

Demystifying the Climate Benefit of EV Transition in India

Opportunity to Decarbonise through Vehicle Electrification is Complex

Highlights

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Why is this research important?

Premise:

- Battery-driven EVs hold promise to decarbonise India's rapidly growing motorised road transport.
- Achieving **significant GHG emission reductions** through widespread EV uptake **is not a given**.

Research objectives:

- Examine **complexities** of climate impact of EV based on **data-driven analysis** that **best reflects real-world EV use**.
- Offer **actionable insights** that enable policies and on-ground implementation to **tap mitigation potential of EVs**.
- Help in understanding **future prospect** of reducing GHG emissions on account of EV transition.

USP of the research:

- **First significant effort** to quantitatively analyse **impact of heterogeneities** in underlying factors, such as:
 - **Diversity of vehicle energy performance** within and across 10 different segments.
 - **Time-of-day profile of CO₂ emission intensity** of grid electricity considering variability in share of RE in supply-mix.
 - **Differences** in electricity supply mix at **city-/ state-level**.

Past attempts heavily relied on simplistic analysis

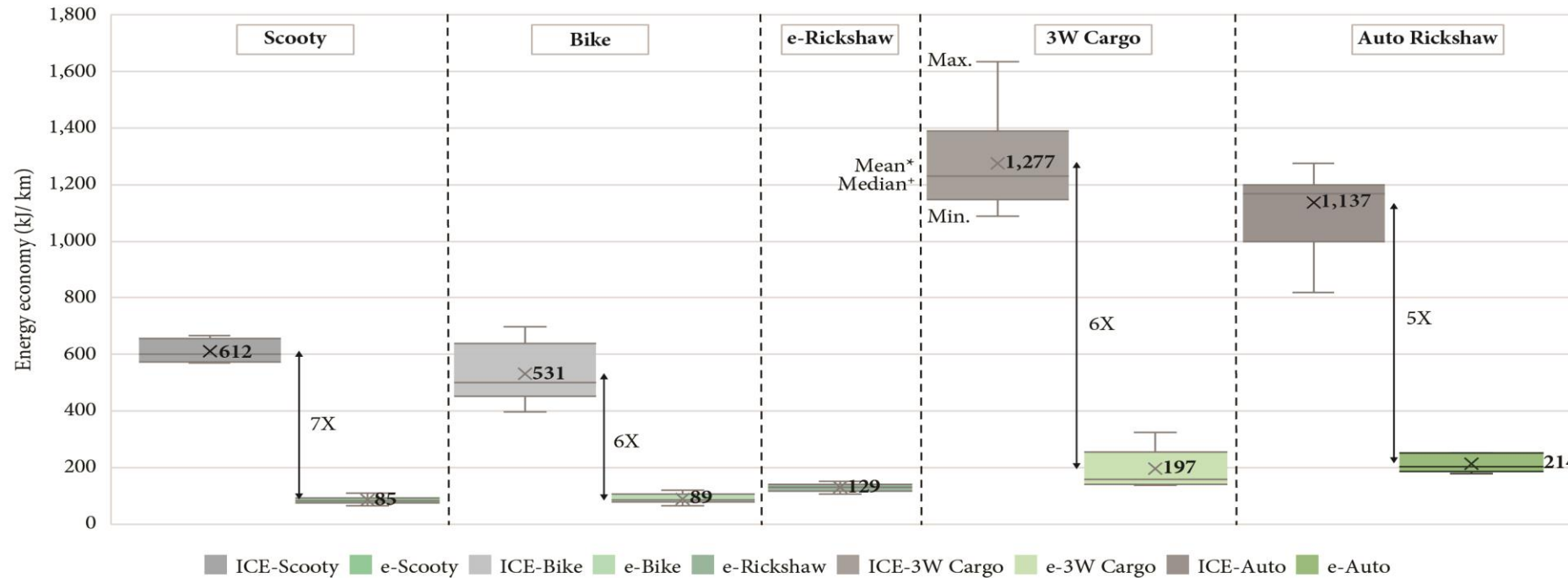
Pitfalls in current run-of-the-mill evaluation approach

- **Cherry-picking vehicle models**, be electric or conventional, for comparison leads to **misleading generalisations**.
 - There's a wide range of energy efficiencies that exist within vehicle segments.
 - For example, in a sample of 15 popular petrol sedan models, certified vehicle fuel economy varies almost 2X.
- **Overlooking the dynamics of grid electricity supply** disregards the **fluctuating generation profile of RE**.
 - Applying annual average emission factor of grid electricity does not reflect temporal variation in electricity supply mix.
- **Ignoring the fact that EV charging is not a constant load** masks **implications of skewness** in charging pattern.
 - Daily mobility pattern in general is super dynamic and so is EV charging. Latter is largely night-time heavy.

All these simplistic considerations potentially leave room to misrepresent true climate impact of EV adoption.

Electric drivetrains outperform in energy efficiency (1/2)

Comparison of energy economies in two-wheeled and three-wheeled segments at model stock level



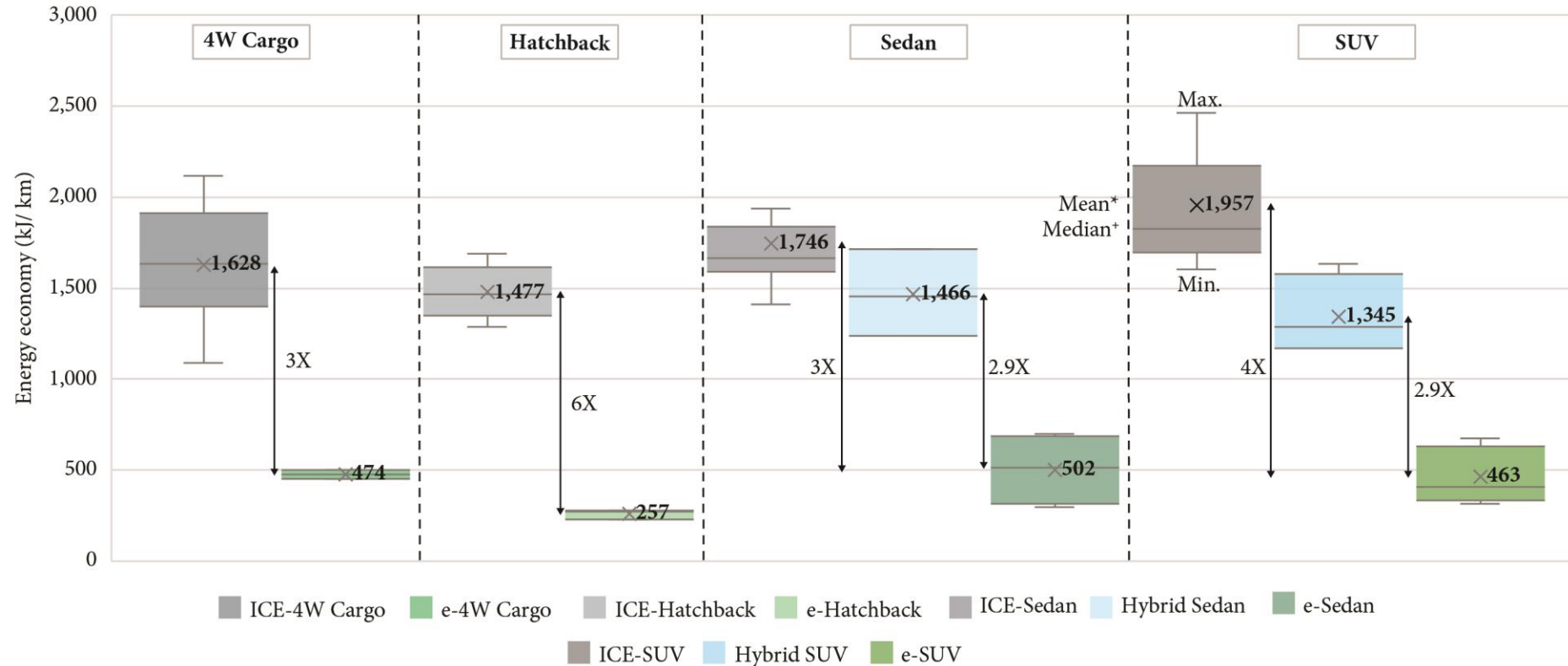
Note:

- Model stock refers to group of models of a particular technology in a vehicle segment.
- Mean refers to the average of the energy economy values of different models in a segment. It is not a weighted average based on vehicle sales.
- Median refers to the middle value of the given data when all the values are arranged in ascending order.
- Values on box & whisker diagrams indicate mean energy economies for different variants in each vehicle segment.
- A line arrow indicates estimated gap in average energy economy between electric and ICE or strong hybrid vehicle model stocks.
- Adjacent value shows the times mean energy efficiency of ICE or strong hybrid model stock is lower than that of electric model stock.

- EE of e-scooters and e-rickshaws hardly exhibits a range whereas it is conspicuous in case of petrol bikes.
 - Whether or not there are sub-classes (based on engine size) is the underlying factor.

Electric drivetrains outperform in energy efficiency (2/2)

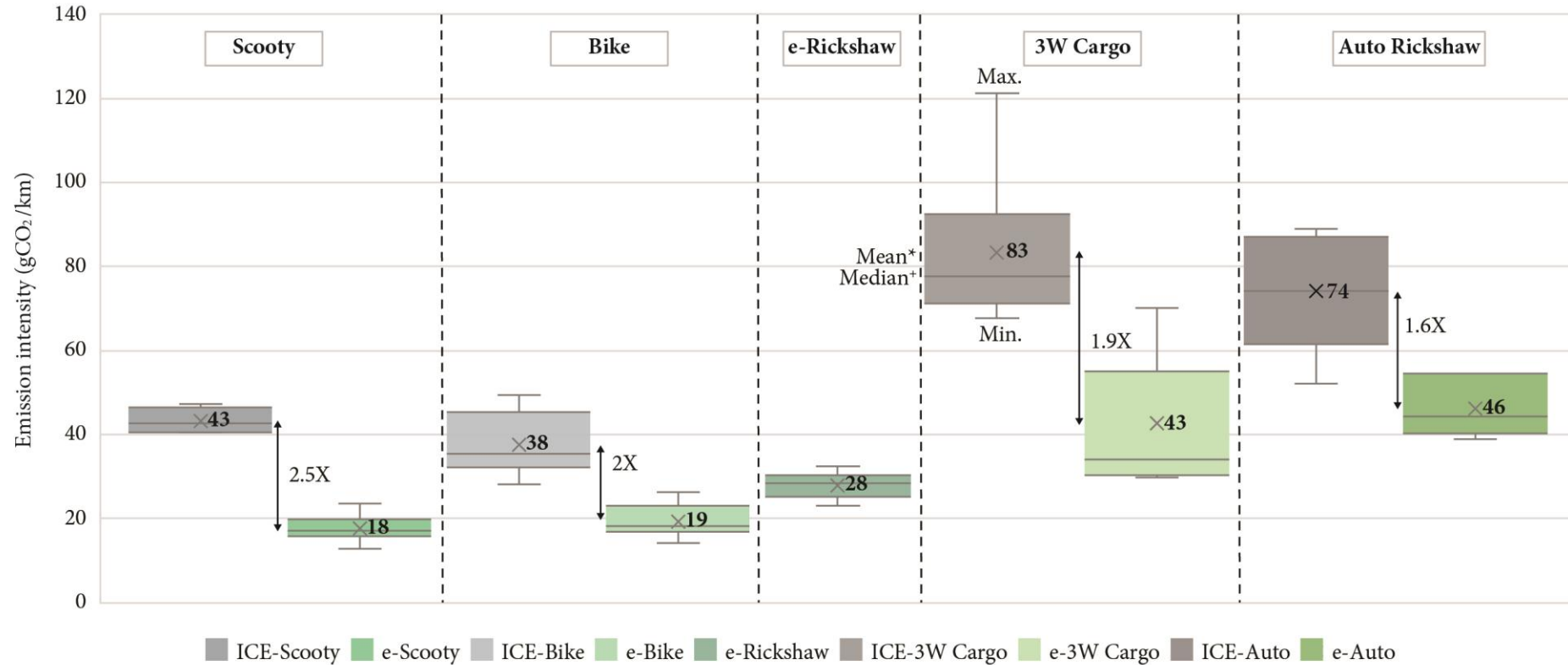
Comparison of energy economies in four-wheeled segments



- **EE gap narrows** when comparison is made between **strong hybrid** and pure **EV** model stocks.
- On average, **EVs** have end-use **energy consumption** levels **at least 3 times lower** than conventional counterparts.
- **Advancements** in battery technology and power electronics to **improve EV efficiency**.

But grid electricity (tank of an EV) dictates climate benefit

Comparison of CO₂ emission intensities (gCO₂/ km) in two-wheeled and three-wheeled segments at model stock level

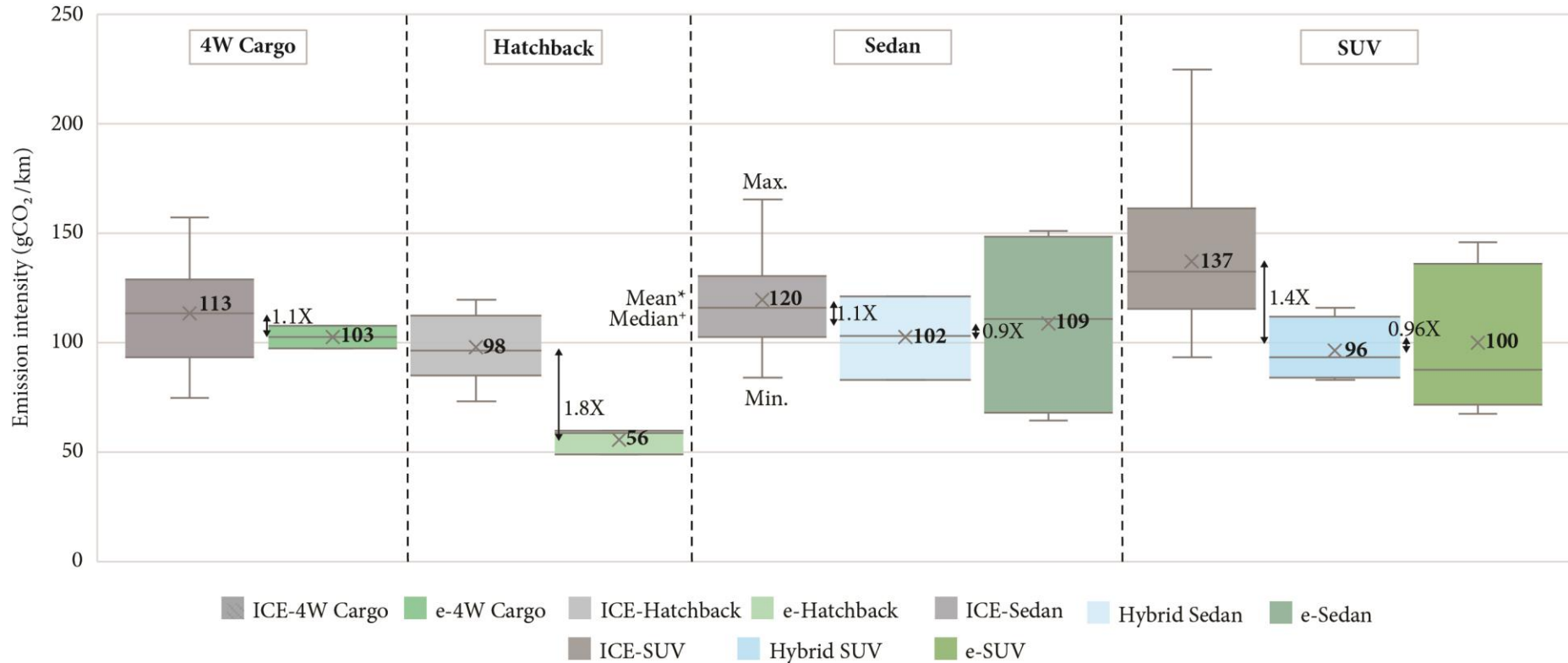


Note: The calculations are based on CEA-published national annual average CO₂ emission factor for grid electricity in FY 2021-22 which is 715 gCO₂/kWh.

- Impact of coal-dominated supply-mix of grid electricity on gCO₂ per km of electric model stock is discernible.
- Where on average an e-scooter is 7 times more efficient than ICE one, its CO₂ footprint is only 2.5 times less.

The impact is starker in case of four-wheeled EVs

Comparison of CO₂ emission intensities (gCO₂/ km) in four-wheeled segments

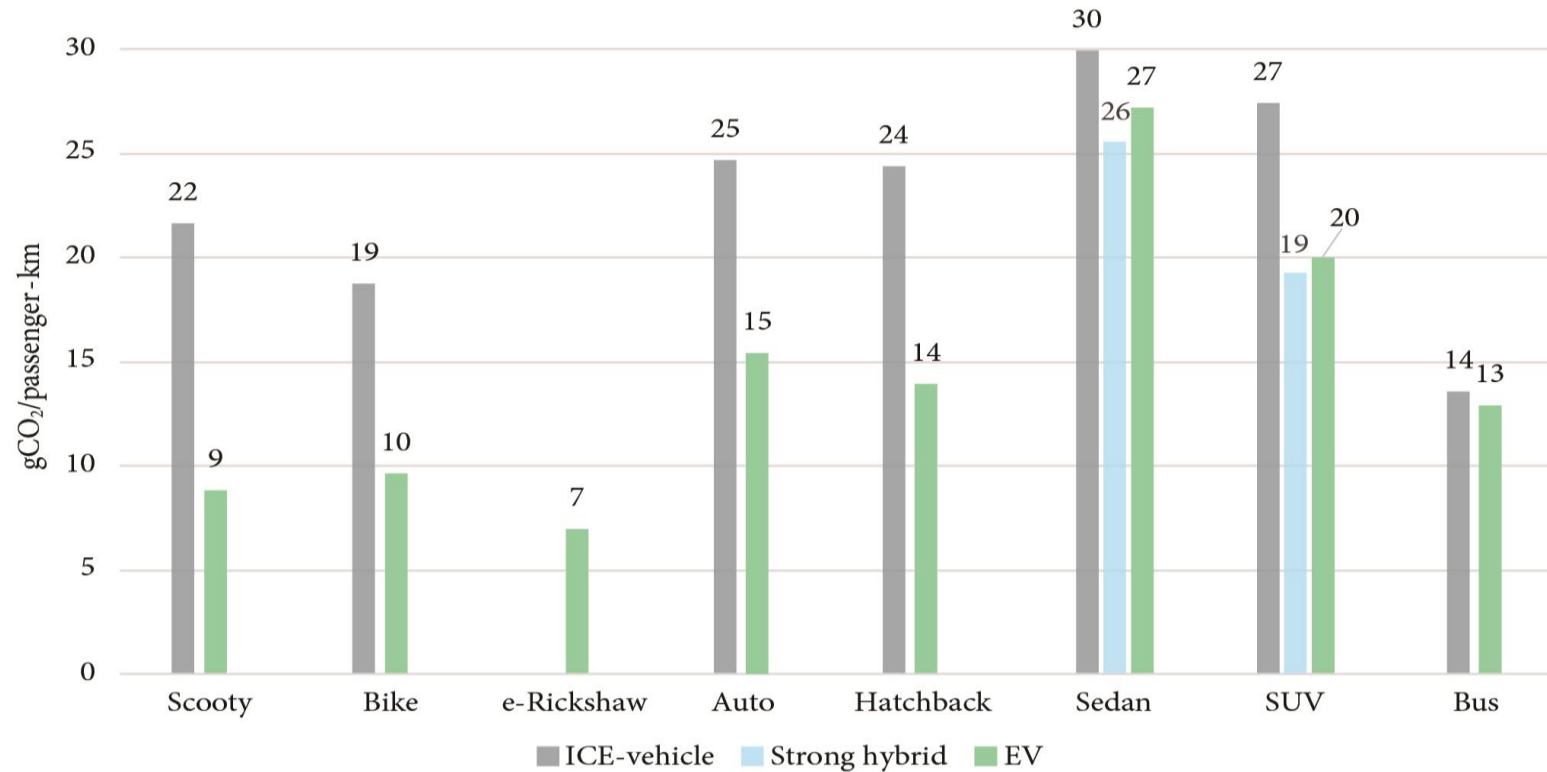


Note: Calculations are at model stock level, based on CEA-published national annual average CO₂ emission factor for grid electricity in FY 2021-12.

- **Fall in climate benefit** of electric drivetrain is starkly apparent when **compared with strong hybrid models**.
- Specific emissions for **strong hybrids** are **at par or slightly less** than **electric sedans and SUVs**.

Vehicle electrification is not about adding batteries but transporting passengers (and cargos)

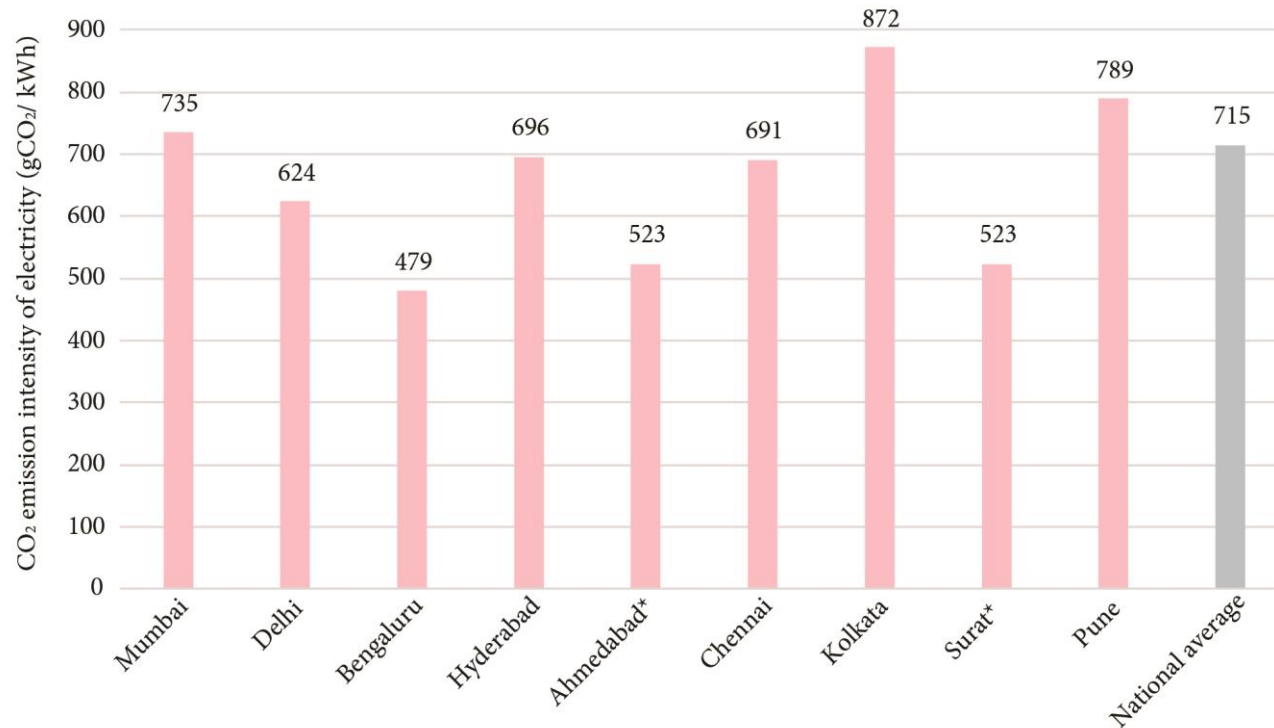
Comparison across vehicle segments and technologies based on CO₂ emissions per passenger-km



- CO₂ per passenger-km for an ICE-bus are at par of an e-hatchback and lower than any type of sedan or SUV.
 - This comparison is starker if one considers lower occupancy of cars which is often the reality.
- It is paramount to realise modal shift from cars to public bus transport.

EVs do not have similar carbon footprints across India

CO₂ emission intensities of electricity across nine Indian cities in FY 2021-22



- Power procurement baskets of utilities supplying to these cities differ.
- Electricity in **3 cities** out of the sample has a **higher carbon load than national average**.
- Differences in gCO₂ per kWh of supplied electricity at city-/ state-level have proportionate impacts on emissions from EV use.
- Regulations like RPO nudge distribution utilities to increase share of RE in their supplies.
 - Utilities in RE-rich states are better placed to achieve RPO targets.

*Ahmedabad and Surat have same distribution utility, and there is a common true-up petition.

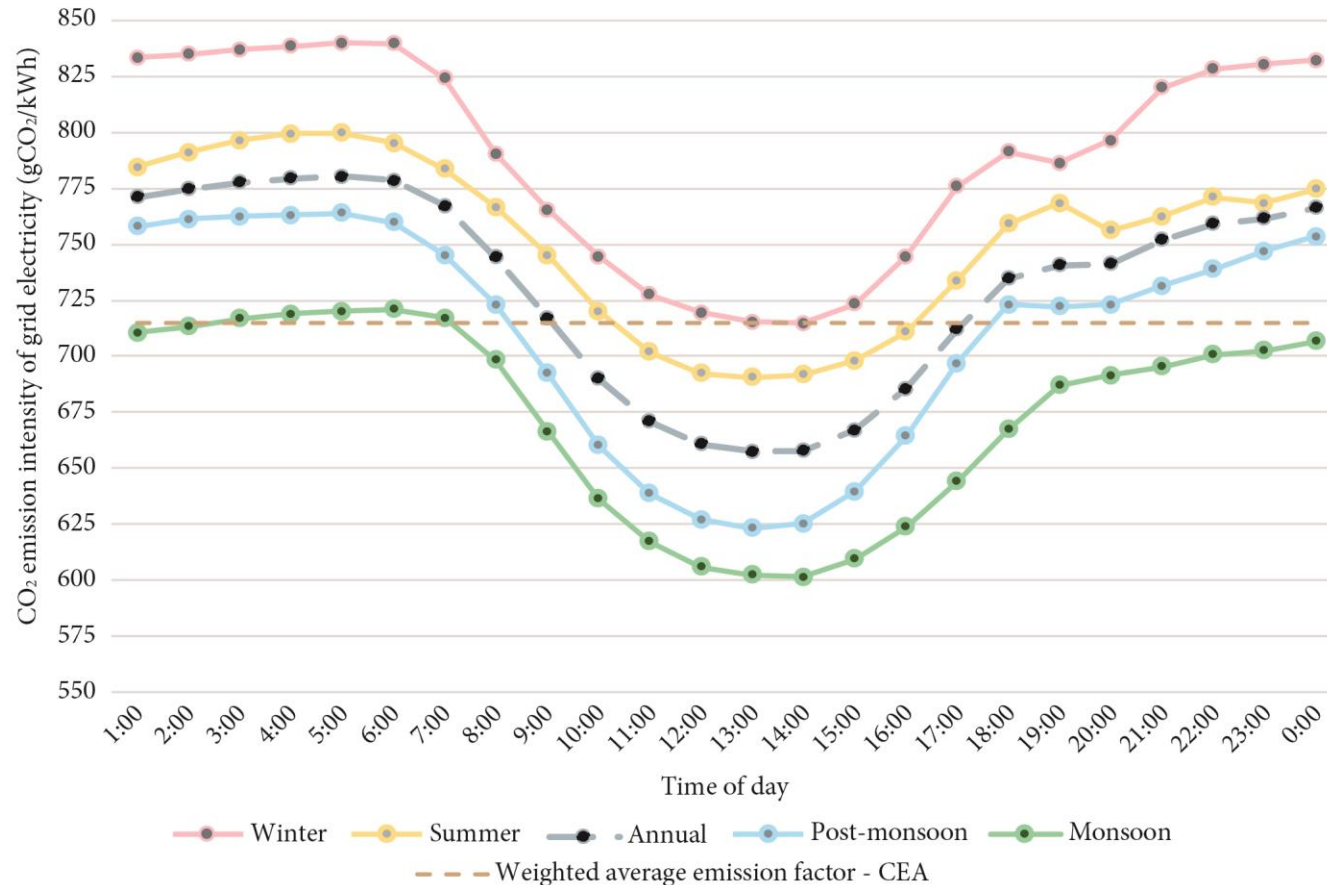
Note:

- These nine Indian cities are with populations of over four million and are identified and listed in the Ministry of Power's revised consolidated EV charging infrastructure guidelines and standards.
- The study has estimated annual average CO₂ emission intensity of electricity supplied in each of these cities by one or more distribution utilities by perusing true-up petitions for FY 2021–22 or the latest available before, filed by the utilities, to get data on power procured from different sources. For details, please refer to the working paper.
- Estimated CO₂ emission intensities of electricity for the nine cities should be considered indicative only.

Acronyms: RPO (Renewable Purchase Obligation); kWh (kilo Watt-hour)

Time-of-day charging has a major impact on CO₂ emissions

Temporal pattern of CO₂ intensity of grid electricity in 2022



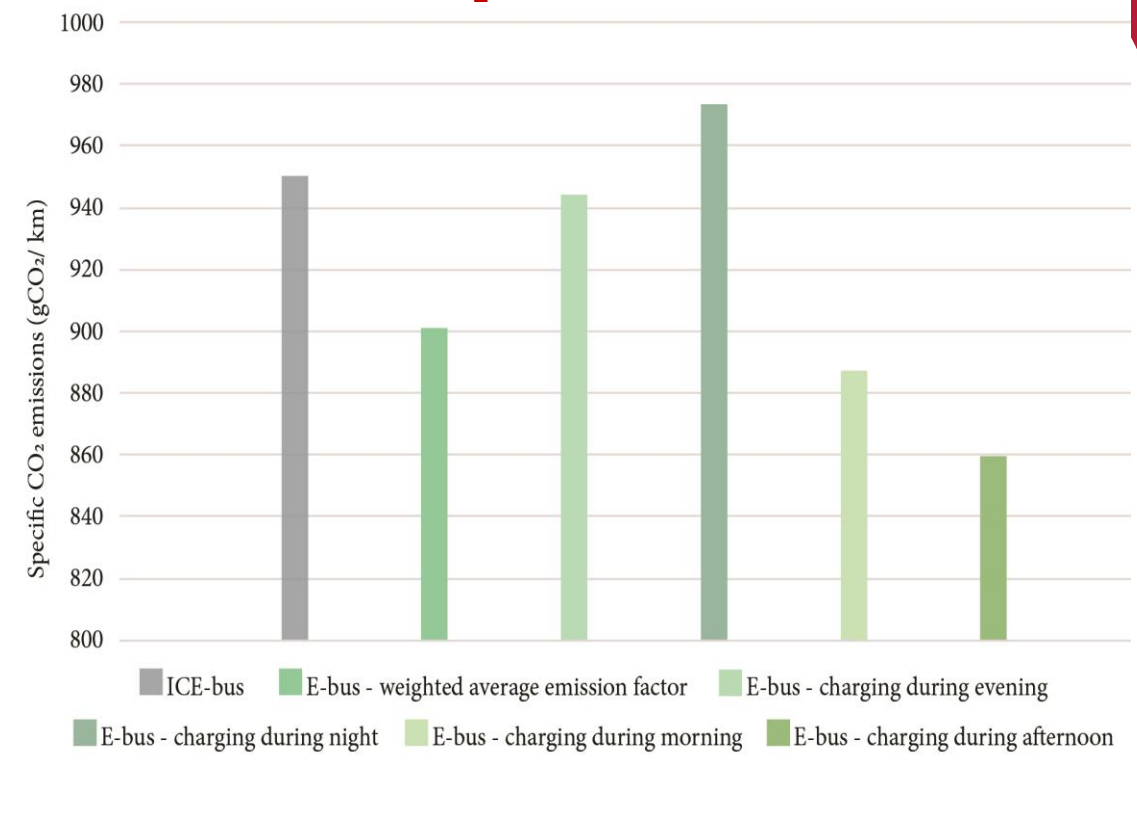
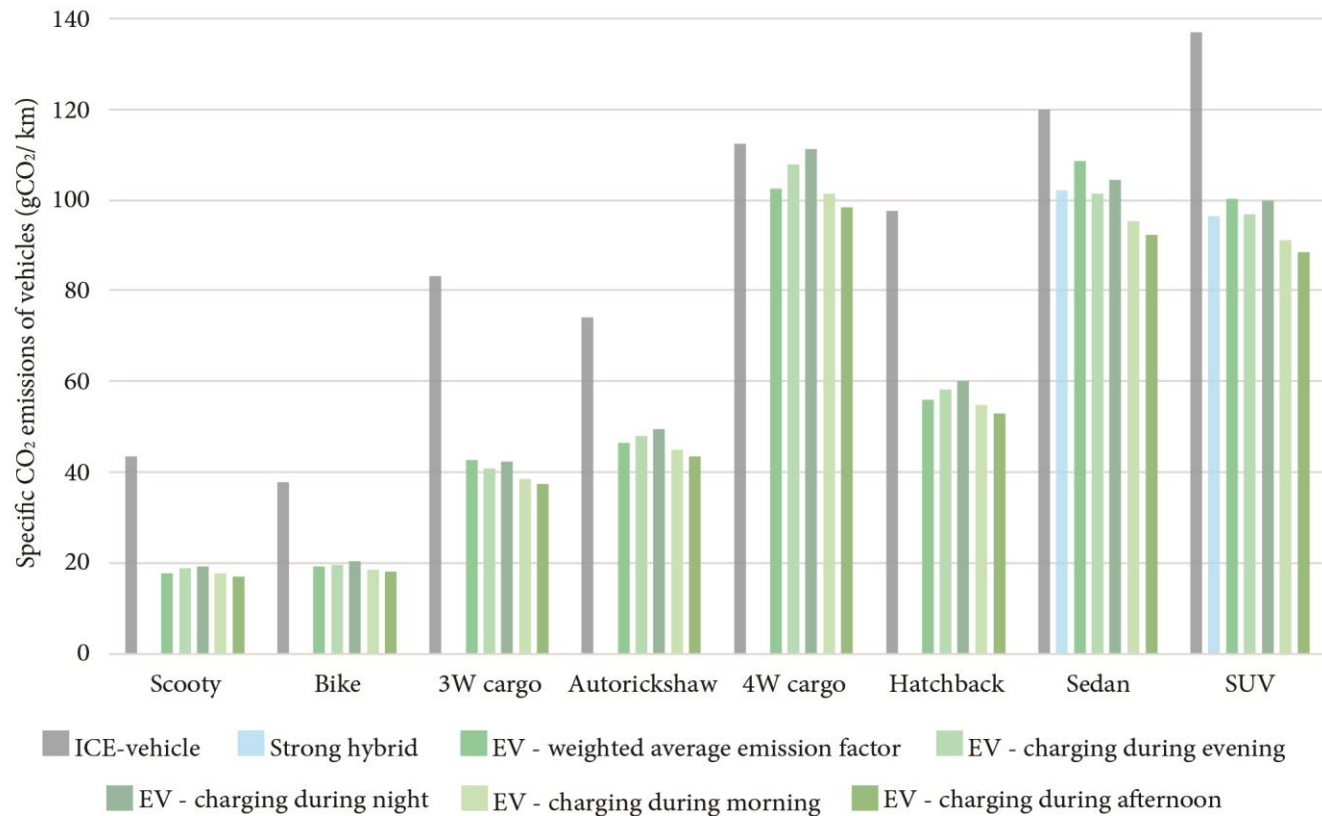
- Annual average EF of grid electricity masks impact of ToD variation in electricity supply-mix and EV charging demand.
- Share of zero-carbon electricity in grid power supply is highly skewed.
 - This is due to rising share of solar energy.
- gCO₂ per kWh of grid electricity is low during mid-day and climbs up during non-solar hours.
 - Gap between maximum and minimum hourly gCO₂ per kWh values is about 19%.
- EVs may deliver significant, limited, or even negative GHG emissions savings depending on their charging alignment with periods of high RE supply.

Note:

- carbontracker.in, the Centre for Social and Economic Progress’s webtool, captures real-time data on India’s electricity generation by type of source. The underlying generation data that is processed by the tracker is sourced from the Ministry of Power’s MERIT India portal.
- Winter is from December to February, summer spans from March to May, monsoon lasts from June to August, and post-monsoon is from September to November.

Daytime charging of EVs crucial to reduce GHG emissions

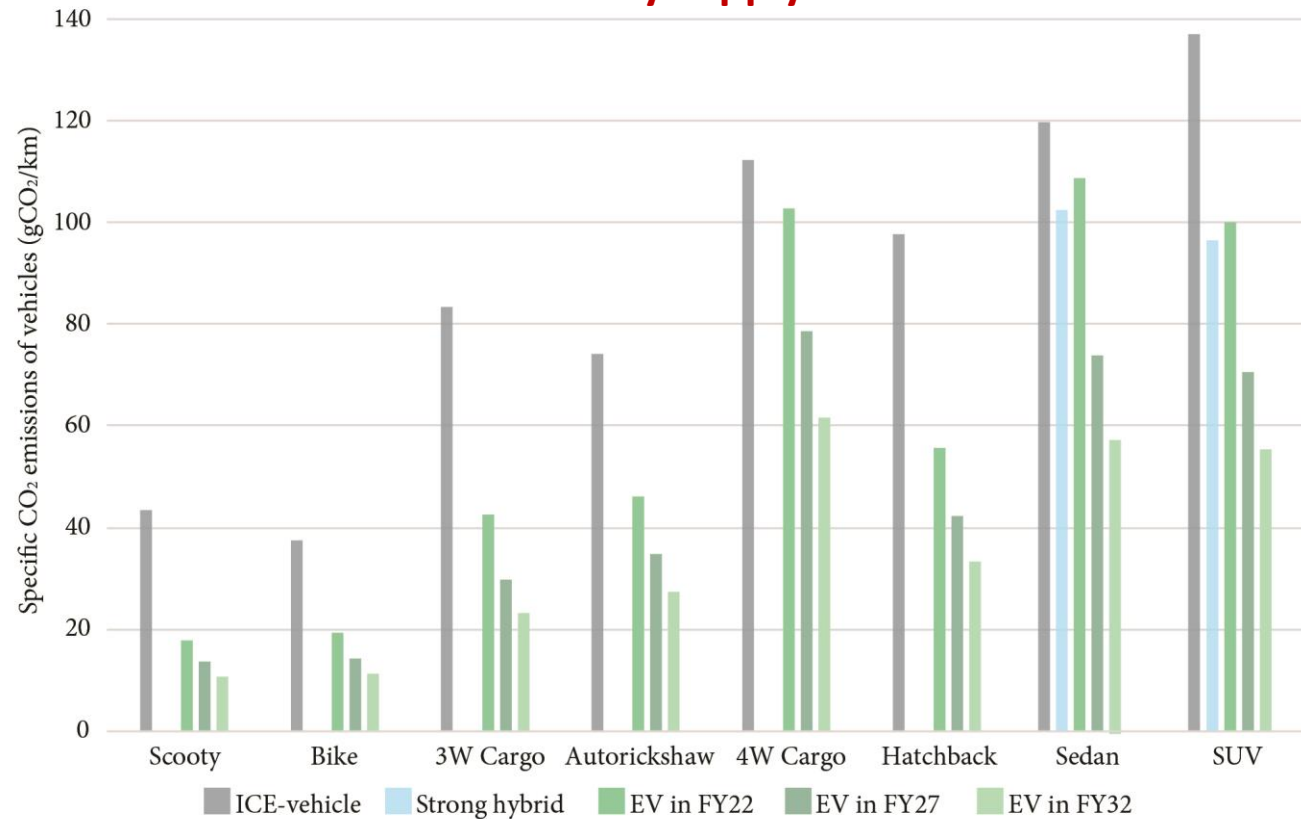
Time-of-day CO₂ emission intensities of non-heavy-duty EVs in 2022 | **Variation in specific CO₂ emissions of an e-bus with ToD**



- Choosing the **right time to charge** can significantly **alter emissions profile** of an EV.
- **Daytime charging avoids 10% extra CO₂ emissions** than during evening **in present scenario**. This translates to:
 - Additional yearly emission savings of 10 kg CO₂ per e-scooter and 106 kg per e-sedan.
 - **Avoiding 20 kilo-tonnes of CO₂ more annually** considering total number of e-two-wheeled vehicles and e-cars on road.
- Impact is **profound for e-buses**; **daytime charging** is not just beneficial but **essential for emission reductions**.

Future desired RE growth progressively makes EVs greener

Specific CO₂ emissions of EVs vis-à-vis conventional vehicles in as-is and future electricity supply-mix scenarios

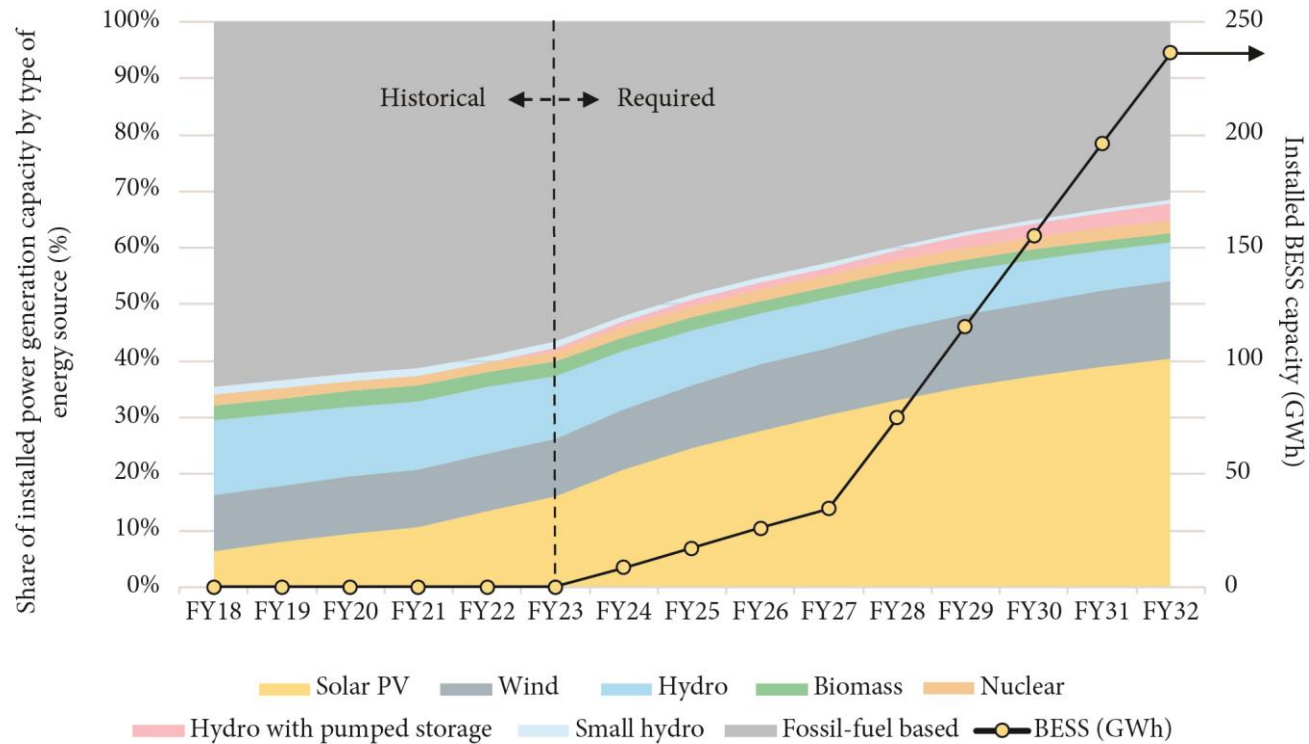


- India's NEP draws a desired low-carbon pathway for electricity sector till FY 2031-32.
- If desired non-fossil-fuel-based power generation capacity is achieved,
 - **non-fossil-fuel sources** would contribute **39%** and **49%** of total gross electricity generation in **FY 2026-27** and **FY 2031-32** respectively.
 - national annual average emission factor would be **548 gCO₂/kWh** in **FY 2026-27** and **430 gCO₂/kWh** in **FY 2031-32**.
 - **EVs across all segments** would be **the most climate-friendly alternative** (based on national annual average EF) among mainstream options.
- **Midday charging** potentially allows **EVs** to become **lowest-emission alternative even today**.

Note: The CO₂ emissions values for EVs in FY 2026-27 and FY 2031-32 are based on CEA-estimated national annual average CO₂ emission factor for grid electricity for the corresponding period in the desired electricity supply scenario.

However, unlocking deep emission cuts will be challenging

Historical and projected power generation capacity mix



Note:

- Data for required power generation and BESS capacity are sourced from NEP.
- How much and how long proposed storage capacity additions will be able to supply RE during non-solar hours daily all year round have not been studied.

- To achieve desired low-carbon power mix, India has to install yearly:
 - 43 GW between FY 2023-24 and FY 2026-27
 - 53 GW between FY 2026-27 and FY 2031-32.
- In contrast, the country added non-fossil-fuel-based capacity of **11.5 GW annually** in past 5 years.
- **Very high required run rate with limited runway** left to achieve desired power generation mix.
- Without enough LDES capacity, daily distribution of **RE supply** will be remain **skewed towards midday**.
 - As per NEP, **share of solar energy** supply will nearly **triple by FY 2026-27** and **quadruple by FY 2031-32**.
 - At present, utility-scale energy storage capacity is almost non-existent.
- **Daytime charging** of EVs will **remain important in future** with rapid rise in share of solar energy.

A Call to Action for a sustainable electric mobility future

A holistic and realistic approach with coordinated action from policymakers, industry stakeholders, and consumers is necessary.

Align EV charging with hours of high RE availability

- Introduce ToD electricity tariffs tailored for each distribution utility
- Provide public charging at workplaces to encourage daytime charging
- Leverage charging flexibility in case of battery swapping

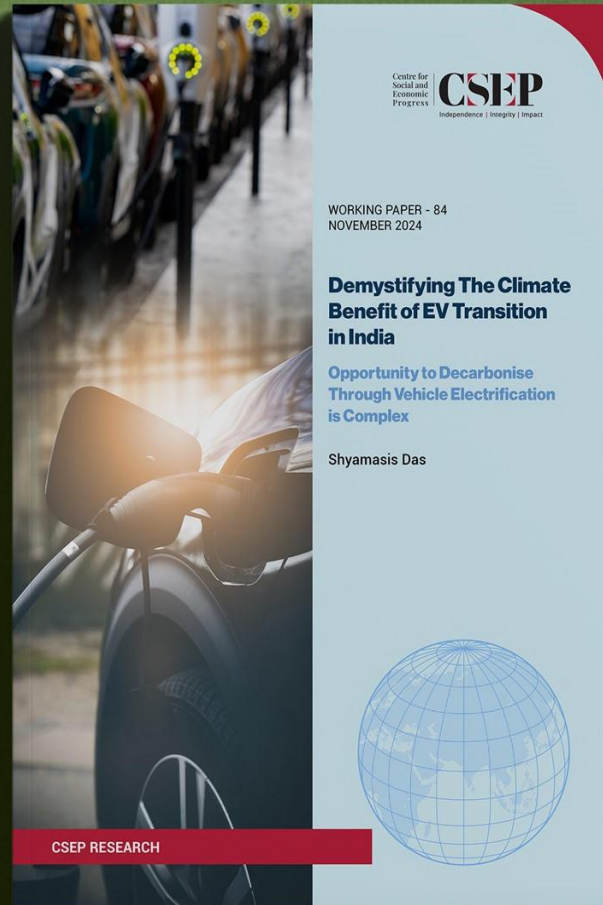
Promote EV models with higher energy efficiency

- Mandate energy labelling of traction battery packs and systems
- Set more stringent CO₂ emission targets under future CAFE enforcement cycles with expanded scope (cover more segments)

Couple EV charging infrastructure with distributed RE resources

- Facilitate through innovative renewable-energy-as-a-service mechanisms
- Employ end-of-mobility-life batteries for RE storage at charging stations to charge EVs during non-solar hours

Thank you!



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Demystifying The Climate Benefit of EV Transition in India

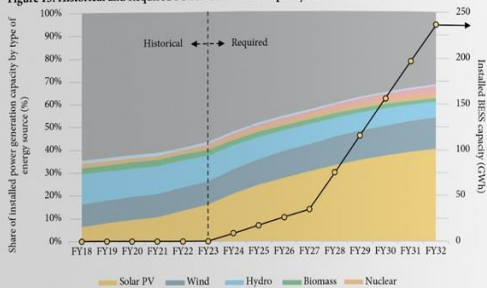
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Figure 13: Historical and Required Power Generation Capacity Mix



Legend: Solar PV, Wind, Hydro, Biomass, Nuclear, Hydro with pumped storage, Small hydro, Fossil-fuel based, BESS (GWh)

consumption, be it in the form of EV charging even during daytime, is likely to result in a greater need for coal-based thermal power until renewable energy reaches surplus and curtailment stage.

7. Conclusion: Major Findings and Policy-Relevant Recommendations

The range of analyses on operational GHG emissions of EVs vis-à-vis conventional vehicles in different contexts leads to several major findings and in turn, warrants some key policy actions.

7.1 Key Findings

Following are the 10 major outcomes of this research:

- The climate dividends from the energy efficiency superiority of EVs over ICE and strong hybrid vehicles are diminished significantly by the current coal-dominated supply mix of India's grid electricity. This is especially conspicuous when the electric format is pitted against the strong hybrid version in the sedan and SUV segments.
- The electricity supply blend across the country is not homogeneous owing to the varied power procurement baskets of distribution utilities (licensees). Electricity supplied in Kolkata, Pune, and Mumbai is more carbon intensive than the national average, while Bengaluru has the greenest power among the sampled nine cities. Consequently, CO₂ emissions from EV charging differ considerably from one city or state to another.
- The rapid rise in the share of VRE, especially solar, and the absence of long-duration energy storage capacity potentially skews the daily distribution of low-carbon electricity. Emissions calculations based on the annual average emission factor of grid electricity mask the impact of temporal variation in electricity supply mix, which is especially important in the case of a dynamic load like EV charging.
- Considering the majority of EV charging sessions occur during the evening and night-time when the share of renewable energy plummets, the ability of EVs to decarbonise India's motorised road transport needs to be properly qualified. There

is an urgent need for interventions to encourage and enable daytime alignment of EV charging.

- The importance of daytime charging cannot be overstated in case of e-buses. Evening and night-time charging that meets bulk of the charging requirement of an e-bus fleet currently is likely to cause similar or even greater CO₂ emissions than conventional buses.
- Two-wheeled and three-wheeled EVs are found to emit less CO₂ emissions than their ICE counterparts even when they are charged during the evening or night. Alignment of their charging with solar hours potentially offers significant emission cuts.
- Provided future power generation capacity addition follows the projected low-carbon trajectory, as per the National Electricity Plan, within this decade vehicles with electric drivetrain will be able to curb GHG emissions across all vehicle segments.²⁹ Interestingly midday charging gives EVs a similar emissions edge over conventional vehicles even today.
- Solar-heavy decarbonisation efforts in the power sector will be a challenge for making EV charging green unless adequately complemented by long-duration energy storage capacities.
- The conditional climate benefit of vehicle electrification is valid for other types of electricity end-uses too, particularly one with a variable demand profile like residential electricity consumption.
- EVs can potentially enhance their energy efficiency supremacy over conventional vehicles in the coming years on the back of improvement in the energy density of EV batteries and increased efficiency of electric drivetrains, whereas reasonable improvement in fuel economy of ICE powertrains has almost plateaued.

Based on the range of insights into the real or conditional opportunity to avoid GHG emissions through EV transition, and the associated challenges, ministries, regulators, and implementing authorities at both Central and State levels may be able to take more informed policy decisions.

²⁹ Due to very limited natural gas availability for power generation and inadequate surplus reservoir capacity of the large hydro power plants. Subject to grid stability requirements.

³⁰ This is with a caveat that the highly skewed daily profile of renewable energy availability due to VRE and lack of flexibility of charging demand to shift to solar hours may pose a major challenge.

Link to download: <https://csep.org/working-paper/demystifying-the-climate-benefit-of-ev-transition-in-india/>

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