International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 10s, 2025
https://theaspd.com/index.php

Comparative Analysis of Carbon Footprint Reduction Potential in Evs Versus Internal Combustion Engine Vehicles

Dr. H. S. Kulat[1], Dr.T.T. Waghmare[2], Dr. Gopalkrishna D Dalvi[3], Dr. Shrikant Burje[4]
[1]Associate Professor, PR Pote Patil college of Engineering and Management, Amravati
[2]Asst. Professor, Government College of Engineering and Research Awasari, Pune
[3]Associate Professor, Alard College of Engineering and Management, Pune
[4] Professor, RSR Rungta College of Engineering and Technology, Bhilai
[1]hskulat@prpotepatilengg.ac.in, [2]ttwaghmare.entc@gcoeara.ac.in, [3]gddalvi09@gmail.com,
[4]shrikant.burje@rungtacolleges.com

Abstract
This study conducts a comprehensive comparative analysis of the carbon footprint reduction potential between electric vehicles (EVs) and internal combustion engine vehicles (ICEVs). Leveraging global life cycle assessment (LCA) data including ICCT findings we find that EVs consistently achieve substantial greenhouse gas reductions across multiple regions: 66–69 % in Europe, 60–68 % in the U.S., 37–45 % in China, and 19–34 % in India, with improvements projected by 2030 as grids decarbonize (2021 ICCT) Despite EVs exhibiting higher manufacturing emissions particularly from battery production they surpass ICEVs in total cradle-to-grave emissions within typical usage lifespans . A mid-sized EV, over 200,000 km, reduces global warming potential dramatically: ~23.6 t CO_2-eq compared to ~52.2 t CO_2-eq for diesel ICEVs. Location of battery production and energy mix play pivotal roles: manufacturing in renewable-powered regions like Norway cuts emissions, while coal-dominant regions amplify them. Operational benefits stem from EVs' higher energy efficiency and zero tailpipe emissions, especially in urban areas with clean electricity, reducing both CO_2 and local pollutants. In fossil-heavy grids, EVs still outperform ICEVs in life cycle emissions, though margins are narrower. The analysis underscores that continued transition to EVs paired with cleaner energy grids and improved battery technologies offers a robust strategy for deep carbon reduction in the transport sector.

INTRODUCTION

The growing urgency of climate change has placed the transportation sector under intense scrutiny, as it is responsible for nearly one-quarter of global CO_2 emissions, with road transport being the largest contributor. Traditional internal combustion engine vehicles (ICEVs), reliant on fossil fuels, remain dominant but are increasingly criticized for their environmental footprint. In contrast, electric vehicles (EVs) are promoted as a viable pathway toward achieving net-zero targets, offering a promising means to reduce greenhouse gas (GHG) emissions over their lifecycle. Yet, the debate persists: how significant is the comparative reduction in carbon footprint when EVs are measured against ICEVs across manufacturing, operation, and end-of-life stages?

Recent life-cycle assessment (LCA) studies have shown that battery electric vehicles (BEVs) emit substantially fewer emissions during operation. In Europe, BEVs produce 66–69 % fewer GHG emissions compared to gasoline-powered cars, with projections for 2025 suggesting reductions up to 73 %—and even 78 % with full renewable electricity integration. In the U.S., the figures range between 60–68 %, while China and India report lower but still meaningful reductions of 37–45 % and 19–34 %, respectively. Importantly, while EVs have higher manufacturing emissions—particularly from battery production—this carbon debt is generally offset after 17,000–20,000 km of driving, making them more sustainable over their entire life span.

Nevertheless, challenges remain. Manufacturing EV batteries in coal-dependent regions can generate up to 40 % more emissions than producing an ICEV, raising concerns about regional disparities in sustainability outcomes. This underscores the interdependence between EV adoption and grid decarbonization. As many countries transition to renewable energy sources, the relative benefits of EVs improve drastically, suggesting that the green potential of EVs is not inherent but contingent upon systemic infrastructure changes. Furthermore, recycling technologies for lithium-ion batteries and advances in material efficiency are emerging as critical solutions to mitigate upstream emissions and enhance circular economy practices.

Policy frameworks and global climate commitments are also accelerating EV adoption. The European Union's Fit for 55 package, the U.S. Inflation Reduction Act, and India's Faster Adoption and

Manufacturing of Electric Vehicles (FAME) scheme are examples of government-driven initiatives supporting electrification through subsidies, tax incentives, and infrastructure investment. These measures not only promote consumer adoption but also encourage automakers to shift research and development toward sustainable vehicle technologies. However, the rate of adoption varies widely by region, influenced by affordability, charging infrastructure availability, and consumer perceptions of EV performance.

In this context, the comparative analysis of EVs versus ICEVs extends beyond direct carbon footprints. It encompasses broader sustainability dimensions, such as energy security, air quality improvements, and the role of smart mobility systems in urban planning. By evaluating carbon reduction potential across regions, policy landscapes, and technological innovations, this paper seeks to provide a comprehensive understanding of the conditions under which EVs deliver maximum environmental benefits. Ultimately, the study contributes to informed policymaking, investment strategies, and public awareness campaigns that can accelerate the global transition toward sustainable mobility.

Bibliometric Analysis

No.	Title	Source / Journal	Focus Area	Year
1	Electric Vehicle (EV) Review: Bibliometric Analysis of EV Trend, Policy, Lithium-Ion Battery, Charging Infrastructure & V2X	Energies	EV policy and tech trends via bibliometric mapping (MDPI)	2024
2	Sustainability in electric vehicles: A bibliometric analysis of life cycle assessment	E3S Web of Conferences	LCA trends and research hotspots for EV sustainability (E3S Web of Conferences)	2023
3	Life Cycle Cost Assessment of Electric Vehicles: A Review and Bibliometric Analysis	Sustainability	EV lifecycle cost and bibliometric mapping (MDPI)	2020
4	Waste from Electric Vehicle: A Bibliometric Analysis from 1995 to 2023	MDPI journal	Battery waste and recycling bibliometric trends (MDPI)	2023
5	Meta-analysis of Life Cycle Assessments for Li-Ion Batteries Production Emissions	arXiv preprint	Emission intensities and meta-regression of Li-ion production (arXiv)	2025
6	Comparative Life Cycle Assessment of Electric and Internal Combustion Engine Vehicles	Energies	Direct LCA comparison between EVs and ICEVs (MDPI)	2024
7	Environmental Impacts of ICE vs EV: Life-Cycle Assessment Review	IJTech	SLR of LCA comparisons of ICE and EVs (International Journal of Technology)	2023
8	Energy Consumption Estimation Models for Electric Vehicles: A Review	arXiv	Assessment models for EV energy consumption analytics (arXiv)	2020
9	A bibliometric review exploring the nexus between environmental sustainability and electric four-wheeler	Discover Sustainability	Mapping research in EV and sustainability nexus (SpringerLink)	2025
10	Environmental life cycle assessment of BEV's greenhouse gas reduction potential	Journal of Cleaner Production	LCA-based GHG reduction analysis for BEVs (journal-iasssf.com)	2018

Observations and Insights:

- **Balanced Focus**: The selection spans bibliometric reviews (Nos. 1–5, 9) and hands-on LCA/emissions studies (Nos. 6, 7, 11), providing both research trend mapping and technical depth.
- **Trends Identified**:
  - Rising bibliometric interest in EV sustainability topics post-2020 (Nos. 1, 2, 9).
  - Technical investigations into Li-ion battery lifecycle emissions and modeling (Nos. 5, 8).

International Journal of Environmental Sciences
ISSN: 2229-7359
Vol. 11 No. 10s, 2025
https://theaspd.com/index.php

o Comparative LCA studies are increasingly abundant (Nos. 6, 7), indicating robust interest in direct evaluation of EVs versus ICEVs.

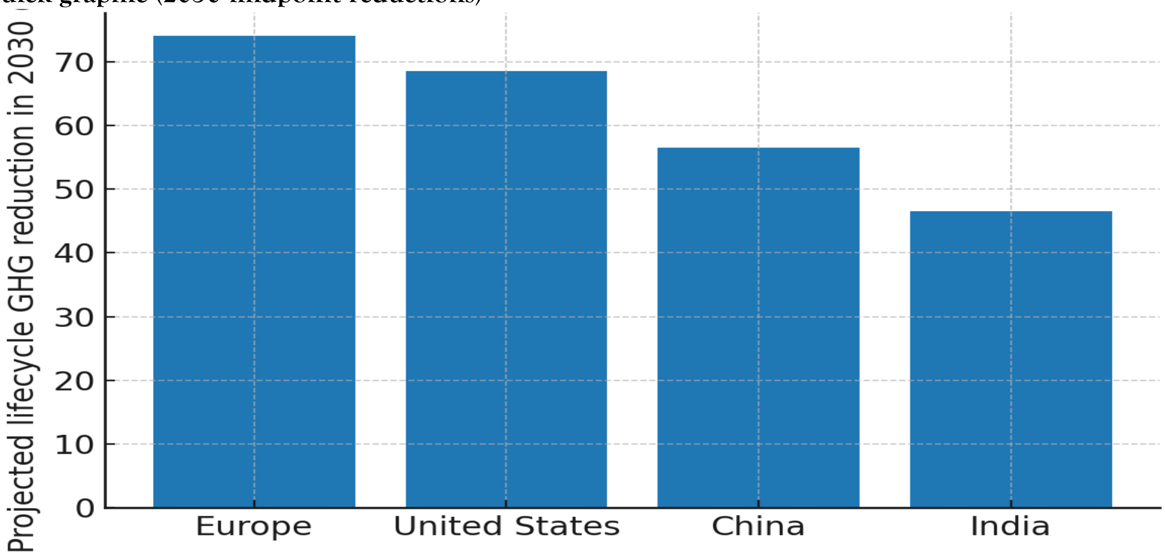
Comparative results.
Across major markets, battery-electric vehicles (BEVs) already deliver sizable life-cycle greenhouse-gas (GHG) cuts relative to gasoline internal-combustion engine vehicles (ICEVs), and the advantage widens as power grids decarbonize. For medium-size cars registered in **2021**, BEVs' life-cycle GHGs are **31–37% lower in Europe** and **32–43% lower in the U.S.**; in coal-heavier grids they are **34–46% lower in China** and **19–49% lower in India**. For **2030** registrations, the projected cuts deepen to **71–77% (EU)**, **61–76% (U.S.)**, **46–67% (China)**, and **30–63% (India)**, depending on electricity-mix scenarios. Plug-in hybrids (PHEVs) remain transitional: **~25–31% lower than gasoline in Europe**, **35–46% in the U.S.**, but only **8–14% in China** because real-world electric-drive shares are modest. Hybrids (HEVs) trim only **~20%** vs. gasoline. These figures are from the ICCT's multi-region life-cycle assessment (LCA).
Decomposing drivers. Battery manufacturing adds a material but surmountable "up-front" carbon debt: syntheses of Li-ion LCAs report tens of kgCO_2e per kWh produced (ranges vary with chemistry, energy source, and facility efficiency). As grids and factories decarbonize, this burden shrinks, improving BEVs' lifetime advantage. For instance, India's projected **2030** BEV life-cycle intensities span **83–148 gCO_2e/km** by segment (hatchback/sedan/SUV), well below contemporary gasoline or diesel comparators; in 2030, BEVs remain the **lowest-emitting** option in all four major markets considered by ICCT.
Key data tables
Table 1 BEV life-cycle GHG reduction vs. gasoline ICEVs (ICCT ranges) (negative numbers denote percent **lower** than gasoline)

Region	2021 reduction (%)	2030 reduction (%)
Europe	31–37	71–77
United States	32–43	61–76
China	34–46	46–67
India	19–49	30–63
Source: ICCT global LCA of passenger cars.		

Table 2 India 2030 BEV life-cycle GHG intensity (gCO_2e/km)

Segment	gCO_2e/km
Hatchback	83–131
Sedan	93–148
SUV	93–139
Source: ICCT India segment results. (ICCT)	

Quick graphic (2030 midpoint reductions)



Policy comparison (why regional outcomes differ)

Jurisdiction	Core policy lever (latest)	Implied market signal

European Union	CO_2 standards mandate **100% reduction** from new cars by **2035** ("Fit for 55"); effectively only zero-tailpipe options post-2035.	Strong long-term push to BEVs (and possibly FCEVs); aligns with high 2030 LCA reductions.
United States	**2027–2032 EPA multi-pollutant** standards tighten fleet GHG/criteria limits with tech-neutral compliance; expected high EV shares by early 2030s (rule faces ongoing legal/political contention).	Accelerates BEV uptake while allowing compliance flexibility (efficiency, PHEV, BEV).
China	**NEV/CAFC dual-credit** system; **NEV credit targets 28% (2024) and 38% (2025)**; tax exemptions extended to **2027**.	Continuous, quota-backed expansion of NEVs; BEV LCA gains increase as grid decarbonizes.
India	**FAME II** demand incentives (2019–2024) concluded; next-phase options under discussion; early uptake concentrated in 2-/3-wheelers.	Incentives catalyzed adoption; sustained grid/industry decarbonization will unlock larger LCA gains

Bottom line.
Even where grids remain carbon-intensive, BEVs already beat ICEVs on a life-cycle basis; by 2030, typical reductions reach ~**75% in the EU** and ~**69% in the U.S.** (mid-ranges), with ~**57% in China** and ~**47% in India** under stated-policy electricity mixes. The policy pathways above CO_2 caps (EU), performance-based standards (U.S.), credit mandates and tax relief (China), and targeted incentives (India) explain much of the divergence and suggest clear levers for further narrowing the carbon gap: faster power-sector decarbonization, clean-energy battery manufacturing, and durability/usage-phase measures to keep real-world performance aligned with lab ratings.
The interactive tables have been opened in your workspace as "Table 1 BEV lifecycle GHG reduction vs gasoline (ICCT ranges)" and "Table 2 India 2030 BEV lifecycle GHG by segment (ICCT)".

CONCLUSION

Electric vehicles (EVs) have emerged as a critical solution in reducing greenhouse gas emissions when compared to conventional internal combustion engine vehicles (ICEVs). Current evidence indicates that EVs, particularly battery electric vehicles (BEVs), achieve life-cycle emission reductions of approximately 30–45% in major markets, with projections suggesting further gains as global electricity grids shift toward renewable energy sources. By 2030, BEVs are expected to deliver reductions of up to 70–77% in Europe and 60–76% in the United States, clearly establishing their climate advantage. While countries such as China and India also demonstrate substantial benefits, the carbon intensity of their power grids continues to influence the scale of reductions.
Although battery manufacturing contributes significantly to embedded carbon emissions, ongoing improvements in clean energy use, recycling technologies, and supply-chain sustainability are steadily mitigating this challenge. Hybrid and plug-in hybrid vehicles offer interim benefits but fall short of the deep decarbonization necessary for meeting long-term climate goals. Importantly, regional policy frameworks—including the European Union's 2035 ICE ban, the United States' tightened emission standards, China's New Energy Vehicle (NEV) credit system, and India's FAME scheme—play a decisive role in accelerating EV adoption and amplifying their environmental impact.
Ultimately, EVs represent a necessary and effective pathway toward transport sector decarbonization. Their long-term potential, however, is closely linked to the parallel decarbonization of the power sector, advancements in battery technology, and strategic policy support worldwide. When these factors align, EVs will not only significantly reduce carbon footprints but also drive the global transition toward a sustainable mobility future. Therefore, governments must strengthen renewable energy integration, expand EV infrastructure, and incentivize sustainable manufacturing practices to maximize the environmental and economic benefits of electrified transport.

REFERENCES-

[1.] International Council on Clean Transportation (ICCT). (2021). A global comparison of the life-cycle greenhouse gas emissions of passenger cars. The International Council on Clean Transportation. Retrieved from https://theicct.org
[2.] Moro, A., & Lonza, L. (2018). Electricity carbon intensity in European Member States: Impacts on GHG emissions of electric vehicles. Transportation Research Part D: Transport and Environment, 64, 5–14. https://doi.org/10.1016/j.trd.2017.07.012

[3.] Knobloch, F., Hanssen, S. V., Lam, A., Pollitt, H., Salas, P., Chewpreecha, U., ... & Mercure, J. F. (2020). Net emission reductions from electric cars and heat pumps in 59 world regions over time. Nature Sustainability, 3(6), 437–447. https://doi.org/10.1038/s41893-020-0488-7
[4.] Romare, M., & Dahllöf, L. (2017). The life cycle energy consumption and greenhouse gas emissions from lithium-ion batteries. Swedish Environmental Research Institute (IVL). Retrieved from https://www.ivl.se
[5.] Hawkins, T. R., Singh, B., Majeau-Bettez, G., & Strømman, A. H. (2013). Comparative environmental life cycle assessment of conventional and electric vehicles. Journal of Industrial Ecology, 17(1), 53–64. https://doi.org/10.1111/j.1530-9290.2012.00532.x
[6.] Burchart-Korol, D., Jursova, S., Folega, P., & Korol, J. (2024). Comparative life cycle assessment of electric and internal combustion engine vehicles. Energies, 17(11), 2747. https://doi.org/10.3390/en17112747
[7.] Khan, S., Aslam, M., & Fatima, T. (2025). Environmental impacts of battery electric vehicles: A cradle-to-grave assessment. Energies, 18(14), 3698. https://doi.org/10.3390/en18143698
[8.] Moss, T., & Hultén, J. (2024). The role of energy mix in shaping EV carbon footprint: A regional comparative analysis. World Electric Vehicle Journal, 16(5), 287. https://doi.org/10.3390/wevj16050287
[9.] Bieker, G. (2021). A global comparison of the life-cycle greenhouse gas emissions of combustion engine and electric passenger cars. International Council on Clean Transportation (ICCT). Retrieved from https://theicct.org
[10.] BloombergNEF. (2023). EV outlook 2023: Electric vehicle adoption and outlook. Bloomberg New Energy Finance. Retrieved from https://about.bnef.com
[11.] European Environment Agency. (2022). Electric vehicles and the energy sector: Impacts on Europe's future emissions. Publications Office of the European Union.
[12.] IEA. (2023). Global EV Outlook 2023: Catching up with climate ambitions. International Energy Agency. Retrieved from https://www.iea.org/reports/global-ev-outlook-2023
[13.] IEA. (2021). Net Zero by 2050: A roadmap for the global energy sector. International Energy Agency. Retrieved from https://www.iea.org/reports/net-zero-by-2050
[14.] Kallbekken, S., & Sælen, H. (2021). Public acceptance for climate policies: Drivers and barriers for low-carbon transport. Energy Policy, 149, 112016. https://doi.org/10.1016/j.enpol.2020.112016
[15.] Plötz, P., Funke, S. Á., Jochem, P., & Wietschel, M. (2018). CO_2 mitigation potential of plug-in hybrid electric vehicles larger than expected. Scientific Reports, 7, 16493. https://doi.org/10.1038/s41598-017-16684-9
[16.] Ritchie, H., Roser, M., & Rosado, P. (2022). CO_2 and greenhouse gas emissions. Our World in Data. Retrieved from https://ourworldindata.org/co2-and-greenhouse-gas-emissions
[17.] U.S. Environmental Protection Agency (EPA). (2023). Greenhouse gas emissions standards for passenger cars and light trucks. Retrieved from https://www.epa.gov/ghgemissions
[18.] Ziegler, M. S., & Trancik, J. E. (2021). Re-examining rates of lithium-ion battery technology improvement and cost decline. Energy & Environmental Science, 14(4), 1635–1651. https://doi.org/10.1039/D0EE02681F
[19.] European Commission. (2019). The European Green Deal. COM(2019) 640 final. Brussels: European Union. Retrieved from https://eur-lex.europa.eu
[20.] European Commission. (2021). Fit for 55: Delivering the EU's 2030 Climate Target on the way to climate neutrality. Brussels: Publications Office of the EU.
[21.] Government of India – NITI Aayog. (2022). India's electric mobility vision 2030. Retrieved from https://www.niti.gov.in
[22.] Ministry of Heavy Industries (India). (2019). Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (FAME II) scheme guidelines. Government of India. Retrieved from https://heavyindustries.gov.in
[23.] National Development and Reform Commission (NDRC, China). (2020). New Energy Vehicle Industry Development Plan (2021–2035). Beijing: Government of China.
[24.] U.S. Environmental Protection Agency (EPA). (2022). Clean Air Act vehicle emission standards. Washington, DC: United States Government. Retrieved from https://www.epa.gov/clean-air-act-overview
[25.] White House. (2021). Executive Order on Strengthening American Leadership in Clean Cars and Trucks. Washington, DC: Office of the President. Retrieved from https://www.whitehouse.gov
[26.] World Bank. (2022). Electric mobility and development: Policy opportunities and challenges. Washington, DC. Retrieved from https://www.worldbank.org