# *HOW MUCH DO E-SCOOTERS REALLY COST? LIFE CYCLE ENVIRONMENTAL AND COST COMPARISON OF SCOOTERS IN TAIWAN*

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## Overview

The 2015 Paris Agreement commits countries to limit the global average temperature rise to well below 2 °C above pre-industrial levels and achieve carbon neutrality between 2050 and 2100. The transport sector accounts for around one-fourth of the global $CO_2$ emissions, and road transport is responsible for three-quarters of transport emissions[1]. Thus, to achieve the climate goals, the ground transportation sector across the globe is a must to be decarbonized—including Taiwan. In Taiwan, about 14% of all carbon emissions are from transportation, and almost all of them were from road transportation[2]. With nearly 612 scooters per 1000 populations, the Taiwanese government set various regulations to limit the emissions from scooters. For example, all scooters produced after 2021 must conform to Phase 7 Emission Standard (similar to Euro 5). Moreover, the government has provided financial incentives since 2016 to encourage people to retire their old, high-emitting scooters and switch to cleaner ones—including electric scooters (e-scooters).

Nowadays, electric vehicles (EVs) are considered as an alternative for global climate change mitigation and local air pollution reduction. Nevertheless, EVs market growth is impeded by their high purchase costs and lifetime carbon footprint advantages are still unclear. Since vehicles (including scooters) can be used in the long term and their emissions are not only from the vehicle operation, their price tags and zero tailpipe emissions only tell part of the story. In Taiwan, it remains questionable whether e-scooters are indeed more costly, especially considering their carbon emission reduction potentials, compared to conventional internal combustion engine scooters (ICE scooters). Thus, total cost of ownership (TCO) and life cycle analysis (LCA) analyses are conducted to evaluate the costs and carbon intensities of 156 scooters (35 battery swapping, 12 battery charging, 64 Phase 6 and 45 Phase 7 gasoline scooter models) on Taiwan's market today. For further detailed analysis, we separate out lightweight e-scooter models (similar to 50c.c. gasoline-powered scooter). Moreover, this study also develops an interactive tool to help the public and decision-makers better understand "How much do e-scooters really cost?" The study scope includes gasoline-powered scooters complying with Phase 6 and Phase 7 emission standards as well as e-scooters charged by battery swapping and battery charging. The interactive online tool can be found here: https://how-much-e-scooter.netlify.app/

## Methods

**Life Cycle Analysis (LCA).** The system boundary of this study includes vehicle manufacturing, upstream fuel production as well as vehicle operation. We derive the carbon emissions from the scooter and battery manufacturing based on the published literature[3,4], which are 2.2290 kgCO2eq/kg for e-scooter, 2.4988 kgCO2eq/kg for gasoline-powered scooter, and 10.3994 kgCO2eq/kg for battery production. Regarding the upstream fuel production stage, we obtain the emissions from gasoline production and carbon intensity of electricity generation from Carbon Footprint Information Platform[5] and the Bureau of Energy[6]. Carbon emissions from gasoline use (i.e., gasoline vehicle operation stage) for different vehicle models are taken from Eco-friendly Vehicle Guide Platform[7].

**Total Cost of Ownership (TCO).** TCO refers to the costs incurred during vehicle lifespan, including vehicle purchase cost, fuel costs, and non-fuel operating and maintenance costs. Most of the data and technical parameters are obtained from the government's statistics and automotive manufacturers. Noted that 1) the impacts of the government subsidies for e-scooter purchases are explored in the study; 2) the fuel costs (or charging costs) of e-scooters with swappable batteries depend on the riding plans that customers subscribe[8]; 3) the discount rate of 6% and the depreciation rate of 25% per year are chosen.

## Results

As shown in Figure 1(a), the lifecycle carbon footprints and ownership costs of the scooters in Taiwan differ from one to another. Within the same powertrain technology, lower emissions are generally corresponding to lower costs. Moreover, due to the much higher fuel costs (i.e., recharging/swapping), the TCO of unsubsidized e-scooters are mostly greater than that of gasoline-powered counterparts (Figure 2(a)). But with the purchase subsidies, e-scooters become more TCO attractive (Figure 2(b)). In addition, within battery powertrain technology, ones with charging mode are usually less costly compared to those with battery swapping mode.

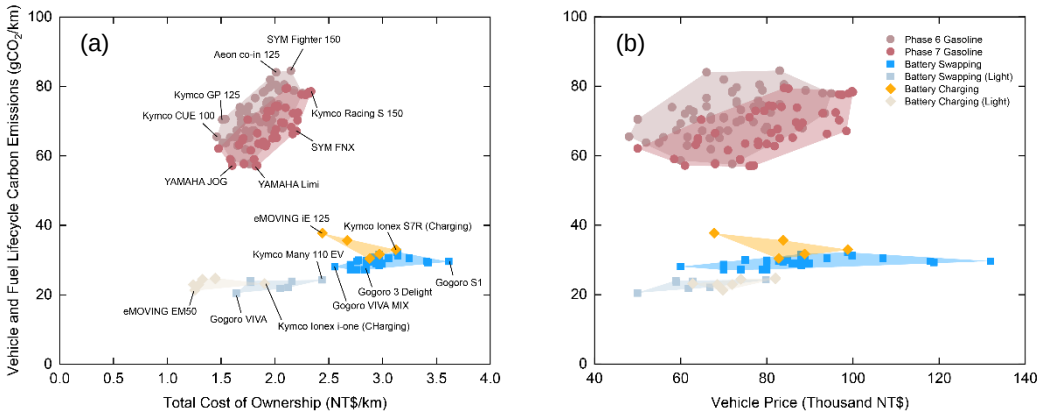


**Figure 1. (a) TCO to Life Cycle GHG emissions plot for scooters in Taiwan; (b) Vehicle price only.**

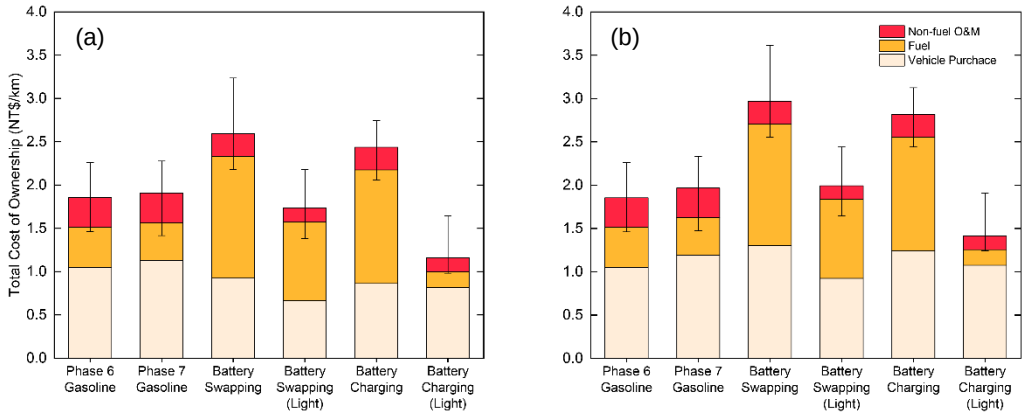


**Figure 2. TCO breakdown (a) with subsidies and (b) without subsidies.**

## Conclusions

This study presents the diversity of customer ownership costs and carbon emissions across the scooter market in Taiwan. The subsidized e-scooters are currently more costly than the gasoline ones, but these incremental costs are expected to fluctuate in the following decade when the battery costs drop and the subsidies are phased out. On the other hand, the lifecycle emissions of e-scooters will keep decreasing with the expansion of renewable energy. These temporal variations in TCO competitiveness and carbon emission mitigation potentials out to 2030 are being examined. The research findings and the developed interactive tool will be used to inform policy and decision making about potential trade-offs, facilitating the smooth transition from fossil fuels to electrification. Besides, although the e-scooter battery-swapping ecosystem is less TCO attractive, its market share has been greater than e-scooters with charging mode. This highlights the fact that TCO is not the only factor affecting consumer adoption; other determinant factors include charging convenience and consumer familiarity also play an important role—which should be taken into account when the government designs the vehicle electrification policies.

## References

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