

INDIA BHARAT STAGE VI EMISSION STANDARDS

ICCT POLICY UPDATES

SUMMARIZE
REGULATORY
AND OTHER
DEVELOPMENTS
RELATED TO CLEAN
TRANSPORTATION
WORLDWIDE.

On February 19, 2016, the Indian Ministry of Road Transport and Highways (MoRTH) issued a draft notification of Bharat Stage (BS) VI emission standards for all major on-road vehicle categories in India.¹ The standards apply to light- and heavy duty vehicles, as well as two- and three-wheeled vehicles. As proposed, the BS VI standards will go into effect for all vehicles in these categories manufactured on or after April 1, 2020. The draft BS VI proposal specifies mass emission standards, type approval requirements, and on-board diagnostic (OBD) system and durability levels for each vehicle category and sub-classes therein. In addition, reference and commercial fuel specifications are included in the BS VI proposal. The adoption of the proposed BS VI emission standards will essentially bring Indian motor vehicle regulations into alignment with European Union regulations for light-duty passenger cars and commercial vehicles, heavy-duty trucks and buses, and two-wheeled vehicles. While not yet reaching European levels, more stringent emission standards are also set for three-wheeled vehicles.

With this proposal, the Indian Government has confirmed its intent to leapfrog BS V level emission standards and move directly to the more stringent and robust BS VI level. The proposed BS VI standards are far-reaching in scope and incorporate substantial changes to existing Bharat Stage III and IV emission standards. Of particular note is the tightening of particulate matter (PM) mass emission limits and the introduction of particle number (PN) limits for light- and heavy-duty vehicles (LDV, HDV) fitted with gasoline direct injection (GDI) and compression ignition (CI), or diesel, engines. As evidenced by the adoption of nominally equivalent PM and PN standards in Europe, this step will likely lead to the near-universal application of diesel particulate filters (DPF) to control PM emissions from new diesel LDVs and HDVs.

A second important component of the BS VI standards is the expansion of type approval and in-service conformity test requirements for LDVs and HDVs. For LDVs, provisions are included in the BS VI proposal for real-world driving cycle emission measurements using portable emissions measurement systems (PEMS). For HDVs, the European Stationary Cycle (ESC) and European Transient Cycle (ETC) used for BS III and IV type approval are replaced with the World Harmonized Steady-State Cycle (WHSC) and World Harmonized Transient Cycle (WHTC), respectively. The WHSC and

¹ Gazette of India BS VI notification: <http://egazette.nic.in/WriteReadData/2016/168300.pdf>

WHTC are more representative of real-world driving conditions and better capture driving modes in which pollutant emissions can be elevated. In addition, off-cycle emissions testing requirements and in-service conformity testing for type approval and in-service vehicles using PEMS are introduced for HDVs in the BS VI proposal. For both LDVs and HDVs, these requirements will help to ensure that emissions performance demonstrated in laboratory testing is also maintained under real-world driving conditions.

Additional noteworthy aspects of the BS VI proposal include enhanced OBD requirements for all vehicle classes, with first-ever OBD specifications for two- and three-wheeled vehicles, and the introduction of emission limits on nitrogen oxides (NO_x), carbon monoxide (CO), and hydrocarbon (HC) for two-wheelers that are equivalent to proposed BS VI norms for light-duty gasoline passenger vehicles. This step will ensure that BS VI two-wheelers will be as clean as BS VI gasoline passenger vehicles on a per-kilometer-driven basis.

POLICY BACKGROUND

Indian regulations for four-wheeled vehicles follow European Union regulatory pathways. The implementation of progressive standards in India has generally lagged behind equivalent EU standards by about 5 years in major cities and 10 years nationwide. In general, standards for two- and three-wheeled vehicles have been developed independently, and do not follow the European model. Currently, emission standards for motor vehicles in India are at BS III or BS IV levels. Nationwide implementation of BS IV standards for new vehicles is expected beginning in April 2017. Implementation dates for BS III and IV emission standards for major vehicle categories are shown in Table 1.

Table 1. BS III and BS IV implementation dates

Vehicle category	BS III Implementation date	BS IV Implementation date
M, N Category vehicles GVW ≤ 3,500 kg	2005: select cities 2010: nationwide	2010: select cities 2017: nationwide ¹
M, N Category vehicles GVW > 3,500 kg	2005: select cities 2010: nationwide	2010: select cities 2017: nationwide ¹
Two-wheeled vehicles	2010	2017
Three-wheeled vehicles	2010	2017

¹ <http://egazette.nic.in/WriteReadData/2015/165494.pdf>

On January 6, 2016 the Indian Ministry of Road Transport and Highways (MoRTH) announced its decision to leapfrog from BS IV to BS VI emission standards in an accelerated fashion, with full implementation of BS VI level emission standards beginning in 2020.² This announcement was supported by corresponding actions taken by the Ministry of Petroleum and Natural Gas (MoPNG) to ensure a nationwide supply of BS VI fuel along with the proposed BS VI emission standard implementation date of April 1, 2020. The announcement by the MoRTH effectively

² <http://pib.nic.in/newsite/PrintRelease.aspx?relid=134232>

withdrew a draft regulatory roadmap released in November 2015 that proposed adoption of BS V and BS VI emission standards in 2019 and 2021, respectively. The proposed BS VI regulation will be the first global instance of leapfrogging from Euro 4/IV level directly to Euro 6/VI level motor vehicle emission standards. This precedent-setting step marks a new path forward for all developing country markets to follow to accelerate the adoption of clean vehicle technologies and fuels. The notification comes at a time when many Indian cities are struggling with severe air-quality problems and is an important step in addressing these issues.

OVERVIEW OF PROPOSED STANDARDS

The draft BS VI regulation sets forth mass emission standards, type approval requirements, OBD system specifications, and durability levels for all major vehicle categories in India. Several elements of the BS VI regulation are not fully defined in the draft regulation. These details will be introduced in a forthcoming implementing standard, AIS 137. The following sections summarize key aspects of the draft BS VI proposal for individual vehicle categories.

CATEGORY M AND N VEHICLES WITH GVW \leq 3,500 KG (LIGHT-DUTY VEHICLES)

BS VI emission standards are defined for category M and N vehicles with gross vehicle weight (GVW) not exceeding 3,500 kg. Vehicle types in these categories include light-duty passenger and commercial vehicles. Emission standards are set separately for vehicles equipped with spark ignition (SI) and compression ignition (CI) engines, and vary both in terms of the types of pollutants that are regulated as well as the levels at which emission limits for commonly regulated pollutants are set. In both cases, emission limits are numerically equivalent to Euro 6 standards for similar engine types. A full listing of proposed BS VI emission norms can be found on transportpolicy.net.³ Figures 1 and 2 show comparisons of BS IV and VI emission limits for select pollutants for vehicles equipped with CI and SI engines, respectively.

Given the widespread dieselization of the Indian light-duty fleet, reductions in allowable pollutant emission rates for vehicles equipped with CI engines are among the most significant aspects of the BS VI proposal. As shown in Figure 1, proposed BS VI NO_x and PM emission limits for light-duty diesel vehicles are considerably lower than BS IV levels. NO_x emission limits are reduced by 68% relative to BS IV levels, though remain between 33% and 52% higher than BS VI emission limits for corresponding light-duty gasoline vehicle classes. PM emission limit reductions vary by vehicle class and range from 82%–93%. For all light-duty diesel vehicle classes, the tightening of the PM emission standard is accompanied by the introduction of a particle number emission limit of 6×10¹¹/km. Together, the more stringent PM standard and new PN limit will ensure vehicle manufacturers use DPFs, the best available PM control technology for diesel engines.

For light-duty vehicles equipped with SI engines, reductions in pollution emission limits relative to BS IV levels are more modest. As shown in Figure 2, BS VI emission limits for CO and HC remain unchanged from BS IV values, while NO_x limits are

³ http://transportpolicy.net/index.php?title=India:_Light-duty:_Emissions

reduced by 25%. The BS VI proposal introduces PM and PN emission limits for light-duty gasoline vehicles, though these standards only apply to vehicles equipped with direct injection engines. PM and PN emission limits for gasoline direct injection (GDI) vehicles are set at the same level as those for light-duty diesel vehicles, though manufacturers may meet an optional 6×10^{12} /km PN limit rather than the more stringent 6×10^{11} /km during the first three years of BS VI implementation. These provisions should promote the use of gasoline particulate filters (GPF) to control PM emissions from GDI vehicles.

The most significant change to vehicle type approval procedures for light-duty vehicles specified in the proposed BS VI regulation is the inclusion of provisions for in-service conformity testing using portable emissions measurement systems (PEMS). These provisions should help to ensure emissions performance demonstrated in laboratory-based emissions testing is maintained under real-world driving conditions. It should be noted that the procedures for PEMS testing of real-world driving emissions are not included in the BS VI proposal and will be fully specified in the forthcoming AIS 137 implementing standard. These procedures should include conformity factors that define allowable levels of excess emissions above the emission limits established for laboratory-based type approval testing. The stringency of BS VI real driving emission requirements and corresponding emissions benefits will depend on the levels at which these conformity factors are set.

The in-use emissions performance of light-duty vehicles in India should also be improved under the BS VI proposal through the inclusion of more stringent OBD and durability requirements for vehicles in this category. BS VI OBD requirements will be introduced in two phases, with preliminary OBD thresholds (BS VI-1 OBD) applicable for all vehicles manufactured on or after April 1, 2020, and final thresholds (BS VI-2 OBD) applicable from April 1, 2023. Proposed threshold values for BS VI-1 OBD and BS VI-2 OBD are equivalent to preliminary and final Euro 6 threshold limits, respectively.⁴ In-use performance ratio (IUPR) monitoring requirements, which specify the minimum operating frequency required of OBD monitors, will be introduced at the same time as BS VI-2 OBD thresholds. While full OBD and IUPR monitoring requirements will be specified in AIS 137, provisions included in the draft BS VI regulation indicate OBD system monitors will be required to operate for, at minimum, 10% of the vehicle operating time. In addition to OBD requirements, the BS VI regulation also follows Euro 6 specifications for establishing the durability of pollution control devices. In this case, deterioration factors and the minimum distance requirements (160,000 km) for bench aging durability tests both follow Euro 6 precedents.

The draft notification does not specify whether or when the world harmonized light-duty vehicles test procedure (WLTP) will be adopted in India.

4 Commission Regulation (EU) No 459/2012: <http://eur-lex.europa.eu/legal-content/EN/TXT/?uri=CELEX%3A32012R0459>

CATEGORY M AND N VEHICLES WITH GVW > 3,500 KG (HEAVY-DUTY VEHICLES)

BS VI emission standards for larger goods movement and passenger transport vehicles are defined separately under the proposed BS VI regulation for category M and N vehicles with GVW exceeding 3,500 kg. Importantly, emission standards for these vehicle categories cover heavy-duty vehicles, which are estimated to be the largest on-road source of PM and NO_x emissions in India.⁵ Both the pollutants included in the BS VI regulation for heavy-duty vehicles and the mass emission limits for these pollutants follow Euro VI specifications. A full tabulation of proposed BS VI emission limits can be found on transportpolicy.net.⁶ In addition, a comparison of BS IV and BS VI NO_x and PM emission limits for heavy-duty diesel vehicles is presented in Figure 1.

From an air quality and human health perspective, perhaps the single most important aspect of the BS VI regulation is the tightening of the PM emission limit and introduction of a PN limit for heavy-duty diesel vehicles. As shown in Figure 1, the PM standard for these vehicles is reduced by 50% and 67% from BS IV levels as measured on steady-state and transient dynamometer test cycles, respectively. The more stringent PM standard is accompanied by a particle number emission standard of 8×10¹¹/kWh for steady-state cycle testing and 6×10¹¹/kWh for transient cycle testing. As was the case for light-duty diesel vehicles, these steps will likely force manufacturers of heavy-duty engines sold in India to utilize DPFs to control PM emissions from BS VI emission level engines. Given the importance of heavy-duty diesel vehicles as a source of PM emissions and the large PM and PN control efficiencies offered by DPF systems,⁷ these restrictions should greatly reduce the PM emissions burden of on-road vehicle in India.

The increased stringency of BS VI standards relative to BS IV is a consequence of not only reductions in pollutant mass emission limits, but also of the introduction of type approval test cycles and requirements designed to minimize discrepancies between laboratory and real-world emissions performance. Laboratory test cycles currently used for type approval, the ESC and ETC, are replaced with the WHSC and WHTC in the BS VI regulation. The WHSC and WHTC are more representative of real-world driving conditions and better capture driving modes where pollutant emissions can be elevated, such as low-speed, low-load driving. Specifically, the WHSC include average engine load about half that of the ESC, while the WHTC requires both cold and hot start conditions and includes more than twice the idling time of the ETC.⁸

In addition to more stringent test cycles, additional type approval and in-service conformity test requirements are included in the BS VI to ensure emissions performance demonstrated in the laboratory is maintained in real-world driving conditions. World-Harmonized Not-To-Exceed (WNTe) off-cycle laboratory testing limits for CO, HC, NO_x, and PM are adopted following UNECE Regulation No 49. Also, in-service conformity testing is required to show that emissions performance

5 Bansal G. & Bandivadekar, A. (2013), Overview of India's Vehicle Emissions Control Program: Past Successes and Future Prospects. <http://www.theicct.org/indias-vehicle-emissions-control-program>

6 http://transportpolicy.net/index.php?title=India:_Heavy-duty:_Emissions

7 DPFs are estimated to reduce PM mass emission by > 90% and PN emissions by > 99% relative to an uncontrolled diesel engine. (ICCT (2015), Accelerating progress from Euro 4/IV to Euro 6/VI vehicle emission standards).

8 ICCT (2015), Accelerating progress from Euro 4/IV to Euro 6/VI vehicle emission standards. <http://www.theicct.org/briefing-leapfrogging-to-euro-6-vi-mar2015>

is maintained over the useful life of the engine. In-service conformity factors, which define allowable emissions above regulated emission limits, are set for gaseous pollutants. Finally, specifications for PEMS demonstration testing at type approval are included in the BS VI regulation. For each of these requirements, specific procedures will be defined in the AIS 137 implementing standard.

As was the case for light-duty vehicles, BS VI OBD requirements will be introduced in two stages, with BS VI-1 OBD applicable for new models on April 1, 2020 and all models on April 1, 2021 and BS VI-2 OBD applicable beginning April 1, 2023. Full specifications for BS VI OBD systems will be included in AIS 137, though threshold limits for both BS VI phases are included in the draft rule. Generally, threshold limits are equivalent to phase-in and general requirements specified for Euro VI, with the sole exception being that no limit is set for PM under BS VI-1 OBD requirements for CI engines. Rather than a threshold limit, performance monitoring for the wall-flow diesel particulate filter is specified. No further details of what, specifically, performance monitoring will consist of are included in the draft rule, and will be further detailed in the AIS 137 implementing standard.

TWO-WHEELED VEHICLES

Two-wheeled vehicles, such as motorcycles and mopeds, are the largest vehicle class in India, both in terms of current vehicle population, as well fraction of new vehicle sales. As such, they represent an important source of pollutant emissions and have a significant impact on air quality, particularly in urban areas of the country. As proposed, the BS VI regulations largely align emission limits for two-wheeled vehicles with the most stringent standards adopted for similar vehicle types in the EU, and ensure that these vehicles will generally be no more polluting than BS VI four-wheel passenger vehicles.

BS VI emission standards are set for Class 1-3 two-wheelers equipped with SI engines, which account for the majority of the two-wheeled vehicle population in India, and separately for two-wheelers fitted with CI engines. Separate standards are also set for two-wheelers with SI engines less than 50 cubic centimeters and maximum rated speed less than 50 km/h. This class of two-wheeled vehicles largely consists of pedal-powered mopeds, which make up a very small fraction of the market.⁹ In all cases, BS VI standards will apply to vehicles manufactured on or after April 1, 2020. Mass emission limits specified in the BS VI standards can be found on transportpolicy.net.¹⁰ Figures 1 and 2 include comparisons of BS VI and BS IV mass emission limits for CI and SI two-wheelers, respectively.

For Class 1-3 SI two-wheelers, BS VI CO, NO_x, and HC emission limits are equivalent to Euro 5 limits for similar L-category vehicles, which have been adopted and will be implemented beginning in 2020 for new vehicle types and in 2021 for all vehicles.¹¹ This means that, for two-wheeled vehicles, the BS VI regulation essentially harmonizes emission limits, as well as implementation schedules with Europe. Relative to BS IV levels, NO_x emission limits for these two-wheeled vehicle classes

9 ICCT (2014) Bharat Stage IV Emission Standards for Two-Wheelers in India. <http://www.theicct.org/policy-update-bharat-stage-iv-emission-standards-two-wheelers-india>

10 http://transportpolicy.net/index.php?title=India:_Motorcycles:_Emissions

11 Regulation (EU) No 168/2013 of the European Parliament and of the Council. <http://eur-lex.europa.eu/legal-content/EN/ALL/?uri=CELEX%3A32013R0168>

are reduced by between 70 and 85%. In the BS VI standards, an independent tailpipe HC emission limit of 0.10 g/km is also introduced. In previous regulatory stages, HC emissions from two-wheelers were regulated under a combined NO_x+HC standard. By setting independent emission standards for both HC and NO_x, BS VI emission standards will help to ensure that emission control strategies do not reduce emissions of one pollutant at the expense of the other.

Hydrocarbon emissions from gasoline two-wheelers are further controlled through the tightening of the evaporative emissions limit. Under BS IV standards, manufacturers are able to meet either a 2.0 or 6.0 g/test evaporative emissions limit, with vehicle models meeting the 2.0 g/test subject to less a stringent tailpipe NO_x+HC limit. Under the BS VI regulation, all gasoline powered vehicle models are required to meet a 1.5 g/test evaporative emissions limit, and no flexibility provisions are included for meeting tailpipe and evaporative emission limits. These steps will help to reduce complete vehicle HC emissions.

As shown in Figures 1 and 2, emission limits for diesel and Class 1-3 gasoline two-wheeled vehicles are, for the most part, numerically equivalent to limits for light-duty passenger vehicles (Class M1, M2). Exceptions include a slightly higher NO_x limit for CI two-wheelers (0.09 g/km vs. 0.08 g/km for light-duty diesel passenger vehicles), and the omission of a PN limit for two-wheeled vehicles powered by GDI engines.

OBD system specifications for two-wheelers are included for the first time in proposed BS VI regulations. Specific OBD Stage II system requirements are shown in Table 2 and apply to Class 1-3 gasoline and all diesel two-wheelers.

Table 2. BS VI OBD Stage II system specifications for two- and three-wheeled vehicles.

Monitoring item
Circuit continuity for all emission related power train components (if equipped)
Distance traveled since malfunction indicator lamp (MIL) ON
Electrical disconnection of electronic evaporative purge control device (if equipped)
Catalytic converter monitoring
EGR system monitoring
Misfire detection
Oxygen sensor deterioration

The BS VI regulation also sets OBD emission thresholds for these two-wheeled vehicle classes. Threshold limits are set for CO, NO_x, non-methane hydrocarbons (NMHC), and PM, and are numerically equivalent to Euro 5 thresholds for similar L-Category vehicle types.

Durability mileage for two-wheeled vehicles is set at 35,000 km in the BS VI standards, which represents a moderate increase from the 30,000 km requirement included in the BS IV regulation. This mileage is equivalent to Euro 5 requirements for two-wheel motorcycles with rated maximum speed greater than 130 km/h and exceeds Euro 5 requirements for other two-wheel vehicle types, which are set at either 11,000 or 20,000 km.

THREE-WHEELED VEHICLES

Three-wheeled vehicles in India primarily consist of autorickshaws and small three-wheeled goods carriers. These vehicles use a variety of fuel types, including gasoline, diesel, and compressed natural gas (CNG). Proposed BS VI emission standards for this vehicle category are generally less stringent than Euro 5 standards for similar L-Category vehicles, though should provide meaningful emission reductions relative to BS IV standards. A full tabulation of proposed BS VI emission limits for three-wheeled vehicles can be found on transportpolicy.net.¹² As with other vehicle types, a comparison of BS IV and BS VI limits for select pollutants is included in Figure 1 for CI vehicles and Figure 2 for SI vehicles.

With respect to mass emission limits, important aspects of the BS VI proposal include a 44% reduction in the PM emission limit for three-wheelers equipped with CI engines, and the introduction of independent NO_x and HC standards in place of a combined NO_x+HC standard for both CI and SI three-wheelers. For three-wheelers equipped with SI engines, this requirement will likely force a shift from carbureted engines tuned to lean operation to engine systems employing fuel injection, stoichiometric combustion, and three-way catalytic converters.¹³ Similar to two-wheeled vehicles, evaporative HC emissions for gasoline three-wheelers are limited to 1.5 g/test in the BS VI regulation and dual evaporative and tailpipe emissions compliance options from BS IV standards are removed. Finally, restrictions on crankcase emissions are included in the BS VI proposal.

BS VI regulation specifies OBD requirements for three-wheeled vehicles for the first time, and system requirements follow those for two-wheeler BS VI OBD systems as shown in Table 2. OBD threshold limits are set for CO, HC, and NO_x separately for gasoline and diesel vehicles. Also, as was the case for two-wheelers, durability mileage is set at 35,000 km for BS VI three-wheelers.

The BS VI regulation makes no changes to the test cycle currently used for three-wheeler type approval, the India Drive Cycle (IDC). This is contrast to two-wheelers, for which the Worldwide Harmonized Motorcycle Test Cycle (WMTC) was adopted in BS IV standards. In general, the WMTC is a more aggressive cycle than the IDC, with a higher maximum speed and steeper acceleration ramps.

OTHER REGULATORY DETAILS

In addition to emission standards for new vehicles, the BS VI regulation also includes specifications for reference and commercial fuels. Fuel types include diesel, gasoline, and hydrogen. A key aspect of the fuel specifications is a limit on the maximum allowable sulfur content in gasoline and diesel fuels of 10 ppm. Especially for diesel engines, low sulfur fuels are necessary for the application of advanced emission control technologies, such as DPFs, which will be required to meet BS VI emission standards.

Specifications for several other BS VI gasoline and diesel fuel parameters do not directly follow European values. Key differences between BS VI and European commercial fuel parameters are summarized in Table 3.

¹² http://transportpolicy.net/index.php?title=India:_Motorcycles:_Emissions

¹³ ECMA, <http://www.ecmaindia.in/iestandards.aspx?mpgid=24&pgid1=25&pgidtrail=58#faq5>

Table 3. Notable differences in specifications for BS VI and European commercial fuels.

Fuel type	Parameter	Units	BS VI specification	European specification ¹⁴
Regular grade gasoline	Minimum Research Octane Number (RON)	—	91	95
	Minimum Motor Octane Number (MON)	—	81	85
	Maximum olefin content	% volume	21	18
	Maximum oxygen content	% mass	2.7	3.7
Diesel	Maximum 95% distillation boiling point	°C	370	360
	Density @ 15 °C	kg/m ³	820-860	845 (maximum)
	Maximum polycyclic aromatic hydrocarbon (PAH) content	% mass	11	8

Additional provisions are included in BS VI specifications for commercial fuels sold in North Eastern States, where a higher aromatic content is permitted for gasoline and a lower minimum cetane number is permitted for diesel fuel.¹⁴ In each case, these provisions expire April 1, 2023. Thereafter, fuel sold in this region will be required to meet nationwide BS VI specifications.

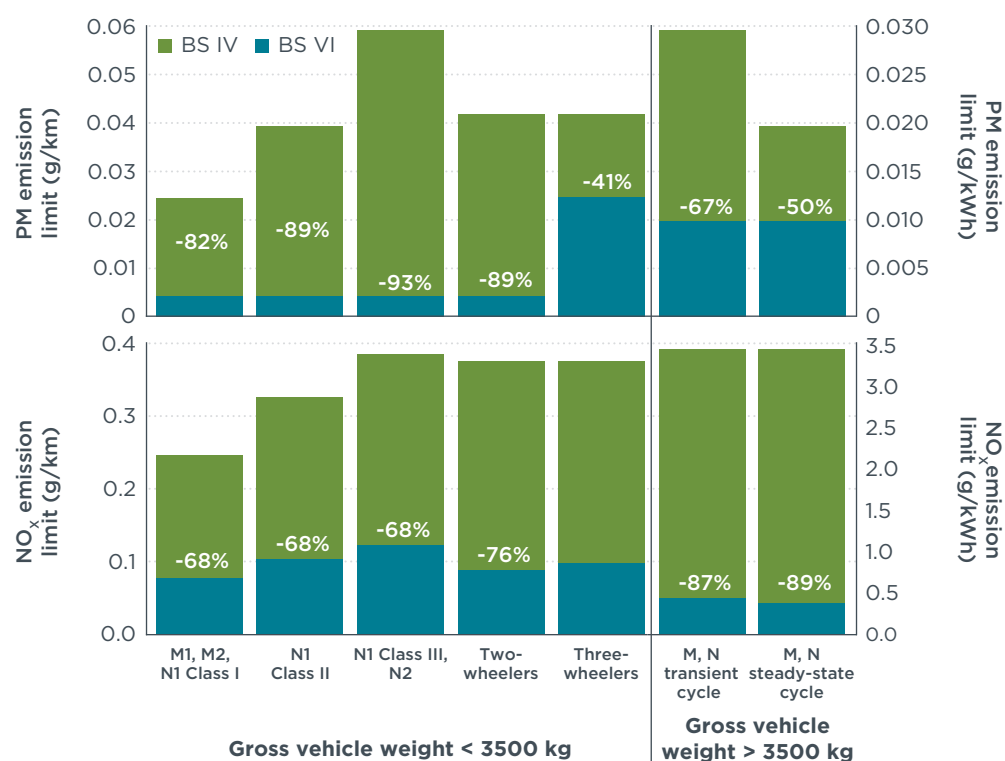


Figure 1. BS IV and VI emission limits for compression ignition vehicles. Note all regulated pollutants are not shown here. An independent BS IV NO_x limit is not defined for three-wheeled vehicles. Shown here is the combined NO_x+HC limit equal to 0.380 g/km.

¹⁴ While provisions are in place, the limit on maximum aromatic content of gasoline sold in North Eastern States is raised from 35% to 40% by volume. Similarly, the limit on the minimum cetane number for diesel sold in North Eastern States is lowered from 51 to 48.

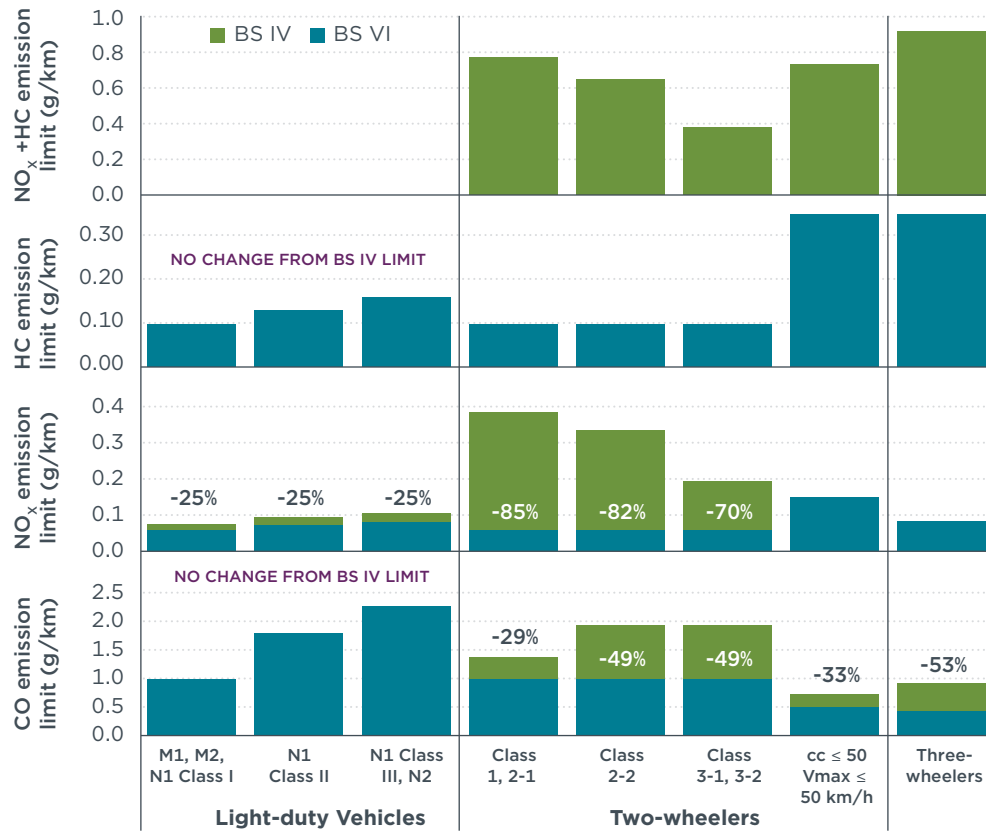


Figure 2. BS IV and VI emission limits for spark ignition vehicles. In addition to the pollutants shown here, BS VI PM and PN emission limits are specified for LDVs equipped with gasoline direct injection engines. For two- and three-wheelers, BS IV HC+NO_x emission limits shown are for vehicles meeting a 2.0 g/test evaporative emissions standard. Tailpipe HC+NO_x emission limits are more stringent for vehicles certified with evaporative emissions between 2.0 and 6.0 g/test.