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The electric powered two-wheeled vehicle market in both global and European perspectives

Abstract Nowadays, many countries in the world are taking action to reduce carbon dioxide emissions. One of the solutions is to promote energy-efficient and environmentally friendly transport systems of which a specific example is electric vehicles (EV) including cars, motorcycles and mopeds. The article analyses the global development of electric two-wheeled vehicles (ePTW) with China the world leader in the development of ePTW electromobility. China's high position is due to both economic conditions (domestic raw material base, location of production plants) and top-down state support. Today, it is the financial support of programs promoting the purchase of electric motorcycles and mopeds that is the most important factor in increasing their sales. Electric mopeds have now become the fastest growing means of urban transport in many European countries influenced by electric bicycles being classified as e-mopeds.

Key words: electric vehicles; electromobility; Europe; motorcycles, mopeds; PTW; two-wheeled vehicles

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Introduction

In order to reduce carbon dioxide emissions, most countries around the world focus on designing and developing energy-efficient and environmentally friendly transportation systems. One of the solutions proposed to tackle this problem is to power vehicles by electricity from batteries (battery electric vehicles – BEVs) (Tran et al. 2012). Examples of this type of transportation, especially over short distances, are electric motorcycles (e-motorcycles) and electric mopeds (e-mopeds). These vehicles have already gained significant popularity due to advantages such as low noise levels, good economy of operation, and zero exhaust emissions at point of use. At the same time, it should be noted that the so-called environmental friendliness of electric vehicles depends on the source

of electricity production in a given country. In the case of Poland, despite efforts to develop alternative energy sources, the share of renewable energy sources (RES) was around 30% in 2024 (Electricity in Poland 2024 https://lowcarbonpower.org/region/Poland).

It is widely recognised that the future of the automotive industry will be characterised by a complex mix of vehicle powertrain systems, with electric energy likely to play a key role in the diversification of such technologies. Currently, this trend is most visible in the four-wheeled segment where sales of battery-powered electric vehicles and fuel cell electric vehicles are growing rapidly. Electrification has the potential to transform traditional PTW (powered two- or three-wheelers) powered by internal combustion engines (ICE) into electric vehicles (EVs). It should be noted that PTW vehicles account for approximately 30% of global mobility and represent an essential component of transport, particularly in China, South Asia and Southeast Asia, with around 45 million units sold in 2021 (Gupta et al., 2023a). In regions where two-wheelers are the primary mode of transportation, they consume over 50% of total fuel and are responsible for 5–10% of CO_2 emissions (Gupta et al., 2023b).

The main issue with battery electric vehicles (BEVs) is the limited distance they can travel on a single charge. The range of an electric vehicle is primarily determined by the vehicle's power output and battery capacity. In the 21st century, electric motorcycle manufacturers use commercially available lithium-ion batteries instead of lead-acid batteries, in order to gain an advantage in power density (4–5 times greater than that of a typical lead-acid battery) (Zhang et al., 2018). However, the distance an electric vehicle can travel on a single charge is also largely influenced by its weight and by external conditions (e.g. road surface quality and air temperature). For operation in cities, a range of 100 km seems sufficient for their users. Additionally, infrastructure dedicated to electric vehicles is being developed, including electric vehicle charging stations (Zawieska, 2019) which allows for charging, for example, during the time spent at work.

All these mentioned technological and infrastructural changes mean that electric motorcycles and mopeds may hold a significant share in individual transportation across urban areas in the future. Even today, electric scooters are widely used in many cities for shared transportation (Strojna et al., 2022; Kuźma et al., 2022). In Poland, the first electric scooters were introduced to vehicle rentals in 2017, and in the following years the number of scooters made available increased significantly (Nowak, 2019). It is predicted that their use will be larger than shared cars and will reach about 9,000 vehicles in 2025 (Kuźma et al., 2022).

An additional advantage of electric motorcycles and mopeds is their small dimension, which is important not only throughout the life cycle of the product (construction and subsequent disposal costs) but also has a positive impact on parking spaces and mobility (Dorocki, Wantuch-Matla, 2021). This fact undeniably affects the reduction in fuel consumption and emissions during the search for free parking spaces – it is recognised that in many Polish cities, during peak hours, more than half of the vehicles participating in traffic do not travel to a destination but move in search of free parking spaces (Duda-Wiertel, 2021).

Therefore, it seems that along with the technological progress related to the efficiency and speed of battery charging, through activities aimed at promoting alternative means of transport in cities, PTW electric vehicles may become a significant means of urban transport in the near future.

The aim of the article

The following study aims to provide an overview of changes in the market for two- or three-wheeled electric vehicles globally and with a detailed analysis of the European market. The article focuses on an analysis of changes in the number of electric vehicles sold and registered in the period from the beginning of the 21st century to the 2020s, with particular emphasis on the period before and after the COVID-19 pandemic (2019–2024). It is also an attempt to present changes in the market for ePTW vehicles regionally and to demonstrate the main factors influencing contemporary trends in electromobility.

Due to legal and technical conditions, ePTW (electric powered two or three wheeled) vehicles are divided into mopeds (usually equipped with an electric motor with a power of no more than 4 kW, whose design limits its speed to 45 km/h) and motorcycles (vehicles reaching a speed of more than 45 km/h). Electric mopeds also include, in many countries, electric bicycles and scooters that reach speeds above 25 km/h.

The article uses published reports on the electric vehicle market (Global EV Outlook, 2024) as well as statistical data published by Eurostat and the European Association of Motorcycle Manufacturers (ACEM).

The subject of electric motorcycles is discussed in numerous academic articles and the number on electric motorcycles and mopeds is constantly growing (Yuniaristanto et al., 2023). The articles mainly concern technical issues in EVs there are very few studies on changes to the ePTW market referring to changes in domestic markets (Aversa, 2024; Ayözen et al., 2022; Coban, Lewicki, 2022; Nguyen, 2022; Olayode et al., 2024; Özgür, 2022; Zhao et al., 2024). There are very few academic studies on changes to the global two-wheeled EV market.

Determinants of the development of the global electric vehicle market

Few areas, in terms of "clean energy," are developing as dynamically as the electric vehicle (EV) market whose global sales had already doubled in 2021 compared to the previous year, reaching 6.6 million units.

China is also responsible for 95% of new registrations of two- or three-wheeled electric vehicles (ePTW) worldwide. Electric motorcycles and mopeds constitute half of the sales volume in China itself, while the pace of developing battery charging infrastructure there is faster than in most other regions of the world.

On the other hand, ePTW sales still remain negligible in emerging and developing economies where there are only a few available electric vehicle models. The COVID-19 pandemic and the war in Ukraine have disrupted global supply chains and these have adversely affected the automotive industry. In the long run, however, efforts made by governments to electrify transport constitute a solid foundation for further growth in the sales of electric two-wheeled vehicles. Nowadays, it seems that governmental policies supporting electromobility are the most important impulse for the development of this means of transport.

An example is furnished by the United Kingdom where low-emission vehicles, including motorcycles, are eligible for a subsidy amounting to 35% of the vehicle purchase price. The maximum discount available for motorcycles is GBP 500. To be eligible for the subsidy, a given vehicle must meet the following standards: no CO_2 emissions, be able

to cover at least 50 km between battery recharges, and carry a suggested retail price of less than GBP 10,000, including VAT and delivery fees.

In Poland, the "*Mój elektryk*" ('my electric vehicle'; it also means 'my electrician') project has been implemented since November 2021 where in addition to electric cars, entrepreneurs and representatives of social and professional groups are indicated in the regulations (e.g. individual farmers, representatives of public finance sector units, associations, cooperatives and religious organisations) may apply for subsidies for the purchase of mopeds and electric motorcycles. The project does not include individuals, as was the case with subsidies for electric cars. As a result, for June 2024, a subsidy of up to PLN 4,000 was granted to 593 L-class vehicles, as part of which purchases of 496 PTW vehicles were subsidised. L1e – L7e vehicles accounted for only 3.22% of the submitted applications and 2.44% of the total approved.

Other incentives for owners of electric vehicles in Poland include the right to drive electric vehicles along designated bus lanes, free parking in paid parking zones including city centres, and permission to park the vehicle in designated parking spaces at public charging stations for electric vehicles.

France is one of the European countries that has been supporting the purchase of EVs for several years. In 2024, ecological bonuses for the purchase of an electric moped or motorcycle could have accounted for up to 50% of a vehicle's purchase price, which is proportionally much more than that applicable to passenger cars. The amount of the bonus varies depending on the engine power of the vehicle and the capacity of its battery, however the amount may not exceed EUR 900. Such a vehicle must be purchased new or rented for a minimum of two years and cannot change ownership for one year from the date of purchase or rental, and thereafter until it has travelled 2,000 kilometres. No individual can receive a subsidy more than once every three years. Companies will be able to receive financial support as often as they purchase an eligible vehicle, without restrictions on number or duration of use. In the case of a motorcycle or an electric moped with a nominal power of less than 2000W, the ecological bonus is limited to EUR 100. If the rated motor power is greater than or equal to 2000W, the bonus may amount to EUR 900. The support is considered to be EUR 250 per kWh of the capacity possessed by the first battery, within the limit of 27% of the purchase price including vehicle tax. In France, it is also possible to receive a subsidy for replacing an ICE with an electric one in motorcycles and mopeds, and modernisation assistance is offered to individuals and companies based. Support is EUR 1100 and may be increased by an additional EUR 1000 if the applicant resides in a low emission zone. There are also subsidies for those who want to scrap an old vehicle and replace it with an electric one.

Italian authorities also provide financial support, the so-called Ecobonus, however, it is intended not only for the purchase of mopeds and electric motorcycles, but also single-track motor vehicles, being an alternative to cars. For comparison, there are no bonuses for buyers of electric motorcycles in Germany, however, they may be exempt from vehicle tax.

On the other hand, the Spanish *Moves* plan provides funding for the purchase of motorcycles with an engine displacement exceeding 50cm^3 and a speed of 45 km/h but weighing no more than 350 kilograms. In addition, they must have an electric range equal to or greater than 70 km and their price must not exceed EUR 12,100 before tax. Therefore, the program does not include mopeds or larger L-class vehicles. In many countries,

subsidies for the purchase of mopeds and electric motorcycles may also be obtained from local authorities such as in Madrid, Munich or Nice.

The above-mentioned measures in European countries are largely dictated by the policy of economic independence from oil (Wodnicka, Malinowski, 2023). At the same time, the European Green Deal implemented in the EU affects the energy transition, not only in the field of energy and industry, but also transport (Kazak et al., 2023).

As a result of global efforts to develop alternative energy sources in transport by various public and private entities, it is assumed that in 2030 electric vehicles will account for more than 30% of vehicles sold worldwide. On the other hand, the share of ePTW in the sales of electric vehicles may be even higher. At the same time, the global value of the electric energy market for charging electric vehicles is expected to increase by more than 11–20% (Kapustin, Grushevenko, 2020), reaching about USD 200 billion, which is equivalent to only about one tenth of today's oil market value.

Simultaneously, there are significant differences between countries in terms of the rate of infrastructure development dedicated to electric vehicles. The right number of stations for EV charging will depend on local characteristics, such as housing resources, prevailing travel distance, population density and the possibility of charging vehicles at home. It is assumed that charging EVs at home and at work is likely to meet a significant part of the overall demand, but the number of public charging facilities must increase about ninefold and reach more than 15 million units in order to provide consumers with an adequate and convenient range (Raj, 2024).

The concurrent electrification of public transport (Guzik et al., 2021; Kołoś et al., 2023; Połom, 2018) and the implementation of decentralised renewable sources of electricity, such as solar energy, will make the management of distribution in the power grid more complex. Therefore, with the development of electricity-based transport, digital network technologies and intelligent charging will become key to an integral vehicle charging network.

Electrification of transport will increase the demand for electricity; however, it is expected that electric vehicles will account for only about 4–5% of the total final demand (Bogdanov et al., 2024).

As mentioned above, sales growth of EVs slowed down during the COVID-19 pandemic (2020–2023) as a consequence of disruption to the supply chain of components, including batteries. While the war in Ukraine has led to even greater difficulties in obtaining raw materials for their production. Following these events, the prices of raw materials such as cobalt, lithium and nickel have soared abruptly. In May 2022, the price of lithium used in batteries was more than seven times higher than at the beginning of 2021. However, given current oil prices, the relative competitiveness of EVs remains unchanged. Today, China produces three-quarters of all lithium-ion batteries with 85% of their total production (Popa, 2024). Russia, however, supplies 20% of global high-purity nickel.

In the 21st century, most of the companies specialising in the production of the machines used for manufacturing battery cells are located in China, Japan and South Korea. However, many Asian suppliers involved in battery cell production are already operating at maximum manufacturing capacity, leaving little room for expanding production. It is predicted that more than 50 large new factories are needed to meet the global demand for batteries (Xu et al., 2020). The growing sales of EVs and the global demand for batteries have contributed to increasing the production of this product range in many regions worldwide. The fastest growth in 2023 and 2024 was recorded in the United

States and Europe, which together accounted for 40% of the market, while China holds around 35% of global production. Nevertheless, the United States remains the smallest market of the top three, with around 100 GWh in 2023, compared to 185 GWh in Europe and 415 GWh in China (Global EV Outlook, 2024). In Europe, the positions of the largest battery producers are occupied by Poland, which was responsible for about 60% of all EV batteries produced in the region in 2023, and Hungary with a market share of almost 30% (Makaroff, 2024). On the other hand, Germany is the EV leader in Europe, with a 50% share of European production in 2023, next are France and Spain with just under 10% (Global EV Outlook, 2024). This indicates a discrepancy between vehicle and battery production in Europe, which does not occur in the case of China.

Therefore, one of the challenges for the development of EVs outside China might be interruptions in the supply of the raw materials needed for battery production. This may be the result of both global crises and decisions dictated by political considerations, as exemplified by the trade policy of the United States and its trade war against China (Bekkers et al., 2025). The solution seems to be the supply of nickel from Canada, Australia and Indonesia which already produce 40% of this raw material. However, changes in these supply routes require time and may cause its price to rise.

Therefore, it seems that the two largest factors that may affect the development of the EV market are the policies of individual countries in terms of promoting and supporting the production of vehicles running on electricity. An example is furnished by the Polish electric car design by Izera (Lis-Plesińska et al., 2024)), and including electric mopeds and motorcycles, as well as political factors related to the production of batteries powering electric vehicles.

Urbanisation, lack of transportation accessibility, high car maintenance costs (including rising fuel prices), and concerns about environmental pollution are some of the key issues driving changes in decisions regarding modern transportation preferences. Most developed countries have in the 21st century taken steps to promote electric mobility, which aligns with their efforts to reduce emissions and achieve clean energy targets. Concerns about environmental pollution and the greenhouse effect have influenced governments of various countries to support alternative forms of transport other than ICE vehicles. Two- and three-wheeled vehicles (PTW) are some of those forms of personal transport which are an attractive alternative to other means. Compared to a conventional car, PTW vehicles ensure several benefits as they are less expensive for the consumer in terms of initial purchase costs, fuelling and maintenance (Dorocki, 2022). They also emit roughly half the amount of carbon dioxide generated by standard cars, and it is believed that in the future, they will emit even less (Ntziachristos et al., 2006). The popularisation of single-track vehicles has also helped alleviate traffic congestion in areas where rapid urbanisation is creating an increasing demand for mobility solutions.

Although the first electric motorcycle projects were created in 1911 (Łebkowski, 2017), it was not until 100 years later that the idea of the widespread development of electric motorcycles returned. For e-motorcycles, the engine can be integrated into the wheel hub or, through gearboxes, transfering the drive from the engine to the vehicle wheels. Electric motors boast the advantage of operating efficiently across a wide range of speeds, eliminating the need for multi-gear transmissions. Moreover, an electric motor can deliver maximum torque from initial acceleration all the way up to the rated top speed. Therefore, PTW vehicles can be equipped with either geared motors (mounted to the vehicle frame) or gearless motors (integrated into the wheel hub). EVs, compared

to those with an ICE, are therefore cheaper and less complex in design, however, their overall cost is further increased by the price of the battery.

It should be emphasised that aside from changing the type of powertrain, converting PTW vehicles with ICEs to electric ones does not require complicated or costly modifications to their design. Numerous solutions have already appeared on the market offering the transformation of existing PTW vehicles with ICEs.

At the same time, large cities are introducing clean transport zones (CTZ) limiting the traffic of ICEs (Ruczkowski, 2024). So far, in Poland, internal combustion motorcycles are exempt from the ban on entering these zones (e.g. Warsaw and Krakow), however, it should be expected that in the future, traffic restrictions in these zones will also apply to PTW vehicles, especially those with two-stroke engines.

Regardless of the details of vehicle design, most of the world's manufacturers of PTW vehicles already offer numerous EVs, those intended for short-distance travel in urban areas are a special case. BMW has publicly confirmed that, from 2026, it will introduce battery power to an even broader range of motorcycle categories while another global top player, Honda (Kilar, Cieluch, 2008), is planning to introduce 10 electric models in 2025 and increase this to 30 in the following five years. The company is planning to sell four million electric motorcycles per year and to reduce production costs of electric motorcycles by half compared to current prices.

One example of the changes taking place on the EV market is the fact that in 2021 new market entrants, offering competitively priced products, controlled over 75% of electric single-track vehicle sales in India.

Therefore, it is expected that the global market for electric motorcycles and mopeds will witness a significant expansion of new manufacturers due to growing advances in e-mobility technology, mainly in developing countries, where PTW vehicles are deeply rooted in the transportation culture of their populations. However, global giants in the motorcycle industry, such as BMW, Ducati, Indian Motorcycle, Triumph, Suzuki, HD and Honda, are also expanding their production in developing countries, including India and Brazil, as well as in regions such as Africa and Southeast Asia (Brondoni, 2021; Mishima, 2024; Aversa, 2024). Moreover, the growth of the global automotive market is driven by the rising disposable income of the middle classes worldwide and the increasing demand for affordable and convenient means of transport.

It is believed that the development of EVs will follow two directions. One of them will be innovative startups that will operate the electric two-wheeled sector in the B2C system, where vehicle owners travel only 30–40 km per day and will prefer charging the battery at home or in public car parks. In contrast, large companies will expand B2B services in the logistics sector, where vehicles cover much longer distances under time and driver pressure. These companies may therefore prefer to replace the battery in easily accessible locations, such as petrol stations. At the same time, in the case of ePTW vehicles, battery replacement systems are already becoming standard due to the battery being smaller compared to electric cars.

It can thus be concluded that the development of e-mobility has significantly influenced the diversification of production and the emergence of many new manufacturers of PTW vehicles. This is especially true for new companies from China which has become a global giant among EV manufacturers, including motorcycles and electric mopeds.

The global market for electric motorcycles and mopeds

The market for electric two-wheeled vehicles is expected to grow dynamically in the coming years and there is also a wide range of forecasts for this market as regards its development directions, providing growth opportunities for original equipment manufacturers and first-tier suppliers operating in this segment. The shift to electric powertrains in PTW vehicles requires changes in their design and technical specifications.

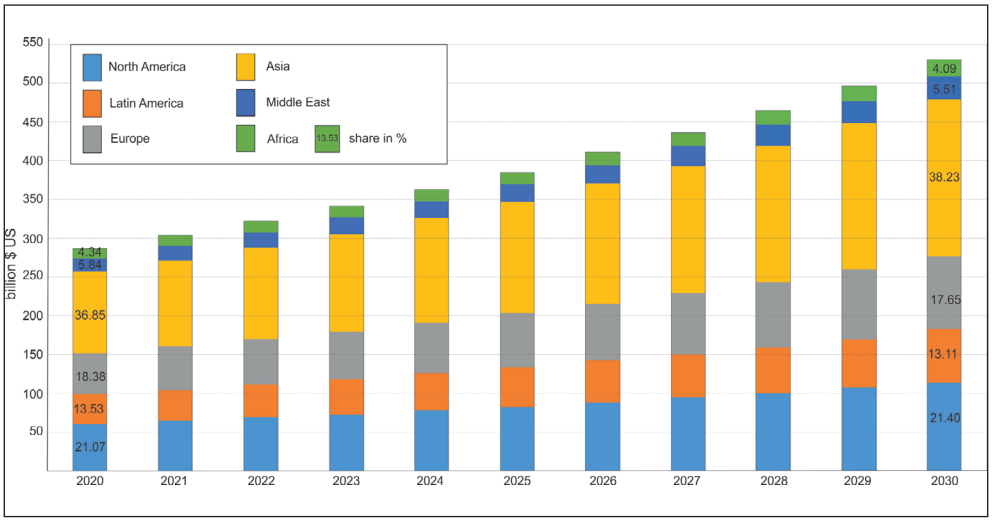
The global market for mopeds and electric motorcycles is valued at USD 4.12 billion in 2022 and is expected to reach USD 27.24 billion by 2031 with a compound annual growth rate (CAGR) of 23.58% over the 2023–2031 forecast period (IEA, 2024). The distribution of the motorcycle and electric moped market corresponds to the regional popularity of single-track vehicles worldwide with the greatest number being recorded in Asia. The ePTW market in the APAC region is projected to reach 31.2 million units by 2025, with a CAGR of 7.6% during the forecast period (Figure 3). The size of the e-moped market in this region alone was valued at USD 24.85 billion in 2022 and will continue to grow until 2030 with an average CAGR of 11.9%.

The PTW market in Asia has witnessed significant growth in the recent past, due to rapid urbanisation in APAC's developing economies. The growing demand for lightweight vehicles in developing countries, and initiatives for public awareness of deteriorating air quality in developed countries, have contributed to the popularisation of this type of vehicle.

The most significant example of changes in automotive mobility culture is the United States of America (Bohren, 2016). In the country where automotive culture dominated for decades, as evidenced by the widely used image of American cars firmly embedded in the American lifestyle, a societal shift in attitudes toward alternative means of transport began in the early 21st century, triggered by the 2008 financial crisis (Editors, 2024). An iconic example of the cultural shift in the approach to the use of lightweight PTW vehicles in day-to-day mobility can be seen in the film titled "Larry Crowne" with Hollywood stars Tom Hanks and Julia Roberts. In this film, the main character abandons a large "fuel-guzzling" SUW, replacing it with a small economical Japanese moped (McClain, 2019). Another example is Piaggio's 2012 *Vespanomic* campaign in the USA. The Italian company aimed to change the mindset of an American people attached to their large cars with V8 engines, or their heavy and large motorcycles like the American symbol of freedom, the Harley-Davidson, and encouraged the use of mopeds as an economical means of everyday communication (Dorocki, 2018). The modern Generation Z in America is increasingly moving away from a deeply rooted automotive culture (Getahun, 2023), inclining towards other means of transport, including lightweight motorcycles (Efthymiou et al., 2013).

An important factor stimulating the demand for motorcycles is the demographic structure of societies in countries such as China, India, Brazil and Mexico. In these countries, the proportion of young people is much higher than in developed countries (Mondal et al., 2021; Gu et al., 2021) struggling with the problem of an ageing population (Poborski, Kraska, 2022). It is the young who are the main buyers of single-track vehicles, due to the fact that PTWs are cheaper than cars (Verma et al., 2017) and legislation allows minors to use them. At the same time, motorcycles and mopeds are an important element of youth culture both in Latin America and Asia (Hagen et al., 2016; Romy, Dewan, 2021).

Figure 1. Projected regional diversification of the PTW market in 2020–2030



Source: Global EV Outlook, 2024

For the above reasons, it is predicted that in the forthcoming years, China, followed by India and South America, will contribute to the largest global development of the PTW market, including single-track electric vehicles. China is one of the key motorcycle manufacturers due to its inexpensive workforce and the availability of raw materials while the Indian motorcycle market is focused mainly on inexpensive and economical vehicles with small engine displacements. This region has witnessed an unprecedented demand for motorcycles due to new infrastructure developments and the construction of paved roads. China and India as well as other developing countries are dominated by the motorcycle segment with engine displacement of up to 125cm^3, which accounts for approximately 50% of the total market. Motorcycles with engine displacements up to 250cm^3 constitute another 25% of the market.

It should be noted that the growth of the Chinese motorcycle market, as well as the markets of other developing countries, slowed down in 2024. Total domestic sales decreased by approx. 14%, and the electric segment lost approx. 7% of sales. This drop stems from the rising income per capita in China, which has boosted the popularity of cars as a personal means of transport. At the same time, a ban on the use of PTW was introduced in centres of large cities in order to reduce the number of road accidents and stimulate the development of public transport. The new middle class in China, as in other developed countries, treats PTW as a recreational product, therefore, while the entire domestic motorcycle market is shrinking, the premium segment (with engine displacement larger than 250 cm^3) is growing rapidly thanks to imports and new domestic manufacturers of more expensive models, such as Voge, CF Moto, Kove, Benelli or QJ Motor

The Chinese market for electric vehicles is the largest in the world (it accounts for almost 80%) and is now, thanks to a new generation of batteries, changing towards advanced technological solutions, elevated specifications and models with higher power ratings. This has also brought about a decline in sales of e-motorcycles and e-mopeds. One of the effects of the transformation within the EV industry is its involvement in the development of a new generation of vehicles, more competitive in terms of technical

specifications, available options and power, which increases their price, causing in turn a decrease in the sales of new, but also more expensive, models.

Nevertheless, China is still, just ahead of India, the largest motorcycle market in the world, including electric. Other developing countries of Southeast Asia have also experienced dynamic development of the ePTW market in the recent years and attention is drawn to the dynamic development of the automotive industry in Vietnam, which has become the fourth largest in the world (behind Indonesia) (Nguyen, 2022). Although the PTW market in Poland has also sharply diminished in recent years, the sales of electric two-wheelers has increased significantly from 5.4% of total PTW market share in 2019 to 10% in 2021. Vietnam is second in the world, behind China, as regards the prevalence of electric motorcycles and mopeds. The market for electric two-wheeled vehicles (e2W) is led by local companies VinFast and Pega, whose market shares in the EV market in 2020 amounted to 43.4% and 15.7%, respectively. Overall, seven Vietnamese companies cover almost 80% of the e2W market (Le et al., 2022) mainly offering mopeds and light motorcycles (up to 100 kg) with an average range of 70–80 km. It should be noted that foreign automotive companies functioning in Vietnam (e.g. Honda, Yamaha and Piaggio) (Lin et al., 2013; Dorocki, 2018b) which dominate the market of those with an ICE (approx. 80% of the market), are not present on the EV market. Their participation in the development of EVs is limited to creating infrastructure for charging or replacing batteries. In 2021, Honda, Yamaha, Piaggio and KTM formed the Swappable Batteries Motorcycle Consortium (SBMC) to develop joint technical specifications for battery swap systems and extend the use of these specifications to a global level. Hence, it seems that the Asian market is becoming a testing ground for the world development of ePTW.

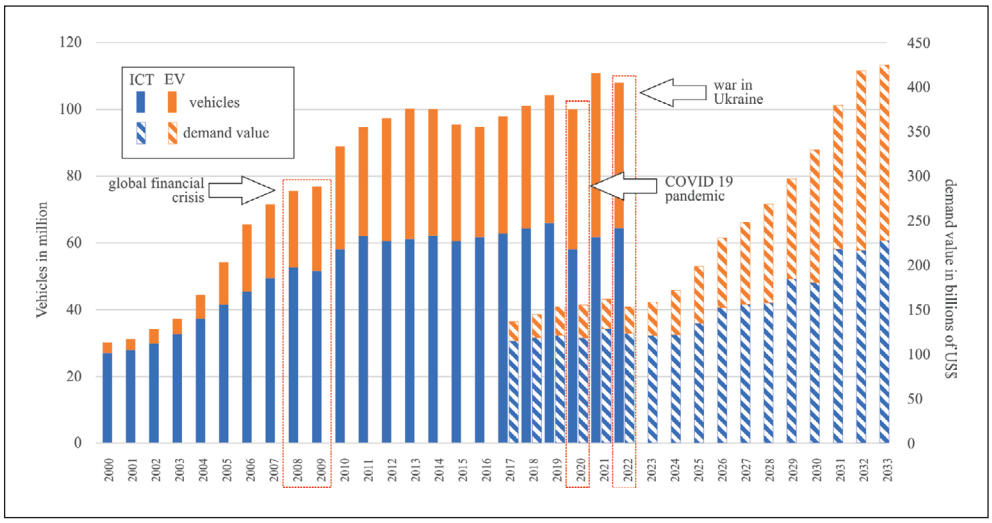
Table 1. Regional diversity in the number and share of PTWs by type

PTW	ASEAN	China	India	Far East	Europe and North America	Latin America	Africa
units in millions	12	15	15.1	2.3	2.1	2.8	1
units/100 people	1.78	1.06	1.07	0.35	0.19	0.42	0.08
CAGR (2022–30) %	4–5	0–1	6–7	5–6	5–6	5–6	12–14
scooters %	70–75	80–85	28–30	25–30	25–30	0–1	0–1
lightweight motorcycles %	5–10	0–5	60–65	65–70	10–15	70–75	90–95
heavyweight motorcycles %	0–5	0–5	4–5	0–5	50–60	0–5	0–5
e2W %	2	15	4	<1	8	<1	<1

Source: Gupta et al., 2023

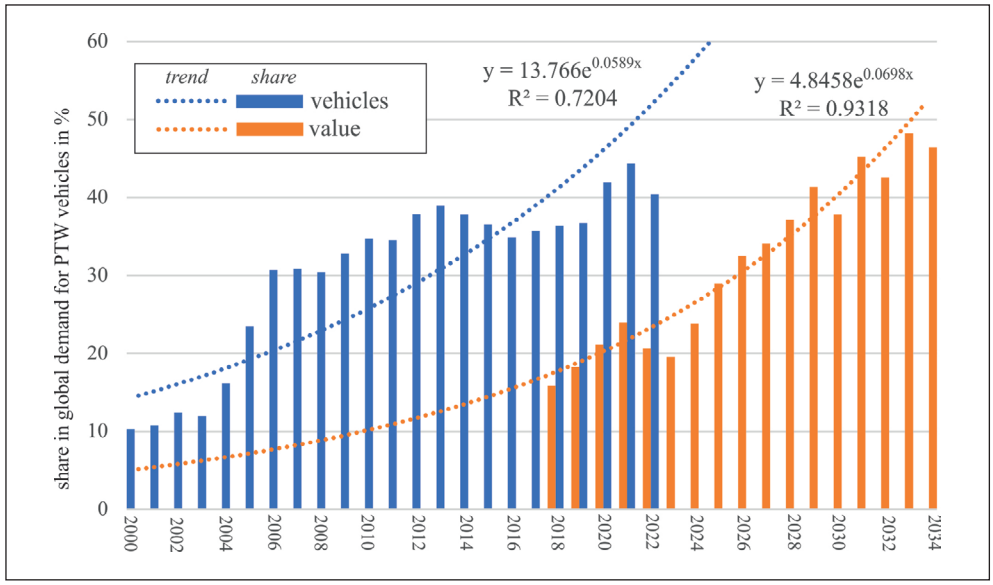
It may therefore be concluded that Asia is the largest and fastest growing market for PTWs, including EVs, however, it is acknowledged that in the next decade it is the African continent that will record the fastest growth (Table 1). In Asia, scooters and lightweight motorcycles dominate in day-to-day operation (Dorocki, 2018a), while in the developed countries of Europe and North America, heavy motorcycles used for tourism and recreation prevail (Dorocki, 2021), and the share of EVs in overall automotive numbers is still small. China has the largest share of e2W vehicles (approx. 15%), although the share of new ePTW is constantly increasing in almost all regions.

Figure 2. The dynamics of the PTW market between 2000 and 2033



Source: the Author's original study

Figure 3. Change in the shares of EVs in the global PTW market from 2000 to 2034



Source: the Author's original study

Therefore, when analysing changes in the market size of new PTW's since 2000, their more than threefold increase from 30.15 million units to 108.04 million units in 2022 may be noticed (Figure 2). At the same time, it is estimated that the value of this market over the decade from 2023 to 2033 will increase from about USD 158 billion to USD 425 billion indicating an increase of almost 170% compared to the initial year. At the same time, it should be noted that factors such as the financial crisis, the COVID-19 pandemic or the war in Ukraine (June 2023) significantly affect the PTW market. This

is related not only to disruptions in the supply chain in the production of vehicles, but also a reduction in demand, mostly in developed countries, where they are treated mainly as luxury goods. The tariff war initiated in 2025 by the president of the United States, which also targets motorcycles, may contribute to decelerating the development of the PTW market (https://www.acem.eu/industry-calls-for-motorcycles-to-be-removed-from-the-u-s-eu-trade-war).

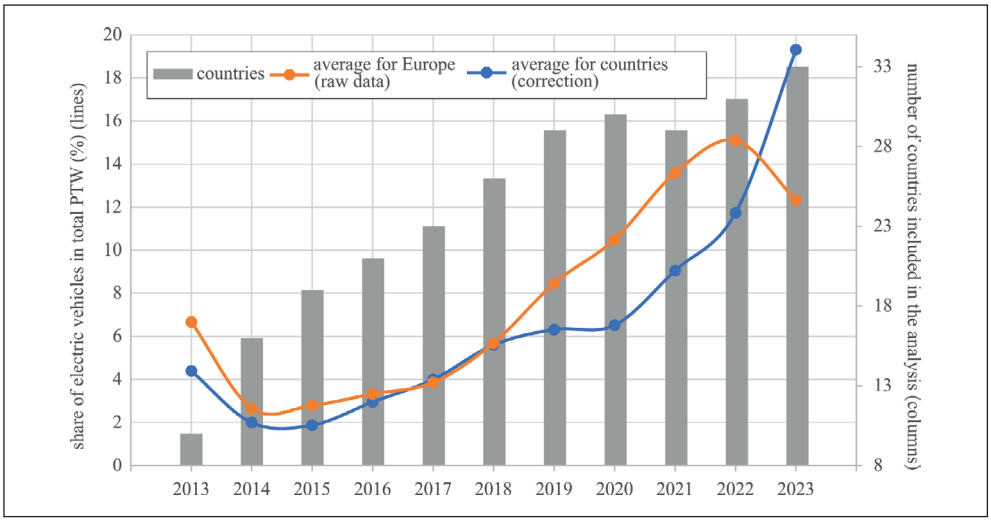
At the same time, along with the development of the PTW vehicle market since the beginning of the 21st century, a steady increase in the share of EVs among newly purchased motorcycles and mopeds can be observed (Figure 3). The share of EVs in the total number of PTW vehicles increased from around 10% in 2000 to approximately 40% in 2022 and it is projected that by the 2030s, around half of all new PTW vehicles on the market will run on electricity. The growth trend in the number of electric PTW vehicles is higher than the growth trend in their market value share confirming the thesis that manufacturers of mopeds and motorcycles are focused on improving the quality of EVs rather than lowering their price. An example can be seen in Chinese electric cars which are more technologically advanced than Western cars in many models, resulting in higher prices compared to popular American or European brands.

The European electric PTW market

In the case of Europe, the development of two-wheeled electromobility is much slower than in Asia. In addition, there is a large variations in the legal conditions applicable in individual countries. Many European countries have introduced insurance requirements for electric bicycles and scooters exceeding a speed of 25 km/h, classifying them in statistics as mopeds, while in other countries such requirements do not exist. This creates a problem in analysing the shift in the share of EVs in the total number of PTW vehicles over time, as well as conducting regional comparisons. Therefore, further analyses are based on data adjusted using average values (interpolation) and trend lines based on linear regression (extrapolation) (Dagum, Cholette, 2006).

Regardless of issues with data availability and comparability, analysing the share of EV registrations in the total of PTWs in Europe over the period from 2013 to 2023 shows a noticeable upward trend (Figure 4). Both the average share of e2W registrations within the total for PTW vehicles in the whole of Europe, as well as the adjusted average for individual countries during the period under study, increased by approx. 5%, reaching around 15%. The largest increase in the share of EVs has occurred after 2020 caused by technological developments, as well as policies intended to curb exhaust emissions (Yasir et al., 2023). On the other hand, the COVID-19 pandemic significantly contributed to changes in the preferences regarding the use of various modes of transportation (Awad-Núñez et al., 2021). Interest in bicycles, including electric ones, and in motorcycles was on the rise at that time (Monterde-i-Bort et al., 2022; Wada et al., 2022). During the COVID-19 pandemic, interest in electromobility also increased (Rokicki et al., 2021; Figura, Gądek-Hawlena, 2022) while the increase in the share of EVs continued until 2022. In the following period, only some countries recorded an increase in the share of electric PTW vehicles, also caused by legal changes classifying electric bicycles as mopeds, an effect visible in the difference between the average share for EVs for Europe and the adjusted average for individual countries.

Figure 4. Change in the share of EV registrations in the total number of PTW vehicles between 2013 and 2023 in Europe*



* selected European countries as well as Turkey and Cyprus

Source: author based on data from the Eurostat database

The variation in the share of EVs in the total number of PTW vehicles is very high and mainly depends on the transport culture preferred in a given country and its government's policy supporting electromobility. Among the analysed countries, the highest share of electric PTW vehicle registrations, over 20% of all vehicles, was recorded in 2023 in Belgium, the Netherlands, Lithuania, and Turkey (Figure 5). It can be assumed that the popularity of ePTW vehicles is the outcome of various factors, one of which is the general increase in the popularity of EVs in a given country, usually the result of national transport policy including the presence of a dedicated infrastructure. Secondly, the popularity of EVs may be influenced by the wealth of a society and its transport culture, including the overall popularity of PTW vehicles. In third place one should mention the presence of domestic companies manufacturing electric PTW vehicles (Li et al., 2020; Yeğin, Ikram, 2022; Zang et al., 2022; Song et al., 2022; Şen et al., 2023).

In the case of Belgium and the Netherlands, the transport culture of micromobility is highly developed (Vanpée et al., 2022; Zema et al., 2022) applying to both bicycle and moped transport. In these countries, not only electric bicycles, but also electric scooters exceeding a speed of 45 km/h are treated as mopeds (Sokolowski, 2020). The wealth of a society, the development of infrastructure dedicated to single-track vehicles, EV charging stations, and a high degree of urbanisation all influence the popularity of electric mopeds and bicycles.

Another country with a high percentage of electric PTW vehicles is Lithuania. In this country, per capita transportation (fuel) expenses are among the highest in Europe (Valentukevičienė, Piekut, 2024), which has positively influenced the popularity of EVs which are cheaper to operate. The implementation of electromobility in Lithuania began in 2015 and included legal changes, support for the automotive industry regarding EVs, as well as direct financial assistance from the government for the purchase of such vehicles (Raslavičius et al., 2015). In Lithuania, the state's top-down policy forced the

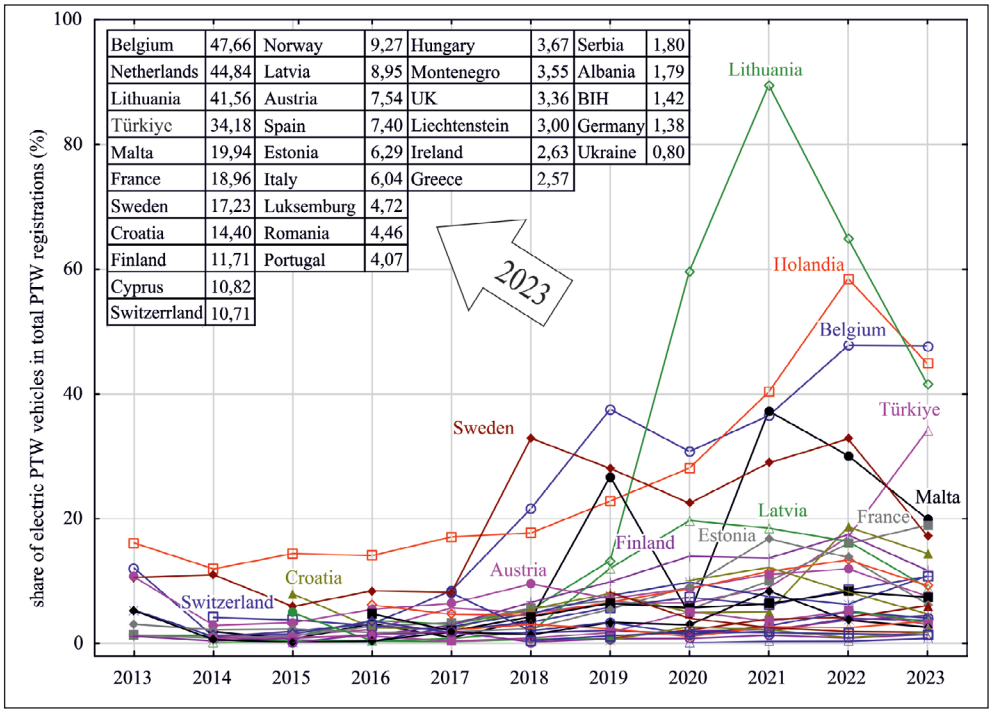
government and public institutions to purchase EVs, which significantly influenced their popularisation (Petrauskiene et al., 2020). Another important incentive for e-mobility offered by the Lithuanian government was a charging infrastructure free until 2023 (Gesevičius et al., 2021) and by 2024, there were 5,722 battery electric vehicles (BEV) per million inhabitants, while in Poland the figure was only 2,090 (EAFO) which is almost three times lower.

At the same time, Lithuania is the location of many companies operating in the electromobility industry, including those offering electric bicycles and scooters. Companies located here include Baltik Vairas, Pon.Bike, Continental, Rehau, Zbike, Ako, Timyo and Rubbee (engines for converting traditional bicycles into electric ones), as well as the Italian company Askoll. Companies in the EV charging sector are also developing rapidly, including Inbalance Grid, Elektrum, Elinta Charge, CHRG Network and EMUS.

An important factor contributing to the popularity of EVs is its demographically young society and the high percentage of educated young people, including a significant proportion of women with higher education. This contributes to a high level of environmental awareness in the society and an openness to new technological solutions.

In the case of Turkey, electromobility is strongly supported by the state and has been experiencing significant growth since the 2020s (Coban, Lewicki, 2022; Dalkic-Melek et al., 2024). Governmental support for the development of electromobility has been influenced by the country's need to achieve energy independence from imported liquid fuels

Figure 5. Change in the share of EV registrations in the total of PTW vehicles between 2013 and 2023 in selected European countries, as well as in Turkey and Cyprus



Commas need to be replaced by points in the percentage figures + Holandia on graph

Source: author based on data from the Eurostat database

(Muneer et al., 2011). In Turkey, not only are components for foreign electric vehicles (Renault-Nissan) produced (Túry, 2019), but in 2022, the production of Turkish electric cars was launched by the company Togg (Mordue, Sener, 2022). Electric motorcycles and mopeds are also produced in Turkey by companies such as Volta Engine, Arora Motor, Apachi and Elesco.

At the same time, transport with the use of PTW vehicles has been widespread in Turkey for many years (Chiu, Guerra, 2023), and nowadays e-mobility is also gaining popularity (Özdemir-Öztürk, Barutcu, 2022). The research conducted here demonstrates that Turkish society is in favour of developing electric transport (Ramadani et al., 2025) and it should be noted that the Turkish post office introduced electric scooters for postal deliveries in 2021 (Ayözen et al., 2022). According to the Turkish Motorcycle Industry Association (*Motosiklet Endüstrisi Derneği*, MOTED), electric motorcycles have become a new target of the Turkish consumer – 6,000 electric motorcycles were sold in the first four months of 2022. April 2022 was a record-breaking month for the Turkish motorcycle world, and the market for these single-track vehicles grew by 95% with approximately 44,000 being sold (Özgür Dil, 2022). In 2024, Turkey rose to the 10th place in the global ePTW vehicle market, however, 2025 brought a decrease in sales of both ICE and EVs, despite the persistently high inflation which is driving the automotive market in Turkey (Ustabaş, Buyun, 2024).

In the case of two other countries with a high percentage of electric PTW vehicles, Malta and France (approx. 20%), such a high share was achieved owing to the government's policy supporting e-mobility. Malta supports the purchase of both motorcycles and electric mopeds, as well as electric bicycles while at the same time the government provides compensation for scrapping ICE vehicles (including PTW vehicles). Despite Malta introducing a ban on electric scooter rental businesses in 2024, which resulted in approximately 1,600 of these vehicles disappearing from the streets, the popularity of EVs continues to increase each year.

France is among those countries in Europe which have very strict regulations on emissions of pollutants from transport and strongly supports e-mobility. The French government very early introduced subsidies for EVs, including PTW. In France, in 2025, the electric motorcycle segment recorded a significant increase of 28.9% while at the same time, a study conducted by the Solly Azar AAA Data Observatory demonstrated that the number of petrol-powered two-wheelers had decreased by 2.3% since the beginning of 2023. This increase is partly the result of the rising popularity of the scooter segment (an increase of approx. 16.1%) while the demand for electric motorcycles is also influenced by France's commitment to reducing carbon dioxide emissions. On the other hand, local authorities have introduced parking fees for L-class vehicles and encourage the use of public transport which has resulted in a decrease in the number of registrations of electric PTW vehicles in large cities. In Paris, this decrease was approximately 10% in 2023. France abolished registration fee exemptions for electric cars in most regions as of 1 May 2025 but it should also be noted that France produces a variety of electric two-wheelers, including electric bicycles, mopeds and motorcycles, such as Solex, O2feel, Motowatt and RED Electric. Electric motorcycles and mopeds are also offered by big brands of the automotive sector such as Renault (together with Ateliers HeritageBike) and Peugeot (Dorocki, 2010). In France and other countries, EVs are the basis for the development of shared mobility (Kuźma et al., 2022) referring mainly to scooters and electric mopeds (Dorocki, 2022; Zhao et al., 2024). Many companies have also emerged

in France offering electric vehicle rentals, examples include Cityscoot (Paris); RedE (Nancy), KNOT (Strasbourg), Eccity (Grasse) or WeTrott (Versailles). The development of these companies can significantly affect the number of these vehicles in road traffic.

It should be noted that, regardless of the country analysed, a high share of EVs is also related to the high number of vehicles classified as mopeds (including bicycles and electric scooters). This suggests that these vehicles are largely used by young people (low age requirement – often under 18) and in everyday commuting to work or school. In 2023, about 27,000 electric two-wheelers were sold in France, of which 67.5% were electric mopeds representing a decrease of approximately 25% compared to 2022 data, with a simultaneous increase in the share of electric motorcycles in the total sales of electric PTW vehicles.

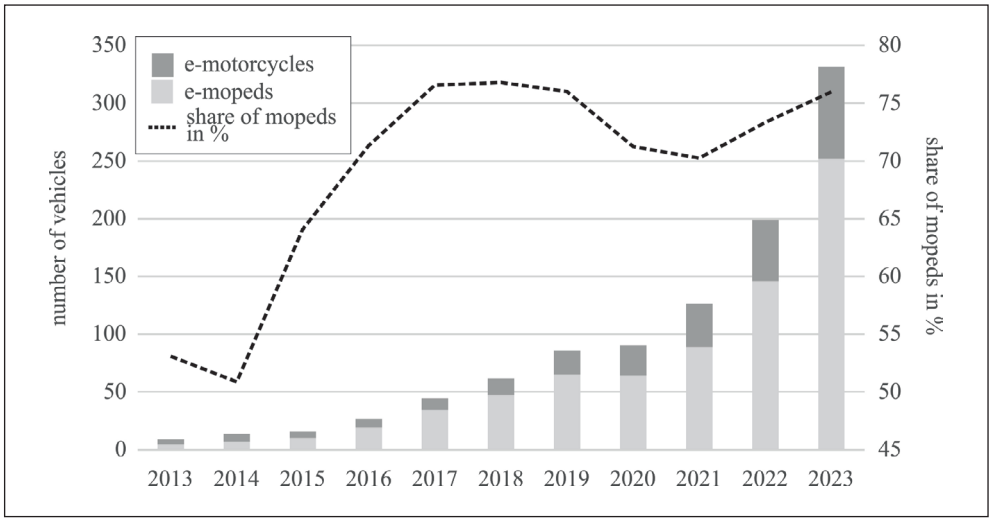
Referring also to data for the whole of Europe, mopeds account for the largest share of all new electric PTW vehicles, representing approx. 75% of all electric PTW vehicles (Figure 7). In the total number of mopeds registered in Europe, the share of EVs in 2023 was less than 13% (Figure 6) while even lower is the share for electric motorcycles, which does not exceed 3% of the total. A small increase in the share of EVs occurred in 2022, which may have been the result of the COVID-19 pandemic and a growing interest in recreational motorcycles, including enduro and cross models whose electric versions are becoming increasingly popular (Arnold et al., 2024; Ingram-Sills, 2024). At the same time, it should be noted that in the case of electric motorcycles, their share in individual countries varies little. In 2023, Switzerland (9.6%) and France (9.4%) had the highest share with Lithuania (5.8%) and Spain (4.4%) also recording high values. In the case of electric mopeds, international diversity in Europe is very high mainly depending on the prevailing transport culture in a given country and on the legal conditions for registering EVs. In countries such as Germany and Malta, the share of electric mopeds is over 90% of all registered mopeds in 2023. This high share results from many electric bicycles being classified as mopeds due to their power and speed which they can attain. It seems that if electric bicycles were not included, the share of e-motorcycles, for example for Germany, would not exceed 40%. To a large extent, the share of e-mopeds depends on the wealth of the society and the level of urbanisation (the lowest shares were recorded in Bosnia and Herzegovina and Albania, at less than 2%).

Due to difficulties in tracking the continuity of change in the share of ePTW vehicles in all European countries, further analysis for selected countries was based on data from the European Association of Motorcycle Manufacturers (ACEM). Economically developed countries of Western Europe, in which the popularity of PTW vehicles is significant, were selected for the analysis (Dorocki, 2018a).

Based on the share of EVs among all registered PTW vehicle types in selected Western European countries between 2011 and 2014, a consistent trend can be observed. A noticeable increase in the share of vehicles with an electric engine occurred over the period of 2016–2017, to significantly accelerate in 2018 and for electric motorcycles (Figure 7A) and electric mopeds, (Figure 7B) the increase continued until 2022. In the case of motorcycles, the dominant share of EVs is very clear and after 2022, a clear decrease occurs in almost all analysed countries. In the case of electric mopeds, the decrease in the share of vehicles of this type registered after 2022 is not so pronounced.

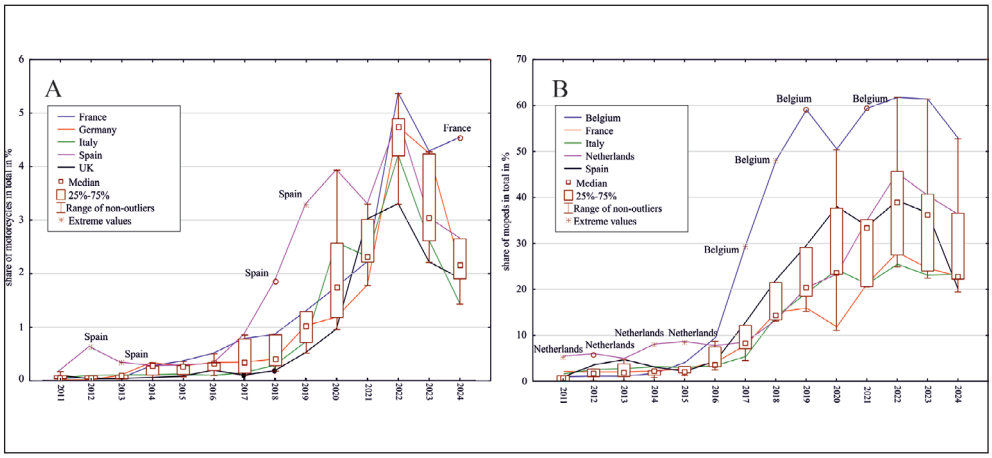
It seems that the increase in the share of EVs in 2022 resulted, on the one hand, from the prevailing COVID-19 pandemic, and, on the other, from the increase in fuel prices in Europe, with its peak in 2022 according to Eurostat.

Figure 6. The number of registered electric PTW vehicles in Europe between 2013 and 2023



Source: author based on data from the Eurostat database

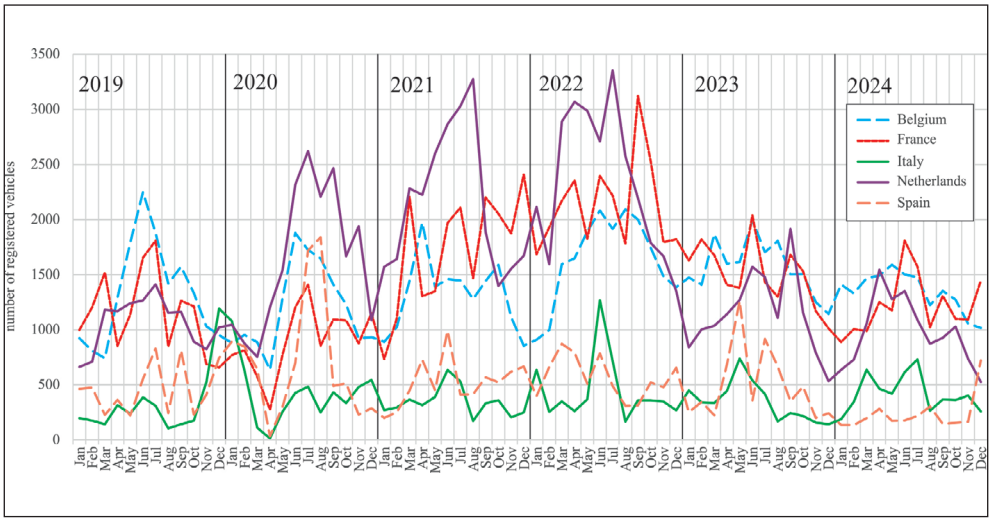
Figure 7. Share of electric motorcycles (A) and electric mopeds (B) in the total number of vehicles from 2011 to 2024 in selected European countries



Source: author based on ACEM data

For electric mopeds, it should be noted that in most EU countries, this type of vehicle also includes electric bicycles exceeding a speed of 25 km/h (Olayode et al., 2024). From the period 2019–2024, a noticeable increase in the number of electric mopeds in almost all of the analysed European countries occurred in the spring of 2020 with the increase most visible in the Netherlands and France (Figure 8). After this period, a decrease in the registration of electric mopeds occurred with visible fluctuations in month-to-month figures. Observing the relative values of e-motorcycle registration, represented by the monthly percentage share of these vehicles in each analysed country, the dominance in the summer months of June and July is noticeable: (Figure 9). There was also a clear decrease in the registration of electric mopeds at the beginning of the COVID-19 pandemic

Figure 8. The number of registered electric mopeds in 2019–2024 in selected European countries

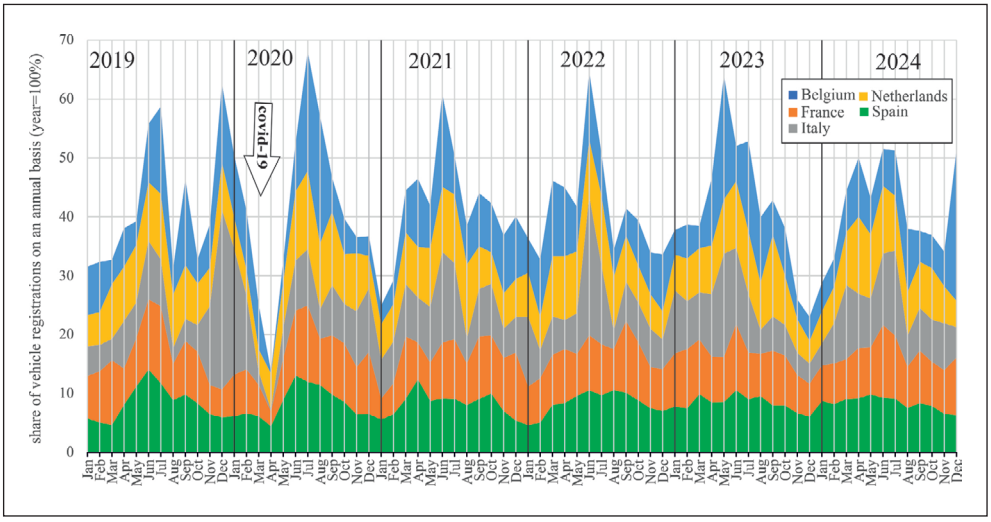


Source: author based on ACEM data

in the spring of 2020, and at the end of 2023, when a clear economic slowdown occurred in Europe in the wake of the pandemic (Quaglia, Verdun, 2023).

The noticeable periodicity of the registration volume on a month-to-month basis is related to both climatic conditions and cultural factors (e.g. religious holidays, holiday trips) as well as economic factors (e.g. sales and price reductions). In the case of Belgium and the Netherlands, the impact of climate on the sale of electric mopeds can be clearly seen. The highest share is in the summer holiday months, while a drop occurs in winter. In France, Italy and Spain, registrations also predominate in June and July, but high average values are also recorded in December, and in the case of Italy, even in January.

Figure 9. The share of registered electric mopeds in 2019–2024 in selected European countries on a monthly basis (year = 100%)



Source: author based on ACEM data

It should be noted that the annual distribution of the registrations of electric mopeds in Europe refers to this type of vehicle, regardless of the type of drive. In order to determine the popularity of electric mopeds only, their share in the volume of registered mopeds was analysed and the largest monthly fluctuations in the share of e-mopeds were recorded in the southern countries of Italy and Spain. In the case of Italy, the largest share (approx. 50%) was recorded at the turn of 2019/2020, to remain at an average level of 20–25% in the following years, while for Spain, the highest share of approx. 60% was recorded in 2020 and in the spring of 2023. In the following months, a downward trend was visible, finishing at the end of 2024. For Belgium and the Netherlands, the trend in the share of electric mopeds in overall registrations is similar with an increase in 2019 is followed by a decrease in 2020, then by subsequent growth until 2022/2023. However, the second half of 2024 brings a clear drop. In France, an upward trend is visible from mid-2020 to mid-2022 (pandemic period) and then slightly less.

The noticeable decrease in the number and share of electric mopeds in some European countries is a consequence of the increasing popularity of electric bicycles and scooters. These vehicles are an important substitute for mopeds, due to the greater mobility associated with both smaller dimensions and lower costs of purchase and operation. At the same time, differences between these three types of vehicle are disappearing which has consequences in the introduced legal standards, equalising the conditions of use of all these three vehicles in road traffic in many European countries (Olayode et al., 2024).

In the case of electric motorcycles, their popularity among motorcyclists is much lower than in the case of mopeds due to the specificity of their operation. While mopeds are mainly used for everyday transportation, motorcycles are usually vehicles used for leisure and tourism (Dorocki, 2021).

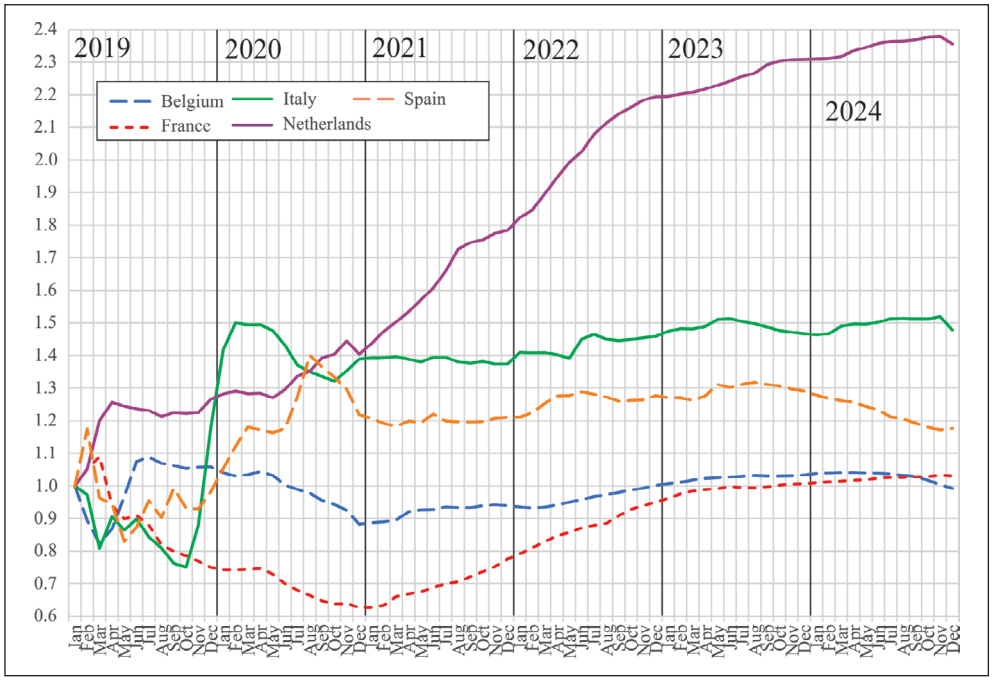
Analysing the multitude of electric motorcycle registrations in selected European countries (Great Britain, Germany, France, Italy, Spain), an increase between 2019 and 2022 can be observed.

Finalising the reflections on the dynamics of electric PTW development in Europe, the proportion of standardised cumulative monthly registrations of EVs relative to ICE vehicles for the years 2019–2024 was calculated, using January 2019 (100%) as the reference point. These values were calculated separately for mopeds and motorcycles for selected European countries. A value of 1 indicates that the monthly change for ICE vehicles and EVs is the same, values above 1 indicate a higher growth rate for electric vehicles, while values below 1 indicate a higher growth rate for ICE vehicles.

Comparing the values of the index developed for mopeds across different countries reveals significant differences in the trend between 2019 and 2024 (Figure 10). In the case of France, after an initial rapid increase in the registration of electric mopeds compared to those with ICEs in 2019, there was a noticeable decline (to approx. 0.6) by the end of 2020. From 2021, the value of the index increases to exceed the value of 1 in mid-2023. However, the increase in the number of electric mopeds was only slightly higher than that of ICE vehicles. A similar trend can be observed in Belgium where the decline began in mid-2019 and lasted until the end of 2020, reaching a value of 0.9. Then the value increases to reach the level of 1 in 2023. Similar to France, the growth rate of electric moped registrations was only slightly higher than that of ICE mopeds.

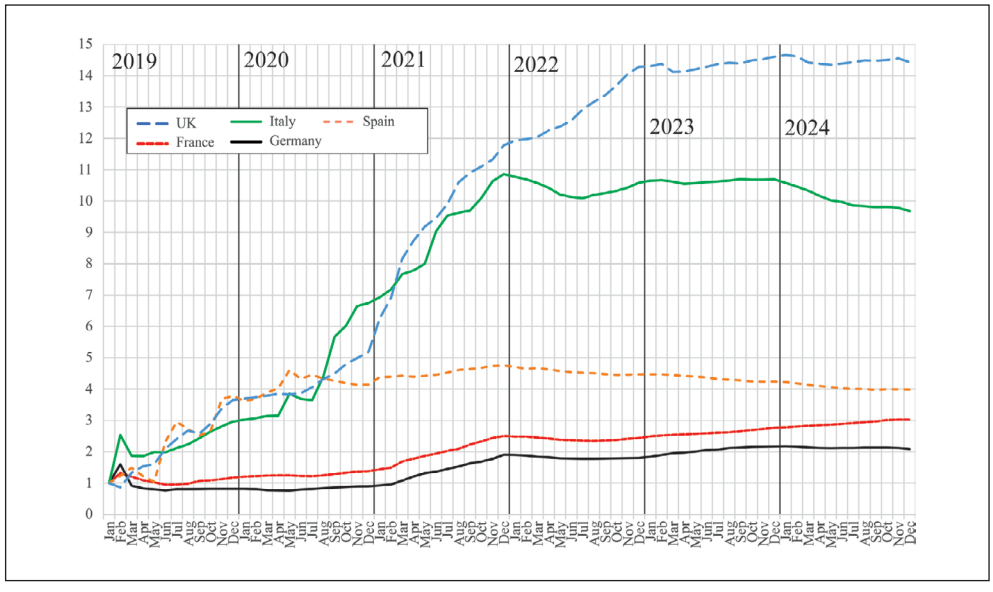
In the cases of Spain and Italy, after an initial decline in the index value in the second half of 2019, there was a rapid increase lasting until 2020, reaching a value of 1.5 in February for Italy and 1.4 in August for Spain. Then, after a slight decline, index values

Figure 10. Compounded monthly changes in the number of registered electric mopeds compared to registered ICE mopeds in selected European countries from 2019 to 2024



Source: author based on ACEM data

Figure 11. Change in the cumulative growth rate of registered electric motorcycles compared to registered ICE motorcycles in selected European countries from 2019 to 2024, presented on a monthly basis



Source: author based on ACEM data

remained above 1 over the following years, indicating a faster growth rate in the registration of electric mopeds compared to mopeds with an ICE. In 2024, a downward trend can be observed in Spain, while in Italy the index value oscillates around 1.5. On the other hand, in the case of the Netherlands, the increase in the registration of electric mopeds in relation to ICEs over the entire period under study was greater and increased, reaching approx. 2.38 in 2024.

Analysing the distribution of the rate of change in registrations of electric motorcycles compared to ICE motorcycles, the values were significantly higher than in the case of mopeds. The fastest increase in electric motorcycle registrations compared to those equipped with ICEs was recorded from autumn 2020 to December 2021 for Italy and the United Kingdom (Figure 11). In the following years, the value for Italy decreased from 11 to 10, and showing a further decreasing trend in 2024. In the United Kingdom, however, the index value increased from 12 to 14 and continued to show an upward trend in 2024. For Spain, until mid-2020, the index value kept increasing and was similar to that of Italy and the United Kingdom; however, in the following years, after a slight increase (approx. 5) it dropped to 4. In Germany and France, the index values had a very similar distribution and comparable growth, reaching a level of 2 for Germany and 3 for France in 2024.

Conclusions

Based on the analyses conducted, it should be concluded that in the last decade there has been a clear global increase in the popularity of electric PTW vehicles. This growth is observed in both developing and economically developed countries. The Southeast Asian region remains the main global market for electric mopeds and motorcycles, with China being the world leader in the development of electromobility. In Europe, the development of the e2w market is highly diverse and depends on government policies and support for the development of electromobility, as well as cultural conditions. An important factor influencing the popularity of EVs is also the presence of domestic manufacturers of electric motorcycles and mopeds. It should be noted that when analysing the development of the EV market, motorcycles and mopeds, which also include electric bicycles and scooters exceeding 25 km/h, must be considered separately. It is also important to recognize that the COVID-19 pandemic period had a strong impact on the automotive market. During the pandemic, there was an increase in interest in individual means of transport, a result of both fear of using public transport and a way to spend free time during the lockdown.

Referring to European countries, several factors can be identified that influence the growing popularity of electric motorcycles. First and foremost, it is government policies supporting electromobility, confirmed by studies analysing consumer behaviour in relation to the choice of EVs. Financial support for their purchase is provided not only by the state but also by manufacturers. Secondly, local conditions should be highlighted, particularly those related to residents' transportation culture and pro-environmental attitudes. Another important factor is the financial aspect, including the price difference between ICE and EVs, as well as their operating costs. The increasing variety of available vehicle models, along with new technological solutions that improve both travel comfort and the range that these vehicles can achieve, have also positively influenced their growing popularity. Finally, it should be emphasised that an important factor in the development of electromobility in a given country is the presence of domestic manufacturers of these vehicles on the internal market. This is also easily related to the accessibility of servicing

for these vehicles whikle favouring domestic brands is a common consumer trend observed in many countries.

It seems appropriate that further research on the changes in the electric PTW vehicle market should also include Eastern and Northern European countries, where PTW vehicle transport is not as popular as in Western Europe.

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