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Decarbonizing India's Transport Sector: A Policy Analysis of Fuel Efficiency and Emission Standards

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Abstract
India's transport sector is a significant contributor to greenhouse gas emissions, posing a critical challenge to the country's sustainable development ambitions. In alignment with Sustainable Development Goals 7 (Affordable and Clean Energy) and 13 (Climate Action), decarbonizing the transport sector has become a policy imperative. This paper critically analyzes India's fuel efficiency and emission standards—specifically the Bharat Stage (BS) emission norms and the Corporate Average Fuel Efficiency (CAFE) regulations—assessing their effectiveness in reducing vehicular emissions and promoting energy efficiency. It explores the evolution of these standards, implementation challenges, and their alignment with international best practices. By evaluating current outcomes and identifying gaps in enforcement and policy coherence, the study offers targeted recommendations to enhance regulatory frameworks and accelerate India's transition toward a low-carbon transport future.

Keywords: Greenhouse gas emissions, Sustainable Development Goals, fuel efficiency.

1. Introduction:

India's transport sector plays a critical role in driving economic growth and enabling mobility, yet it is also a significant contributor to the country's greenhouse gas (GHG) emissions and energy consumption[1]. With over 300 million vehicles on the road and a continued dependence on fossil fuels, the sector accounts for nearly 13% of India's energy-related CO_2 emissions[2]. The urgency to mitigate these emissions has grown in light of India's commitments under the Paris Agreement[3] adopted in 2015 and its aim to achieve net-zero emissions by 2070. At the same time, the country is striving to meet the United Nations Sustainable Development Goals (SDGs)[4], particularly SDG 7 (Affordable and Clean Energy) and SDG 13 (Climate Action), which call for a transition to sustainable energy systems and urgent climate mitigation efforts.

A standard internal combustion engine vehicle emits an estimated 24 tonnes of emissions over its life cycle[5]. As the economies of developing country is growing, they are manufacturing motor vehicles to provide better and convenient transportation service to the public, leading to the increase in demand

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[2] Hossain, M. S., Fang, Y. R., Ma, T., Huang, C., Peng, W., Urpelainen, J., ... & Dai, H. (2023). Narrowing fossil fuel consumption in the Indian road transport sector towards reaching carbon neutrality. *Energy Policy*, *172*, 113330.

[3] United Nations Framework Convention on Climate Change. (2015, December 12). *Paris Agreement* (T.I.A.S. No. 16-1104). https://unfccc.int/sites/default/files/english_paris_agreement.pdf

[4] *THE 17 GOALS | Sustainable Development.* (n.d.). https://sdgs.un.org/goals

[5] Towoju, O. A., & Ishola, F. A. (2020). A case for the internal combustion engine powered vehicle. *Energy Reports*, *6*, 315-321.

for petrol. Almost 50% of the world's oil production is consumed by road vehicles[6]. Fossil fuel such as coal, petrol, diesel, etc. being a non-renewable source of energy are declining and has been phased out in most of the commercial and industrial sectors including electricity generation.

In response to these challenges, India has implemented a range of regulatory measures aimed at reducing emissions and improving fuel efficiency in the automobile sector. The two most prominent initiatives in this context are the Bharat Stage (BS) emission norms[7], which regulate tailpipe emissions from vehicles, and the Corporate Average Fuel Efficiency (CAFE) standards[8], which mandate fleet-level improvements in fuel consumption. These policies, while ambitious, operate in a complex policy environment marked by technological, infrastructural, and enforcement challenges.

This paper undertakes a critical policy analysis of India's fuel efficiency and emission standards to evaluate their effectiveness in supporting the country's decarbonization goals. It examines the evolution of these regulatory frameworks, assesses their alignment with international best practices, and analyzes their implementation outcomes. By identifying policy gaps and enforcement issues, the study aims to offer actionable recommendations to strengthen India's low-carbon transition in the transport sector and contribute meaningfully to its sustainable development objectives.

2. Overview of India's Transport Sector

India's transport sector is one of the fastest growing in the world, playing a critical role in facilitating economic development, trade, and social connectivity. It includes a diverse mix of road, rail, air, and water transport, with road transport being the dominant mode, accounting for over 70% of freight and 90% of passenger traffic[9]. The rapid urbanization, population growth, and increasing disposable incomes over the past two decades have led to a substantial rise in the demand for personal and commercial vehicles, contributing to a dramatic expansion of the vehicle fleet, from about 50 million in 2000 to over 300 million in 2023[10].

However, this expansion has come at a significant environmental cost. The transport sector is the third-largest source of greenhouse gas emissions in India, after energy and industry[11]. Road transport alone contributes to over 90% of the sector's CO_2 emissions, primarily due to the heavy reliance on fossil fuels such as petrol and diesel[12]. Additionally, urban air quality in major Indian cities has deteriorated, with vehicular emissions identified as one of the leading sources of pollutants like particulate matter (PM2.5 and PM10), nitrogen oxides (NOx), and carbon monoxide (CO)[13].

Energy consumption in the sector has also increased sharply, with transport accounting for nearly 18% of total final energy consumption in India[14]. The rising fuel demand has implications not only for emissions but also for energy security, given the country's dependence on crude oil imports. Moreover,

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[7] International Energy Agency. (2023, February 1). *Bharat Stage (BS) VI emission standards*.

[8] National Highway Traffic Safety Administration. (n.d.). *Corporate Average Fuel Economy (CAFE)*.

[9] Ramanathan, R., & Parikh, J. K. (1999). Transport sector in India: an analysis in the context of sustainable development. *Transport Policy*, *6*(1), 35-45.

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[13] World Health Organization. (2021). *WHO global air quality guidelines: particulate matter (PM2. 5 and PM10), ozone, nitrogen dioxide, sulfur dioxide and carbon monoxide*. World Health Organization.

[14] Paladugula, A. L., Kholod, N., Chaturvedi, V., Ghosh, P. P., Pal, S., Clarke, L., ... & Wilson, S. A. (2018). A multi-model assessment of energy and emissions for India's transportation sector through 2050. *Energy Policy*, *116*, 10-18.

India faces a dual challenge, ensuring equitable access to mobility while transitioning to cleaner, more efficient modes of transport.

Recognizing the urgent need for intervention, the Indian government has introduced a series of regulatory measures and policy initiatives to reduce the environmental footprint of the transport sector. These include the implementation of Bharat Stage emission norms, Corporate Average Fuel Efficiency (CAFE) standards, promotion of electric vehicles under the FAME scheme, and recent emphasis on alternative fuels like ethanol, hydrogen, and compressed biogas. Nevertheless, the effectiveness of these measures in achieving large-scale emission reductions depends on robust enforcement, technological innovation, consumer behavior, and coordinated policymaking across multiple levels of government.

3. Policy Framework for Fuel Efficiency and Emission Standards

India's regulatory approach to mitigating emissions from the transport sector is centered around two major policy instruments: the **Bharat Stage (BS) emission norms** and the **Corporate Average Fuel Efficiency (CAFE) standards**. These frameworks together aim to control air pollutants from vehicles and improve fuel economy, thereby contributing to broader climate and energy goals. The Bharat Stage norms, first introduced in 2000 and modelled after European standards, regulate the emission of pollutants such as carbon monoxide (CO), hydrocarbons (HC), nitrogen oxides (NOx), and particulate matter (PM) from internal combustion engine vehicles[15]. The transition from BS-IV to BS-VI in April 2020 marked a significant policy leap, bypassing the BS-V stage entirely. BS-VI mandates stringent limits on both particulate and gaseous emissions and requires advanced technologies like diesel particulate filters (DPFs), selective catalytic reduction (SCR), and onboard diagnostics (OBD) systems, thereby pushing automakers to adopt cleaner engines and fuels.

Complementing these emission standards are the CAFE regulations, which focus on improving the average fuel efficiency of vehicle fleets sold by manufacturers. Introduced in 2017 under the Energy Conservation Act, 2001 and administered by the Bureau of Energy Efficiency (BEE)[16] in coordination with the Ministry of Power and Ministry of Road Transport and Highways (MoRTH), CAFE standards are designed to ensure that automakers progressively reduce fuel consumption per kilometer across their vehicle offerings. Phase I of the CAFE norms targeted an average fuel consumption of 130 gCO_2/km for passenger cars by 2022, while Phase II, effective from 2022 onwards, mandates a tougher limit of 113 gCO_2/km[17]. Compliance is assessed based on vehicle sales-weighted averages, and non-compliance attracts financial penalties under the framework.

Both BS and CAFE standards form a crucial part of India's strategy to decarbonize the transport sector and align with its Nationally Determined Contributions (NDCs)**[18]** under the Paris Agreement. However, their effectiveness relies heavily on proper implementation, continuous technological advancements, and coordinated policy support. Enforcement mechanisms, real-world emissions testing, fuel quality upgrades, and consumer incentives are essential components that determine the success of these regulations. Moreover, with the automotive industry undergoing a paradigm shift towards electric mobility and alternative fuels, the policy framework must evolve in tandem to remain relevant and impactful.

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[15] Gajbhiye, M. D., Lakshmanan, S., Aggarwal, R., Kumar, N., & Bhattacharya, S. (2023). Evolution and mitigation of vehicular emissions due to India's Bharat Stage Emission Standards–A case study from Delhi. *Environmental Development*, *45*, 100803.

[16] Bureau of Energy Efficiency. (n.d.). *Bureau of Energy Efficiency*.

[17] Singh, M. (2024). *Rapid and Equitable Transport Decarbonization in the Age of Electrification*. Stanford University.

[18] United Nations Framework Convention on Climate Change. (n.d.). *Nationally determined contributions (NDCs)*. Retrieved April 26, 2025

4. International Comparisons

India's efforts to regulate vehicle emissions and improve fuel efficiency through the Bharat Stage norms and CAFE standards can be better understood when examined alongside global practices. Internationally, countries like the European Union (EU), the United States (US), and China have developed comprehensive and evolving frameworks to tackle emissions from the transport sector. The EU, widely regarded as a global leader in environmental regulations, has implemented the Euro emission standards, currently at Euro 6, which are closely aligned with India's BS-VI norms[19]. However, the EU complements these standards with robust real-driving emissions (RDE) testing and in-service conformity checks to ensure that vehicle emissions remain within permissible limits under actual road conditions, an area where India still faces challenges.

In terms of fuel efficiency, the US Corporate Average Fuel Economy (CAFE) standards[20] are among the most longstanding, introduced in the 1970s. The US mandates fuel economy improvements across a range of vehicle classes and ties regulatory targets to vehicle footprint and technology-neutral benchmarks, giving automakers flexibility in compliance. Additionally, the Environmental Protection Agency (EPA) and National Highway Traffic Safety Administration (NHTSA) conduct periodic testing and enforcement. China, which shares many market dynamics with India, has aggressively upgraded its emission standards (China 6a and 6b) and set ambitious New Energy Vehicle (NEV) quotas to push the adoption of electric and hybrid vehicles[21]. It also enforces stringent fuel consumption limits across vehicle segments and invests heavily in public transport electrification.

While India's policy frameworks are generally aligned in spirit with these international regimes, significant differences exist in terms of stringency, testing infrastructure, enforcement capacity, and pace of technological adoption. For instance, India's CAFE norms are currently less stringent compared to the EU or US benchmarks. Furthermore, real-world emissions testing and post-market surveillance are still at a nascent stage in India. Learning from these global experiences, India can benefit by incorporating more adaptive, technology-neutral regulations, ensuring transparent compliance monitoring, and facilitating greater policy integration with electrification goals. A calibrated approach that balances environmental imperatives with domestic economic realities can help India emulate global best practices while tailoring solutions to its unique challenges.

5. Challenges and Gaps

Despite the progressive evolution of India's emission and fuel efficiency standards, several challenges and systemic gaps hinder their full realization and impact. One of the primary concerns is the lack of robust enforcement mechanisms. While Bharat Stage norms and CAFE standards have been notified, effective implementation across the country remains uneven due to inadequate testing infrastructure, limited real-world emissions monitoring, and weak regulatory oversight, particularly at the state and local levels. Post-market surveillance, critical for ensuring continued compliance after vehicle sales, is still underdeveloped, allowing discrepancies between lab-certified and on-road emissions to persist. Additionally, fuel quality standards, especially in rural and remote areas, do not always match the requirements of BS-VI engines, potentially undermining emission control technologies.

Another key gap lies in the economic and technological readiness of manufacturers, especially small and medium-sized enterprises (SMEs), which often lack the capital and R&D capabilities to swiftly adapt to stringent norms. While larger automakers have invested in engine upgrades and cleaner technologies, compliance costs remain high, and in the absence of fiscal incentives or policy certainty,

[19] Vashist, D., Kumar, N., & Bindra, M. (2017). Technical challenges in shifting from BS IV to BS-VI automotive emissions norms by 2020 in India: a review. *Archives of Current Research International*, *8*(1), 1-8.

[20] National Highway Traffic Safety Administration. (n.d.). *Corporate Average Fuel Economy (CAFE)*.

[21] Li, J. (2020). Charging Chinese future: the roadmap of China's policy for new energy automotive industry. *International Journal of Hydrogen Energy*, *45*(20), 11409-11423.

some players are reluctant to innovate. The lack of consumer awareness and market-based incentives for purchasing fuel-efficient or low-emission vehicles further compounds the issue. Consumers tend to prioritize upfront costs over long-term environmental and fuel economy benefits, limiting the demand pull necessary for rapid transitions[22].

Moreover, policy fragmentation across sectors and ministries affects the coherence and coordination of India's low-carbon transport strategy. Fuel efficiency and emissions policies often operate in silos, without adequate integration with broader goals such as vehicle electrification, public transport development, or alternative fuels promotion. This results in overlaps, regulatory uncertainty, and missed opportunities for synergies. Finally, urban planning and infrastructure limitations, such as traffic congestion, poor public transit, and limited charging or refueling infrastructure for alternative vehicles, further dilute the potential impact of vehicle-specific efficiency and emissions measures.

Addressing these challenges requires a multi-pronged approach involving regulatory reform, stakeholder capacity building, consumer engagement, and investment in cleaner technologies and infrastructure. Without these complementary efforts, India risks falling short of its ambitious transport decarbonization and climate commitments.

6. Synergies with Other Policies

India's drive to decarbonize its transport sector through fuel efficiency and emission standards is closely interlinked with a range of complementary policy initiatives aimed at advancing clean energy, sustainable mobility, and climate resilience. One such significant initiative is the Faster Adoption and Manufacturing of Hybrid and Electric Vehicles (FAME) Scheme[23], which promotes electric mobility by providing financial incentives for electric two-wheelers, three-wheelers, passenger cars, and buses. By encouraging a shift away from internal combustion engine (ICE) vehicles, the FAME scheme supports the long-term goals of both the Bharat Stage and CAFE standards by reducing overall vehicle emissions and fuel consumption. In tandem, the Production Linked Incentive (PLI) scheme[24] for the automobile and auto components sector incentivizes the domestic manufacturing of advanced automotive technologies, including electric vehicles (EVs) and high-efficiency engines, thereby promoting cleaner and more efficient vehicles in the market.

Additionally, the National Electric Mobility Mission Plan (NEMMP)[25] and various state-level EV policies further align with emission and efficiency targets by creating a broader framework for electrification, infrastructure development, and investment in innovation. The synergy extends to India's biofuels policy, which mandates blending ethanol and compressed biogas with conventional fuels to reduce carbon intensity in transport fuels. These initiatives complement fuel efficiency goals by offering lower-emission alternatives to petroleum-based fuels. Moreover, the government's National Hydrogen Mission seeks to develop green hydrogen as a clean fuel for heavy-duty transport and freight mobility, creating new pathways for sectoral decarbonization.

Urban transport and public mobility initiatives, such as the Smart Cities Mission and policies promoting mass transit systems (like metro rail and bus rapid transit), also support the fuel efficiency agenda by reducing the dependence on private vehicles and lowering per capita emissions. Similarly, the Energy Efficiency Services Limited (EESL) has undertaken bulk procurement and deployment of

[22] Hoppe, J. (2025). *A New Era of Climate Policy: Insights into Effective and Feasible Mitigation Policies for Net Zero Emissions* (Doctoral dissertation, ETH Zurich).

[23] Sangodkar, M. R. V. (2021). Faster adoption and manufacturing of hybrid & electric vehicles (fame India) scheme overview. *The GCCE Peer Reviewed Journal of Multi-Disciplinary Research*, *11*, 27.

[24] Wandhe, D. P. (2024). An Overview on Production Linked Incentive (PLI) Scheme by The Government of India. *Available at SSRN 4693578*.

[25] Das Mercês João, A. (2017). *Electric vehicles in India and the national electric mobility mission plan 2020* (Doctoral dissertation, Wien).

electric vehicles for government use, demonstrating public-sector leadership in transport decarbonization.

Together, these overlapping and mutually reinforcing policies form a comprehensive ecosystem that enhances the effectiveness of fuel efficiency and emission standards. Their integration ensures that technological, infrastructural, and behavioral changes occur in a coordinated manner, accelerating India's transition to a sustainable and low-carbon transport system.

7. Recommendations

To accelerate the decarbonization of India's transport sector and enhance the effectiveness of fuel efficiency and emission standards, a set of targeted and actionable recommendations is essential. First, there is a pressing need to strengthen enforcement mechanisms by expanding the capacity of testing facilities, establishing robust real-world emissions monitoring systems, and ensuring regular post-market surveillance. This would bridge the gap between certified and actual emissions and improve regulatory compliance across the board.

Second, policy integration and institutional coordination must be improved. A unified framework that aligns Bharat Stage norms, CAFE standards, EV policies, and alternative fuel strategies will ensure greater synergy and reduce regulatory overlap. Cross-ministerial coordination among the Ministry of Road Transport and Highways (MoRTH), Ministry of Power, Ministry of Environment, and NITI Aayog is key to building a coherent low-carbon transport roadmap.

Third, India should support manufacturers, especially small and medium enterprises, through fiscal incentives, R&D grants, and technology transfer programs. This will help them adopt cleaner and more efficient technologies without compromising competitiveness. At the same time, consumer-side incentives such as tax rebates, fuel efficiency labelling, and scrappage benefits can create demand for cleaner vehicles and encourage behavioral change.

Fourth, the adoption of technology-neutral and forward-looking standards is critical. Rather than prescribing specific technologies, regulations should set performance-based goals that allow manufacturers the flexibility to innovate. This includes preparing for next-generation emission standards (BS-VII) and incorporating well-to-wheel emission accounting for all vehicle types, including electric and hydrogen-powered ones.

Finally, India must invest in supportive infrastructure, such as electric charging stations, hydrogen refueling points, and quality fuel distribution systems, especially in tier-2 and tier-3 cities. Combined with public awareness campaigns, capacity-building programs, and international collaborations for best practices, these measures can collectively ensure that India's transport sector contributes meaningfully to its SDG 7 (affordable and clean energy) and SDG 13 (climate action) targets.

Conclusion

India's transport sector is at a critical juncture, with rapid urbanization and increasing vehicle ownership driving both economic growth and environmental challenges. The country's commitment to achieving Sustainable Development Goal (SDG) 7 (Affordable and Clean Energy) and SDG 13 (Climate Action) necessitates urgent action to decarbonize its transport system. While the Bharat Stage emission norms and CAFE standards have laid the foundation for reducing emissions and improving fuel efficiency, their effectiveness remains limited by gaps in enforcement, technological readiness, and infrastructure development.

This paper has analyzed the key policy frameworks that underpin India's transport decarbonization efforts, highlighting the synergies with other complementary initiatives such as the FAME scheme, the National Electric Mobility Mission Plan, and biofuels policies. It also identified significant challenges, including the need for stronger enforcement mechanisms, improved policy integration, and better support for manufacturers and consumers. By addressing these gaps, India can accelerate

its transition to a low-carbon, sustainable transport system that not only mitigates climate change but also improves air quality, energy security, and public health.

The recommendations outlined in this paper provide a pathway for policymakers, industry stakeholders, and civil society to work together in overcoming existing barriers and ensuring the success of India's emission and fuel efficiency standards. Through enhanced coordination, technological innovation, and infrastructure investment, India has the potential to set a global example in the decarbonization of its transport sector while fulfilling its climate commitments and achieving long-term sustainability goals.