and Thailand are positioning themselves as regional hubs for EV production, leveraging their automotive parts and manufacturing capabilities [3, 4, 14]. These countries possess favorable conditions for attracting investments to develop supply chain for battery-powered vehicles, including E2Ws. National policies and incentives are key to fostering an environment conducive to enhancing domestic E2W production. Incentives for local producers and distributors in these countries are available but still limited.

In Indonesia, the government has implemented several financial measures to support its ambitious E2W production goals. Indonesia has pledged to achieve an annual production capacity of 3.1 million E2Ws by 2035 [21]. The Asian Transport Outlook (2023) [27] highlights various fiscal incentives to boost E2W production, such as corporate tax reduction for EV and EV component manufacturers, import duty reduction, lower vehicle testing and certification cost, and preferential luxury goods tax.

Similarly, Thailand's government has introduced financial incentives to achieve its target of producing 650,000 e-motorcycle by 2030 [21]. The incentives include tax holiday for manufacturers of E2W components, import duty reduction on raw materials, supplies, and components, as well as excise tax waiver [28]. Additionally, companies invest more than 5 billion baht (approximately USD 140 million) locally are eligible for an eight-year corporate tax exemption, while manufacturers of batteries benefit from up to 90% tax exemption on raw materials needed for local battery production. Consequently, Great Wall Motors has recently initiated a programme

of investment aimed at a battery pack assembly plant in Thailand. Furthermore, SAIC decided to build an EV Battery components factory and logistics centre by 2025 [29].

Vietnam's national automobile development strategy for 2025, with a vision for 2035, encourages investment in the production of environmentally-friendly vehicles, including E2Ws. The government is also proposing special investment incentives for EV manufacturing and assembling industries, as well as battery production [30]. The proposal also plans to include import tax reduction on equipment, production, and components of EVs and batteries [30].

### **Challenge 3: lack of standardization in batteries, charging, and swapping**

Industry standardization across the value chain – from components, batteries and vehicles to charging infrastructure – is essential for fostering innovation and encouraging mass production. Indonesia, Thailand, and Vietnam have introduced several standards related to batteries, charging, and swapping, such as SNI 8872 and IEC 62,660 in Indonesia [31], TISI 62,196 [32] in Thailand, and QCVN 91 [33] in Vietnam. Table 1 summarizes the available standards that applicable in those countries. However, some of the current standards are voluntary, making it challenging to enforce.

The lack of mandatory standards can deter vehicle manufacturers from investing in E2W production, as they prefer to wait for the establishment of comprehensive technical regulations. Standardizing battery sizes and technical specifications would streamline the deployment of battery-swapping stations by enabling companies to clearly identify the battery types required. In addition, standardization in battery and charging equipment would allow component manufacturers to produce consistent models at scale, reducing production costs and addressing interoperability challenges across vehicles and charging systems.

### **Challenge 4: battery technology is still developing**

Li-ion battery is currently in high demand and used in the E2W markets in Indonesia and Thailand, accounting 83% and 71% of the market, respectively, while lead-acid battery is more prevalent in Vietnam at 85% [34]. Lead-acid batteries are relatively cheaper and tolerant of higher temperature but are heavier and pose significant environmental concerns [35]. Meanwhile, Li-ion batteries are more compact and have faster charging rate, but quite sensitive to high temperature [35]. E2Ws in these countries typically have battery capacities ranging from 1 kWh and 1.5 kWh, providing a maximum range of 70 to 90 km [36].

Nevertheless, battery technology for E2Ws is rapidly advancing. Over the past decade, Li-ion battery development have improved performance and lowered costs. Ongoing research continues on increasing capacity, reducing charging times, and further cutting costs [37].

Furthermore, the demand for advanced battery technology is increasing with the rise of commercial use cases of E2W in Southeast Asia are emerging, including ride-hailing, micro transit, logistics delivery, which runs longer distance and duration compared to private ones. For example, Lazada Logistics, a key player in Southeast Asian e-commerce, recently disclosed the introduction 100 electric motorcycles following a successful six-months delivery pilot program [38]. Ride-hailing services through digital platforms and applications, such as GoJek, GrabBike, and PinBike, have further driven the adoption of E2Ws in Indonesia, Thailand and Vietnam, due to its convenience and affordability. GoJek, for instance, started in 2010 with 20 motorcycle taxi drivers and has grown into a \$3 billion tech giant with over 400,000 drivers in 50 cities [3]. It recently entered into a joint venture to manufacture E2Ws [39]. Similarly, Vietnam's Vin Group's SM Green Taxi (GSM) has started an electric 2Ws and 4Ws rental business in Da Nang with logistics transportation company Ahamove, and is expanding the electric taxi ecosystem by signing E2W agreements with ride-sharing platform Be and taxi companies Lado and En Vang [38].

However, the current E2W models are insufficient to meet the demands of these emerging commercial use cases. According to UNEP database [40], the certified maximum range per charge for E2W that are available in these three countries is 85 km. Meanwhile, studies show that motorcycle-taxi drivers typically drive over 100 km per day [41], requiring drivers to charge or swap the batteries in between. Most available public charging stations are currently slow-charging, leading to long charging time and unproductive downtimes, which could affect the earnings of drivers and businesses. In addition, not all E2W are equipped with swappable batteries. Local producers and distributors should address these gaps by designing E2Ws that meet the needs of emerging commercial use-cases.

### **Challenge 5: lack of agility to adapt with emerging digital mobility and commercial services**

In Southeast Asia's E2W market, the lack of agility to adapt to emerging digital mobility and commercial services is primarily rooted in IT infrastructure limitations. Despite the rapid proliferation of digital platforms for mobility services, including ride-hailing and delivery, the existing IT infrastructure are often inadequate for seamless integration with E2W operations.

A significant issue lies in the lack of compatibility and interoperability among the IT systems of various service providers. This can result in fragmented data ecosystems, making it difficult for companies to access and leverage valuable insights for optimizing fleet management, customer engagement, and operational efficiency. Furthermore, inadequate IT infrastructure may hinder the development of innovative features and services that cater to the evolving needs of users in the digital age. Without robust IT systems that can adapt to the dynamic landscape of digital mobility, E2W companies may struggle to stay competitive and meet the growing demand for their services.

#### **Challenge 6: nascent market for battery recycling and vehicle retrofitting**

The growing adoption of EV worldwide signal an impending surge in end-of-life EV batteries, including those from E2Ws. This trend necessitates a concerted effort to support local businesses involved in the reuse, remanufacturing, and recycling of these batteries, in collaboration with battery manufacturers. However, battery disposal poses unique challenges, especially in countries with lower EV market penetration. In such cases, the limited volume recyclable batteries render the recycling business less profitable. In Thailand, there are indications of future EV batteries recycling by three different companies [42], while, these services remain unavailable in Indonesia and Vietnam, and are limited across other Southeast Asian countries.

The conversion of internal combustion engine (ICE) vehicles, including 2Ws, to electric vehicles offers a promising alternative to new vehicle purchases. Retrofitting businesses utilize this opportunity to convert ICE vehicles to electric, reducing fuel consumption and emissions, and contributing to improved air quality and reduced greenhouse gas (GHG) emissions. According to a study by GGGI [43], retrofitting results in a lower total cost of ownership and CO<sub>2</sub> emission are lower compared to both new ICE and new EV. Additionally, Indonesian Ministry of Energy and Mineral Resources also pointed out that the conversion project could reduce fuel costs from USD 20 to USD 5 per month [44], offering both economic and environmental benefits. Nevertheless, the lack of adequate regulations for retrofitting vehicles (with specific standards for quality assurance), a small market, and limited consumer awareness have led to perceptions of retrofitting as costly and niche. Government intervention in promoting retrofitting businesses and establishing quality standards could help expand this market.

#### **Challenge 7: scarcity of raw materials**

Similar to other types of EVs, the production of E2W also faces due to the scarcity of raw materials, particularly

for batteries. The global battery market is growing rapidly and projected to tenfold between 2020 and 2030 [45]. Jones (2020) projected that the 2030 demand for cobalt, lithium, manganese, and nickel from EVs alone is going to increase significantly by 40, 20, 5, and 5 times compared to the consumption level in 2015, respectively [46]. While this could benefit resource-exporters countries, the associated price volatility and environmental and social consequences present challenges for resource-wealth countries [47].

Several Southeast Asian countries contribute significantly to mining raw materials for EVs such as cobalt, graphite, manganese, and nickel. Indonesia and Philippines lead the global nickel producers by comprising of 31% and 13% of global share, respectively [47]. While Malaysia, Myanmar, and Vietnam contribute to Manganese mining each below 2% of the global share [47].

Since 2020, Indonesian has imposed a ban on nickel export (East Asia Forum, 2023) to stimulate local investment on EV battery by multinational companies. In response to this, LG Energy Solutions, a global battery manufacturing company, is building a battery cell production plant in the Karawang Industrial Complex near Jakarta together with Hyundai Motor Company. China's CATL has decided to establish a vertically integrated production system, including nickel mining, by establishing a production plant in Indonesia by 2026 through a joint venture with a local company.

#### **Challenge 8: high production cost and limited availability of components**

The growth of the E2W market in Southeast Asia is hindered by high production costs and limited availability of components. Manufacturing E2Ws entails significant initial investments, particularly in research, development, and production infrastructure. Additionally, the scarcity of specialized components in the local market, such as batteries and electric motors, further drives up production costs and restricts the scalability of E2W production in the region.

To mitigate these challenges, forming strategic alliances with established global suppliers of batteries, motors, and other components is essential, particularly in light of recent geopolitical trade disputes. Moreover, to reduce production costs and improve supply chain resilience, governments and industry stakeholders must collaborate on initiatives aimed at localizing component production. Encouraging investment in domestic manufacturing capabilities, incentivizing component localization, and fostering partnerships between local and international companies are crucial steps towards overcoming the barriers to growth in the E2W market in Southeast Asia.

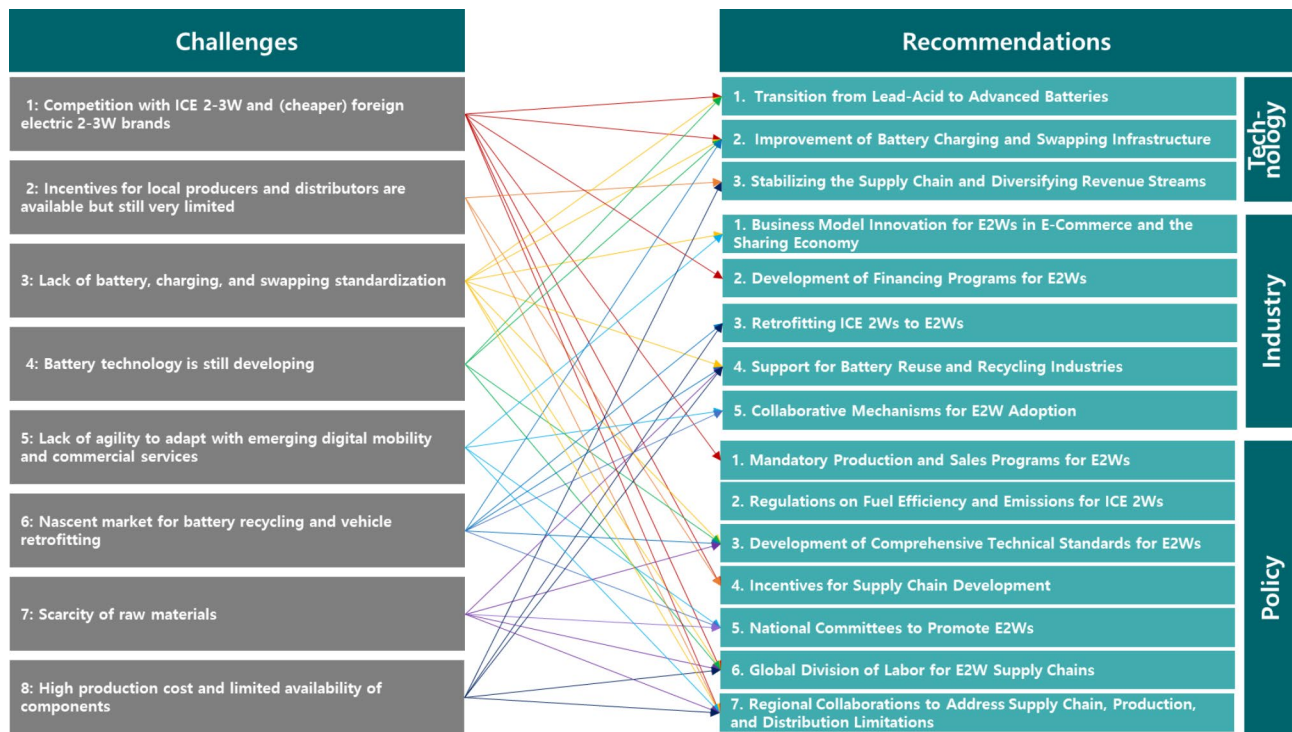


Fig. 2 Recommendations to address the challenges

**Recommended actions**

The E2W market in Southeast Asia exhibits substantial potential for significant expansion. However, realizing this potential requires a holistic approach that integrates technology, industry, policy, and surrounding infrastructure. This section seeks to provide insights and recommendations from the supply side perspective for establishing a robust E2W ecosystem in the Southeast Asian market. Based on the previous analysis, eight key challenges were identified across three Southeast Asian countries, hindering market expansion. To address these challenges, targeted recommendations are identified and explained, which are grouped at technological, industrial and policy levels (see Fig. 2).

**Connections between challenges and recommendations**

The connections illustrated in Fig. 2 establish a critical linkage between the challenges faced by the E2W market in Southeast Asia and the corresponding recommendations to address them. The arrows signify how each challenge aligns with targeted interventions, reflecting a systematic approach to overcoming barriers and fostering the adoption and production of E2Ws in the region.

**Challenge 1**

Competition with ICE 2Ws and Cheaper Foreign Electric 2Ws.

Transitioning from lead-acid to advanced lithium-ion batteries enhances the performance, cost-effectiveness,

and market competitiveness of locally manufactured E2Ws. Furthermore, innovative business models, such as those for e-commerce and the sharing economy, strengthens the value proposition of E2Ws, making them more appealing to consumers compared to ICE vehicles.

**Challenge 2**

Limited Incentives for Local Producers and Distributors.

Addressing this challenge requires implementing incentives to strengthen E2W supply chain and mandatory production and sales programs. These measures aim to create a conducive environment for local manufacturers to scale their operations while ensuring market demand through regulatory mandates.

**Challenge 3**

Lack of Standardization in Batteries, Charging, and Swapping.

Developing comprehensive technical standards for E2Ws is essential to addresses this gap. Standardization promotes interoperability, reduce costs and enhances confidence among manufacturers and consumers. It also streamlines infrastructure investments and improves operational efficiency across E2W ecosystem.

**Challenge 4**

Battery Technology is Still Developing.

Improving battery charging and swapping infrastructure must be aligned with the advancements in emerging

battery technologies. Deploying advanced infrastructure addresses concerns about range and convenience, thereby encouraging greater adoption of E2Ws.

#### **Challenge 5**

**Lack of Agility to Adapt to Emerging Digital Mobility and Commercial Services.**

To enhance agility and adaptability in the E2W market, it is recommended to stabilize supply chains and diversify revenue streams, including IoT-driven predictive maintenance. These strategies enable manufacturers to harness data and technology, ensuring competitiveness and the ability to meet evolving consumer demands.

#### **Challenge 6**

**Nascent Market for Battery Recycling and Vehicle Retrofitting.**

Supportive battery reuse and recycling industries is crucial to fostering a circular economy and addressing these challenges. Additionally, retrofitting ICE vehicles to E2Ws offers a complementary solution, reducing waste and emissions while unlocking new market opportunities.

#### **Challenge 7**

**Scarcity of Raw Materials.**

To overcome resource constraint, it is recommended to adopt a global division of labor for E2W supply chains and establish strategic partnerships. By leveraging regional strengths and promoting international collaboration, Southeast Asia can secure access to critical materials and stabilize production.

#### **Challenge 8**

**High Production Costs and Limited Availability of Components.**

Incentivizing supply chain development and investing in local manufacturing capabilities can directly address this challenge. By fostering partnerships and attracting investment, the region can reduce dependency on imported components and achieve cost reductions.

#### **Recommendation for technological advancement**

##### ***Transition from lead-acid to advanced batteries***

The shift from lead-acid to advanced lithium-ion batteries for E2Ws in Southeast Asia would significantly improve vehicle performance, offering enhanced energy efficiency, extended range, and longer battery life. This transition is especially critical for delivery services and motorbike-taxis that require ranges of 80–100 km. Although lithium-ion batteries have higher upfront cost, they have operational economy and reduce the total cost of ownership in the long run, making them more economically viable for both businesses and individual in

highly demanding cities such as Jakarta, Bangkok, and Ho Chi Minh City. Additionally, advancements in materials and motor efficiency will reduce battery weight, resulting in improved vehicle performance [3].

#### **Improvement of battery charging and swapping infrastructure**

Developing an extensive network of charging and battery-swapping stations across Southeast Asia's dense urban centers has the potential to significantly reduce range anxiety, which is a key barrier to E2W adoption. Consequently, cities such as Bangkok, Jakarta, and Hanoi will be well-positioned to facilitate a greater uptake of E2W, particularly for commercial uses. Government-led initiatives to incentivize private investment in charging infrastructure, as seen in China, could accelerate the deployment of such networks [48, 49]. Furthermore, the standardization of battery and charging technology across the region would help reduce costs, improve interoperability between systems, and promote broader market growth [50].

#### **Stabilizing the supply chain and diversifying revenue streams**

In order to mitigate the risks associated with global supply chain disruptions and ensure consistent access to key components, E2W companies in Southeast Asia should prioritize the stabilization of supply chains and diversify their revenue streams through the provision of supplementary services. One promising avenue is the integration of the Internet of Things (IoT)-driven technology for vehicle maintenance. Predictive maintenance and software updates can enhance vehicle reliability while generating recurring revenue streams. Offering connectivity services will further enhance customer satisfaction and loyalty, providing companies with a competitive edge in the evolving E2W market. This strategy will lead to sustained growth and profitability in the region's EV sector.

#### **Recommendation for industrial collaboration and innovation**

##### ***Business model innovation for E2Ws in E-commerce and the sharing economy***

Manufacturers can better meet the needs of Southeast Asia's rapidly expanding e-commerce and ride-sharing industries by designing E2Ws tailored for these high-demand sectors. For instance, developing E2Ws with extended range, fast charging capabilities, and cold-chain storage for food delivery would drive increased adoption by on-demand delivery providers such as Grab and GO-JEK. Additionally, collaboration with these platforms for data sharing on driver behavior and usage patterns would enable manufacturers to optimize their designs to align more effectively with local market demands,

thereby improving both vehicle performance and user satisfaction.

#### ***Development of financing programs for E2Ws***

Establishing robust financial programs for E2Ws, particularly in partnership with international public funds such as the Green Climate Fund and multilateral development banks, can enhance E2W deployment and help address the upfront cost barrier for consumers and businesses [51]. These financial programs would will encourage greater shift to E2Ws over ICE counterparts, particularly when private financial institutions establish residual values for batteries and offer lower upfront costs [52]. Public-private partnership (PPP) schemes would further promote financing solutions, facilitating easier adoption of E2Ws for both individual and commercial.

#### ***Retrofitting ICE 2Ws to E2Ws***

Retrofitting ICE 2Ws to electric presents a viable opportunity for transitioning Southeast Asia's large existing fleet of motorbikes towards electrification. This approach not only reduces waste and emissions but also provides a cost-effective solution for businesses seeking to expand their low-emission vehicles fleets. Furthermore, integrating carbon emissions monitoring ensures compliance with environmental regulations [53], enhancing the marketability of retrofitted vehicles. Linking retrofitting efforts with the used vehicle market will create new revenue streams for dealerships and service providers, contributing to the sustainability and economic viability of second-hand vehicle solutions.

#### ***Support for battery reuse and recycling industries***

Targeted initiatives for battery reuse, remanufacturing, and recycling, specifically for E2Ws, can significantly reduce the environmental impact of end-of-life batteries. Collaborating with battery suppliers to establish recycling facilities and promote remanufacturing processes will foster circular economy for battery materials, enhancing the sustainability of E2W production and usage. This strategy ensures that Southeast Asia can accommodate the rising number of E2Ws without exacerbating waste management challenges.

#### ***Collaborative mechanisms for E2W adoption***

Integrating digital platforms, financial mechanisms, and government policies can accelerate E2W adoption by fostering synergies among these elements. Digital platforms can generate demand and provide user data to inform policies and financing models. Financial mechanisms, such as tailored loans or incentives, can lower entry barriers for users, especially in ride-hailing and delivery sectors. Governments can support these efforts through

subsidies, tax incentives, and infrastructure development, including public charging stations.

Collaborative efforts, such as public-private partnerships, can ensure coordinated action, leveraging platform data for optimized infrastructure placement and funding models. Together, these mechanisms can create a sustainable ecosystem, reducing financial and logistical barriers while accelerating E2W adoption in Southeast Asia.

#### ***Recommendation for supportive policies***

##### ***Mandatory production and sales programs for E2Ws***

The implementation of mandatory production and sales targets for E2Ws by the government will incentivize manufacturers to scale up production and invest in necessary infrastructure to meet growing demand. For instance, expanding Thailand's "30 by 30" policy to include specific targets for E2Ws could accelerate the shift towards electric mobility, encouraging wider adoption across the Southeast Asian region.

##### ***Regulations on fuel efficiency and emissions for ICE 2Ws***

The introduction of stringent regulations on fuel efficiency and emissions for ICE 2 W will push manufacturers to develop more efficient and lower-emission technologies. This regulatory pressure will also expedite the transition to E2Ws. Aligning with standards, such as Euro 6, can reduce the cost gap between ICE vehicles and EVs, thereby motivating manufacturers to prioritize E2W production.

##### ***Development of comprehensive technical standards for E2Ws***

The establishment of comprehensive technical standards for E2Ws, including charging infrastructure and battery management, will drive investment in the E2W sector across Southeast Asia. Harmonized standards will promote interoperability among E2W brands, facilitating wider adoption, and ensuring consistent quality across the region.

##### ***Incentives for supply chain development***

Providing financial incentives such as tax exemptions, investment credits, and subsidies can ease the early-stage transition to E2W production, particularly in regions where production costs are higher for E2Ws compared to ICE vehicles. These incentives will encourage investment in E2W assembly plants and supply chain development, fostering local production capabilities and gradually lowering costs.

##### ***National committees to promote E2Ws***

Establishing national committees dedicated to the promotion of the E2W industry in each Southeast Asian country will facilitate the development of coherent policies, technical standards, and financial incentives tailored

to the local market conditions. These committees, fostering collaboration between public and private stakeholders, will ensure a coordinated and strategic approach to the development and deployment of E2Ws across the region.

#### **Global division of labor for E2W supply chains**

Positioning Southeast Asia as a key player in the global E2W supply chain, through specialization in areas such as in battery production, vehicle manufacturing, and end-of-life recycling, can attract investment and expertise from leading EV and battery-producing countries. This approach would foster the development of a robust supply chain that serve both local and international markets, contributing to economic growth and technological advancement in the region.

#### **Regional collaborations to address supply chain, production, and distribution limitations**

Regional collaboration can play a vital role in addressing the supply chain, production, and distribution challenges faced by the E2W industry in Southeast Asia. By leveraging the strengths of each country, resource sharing and partnerships can stabilize supply chains, while joint investments can establish regional manufacturing hubs and expand production capacity. Standardizing technologies and aligning regulations can further reduce production costs and enhance interoperability, while trade agreements can lower the costs of raw materials and products, boosting market competitiveness.

On the distribution side, coordinated development of cross-border charging and logistics infrastructure can improve E2W mobility. Knowledge sharing and the dissemination of successful case studies can also accelerate innovation and technological advancement. Through such collaborations, Southeast Asia can build a cost-efficient and sustainable E2W ecosystem while enhancing its competitiveness in the global electric mobility market.

#### **Conclusion**

Southeast Asia stands at a critical juncture where the pursuit of economic growth must be balanced with the pressing need to mitigate the effects of climate change. The transition to E2Ws presents a distinctive opportunity to decarbonize the transport sector while simultaneously fostering industrial and economic growth and securing employment in the region. However, several challenges hinder the widespread adoption of E2Ws. These include the competition with more affordable ICE vehicles, limited incentives for local producers, and the lack of battery standardization and recycling infrastructure.

To overcome these challenges and unlock the full potential of the E2W market, a multifaceted approach is required. This includes technological advancements

to improve vehicle range and performance, the expansion of charging infrastructure, the standardization of EV technologies, and the stabilization of supply chain. In parallel, industry efforts should focus on innovative business models linked to e-commerce and the sharing economy, as well as vehicle retrofitting and the development of local battery reuse, remanufacturing, and recycling businesses.

At the policy level, governments should introduce mandates for E2W production and sales, enforce stringent fuel efficiency and emissions regulations for ICE vehicles, and establish comprehensive technical standards for the entire E2W ecosystem. Financial incentives and the creation of national committees and promotion agencies can further accelerate the growth of the E2W sector.

Ultimately, a concerted effort from stakeholders across technology, industry, and policy sectors is essential to create a conducive ecosystem for E2Ws in Southeast Asia, unlocking the region's potential for sustainable growth and contributing to global climate action.

#### **Abbreviations**

EVs	Electric Vehicles
ICE	Internal Combustion Engine
GCF	Green Climate Fund
MDBs	Multilateral Development Banks
E2W	Electric Two-Wheeler
SNI	Standar Nasional Indonesia (Indonesian National Standard)
IEC	International Electrotechnical Commission
TISI	Thai Industrial Standards Institute
QCVN	Quốc Gia Việt Nam (Vietnamese National Standard)
TKDN	Tingkat Komponen Dalam Negeri (Domestic Components Level)
IoT	Internet of Things
GHG	Greenhouse Gas
AAF	ASEAN Automotive Federation
UNEP	United Nations Environment Programme
CATL	Contemporary Amperex Technology Co. Limited
ASEAN	Association of Southeast Asian Nations

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#### **Author contributions**

Hyung Ju Kim wrote the main manuscript text. Shritu Shrestha and Kanya Pranawengkapti added manuscript text. All authors reviewed the manuscript. Kanya Pranawengkapti prepared Fig. 1. and Hyung Ju Kim prepared Fig. 2.

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No datasets were generated or analysed during the current study.

#### **Declarations**

##### **Ethics approval and consent to participate**

This research project did not require ethics approval and consent to participate as it did not involve human subjects or sensitive data.

### Consent for publication

This research project did not contain any individual person's data in any form.

### Competing interests

The authors declare no competing interests.

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