POLICY BRIEF

FUEL EFFICIENCY IMPROVEMENT AND EMISSION STANDARDS IN ROAD TRANSPORT

THE ENERGY AND RESOURCES INSTITUTE
Creating Innovative Solutions for a Sustainable Future

Suggested Citation

Mattoo R and Saxena P. (2023). Fuel Efficiency Improvement and Emission Standards in Road Transport. New Delhi, India: The Energy and Resources Institute.

Author

Ms Ruchika Mattoo, *Associate Fellow*
Mr Piyush Saxena, *Research Associate*

Principal Investigator

Mr Sharif Qamar, *Associate Director*

Reviewers

Mr Shri Prakash, *Distinguished Fellow*

Mr I V Rao, *Distinguished Fellow*

PUBLISHED BY

The Energy and Resources Institute (TERI)

FOR MORE INFORMATION

Transport and Urban Governance Division, TERI, Core – 1B, 3rd Floor, Indian Habitat Centre, Lodhi Road,
New Delhi 110003, India. Tel: +91 11 2468 2100 or 2433 9605 | Email: sharif.qamar@teri.res.in | Web: www.teriin.org

TABLE OF CONTENTS

1. Background

In the past two decades, India has shown tremendous economic growth, thereby becoming one of the fastest-growing economies in the world. In the coming years, India will play a major role in the global energy markets. The rapid economic growth increases transportation activities, and simultaneously dependency on fossil fuels. The energy consumption in transport sector has increased by more than three folds since 2000 and more than two folds in last decade (International Energy Agency (IEA), 2022). Considering the same growth trend, it has been estimated by 2030, approximately 200 million tonnes of oil equivalent (MTOE) of annual energy supply will be required to achieve the energy consumption of transport sector.[1]

The transport sector is also responsible for 13.5% of India's energy-related CO_2 emissions (Climate Action Tracker, December, 2020) which contribute around 300 million tonnes of CO_2 ($MtCO_2$) annually; including maritime transport (International Transport Forum, 2021). Carbon emission from the transport sector is estimated to grow by four folds to 1,164 MT by 2050 and its share in total emissions will increase to 19%.[2] In addition to national emissions, this sector is also responsible for local air pollutants with significant negative impact on the human health.

Keeping in mind the future estimates of energy consumption and carbon emissions in the transport sector, a serious concern arises on energy security and carbon emission mitigation efforts of the country. Significant efforts are required to decarbonize the transport sector in line with the Nationally Determined Contributions (NDCs) targets, to achieve overall zero carbon emissions in the country.

The main aim of this policy brief is to review and understand the existing policies, effective decarbonization strategies, and pathways adopted by the state and central governments. The objective is also to strengthen the fuel efficiency and tail pipe emission norms/policies by identifying the current gaps and tightening the norms by providing recommendations based on stakeholder consultation and discussion with experts.

2. Why Decarbonization of Transport sector is crucial?

Transport sector in India contributes to approximately 5% of the country's GDP (MoSPI, 2023). India's import dependence on crude oil was 85.5% in FY 2021–22 (PPAC, 2022). As per the Intergovernmental Panel on Climate Change (IPCC), there is an immediate need for transport decarbonization policies, which can help manage fuel oil demand and emissions.

The development of the transport sector is a priority area for the government. Emissions from the transportation sector are mainly driven by fossil fuel consumption in the road transport, which accounts for about 87% of passenger traffic and 60% of freight traffic movement in the country (MoEF&CC, 2022).

1 Details available at https://beeindia.gov.in/content/e-mobility
2 Decarbonization in Transport Sector: Present Status and Future Pathways, 2021

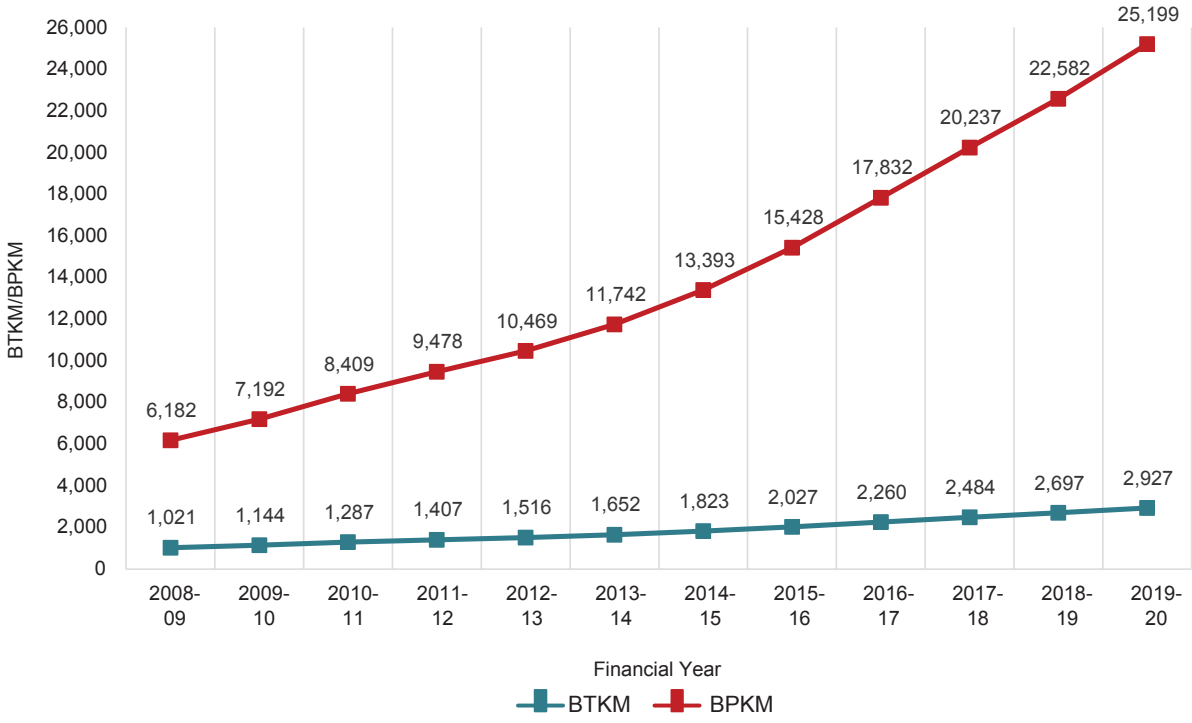

Figure 1: Road-based transport activity

Source: Road Transport Yearbook, MoRTH (2019-20)

India's rapid urbanization and economic growth has accelerated both passenger and freight transport demands, which have led to the need for prioritizing adoption of low carbon technologies, also strengthening the country's energy security. Figure 1 represents the trend of passenger and freight traffic movement by road, showcasing a serious concern in terms of energy efficiency and increasing emissions. In road transport, passenger activity has increased by 308% while freight activity has increased by 187%, from FY 2008–09 to 2019-20. There is a need to ensure that increasing mobility requirements arising from economic growth are met through sustainable options, such as electrification, alternative fuel, and innovative technologies. In addition to the gradual transition to these options, conventional vehicles will have to meet improved performance standards for fuel efficiency and emission reduction.

3. Vehicular Market Segments in India

India's automotive industry is the fourth largest market globally and contributes 7% of the country's GDP (Autobei Consulting Group, 2019). In FY 22–23, the annual production of automobiles was 25.9 million vehicles, which comprise passenger vehicles, commercial vehicles, three-wheelers, two-wheelers, and quadricycles (SIAM, 2023). The domestic sales of automobiles in FY 22–23 was 21.2 million (SIAM, 2023).

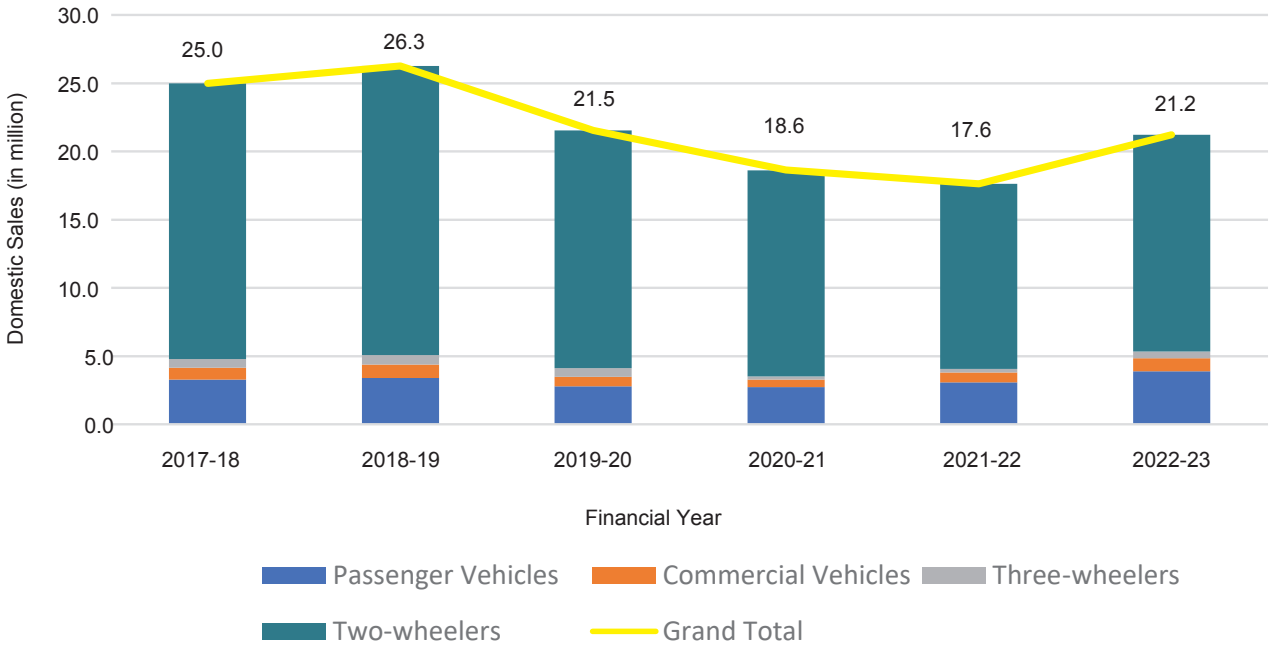

Figure 2: Domestic vehicle sale over the year

Source: Society of Indian Automobile Manufacturers, 2023

In 2022, there were over 304.8 million registered vehicles in India.[3] The two-wheeler segment contributed the highest sales share (76.9%), followed by passenger vehicles (17.5%).

Owing to the COVID-19 pandemic, domestic sales witnessed a dip from FY 2019 till FY 2021. However, FY 2022 witnessed increased sales as compared to FY 2019 and 2021. Further, substantial growth is expected in the Indian auto industry, post-recovery from the pandemic (IBEF, 2022).

3.1 Growth potential of the Indian automobile industry

The Automotive Mission Plan (AMP) 2016–26 is a collaborative effort by the government and automotive

Table 1: Future automotive growth demand

Category-wise demand (million units)			
Category	**FY 2015**	**FY 2021**	**FY 2026**
Passenger cars	3.2	3.1	9.4
Commercial vehicles	0.7	0.7	2.0
Two-wheelers	18.5	13.5	50.6
Three-wheelers	0.9	0.3	2.8
Total	**23.3**	**17.6**	**64.8**

Source: Final Draft Automotive Plan, 2016–26

3 Details available at https://vahan.parivahan.gov.in/vahan4dashboard/

industry to develop the roadmap for its growth. According to the AMP by 2026, the automobile industry has the potential to contribute about 12% of the total GDP (Ministry of Heavy Industry, 2016).

From FY 2010 to FY 2020, the total vehicle population grew at an annual compound growth rate of 9.8% (MoRTH, 2023). It has been estimated that the overall energy requirement in India shall rise from 817 MTOE in FY 2018, to 1,392 MTOE in FY 2030 (SAARC Energy Outlook 2030). In-line with India's ambition to become a USD 5 trillion economy by 2025, fuel efficiency improvement will play a crucial role in optimizing the fuel requirements.

3.2 Overview of fuel consumption trends

India's road transport sector is majorly driven by diesel and petrol. The total consumption of petroleum products stood at 222.3 million metric tonne (MMT) in FY 2022–23 (PPAC, 2023). In the last decade, total diesel consumption has increased by 24% (from 69.1 MMT in FY 2012–13 to 85.9 MMT in FY 2022–23). Further, total consumption of motor spirit/petrol has increased by 121% (from 15.8 in FY 2022–23 to 34.9 MMT in FY 2022–23).

Figure 3 highlights the end-use share of diesel in India. The diesel retail segment accounts for 68% of the petrol-diesel basket, while the transport segment accounts for 87% and the non-transport segment contributes for the remaining 13%.[4] There are significant changes in the consumption patterns of the transport sector. Due to extensive economic activities, diesel consumption by trucks (HCVs and LCVs) has increased from 33% in 2011-12 to 64% in 2020-21 (PPAC, 2022).

Figure 4 highlights the end-use share of petrol in India. Petrol consumption showed a decrease in the share of two-wheelers, from 61% in FY 12, to 59% in FY 22; while in cars/utility vehicles segment, an increase to 40% in FY 22 (from 36% in FY 12) has been observed (PPAC, 2022).

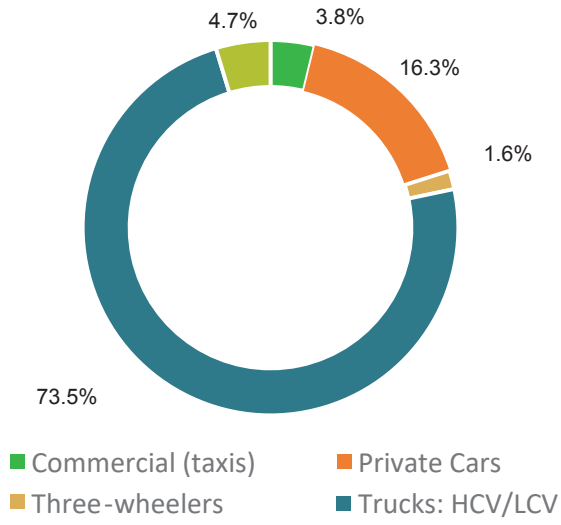

Figure 3: All India end-use share of diesel in the transport sector, 2020–21

Source: PPAC, 2022

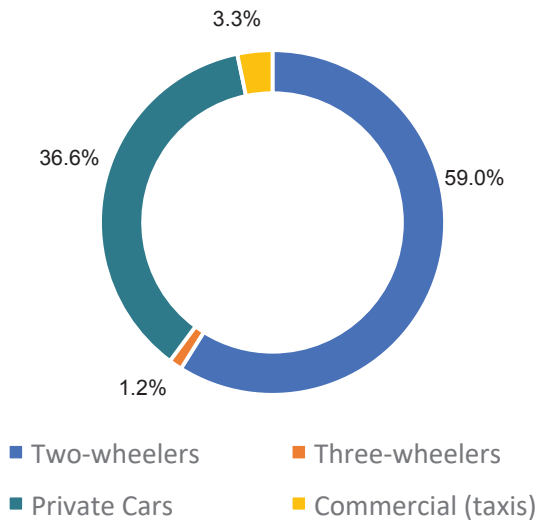

Figure 4: End-use share of petrol in the transport sector, 2020–21

Source: PPAC, 2022

4 Details available at: https://www.ppac.gov.in/WriteReadData/Reports/202203291206002029009ExecutiveSummarySectoralConsumptionStudy.pdf

Based on SIAM-4W fuel efficiency data, Table 2 represents fuel efficiency improvement (%) from FY 2010–11 to FY 2020–21 for various engine capacity (cc) class.

From FY 2010–20, vehicles with engine capacities in the range of 1,800 to 3,000 cc have become more fuel efficient (15% in petrol and 17% in diesel vehicles). With increase in engine capacity, its mechanical efficiency decreases due to increase in frictional losses. The overall efficiency improvement in the vehicles with engine capacities less than 3000 cc is approximately similar in petrol and diesel vehicles. However, fuel efficiency of bigger engine (>4,200 cc) has decreased in the last decade (FY 2010–2020).

Table 2: Improvement in fuel efficiency (2010–2020)

Engine Capacity (cc)	Fuel Type		
	Gasoline	Diesel	CNG
600–1,800	8.0%	8.1%	23.3%
>1,800–3,000	15%	17%	-
>3,000–4,200	1%	-	-
>4,200	-2%	-	-

Source: TERI Analysis based on SIAM 4-W FE data

4. Policy Landscape

With the growth in vehicular population and dependency on fossil fuels, the government is taking several efforts to moderate the rising demand for fossil fuels. Bureau of Energy Efficiency (BEE) is the nodal agency responsible for monitoring and reporting a summary of annual fuel consumption by automobile manufacturers during each financial year.

In the late 1980s and 1990s, as per Supreme Court judgments, India initiated first steps towards mitigating the public health impacts of vehicle and fuel emissions. The preliminary steps comprised of eradicating lead in petrol, switching to compressed natural gas (CNG) for auto-rickshaws and buses in Delhi (subsequently in other cities), and establishing emission standards known as Bharat Stage emission standards (BS) for new vehicles based on Euro standards from the European Union.

4.1 Overview of fuel efficiency norms

Fuel efficiency of vehicles is indicated by mileage (km/l), or CO_2 emissions generated per litre of fuel consumed. Fuel efficiency is generally used to compare the performance of different models in terms of ratio of units of fuel consumed and distance travelled. Some countries regulate fuel efficiency standards as litres of fuel used per 100 kilometres driven, while other countries regulate fuel efficiency standards as kilometres driven per gallon of fuel used.

4.1.1 Corporate Average Fuel Efficiency (CAFÉ) norms

Corporate Average Fuel Efficiency (CAFÉ) norms were first notified by the Government in 2017, under the Energy Conservation Act, 2001 to mitigate fuel consumption by lowering CO_2 emissions; aiming to reduce oil dependency and air pollution. These norms are applicable for petrol, diesel, liquefied petroleum gas (LPG), CNG, hybrid, and electric passenger vehicles with GVW<3,500 kgs. It relates the gasoline equivalent corporate average fuel consumption (in litres/100 km) to the corporate average kerb weight of all the cars sold by any original equipment manufacturer (OEM) in a fiscal year. The corporate average fuel consumption is estimated by averaging the standard fuel consumption of all vehicles sold each year. This fuel consumption is measured under standard conditions in national

accredited labs. There is a limit set on the total emission of CO_2 emitted, as the amount of CO_2 a car emits has direct correlation with the amount of fuel it consumes.

These standards were introduced in two phases—the first CAFÉ norms stage I fuel consumption standards were introduced effective 2017–18, and the CAFÉ norms stage II standards came into force in 2022–23 (Automotive Research Association of India (ARAI), 2020).

Table 3: CAFÉ norms for passenger cars

	CAFÉ norms stage I	CAFÉ norms stage II
Effective year	2017–18 onwards	2022–23 onwards
Average kerb weight (kg)	1,037	1,082
Average fuel consumption (litres/ 100 kms)	< 5.5	< 4.78
CO_2 emissions (grams of CO_2/km)	< 130	< 113

Source: BEE official website

4.1.2 Super credits

CAFÉ norms allow manufacturers of passenger cars to earn credit points based on a specific model's performance for fuel efficiency and features which would help get better fuel efficiency. These credit points are referred to as super credits. The CAFÉ norms allow super credits for battery electric vehicles (BEV), plug-in hybrid electric vehicles (PEV), and hybrid electric vehicles (HEV). The norms also allow super credits for technological features, like tyre pressure indicator, six speed transmission, start stop system, regenerative braking, etc.

In case of the features, CO_2 emissions are taken as 98% of the test value for calculations. Table 4 represents the derogation factor used for calculating super-credits for different vehicle types.

Table 4: Derogation factors for super credits for different categories of vehicles

Vehicle Type	Volume derogation factor for super-credits
BEV	3
PHEV	2.5
HEV	2

Source: Amendment no. 6, MoRTH/CMVR/TAP-115/116

4.1.3 CAFÉ norms for other vehicular segments

Fuel efficiency norms in India have been implemented only for passenger cars and standards are based on the gross vehicle weight (GVW) and axle configuration. For real-world performance, test parameters are just as relevant as the norm value. At present, the Modified Indian Driving Cycle (MIDC) is used to test passenger cars and light duty vehicles (LDVs) in India. To measure the fuel efficiency performance in heavy-duty vehicles (HDVs), vehicles are tested on constant speed fuel consumption (CSFC) driving cycle. Fuel consumption in the CSFC driving cycle is evaluated over a set speed, without any transient behaviour.

Two-Wheelers/ Three-Wheelers	Passenger Car (M1) (GVW<3.5 tonnes)	Light and Medium Commercial Vehicle (M2, M3, N2) (GVW 3.5–12 tonnes)	Heavy-Duty Diesel Vehicle (GVW >12 tonnes)
• Two-wheelers in India are tuned for fuel efficiency, and are most fuel efficient in their category • No mandatory fuel efficiency norms for two-wheelers, and three-wheelers	• CAFÉ Phase I (2017–18) 5.5L/100km (129.8 gm • CO_2/km) @1037 kg CAFÉ Phase II (2022–23) 4.78L/100km (113 gm • CO_2/km) @1082 kg	• M2 and M3 passenger carriage vehicle • N2 commercial goods carriage vehicle • MIDC testing cycle is used for LDVs • Fuel efficiency norms are yet to be decided	• Evaluation of fuel economy using CSFC test • Fuel consumption determined at 40 and 60kmph with fully laden condition, and for bus at 50 kmph • Mandated from April, 2023

Figure 5: Fuel efficiency norms for the various vehicle segments

Source: TERI analysis based on BEE data

4.1.4 Fuel efficiency norms: International Experience

In terms of CO_2 emission targets, Indian standards are more stringent than USA. In India, CO_2 emission targets are 113 grams per km, while it is 126.25 grams of CO_2 per km in USA. Compared to European standards, Indian CO_2 emission targets are less stringent. In terms of fuel efficiency, Indian standards are more stringent than USA and China, as it targets lower fuel consumption per kilometre as compared to other countries.

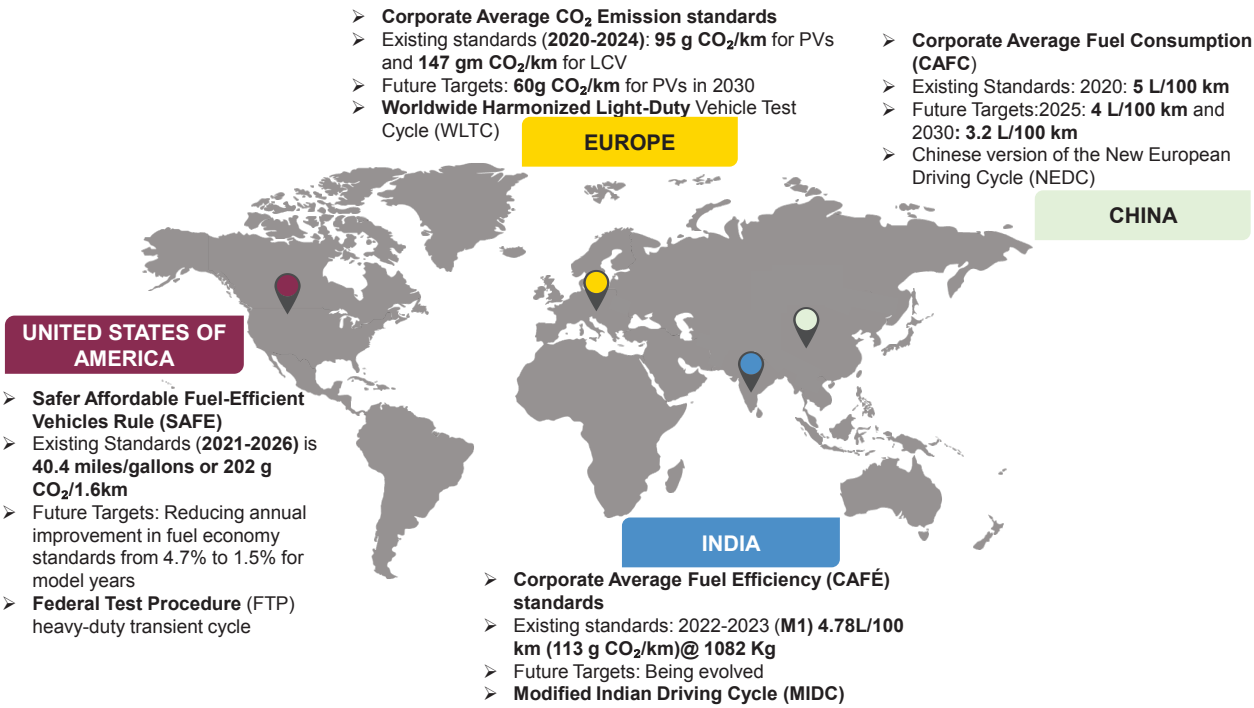

Figure 6: CAFÉ norms—International experience

Source: Global Fuel Economy Initiative, 2021, IEA

4.2 Overview of Bharat Stage emission standards (BS)

Deteriorating quality of air has always been a concern worldwide, especially with growing vehicular emissions. Proper measures must be set in place to curb vehicular pollution. BS emission standards were instituted to regulate and control the emissions from the motor vehicles. These standards are usually set by the Central Pollution Control Board (CPCB) under the MoEF&CC, and are generally derived from regulations implemented in European countries. India started adopting emission standards based on EU with BS-I (Euro I) in 2000. BS emission standards are updated regularly to make vehicles more environmental friendly.

4.2.1 Existing emission regulations in India

With BS-VI standards, the particulate matter (PM) emissions have been tightened. Moreover, the limit for particle number (PN) has been introduced for light and heavy-duty vehicles fitted with gasoline direct injection (GDI) and compression ignition (diesel engines). Several other parameters have been planned under the BS-VI emission regulations, to be implemented in a phased manner.

BS-VI introduced real driving emission (RDE) and in-service conformity test (ISC) requirements for LDVs and HDVs. RDE and ISC have been implemented in vehicles manufactured from April 1, 2023. It mandates vehicles to be tested on real-world driving cycles using portable emissions measurement systems (PEMS). This step will bridge the existing gap between emissions occurring during the time of certification, for type approval and conformity of production, with real-world conditions (Singh et al, 2022).

The BS-VI standards call for enhanced on-board diagnostic (OBD) requirements as well; for all vehicle classes, with first-ever OBD specifications for two and three-wheelers.

While major progress has been made in this regard, there is an opportunity to further tighten norms either aligning with Euro VII, or adapting norms for Indian scenario, and decide the timeline for the next phase of BS norms as BS-VII.

4.2.2 Future roadmap of emission standards

Starting from April 2023, real driving emissions (RDE) have been implemented in India as the second phase of BS-VI. Further, Europe has implemented WLTC to

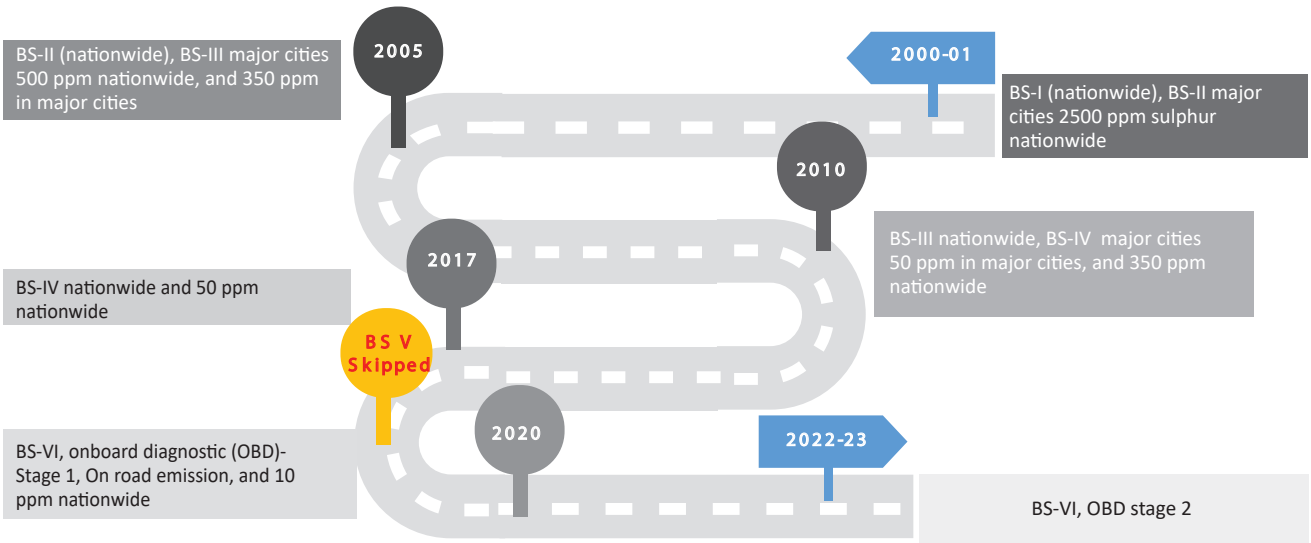

Figure 7: Timelines of Bharat Stage Emission Standards

Source: BEE and ARAI, 2022

bridge the gap between real-world fuel consumption and emissions. Currently, Indian Driving Cycle utilises the speed-distance-time map for testing both fuel efficiency and emissions norms in India. However, India must adopt Worldwide Harmonized Light Vehicle Test Procedures (WLTP) testing process as it is more effective in comparison with the current test cycles. The WLTP process accounts for slopes and gradients, as well as engines run at higher engine speeds.

With full compliance to BS-VI (all clauses of Euro VI), there is a need to debate whether India should still adopt Euro VII as next stage emission regulation, or research and evolve a standard addressing critical issues for air quality in India. This requires a study of the various pollutants and their contributing factors to Indian air quality for formulating the norms to be adopted. For example, in India the main pollutant causing a higher air quality index (AQI) is PM. India can focus on such parameters with advanced research so that better air quality can be achieved, instead of implementing what Europe has announced as Euro VII—based on the European critical situation which may be different from India.

5. Gaps in Existing Fuel Efficiency and Tailpipe Emissions

India was world's third largest energy consumer in 2021 (Enerdata, 2021). The transport sector, which is the third highest consumer after industrial and building sectors, is responsible for 15% of India's energy consumption. (International Energy Agency (IEA), 2021). According to the AMP, the automobile industry is expected to grow phenomenally. Hence, the consumption of fossil fuels and emissions will also increase.

Fuel efficiency and tailpipe emissions standards are two important measurers taken by the government to reduce dependency on fossil fuels and improve air quality. The following are a few identified gaps in the existing standards/norms, which require urgent rectification to further improve the standards.

Lack of a clear, long-term roadmap for efficiency and emission improvement

One of the main challenges faced by India is the delay in establishing the future roadmap of standards. The process to tighten the standards for 2026 and 2030 timeframes should begin immediately to give a clear direction and time to the sector to improve.

Missing CAFÉ norms for other vehicle segments

Apart from passenger cars there are other vehicular segments which contribute to efficiency improvement. Presently, CAFÉ norms in India have been implemented only for passenger cars. There are no fuel efficiency standards for other vehicle segments, such as MDVs, and two-wheelers. As the Indian market is dominated by two-wheelers, there is a need for implementing fuel efficiency norms for two-wheelers.

Need to upgrade existing test cycles

Inadequate reflections of the real-world driving conditions in current test cycles in India should be addressed immediately. Urgent attention is required to improve the efficiency of the vehicles through more stringent limits. India should start working for the implementation of WLTP testing process.

More stringent targets for future timeframes

Having more stringent targets for both standards (emissions and fuel efficiency) in the future timeframe will encourage manufacturers to adopt more efficient vehicles with improved powertrains and transmission technologies, that will better align to India's net zero target. Along with tightening the standards, attention must be paid to the design of super-credits to ensure real world fuel savings.

6. Recommendations

Fuel efficiency and emission regulations are critical measures for India to meet its NDCs. The regulations are also important to reduce oil dependency and further strengthen energy security. Based on stakeholders' (from different domains) consultations and literature review, some recommendations are given here to improve the existing standards and regulations:

Emissions and CAFÉ regulation to be implemented in same timeframe

Currently, corporate fuel economy norms for passenger vehicles, and emission standards are implemented separately. To optimize the development timelines and costs, MoRTH should decide simultaneous implementation of both standards, keeping in mind importance of both, rather than delaying one for the other. This would help OEMs and component manufacturers in better planning and optimizing activities.

Tightening existing norms and regulations for future timeframe

In the HDV segment, fuel economy standards are currently lagging from the leading markets. As other countries are tightening fuel economy standards, considering the climate impacts, India should follow suit to achieve economic and environmental benefits, while making the HDV industry globally competitive.

It is recommended that an India-specific emissions study should be done, on the basis of which future emissions norms focusing on India-specific situations should be evolved in the form of targets for future emission norms. Only focusing on tailpipe emissions will not fulfil India's COP targets. Considering India's specific situation and availability of vast biological resources, there is a need to integrate carbon neutral ethanol and carbon negative (Bio-CNG) biofuels in upcoming CAFÉ considerations.

Alternative fuel options

India is the fourth largest emitter of methane, which has an impact that is 28 times more adverse than that of CO_2 in global warming.[5] If methane gas is captured and cleaned, it can substitute natural gas as a fuel for automobiles. This can be a game changer for India's energy security. This can be achieved if dairy waste can be consumed as feedstock for generating biogas and can substitute natural gas after purification. Provisions for including such fuel vehicles should be integrated into CAFÉ regulations. The Sustainable Alternative towards Affordable Transport, or SATAT scheme, started by MoPNG to encourage entrepreneurs to set up compressed biogas (CBG) plants, needs an aggressive push for pan-India implementation and has the potential to change the rural economy.

Technological interventions

The transport sector is the third largest CO_2 emitter, with road transport contributing more than 90% of CO_2 emissions. Hence, there is an urgent need for technological interventions for greening transport to restore the equilibrium. The Indian automobile industry is the fastest growing automobile industry in the world and there is a significant amount of focus on carbon neutral fuels. Though EVs have zero tailpipe emission, there are apprehensions about the lifecycle analysis of EVs, in comparison with conventional ICE. In line with the National Solar Mission, the government should encourage the auto industry to adopt solar energy for charging EVs, resulting in total elimination of fossil fuels for EVs (having a very positive impact on air quality). There is a need to give priority to immediately available carbon neutral fuels, like ethanol/bio-CNG, and continue improving carbon footprint of electricity, so that we can reduce GHG emissions.

5 Details available at https://www.indiaspend.com/explainers/chasing-methane-why-curbing-methane-emissions-is-crucial-to-fighting-climate-change-828127

Innovative Testing Procedure

Worldwide Harmonized Light Vehicle Test Procedures (WLTP) for LDVs have been adopted by most of the countries, for determining the levels of pollutants from ICE and hybrid cars. Though the Automotive Industry Standards Committee (AISC) has agreed to implement WLTP from 2027, the Indian automobile industry should immediately implement WLTP to include a wide range of on-road driving conditions.

Most of the countries are shifting towards developing testing procedures and cycles that can be successfully translated into real driving conditions. India should also modify the CSFC fuel economy testing procedure for HDVs to a simulation-based approach, like the vehicle energy consumption calculation tool (VECTO). This will save testing cost, time, and (combined with real-world drive cycle) will result in more realistic fuel consumption data. The implementation of Indian version of VECTO should be inclusive in future fuel efficiency standards.

Long-term road map for improvement

There is an urgent need for a long-term road map for emission reduction and fuel efficiency improvements. This would help in improving air quality and strengthening energy security for transformation to zero emission vehicles. Until then, we also need to clearly spell out the priority for alternative fuels and powertrains that can improve CO_2 emissions. A clear policy goal of increased stringency will provide the automobile industry and consumers with confidence to shift to zero emission vehicles.

Implementation and enforcement mechanism

Currently, the government of India has different tax slabs for passenger vehicles depending upon parameters such as type of vehicle (EVs/hybrid/ICE), engine size, fuel type, and length of the vehicle, etc. For a cleaner environment, the government should consider a differential tax structure for new passenger vehicles depending upon CO_2 emissions. With respect to the older passenger vehicles on road emission test should be mandatory and a high penalty should be applied if there is noncompliance, or such older vehicles can be recommended for scrappage.

Delayed implementation of norms leads to a huge loss for the nation in terms of emissions and oil imports. Hence, periodic updates of standards with timely implementation is critical to move towards decarbonization.

7. Conclusion

There is a serious concern for energy equilibrium and deteriorating air quality as the transport sector is growing rapidly. An exponential increase in fuel consumption is expected at a time when the country is tackling energy insecurity and the aftereffects of climate change. Hence, there is a need to adopt an accelerated path for total decarbonization. With the adoption of BS-VI emission standards in 2020, India has taken substantial steps to reduce vehicular emissions; however, similar measures have not been applied to fuel efficiency norms. Thus, the standards need to be much stricter in the future to drive manufacturers to adopt zero-emission vehicles, as well as other alternative fuel options.

CAFÉ norms are sales-weighted corporate average standards, while BS emission standards require each model to comply based on lab testing, therefore, both plays an important role in accelerating the path to achieve India's net zero targets.

There is an urgent need to implement the on-road testing parameter introduced in BS-VI standards, to bridge the gap between lab-based and on-road driving test. India should set stringent targets for the future timeframes of 2027 (WLTP and CAFÉ-III) and 2032 (CAFÉ -IV) which should be synchronized with India's specific situation of carbon neutrality targets as well as its local emission challenge.

8. References

Autobei Consulting Group. (2019). *Indian Automobile Industry Outlook*.

Automotive Research Association of India (ARAI). (2020). *India's Initiative Towards Tighter Emission & Fuel Efficiency Norms*. Automotive Research Association of India (ARAI).

Bureau of Energy Efficiency (BEE). (2019). *Roadmap of Sustainable and Holistic Approach to National Energy Efficiency*. New Delhi: Ministry of Power, Government of India.

Bureau of Energy Efficiency. (2021). *Impact of Energy Efficiency Measures 2019-20*. New Delhi: Bureau of Energy Efficiency.

Climate Action Tracker. (December, 2020). *Decarbonising the India transport sector pathways and policies*.

IBEF. (2022). *Automobile Industry Report*. New Delhi: India Brand Equity Foundation (IBEF).

International Energy Agency (IEA). (2021). *E4 Country Profile: Energy Efficiency in India*. Retrieved from https://www.iea.org/articles/e4-country-profile-energy-efficiency-in-india

International Energy Agency (IEA). (2021). *India 2020 Energy Policy Review*. International Energy Agency (IEA).

International Energy Agency (IEA). (2022). *India Energy Outlook 2021*. International Energy Agency (IEA).

International Energy Agency (IEA). (2022). *World Energy Outlook*. International Energy Agency (IEA).

International Transport Forum. (2021). *Decarbonising India's Transport System: Charting the Way Forward*. Paris, France: International Transport Forum.

Ministry of Environment, Forest and Climate Change. (2022). *India's Long term Low Carbon development strategy*.

Ministry of Heavy Industry. (2016). *Final Draft Automotive Mission Plan 2016-26*. New Delhi.

New Climate Institute and Climate Analytics. (2020). *Decarbonising the Indian transport sector pathways and policies*. Climate Action Tracker.

Petroleum Planning and Analysis Cell (PPAC). (2020-21). *Indian Petroleum and Natural Gas Statistics*. New Delhi: Petroleum Planning and Analysis Cell (PPAC).

Petroleum Planning and Analysis Cell (PPAC). (March 2022). *Snapshot of India's Oil and Gas Data*. New Delhi: Petroleum Planning and Analysis Cell (PPAC).

Petroleum Planning and Analysis Cell. (2013). *All India Study on Sectoral Demand of Diesel and Petrol*. New Delhi: Petroleum Planning and Analysis Cell.

Petroleum Planning and Analysis Cell. (2021). *All India study on Sectoral Demand for Petrol and Diesel 2020-2021*. New Delhi: Petroleum Planning and Analysis Cell.

Roychowdhury, A., & Chattopadhyaya, V. (2021). *India's Fuel Economy Benchmarks*. New Delhi: Centre for Science and Environment.

Singh, S., Kulshrestha, M. J., Rani, N., Kumar, K., Sharma, C., & Aswal, D. K. (2022). An Overview of Vehicle Emission Standards.

THE ENERGY AND RESOURCES INSTITUTE

Creating Innovative Solutions for a Sustainable Future

For more information, please visit: **www.teriin.org**