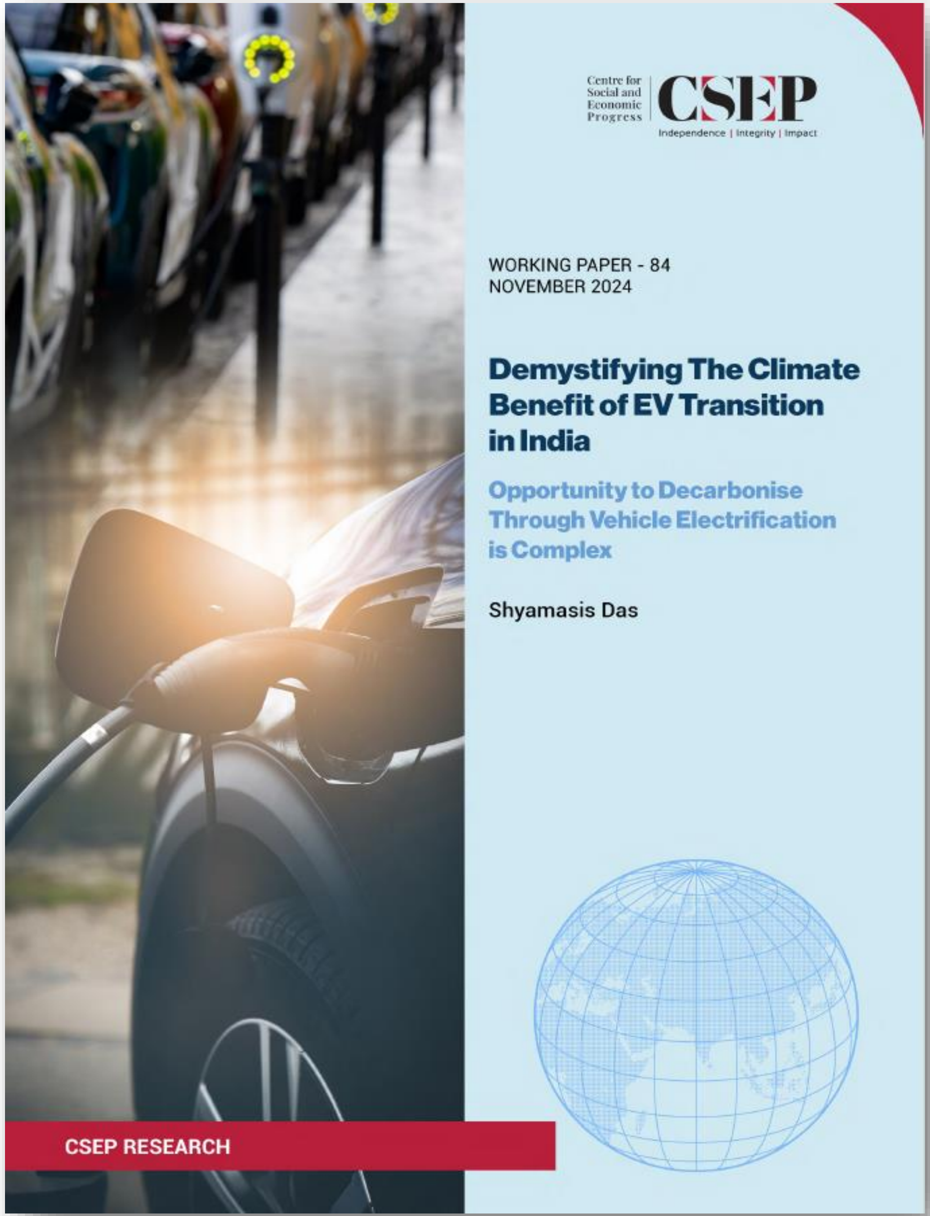

Demystifying the Climate Benefit of EV Transition in India

Opportunity to Decarbonise through Vehicle Electrification is Complex

Highlights

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December 2024

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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 CO_2 emission intensity of grid electricity considering variability in share of RE in supply-mix.
  - Differences in electricity supply mix at city-/ state-level.

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Acronyms: EV (electric vehicle); GHG (greenhouse gas); CO_2 (carbon dioxide); RE (renewable energy)

Past attempts heavily relied on simplistic analysis

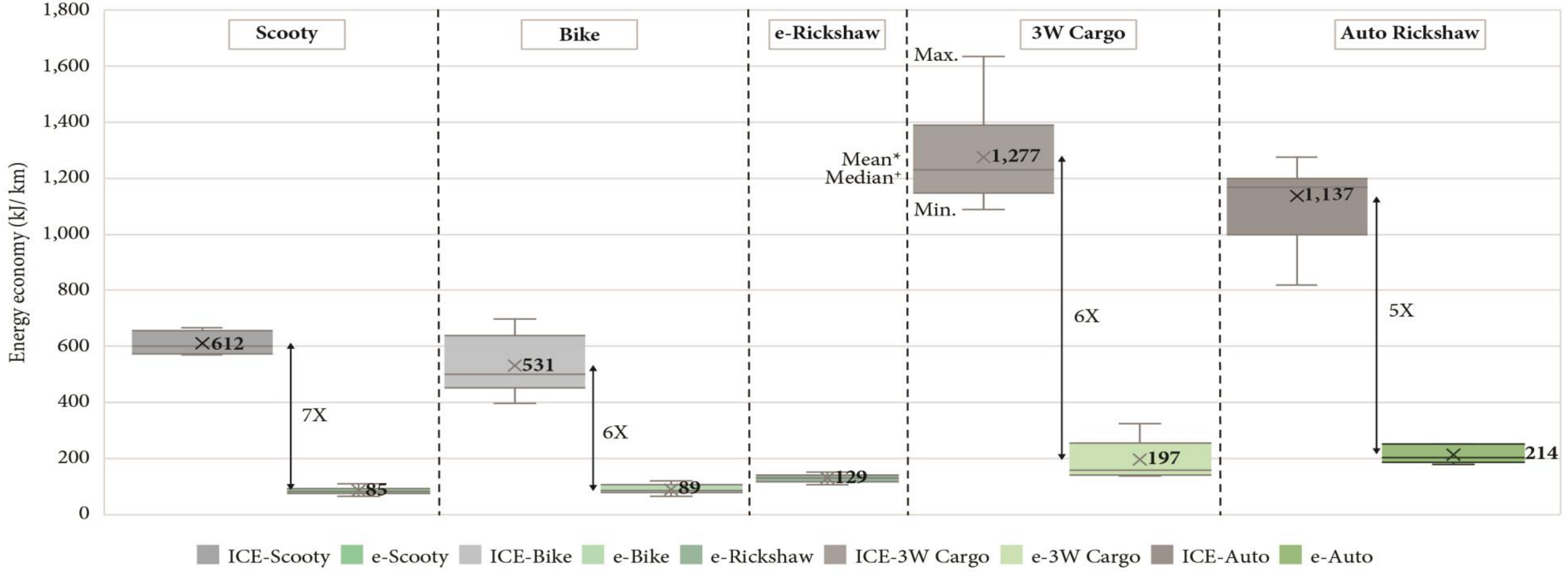
Pitfalls in current run-of-the-mill evaluation approach

- 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:

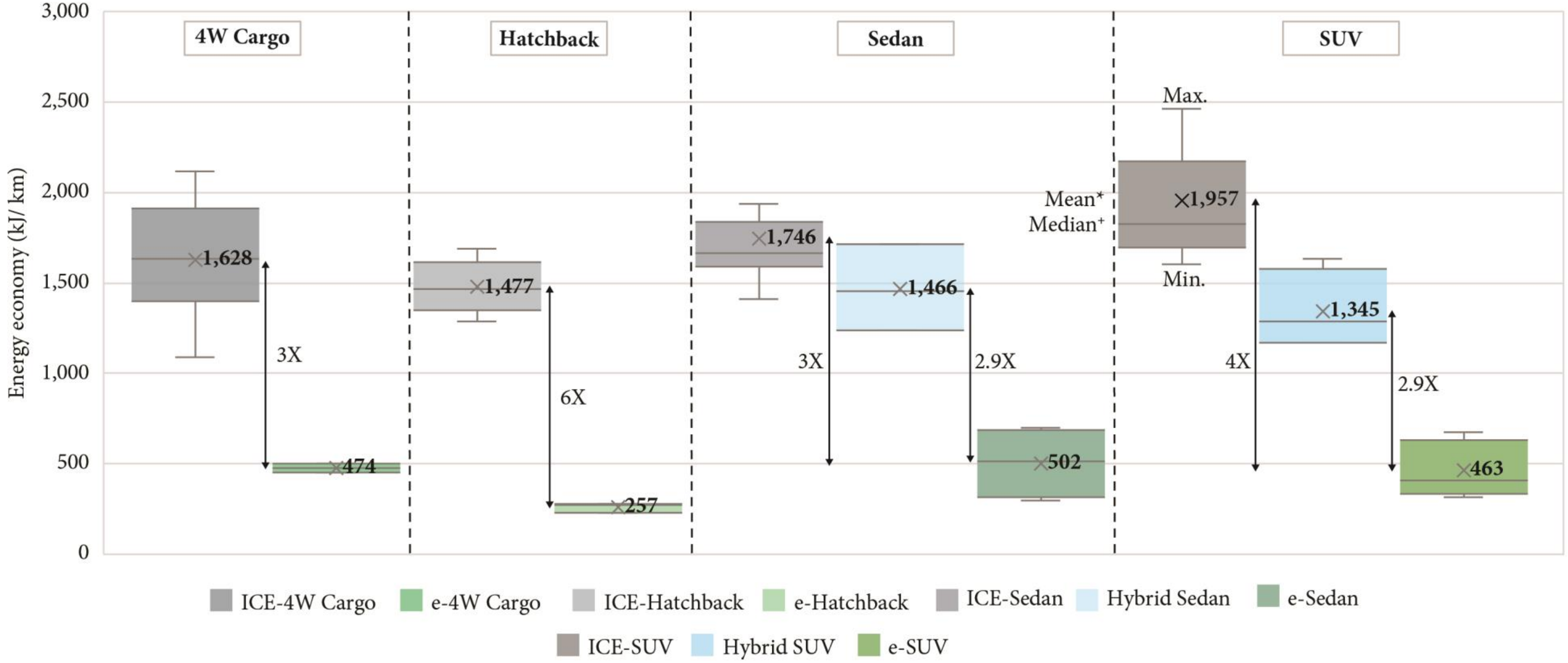
- Model stock refers to group of models of a particular technology in a vehicle segment.
- Mean refers to the average of the energy economy values of different models in a segment. It is not a weighted average based on vehicle sales.
- Median refers to the middle value of the given data when all the 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.

Acronyms: EE (energy efficiency); ICE (internal combustion engine); kJ (kilo Joule); km (kilometre)

Electric drivetrains outperform in energy efficiency (2/2)

Comparison of energy economies in four-wheeled segments

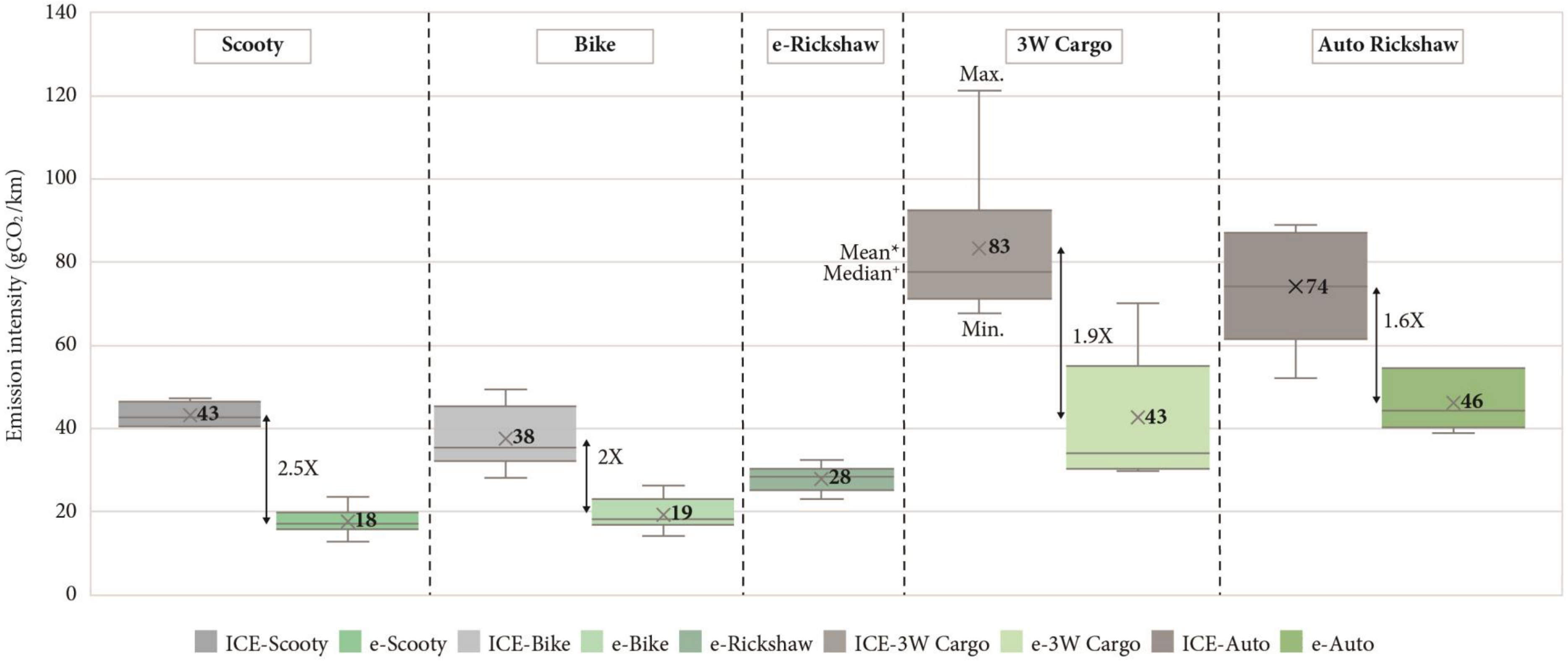


- EE gap narrows when comparison is made between strong hybrid and pure EV model stocks.
- On average, EVs have end-use energy consumption levels at least 3 times lower than conventional counterparts.
- Advancements in battery technology and power electronics to improve EV efficiency.

Acronym: SUV (sports utility vehicle)

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

Comparison of CO_2 emission intensities (gCO_2/ km) in two-wheeled and three-wheeled segments at model stock level



Note: The calculations are based on CEA-published national annual average CO_2 emission factor for grid electricity in FY 2021-22 which is 715 gCO_2/kWh.

- Impact of coal-dominated supply-mix of grid electricity on gCO_2 per km of electric model stock is discernible.
- Where on average an e-scooter is 7 times more efficient than ICE one, its CO_2 footprint is only 2.5 times less.

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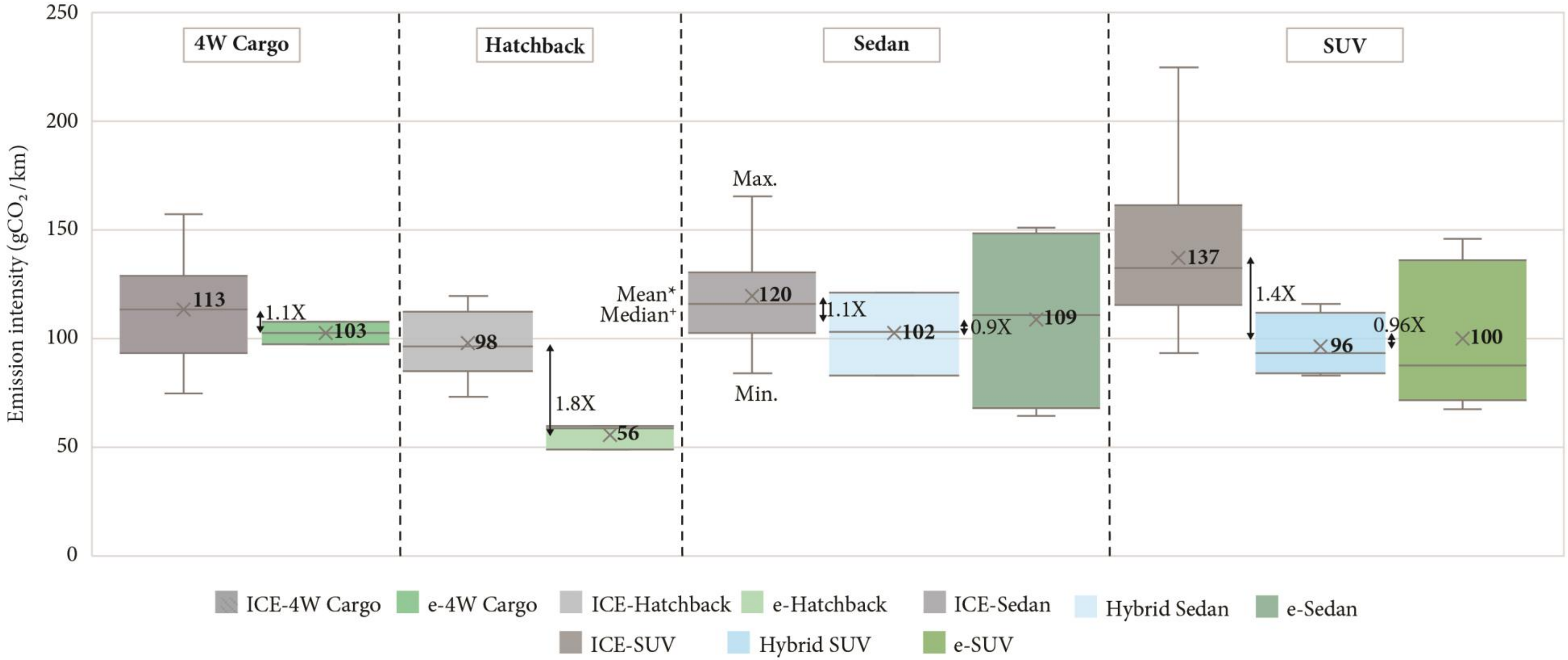
Acronyms: gCO_2 (gram CO_2); FY (financial year); CEA (Central Electricity Authority)

The impact is starker in case of four-wheeled EVs

Comparison of CO_2 emission intensities (gCO_2/ km) in four-wheeled segments

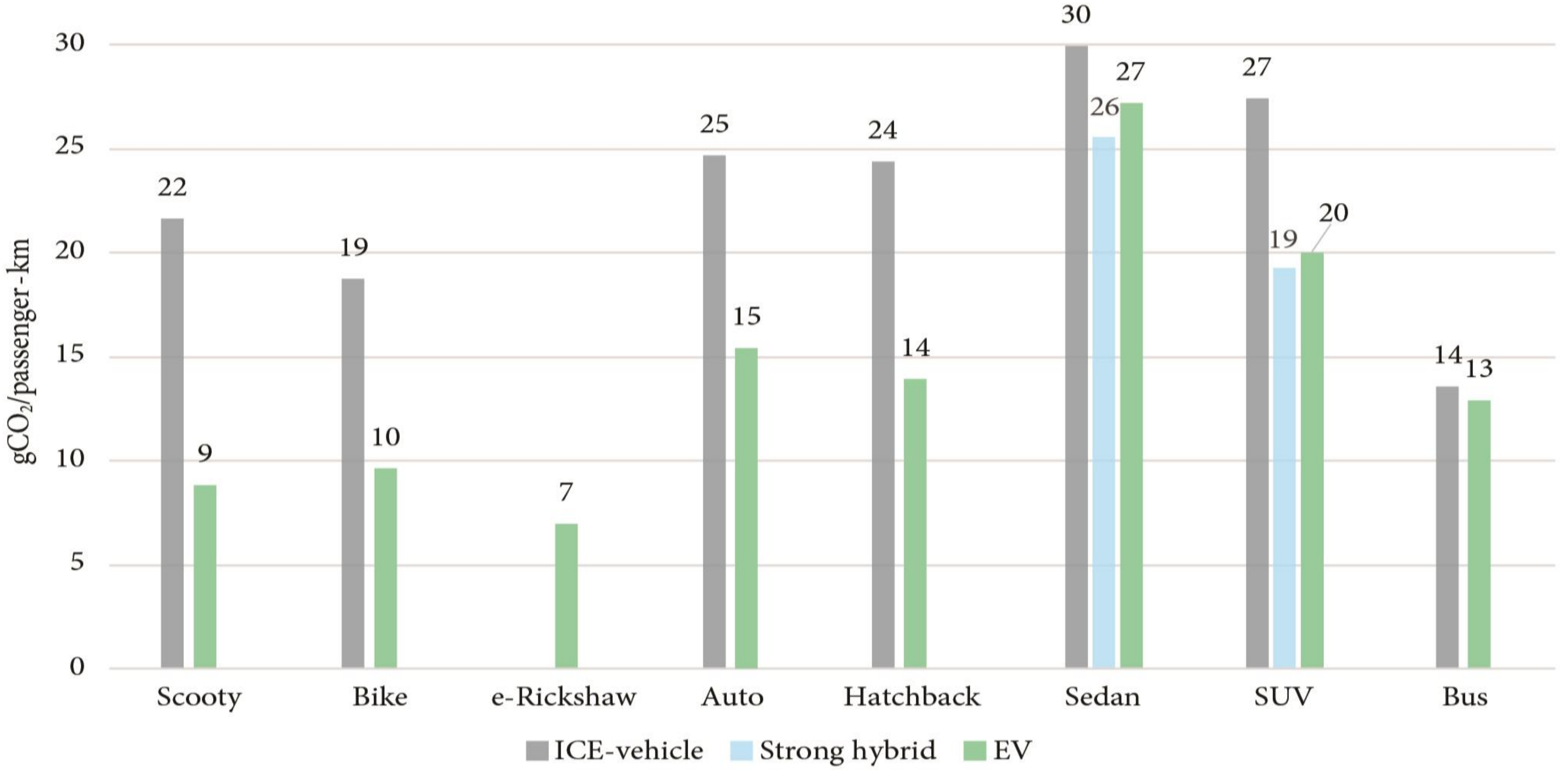


Note: Calculations are at model stock level, based on CEA-published national annual average CO_2 emission factor for grid electricity in FY 2021-12.

- 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 CO_2 emissions per passenger-km

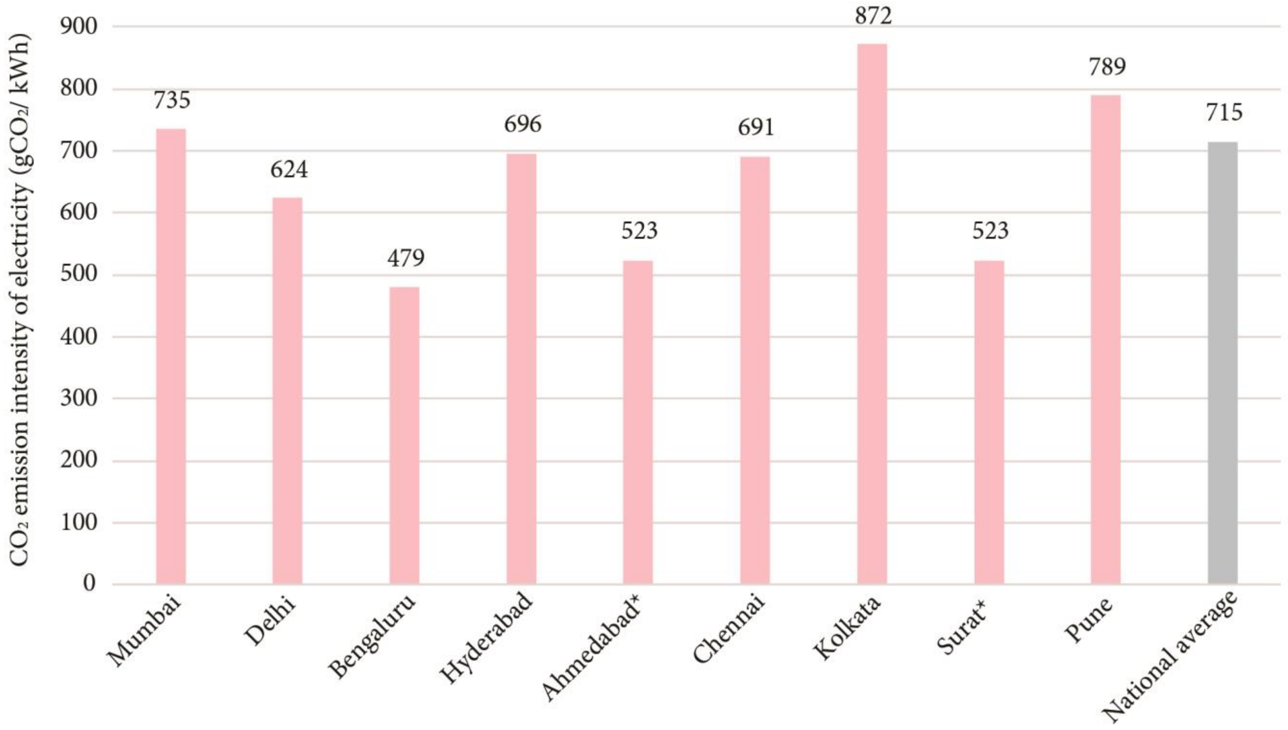


- CO_2 per passenger-km for an ICE-bus are at par of an e-hatchback and lower than any type of sedan or SUV.
  - This comparison is starker if one considers lower occupancy of cars which is often the reality.
- It is paramount to realise modal shift from cars to public bus transport.

Note: CEA-published national annual average CO_2 emission factor for grid electricity for FY 2021-22 has been applied in case of EVs.

EVs do not have similar carbon footprints across India

CO_2 emission intensities of electricity across nine Indian cities in FY 2021-22



*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 CO_2 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 CO_2 emission intensities of electricity for the nine cities should be considered indicative only.

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

- 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 gCO_2 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.

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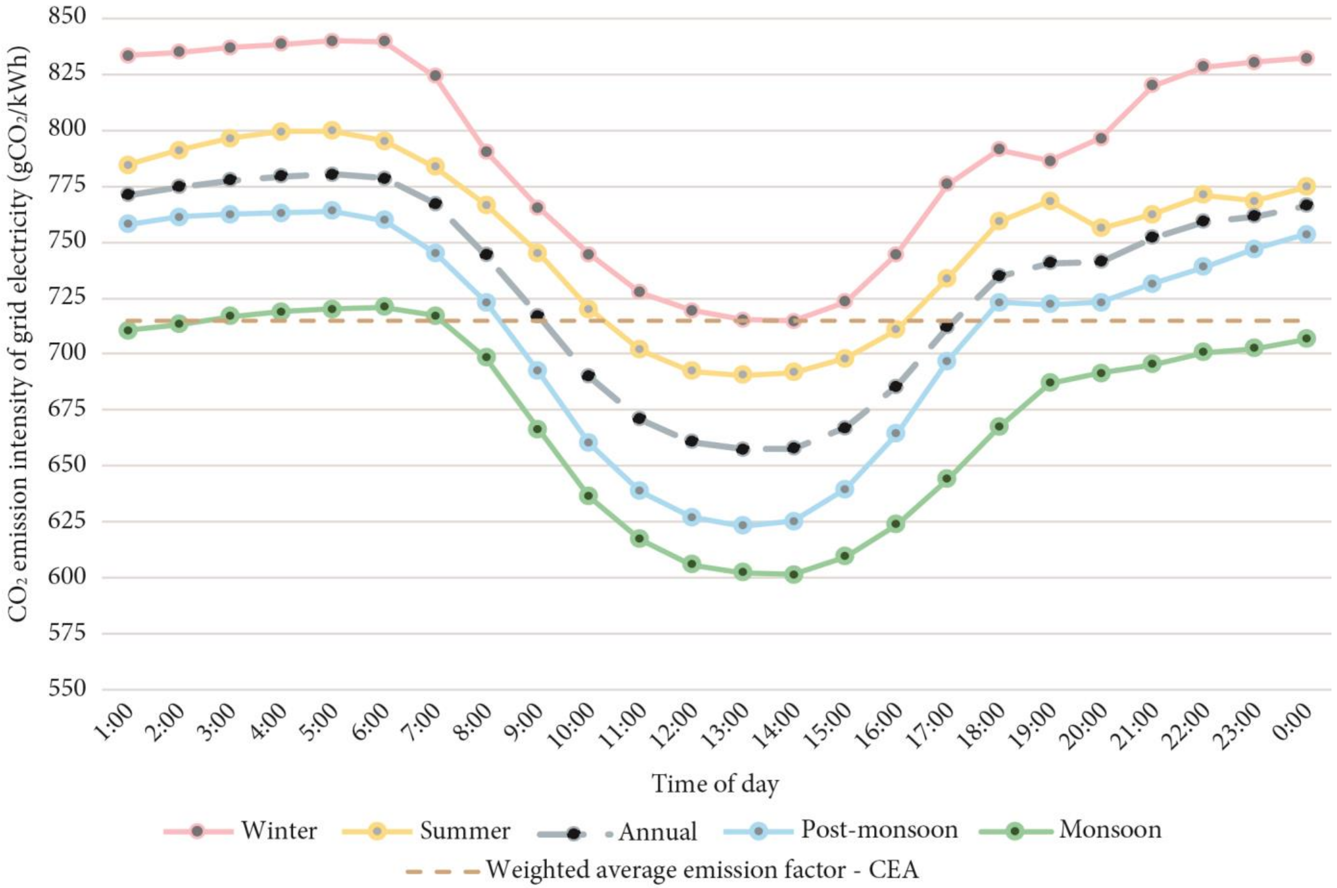
Time-of-day charging has a major impact on CO_2 emissions

Temporal pattern of CO_2 intensity of grid electricity in 2022



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.

- 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.
- gCO_2 per kWh of grid electricity is low during mid-day and climbs up during non-solar hours.
  - Gap between maximum and minimum hourly gCO_2 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.

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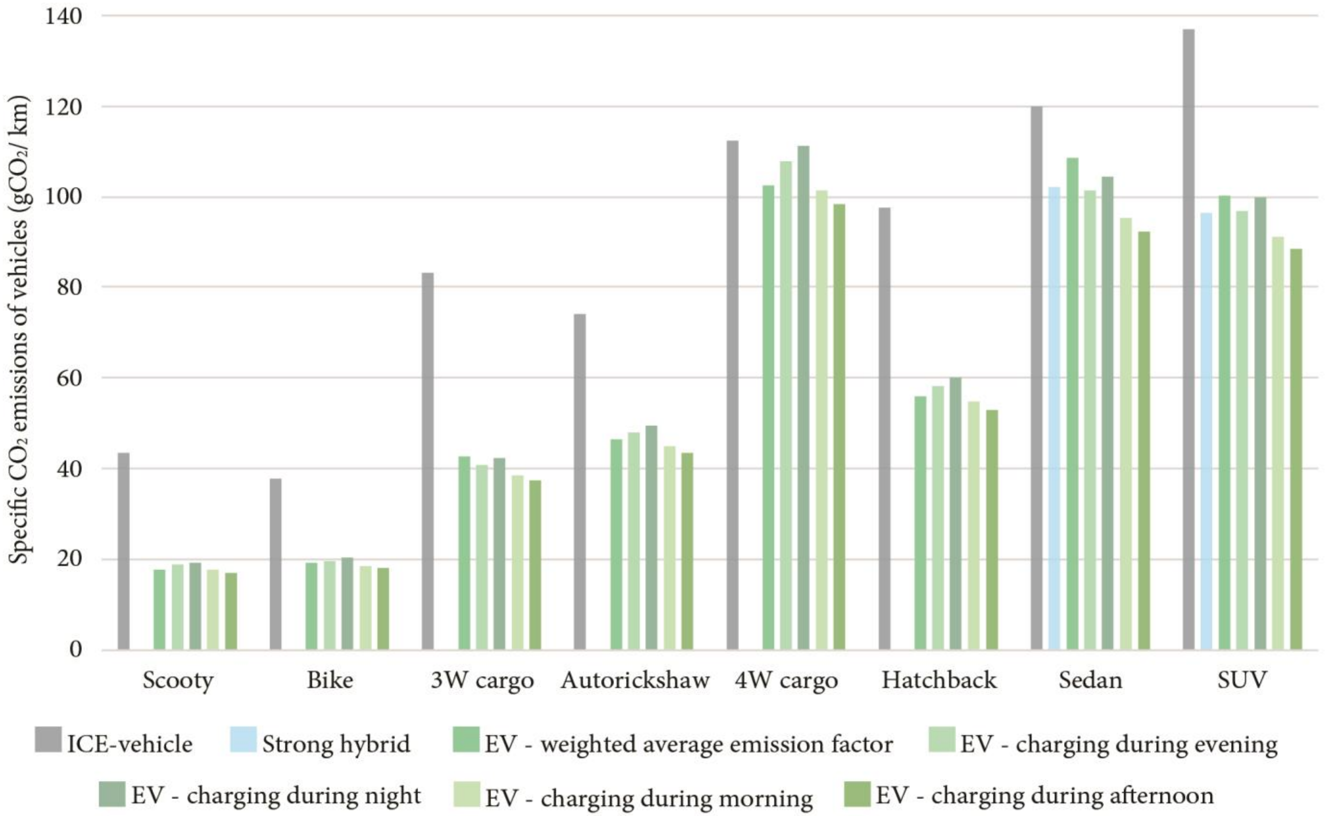
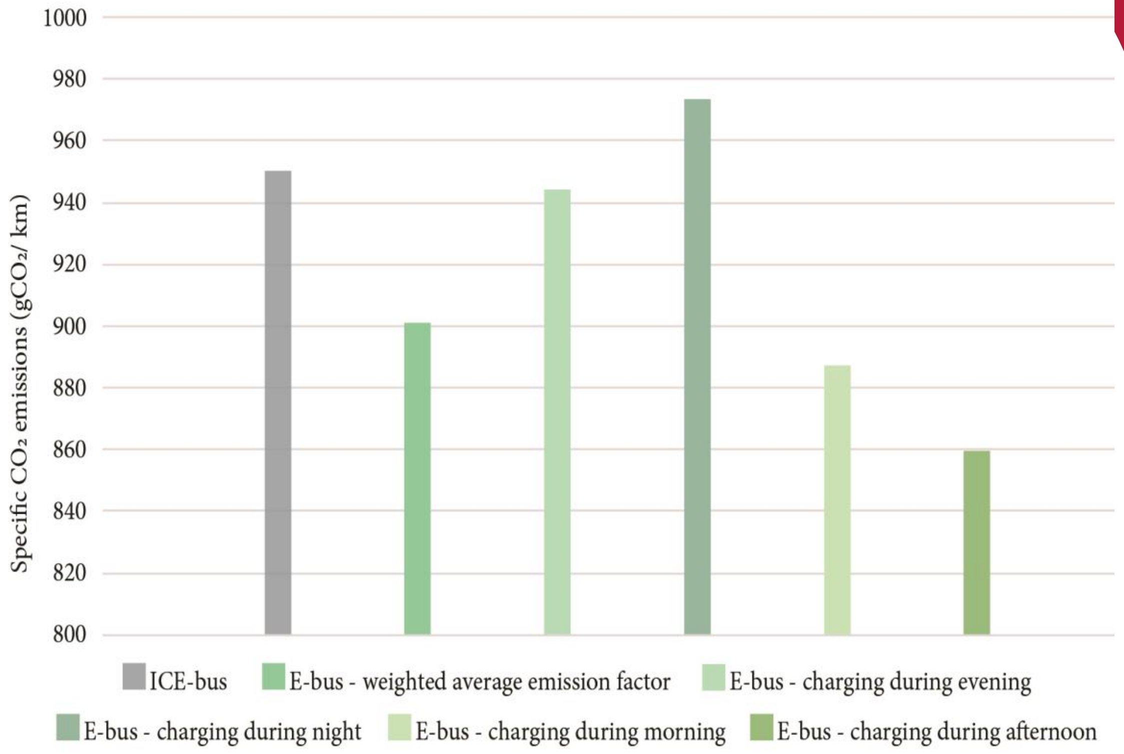
Acronyms: EF (emission factor); ToD (time-of-day)

Daytime charging of EVs crucial to reduce GHG emissions

Time-of-day CO_2 emission intensities of non-heavy-duty EVs in 2022



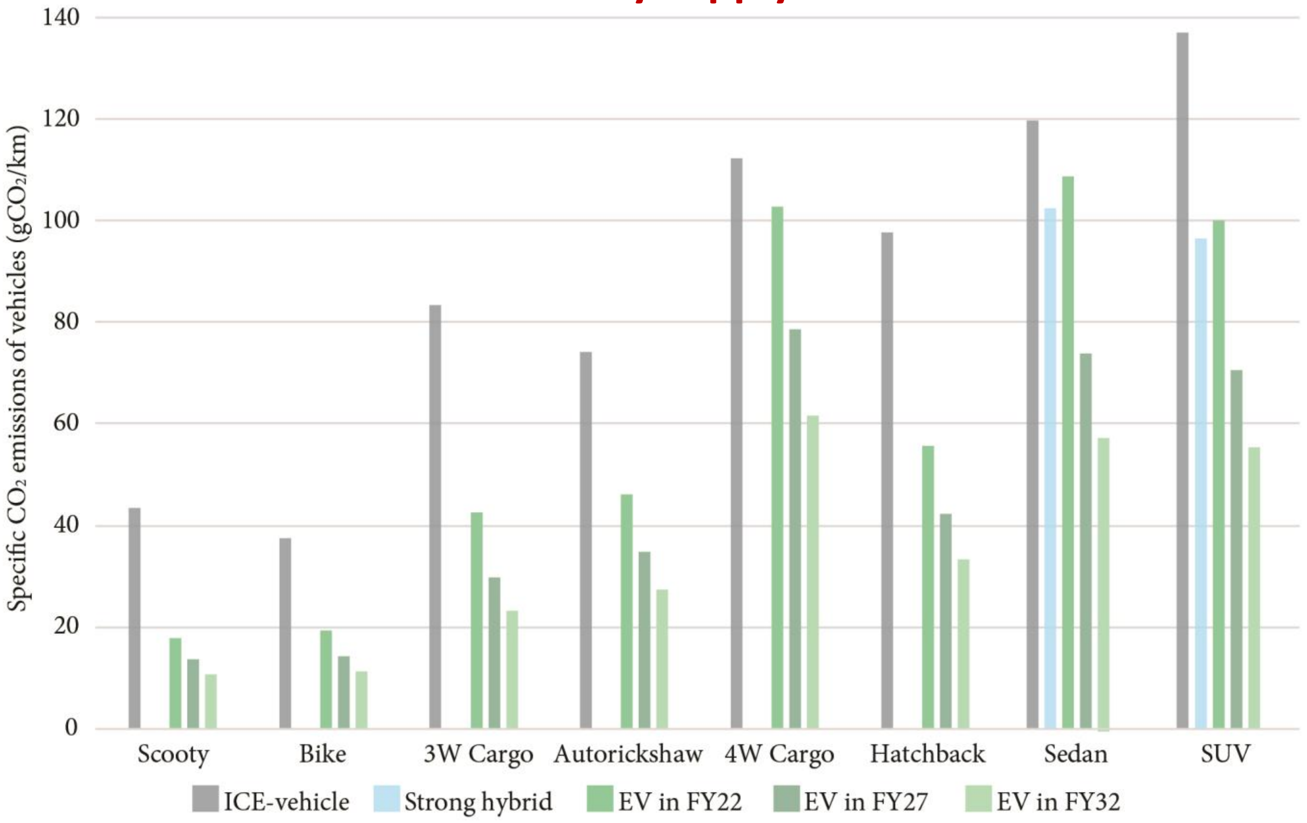
Variation in specific CO_2 emissions of an e-bus with ToD



- Choosing the right time to charge can significantly alter emissions profile of an EV.
- Daytime charging avoids 10% extra CO_2 emissions than during evening in present scenario. This translates to:
  - Additional yearly emission savings of 10 kg CO_2 per e-scooter and 106 kg per e-sedan.
  - Avoiding 20 kilo-tonnes of CO_2 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 CO_2 emissions of EVs vis-à-vis conventional vehicles in as-is and future electricity supply-mix scenarios



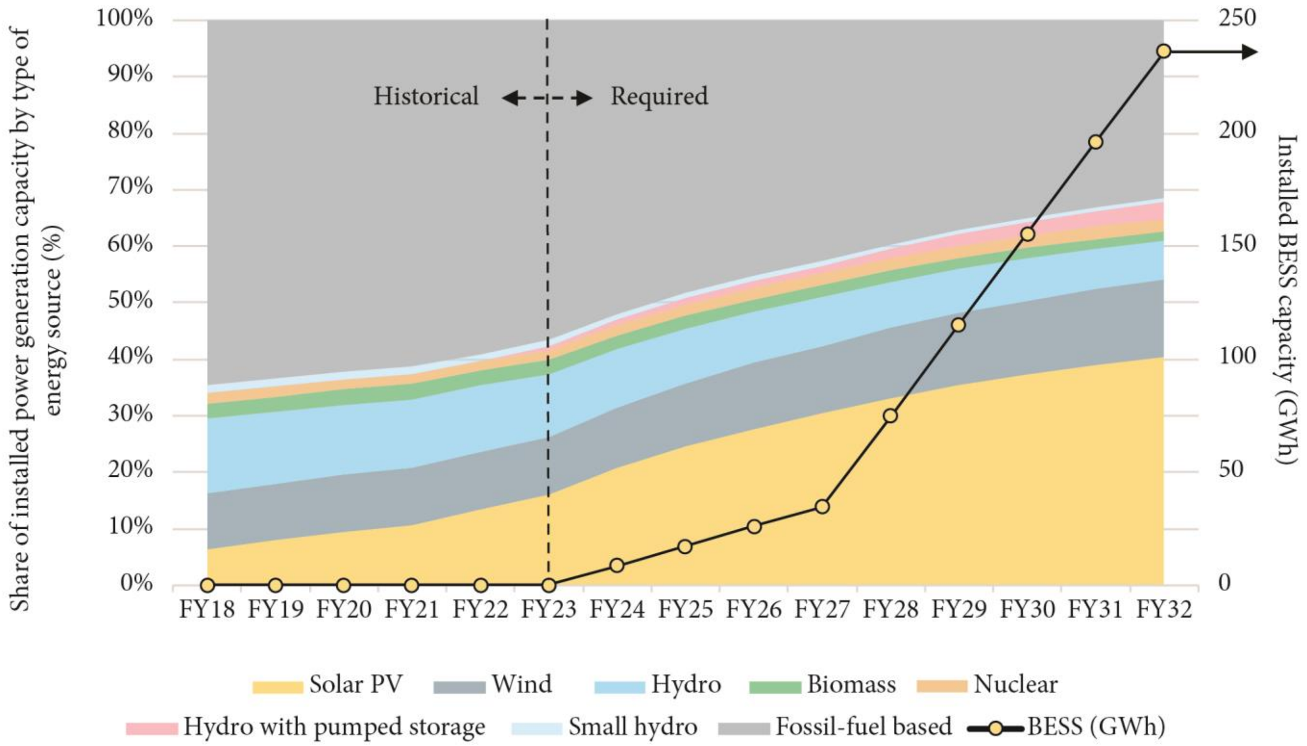
Note: The CO_2 emissions values for EVs in FY 2026-27 and FY 2031-32 are based on CEA-estimated national annual average CO_2 emission factor for grid electricity for the corresponding period in the desired electricity supply scenario.

- 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 gCO_2/kWh in FY 2026-27 and 430 gCO_2/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.

Acronym: NEP (National Electricity Plan)

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.

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Acronyms: LDES (long duration energy storage); GW (Giga Watt)

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 CO_2 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

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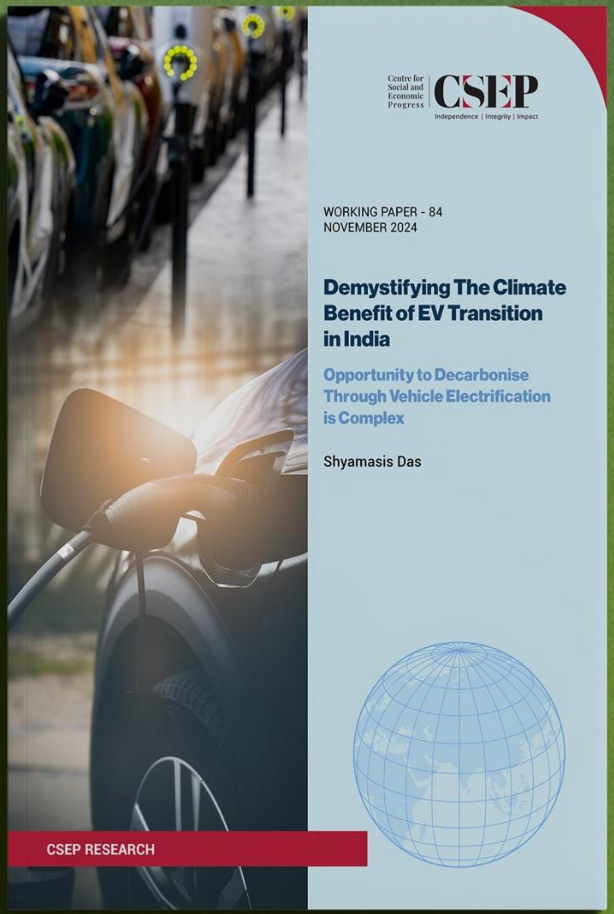
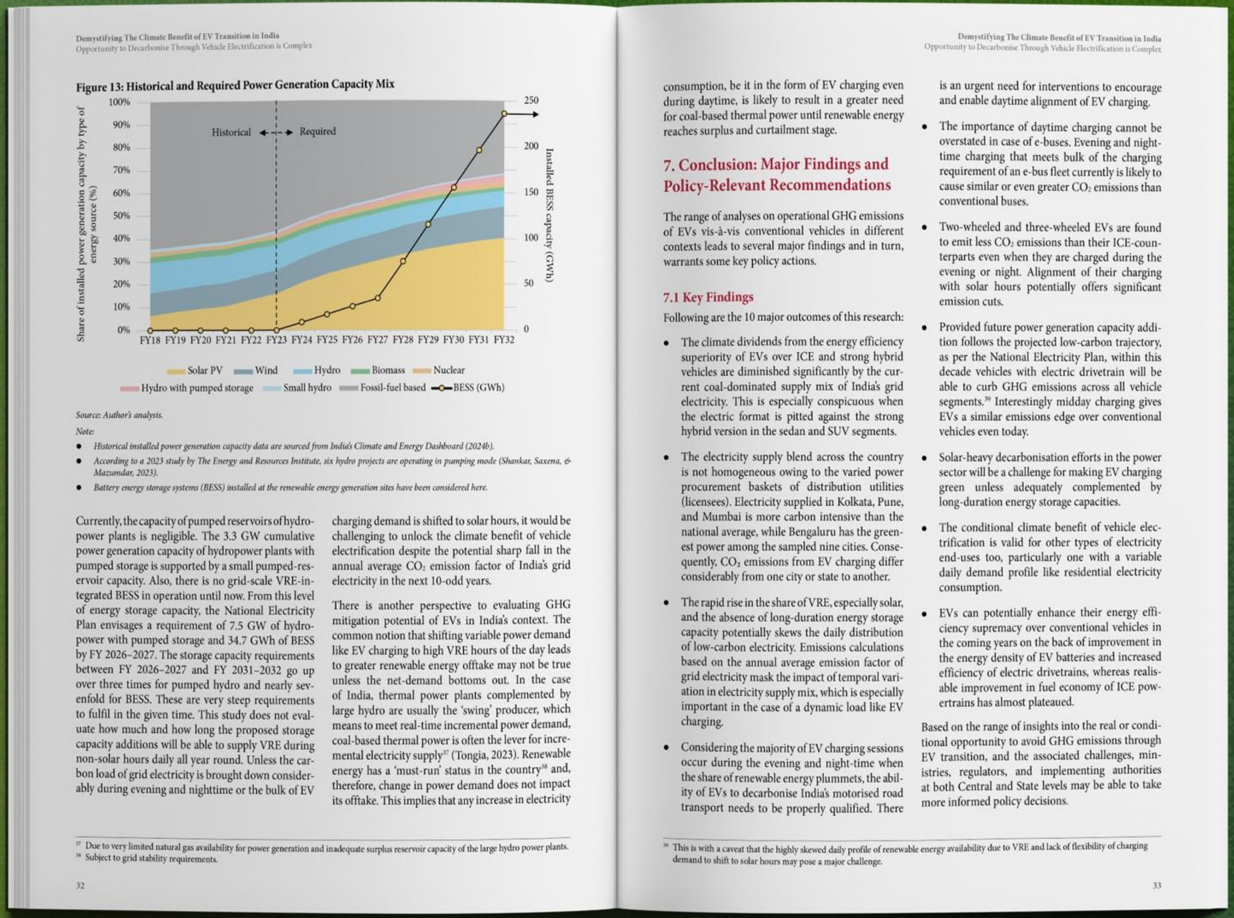
Acronym: CAFE (Corporate Average Fuel Economy)

Thank you!





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

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