BRIEFING

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Fuel consumption standards for the new two-wheeler fleet in India

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Two-wheelers constituted more than 80% of total vehicle sales in India in fiscal year (FY) 2020–21.[1] Predominantly powered by internal combustion engines (ICE), they also accounted for 60% of India's petrol consumption, and for the calendar year 2020, tailpipe carbon dioxide (CO_2) emissions from the two-wheeler segment have been estimated at nearly 38 megatonnes.[2] Currently, the two-wheeler segment is not subject to any fuel consumption standards, and fleet average CO_2 emissions were 41.2 gCO_2/km in FY 2018–19.[3] A variety of technologies for reducing CO_2 emissions from new two-wheelers are available, and these include fuel efficiency improvements for combustion engines and electric two-wheelers.

Prior to Bharat Stage (BS) VI emission norms, which have been in effect since April 1, 2020, ICE two-wheelers were equipped with obsolete carburetor-based engines that left little room for adoption of modern fuel-saving technologies. Post BS VI, however, there has been a shift to fuel injection that brings with it the opportunity to adopt several modern ICE technologies from the passenger car. It seems natural that these technologies could also be applied in two-wheelers, limited only by cost-bracket considerations and vehicle size. These incremental technologies can unlock opportunities for significant efficiency benefits, and as this briefing will demonstrate, setting corporate average fuel consumption standards for the new two-wheeler fleet would be an effective way to spur the adoption of modern ICE technologies and accelerate the electrification of the fleet. This is also important from a greenhouse gas (GHG) emissions perspective, as tailpipe CO_2 emissions alone from India's two-wheeler fleet are projected to grow substantially between 2020 and 2050 under a business-as-usual scenario (BAU) in which electric two-wheelers remain a negligible presence in the fleet.[4]

1 Society of Indian Automobile Manufacturers, "Automobile Domestic Trends," accessed July 2021, https://www.siam.in/statistics.aspx?mpgid=8&pgidtrail=14.
2 1 megatonne is equivalent to 1 million (10^6) tonnes.
3 Based on SIAM declared fuel economy value (in kilometers per liter) for FY 2018–19. The fuel consumption mentioned in this briefing corresponds to the fuel economy value converted to liters per 100 kilometers. The CO_2 emissions in grams per kilometer corresponds to the value calculated using fuel consumption and the emission factor used in passenger vehicle fuel efficiency standards.
4 Gaurav Bansal and Anup Bandivadekar, *Overview of India's vehicle emissions control program,* (ICCT: Washington, DC, 2013), https://theicct.org/sites/default/files/publications/ICCT_IndiaRetrospective_2013.pdf

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In a recent white paper, we presented results of our evaluation of the fuel consumption reduction potential of ICE two-wheelers in three market segments: small motorcycles with engine displacement less than 150 cc; large motorcycles with engine displacement more than 150 cc; and scooters with engine displacement less than 150 cc.[5] We also identified the percentage of ICE technologies which can be combined in the fleet with electric two-wheelers in order to reach a particular CO_2 emission level, and considered the associated compliance costs.

This briefing shows the likely benefits of implementing stringent fuel consumption standards in terms of the reduction in the petroleum consumption of the fleet and GHG emissions reductions. We also present feasible levels of stringency for fuel consumption standards.

POTENTIAL PETROLEUM CONSUMPTION AND GHG EMISSIONS REDUCTIONS

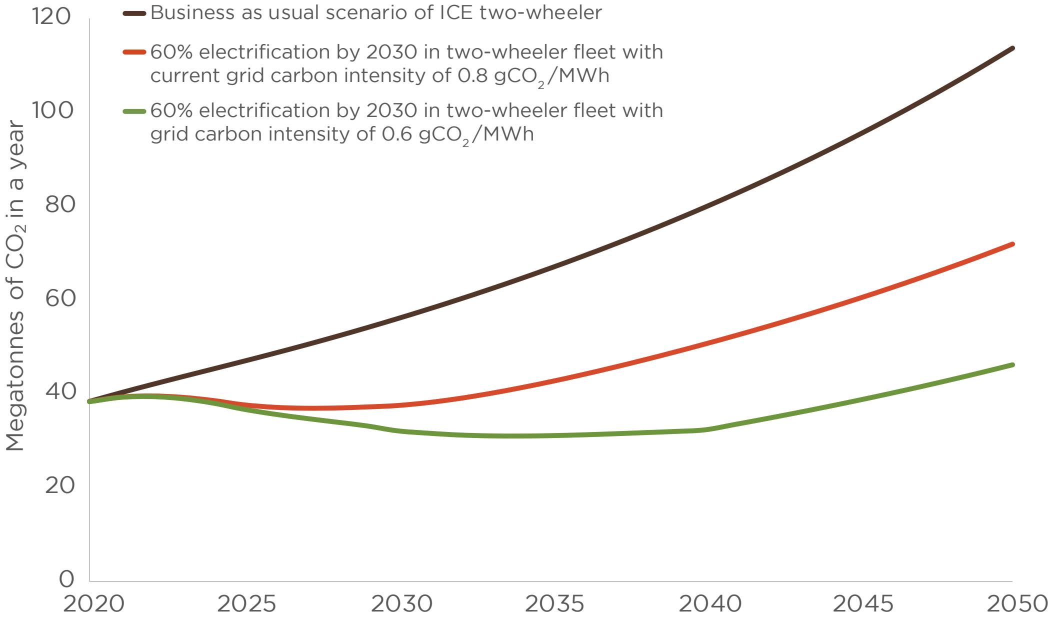


Figure 1. Tailpipe emissions reductions from two-wheelers with 60% penetration of electric vehicles in the fleet by 2030.

Figure 1 was created from the India Emissions Model (IEM), which was developed by ICCT and estimates two-wheeler sales growth based on the vehicle kilometers traveled by two-wheelers.[6] Without any efforts to reduce fuel consumption levels, which is a BAU scenario with only a negligible amount of electric two-wheelers sold, tailpipe CO_2 emissions from the fleet grow to 56 megatonnes by 2030. With 60% electric two-wheeler penetration[7] by 2030, meanwhile, that CO_2 emissions level can be brought down by nearly 42% (~32 megatonnes) in 2030. Cumulatively, the reduction is nearly 117 megatonnes of CO_2 by 2030 and approximately 487 megatonnes of CO_2 by 2040.

5 Sunitha Anup, Ashok Deo, and Anup Bandivadekar, *Fuel consumption reduction technologies for the two-wheeler fleet in India,* (ICCT: Washington, DC, 2021), https://theicct.org/publications/2w-fuel-reduction-india-mar2021
6 Bansal and Bandivadekar, *Overview of India's vehicle emissions control program.*
7 The assumption of Indian grid carbon intensity is 170.3 gCO_2/MJ in 2020, 94.2 gCO_2/MJ in 2030, and 23.3 gCO_2/MJ in 2040 for cleaner grid.

In terms of fuel savings, the benefit of 60% electrification in the two-wheeler segment by 2030 can be estimated as reduction of nearly 10 million tonnes of oil equivalent (Mtoe[8]) in the year 2030 and approximately 16 Mtoe in the year 2040. Cumulatively, avoided petroleum consumption reaches nearly 49 Mtoe by 2030 and approximately 187 Mtoe by 2040. Based on the current gasoline retail price of INR 100 per liter (US$1.34), this translates into fuel savings of nearly US$75 billion by 2030 and nearly US$284 billion by 2040.

To measure more than just the fuel consumed in the vehicle and the resultant tailpipe CO_2 emissions, life-cycle analysis (LCA) is a tool that examines the emissions associated with the vehicle across its lifetime, including the emissions of producing the batteries and the rest of the vehicle, of the fuel and electricity production (well-to-tank, WTT), and of the consumption of these fuels in the vehicle (tank-to-wheel, TTW). In addition to CO_2, we conducted an LCA for two-wheelers in India that includes methane (CH_4) and nitrous oxide (N_2O). These are mostly translated into grams of CO_2 equivalent ($gCO_{2\ eq.}$) based on their 100-year global warming potential (GWP). The contribution of methane to global warming, however, is more than other GHGs in the first 20 years after emission and thus this LCA considers the 20-year global warming potential for methane.

Table 1 summarizes the life-cycle GHG emissions of two-wheelers with electric and ICE powertrains for vehicles registered in India in FY 2020–21.[9] It considers the Intergovernmental Panel on Climate Change's (IPCC) life-cycle GHG emission factors of the different electricity generation technologies and reflects the projected improvement of the electricity mix in India according to the International Energy Agency's (IEA) Stated Policy Scenario, which includes transmission and distribution losses in the electricity grid. While the ICE motorcycle and scooter correspond to the market average in FY 2020–21, the electric models are represented depending on various battery capacities available in the current market. For motorcycles, notice that

Table 1. Life-cycle GHG emissions of gasoline and electric-two wheelers registered in India in 2021

Type	ICE small motorcycle (97.2 cc)	Electric motorcycle (3.5 kWh)	Electric motorcycle (2.7 kWh)	ICE scooter (109.5 cc)	Electric scooter (2.9 kWh)
Well-to-tank g $CO_{2\ eq.}$/km	11.0	28.7	21.7	12.8	31.7
Tank-to-wheel g CO_2 eq./km	38.3	0.0	0.0	43.4	0.0
Vehicle production g CO_2 eq./km	4.9	5.0	3.9	4.7	4.2
Battery production g CO_2 eq./km	0.0	2.0	1.6	0.0	1.7
Total g CO_2 eq./km	54.2	35.7	27.1	60.9	37.5
Life-cycle GHG savings compared to ICE	—	34.1%	50.0%	—	38.4%

8 The tonne of oil equivalent is a unit of energy defined as the amount of energy released by burning one tonne of crude oil. Mtoe is the acronym, and it stands for million (or mega) tonnes of oil equivalent. In this briefing, the prefix mega is used to denote the factor of one million quantity of CO_2 emissions and Mtoe is used to denote the factor of one million quantity of fuel consumed.

9 The GHG emissions corresponding to the production and recycling of the vehicles are based on carbon intensity of 5.2 kg CO_2 eq. per kg and vehicle curb weights of 108–130 kg. For the electric vehicles, the GHG emissions of the production of the batteries is considered with a carbon intensity of 69 kg $CO_{2\ eq.}$ per kWh battery capacity. These emissions are spread over a vehicle lifetime mileage of 120,000 km. In the fuel cycle, a fuel consumption of 1.8 L/100 km and 2.2 L/100 km are considered for the gasoline-powered motorcycle and the scooter, while for the electric motorcycle and scooter an electricity consumption of 4.1 kWh/100 km and 3.7 kWh/100 km are considered. For the fuel mix, the WTT carbon intensity of 0.64 kg CO_2 eq./L and TTW carbon intensity of 2.17 g CO_2 eq./L consider an increase of the molasses and cellulosic ethanol share from 5% in 2021 to 12% in 2032. The WTT emissions of the electricity production are considered as 767 g CO_2 eq./kWh. Find the methodology and data sources in Georg Bieker, *A global comparison of life-cycle greenhouse gas emissions of combustion engine and electric passenger cars,* (ICCT: Berlin, Germany, 2021), https://theicct.org/publications/global-LCA-passenger-cars-Jul2021

the electric variant with a battery capacity of 3.5 kWh has nearly 34% lower life-cycle GHG emissions than comparable combustion engine vehicles, and the variant with battery capacity of 2.7 kWh has 50% lower emissions. The electric scooter corresponds to nearly 38% lower life-cycle GHG emissions than the ICE models.

LEVELS OF CORPORATE AVERAGE FUEL CONSUMPTION STANDARDS FOR 2025 AND 2030

Corporate average fuel consumption standards would be effective for India's two-wheeler fleet. For any particular level of fleet average gCO_2/km that would be set, manufacturers can comply by adopting various ICE technologies or increasing the market share of electric two-wheelers, or some combination of the two strategies. To help identify feasible and cost-effective levels for a potential standard, we assume that the basic market composition in terms of share of motorcycles and scooters remains the same in India going forward. Based on that, the sales weighted gCO_2/km of an ICE two-wheeler and electric two-wheeler are estimated,[10] and Figure 2 shows the possible values of fleet average CO_2 emission standards for different choices of ICE CO_2 reduction percentages and electric two-wheeler sales percentages. As illustrated, for a fleet average CO_2 target set at 25.3 gCO_2/km, the compliance curve spans from 0% electric two-wheelers on one end, meaning that manufacturers could meet this standard solely by improving the fuel economy of the ICE vehicles, to slightly more than 45% electric two-wheelers penetration on the other end, which means this amount of electric two-wheelers market share can meet the target without any improvements to the ICE two-wheelers.

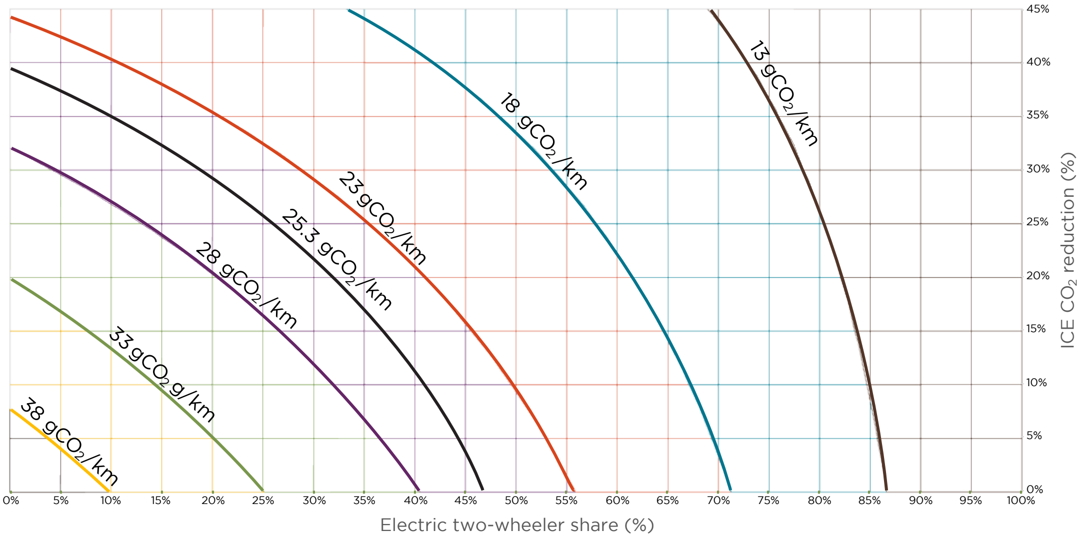


Figure 2. Representation of the new vehicle fleet average gCO_2/km for 2025 that can be achieved by choosing ICE efficiency improvement and/or electric two-wheelers with no multiplier.

10 The current market share of small motorcycles is 60%, scooters are 30%, and large motorcycles are 10%. The fleet average of the ICE two-wheeler is based on the fuel consumption level of FY 2018–19, 41.2 gCO_2/km. The weighted average gCO_2/km of electric two-wheelers is estimated from the electrical energy consumption in kWh/km of a motorcycle/scooter. Electric two-wheelers are not considered in the large motorcycle segment at this time.

As seen from Figure 2, the boundary curve (black in color) corresponding to 25.3 gCO_2/km represents the choices in achieving the fleet average target of 25.3 gCO_2/km. However, our prior analysis showed that going for ICE fuel efficiency improvement beyond 23% improvement will prove costlier, and thus beyond this threshold of 23%, it is cost effective to increase the market share of electric two-wheelers. The cost-effective combination of electric two-wheeler market share and ICE two-wheelers which have adopted 23% fuel efficiency improvement are shown in Figure 3 for two plausible levels of fleet average gCO_2/km, for 2025 on the left and 2030 on the right.

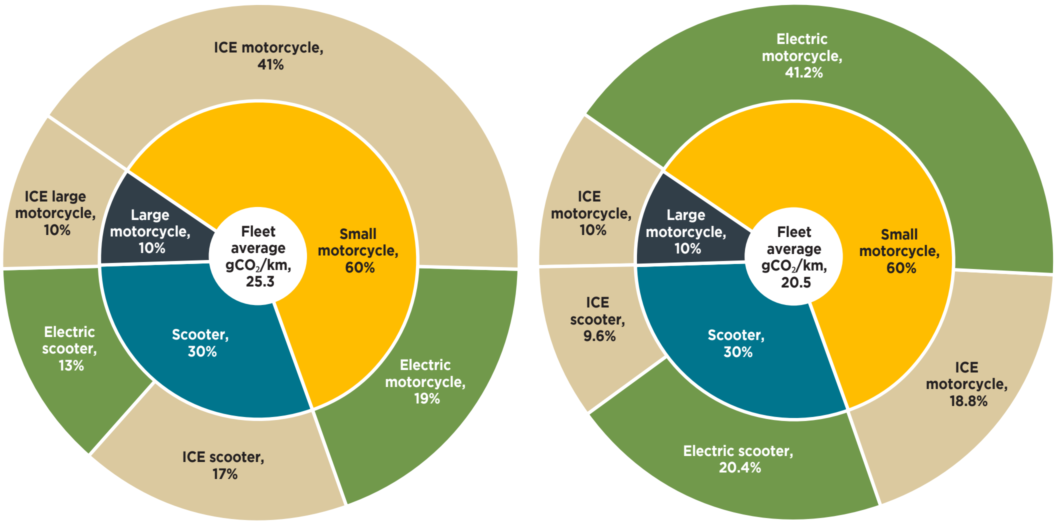


Figure 3. Electric and ICE two-wheeler penetration percentage in the new vehicle fleet to achieve the fuel consumption level of (a) 25.3 gCO_2/km for 2025 and (b) 20.5 gCO_2/km for 2030.

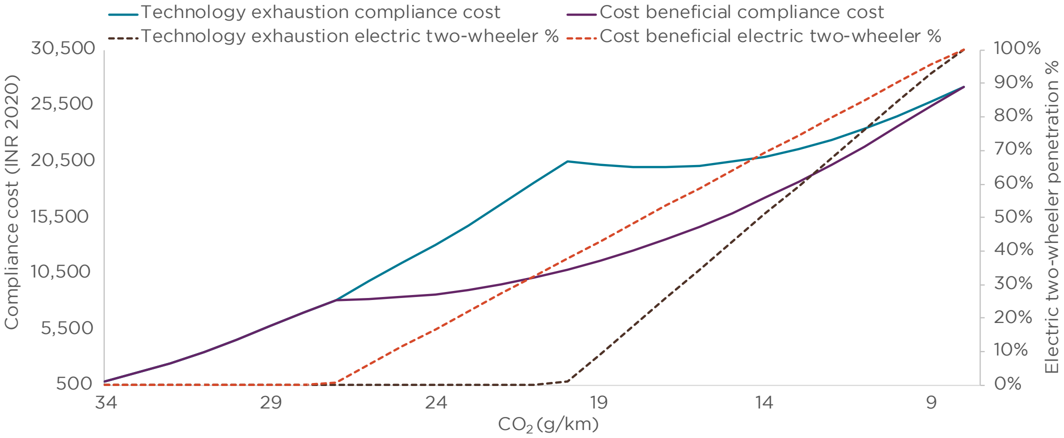
When the market share of electric two-wheelers in the fleet is 19% of electric motorcycles and 13% electric scooters (this adds up to 32% electric two-wheelers in the fleet), the fleet average fuel consumption level is 25.3 gCO_2/km, as shown in Figure 3 (a). Similarly, if the market share of electric motorcycles is 41.2% and that of electric scooters is 20.4% (this adds up to 62% electric two-wheelers in the fleet), the fleet average fuel consumption level is 20.5 gCO_2/km in 2030, as shown in Figure 3(b). In other words, setting the two-wheeler fuel consumption standard at a level equal to or below 20.5 gCO_2/km would be likely to ensure that at least 60% of new two-wheeler sales are electric in 2030. This fleet average CO_2 level for 2030 would correspond to a nearly 50% reduction from the current fleet average CO_2 level. Such a reduction might be considered an ambitious and stringent step, but from our supporting study we can see that this target is feasible.

MODEST PAYBACK PERIODS FOR STRINGENT FUEL CONSUMPTION STANDARDS

Based on our supporting study, Figure 4(a) shows the manufacturer compliance cost curves of small motorcycles evaluated for 2025. In the pathway where all ICE technologies are exhausted before electric two-wheelers are introduced, technologies such as engine friction reduction, low-rolling-resistance tires, 5-speed manual transmission, and idle start-stop can achieve a 23% CO_2 reduction at a cost of less than INR 8,400. The consumer payback period for these technologies is 6 years.[11] However,

11 Payback period refers to the number of years required for operational savings to recover the initial investment in a vehicle technology—that is, to recover the cost of the purchase for a consumer. The payback period estimation here is based on a retail gasoline price of INR 100 per liter, as in July 2021, and average driving per year is assumed to be 10,000 km.

below a CO_2 level of 27 gCO_2/km for motorcycles, the incremental cost of reducing each gram of CO_2 emissions becomes cheaper with an electric motorcycle than by using the ICE technologies.



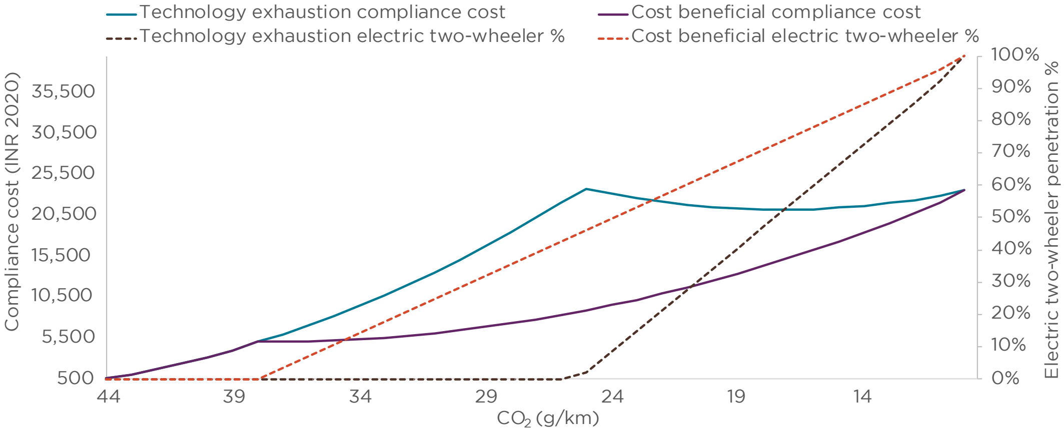


Figure 4. Compliance cost curves without multiplier for (a) motorcycle and (b) scooter evaluated for 2025.

If electric two-wheelers were to be assigned multipliers (supercredits), then the incremental compliance cost of an electric two-wheeler would be even less. With a multiplier of 1.5, the cost an electric two-wheeler is spread over one and a half vehicles. When applying a multiplier of 1.5 in this analysis, we found that electric motorcycles are less expensive than ICE motorcycles beyond 33 gCO_2/km.

Figure 4 (b) shows the manufacturer compliance cost curves of scooters evaluated for 2025. Using the ICE technology exhaustion pathway with technologies such as engine friction reduction, low-rolling-resistance tires, and idle start-stop, ICE scooters can remain cost competitive until the scooter CO_2 level of 38 gCO_2/km. This CO_2 level corresponds to a 16% CO_2 reduction in emissions. These technologies are estimated to cost less than INR 5,000 and have a consumer payback period of 4 years. Below that CO_2 level, it is cheaper to deploy an electric scooter than to add further incremental ICE technology. Additionally, with the adoption of a multiplier of 1.5, electric scooters are less expensive than ICE scooters beyond the CO_2 level of 44 gCO_2/km.

The consumer payback period of the technologies for a small motorcycle and scooter are shown in Figure 5. For the small motorcycle, PK1 refers to low-friction lubricant, low-rolling-resistance tires, low-drag brakes, and engine friction stage 1; PK2 refers to engine friction stage 2 and 5-speed manual transmission along with PK1; PK3 refers to idle start-stop and high compression ratio along with PK2; PK4 refers to advanced start-stop with electronic-clutch along with PK3; and PK5 refers to mild hybridization along with PK4. In the scooter, PK1 refers to low-friction lubricant, low-rolling-resistance tires, low-drag brakes, and engine friction stage 1; PK2 refers to engine friction stage 2, idle start-stop, and high compression ratio along with PK1; PK3 refers to advanced start-stop with continuously variable transmission (CVT) modification along with PK2; PK4 refers to improved CVT along with PK3; and PK5 refers to mild hybridization along with PK4.

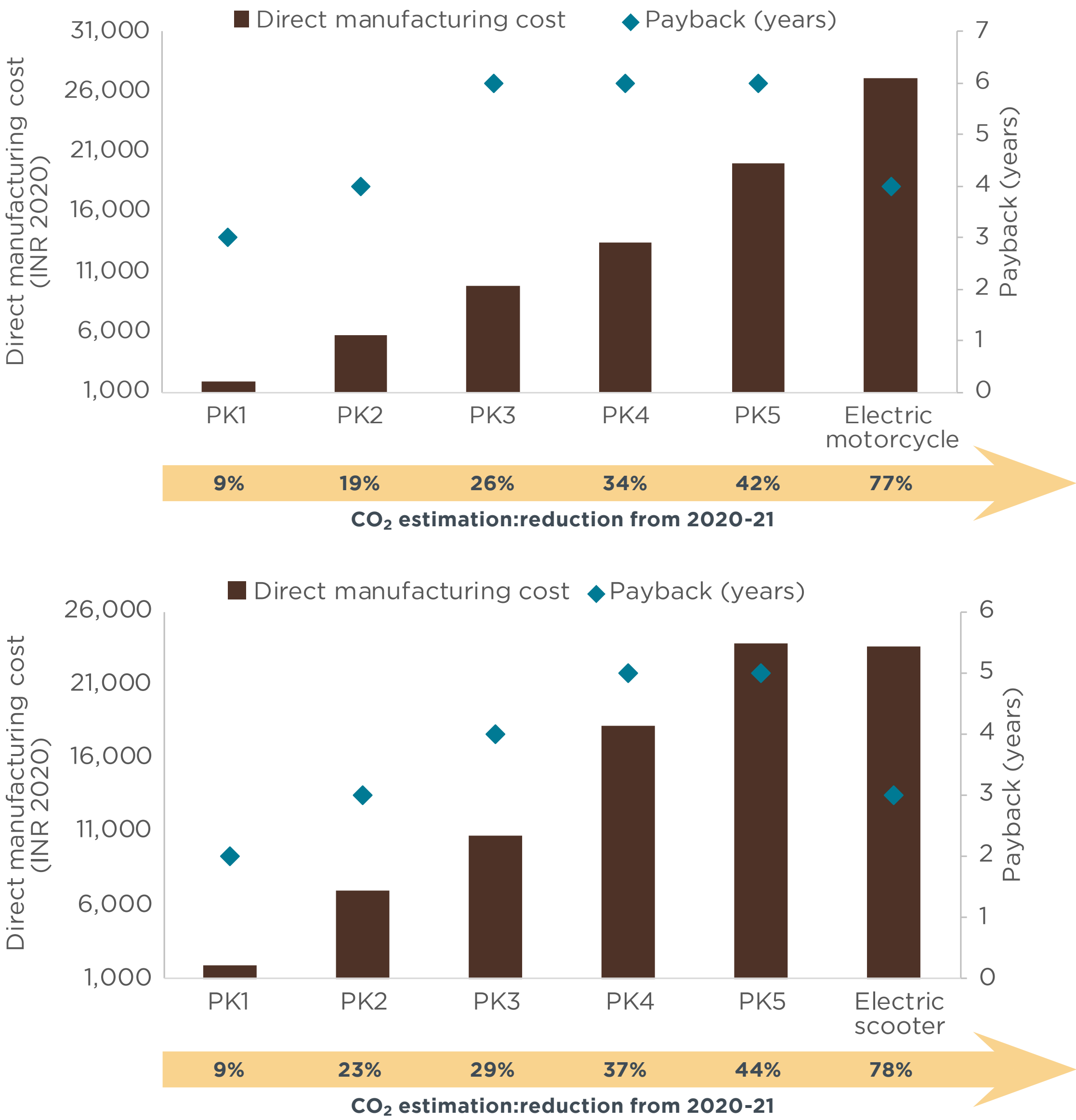


Figure 5. Comparison of direct manufacturing cost for 2025 by adoption of various technology packages and the consumer payback periods in (a) small motorcycle and (b) scooter.

A similar estimation of direct manufacturing costs of technologies for 2030 was also carried out in our white paper and it was seen that the compliance cost curves shift down as compared to those for 2025. The compliance cost in 2030 was seen to be at least 5% less than the compliance cost in 2025.

KEY TAKEAWAYS

A stringent fleet average fuel consumption standard is needed to promote electrification

- Because a fleet average target of 30.7 gCO_2/km can be achieved with ICE technologies alone in both the motorcycle and scooter segments, India's fleet average target must be lower than this level if it is to promote electrification in the market. A target of 30.7 gCO_2/km or higher will reduce fuel consumption from its current level but is unlikely to reduce the dominance of ICE two-wheelers.

- Based on our cost analyses, setting the fleet average fuel consumption standard at 25.3 gCO_2/km in 2025 would be expected to yield nearly 32% electric two-wheeler market penetration. This target can be achieved with a manufacturer compliance cost of INR 9,300 and the consumer payback period would be 6 years.

- By 2030, the fleet average standard can be further strengthened to in the range of 20.5 gCO_2/km. Even without a multiplier, at this level, a 62% electric two-wheeler market penetration can be achieved cost beneficially, with a manufacturer compliance cost of INR 7,100 and the consumer payback period would be 3 years.

Electrification is key to achieving sizeable GHG and petroleum consumption reductions

- At 60% electric for new sales in the two-wheeler segment by 2030, our projections show emission levels would be about 32 megatonnes CO_2 annually, far lower than they would have reached in the BAU scenario, which is nearly 56 megatonnes. Additionally, electrification of 60% in the new two-wheeler fleet would enable a nearly 16% reduction in 2030 from the current level of 38 megatonnes of CO_2. Additionally, the cumulative benefit of emissions savings which can be achieved are nearly 117 megatonnes of CO_2 by 2030 and approximately 487 megatonnes of CO_2 by 2040.

- In terms of petroleum consumption, the benefit of 60% electrification in the two-wheeler segment by 2030 can be estimated as reduction of nearly 10 Mtoe in the year 2030 and approximately 16 Mtoe in the year 2040. Cumulatively, the energy consumption reduction that can be achieved is nearly 49 Mtoe by 2030 and approximately 187 Mtoe by 2040. Based on the current gasoline retail price of INR 100 per liter, this cumulative benefit of fuel consumption reduction is capable of fuel savings of nearly US$75 billion by 2030 and nearly US$ 284 billion by 2040.