

## **Technical Challenges in Shifting from BS IV to BS-VI Automotive Emissions Norms by 2020 in India: A Review**

**Devendra Vashist<sup>1\*</sup>, Naveen Kumar<sup>1</sup> and Manu Bindra<sup>1</sup>**

<sup>1</sup>*Department of Automobile Engineering, Manav Rachna International University, Faridabad,  
Haryana, India.*

### **Authors' contributions**

*This work was carried out in collaboration between all authors. Author DV designed the study, analyzed the view points, wrote the protocol and prepared the first draft of the manuscript. Authors NK and MB managed the literature searches and analyses of the study. All authors read and approved the final manuscript.*

### **Article Information**

DOI: 10.9734/ACRI/2017/33781

#### Editor(s):

(1) Sivakumar Manickam, Department of Chemical and Environmental Engineering, The University of Nottingham Malaysia Campus, Malaysia.

#### Reviewers:

(1) Ridvan Arslan, Uludağ University, Bursa, Turkey.  
(2) Hasan Aydoğan, Selcuk University, Turkey.

Complete Peer review History: <http://www.science domain.org/review-history/19541>

**Review Article**

**Received 29<sup>th</sup> April 2017**  
**Accepted 10<sup>th</sup> June 2017**  
**Published 15<sup>th</sup> June 2017**

### **ABSTRACT**

Automotive vehicles emit several exhaust gases and pollutants. The largest part of these gases consists of nitrogen (N<sub>2</sub>), water vapor (H<sub>2</sub>O) and carbon dioxide (CO<sub>2</sub>) these are not toxic. Harmful gases i.e carbon monoxide (CO) produced because of incomplete combustion, nitrogen oxides (NO<sub>x</sub>) generated at high temperatures, hydrocarbons (HC) obtained from unburnt fuel, particulate matter (PM, mostly soot) and oxides of sulphur (SO<sub>x</sub>) due to sulphur content in fuel, are referred as pollutants. India's Emission Standard were formulated in 1991 has reached today to direct transition to BS VI from BS IV norms. This decision to leapfrog fuel standards has managed to disrupt oil and auto Industry. In this paper challenges faced by these industries for this transition based on technical understanding are discussed. For diesel engines diesel particulate filter for moving to BS V and Selective Catalytic Reduction for BS VI is critically analyzed. For S.I engines technologies that are likely to be commercialized which will help vehicles to comply with BS VI norms are explained. Technology up gradation, its validation and assimilation of this technology by

\*Corresponding author: Email: devendra.fet@mriu.edu.in;

customers are some of the major issues faced by the auto sector. Reduced time line, selection of appropriate technology for refining, revamping of the existing units and simultaneous distribution of two types of oil are the major challenges faced by the oil refineries. An investment of Rs. 1.5 lakh crore by automotive industry and Rs 80,000 crore by oil refineries has to be made for up gradation to BS VI by 2020.

*Keywords: Bharat stage emission norms; diesel particulate filter; selective catalytic reduction; particulate matter; oil refineries.*

## 1. INTRODUCTION

Air quality is an issue of social concern worldwide in the backdrop of rising industrial and vehicular air pollution. While pollution does arise from many different sources, vehicular exhaust is an important source of pollution of ambient air and there is an urgent need to check the extent of vehicular pollution, especially since there has and is likely to continue to be a large increase in the stock of road vehicle traffic in the country. Between 2000 and 2013, air pollution levels increased dramatically across India [1]. The decision taken by the government to miss Bharat Stage (BS) V norm and directly shift to BS-VI norm has disturbed the economics of two large industries i.e Oil and Auto manufacturing. Obviously environment will benefit from this financially the resources of these two sectors will suffer [2]. BS Emissions norms devised 17 years down the line were meant for regulating air pollution from generators and engines. Central Pollution Control Board is the devising agency for BS standards who took European regulations as base line. The road map for phased implementation of BS norms was laid out by government well in advance until a decision was taken to miss one step of BS V norm. The deadline for BS IV pan-India was April 2017 and the two sectors has successfully achieved this deadline. Air pollution trend will become irreversible if more number of vehicles with poor quality fuels and technology comes on the road according to EPCA report [2,3,4,5,6]. Following of BS VI norms will ensure that future engines will emit very less toxic emissions; they will be fuel efficient and thus not pose any danger to the environment.

In this paper technologies that will be required for shifting to BS VI standards are made known with the challenges faced by oil and Auto sector who will act as change agents in the whole process are clearly discussed.

### 1.1 BS Emission Norms

The BS or Bharat Stage emission standards are norms/ standards framed by Indian government to control / check the levels of air pollutants from internal combustion engines. India is five years back in comparison to the European nations in following the emission standards [7,8,9,10]. Sale and registration of vehicles which are not compliant with BS-IV emission norms has been banned from April 1, 2017 across the country [11]. At present refineries are supplying BS VI fuel all over India [12].

Emission norms were introduced in India in 1991 which were further upgraded in 1996. Because of this up gradation most of the most vehicle manufacturers had to incorporate technology upgrades like catalytic converters to cut exhaust emissions [13]. Taking environment into consideration fuel specifications were notified in April 1996 which were to be enforced by year 2000. They standards were known by the name of BIS 2000 standards. In 1999 on the orders of supreme court BS-I and Bharat Stage-II were notified by the Indian Government. These standards were nearly equivalent to Euro I and Euro II norms. At that time National Capital Region (NCR) has to follow BS-II while rest of India followed BS-I. BS-III and BS-II fuel quality norms came into force for 13 major cities, and for the rest of the country respectively in April 2005, these action plan were in line with the Auto fuel policy 2013. There after BS-IV and BS-III fuel quality norms came into existence from April 2010 in 13 major cities and the rest of India respectively. Presently, BS-IV auto fuels are being supplied across all over India. Due to exponential increase of air pollution which lead to common citizen's life at risk, Government took a decision that the country will switch over directly from BS-IV to BS-VI fuel standards [14,15] by April 1, 2020. The decision was taken after due consultation with Ministry of Petroleum and National Gas, Department of Heavy industry and Ministry of Environment and Forest.

Accordingly, a draft notification to amend the Central Motor Vehicles Rules, 1989 has been forwarded to the Government of India Press on 22.02.2016 for publication in the Gazette of India, giving 30 days' time to the public, inviting suggestions/comments on the notification before finalizing the same [16]. In the notification particulate matter standards for two-wheelers and three-wheelers were notified for the first time. As such in big cities due to large number of two wheelers even small particulate emissions can accumulate into a big particulate load. A comparative timeline of incremental implementation of emission standards in India, Europe and China is presented in Fig. 1.

A comparative table has been presented in Tables 1 and 2 depicting the BS-IV and BS-VI emission standards for petrol and diesel vehicles [17]. Observing the table it is noted that there is no change in the values of CO and HC emission but the values for NO<sub>x</sub> and PM are on the lower side for BS VI norms. Similarly in diesel engines emission there are reduction in the NO<sub>x</sub>, HC + NO<sub>x</sub> and PM for BS VI norms. The data presented is for M&N category vehicles with GVW<3.5 tons. For BS VI norms Particulate

matter is measured in terms of number of particles emitted per kilometer.

**Table 1. Petrol engine emissions in g/km**

Emission norm	CO	HC	NO <sub>x</sub>	PM
BS-III	2.3	0.2	0.15	na
BS-IV	1	0.1	0.08	na
BS-VI	1	0.1	0.06	6*10 <sup>11#</sup>

# Number of particles per Km

**Table 2. Diesel engine emissions in g/km**

Emission norm	CO	HC	NO <sub>x</sub>	HC + NO <sub>x</sub>	PM
BS-III	0.64	na	0.5	0.56	0.05
BS-IV	0.5	na	0.25	0.3	0.025
BS-VI	0.5	na	0.06	0.17	6*10 <sup>11#</sup>

## 2. TECHNOLOGY INVOLVED TO UPGRADE FROM BS-IV TO BS VI NORMS FOR ENGINES

Two strategies that are adopted by the manufactures for improved emission control for two category of fuel is shown in the Table 3.

**Table 3. Technologies used in petrol & diesel engines for improved emission control [18]**

Technologies used in petrol engines for improved emission control		Technologies used in diesel engines for improved emission control	
<b>In cylinder control</b>	<ul style="list-style-type: none"> <li>Air fuel management for cold start control on fuel injection, engine valve train optimization and turbocharging.</li> <li>Incremental improvements to combustion system.</li> <li>Exhaust gas recirculation (EGR) with electronic control systems.</li> </ul>	<b>In cylinder control</b>	<ul style="list-style-type: none"> <li>High pressure fuel injection (up to 1900 bar)</li> <li>Variable geometry turbines for improved air fuel management.</li> <li>Variable valve timing and fuel injection for regeneration of diesel particulate filter.</li> <li>Continuous R&amp;D for combustion system improvement.</li> <li>Exhaust gas recirculation with DC motor actuator</li> </ul>
<b>After treatment</b>	<ul style="list-style-type: none"> <li>Improvements to three way catalytic converter (3WCC) operation.</li> <li>Use of gasoline particulate filters (GPFs) for direct injection engines</li> </ul>	<b>After treatment</b>	<ul style="list-style-type: none"> <li>PM after treatment with diesel particulate filters and diesel oxidation catalysts.</li> <li>NO<sub>x</sub> reduction based on selective catalytic reduction (SCR) or lean NO<sub>x</sub> traps (LNT).</li> </ul>

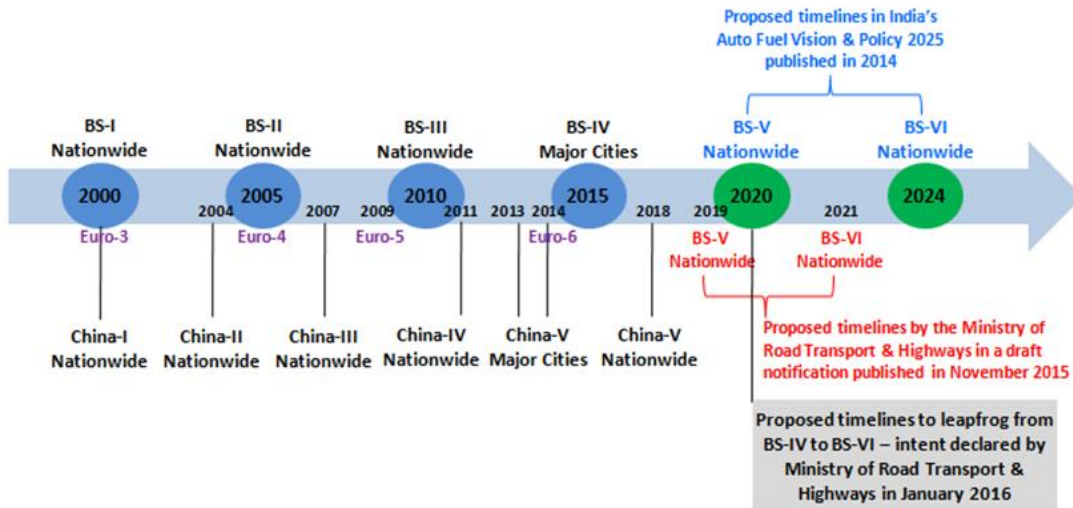


Fig. 1. Comparative timeline of incremental implementation of emission standards

## 2.1 Diesel Engine

In the case of diesel Engines three devices i.e Catalytic converter, Diesel Particulate Filter (DPF) and Selective Catalytic Reduction (SCR) are fitted in series. Although catalytic convertor is there in BS IV vehicles two extra devices DPF and SCR are to be fitted extra to make vehicle BS VI compliance vehicle [13,18,19].

## 2.2 Petrol Engine

For SI conversion from BS IV to BS VI engine includes –

- Re-design of ports and exhaust system improvements to achieve more effective scavenging and reduced mixture short-circuiting,
- Higher compression ratios along with improved carburetion by electronic carburetion/ electronically managed fuel injection / port injection or direct injection to achieve better control on air-fuel ratios,
- Lean & charge stratification with controlled auto ignition and variable ignition timing for better & complete combustion of fuel,
- Combustion chamber re-design & spark-plug re-location to reduce knocking on account of the higher compression ratios.
- Pistonre-design to minimize crevice volumes & friction losses, complete transitioning to microprocessor based electronic control, enhance don-board diagnostic system.

It is almost certain that fuel injection may completely replace conventional carburetor with the next stringent BS-VI emission norms in India. Two types of fuel injection systems that can be used on small 2-stroke, spark ignition, gasoline engines fitted on 2 & 3-wheeled vehicles includes viz. Air Assisted Direct Injection (AADI) and High Pressure Direct Injection (HPDI).

## 3. IMPROVEMENTS IN FUELS AND ADOPTED TECHNOLOGY

Euro 5 and Euro 6 emission standards is needed to be implemented at the earliest because diesel emissions close gap with petrol emissions only at the Euro 6 stage to address the hazard risk as per the report of Environment Pollution (Prevention and Control) Authority (EPCA) [16]. Sulphur content are very much lower in BS IV and BS VI as compared to BS III. In diesel, the sulphur content is progressively reduced from 350 ppm (parts per million) in BS III to 50 ppm in BS IV and 10 ppm in BS VI. In petrol, the sulphur specification gets reduced from 150 ppm to 50 ppm to 10 ppm. The same has been shown in Fig. 2.

### 3.1 Technology Involved

In the refineries diesel has seven or eight different streams with content sulphur ranging from 0 to 500 ppm. These streams are mixed in different ratios which further add properties to make the final diesel components. So when diesel with 50 ppm, or petrol with 10 ppm, is to be prepared all the streams will have to be

hydro-treated. From the different streams sulphur has to be removed. This Hydro-treatment process is an established refinery process for reducing sulphur and nitrogen. A comparative chart Table 4 compares proposed Indian gasoline specifications with those of Euro 6 norms. For the parameters discussed here, octane number and olefin content, specifications

for premium grade BS VI gasoline match Euro 6 values.

Diesel fuel parameters for which BS VI specifications differ from Euro VI specifications include density, 95% distillation boiling point, and PAH content. Table 5 compares proposed Indian diesel specifications BS IV with BS VI and Euro 6

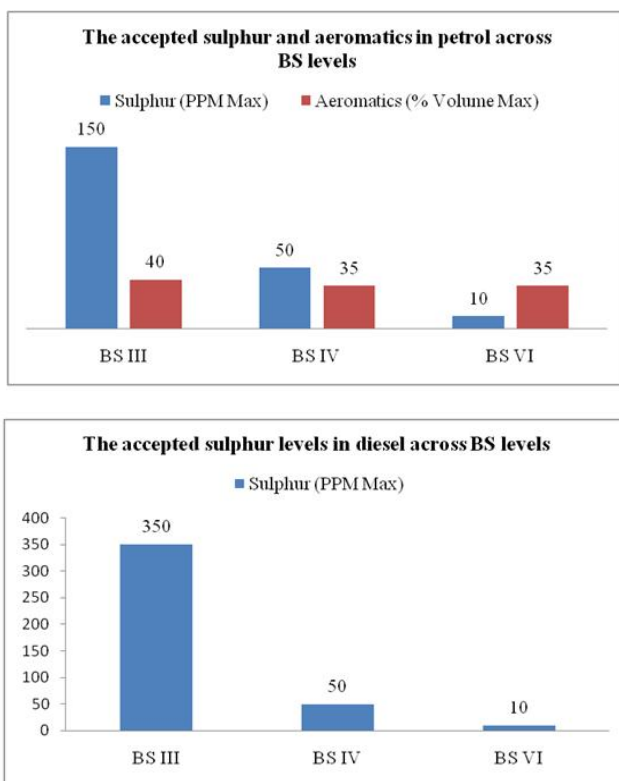


Fig. 2. Comparative chart for petrol and diesel content (BS norms) [2]

Table 4. Proposed Indian gasoline specifications with those of Euro 6 [14]

Fuel parameter	BS IV	BS VI	Euro 6
Sulfur, ppm, max	50	10	10
Research Octane (RON), min.	91	91/95	95
Density kg/m <sup>3</sup>	720-775	720-775	-
Anti-Knock Index (AKI), min.	81	81/85	85
Olefins, vol%, max.	21/18	21/18	18

Table 5. Proposed Indian diesel specifications with those of Euro 6 [20,21]

Fuel parameter	BS IV	BS VI	Euro 6
Sulfur, ppm, max	50	10	10
Cetane Number (CN), min.	51	51	51
Density kg/m <sup>3</sup>	820-845	820-860	845 (max)
95% Distillation Boiling Point °C	360	370	360
Poly Aromatic Hydrocarbon (PAH) mas% max	11	11	8
Flash Point Abel °C min	35	35	55

#### 4. CHALLENGES / ISSUES

- a. Auto manufacturers prefer Octane 95 to 91 because it allows engines to give more power. Also major car manufacturer Maruti Suzuki has made repeated requests to refineries for parity in Euro and BS standards for increased efficiency and performance of car engines [2].
  - b. The Euro 6-compliant engines are to be first tested in Indian conditions [2].
  - c. As per the oil sector Euro VI cannot be followed blindly because following this will bring down LPG & Diesel production. However small changes from the Euro norms could mean a rise in domestic diesel production.
  - d. BS VI fuel in small quantities has to be provided by oil refineries, for trials to the auto companies in a timely manner [2].
  - e. Implementation issues from the customers: Customers buy vehicles from places where BS IV is not applicable, they bring and run them in cities where BS IV is implemented so BS II and BS III vehicles are still running in large cities i.e where BS IV is in force. The solution to this is in government and regulators have to devise a scrapping policy to phase out vehicles that have engines for lower BS norms.
  - f. Ground level implementation: For the compliance of the updated norms the implementing agencies should randomly select a vehicle from a dealer and verify the manufacturer's claim. Real time emissions can be tested through portable emissions monitoring systems (PEMS). This will help in monitoring actual running data on emissions of on-road vehicles within certified limits [22].
  - g. The government should set up inspection and maintenance centers to check the roadworthiness of vehicles.
- c. Change in vehicle dimension: Two new equipment's DPF and SCR will be required for conversion for which vehicle dimensions, has to be changed. This change may lead to higher taxes on the cars because taxes are less on cars which are less than 4 meters in length. Following the BS VI norm may require vehicle to cross 4 meter mark which auto industry will resist.
  - d. Although auto companies have Euro 6 engines but there will be some issues in getting them programmed to the Indian driving cycle, which will need time.
  - e. Validation issues as per Indian conditions: In BS-V, vehicles have to be fitted with a diesel particulate filter, which needs to be optimized for Indian road conditions. In stage VI, selective catalytic reduction technology has to be optimized. At each stage, the technology would have to be validated over 6 lakh to 7 lakh km. Given the complexity of the process, these technologies can only be optimized in series and not simultaneously.

##### 4.1 Issues Related to Auto Companies on Technology Upgradation

- a. Engine technology agreements have to be reviewed since few companies pay royalty for engine technology. There are sustainable issues for some Auto companies [23].
- b. There is a significant increase in workload for engineering teams who will have to work on critical issues related to stricter norms.

##### 4.2 Issues Related to Oil Refineries

- a. Oil refineries have to ensure that all their 75000 fuel pumps / stations have a supply of BS VI fuel by April 1, 2020. This task is a world's largest customer interface [24].
- b. Technology selection will be another issue has to be taken care of by Indian and global companies. Oil refineries are also utilizing their own technologies which their R&D has developed for diesel hydro-treatment.
- c. Refineries, transport kerosene, aviation turbine fuel, diesel and petrol through same underground multiproduct pipelines. It will be difficult to transport BS IV & BS VI fuel through the same pipeline since during the transition zone both the fuels have to be present. Problem of contamination may arise. When both diesel and petrol are completely converted into BS VI fuel then only it will be easier. This means quantities required by the auto industry before the deadline will have to be moved by road tanker or by other modes of transport.
- d. For supplying BS VI fuel, oil refiners have to bulk up their hydro-treatment units. Existing units are to be revamped / converted, or new units have to be added by the refineries. To make these additions along with running a refinery is a

challenging task for oil refineries. The problem can be solved by installing it in a time-bound manner, without impacting refinery operations, so that there is no disruption in supply.

- e. Issues related to the emissions from the refineries [25] on providing the highly refined fuels.

#### 4.3 Investment Required

- a. Automotive industry would need an investment of Rs. 1.5 lakh crore in order to meet this change. The move will increase the price of cars in India substantially.
- b. Oil refineries will need to invest a staggering Rs 80,000 crore in upgrading petrol and diesel quality to meet cleaner Euro-IV/V fuel specifications by 2020 [24,26,27].

#### 4.4 Auto Component Suppliers Issues

- a. Auto component makers will have shorter time frames to localize design and validate performance of the SCR and particulate filters [10]. These items will have to be imported because the Indian manufacturers will not be able to provide supply on immediate requirements. Also Global suppliers will have to set up their own infrastructure, which mean added expense.
- b. A nationwide distribution infrastructure required for SCR.

### 5. BENEFITS

#### 5.1 Reduction in the Emissions

Once BSVI, emission norm is implemented a reduction of 89% in the particulate matter emissions from two-wheelers will be observed. Also NOx emissions will be reduced by 76%. In case of cars, 82% in PM emissions and 68% in NOx emission reduction is expected to be seen.

### 6. CONCLUSION

From the analysis it can be concluded that for skipping BS-V and shifting directly to BS-VI, both of the emission reducing technologies DPF and SCR need to be fitted in the four-wheelers simultaneously which is a time consuming and money consuming process but have environmental benefits associated with it. Shifting directly to BS-VI within the specified time limit is

a great challenge for the automobile and oil industries in India. The two and three wheelers will also have been fitted with Electronic Fuel Injection system in place of the old Carburetor system, to meet the BS-VI standards. BS-VI will also be undertaking the Particulate Matter reduction which earlier was not considered for BS-III and BS-IV. The sulphur content in BS-VI fuels will be limited to only 10 ppm which will help in reducing PM and NOx emissions from petrol and diesel engines. Technology up gradation, its validation and assimilation of this technology by customers are some of the major issues faced by the auto sector. Reduced time line, selection of appropriate technology for refining, revamping of the existing units and simultaneous distribution of two types of oil are the major challenges faced by the oil refineries. An investment of Rs. 1.5 lakh crore by automotive industry and Rs 80,000 crore by oil refineries has to be made for up gradation to BS VI by 2020. BS-VI will therefore help in reducing the emission of harmful contents to the atmosphere from IC engines.

### COMPETING INTERESTS

Authors have declared that no competing interests exist.

### REFERENCES

1. Monil Shah, Chirag Mistry, Naresh Shimpi. Emission norms (Case Study). International Journal of Science and Research. 2014;217–220.
2. Available:<http://fortuneindia.com/2016/july/indian-oil-gears-up-to-meet-new-fuel-standards-1.8675>
3. Available:<https://delhiair.org/india-and-delhi/what-causes-pollution-in-delhi/>
4. Report of the Expert Committee on Auto Fuel Vision & Policy 2025: Auto Fuel Vision and Policy; 2025. Available:<http://petroleum.nic.in/docs/autopol.pdf>
5. Mylaudy Dr. S Rajadurai, Naveen S. Alignment for BSVI stipulation moving towards carbon neutral earth. International Journal of Recent Development in Engineering and Technology. 2017;6(3):9-14.
6. Fifth Report of Standing Committee on Petroleum & Natural Gas (2014-15). Available:[http://164.100.47.193/Isscommitt ee/Petroleum%20&%20Natural%20Gas/16\\_Petroleum\\_And\\_Natural\\_Gas\\_5.pdf](http://164.100.47.193/Isscommitt ee/Petroleum%20&%20Natural%20Gas/16_Petroleum_And_Natural_Gas_5.pdf)

7. Available:[https://en.wikipedia.org/wiki/Bharat\\_Stage\\_emission\\_standards](https://en.wikipedia.org/wiki/Bharat_Stage_emission_standards)
8. Available:<http://iasscore.in/national-issues/-a-direct-shift-from-bs-iv-to-bs-vi-by-2020>
9. Available:[www.dieselforum.org/about-clean-diesel/what-is-scr](http://www.dieselforum.org/about-clean-diesel/what-is-scr)
10. Srivastava DK, Agarwal AK. Particulate matter emission from single cylinder Engine: Effect of engine load on size and number distribution. SAE International; 2008.  
Available:[https://www.iitk.ac.in/erl/Index\\_files/Technex\\_IIT\\_Kanpur\\_Manuscript.pdf](https://www.iitk.ac.in/erl/Index_files/Technex_IIT_Kanpur_Manuscript.pdf)
11. Available:[http://www.business-standard.com/article/companies/explained-bharat-stage-iv-emission-norms-and-the-history-behind-it-117032900695\\_1.html](http://www.business-standard.com/article/companies/explained-bharat-stage-iv-emission-norms-and-the-history-behind-it-117032900695_1.html)
12. Available:<http://timesofindia.indiatimes.com/india/bs-iv-fuel-in-supply-for-a-month-now-oil-companies/articleshow/57927759.cms>
13. Available:<http://indianexpress.com/article/explained/simply-put-what-needs-to-be-done-to-upgrade-from-bs-iv/>
14. Available:[http://www.fipi.org.in/journal/Jan\\_March17.pdf](http://www.fipi.org.in/journal/Jan_March17.pdf)
15. Report "Impact of Bharat Stage-VI norms on Indian Auto & Auto Component Industry" by Ketan Salhotra.  
Available:<http://auto.economictimes.indiatimes.com/autologue/impact-of-bharat-stage-vi-norms-on-indian-auto-auto-component-industry/1543>
16. Available: <http://www.epca.org.in/>
17. Available:[https://www.araiindia.com/pdf/Indian\\_Emission\\_Regulation\\_Booklet.pdf](https://www.araiindia.com/pdf/Indian_Emission_Regulation_Booklet.pdf)
18. Cost-Effective Green Mobility A joint CII A T Kearney report.  
Available:<http://www.autocarpro.in/features/leapfrogging-bs-vi-suits-india-icct-10492>
19. Arulmurugu A, Karthick BM, Vasanthakumar P, Chendrayaperumal J. Emission control in IC engine - selective catalytic reduction method. International Journal of Engineering Research & Technology (IJERT). 2014;3(2):486-493.
20. Working paper 2016-9, "Technical Background on India BS VI Fuel Specifications". International Council on Clean Transportation; 2016.  
Available: [www.theicct.org](http://www.theicct.org)
21. Available:[https://www.google.co.in/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKEwiG2LjvKMTT\\_AhUCtBQKHdk-A54QFgghMAA&url=http%3A%2F%2Fegazette.nic.in%2Fwriterereaddata%2F2016%2F168300.pdf&usq=AFQjCNFADhOAU50UHSv-thYV0a3pHB12QQ](https://www.google.co.in/url?sa=t&rct=j&q=&esrc=s&source=web&cd=1&cad=rja&uact=8&ved=0ahUKEwiG2LjvKMTT_AhUCtBQKHdk-A54QFgghMAA&url=http%3A%2F%2Fegazette.nic.in%2Fwriterereaddata%2F2016%2F168300.pdf&usq=AFQjCNFADhOAU50UHSv-thYV0a3pHB12QQ)
22. Available:[http://www.oswindia.com/embrace\\_euro\\_feature.html](http://www.oswindia.com/embrace_euro_feature.html)
23. Peter Wells. Sustainable business models and the automotive industry: A commentary. IIMB Management Review. 2013;25(4):228-239.
24. Available:<http://test.iasbaba.com/posts/ias-babas-daily-current-affairs-12th-january-2016/>
25. Eli Berman, Linda TM Bui. Environmental Regulation and Productivity: Evidence from Oil Refineries. The Review of Economics and Statistics. 2001;83(3):498-510.
26. Report of ICRA.  
Available:<http://www.icra.in/Files/ticker/SH-2016-Q2-6-ICRA-Passenger%20vehicles.pdf>
27. Available:<http://auto.economictimes.indiatimes.com/autologue/implementation-of-bharat-stage-vi-norms-in-india/2229>

© 2017 Vashist et al.; This is an Open Access article distributed under the terms of the Creative Commons Attribution License (<http://creativecommons.org/licenses/by/4.0>), which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

*Peer-review history:*  
*The peer review history for this paper can be accessed here:*  
<http://sciencedomain.org/review-history/19541>