A Life-Cycle Investigation into Shifting Pollution From Cities to Rural Power-Generation Regions in India

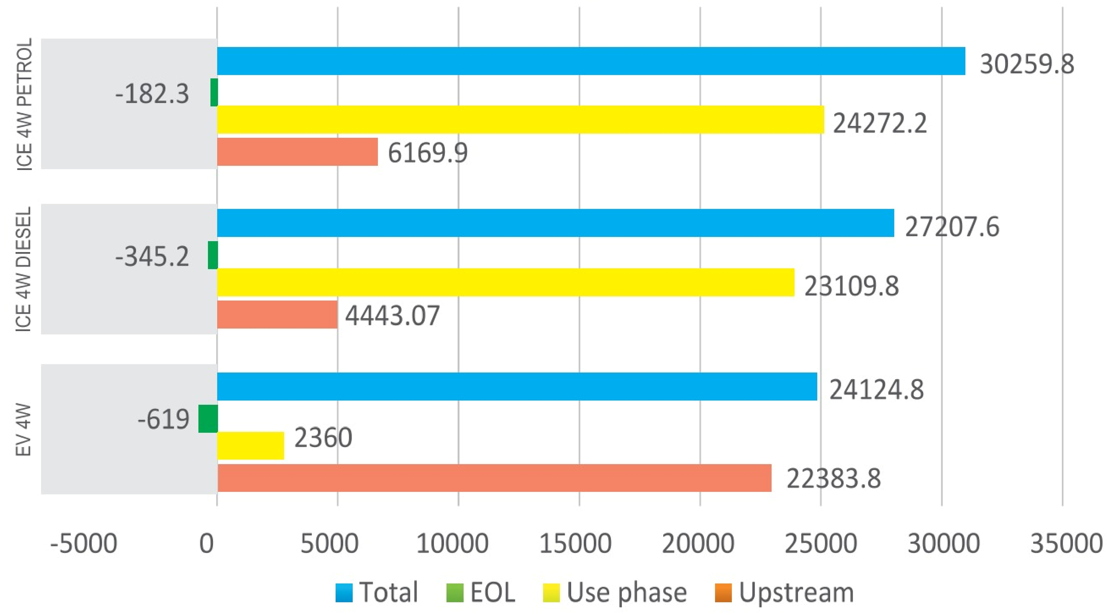
Keshav M, Keshav S, Mahima, Shreyas

Indian Institute of Technology, Bombay (EE 6109: EV Powertrain)

Core Thesis

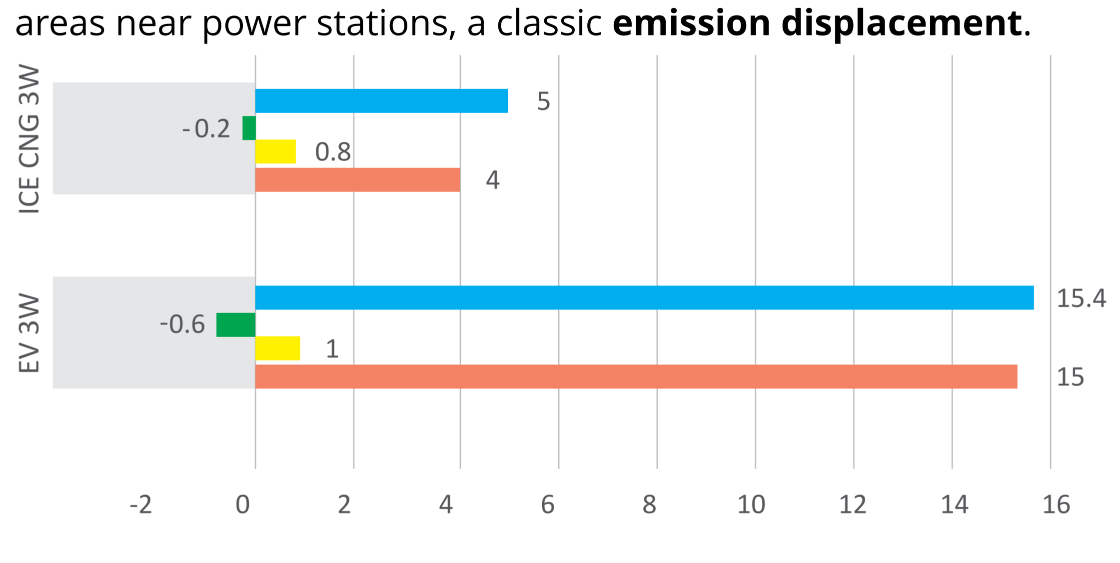
Electric vehicles in India significantly lower urban GHG and tailpipe pollution, but their upstream environmental burden (electricity generation + battery manufacturing) shifts emissions to rural and industrial regions where coal-based power is produced. The real climate benefit of EVs depends entirely on India's grid becoming cleaner.

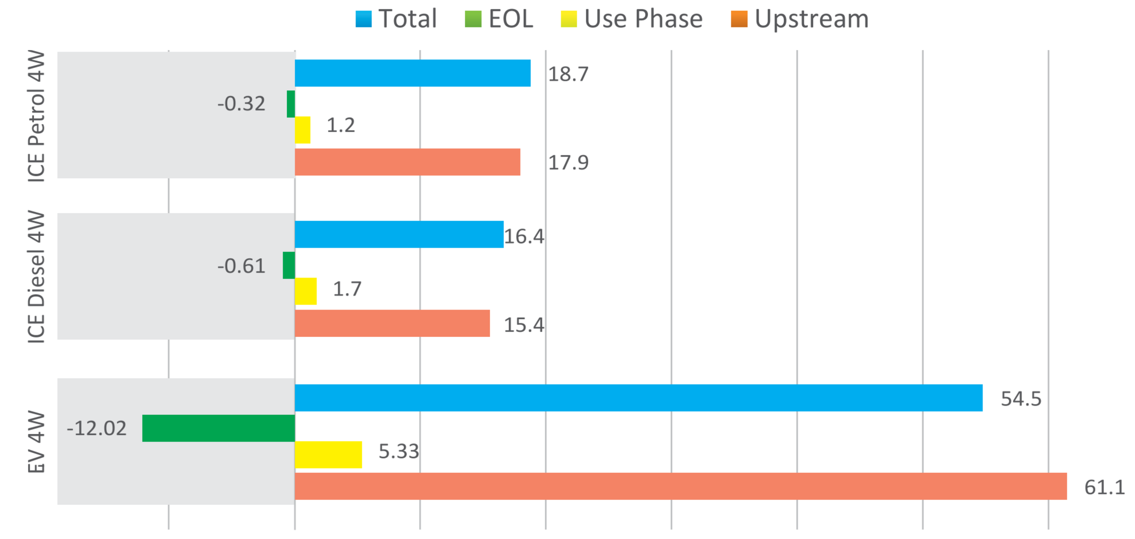
Lifetime CO_2 Emissions: ICEs vs EVs



Fine Particulate Matter (PM2.5)

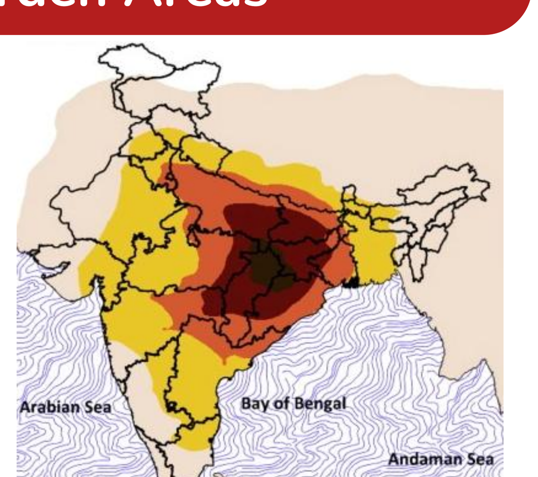
EVs have MUCH HIGHER fine particulate matter (PM2.5) than ICE vehicles due to coal power. EVs clean the cities, but pollute rural areas near power stations, a classic **emission displacement**.



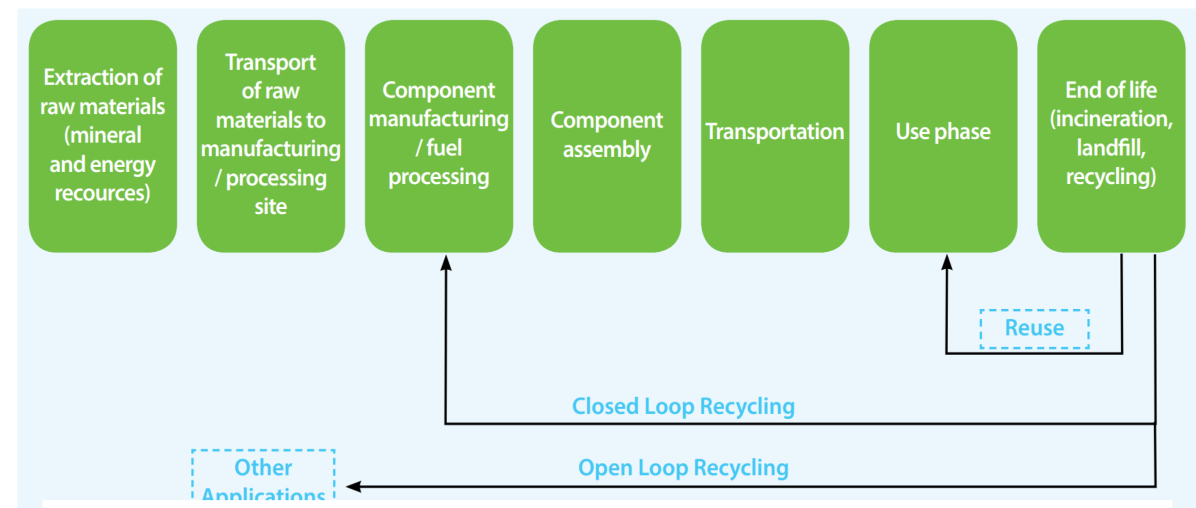


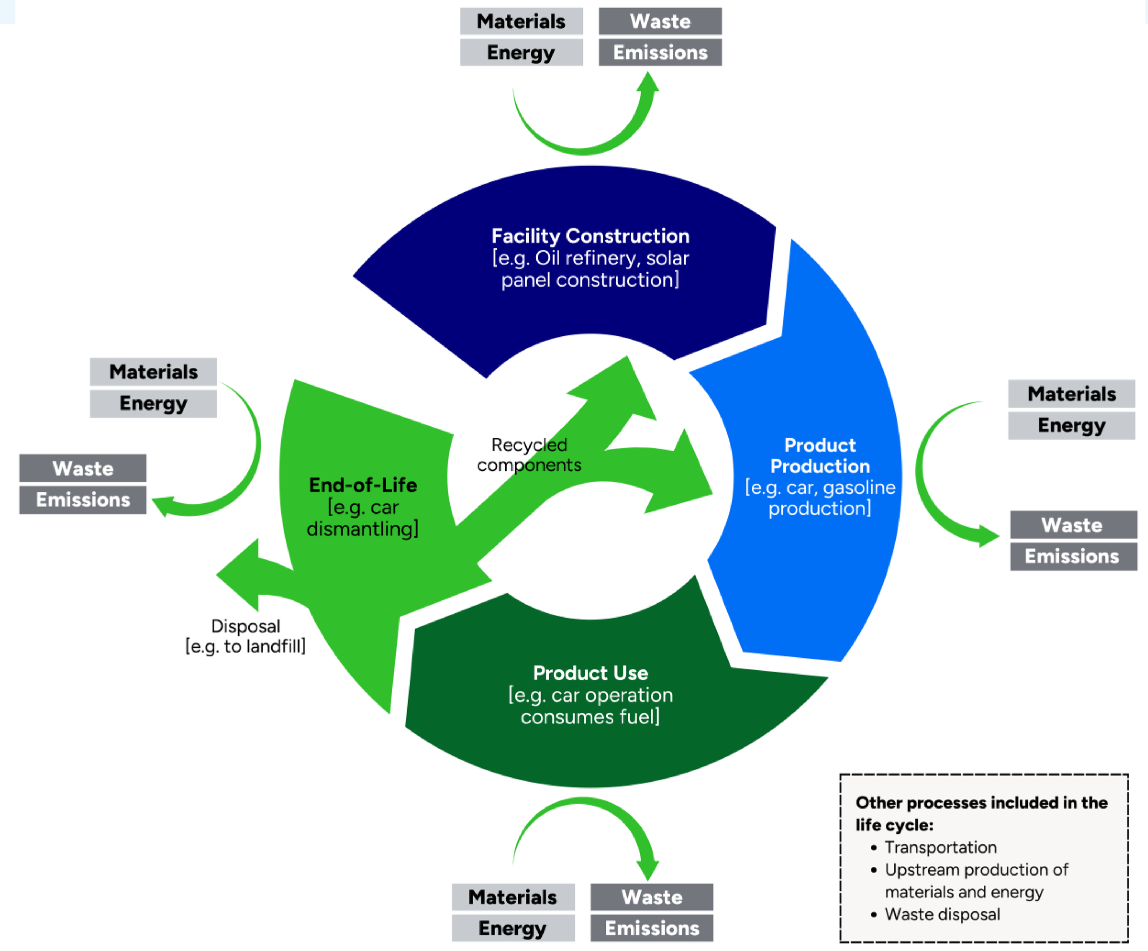
Upstream Burden Areas

- Coal mining regions: Jharkhand, Odisha, MP
- Thermal power clusters Singrauli, Korba, Angul



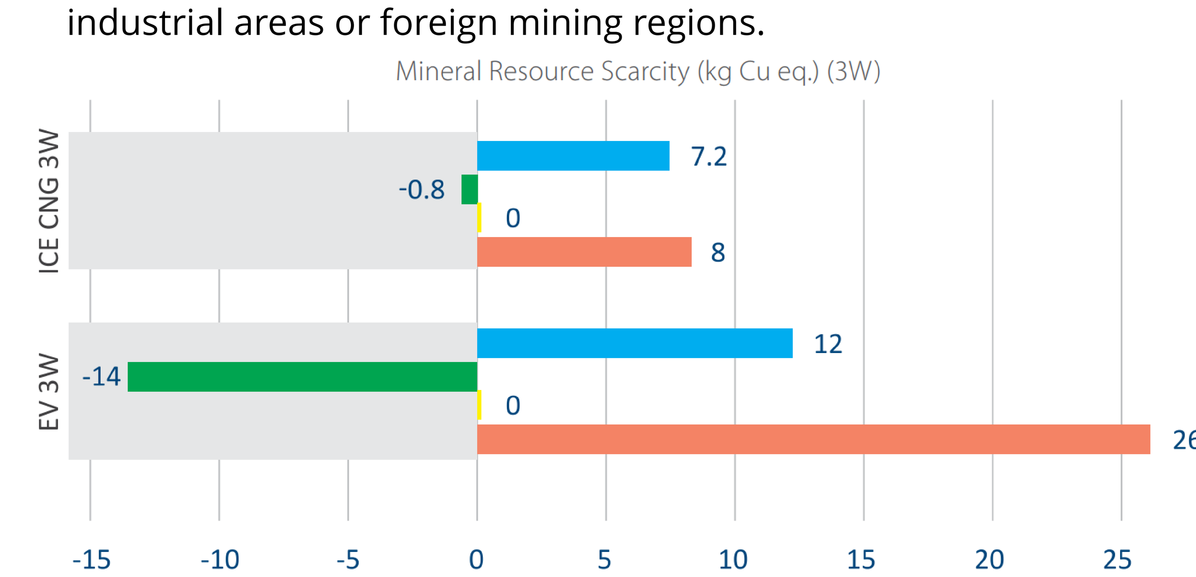
Life Cycle Diagram of Vehicles

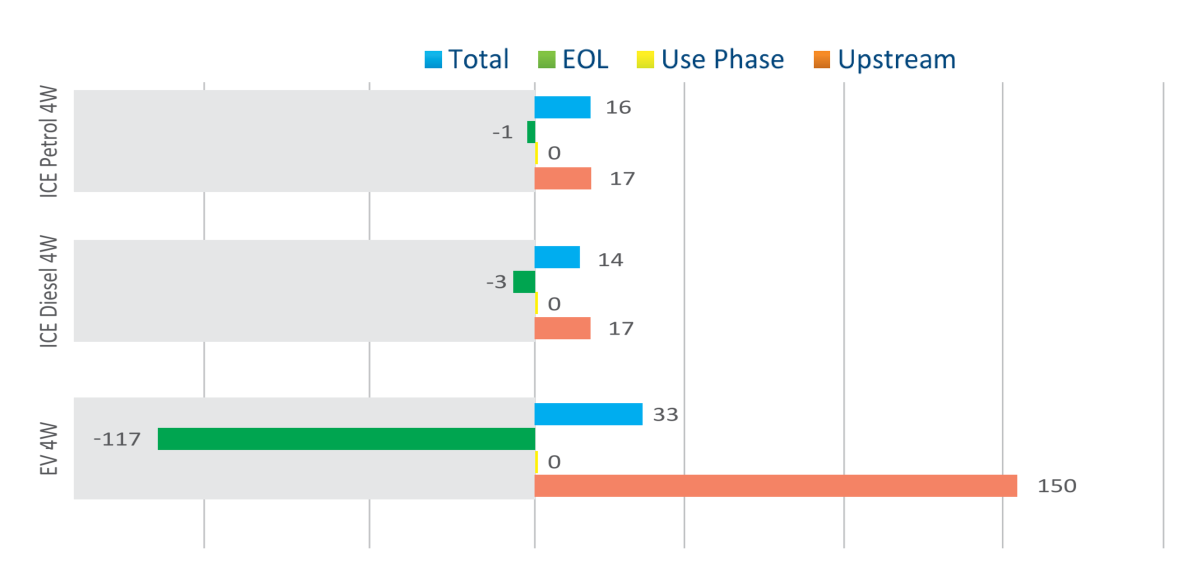




Pollution Due to Battery Manufacturing

- EV battery GWP = 849 kg CO_2 (just manufacturing) for 4W
- Battery manufacturing-> high PM, toxic waste, mineral scarcity.
- This pollution is NON-LOCAL (not in cities), usually in rural industrial areas or foreign mining regions.





What Should We Do ?

Why evaluate the required renewable share for EVs?

EVs marketed as "zero-emission" → **India's coal-heavy grid** Still produce 0.12 kg CO_2/km, only ~17–20% lower than a diesel car (0.144 kg/km)

Emission Shift: This means EVs currently shift emissions from urban tailpipes to rural coal power plants, not eliminate them.

To make EVs meaningfully cleaner, we must determine:
How clean must the electricity grid become for EVs to deliver significant climate benefits?
That is what this calculation answers.

Methodology

A) LCA Baseline Numbers

Functional Unit & Lifetime: 160,000 km (4W) [Source: TERI]

- **Diesel ICE**: ≈ 0.144 kgCO_2/km (0.054 L/km × 2.667 kg/L)
- **Nexon EV**: ≈ 0.151 kWh/km energy use

B) Core Equation & Target

$$EV_{CO_2/km} = E_{EV/km}\ (\text{kWh/km}) \times EF_{grid}\ (\text{kgCO}_2/\text{kWh})$$

Target: $EV_{CO_2/km} \le 0.5 \times ICE_{CO_2/km}$

$$\Rightarrow EF_{grid} \times 0.151\ \text{kWh/km} \le 0.5 \times 0.144\ \text{kgCO}_2/\text{km}$$

$$\Rightarrow EF_{grid} \le \frac{(0.5 \times 0.144)}{0.151}\ \text{kgCO}_2/\text{kWh}$$

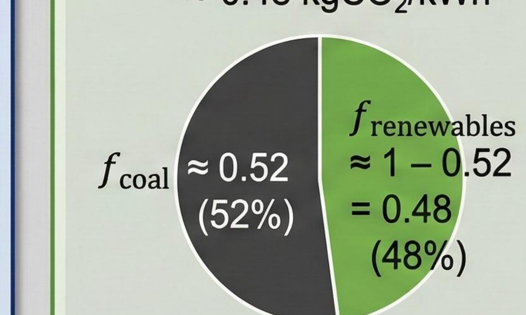
$$\Rightarrow EF_{grid} \le \mathbf{0.48\ kgCO_2/kWh}$$

C) EF to Generation Mix

$$EF_{grid} = \sum f_i \times EF_i$$

Typical Source EFs:
$EF_{coal} \approx 0.98$, $EF_{gas} \approx 0.5$, $EF_{renewables} \approx 0$ (kgCO_2/kWh)

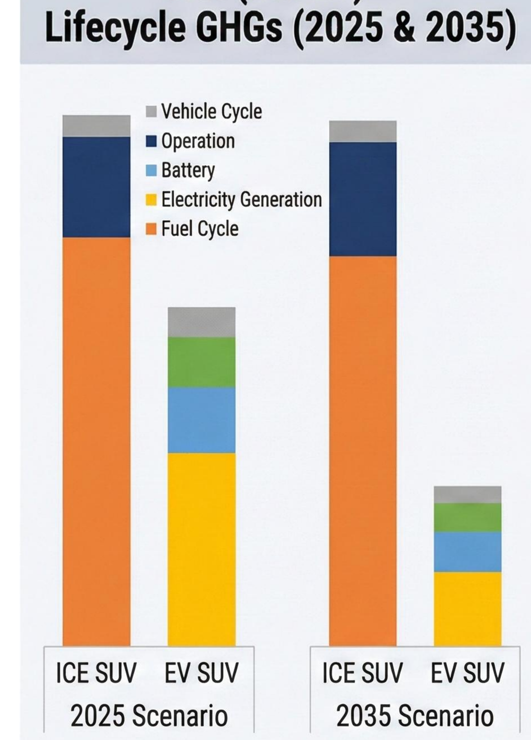
Solved Share for Target EF ≈ 0.48 kgCO_2/kWh

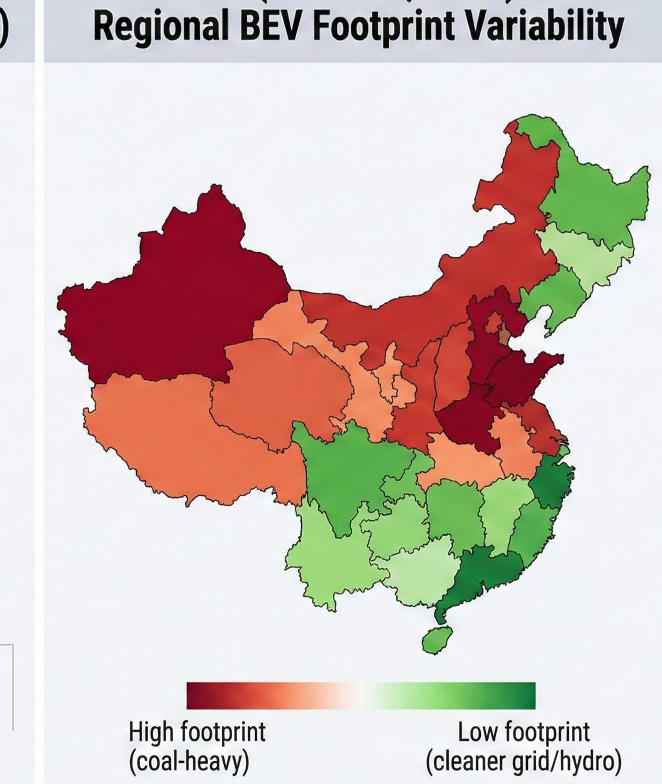


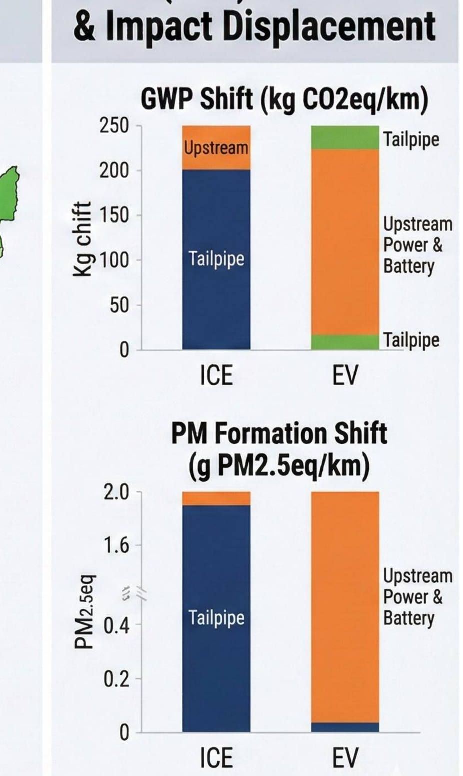
Take current ICE EF Emissions Factor
↓
Take current EV Emissions per Unit Electricity
↓
Calculate Required EF substantial enough for 50% reduction in Total km Emission
↓
Change Grid-Mix to achieve Required EF

Required EF≤ 0.48 | **48%** Renewable

International Evidences of Our Observations



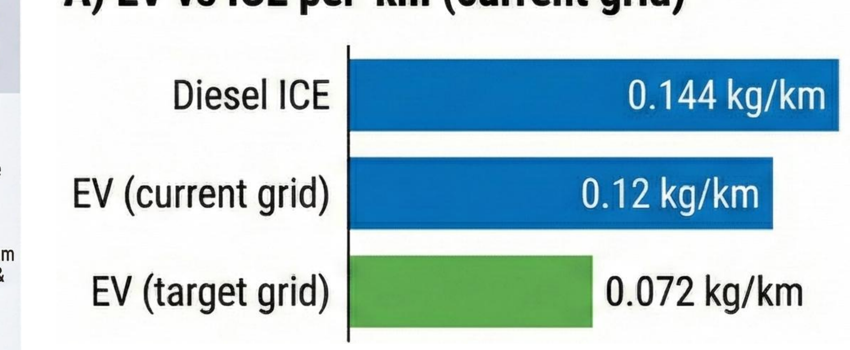




International comparison: How grid mix & region-specific supply chains determine whether EVs reduce or simply relocate emissions.

Results

A) EV vs ICE per-km (current grid)



Poster, Report & References