



University of Wales Saint David

Wales Institute of Science & Art

Sustainability Challenges in Industry

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1 INTRODUCTION

The motorcycle industry has long been an integral part of the automotive sector, contributing significantly to economic growth and culture identity. However, with increasing concerns about environmental sustainability, it becomes imperative to scrutinize the industry's practices and find solutions for a greener future.

The aim of this assignment is to study the environmental impact of the motorcycle industry and propose sustainable strategies and solutions that can be implemented for their future development.

Focus was given in analysing the environmental impact in motorcycle sector, identify the relevant sustainable practices and the associated legislations and study the sustainability and technological challenges the motorcycle industry is facing.

Lastly, prediction for the future outlook of motorcycle sector in terms of sustainability and propose sustainable strategies and solutions for its future development was made. The potential impacts and benefits of these strategies on different stakeholders, such as manufactures, governments and consumers were considered

2 ENVIROMENTAL IMPACTS

The transportation sector is the second-largest carbon-emitting industry. Presently, it accounts for over 20 % of the world's carbon emissions. A recent study revealed that it will experience a 1.7 % annual increase by the year 2030, due to the rising number of motor vehicles. (Pamidimukkala *et al.*, 2023)

Motorcycles have gained popularity worldwide because of their practicality and low fuel consumption, making them an effective mode of transportation in both large and small cities. As a result, the number of motorcycles in many countries have increase significantly. Figure 1 shows the fifteen countries with the highest percentage of households who own motorcycles.

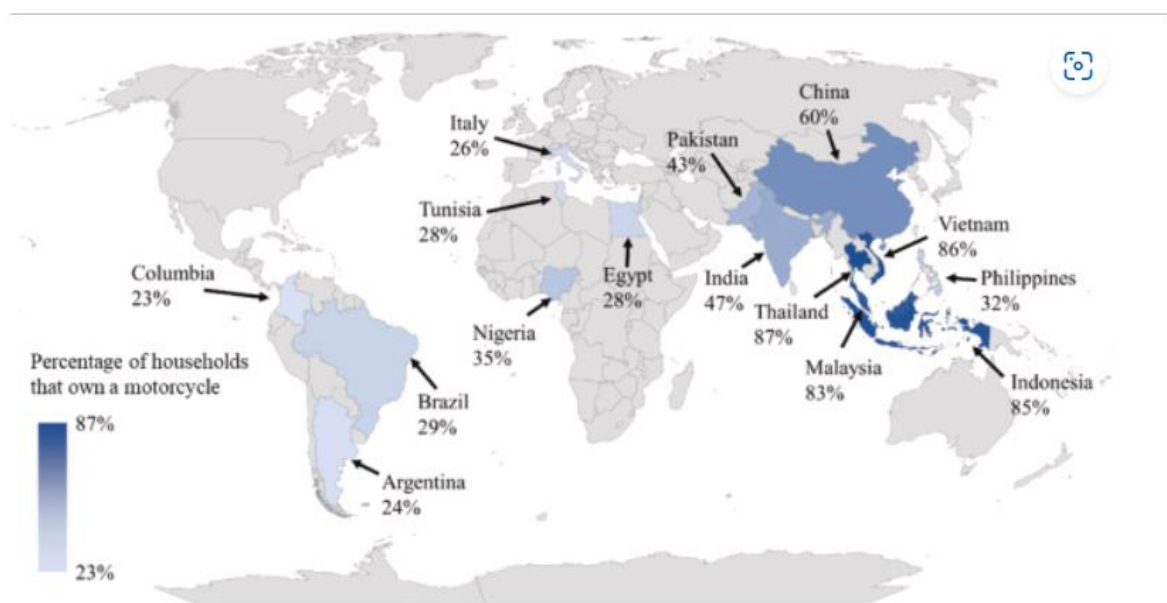


Figure 1 – Countries with the Highest Percentage of Households Owning Motorcycles in 2021 (Charoen-amornkitt *et al.*, 2023)

Motorcycle industries have important environmental impacts, affecting everything from air quality to resource consumption. The last decades it was observed a jumping increase of air pollution and climate change which was affected by greenhouse gas emissions from motorcycle, despite many policies were adopted from variety governments all over the world.

Air pollution is the combination of different substances in the air. When cars burn gasoline, they emit harmful pollutants. There are three important pollutants that come from vehicles: a mixture of solid particles and liquid droplets, the carbon monoxide (CO) and the Nitrogen dioxide (NO₂). When fuel burns, nitrogen and oxygen get in touch and form nitrogen oxides having the emissions from cars, trucks, buses, and off-road equipment. (Brinson and Guzman, 2021)

A study by (CitezenSustainable.com, 2024) related with gases emission for automobile and motorcycles showed that the motorcycle emitted considerable more pollutants than cars as shown in figure 2.

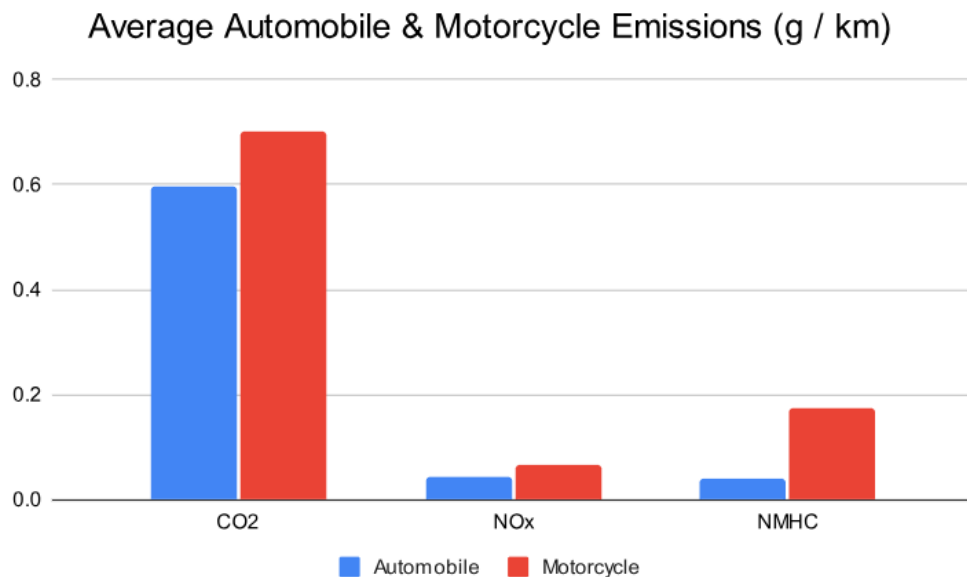


Figure 2 – Average Automobile & Motorcycle Emissions
(CitezenSustainable.com, 2024)

Motorcycles are more polluting than cars because they lack emission control devices like catalytic converters, which neutralize the toxic pollutants from the ICE into less harmful compounds. (Motorgearexpert.com, 2024)

A study by (Ivanova and Wieland, 2023) for tracing carbon footprints to intermediate industries in the United Kingdom is shown in figure 2. Electricity by fossil fuels has the highest share with 254 MtCO₂eq or 25% of the emissions as a source industry with the most of emissions (81%) come from the UK. Following the source industry of extraction and manufacturing of coal, petroleum, and gas with 114 MtCO₂eq or 11% of the UK gross production emissions. The emissions for Motor vehicles and other transport equipment are 4 MtCO₂eq. Other services like Machinery and equipment with 5 MtCO₂eq, metal products and related (4 MtCO₂eq) Electricity and distribution of electricity (4 MtCO₂eq), Metal products and related (4 MtCO₂eq). The Air transport services and jet fuel ranks fourth in terms of GHG emissions associated with UK gross production among the source industries with a total of 75 MtCO₂eq, 87% of which come from UK. (Ivanova and Wieland, 2023)

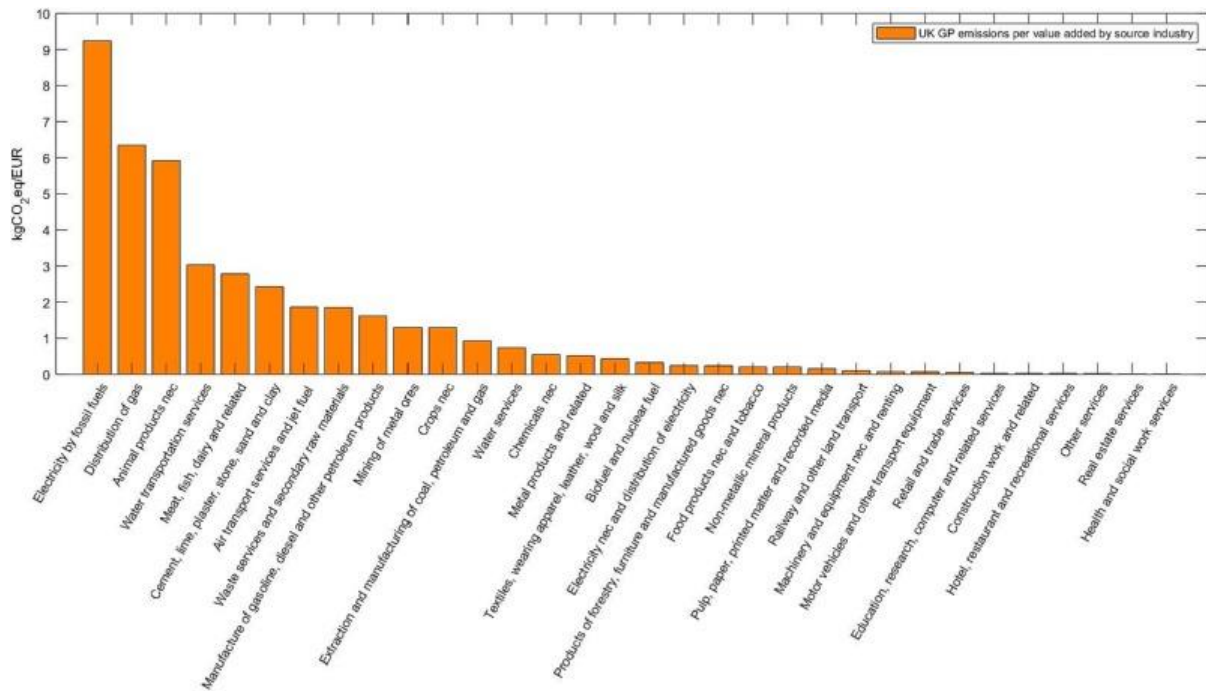


Figure 3– GHG emissions from UK gross production (Ivanova and Wieland, 2023)

Today's global society is dependent on minerals and metals despite mineral reserves are depleted with the passage of time. Up until now, the costs of production have primarily been externalised from the environmental effects of mining. (Ponomarenko, Nevskaya and Jonek-Kowalska, 2021) The mineral reserves like crude oil mineral resources is insufficient in quantity relative to demand. All must pay attention to how minerals may be used sustainably in the future to guarantee the continuation of the services they offer to society. (Prior *et al.*, 2012)

Motorcycles have finite lifespan. The wastes generated after the end of their life can be recycle, or reused or repurposed. Motorcycles are made from various materials that can be harmful for the environment like engine oil, fuel, coolant, brake, fluid, tire, metals and plastic and take decades to be decomposed. (Youmotorcycle.com, 2023) The industry causes about 5% of industrial waste in universe, and with increasing demand for electric vehicles, battery material consumption enlarge considerably. Recycling of these materials helps traders to address environmental warries and allows them to address the issue of resource depletion.(Technavio.com, 2015)

3 SUSTAINABLE PRACTICES AND LEGISLATIONS

Many sustainable practices and legislations are currently being implemented such as alternative fuels, electric and hybrid propulsion, recycling, and emission regulations. Steps should be taken by all stakeholders such as governing bodies, teams, manufacturers, and event organizers to become more responsible. (Senecal and Leach, 2021)

The European emissions legislation for motorcycles is based on Euro 5 standards starting from 2020 apply to sales of 2 and 3-wheel vehicles. (Euro 5, Regulation (EU) No 168/2013, No 134/2014, and 2019/129) This standard applies to category L vehicles: Powered cycles, Mopeds, Motorcycle, Motor Tricycles and Quadricycles.(transportpolicy.net, 2018)

Table 1 - Euro 5 Tailpipe Emission Limits After Cold Start (transportpolicy.net, 2018)

Euro 5 Tailpipe Emission Limits After Cold Start							
Vehicle Category	Vehicle category name	Propulsion class	CO (g/km)	THC (g/km)	NOx (g/km)	PM (g/km)	Test Cycle
L1Ae	Powered cycle	PI/CI/Hybrid	0.50	THC 0.10 NHMC 0.068	0.060	0.0045 [*]	Revised WMTC [†]
L1Be-L7e	All other L-category vehicles	PI/PI Hybrid	1.00		0.060	0.0045 [*]	Revised WMTC
		CI/CI Hybrid	0.50		0.060	0.0045	

Recycling and reuse legislations in EU about motorcycles are not included in End-of-Life Vehicles (ELV) Directive, although the European Commission is considering lumping them in with cars. So certain fluids and heavy metals are in targets of recycling and safe disposal by the End-of-Life Vehicles (ELV) Directive legislation. (britishmotorcyclists.co.uk, 2022)

Also, EU enact the “Fit for 55” climate ambition that contains a set of legislative proposal to achieve the 55% emission reduction target set by co-legislation for 2030 and the alternative fuel infrastructure regulation. The main objectives of the proposed legislation are to ensure sufficient network for recharging/refueling with alternative fuels, to provide alternative solutions and to achieve full interoperability throughout European Union. (consilium.europa.eu, 2023)

With the depletion of the energy resources, alternative fuels like compressed natural gas, LPG, methanol, ethanol or ethanol-gasoline fuel blends like E5, E15, E95, Hydrogen can be used for internal combustion engines (Bae and Kim, 2017) The use of Hydrogen even though has zero CO₂ emission it cannot be stored on adequate quantities on the vehicle especially on a motorcycle. E95 fuel blend can provide better fuel economy and also less CO₂ emissions but the current ICEs have to be redesigned to accept this fuel and also during winter there are

issues in starting the engines which are using this fuel. E5 and E15 fuel blends can be used in the present ICE engine offering fuel economy and reduction in CO₂ emissions.

The last years electric motorcycle and hybrid electric vehicles propulsion are more common. Electric hybrid motorcycles are used an electric motor to supplement a gasoline motor. They have more efficient engines and lower running cost that controversial motorcycles. They also produced fewer emissions and are more eco-friendly and economic. (progressive.com, 2024), (transportpolicy.net, 2018) Models of hybrid monocytes as Kawasaki Hybrid Motorcycle, Honda PCX Hybrid Motorcycle, Piaggio Hybrid Motorcycle Scooter, and Logo Silent Hawk Hybrid Motorcycle. (letgoforaride.com, 2022)

Good practises are adopted from many industries. A sustainable one is used by manufactures of Formula 1 and Moto GP work by developing sustainable fuels of 40% non-fossil origin this decade. From 2007, fully 100% sustainable solutions are used from World Championship. The fuels are made in a lab using materials from carbon capture systems, municipal waste, and non-food biomass. (motosport.com, 2021)

The recycling and the reuse of old motorcycles can become a hobby of a lot of motorcyclists. Over six million vehicles in Europe are reach the end of their life every year and cause problems in the environment. Although the recycling numbers of materials from ELVs are normally high, the scrap metals processed are of low quality and very few amounts of plastic are recycled. It also prohibits avoiding using risky or dangerous substances when manufacturing new vehicles (especially lead, mercury, cadmium, and hexavalent chromium).(Maury *et al.*, 2023)

A successful case for minimize the gas emissions in China is the usage of a county-level emission inventory. As China is the pioneer in manufacturing electric motorcycle, data show that the emissions of VOC and IVOC from motorcycles have mitigation, from 2536.48 Gg and 197.19 Gg in 2006 to 594.21 Gg and 12.66 Gg in 2020.(Zhang *et al.*, 2024)

The quantity of lithium-ion batteries (LIBs) in their "end of life" (EoL) will increase significantly over the years as the market for electric vehicles becomes more popular and latest ideas for recycling are needed. The scrap process in battery production will try to apply stronger recycling policies in the future and this might contribute negatively in the LCA of EV. (startup-energy.org, 2021)

Life Cycle Assessment (LCA)

Fundamentals

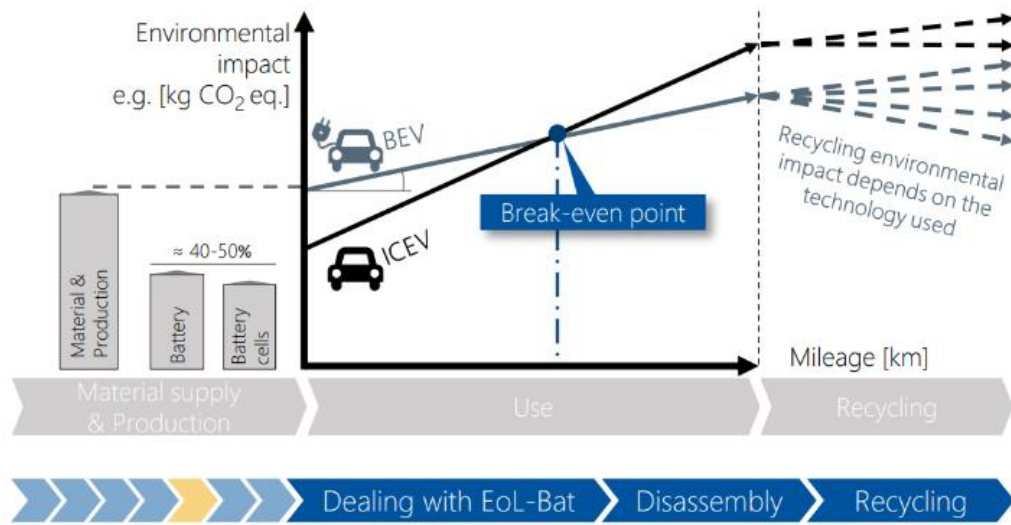


Figure 4 – Life Cycle Assessment (LCA) (startup-energy.org, 2021)

4 SUSTAINABLE AND TECHNOLOGICAL CHALLENGES

Many technological challenges and barriers are faced by the motorcycle sector and must develop strategies and technologies to overcome the barriers to sustainable industries.

Regarding the environmental footprint of vehicles industry are needed more responsible practices. Given that vehicle emissions constitute a substantial portion of greenhouse gas emissions, automakers face force to embrace cleaner technologies and reduce their carbon footprints. (Lin, 2023) Electric motorcycles are a feasible eco-friendly substitute that enable a smooth transportation system with low emissions beside the conventional motorcycles.

The technological challenge become clear by the increasing of use electro-mobility solutions in conjunction with other technological systems like energy storage, renewable energy sources like solar, wind, and geothermal, photovoltaic (PV) panels, and others that can help reduce CO₂ emissions at the district level.(Pignatta and Balazadeh, 2022) Other researchers support the role of alternative fuels such electricity, alcohol, and hydrogen fuel cells, as well as advanced cumulative and oils in environmentally sustainable transport. (Folkson and Sapsford, 2022)

To identify the barriers preventing the purchase of electric car or electric/hybrid motorcycle in a study based in a literature view, it is presented a list of 17 barriers about EVs adoption. There are categorized into technological, environmental, financial, and infrastructure barriers. In technological category are referred the limited driving range, the long charging time, the limited battery life, the poor safety, the doubts about reliability and the quantity of EV models as there are fewer. In environmental category are mentioned problems in battery disposal and environmental effects of battery production. In economic category are pointed out the high purchase price, the high battery replacement cost, the high electricity price for charging and the cost of electrical system adaption at home. In infrastructure category underline the insufficient public charging station, charging problem in the absence of a garage or support centers and facilities for EV maintenance and low reliability of charging power grid. Furthermore, there are few mechanics who are proficient in EV maintenance. (Pamidimukkala *et al.*, 2023)

One challenge is the implementation of lightweight and sustainable materials and related innovations design for the development of modern structural components and vehicles for transportation. Advanced production sectors that make structural components are focusing on replacing heavy materials, with lighter ones, such as lightweight alloys, polymers, and composites. Lightweight alloys and composites make it possible to meet weight-reduction requirements for structural components. (Jagadeesh *et al.*, 2023)

Another challenge is the thermoelectric generators which can recover and produce energy from wasted energy in exhaust. Thermoelectric generators are solid-state energy conversion devices that convert thermal energy directly into electric energy. Among their advantages are their small volume, compact structure, silent operation, lack of vibration, lack of moving parts and low maintenance cost. (Zhao *et al.*, 2024)

Furthermore, there is the kinetic energy recovery system (KERS) which is utilized to capture the kinetic energy generated during the application of brakes to a moving vehicle. The recovered energy can be stored in a flywheel or battery and used later to help boost acceleration. Kinetic energy recovery system helps transform what was formerly wasted energy into useful energy. (sae.org, 2013)

The sustainability of motorcycle industries is depended on the economic factor, so several governments have implemented measures to encourage the adoption of electric vehicles, including tax exemptions, purchase subsidies, and other economic incentives. (Bonisoli, Velepucha Cruz and Rogel Elizalde, 2024)

Besides, is promoted a circular economy (CE) offers like various strategies to reduce consumption and demand of natural resources as well as additional secondary benefits that serve to achieve sustainability targets. (Prochatzki *et al.*, 2023) The policies of every country regulate the smooth operation of global plans about environment, recycling, reusing, manufacturing, resources, sales, maintenance and etc.

The technological challenges interrelated and connected with other factors such economic, social and political factors. The electric mobility plays a crucial role in the world economy, contributing significantly to economic expansion and creating many job opportunities. Socially, as many stakeholders are involved to the supply chain. Notably, major auto manufacturers teamed up in global collaborations with plentiful suppliers, encompassing the sourcing of components, materials, and technologies, thereby emphasizing the complicated interdependence characterizing these stakeholders. The concept of adopting Corporate Social Responsibility (CSR) practices is a transformative paradigm that has emerged and goes beyond profit maximization. (Lin, 2023)

Governments and motorcycle sector would need to act together with singular agreement extended their planning and investment horizons even as they take immediate actions to manage risks and capture opportunities.

5 FUTURE OUTLOOK

The global electric motorcycle makers are valued at USD 30.11 billion in 2023 and is expected in future to grow at a compound annual growth rate (GAGR) of 19,0% between 2023 and 2030.

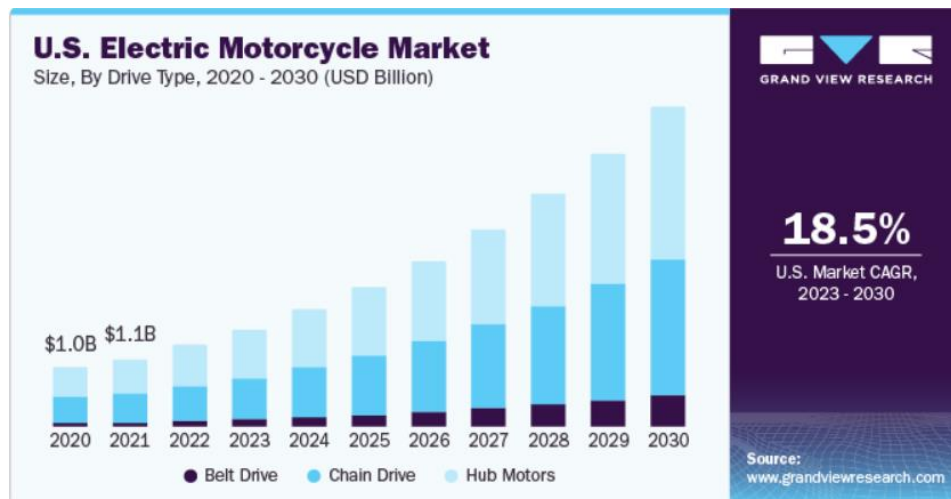


Figure 5 - US Electric Motorcycle Market (grandviewresearch.com, 2022)

The motorcycle market is expected to grow as demand for energy-efficient commuting opinion rises. Furthermore, an increasing interest among the electric motorcycle established two-wheeler stakeholders in offering technologically advanced vehicles, contribute to market growth. (grandviewresearch.com, 2022)

Governments and cities have introduced regulations and incentives to support the decarbonization of road transport. From one hand, the European Commission has proposed a target to reduce the average CO2 emissions of new vehicles by 55 percent by 2030 and from the other, the USA federal government has proposed that zero-emission vehicles constitute half of all new passenger. Several countries have also proposed timelines for the prohibition of the sale of new vehicles equipped with internal combustion engines (ICEs). (Hannon, Krishnan and Sahdev, 2022)

They must strictly implement the legislations are announced such as the End-of-Life Vehicles Directive, the Car Labelling Directive, the EU type-approval system and the CO2 emission performance standards for new passenger and light commercial vehicles.(Schöggl *et al.*, 2024) and Euro 5, regulation about motorcycle mobility.

The NGFS Net Zero 2050 scenario entails a transformation of energy and land-use systems. (2 of 2)

Not exhaustive

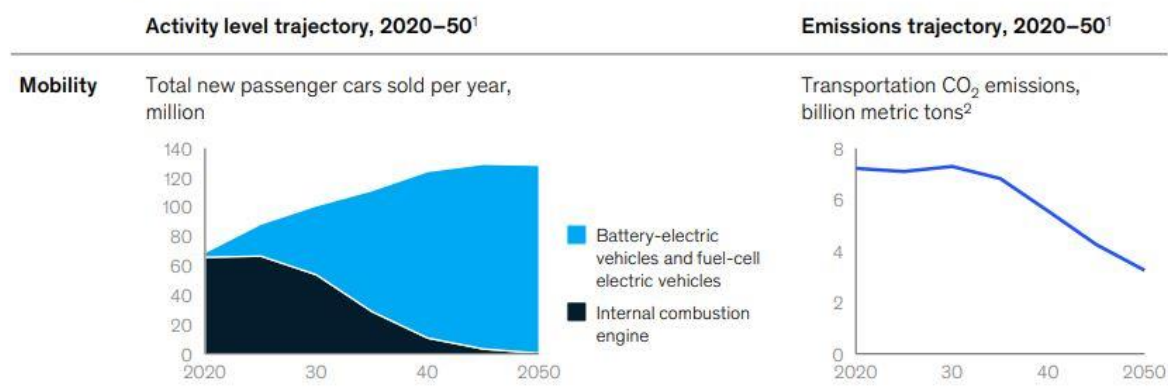


Figure 6 –The NGFS Net Zero 2050 scenario (Hannon, Krishnan and Sahdev, 2022)

The potential impacts and benefits of implemented strategies in motorcycle and generally in all vehicle sectors have great impacts in growing industries.

Firstly, all investors of motorcycle sector must acquire environmental sensibility and culture about the environmental impacts of controversial motorcycles. The enthusiasm of consumers for electric motorcycles must be maximized in the future if the barriers are minimized and advantages must be maximized. Sustainable strategies and solutions must be developed in the future.

Secondly, governments have the potential to implement recovering techniques for used batteries to attract environmentally sensitive consumers to mistrust electric vehicles. (Pamidimukkala *et al.*, 2023) For example, The BASF, through chemistry, can focus on developing high-performance battery materials that will help the rise of electric vehicles and contribute to cleaner air. (automotive-transportation.basf.com, 2024)

Besides, the policymaker can devise a beneficial policy to enhance electric hybrid vehicles sales by introducing tax deductions and other supportive incentives to mitigate the cost of EV road tax. Programs must apply for purchase subsidies for electric vehicles and subsidized batteries replacement. They must give prioritize to comprehensive public education on electric vehicles and especially in motorcycle and educate experts in maintenance of electric vehicles.(Pamidimukkala *et al.*, 2023)

Moreover, manufactures must use the new product development method to enforce the circular economy in automotive sector by designing and producing functional and durable products that can be reused, repaired, and recycled, reducing the waste generation. (Prochatzki *et al.*, 2023) In the future, it is expected that the use of renewable raw materials

and recycled materials will continue and clear elements made of renewable materials will be found more frequently. (Wellbrock *et al.*, 2020)

The transition to EVs presents both opportunities and challenges that will balance in the recent future and recent technological advancements will be critical for a sustainable motorcycle industry.

6 CONCLUSIONS

In conclusion, the motorcycle industry stands at a crossroads where sustainability and technological innovation must go hand in hand. The new technological changes focus their efforts on creating motorcycles with lower emissions, achieved through various means such as utilizing alternative fuels, designing more efficient engines, employing lightweight materials for construction, adopting tires that reduce fuel consumption, and integrating energy recovery systems. The production of electric motorcycles and the use of Kinetic Energy Recovery Systems, especially when powered by renewable energy sources, make electric motorcycles more environmentally friendly. Incorporating recycled materials in motorcycle production, contribute positively in LCA of motorcycles.

With fuel prices rising, the environmental impacts of Internal Combustion Engine (ICE) vehicles, limited parking spaces—especially in big cities—and noise pollution from ICEs, the production of electric motorcycles, especially for short distances, holds promise. The production of such motorcycles has good future potential.

Hydrogen as an alternative fuel presents a viable option, provided it can be safely utilized in vehicles and technological challenges are overcome, without increasing CO₂ emissions during its production compared to potential savings during its use. If this can be achieved economically, it is conceivable that by 2050, ICEs might not be phased out entirely, and a new "global industrial revolution" centered around sustainable transportation may emerge.

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