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Total cost of ownership comparison for electric two-wheelers in Vietnam

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1. Introduction

Electrification of two-wheeler (2W) vehicles is a growing trend worldwide. In China, the global leader in motorcycle electrification, electric two-wheelers (E2W) accounted for 9.5 million out of 10 million total registrations in 2021.[1] In Vietnam, E2Ws were introduced about 10 years ago, and sales have increased significantly since 2015, accounting for 8.3% of total 2W sales in 2020.[2] This number is much higher than in other countries in Southeast Asia with high motorcycle demand, such as Indonesia and Thailand, whose E2W shares reached 1.1% and 0.1%, respectively.[3]

Some 2.9 million 2W vehicles were sold in Vietnam in 2021, accounting for about 92% of all road vehicles in the country in 2019; their popularity can be attributed to their low cost and convenience for personal mobility.[4] Unfortunately, these widely accessible vehicles negatively impact air quality and increase greenhouse gas (GHG) emissions. Therefore, transitioning from petrol-powered 2W to E2W is essential, especially in big cities where the conventional internal combustion engine two-wheeler vehicle (ICE-2W) is one of the major sources of air pollution[5] and may soon be restricted. For

1 "The global electric vehicle market overview in 2022: statistics and forecasts" Virta, accessed January 12, 2023, https://www.virta.global/en/global-electric-vehicle-market?__hstc=51530422.ebaa37e7e5879ff0d945f91d67cc72c4.1673531002603.1673531002603.1673531002603.1&__hssc=51530422.1.1673531002603&__hsfp=2749342364&hsutk=ebaa37e7e5879ff0d945f91d67cc72c4&contentType=standard-page#two.

2 Dinh-Son Tran, Huong Le and Zifei Yang, Two-wheelers in Vietnam: A baseline analysis of fleet characteristics and fuel consumption in 2019 and 2020, (ICCT: Washington, DC, 2022), https://theicct.org/publication/2w-lvs-vietnam-asia-baseline-feb22/.

3 Huong Le and Zifei Yang, Two-wheeler and three-wheeler vehicle market analysis of key ASEAN member states, (ICCT: Washington, 2022), https://theicct.org/publication/asia-pacific-lvs-ndc-tia-23w-market-asean-countries-jun22/.

4 Tran, Le, and Posada, Two-wheelers in Vietnam.

5 Ministry of Natural Resources and Environment (MONRE), "Báo Cáo Môi Trường Quốc Gia 2017 - Chuyên Đề: Quản Lý Chất Thải. Hà Nội, Việt Nam" (2018). (In Vietnamese)

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example, Hanoi plans to ban conventional two-wheelers in core districts after 2025 and will expand the ban to all districts after 2030.[6]

Ultimately, electrification of the 2W fleet is an important mobility solution in places where the availability of public transport is limited. In large cities like Hanoi and Ho Chi Minh City, the two biggest cities in Vietnam, public transport serves only about 9–10% of mobility demand.[7] A transition to E2Ws would offer an immediate solution to mobility needs and reduce the environmental impact of the expected growth in individual transport solutions. In the long term, a transition to a more extensive network of electrically powered public transport (e.g., battery electric buses) would be a more holistic solution for Vietnam's transport and environmental challenges.

Figure 1. Road traffic in Hanoi, Vietnam (photo credit: Dinh-Son Tran)

In this report we compare the total cost of ownership (TCO) of ICE 2Ws against E2Ws. Detailed TCO comparisons are provided for E2Ws with lead-acid and lithium-ion (Li-ion) batteries. As innovative battery swapping options are available for E2Ws in Vietnam, we explore the TCO impacts of battery renting (via swapping) and battery purchase options. The results inform policy recommendations for reducing the cost gap for E2Ws and accelerating their adoption in the country.

Seven 2W models in Vietnam were selected for this analysis; these models represent five 2W sub-classes including electric and ICE models—individual analyses are carried out for mopeds and motorcycles. The analysis is performed for a 10-year period of ownership. Results are shown at the 5th year and over the entire period.

6 Vo Hai, "Hanoi plans motorbike ban after 2025," VNExpress International, December 6, 2021, https://e.vnexpress.net/news/business/economy/hanoi-plans-motorbike-ban-after-2025-4399322.html#:~:text=Hanoi%20plans%20to%20ban%20motorbikes,reduce%20traffic%20congestion%20and%20emissions.

7 Le Anh Tuan, Nguyen Thi Yen Lien, Do Duc Tue, "Study of electric mobility development in Viet Nam," (Bonn: Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, 2021), https://www.ndctransportinitiativeforasia.org/resources-list/study-of-electric-mobility-development-in-viet-nam.

2. Background

E2W battery technology

E2Ws are sold with two distinct types of battery technologies: lead-acid and Li-ion. The type of battery has strong implications for vehicle price, range, and durability. More than 75% of E2Ws in Vietnam are equipped with lead-acid batteries.[8]

Lead-acid batteries employ the same technology used in vehicle batteries over the last century. Compared to Li-ion batteries, lead-acid batteries are cheaper. In 2021, the price of a Li-ion battery was about $132/kWh.[9] According to a study from Nesuan University, the cost of Li-ion batteries is 5 times that of lead-acid batteries of the same capacity.[10]

Lead-acid batteries have lower energy density than Li-ion batteries. As a result, at equivalent capacities, the lead-acid battery is much heavier than the Li-ion battery. An 8 kg Li-ion battery can hold as much energy (21 Ah) as a 41 kg lead-acid battery. Li-ion batteries also require shorter charging times. A 1.45 kWh lead-acid battery takes 11 hours to charge fully, while a 1.58 kWh Li-ion needs only 5.1 hours. A comparison of several E2W models from the same manufacturer powered by lead-acid and Li-ion batteries is described in Table 1.

The lifetime of a lead-acid battery is also much shorter than that of a Li-ion battery. A lead-acid battery can be charged-discharged around 250 to 300 times, equivalent to 1 year of use. Therefore, users must replace the entire battery (usually 4-6 packs) annually, resulting in a higher operating cost compared to a vehicle equipped with Li-ion battery. In addition, proper treatment of these discarded batteries would be needed to avoid significant negative impacts on the environment.

Table 1. Technical data of Li-ion and lead-acid batteries from VinFast products[11]

Battery technology	Model	Vehicle price (million VND)	Vehicle weight (kg)	Battery weight (kg)	100% full charging time (h)*	Range (km)	Life time of battery (cycle count)	Capacity (kWh)	Efficiency (kWh/100 km)
Li-ion battery	Klara S	39.9	108	7.8	4.8	120	1000	1.11	0.92
	Impes	14.9	75	7.8	4.8	70	1000	1.11	1.58
	Ludo	12.9	68	7.8	4.8	75	1000	1.11	1.48
	Theon S (2 batteries)	69.9	145	9.8	6	101	1000	3.38	2.25
	Average		99	8.3	5.1	92	1000	1.58	1.72
Lead-acid battery	Feliz	24.9	126	41.0	12	90	250	1.51	1.68
	Tempes	14.9	103	33.8	10	80	250	1.26	1.58
	KlaraA2	26.9	126	41.0	11	90	250	1.58	1.76
	Average		118	38.6	11	87	250	1.45	1.67

* using a home charging device

8 Le and Yang, Two-wheeler and three-wheeler vehicle market.

9 James Frith, "Battery Price Declines Slow Down in Latest Pricing Survey," Bloomberg, November 5, 2021, retrieved from https://www.bloomberg.com/news/articles/2021-11-30/battery-price-declines-slow-down-in-latest-pricing-survey.

10 Suratsawadee Anuphappharadorn, Sukruedee Sukchai, Chatchai Sirisamphanwong, Nipon Ketjoy, "Comparison the Economic Analysis of the Battery between Li-ion and Lead-acid in PV Stand-alone Application," Energy Procedia, volume 56, 2014, https://www.sciencedirect.com/science/article/pii/S1876610214010297?ref=pdf_download&fr=RR-2&rr=742e7b89489e8373.

11 Technical data of Li-ion and lead-acid batteries from VinFast products were collected from VinFast's website, https://vinfastauto.com/vn_vi

Charging E2Ws in Vietnam

In Vietnam, home chargers and public charging stations can be used to charge E2Ws. Both systems use the same 220 Volt supply. Table 2 presents the specifications of home charging devices and public charging stations from a E2W manufacturer. The two options use the same operating voltage, 220 V, 1 phase. Home charging can use only household voltage range 220 V, which results in low output power and charging time, 4.8–12 hours for full charging. Four hours is the time needed for a full charge from a public station.

For some E2W users, public charging stations are the best alternative for recharging their vehicles. People not living in single family homes need to remove the battery and carry it to their apartment to recharge. But lead-acid batteries are usually not removable. In addition, the average weight of Li-ion battery is 8.3 kg, presenting a physical challenge for some people. Thus, even if home charging is an option for E2Ws, public charging expansion must be considered as the E2W market grows in Vietnam.

Table 2. Characteristics of VinFast charging stations[12]

Charger	Home charging	Public charging station
Operating voltage (V)	220 VAC, 1-phase	220 VAC ± 5%, 1-phase
Capacity per charging port (kW)	0.3-0.7	≥ 1.2
Charging time (hour)	Average 8.1 hours (100% of battery capacity)	4 hours (full standard charging)

Figure 2. Public charging station (photo credit: Huong-Le)

Challenges for E2W development in Vietnam

E2Ws in Vietnam still present certain limitations that make them less attractive than internal combustion engine (ICE) vehicles. Upfront costs of E2Ws are often greater than those of ICE 2Ws. Uncertainty regarding range and durability is also a challenge for this relatively new technology. Furthermore, charging stations and battery swapping services are still limited.[13]

12 "Quy hoạch trạm sạc" VinFast, accessed January 12, 2023, https://VinFastauto.com/vn_vi/he-thong-tram-sac-va-thiet-bi-sac (in Vietnamese).

13 Le Anh Tuan, Nguyen Thi Yen Lien, Do Duc Tue, "Study of electric mobility development in Viet Nam," NDC Transport Initiative for Asia, August 2021, https://www.ndctransportinitiativeforasia.org/resources-list/study-of-electric-mobility-development-in-viet-nam.

Electric two-wheelers equipped with Li-ion batteries tend to be more expensive upfront than E2Ws powered by lead-acid batteries and conventional two-wheeler vehicles. The higher upfront price of Li-ion battery motorcycles may discourage demand for them, pushing the market toward lead-acid battery models or conventionally powered options.

3. Selected 2W models used in the TCO calculation

The comparison of electric and ICE 2W vehicle technology in Vietnam starts with the selection of models that represent the most popular 2W segments in Vietnam, mopeds and motorcycles. As show in Figure 3, motorcycles accounted for 92.2% of 2W sales in Vietnam in 2020; the rest were moped sales.

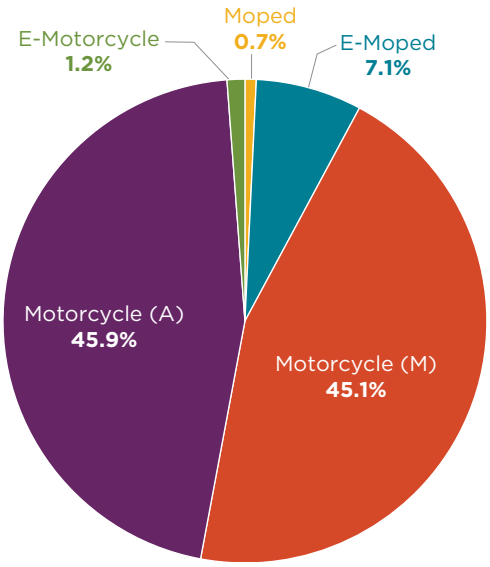

Figure 3. Two-wheeler sales in 2020 by vehicle type.[14] A = Automatic transmission; M = manual transmission.

The comparison presented here focuses on mopeds and motorcycles. Definitions of motorcycles and mopeds are given in the National technical regulation on safety and environmental protection for motorcycles and mopeds issued by the Ministry of Transport (MOT) (QCVN 14:2015/BGTVT).[15] The classification of two-wheelers in Vietnam is presented in Table 3. Motorcycles are vehicles with two wheels, an engine displacement of 50 cm^3 or higher, a maximum speed of more than 50 km/h, and curb weight not exceeding 400 kg. Mopeds are vehicles with two wheels whose maximum speed does not exceed 50 km/h and whose engine displacement is not more than 50 cm^3 for the internal combustion engine and whose motor power, in the case of electric models, is not more than 4 kW.

14 Dinh-Son Tran, Huong Le, Zifei Yang, "Two-wheelers in Vietnam: A baseline analysis of fleet characteristics and fuel consumptions in 2019 and 2020," (ICCT: Washington, DC, 2021) https://theicct.org/publication/2w-lvs-vietnam-asia-baseline-feb22/.

15 Vietnam Ministry of Transport, "QCVN 14:2015/BGTVT: National technical regulation on safety and environmental protection for motorcycles and mopeds," 2015, https://www.mt.gov.vn/Images/FileVanBan/_TT67.signedQCVN.pdf.

Table 3. Classification of two-wheeler vehicles in Vietnam

Class	Vehicle types	Engine displacement (cc)/ Electric engine power (kW)	Maximum speed (km/h)	Transmission
Moped	**Moped**	≤ 50	≤ 50	-
	E-moped	≤ 4	≤ 50	-
Motorcycle	**Motorcycle (M*)**	> 50	> 50	Manual
	Motorcycle (A)**	> 50	> 50	Automatic
	E-motorcycle	> 4	> 50	-

M* = manual transmission, A** = automatic transmission

In this TCO analysis, we compared models in the same subclass. The best-selling model of each category is compared with the best in other categories. For the internal combustion (ICE)-motorcycle category, the comparison was differentiated for automatic and manual transmission models.

The best-selling models mentioned above were taken from 2020 2W sales data in Vietnam. There are five sub-groups, including ICE motorcycle with manual transmission, motorcycle with automatic transmission, electric motorcycle, ICE moped, and electric moped. In 2020, there was no electric motorcycle equipped with a Li-ion battery, therefore, the VinFast Theon S, the model sold from 2022, was selected to cover this subclass. Theon S has specifications similar to the selected ICE motorcycle models; for example, Theon S's power is 7.1 kW compared to 6.9 kW for the Honda Vision. The seven models selected for TCO calculation and comparison are presented in Table 4, including specifications and showroom prices.

Table 4. Selected vehicle models and their specifications

Class		**Motorcycle**				**Moped**		
vehicle type		**E-motorcycle**		**ICE motorcycle**		**E-moped**		**ICE moped**
Model		Pega	Theon	Vision 110	WAVE 100	Klara A2	Klara S	Elegant
Manufacturer		Pega	VinFast	Honda	Honda	VinFast	VinFast	SYM
Market share (%)		0.36	-	17.16	13.67	2.21	0.66	0.56
Battery type		Lead-acid	Li-ion	-	-	Lead-acid	Li-ion	-
Battery capacity (kWh)		**2.3**	**3.38**	**-**	**-**	**1.58**	**1.11**	**-**
Curb weight (kg)		**155**	**145**	**97.5**	**97**	**127**	**108**	**95**
Engine/motor power (kW)		**4**	**7.1**	**6.59**	**6.12**	**1.75**	**1.7**	**2**
Range (km/ charge)		120	150	-	-	90	120	-
Fuel/energy consumption	**ICE (L/100km)**	-	-	1.88	1.9	1.37	-	1.44
	EV (kWh/100km)	1.92	2.25	-	-	1.53	1.02	-
Showroom price (million VND)		35	87.1	30	17.8	26.9	49.6	16.6

Note: Showroom prices are taken from manufacture website on 26/6/2022

4. Methodology for cost calculations

Electric vehicles tend to be more expensive upfront than their conventional vehicle counterparts. The total cost of ownership (TCO) method provides a more holistic approach to comparing costs as it includes not only capital but also operating costs.

Total cost of ownership (TCO)

The total cost of ownership of a 2W vehicle combines the upfront cost and operating costs over time. The upfront cost in this analysis consists of the base price, VAT, registration fee, and license plate fee. Operating costs consist of the cost of fuel/electricity, insurance, maintenance, and battery-related fees (battery rental fee or battery replacement fee). Table 5 provides a breakdown of each of the cost components included in the TCO calculations. Details for each cost item and additional assumptions are provided below.

Table 5. Input factors considered in TCO calculations

TCO factor	Moped			Motorcycle				Year of occurrence
	E-moped (lead-acid)	E-moped (Li-ion)	ICE moped	E-motorcycle (lead-acid)	E-motorcycle (Li-ion)	ICE motorcycle (manual transmission)	ICE motorcycle (automatic transmission)	
Showroom price (million VND)	26.9	49.6	16.6	35.0	87.1	17.8	30.0	26/06/2022
Base price (million VND)	24.21	44.64	14.94	31.50	80.82	16.02	27.00	
VAT (%)	10%	10%	10%	10%	10%	10%	10%	one-time pay
Registration fee (%)	5%	5%	5%	5%	5%	5%	5%	one-time pay
Insurance (VND)	55,000	55,000	55,000	60,000	60,000	60,000	60,000	annually
License plate number fee (VND)	2,000,000	2,000,000	1,000,000	2,000,000	2,000,000	1,000,000	2,000,000	one-time pay
Gasoline price (VND/L)	-	-	26,780	-	-	26,780	26,780	2022
Electric price (VND/kWh)	2,834	2,834	-	2,834	2,834	-	-	2022
Maintenance fee (VND/year)	200,000	200,000	600,000	300,000	300,000	750,000	750,000	annually
Battery replacement cost (VND/battery)	3,000,000	-	-	3,000,000	-	-	-	annually
Battery replacement cost* (VND/battery)	-	8,600,000	-	-	19,900,000	-	-	5th year
Battery rental cost (VND/month)**	-	255,000	-	-	350,000	-	-	monthly

* Applies to the battery purchase option
**Applies to the battery rental option

Base price

The base price of each vehicle is calculated from showroom prices, which were collected from manufacturer websites. Base prices are calculated by subtracting taxes from the showroom price. The showroom price usually includes the base price, value added tax (VAT), and special consumption tax (SCT).

Taxes and fees

Taxes and fees are also important components in the TCO calculation. The taxes and fees currently applied on two-wheelers in Vietnam are listed in Table 6. Since all models selected for TCO calculation in this report are locally assembled vehicles, import tax is

not listed in the table. The SCT only applies to vehicles with engine displacement above 125 cc; thus, all selected models for this analysis are subject to 0% SCT.[16]

Regarding the registration fee, the tax rate is 5% in cities/towns where the provincial People's Committee is based and 2% for the remaining areas. The registration fee is calculated based on the vehicle showroom price or the registration price (which is regulated by the Ministry of Finance), whichever is higher. (In this study, the showroom prices of all models are higher than the price regulated by MoF). This tax rate is for first-time registration. For the 2nd registration, the fee is based on its remaining use value. In this analysis, we assumed that registration fee covers only the 1st registration.

Because taxes and fees do not differ much across cities, we calculate the TCO only for centrally affiliated cities, where the market share of 2Ws is dominant.

Table 6. Taxation and fees related to two-wheeler vehicles[17]

Type of tax/fee	Payment period	Tax based	Tax rate	Regulating agency	Legal document
Registration fee	One-time	Vehicle price or based registration price, and registered area	5% in centrally affiliated cities, provincial cities; 2% in other areas	National Government	Decree No. 140/2016/ND-CP
Value-added tax (VAT)	One-time	Vehicle price + SCT (if any)	10%	National Assembly	Law No. 13/2008/QH12
Compulsory civil liability insurance	Annual	Fixed	Mopeds: 55,000 VND/year; motorcycles: 60,000 VND/year	Ministry of Finance	Circular No. 04/2021/TT-BTC
Granting vehicle license plate	One-time	Vehicle price and registration area	Range from 50,000 VND to 4 million VND	Ministry of Finance	Circular No. 229/2016/TT-BTC

Gasoline price

Fuel prices account for an important part of the TCO of two-wheelers. In our calculation, the price of gasoline was taken by the average of retail gasoline from the first half of 2022. The gasoline price for the calculation is from the Petrolimex website and the average use in the calculations is 26,780 VND per liter.[18]

Another factor that affects the fuel cost is fuel consumption. For this report, the fuel consumption of the ICE models was collected from the manufacturer's website for the Vietnamese market (e.g., honda.com.vn) and corrected by 20% to better reflect real-world use.[19] This 20% increase to obtain real-world fuel consumption values has been identified by ICCT researchers investigating the difference between certification and real-world values.[20] The fuel consumption gap comes from deviations from certification values related to local driving conditions, frequency of maintenance, tire inflation, and other variables.

16 Law No. 27/2008/QH12, The national Assembly. The Law on excise tax. https://vanban.chinhphu.vn/default.aspx?pageid=27160&docid=81144 https://thuvienphapluat.vn/van-ban/EN/Thue-Phi-Le-Phi/Law-No-27-2008-QH12-of-November-14-2008-on-Excise-Tax/88692/tieng-anh.aspx

17 Huong Le and Zifei Yang, Using policy and regulation to pave the way for two-wheeler electrification in Vietnam, (ICCT: Washington, 2022) https://theicct.org/publication/vietnam-asia-e2ws-lvs-mar22/.

18 Petrolimex's main operations are exporting, importing, and trading petroleum and petrochemicals for refining; currently, Petrolimex is selling more than 50% of its fuel through a network of 5.500 gas stations in Vietnam. https://www.petrolimex.com.vn/en.html.

19 Khanh Nguyen Duc, Yen-Lien T. Nguyen, Anh Tuan Le, Tung Le Thanh, "Developing neutron networkd-based prediction model of real-time fuel consumption rate for motorcycles: A case study In Vietnam," Energy Sources, Part A: Recovery, Utilization, and Environmental Effects, issue A, volume 44 issue 2, 2022 https://doi.org/10.1080/15567036.2022.2062070.

20 Uwe Tietge, Sonsoles Diaz, Zifei Yang, and Peter Mock, From laboratory to road international: a comparison of official and real-world fuel consumption and CO2 values for passenger cars in Europe, The United States, China, and Japan, (ICCT: Washington, DC, 2017), https://theicct.org/publication/from-laboratory-to-road-international-a-comparison-of-official-and-real-world-fuel-consumption-and-co2-values-for-passenger-cars-in-europe-the-united-states-china-and-japan/.

Electricity price

In Vietnam, the price of civil electricity is regulated based on usage level. The Ministry of Industry and Trade lists 6 tiers of electricity prices ranging from 1,678 VND/kWh (for use of less than 50 kW) to 2,927 VND/kWh (for use of more than 401 kWh). In this report, price level 5 (out of 6 levels) for domestic electricity is used to calculate the TCO. According to the Institute of Energy, the average energy consumption for a Vietnamese household ranges between 300 and 400 kWh, which translates to an electricity rate of 2.834 VND/kWh; this value is used in our calculations.

Similar to ICE two-wheelers, the E2W's energy consumption is collected from the manufacturer's website in Vietnam (e.g. http://xemayvinfast.vn/). In addition, the electric efficiency of the electric motor that comes with the vehicle is considered to be constant across the life of the vehicle and the energy consumed is 20% higher than that on the website. The 20% increase in energy consumption was applied to be consistent with the real-world correction applied to gasoline fuel consumption data.

Annual travel distance

The analysis assumes annual travel of approximately 7,000 km. ICE vehicles and EVs are used for almost the same purposes, so in this TCO the annual travel distance is assumed to be 7,000 km.[21]

In Vietnam, privately used two-wheelers are the most popular transport mode in road transport, accounting for 92% of trips; thus, in this paper, we analyze only the TCO of two-wheelers used for private purposes.[22]

Ownership and lifetime of two-wheelers in Vietnam

The lifetime of two-wheelers depends on many factors such as driving behavior, road quality, vehicle characteristics, traffic conditions, operational conditions, and maintenance. A study from Ho Chi Minh City found that 73.81% of 2Ws are less than 5 years old, 21.50% are between 6 and 10 years old, and only 4.69% are older than 10 years of age. The average age of 2Ws is 4.15 years.[23] Moreover, motorcycles in Vietnam are unevenly distributed, being concentrated in urban areas, especially in Hanoi and Ho Chi Minh City.[24] In this report, we assume that the lifetime of 2Ws is 5 years and we used that value to define the 5-year ownership for the total cost of ownership calculation.

Maintenance cost

ICE 2Ws and E2Ws both require regular maintenance. Maintenance costs of internal combustion engine vehicles are higher than those of E2W vehicles. Technically, internal combustion engines require more maintenance than electric motors; for example, for replacing the lubricating oils, and in the case of manual transmission ICE 2Ws, for replacing the chain and sprocket. Based on the maintenance price and maintenance period collected by VinFast for each item on the vehicle, the maintenance cost of ICE 2W is 300,000–1,000,000 VND/year, depending on the condition of the vehicle. E2Ws have much lower maintenance costs, according to Vinfast, a company that produces

21 Thi NGA, "Mỗi năm, người Việt đi xe máy trung bình 7.800 km," January 22, 2020, https://kenh14.vn/moi-nam-nguoi-viet-di-xe-may-trung-binh-7800-km-20200122195837562.chn.

22 Le, Lien, Tue, "Study of electric mobility development".

23 Chu Tien Dung, Tomio Miwa, Hitomi.Sato, Takayuki Morikawa, "Analysis on Characteristics of Passenger Car and Motorcycle Fleets and Their Driving Conditions in Developing Country: A Case Study in Ho Chi Minh City, Vietnam." Journal of Eastern Asia Society for Transportation Studies, volume 11, 2015, https://www.jstage.jst.go.jp/article/easts/11/0/11_890/_article.

24 Nguyen Huu Duc, "Analysis on Characteristics of Passenger Car and Motorcycle Fleets and Their Driving Conditions in Developing Country: A Case Study in Ho Chi Minh City, Vietnam," https://www.academia.edu/40844654/Nghiên_cứu_hiện_trạng_giao_thông_xe_máy_Việt_Nam.

both electric and gasoline two-wheelers.[25] Table 7 presents annual maintenance costs for 7 selected models (maintenance costs exclude battery replacement costs for lead-acid battery electric vehicles).

Table 7. Annual maintenance costs for selected models

Class	Motorcycle				Moped		
Vehicle type	**E-motorcycle**		**ICE motorcycle**		**E-moped**		**ICE moped**
Model	Pega S	Theon S	Vision 110	WAVE 100	Klara A2	Klara S	Elegant
Maintenance cost (VND/year)	300,000	300,000	750,000	750,000	200,000	200,000	600,000

Table 8. Taxation and fees related to two-wheeler vehicle[26]

Type of tax/fee	Payment period	Tax based	Tax rate	Regulating agency	Legal document
Registration fee	One-time	Vehicle price or based registration price, and registered area	5% in centrally affiliated cities, provincial cities; 2% in other areas	National Government	Decree No. 140/2016/ND-CP
Value-added tax (VAT)	One-time	Vehicle price + SCT (if any)	10%	National Assembly	Law No. 13/2008/QH12
Compulsory civil liability insurance	Annual	Fixed	Mopeds: 55,000 VND/year; motorcycles: 60,000 VND/year	Ministry of Finance	Circular No. 04/2021/TT-BTC
Granting vehicle license plate	One-time	Vehicle price and registration area	Range from 50,000 VND to 4 million VND	Ministry of Finance	Circular No. 229/2016/TT-BTC

Battery replacement fee

In this study, two options—purchasing a battery and renting one—are considered. Lead-acid batteries for E2Ws need to be replaced annually due to their limited life of 250–300 charging cycles,[27] approximately 1 year of operation. E2Ws with lead-acid batteries need 5–6 packs and each pack costs 350,000–650,000 VND.[28] In this study we assumed the average cost is 500,000 VND/pack in total, so users pay 2.5–3.0 million VND for battery replacement for a lead-acid battery vehicle.

Li-ion batteries tolerate more than 1500 charging cycles and after 5 years of ownership, the full charging capacity of the battery is more than 70%.[29] In this study the 5-year TCO for Li-ion batteries incurs zero replacement costs, but replacement costs are added for the 10-year TCO analysis at the 6th year.

For the renting option, we assume that the manufacturers provide a leasing service and that they assume all the risks. Hence, consumers do not need a budget for battery replacement. The other fees for renting services will be discussed in more detail in the next sub-section.

25 "Bảo dưỡng xe máy cần những gì? Bao lâu nên bảo dưỡng xe 1 lần," VinFast, accessed January 12, 2023, https://vinfastauto.com/vn_vi/bao-duong-xe-may-gom-nhung-gi (in Vietnamese).

26 Huong Le and Zifei Yang, Using policy and regulation to pave the way for two-wheeler electrification in Vietnam, (ICCT: Washington, 2022) https://theicct.org/publication/vietnam-asia-e2ws-lvs-mar22/.

27 "Giải đáp: Tuổi thọ ắc quy xe máy điện VinFast được bao lâu?" VinFast, accessed January 12, 2023, https://vinfastauto.com/vn_vi/giai-dap-tuoi-tho-ac-quy-xe-may-dien-vinfast-duoc-bao-lau (in Vietnamese).

28 "Bình ác quy xe đạp điện giá bao nhiêu?" Thegioixechaydien, accessed January 12, 2023, https://thegioixechaydien.com.vn/binh-ac-quy-xe-dap-dien-gia-bao-nhieu.html (in Vietnamese).

29 "Pin lithium xe máy điện VinFast có gì đặc biệt?" VinFast, accessed January 12, 2023, https://vinfastauto.com/vn_vi/pin-lithium-xe-may-dien-vinfast-co-gi-dac-biet (in Vietnamese).

Battery rental

In this analysis we used the financial scheme for the battery rental service provided by Vinfast as an example for our comparisons. VinFast is the leading E2W manufacturer in Vietnam, with 12 electric two-wheeler models on offer. It is the only company offering battery rental services in Vietnam for both E2Ws and electric passenger vehicles—thus, we use their rental cost information for this comparative analysis. For E2Ws, the leasing options are available only for E2Ws equipped with Li-ion batteries; seven of VinFast's twelve E2W models are powered by Li-ion batteries.

VinFast sells E2W models separate from the Li-ion battery so consumers either buy the battery or rent it. Buying the advanced chemistry battery costs 8,600,000 VND/pack, and each vehicle needs 1-2 packs. For the rental option, consumers do not need to pay for the battery, thus, the upfront cost are much lower. Renting the battery requires a deposit of 1,200,000 VND/pack (to be returned when the contract expires) and the rental fee. The rental option has several forms: the standard form, for driving distance of up to 500 km/month, costs 220,000 VND/month (with an additional 374 VND charged for each additional km); alternatively, an unlimited mileage rental plan costs 399,000 VND/month. In this study, the standard battery renting options are used for the calculations.

Table 9. Battery purchasing and renting fees[30]

	Option	Fee (VND)	Notes
I	**Battery purchase**		
	Battery price	8,600,000 VND/pack	Include VAT and 3 years of warranty
II	**Battery rental**		
1	Battery deposit	1,200,000 VND/pack	Return at the end of the contract term
2	Monthly rental fee		
2.1	Standard battery		No km/month limitation
	• 1 Battery	220,000 VND/month	
	• 2 Batteries	399,000 VND/month	
2.2	Super-economical battery rental package		Maximum of 300 km/month. Additional kilometers driven per month are charged 374 VND/km)
	• 1 Battery	149,000 VND/month	
	• 2 Batteries	299,000 VND/month	

5. TCO RESULTS

The TCO methodology is applied to provide a fair comparison between different technology and financial options. Results are presented in two ways: at the 5th year (0 to 5th year) and as a trendline showing annual TCO values from year 0 to year 10. These results clearly show the upfront cost and the operational cost over time and the impact of cost components on the TCO, especially the battery replacement cost for EVs.

In addition, comparisons are presented only within the same 2W segments: moped segment, and motorcycle segment. First, the TCOs from electric option are compared against ICE. Then, a closer look of the impact of three elements of the TCO of EVs is discussed: battery technology, ownership options, and taxation.

30 "Quy định, chính sách và bảng giá thuê pin VinFast 2021" VinFast, accessed January 12, 2023, https://vinfastauto.com/vn_vi/quy-dinh-chinh-sach-va-bang-gia-thue-pin-vinfast-2021 (in Vietnamese).

Table 10. TCO results after 5 years (all values VND)

TCO factor	Lead-acid (e-moped)	Li-ion (e-moped)	ICE (moped)	Lead-acid (e-motorcycle)	Li-ion (e-motorcycle)	ICE (motorcycle-M)	ICE (motorcycle-A)
Base price	24,210,000	44,640,000	14,939,998	31,500,000	80,820,000	16,020,000	27,000,000
VAT	2,690,000	4,960,000	1,660,000	3,500,000	8,980,000	1,780,000	3,000,000
Registration fee	1,500,000	250,000	830,000	1,750,000	4,355,000	890,000	1,500,000
License plate fee	2,000,000	2,000,000	1,000,000	2,000,000	2,000,000	1,000,000	2,000,000
Insurance fee	275,000	275,000	275,000	300,000	300,000	300,000	300,000
Maintenance cost	1,000,000	1,000,000	3,000,000	1,500,000	1,500,000	3,750,000	3,750,000
Battery replacement cost	12,000,000	-	-	12,000,000	-	-	-
Fuel consumption	2,004,289	1,253,868	15,211,000	2,621,724	2,621,724	21,147,000	20,961,500
TCO	45,679,289	54,378,868	36,915,998	55,171,724	100,576,724	44,887,000	58,511,500

TCO comparison between electric and conventional two-wheelers

Figure 4 shows a comparison of TCO values for moped and motorcycles in Vietnam over a 5-year period. Dashed areas show the operational costs and solid colors show the upfront costs.

Electric mopeds present higher upfront and TCO costs over the period studied compared to ICE mopeds. Electric mopeds equipped with Li-ion show the highest TCO, about 54.4 million VND; this is 19.0% higher than e-mopeds with lead-acid batteries and 47.3% higher than ICE-mopeds. Both electric moped models have significantly higher upfront costs than the ICE moped model, about 30.5 and 51.9 million VND compared with only 18.5 million VND for the ICE moped. Furthermore, the e-moped model with lead-acid battery needs battery replacement annually, dominating the operational cost of this type of vehicle.

Similar to moped models, the Li-ion electric motorcycle has the highest upfront cost and TCO—71.9% higher than the automatic transmission model and 124% higher than a motorcycle with a manual transmission. After 5 years, the TCO of e-motorcycle power by lead-acid battery technology can compete with an ICE motorcycle with automatic transmission, but its TCO is still higher than the ICE motorcycle with manual transmission.

Figure 4. TCO of 7 selected models at 5 years of operation (with batteries purchased for E2W models)

The annual TCO evaluation beyond the 5-year timeframe typical of TCO results is discussed in this section. In the long-term e-mopeds present higher TCO values than ICE counterparts, driven by higher upfront costs. The upfront cost of a lead-acid e-moped is about 1.5 times higher than for an ICE-moped, while Li-ion models are 2.5 times higher, about 45.7 and 51.9 million VND compared with only 18.5 million VND. As shown in Figure 5.a, the cost parity cannot be met after 5 years of operation. In the long term the lead acid battery becomes more expensive than the Li-ion as the lead-acid battery replacement costs accumulate over time.

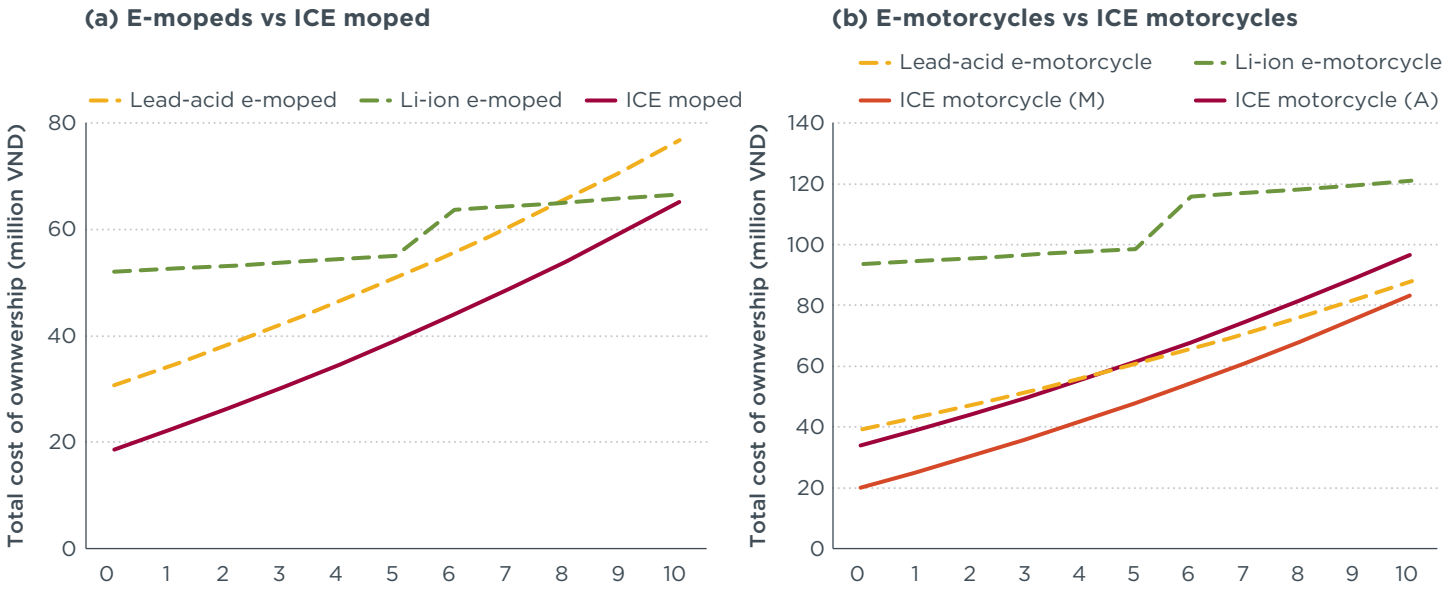

Figure 5. Total cost of ownership of e-mopeds vs ICE moped and e-motorcycles vs ICE motorcycles

Figure 5.b shows the annual TCO of e-motorcycles and ICE motorcycles over a 10-year period. Overall, the E2W TCO is still much higher than the ICE TCO in this sub-class. However, ICE motorcycles have a higher operational cost than e-motorcycles, placing the e-motorcycle with lead-acid battery in a competitive position with ICE motorcycles with manual transmission. By the 6th year, electric motorcycles with lead-acid batteries provide a lower TCO than the ICE 2W models with automatic transmission. In Vietnam the ICE motorcycle with manual transmission holds a similar market share, for example in 2020, approximately 45% of the new motorcycles were sold with manual transmissions, similar to the share with automatic transmissions. In addition, the upfront cost of manual transmission motorcycles is still lower than electric mopeds.

E2W with Li-ion battery models still have the highest TCO compared to other models even after including the lower battery replacement cost of this technology. After 10 years, the Li-ion battery motorcycles present a higher TCO, by 25%, than the automatic transmission ICE models.

The impact of battery technology on the TCO of E2Ws

In 2020, 75% of E2Ws sold in Vietnam used lead-acid batteries.[31] In this section, we compare the TCO results of E2Ws equipped with lead-acid to those equipped with Li-ion batteries. Figure 6 shows the TCO results after 5 years of ownership for 4 models. Overall, the TCO of e-moped models is lower than for e-motorcycle models, and the TCO of lead-acid models is lower than that of Li-ion models.

Electric mopeds equipped with lead-acid batteries present the lowest TCO. The Li-ion moped model has the lowest operating cost, but the upfront cost is much higher than the upfront cost of the lead-acid one. The TCO of the Li-ion moped model by year 5 is 14% higher than the TCO of the lead-acid model, 54.4 million VND and 47.7 million VND, respectively. By year 9, the cost evaluation changes and the higher replacement costs of lead-acid mopeds make the Li-Ion battery model the least expensive one—even after replacing the batteries at year 5.

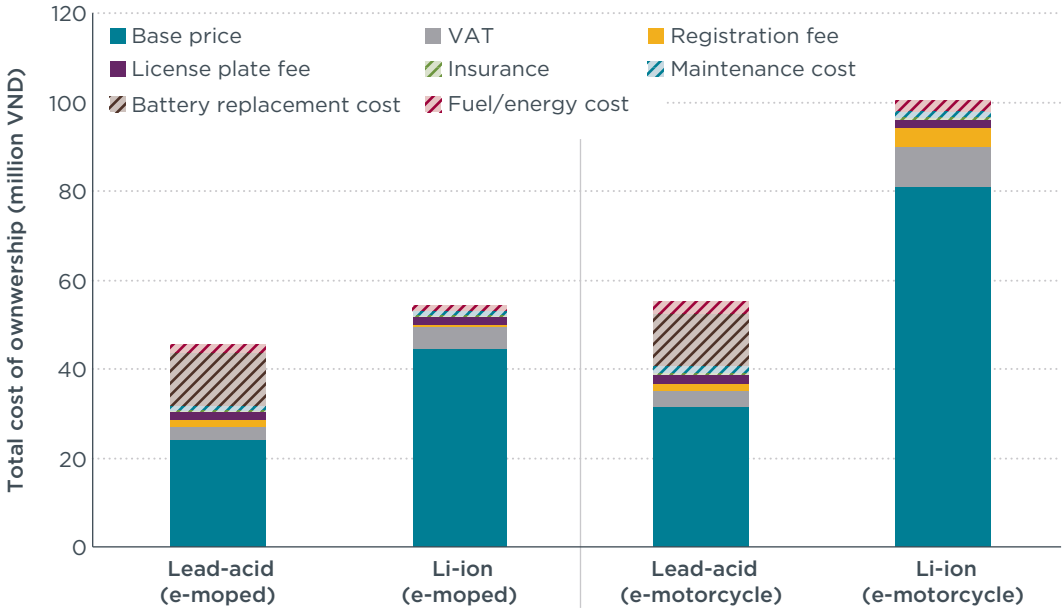

Figure 6. TCO of 4 E2W models at 5 years

31 Le and Yang, *Two-wheeler and three-wheeler vehicle market analysis*.

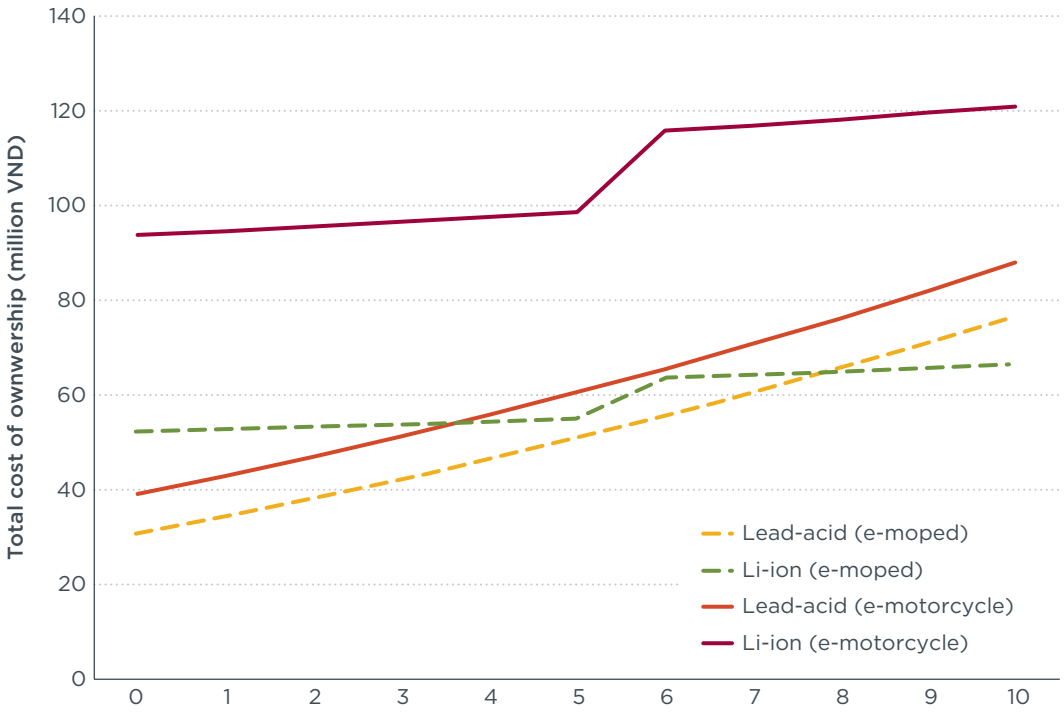

Figure 7. TCO of five models equipped with Li-ion batteries from 1 to 10 years

E-motorcycles with Li-ion batteries have the highest TCO and upfront cost, almost double the TCOs of the three other E2Ws on the chart. This is driven by higher upfront costs of these Li-ion models, which offer better range and speed than similar lead-acid models. Li-ion e-motorcycles provide a range of 150 km and a speed of 99 km/h compared with 120 km and 65km/h for lead-acid e-motorcycles. Furthermore, the power of Li-ion models is 7.1 kW, much higher than the 4.0 kW of the lead-acid model. Even after 10 years of operation, the TCO of lead acid-batteries is lower than that of advanced chemistry options.

It can be concluded that Li-ion battery models help customers save money on operating costs and give better perfomance. The Li-ion option provides a much lower operating cost than the lead-acid models, about 60-70% lower. However, the high upfront costs of advanced chemistry models may not be offset today by operational savings.

Purchasing vs. renting Li-ion batteries for E2Ws

Purchasing the Li-ion battery upfront may seem a more expensive option than rental, because the Li-ion is an expensive component of E2Ws. Renting the battery initially keeps the upfront costs low. But over time, rental fees become higher than the time-distributed cost of a purchased battery. As shown in Figure 8, the upfront cost of the battery rental option results in the lowest TCO in the short term for both mopeds and motorcycles. However, after the 5th year of ownership, the rental option results in a higher TCO than the purchase option.

The trend of increased TCO driven by rental fees worsens over time. Figure 9 shows that by year 10, the TCO of battery rental e-mopeds is 21.9% higher than the TCO of a purchased one. For motorcycles the rented battery option is 23.8% higher than the purchased one. Nevertheless, renting the battery is still an attractive option as consumers benefit from the lower upfront cost associated with renting and take fewer risks from battery damage and replacement costs.

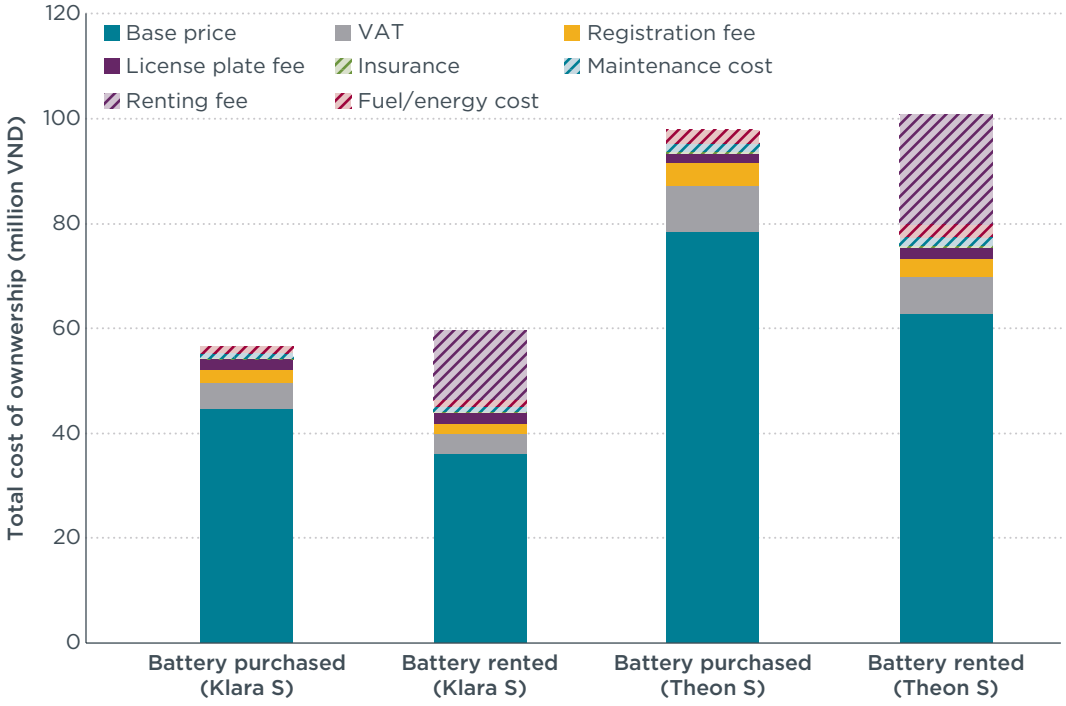

Figure 8. TCO of e-moped and e-motorcycle in two options: purchasing and renting battery at 5 years of operation

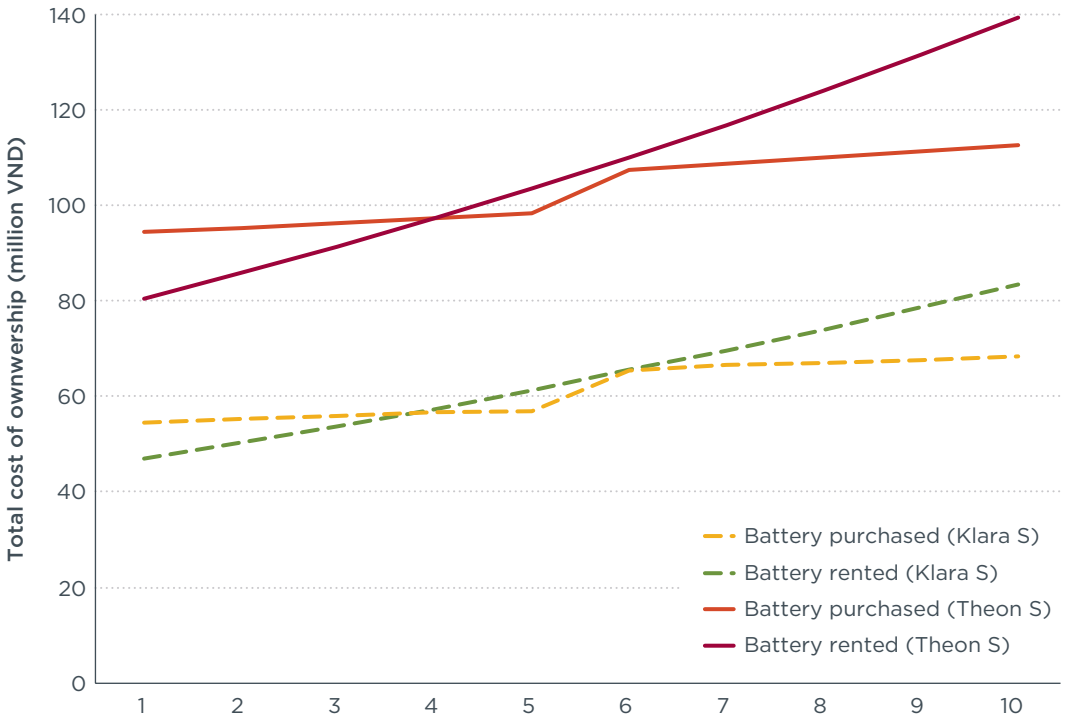

Figure 9. TCO of e-moped and e-motorcycle in two options: purchasing and renting battery from 1 year to 10 years

The impact of taxation and registration fees on the TCO of two-wheeler vehicles

Providing fiscal incentives for owning and operating E2Ws is essential for promoting adoption of E2Ws. In this scenario, we assumed that the EV model's VAT, special consumption tax, registration fee, and license plate fee fall to zero. This potential

reduction in the tax burden reduces the upfront cost of EVs by 13-15%. This reduction does not impact the operational cost. As a result, the TCO by year 5 was reduced by a similar percentage.

As shown in Figure 10 the TCO of EVs is still higher than ICE models, especially for e-motorcycle models equipped with Li-ion batteries. The TCO gap with respect to the ICE moped is now 14.3% for the lead-acid moped and 41.2% of the Li-ion model. Similarly, the ICE motorcycle with automatic transmission is still 52.4% cheaper than the Li-ion models and 13.8% more expensive than the lead-acid battery model. Closing the cost gap between ICE and EV models may require additional incentives.

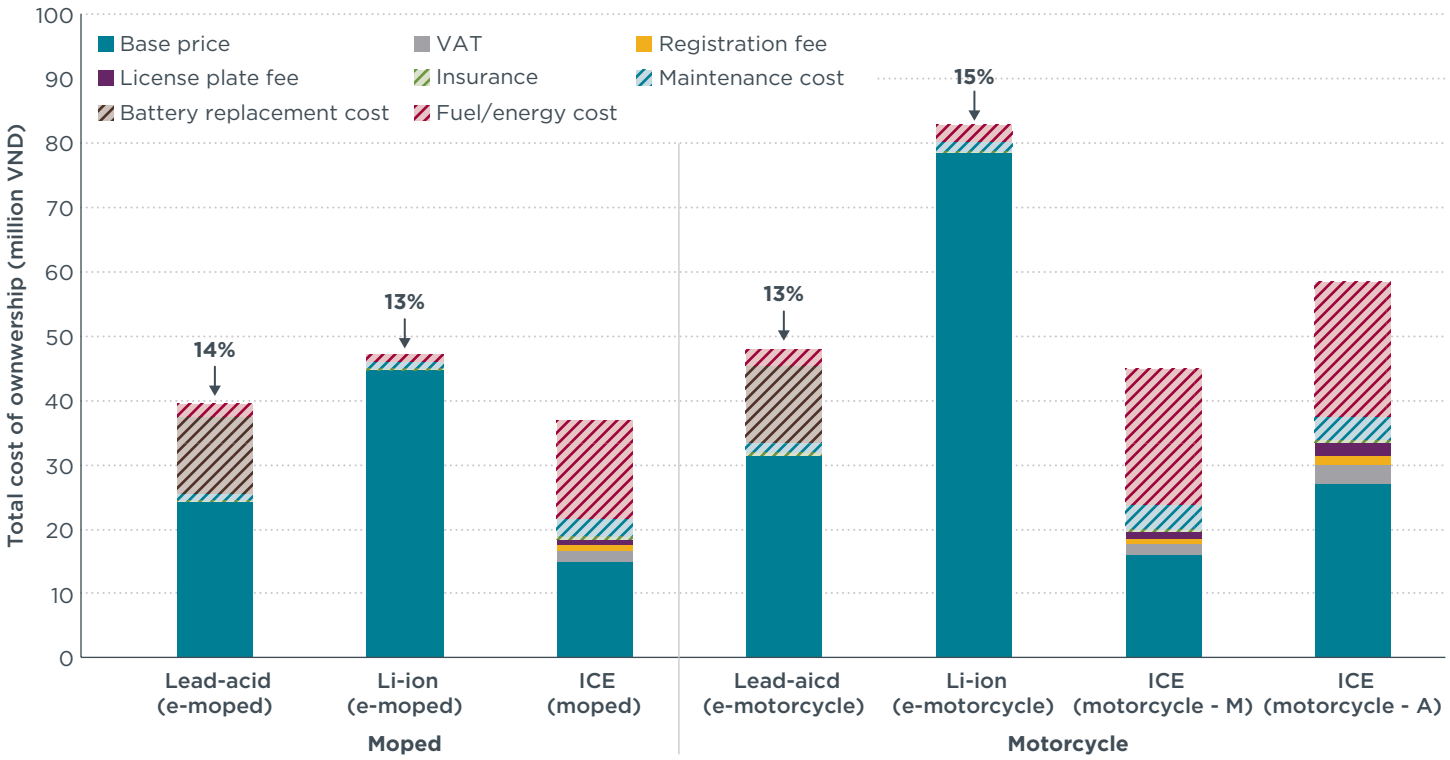

Figure 10. The impact of taxes on TCO of 2Ws

6. Conclusions and recommendations

Two-wheelers are the main transport mode in Vietnam. Accelerating the electrification of this segment is a potential approach to reducing GHG emissions and air pollution in the country and to supporting the country in its effort to achieve carbon neutrality by 2050. In this paper, we analyzed the TCO between gasoline 2Ws and E2Ws, and between E2W models powered by lead-acid batteries and those powered by Li-ion batteries. We also took a closer look at the TCO of E2Ws with two battery options, including battery renting and battery purchase. This section summarizes the key results of TCO analysis. Then, recommendations to reduce the TCO gap between E2Ws and ICE 2Ws are provided.

Summary key findings of TCO analysis

» The TCOs of E2W models are higher than those of the corresponding ICE models after 5 year-periods, driven by high purchase prices.

  » **In the moped segment, e-mopeds equipped with Li-ion batteries have the highest TCO over 5 years**, at 54.4 million VND, which is 19% higher than e-mopeds with lead acid batteries and 47.3% higher than ICE-mopeds. However,

after 10 years, e-mopeds with the lead-acid batteries have the highest TCO, and the TCO of e-mopeds with Li-ion batteries and ICE-mopeds are similar.

  - **In the motorcycle segment, e-motorcycles equipped with Li-ion batteries have the highest TCO after 5 years and 10 years mainly because of high vehicle prices.** This configuration is followed by ICE motorcycles with automatic transmission, e-motorcycles with lead-acid batteries, and ICE-motorcycle with manual transmission.
  - **The upfront costs of E2W models are significantly higher than those for corresponding ICE models**. The upfront costs of E2W models are 16% to 389% higher than for the ICE 2W models. E2W models powered by Li-ion batteries have the highest upfront cost.
  - **Operational costs of all E2W models are lower than the operational costs of corresponding ICE 2W models**. In a five-year period, the operational costs of E2W models are 17% to 83% lower than those of ICE 2W models. However, the savings from operational costs are not enough to make up for the higher upfront costs of Li-ion battery electric models.
- Battery type affects substantially the TCO of E2W models
  - **After 5 years, the TCOs of E2W models powered by Li-ion batteries are higher than the TCOs of E2W models powered by lead-acid battery** because E2Ws with Li-ion battery have significantly higher vehicle purchase costs than models powered by lead-acid batteries.
  - **The operational cost of E2W models powered by lead-acid batteries is higher than the operational cost of E2W models powered by Li-ion batteries** mainly because E2Ws powered by lead-acid batteries require frequent battery replacement. E2Ws with Li-ion batteries have operational costs 60-70% lower than E2Ws with lead-acid models after 5 years.
  - **After 10 years, the TCO of e-motorcycles with Li-ion batteries is still 27% higher than e-motorcycles with lead-acid batteries. However, e-mopeds with Li-ion batteries are 13% lower than e-mopeds with lead-acid batteries.**
  - **Purchasing and renting Li-ion batteries affects the TCO of E2Ws equipped with Li-ion batteries.** The battery renting option offers lower costs in the short term but results in a higher TCO compared to the battery purchasing option in both 5- and 10-year periods, and the gap is widened when the time is longer.
- **Elimination of VAT, registration, and license plate fees are not enough to close the cost gap between ICE and electric 2W models**. Upfront tax reductions (VAT=0 and SCT=0) reduce upfront costs of E2W models by 13–15%. Compared to the current higher price gap of 47.3%–124.1% for E2Ws, the fiscal incentive is not sufficient to fully lower those values to ICE values.

Recommendation

To accelerate E2W development in Vietnam, closing the TCO gap between E2Ws and ICE 2Ws is needed. Following are recommendations that Vietnam government at the national and local level could consider to close this gap.

- **Provide fiscal incentives for E2Ws**. Currently, electric two-wheelers and ICE two-wheelers in Vietnam are subject to the same tax and fee rates. Following the growing interest in electrification and reducing CO_2 emissions, Vietnam should provide incentives for electric two-wheeler users in the form of tax relief for E2W consumers, covering both one-time and annual tax and fees. The government should consider providing direct financial incentives for E2Ws at the point of purchase to directly close the price gap between ICE and electric technologies.

» **Use a feebate system to provide incentives.** Eliminate the tax and even provide subsidies to E2Ws while raising the tax for ICE 2Ws based on their CO_2 emissions. Elimination of VAT, registration and license plate fees are not enough to close the TCO gap between ICE 2Ws and E2Ws. Increasing the tax rates for ICE 2Ws while reducing the tax rates for E2Ws could be necessary to quickly close this gap. In addition, this may also contribute to reducing the attractiveness of ICE 2Ws and increasing it for E2Ws.

» **Direct incentives to consumers are the most effective way to close the purchase price gap between conventional and electric 2Ws.** As demonstrated in this analysis, E2Ws offer a large potential to reduce operational costs due to lower electricity and maintenance costs when compared to petrol motorcycles. The biggest obstacle to accelerating electric 2W adoption is still their higher upfront prices. Unless a consumer is already aware of the long-term operational savings of E2Ws, the price issue would drive consumers toward less expensive options. A direct incentive to consumers would be required to shift them toward the electric option. The magnitude of the incentive should be sufficient to reduce the gap; it can benefit from zero taxes and fees on electric models paired with higher taxes and fees on petrol ones; the incentives can be applied over a defined period of time and reevaluated as battery technology costs decline in the coming years.

» **Incentives for E2Ws should spur more energy-efficient vehicles and drive advanced battery and vehicle technologies.** Vietnam adopted voluntary label and fuel economy standards for motorcycles. Moving from a voluntary program toward a mandatory program would ensure that motorcycle manufacturers and importers are offering the most advanced technology on fuel efficiency for these vehicles. A fuel economy standard or CO_2 emission standard would also provide an additional policy mechanism for the government to incentivize the supply of electric powertrain options in Vietnam. Fuel economy standards are one of the main policy mechanisms used globally to accelerate EV adoption.

» **Some international lessons can also be considered and applied in Vietnam**. For example: offer additional tax advantages by applying more environment- and CO_2-based taxes and road taxes for ICE 2Ws and exempting E2Ws from those taxes. On the incentive side, central incentives are available for E2Ws that meet technical eligibility criteria. One valuable type of incentive is a “scrapping incentive,” a fixed subsidy on the purchase price of an E2W when a “scrapping certificate” of the ICE 2W is provided.