# Fuel consumption reduction technologies for the two-wheeler fleet in India

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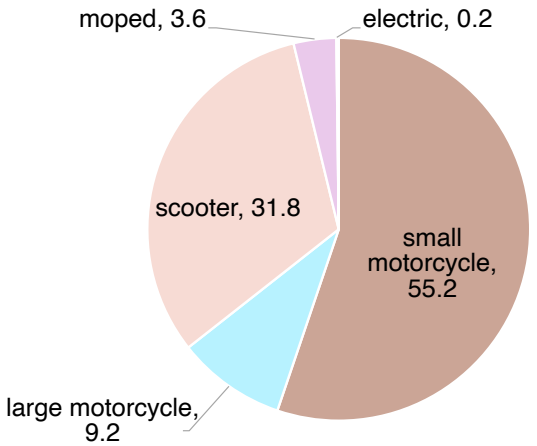
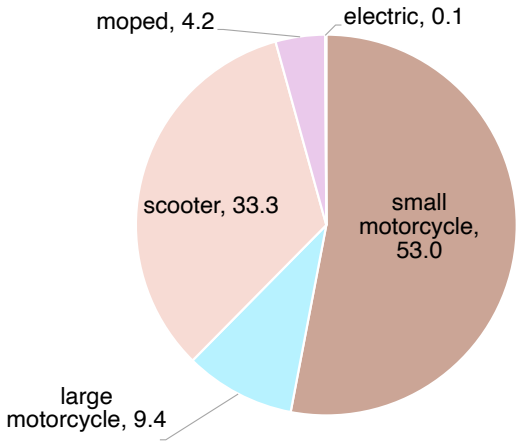
# **Two-wheeler market** in India

- The adoption of **fuel injection technology** is a significant step in the technology level in two-wheeler
- **Motorcycle with engine displacement less than 150 cc** continues to dominate the two-wheeler market

## Market share in 2019-20




## Market share in 2017-18

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https://theicct.org/publications/new-two-wheeler-fleet-india-2017-18

# **Key questions** of the study

1. What are the **prospects** to reduce fuel consumption for the existing two-wheeler fleet?
2. Are these prospects **cost-effective**?
3. How fleet average fuel consumption standard can **enable EV penetration** in two-wheeler?

# **Technology trend** of the BS VI two-wheeler fleet

| Technology type | Small motorcycle | Large motorcycle | Scooter |
|---|---|---|---|
| Engine | Fuel injection, capacitor charge ignition<br><br>Compression ratio 9.9:1 | Fuel injection, single spark electronic ignition<br><br>Compression ratio 8.5:1 | Fuel injection, spark injection<br><br>Compression ratio 10:1 |
| Transmission | 4-speed manual | 5-speed manual | Continuously variable transmission (CVT) |

# Possible **technology additions** for two-wheelers

Engine Technologies

Transmission technologies

Vehicle technologies

| List of technologies | Small motorcycle | Large motorcycle | Scooter |
|---|---|---|---|
| Lubricating oil additives | ✓ | ✓ | ✓ |
| Engine friction reduction | ✓ | ✓ | ✓ |
| Cam phasing | | ✓ | |
| Variable valve lift | | ✓ | |
| Gasoline direct injection | | ✓ | |
| Atkinson cycle | | ✓ | |
| EGR(external) | | ✓ | |
| High compression ratio | ✓ | ✓ | ✓ |
| 5-speed Manual transmission | ✓ | | |
| 6-speed Manual transmission | | ✓ | |
| Dual Clutch Transmission(DCT) | | ✓ | |
| Improved CVT | | | ✓ |
| Electronic clutch | ✓ | | |
| Start stop | ✓ | ✓ | ✓ |
| Low-rolling-resistance tires | ✓ | ✓ | ✓ |
| Low-drag brake callipers | ✓ | ✓ | ✓ |
| Mild hybridization | ✓ | ✓ | ✓ |
| Electrification | ✓ | ✓ | ✓ |

# Cost-Benefit Analysis

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# **Cost and benefits** estimations (2025-2030)

## Cost estimations:

- Direct manufacturing cost by **vehicle category** linked to **incremental** technology improvement for reducing fuel consumption

## Benefit estimations:

- **$CO_2$** reduction
- **Fuel savings**

# **Methodology**-DMC cost & $CO_2$ benefit estimation

- **Direct manufacturing cost(DMC) estimate of a technology**=
  Cost of technology in EU passenger vehicle X Scaling factor X EU Labour cost adjustment X Inflation factor X Currency conversion to INR
- **$CO_2$ reduction benefit** from SAE papers & previous ICCT studies



https://theicct.org/publications/co2-reduction-technologies- european-car-and-van-fleet-2025-2030-assessment

# Methodology-individual DMC cost & $CO_2$ benefit in a **small motorcycle**

| Technology | DMC (INR 2020) | Fuel consumption reduction benefits |
|---|---|---|
| Low-friction lubricant | 203 | 2.8% |
| Low-rolling-resistance tires, low drag brakes | 405 | 2.3% |
| High compression ratio | 772 | 6.0% |
| Engine friction reduction | 2,600 | 8% |
| 5 speed manual transmission vs 4 speed | 2,575 | 7.7% |
| Idle start-stop | 3,253 | 7.7% |
| Advanced start-stop with e-clutch | 3,707 | 8.0% |
| Mild hybridization | 6,549 | 11.2% |

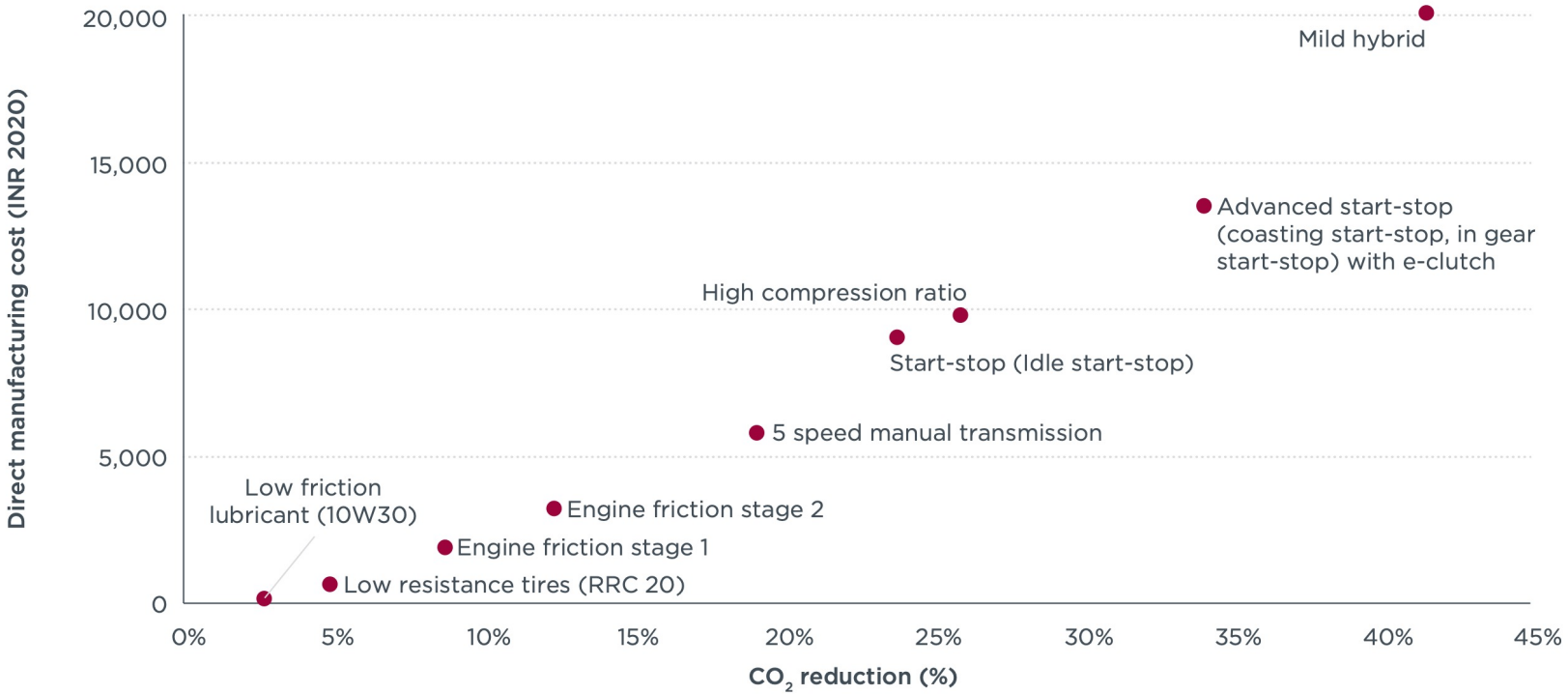
# Methodology-individual DMC costs & $CO_2$ benefit in a **large motorcycle**

| Technology | DMC(INR 2020) | Fuel consumption reduction benefits |
|---|---|---|
| Low-friction lubricant | 203 | 2.8% |
| Low-rolling-resistance tires, low-drag brakes | 405 | 2.3% |
| Intake cam phasing | 625 | 3.0% |
| Exhaust cam phasing | 1,131 | 1.5% |
| Engine friction reduction | 2,600 | 4.4% |
| High compression ratio | 1,603 | 6.0% |
| Idle start-stop | 3,845 | 5.5% |
| Variable valve lift | 4,548 | 3.0% |
| Advanced start-stop | 5,342 | 8.0% |
| 6-speed manual transmission vs. 5-speed | 7,439 | 6.2% |
| GDI + EGR + Atkinson cycle | 11,461 | 7.0% |
| Mild hybridization | 13,604 | 9.0% |
| DCT | 14,089 | 11.6% |

# Methodology-individual DMC cost & $CO_2$ benefit in a **scooter**

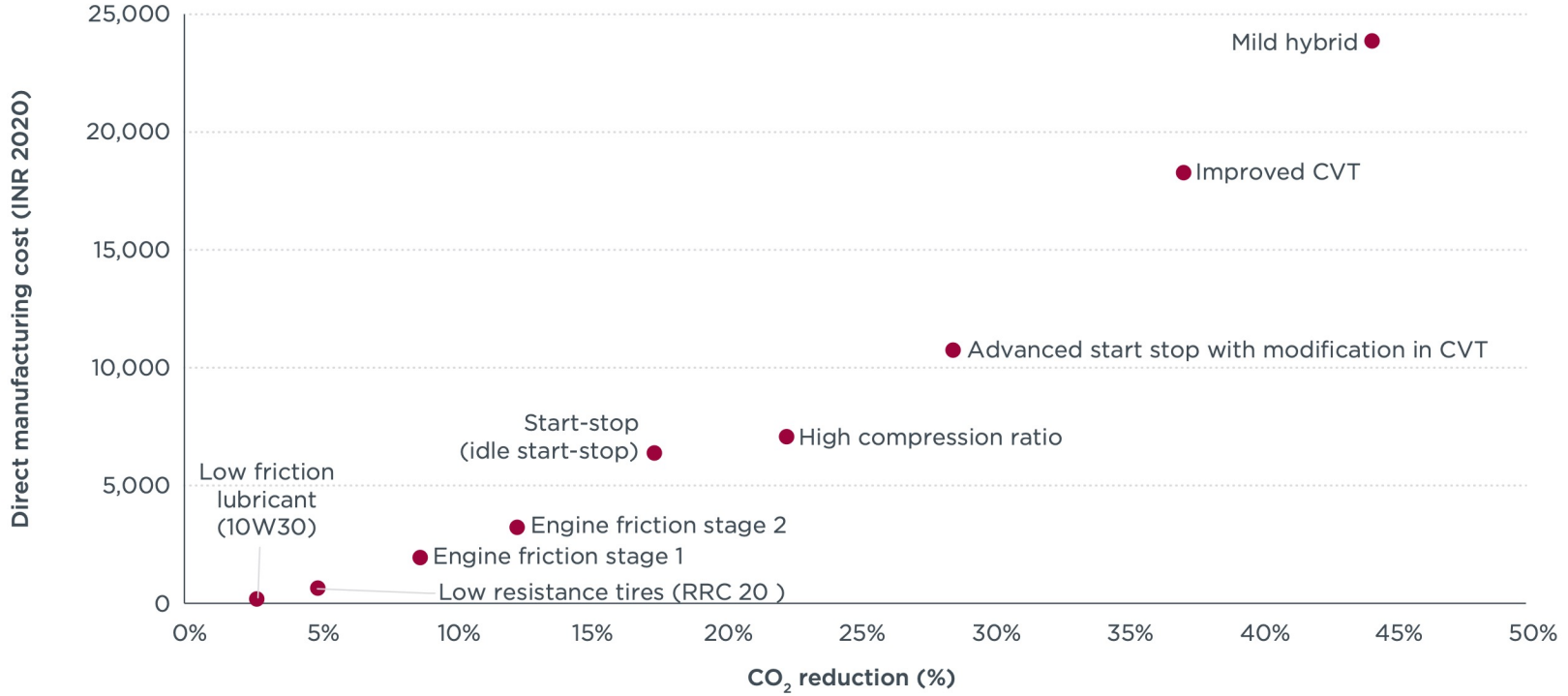
| Technology | DMC(INR 2020) | Fuel consumption reduction benefits |
|---|---|---|
| Low-friction lubricant | 203 | 2.8% |
| Low-rolling-resistance tires, low drag brakes | 405 | 2.3% |
| High compression ratio | 661 | 6.0% |
| Advanced start stop with modification in CVT | 3,693 | 8.0% |
| Engine friction reduction | 2,600 | 8.0% |
| Idle start stop | 3,174 | 5.8% |
| Mild hybridization | 5,606 | 11.2% |
| Improved CVT | 7,500 | 12.0% |

# Methodology approach-**incremental technologies** for a small motorcycle




**$CO_2$ Estimation** :% reduction from 2020

# Methodology approach-**incremental technologies** for a scooter




**$CO_2$ Estimation** :% reduction from 2020

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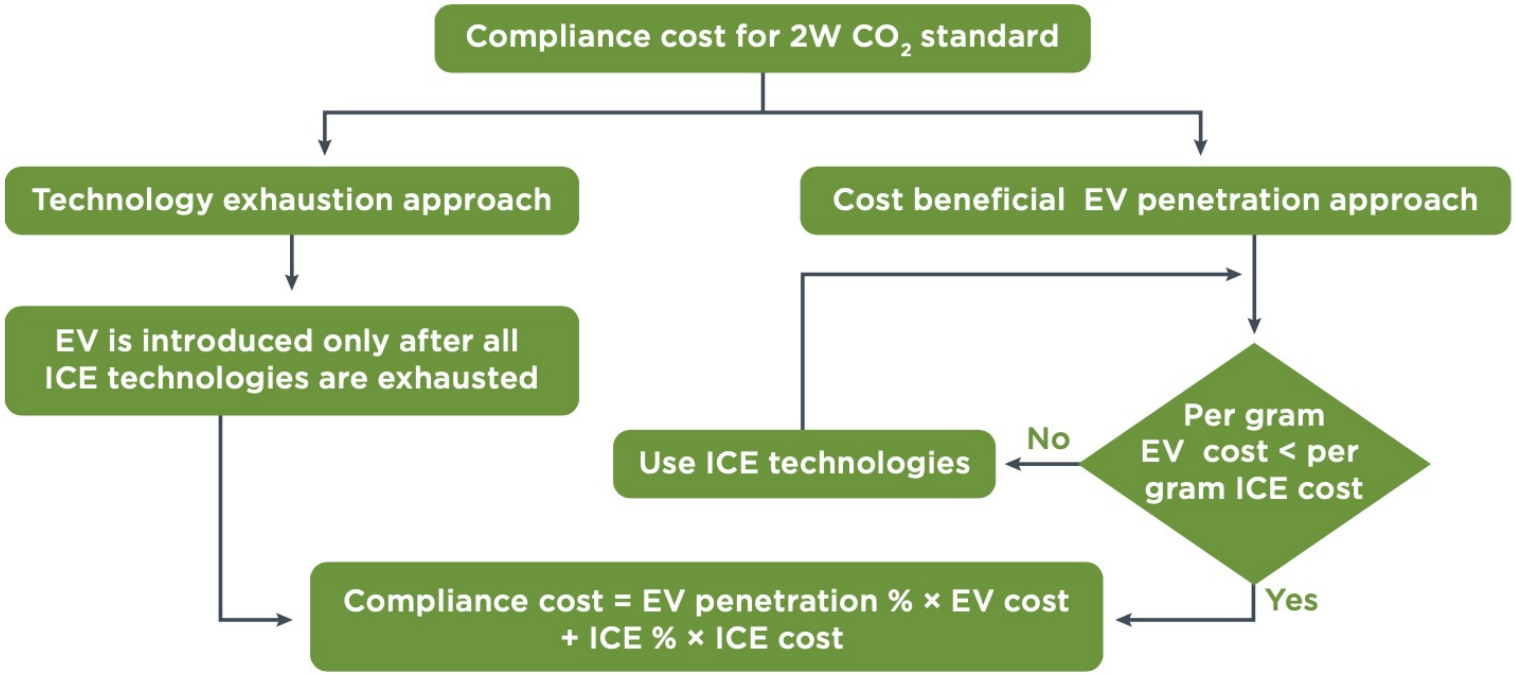
# Methodology-**incremental cost** estimation of electric two-wheeler(E2W)

- **Direct Manufacturing Cost(DMC) of an E2W** reflects the addition of cost of components like battery, thermal management, inverter, control and power distribution module and exclusion of cost of ICE power train

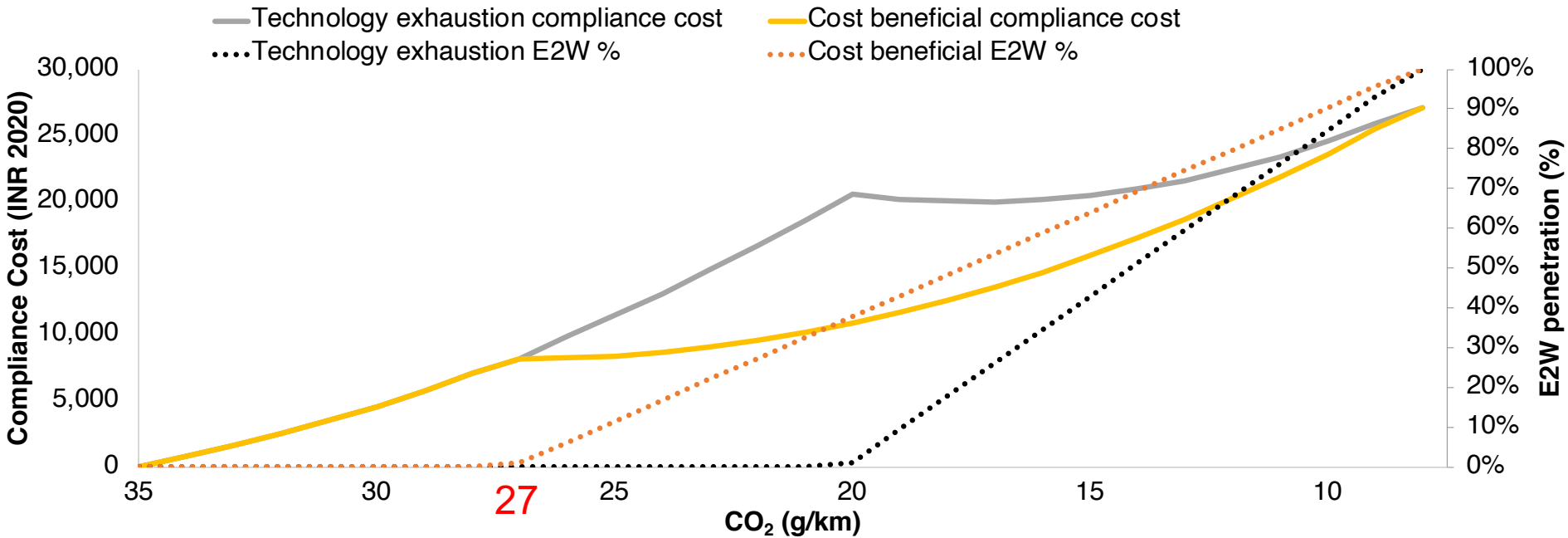
- DMC of an E2W corresponds to **incremental cost** of the E2W as compared to the ICE model

# Results

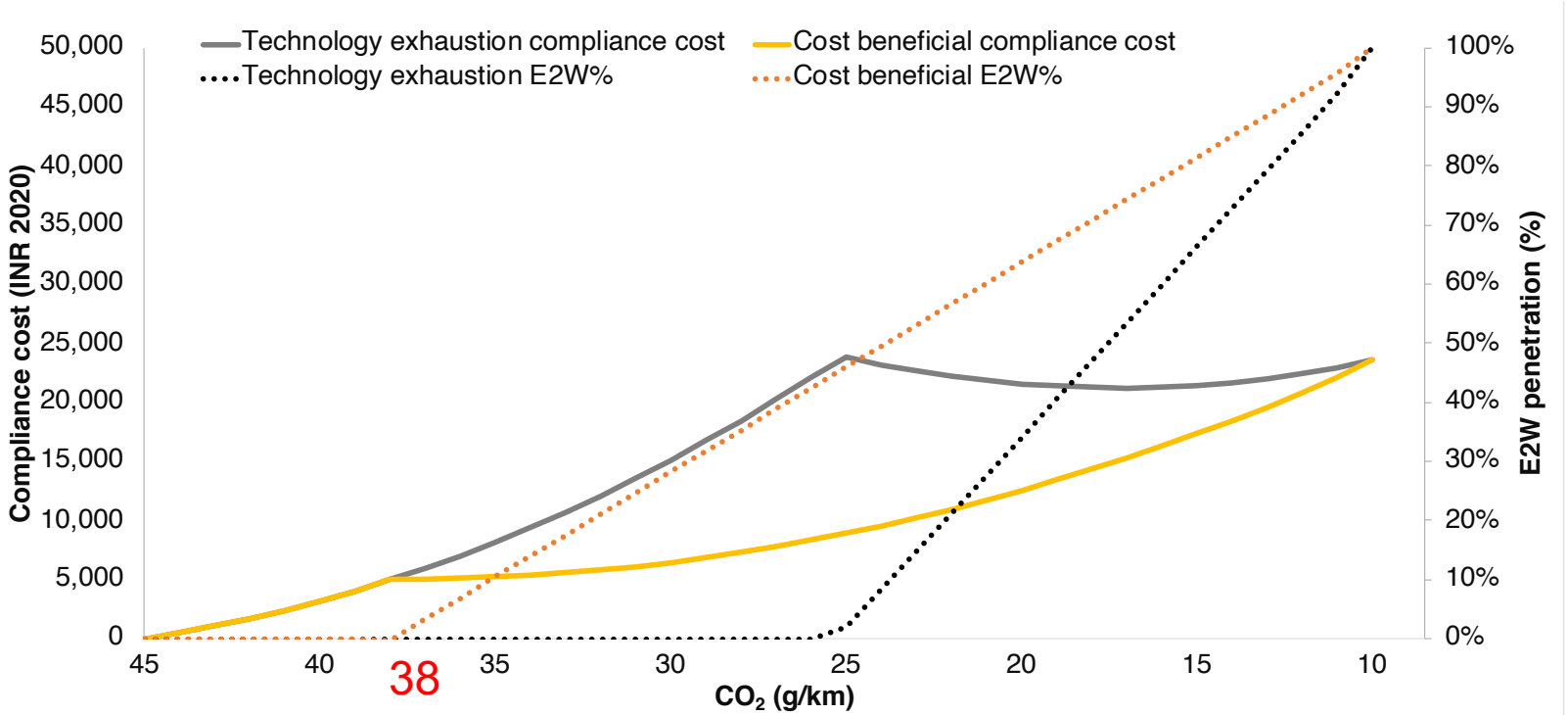
# Estimation of compliance cost



# Cost effectiveness of technology vs electrification evaluated for 2025 in a motorcycle

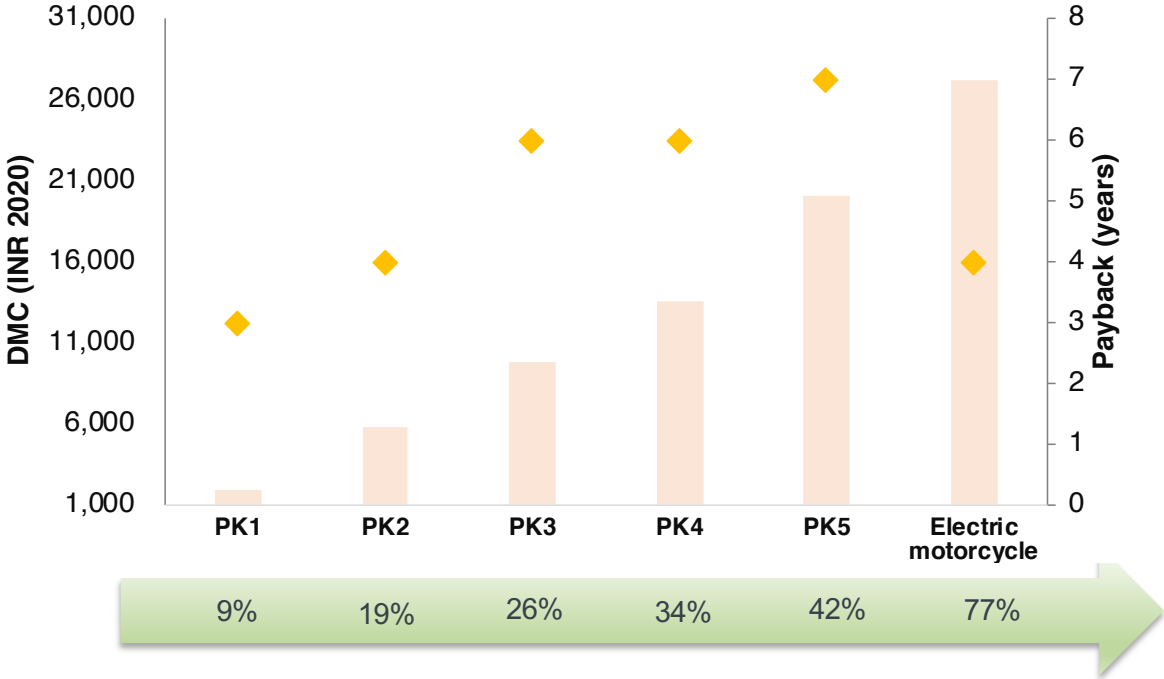


# Cost effectiveness of technology vs electrification evaluated for 2025 in a scooter



# Payback period* in a small motorcycle

| Packages | Technologies |
|---|---|
| PK1 | Low friction lubricant, low-rolling-resistance tires, low-drag brakes, engine friction stage 1 |
| PK2 | PK1,engine friction stage 2,5-speed MT |
| PK3 | PK2,start-stop(idle), high compression ratio |
| PK4 | PK3,advanced start-stop(coasting/in-gear)with e-clutch |
| PK5 | PK4,mild hybrid |
| PK6 | Electric motorcycle |

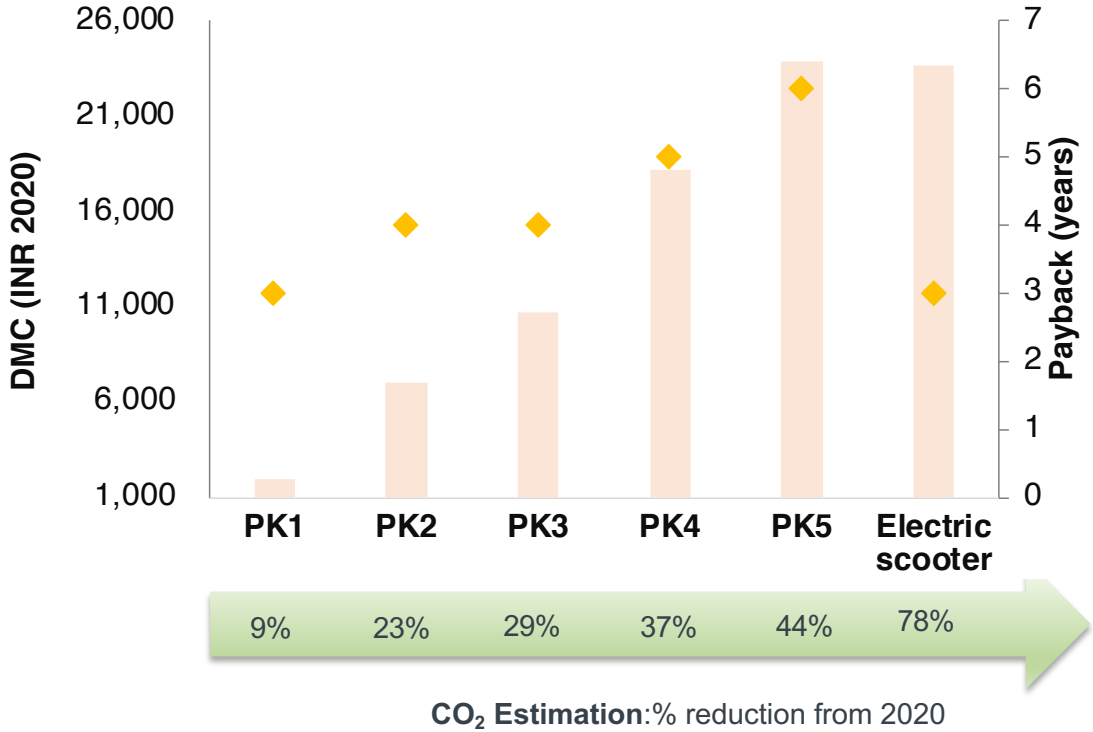



**$CO_2$ Estimation**:% reduction from 2020

**Based on fuel price of INR 90 per litre and average kilometer driven per year 10,000*

# Payback period* in a scooter

| Packages | Technologies |
|---|---|
| PK1 | Low-friction lubricant, low-resistance tires, low drag brakes, engine friction stage 1 |
| PK2 | PK1, engine friction stage 2, start-stop, high compression ratio |
| PK3 | PK2, advanced start-stop with modification in CVT |
| PK4 | PK3, improved CVT |
| PK5 | PK4, mild hybrid |
| PK6 | Electric scooter |




**$CO_2$ Estimation**:% reduction from 2020

** Based on fuel price of INR 90 per litre and average kilometer driven per year 10,000*

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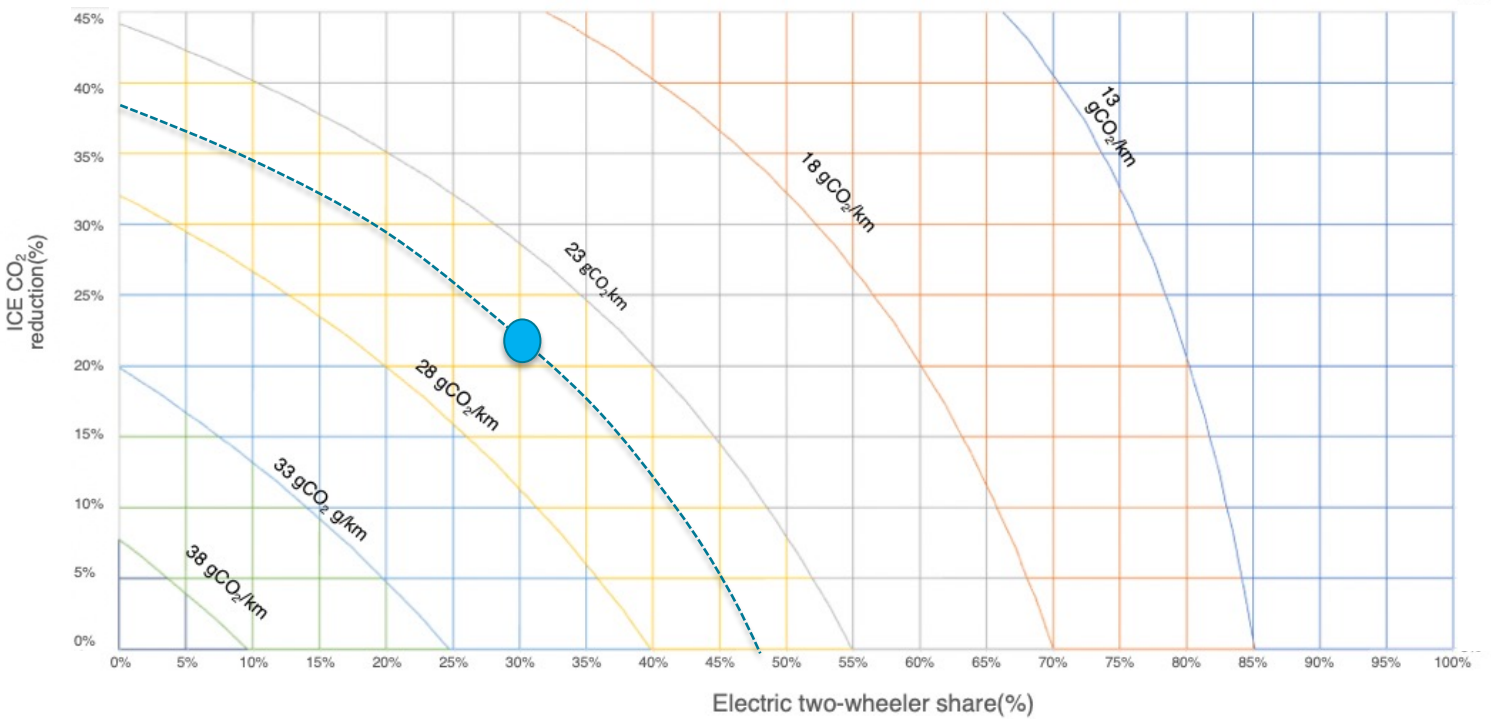
# **Fleet average levels** achieved for different electric two-wheeler share & ICE technology improvement



# Achieving the **fleet average level** of 25.3 $gCO_2$/km for 2025

## By exhausting the ICE technologies

| Type | Segment share(%) | ICE share of segment (%) | EV share of segment(%) | Compliance cost (INR 2020) |
|---|---|---|---|---|
| Small motorcycle | 60 | 100 | 0 | 18,589 |
| Scooter | 30 | 100 | 0 | 22,069 |
| Large motorcycle | 10 | 100 | 0 | 6,346 |
| Fleet average | 100 | 100 | **0** | **18,409** |

## By cost beneficial EV penetration

| Type | Segment share(%) | ICE share of segment (%) | EV share of segment(%) | Compliance cost (INR 2020) |
|---|---|---|---|---|
| Small motorcycle | 60 | 68 | 32 | 10,118 |
| Scooter | 30 | 58 | 42 | 8,327 |
| Large motorcycle | 10 | 100 | 0 | 6,346 |
| Fleet average | 100 | 68 | **32** | **9,203** |

# Achieving the **fleet average level** of 20.5 $gCO_2$/km for 2030

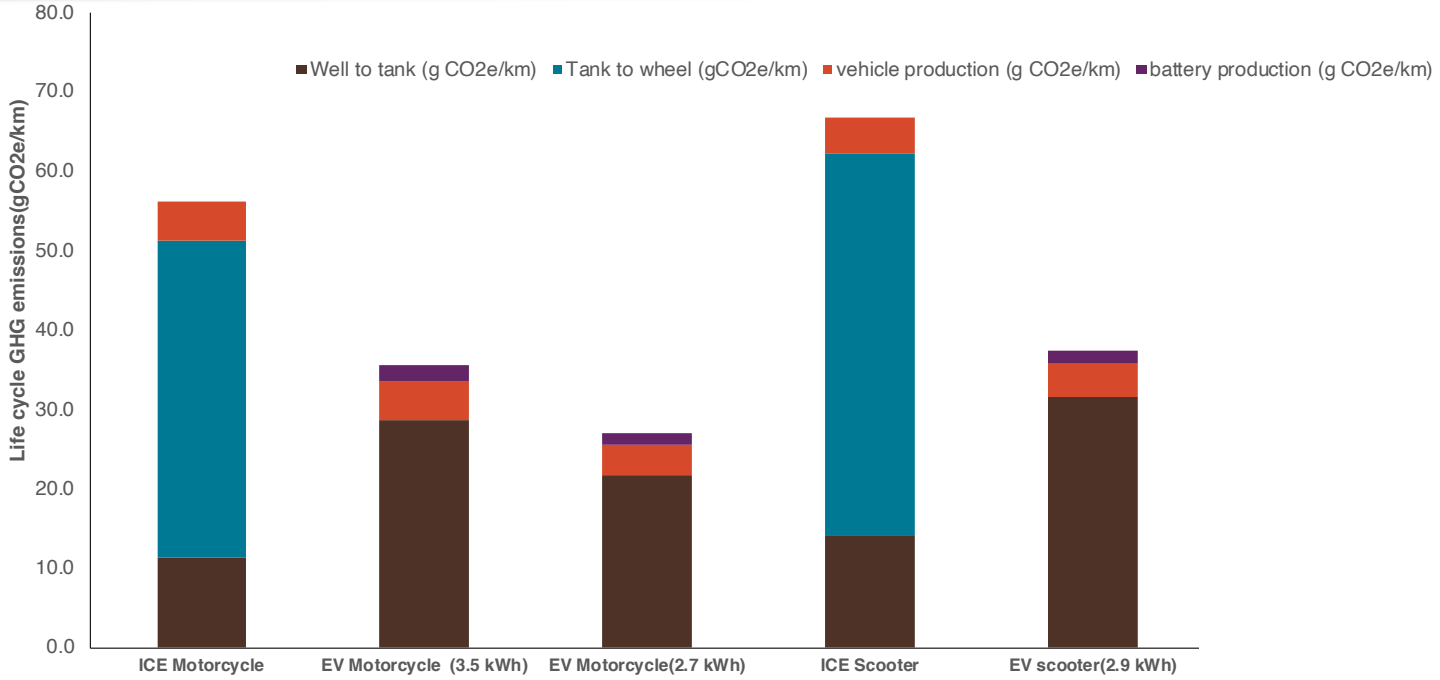
## By exhausting the ICE technologies

| Type | Segment share(%) | ICE share of segment (%) | EV share of segment(%) | Compliance cost (INR 2020) |
|---|---|---|---|---|
| Small motorcycle | 60 | 67 | 33 | 14,970 |
| Scooter | 30 | 66 | 34 | 16,388 |
| Large motorcycle | 10 | 100 | 0 | 6,285 |
| Fleet average | 100 | 70 | **30** | **14,525** |

## By cost beneficial EV penetration

| Type | Segment share(%) | ICE share of segment (%) | EV share of segment(%) | Compliance cost (INR 2020) |
|---|---|---|---|---|
| Small motorcycle | 60 | 31 | 69 | 5,577 |
| Scooter | 30 | 32 | 68 | 10,217 |
| Large motorcycle | 10 | 100 | 0 | 6,285 |
| Fleet average | 100 | 38 | **62** | **7,024** |

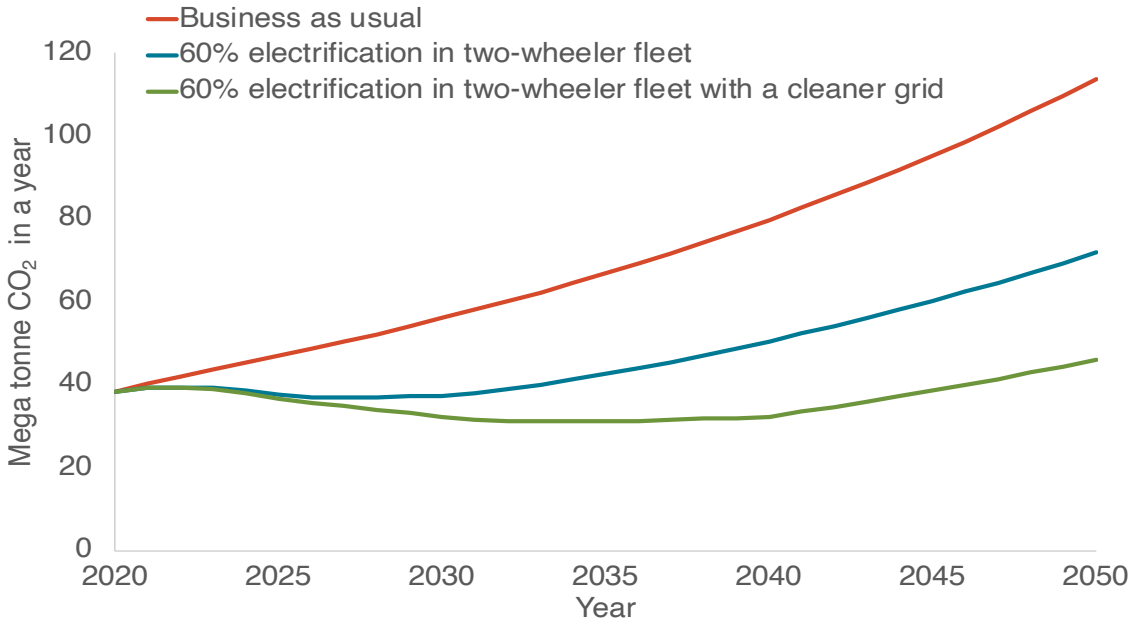
# **Life cycle GHG emissions*** for 2030 for gasoline and electric two-wheelers in India




*Based on carbon intensity of the electricity mix of IEA stated policies scenario for India(includes transmission & distribution loss in the grid) and share of gasoline blend (ethanol) to increase from 5%-12% in the time frame of 2020-2030

# Electrification **benefits** on environment

- With 60% electrification* of two-wheeler segment, cumulative 2021-2030 emission reduction are **117 Mt** and cumulative fuel savings is **~49 Mtoe**
- By 2040, the cumulative emission reduction are **487 Mt** and cumulative fuel savings is **~187 Mtoe**




*Based on Indian grid carbon intensity of 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*

# Summary and Recommendations

- Post BSVI fuel injection technology allows two wheelers to incorporate many cost-effective ICE technologies.
- ICE technologies are cost effective as compared with EV **till 23%** of $CO_2$ reduction.
- Fleet average $CO_2$ reduction target of **25 $gCO_2$/km for 2025 will enable ~30% EV** and **20 $gCO_2$/km for 2030 will enable ~60% EV** in 2W.

# Questions?

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# Comparison of average consumption of ICE 2W and Electric 2W

| Vehicle type | Real world consumption* |
|---|---|
| Electric Motorcycle(100 km range,3.5 kWh) | 3.7 kWh/100km |
| ICE Motorcycle(97.2 cc) | 1.79 litre/100 km(eqvt** to 17.41 kWh/100km) |
| Electric Scooter(75 km range,2.9 kWh) | 4.1 kWh/100km |
| ICE Scooter(109.5 cc) | 2.21 litre/100km(eqvt** to 21.49 kWh/100km) |

**Based on real world values ~20% more than declared values.*
***Based on the conversion factor for passenger cars*

# Methodology-scaling factor estimation

| List of technologies | Scaling parameter |
|---|---|
| Lubricating oil additives | No scaling |
| Engine friction reduction | Number of cylinder |
| Cam phasing | Number of cylinder |
| Variable valve lift | Number of cylinder |
| GDI | Number of cylinder |
| EGR (external) | Number of cylinder |
| High Compression ratio | Engine power |
| Atkinson cycle | Engine power |
| 5/6 speed Manual transmission | Torque ratio |
| 6 speed Manual transmission | Torque ratio |
| DCT/Electronic clutch | Torque ratio |
| Start-stop | Engine power. Sensors reman non-variable |
| Low-rolling-resistance tires & Low-drag brake calliper | RRC value |
| Mild hybridization | Motor power. Sensors remain non-variable |
| Electrification | Energy consumption |

# Effect of multiplier credit- One EV sold is counted as multiplier times for $CO_2$ calculation

| $CO_2$ level (g/km) | EV % for no credits | EV% for 2 multiplier credit | EV% for 3 multiplier credit |
|---|---|---|---|
| 25.3 | 32 | 29.2 | 23.1 |
| 20.5 | 62 | 46.9 | 38.2 |