Challenges & Emission Control Technologies for Heavy-Duty Commercial Vehicles to meet Bharat Stage VI Norms: A Review

Abhishek Anchan

Graduate Scholar, Department of Mechanical Engineering, Dilkap Research Institute of Engineering, Neral, Maharashtra, India

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ABSTRACT - *The immense growth of automotive industry in India is facing challenges. Automotive vehicles emit several exhaust gases and pollutants most of these gases consist of nitrogen water vapour carbon dioxide which are not toxic in nature harmful gases like carbon monoxide (CO), nitrogen oxide (NOx), particulate matter (PM) and oxides of sulphur are referred as pollutants. To improve the current status of exhaust emission from automobile government of India decided to implement Bharat stage VI (BS-VI) norms from the year 2020. The challenge is to meet stringent emission regulation as well as appease requirements of customer in terms of vehicle price, fuel economy and maintenance. Due to skipping of BS-V, Indian original equipment manufacturers (OEMs) are now facing a big challenge of implementing these norms. By April 2020, BS-VI has to be implemented in India as government are very keen to bring this change to keep up with the G-20 countries. The paper provides observation on transition for automakers based on technical understanding are discussed. The paper also focuses on proposed emission standards, emission control technologies and cost involved in implementing these technologies. Also there are challenges for the oil refineries to provide low-sulphur fuel throughout the nation within specified time is also mentioned. Manufacturing Heavy-duty vehicles based on BS-VI norms is the major issue for the OEMs is specifically been addressed and considerable tasks and challenges these industries may face are highlighted in this paper.*

Key Words: Bharat stage VI, Nitrogen oxides (NOx), Particulate matter (PM), OEMs, Oil Refineries, Heavy-duty vehicles (HDV), HCCI Engines, After-treatment exhaust device, Retrofitting programs

1. INTRODUCTION

Air pollution is one of the serious environmental concerns of the urban Asian cities including India, where majority of the population is exposed to poor air quality. It causes health related problems such as respiratory disease, risk of developing cancer and other serious ailments etc. and also contributes to tremendous economic loss especially in the sense of financial resources that are required for giving medical assistance to the affected people. Most of the Indian cities are also experiencing rapid urbanization and the majority of the country's population is expected to be living in cities within a span of next two decades [1].

The transport sector offers an immense challenge and opportunity. In moving people and goods throughout the world, transport plays a vital part in world economic growth, but it also has a significant and growing environmental footprint. The transport sector consumes more than half of global oil production, and releases nearly a quarter of all anthropogenic carbon dioxide emissions. Motor vehicles and engines, especially those fueled with diesel, contribute to ambient air pollution responsible for millions of premature deaths worldwide each year. Heavy-duty vehicles, including commercial freight trucks and buses, will be especially important in balancing the world's future transport needs with the health and environmental impacts. Heavy-duty vehicles contribute disproportionately to oil consumption, greenhouse gas emissions, and air pollution compared with their fraction of the fleet. Worldwide, heavy-duty vehicles represent just 11% of motor vehicles, but they are responsible for almost half of vehicle CO2 emissions and over two-thirds of vehicle particulate emissions [2].

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 [3].

2. BHARAT STAGE EMISSION STANDARDS

Bharat Stage emissions standards are emissions standards instituted by the Government of the Republic of India that regulate the output of certain major air pollutants (such as nitrogen oxides (NOx), carbon monoxide (CO), hydrocarbons (HC), particulate matter (PM), sulfur oxides (SOx) by vehicles and other equipment using internal combustion engines. Prior to 2010, emissions were tested using the ECE R49 test cycle. After 2010, for Bharat III and IV, the ESC and ETC test cycles were used. BS VI will require the application of WHSC and WHTC test cycles [3]. Standards for new heavy-duty engines are listed in table 1.

Table-1 Emission Standards for Heavy-Duty Vehicles and Engines

Year	Reference	Test	CO	HC	CH_4	NOx	PM	PN
			g/kWh					#/kWh
2010	Bharat Stage IV[a]	ESC	1.5	0.46	-	3.5	0.02	-
		ETC	4.0	0.55		3.5	0.03	-
2020	Bharat Stage VI[b]	WHSC(CI)	1.5	0.13	-	0.40	0.01	$8x10^{11}$
		WHTC(CI)	4.0	0.16	-	0.46	0.01	$6x10^{11}$
		WHTC(PI)	4.0	0.16[f]	0.5	0.46	0.01	$6x10^{11}$

Note: a – From 1 Apr 2010 in Delhi, Mumbai, Kolkata, Chennai, Bangalore, Hyderabad, Ahmedabad, Pune, Surat, Kanpur, Solapur, Lucknow, and Agra. As of April 2016, applicable in 10 states, different districts & cities in the states of Rajasthan, Maharashtra, Gujarat and Uttar Pradesh and in 4 Union Territories. Nationwide implementation in April 2017.

b – Proposed limits

2.1 Testing

Heavy-duty vehicle emissions are certified in two phases. First, the engine (including the emission control system) is tested on an engine dynamometer. Then the vehicle impacts are incorporated by reference, which requires using other test data and engineering judgment to establish how the remainder of the vehicle's components would impact engine emissions. Engine emission limits are specified in grams per kilowatt-hour [4].

Unlike Indian light-duty vehicles, which are tested using chassis dynamometer testing, heavy-duty vehicle emissions are certified using two cycles performed on an engine dynamometer: the European Stationary Cycle (ESC) and the European Transient Cycle (ETC). Diesel-operated HDVs must pass both tests to be certified. HDVs operating on CNG do not have to undergo the ESC test.

The proposed BS VI regulation would replace ESC and ETC with WHSC and WHTC, respectively. Further, the regulation proposes the adoption of World Harmonized Not-to-Exceed (WNTE) off-cycle laboratory testing following UNECE Regulation No-49. Specifications for PEMS demonstration testing at type approval are also included in the BS VI regulation. Specific procedures regarding these requirements will be defined in the AIS 137 implementing standard [5].

Test Fuels under Bharat III and IV specifications, fuel used to test emissions from vehicles is cleaner than commercially available fuel. Regulations specify that Bharat IV test diesel can have a maximum sulfur content of 10 ppm, while commercial diesel contains up to 50 ppm and 350 ppm sulfur in Bharat IV cities and the rest of the country, respectively. The lower sulfur content in test fuel means emissions measurements during testing are lower than real-world emissions on the road, particularly for particulate matter (PM) [4, 5].

The proposed BS VI standard specifies OBD requirements for all major on-road vehicle categories in India. For heavy-duty vehicles, the draft proposes introduction of OBD in two stages: BS VI-1 and BS VI-2. BS VI-1 OBD will apply to new type approvals on 1 Apr 2020 and all sales and registrations on 1 Apr 2021, and BS VI-2 OBD will apply to all sales and registrations beginning 1 Apr 2023. Threshold values for BS VI-1 OBD and BS VI-2 OBD follow preliminary and final Euro VI threshold limits, respectively. Full specifications for BS VI OBD systems will be included in AIS 137 [4, 5]. The threshold values for BS VI-1 and BS VI-2 OBD systems are listed in the table below.

Table-2 OBD Threshold Limits, g/kWh

Stage	Implementation Date	Engine Category	CO	NOx	PM
BS VI-1	1 Apr 2020 (type approvals)	Compression Ignition	-	1.5	Performance Monitori

	1 Apr 2021 (all sales)				ng *
		Positive Ignition	-	1.5	-
BS VI-2	1 Apr 2023 (all sales)	Compression Ignition	-	1.2	0.025
		Positive Ignition	7.5	1.2	-

Note: * Performance monitoring as per AIS-137 (for wall–flow Diesel Particulate Filter)

2.2 Durability

BS VI follows Euro VI specifications for the durability of pollution control devices. Manufacturers may either use deterioration factors specified in the standard or evaluate deterioration factors by service accumulation [4, 5]. Minimum service accumulation mileages for different vehicle categories are listed in the following table

Table-3 Minimum Service Accumulation Mileages

Vehicle Category	Mileage
N1 and M2	160,000 km
N2 N3 (GVW≤ 16 ton) M3 (GVW≤ 7.5 ton)	188,000 km
N3 (GVW> 16 ton) M3 (GVW> 7.5 ton)	233,000 km

Note:

N1-Vehicles for the carriage of goods and having a maximum mass not exceeding 3.5 tonnes

N2-Vehicles for the carriage of goods and having a maximum mass exceeding 3.5 tonnes but not exceeding 12 tonnes

N3-Vehicles for the carriage of goods and having a maximum mass exceeding 12 tonnes

M2-Vehicles designed and constructed for the carriage of passengers, comprising more than eight seats in addition to the driver's seat, and having a maximum mass ("technically permissible maximum laden mass") not exceeding 5 tons

M3-Vehicles designed and constructed for the carriage of passengers, comprising more than eight seats in addition to the driver's seat, and having a maximum mass exceeding 5 tons

2.4 Diesel Fuel Specifications

Diesel fuel parameters for which BS VI specifications differ from Euro VI specifications include density, 95% distillation boiling point, and PAH content. Table 4 compares proposed Indian diesel specifications with those set in Euro VI with stringent motor vehicle emission control requirements [6, 7]. The potential impacts of these deviations on air pollutant emissions are discussed in the following sections

Table 4. Comparison of fuel specifications for selected diesel parameters

Fuel parameter	BS VI	Euro VI
Density @ 15°C, kg/m3	820-860	845 (max)
95% Distillation Boiling Point (T95), °C, max.	370	360
Polycyclic aromatic hydrocarbons (PAH), mass %, max.	11	8

DENSITY:

Density is a physical property of diesel fuel and closely related to both the fuel cetane number and aromatic content. As fuel injection is controlled volumetrically in diesel engines, fuel density influences the volume of fuel needed to maintain a constant power output. As density decreases, a greater amount of fuel is required to be metered through fuel injector orifices in a given amount of time. In regards to the effects of density on air pollutant emissions from diesel engines, a review by Lee et al. found reducing density tended to increase HC emissions, had small effects on CO and NOX emissions, and had no effect on PM emissions from heavy-duty diesel engines [8].

95% DISTILLATION BOILING POINT (T95):

The 95% distillation boiling point represents the temperature at which 95 percent of a particular diesel fuel distills in a standardized distillation test, and is used to characterize the back-end volatility of the fuel [9]. Research programs have found back-end volatility to have a relatively small effect on the emissions performance of diesel engines. For example, Lee et al. noted that while reducing T95 may lead to slight increases in HC and CO emissions from heavy-duty engines, the overall effect of variations in back-end volatility on emissions of regulated pollutants is very small [8].

PAH CONTENT:

Polycyclic aromatic hydrocarbons (PAHs) are organic compounds that are mostly colorless, white, or pale yellow solids. Polycyclic aromatic hydrocarbons have two or more single or fused aromatic rings with a pair of carbon atoms shared between rings in their molecules [10]. In general, reducing PAH content of diesel fuels has been shown to reduce emissions of NOX and PM from diesel engines. The European Programme on Emissions, Fuels and Engine Technologies (EPEFE) found a decrease in diesel fuel PAH content from 8% to 1% reduced PM emissions from light and heavy-duty diesel engines by 5% and 4%, respectively. NOX emission reductions tended to be smaller than PM reductions [11].

3. CHALLENGES FROM LEAPFROGGING BS IV TO BS VI

Vehicular emission is a major contributor to the worsening air quality of Indian cities. Emission of NOx, SO_2, CO_2 and particulate matter is taking a toll on people's health. Switching from one Bharat stage (BS) to another Bharat stage (BS) is not a simple task. It requires huge capital investment in refineries and Automobile industries. Ideally, BS V would have been rolled out by 2021 and BS VI in 2024 but leapfrog to Bharat Stage VI norms by 2020 had to be planned because of the carbon footprint obligations [12]. Following are some tenacious challenges for automakers and oil refineries to achieve BS VI emission norms.

Exponential cost increase of vehicle manufacturing could lead due to rising input costs, changing market conditions and various external economic factors.

Introduction of advanced technologies to ensure pollutants emitted by the vehicles should comply with the specified limits. It will also mean a number of changes to be made in the engine systems. The implementation of the advanced emission norms might still be year away, but Refineries and OEMs must race against time to execute the most complex project of their careers.

Leading auto makers have to hike their investments to upgrade existing models and make them BS-VI-complaint. The number of product launches may be declined in the next year. Firms must look at products that won't need much changes before the new norms take effect.

Competitive neutrality means that state-owned and private businesses compete on a level playing field. Governments need to address in order to achieve competitive neutrality. This is essential for auto component manufacturers, oil refineries and OEMs to use resources effectively within the economy and thus achieve growth and development.

Most states in India do not have Inspection and Maintenance (I/M) programs for diesel vehicles. The main goal of I/M program is to identify gross polluters-vehicles that emit well beyond norms and to get those vehicles repaired.
Indian buyers are value-conscious and it may not be easy for firms to simply disclose the additional costs without a perceptible value-inclusion.

4. CHALLENGES TO DEVELOP BS-VI COMPLIANT VEHICLES

❖ Heavy Duty Fuel Economy Norms Compliance

For Indian conditions to start with the implementing agency/Government should establish the fuel consumption standards based on engine improvements by considering extensive test producers based on i) on-road testing, ii) Engine testing iii) Chassis + Engine testing and iv) computer simulation based by adopting the standard driving test cycles to establish fuel efficiency standards help to develop and maintain a level playing field among manufacturers, as all are required to meet a fuel economy target.

❖ Stringent emission norms & OBD

The government should increase stringency of BS VI standards relative to BS IV to meet not only reductions in pollutant mass emission limits, but also to introduce 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, must be replace with the WHSC and WHTC for the BS VI regulation. Full specifications for BS VI OBD systems will be included in AIS-137 [5].

❖ NVH Processing

Diesel engines emit higher radiated noise levels than gasoline engines of the same size. Higher engine mount vibration levels and crankshaft torsionals are more prevalent in modern diesel engines than gasoline engines, because of the diesel engine's high cylinder peak pressures and pressure rise rates [13]. Design of exhaust system is a complex function that affects the noise characteristics and the fuel efficiency of the vehicle.

❖ Light Weighting Technology & Material

Advanced materials are essential for boosting the fuel economy of modern automobiles while maintaining safety and performance. By using lightweight structural materials, cars can carry additional advanced emission control systems, safety devices, and integrated electronic systems without increasing the overall weight of the vehicle [14].

❖ Boost Power to Weight Ratio

The three main factors that cause a vehicle to demand engine power are vehicle speed, weight, and the incline traveled. Note that this is for a steady-state (constant speed) case only. As the required power increases, the amount of fuel burned to produce that power also increases, and the rate of regulated emissions produced will generally increase. This implies that emissions will directly vary with truck class. The higher truck classes are heavier and, thus, produce more regulated emissions [15].

❖ Innovative Packaging

Maintaining adequate clearance between exhaust system components and engine components, engine bays, enclosures and building structures to lessen the impact of high exhaust temperatures on such components.

5. EMISSIONS CONTROL TECHNOLOGY SOLUTIONS

5.1 New Base Engine Development

For BS VI development existing engines can't be used as base line. New engine needs to be developed from scratch. Researchers typically use Euro VI- or US 2010-compliant engines as the baseline for their technology potential analysis in investigating what advancements are possible out to 2020 and beyond. Following are some consideration to create new baseline engines:

- Understanding physical phenomena by technical calculations and simulation
- Generating and Evaluating New Product Ideas
- Designing and Prototyping
- Control Design and Validation
- Calibration Process
- Vehicle Performance Evaluation

5.2 New and Emerging Technologies

This section will review new and emerging technologies that can reduce fuel consumption of diesel engines, including the use of alternative fuels.

❖ Alternative Fuel Technologies

Petroleum crude is presently the main source of automotive fuels although alternative fuels like natural gas, LPG are also being used in large numbers of road vehicles in some countries. The renewable fuels like ethyl alcohol and biodiesel too are being used in the form of blends with the petroleum derived gasoline and diesel fuels. Most important alternative fuel candidates are: ethanol, methanol, natural gas, liquefied petroleum gas (LPG), vegetable oil esters commonly called as 'biodiesel' and hydrogen [16].

Biodiesel:

Biodiesel is a renewable fuel that is produced from a variety of edible and non-edible vegetable oils and animal fats. The term "biodiesel" is commonly used for methyl or ethyl esters of the fatty acids in natural oils and fats, which meet the fuel quality requirements of compression-ignition engines. The influence of biodiesel on emissions varies depending on the type of biodiesel (soybean, rapeseed, or animal fats) and on the type of conventional diesel to which the biodiesel is added due to differences in their chemical composition and properties [15].

Advantages:

- Use of biodiesel results in reduction of CO, HC and PM, but slight increase in NOx emissions is obtained.
- Reduction in CO emissions is attributed to presence of oxygen in the fuel molecule.
- Lower SOF with biodiesel and advanced injection timing also results in lower PM emissions.

Hydrogen:

Interest in hydrogen as a potential alternative automotive fuel has grown due to need of reducing greenhouse gas, CO_2 emissions and to minimize dependence on fossil fuels. Hydrogen can be produced from a variety of fossil and non-fossil sources.

Combustion characteristics of hydrogen and its impact on emissions are given below;

- Hydrogen octane rating is 106 RON making it more suitable for spark-ignited engines.
- Its adiabatic flame temperature is higher by about 110º C compared to gasoline.
- Hydrogen on combustion produces water and there are no emissions of carbon containing pollutants such as HC, CO and CO_2 and air toxics.
- Trace amounts of HC, CO and CO2 however, may be emitted as a result of combustion of lubricating oil leaking into engine cylinder.
- NOx is the only pollutant of concern from hydrogen engines.

- Hydrogen fuelled engines produces almost no CO_2 and its global warming potential is insignificant [16].

Hydrogen fuelled IC engines however are not considered a long term option when compared to fuel cell [16].

❖ Advanced combustion system

Improving combustion efficiency is also one of the important mean to reduce tailpipe emissions, as major part of emissions is because of incomplete combustion. Nowadays to achieve complete combustion low temperature combustion (LTC) is popular. It includes homogeneous charge compression ignition (HCCI) and premixed charge compression ignition (PCCI). The primary goal of advanced combustion methods is to improve combustion and thereby avoid or at least reduce need of after treatment devices which makes whole system complicated and costly. LTC significantly lowers NOx and PM emissions [16].

❖ HCCI Diesel Engine

The objective of application of HCCI (homogeneous-charge compression ignition) concept to the diesel engines is control of NOx and particulates simultaneously which otherwise is difficult to achieve in the conventional CI engines. For HCCI combustion the efforts are directed mainly towards:

- Creation of premixed, lean homogeneous mixture
- Compression ignition and control of rate of combustion to obtain low emissions and optimum engine performance.

Emissions with HCCI Operation

Emission potential of HCCI operation relative to conventional diesel engines is illustrated in the below figure. The HCCI engine employed multiple early injection strategy with compression ratio equal to 13.4:1 and high rates of EGR. The NOx emissions were just 0.074 times (7.4%) and soot emissions were only 5.5% of the conventional CI engine operation. NOx emissions with HCCI operation ranged from 0.01 to 0.06 g/kWh and the soot emissions were below 0.02 g/kWh. Nearly 95% reduction in soot and NOx emissions are obtained compared to the conventional diesel operation. However, due to quenching of combustion in excessively lean mixture HC increased to 348%. CO increased to 487% of the conventional CI engine. As the mixture is not entirely homogeneous and some over rich zones exist more CO is produced [16].

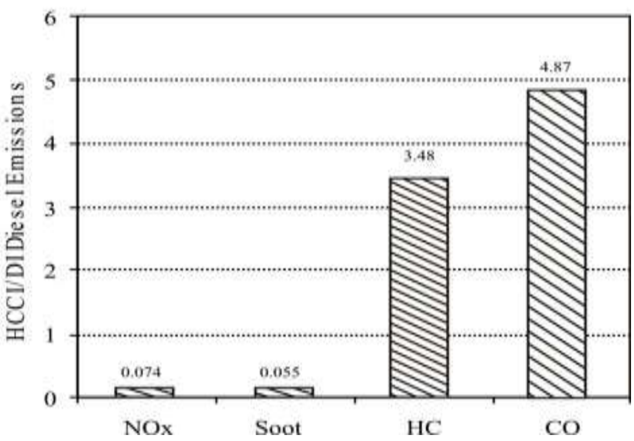

Figure 1: Comparative emissions with HCCI and conventional CI engine operation; multiple early injection strategy of HCCI operation.

❖ Downsizing and Downspeeding of Diesel Engines

Downsizing and downspeeding of diesels are strategies to enhance fuel economy and reduce emissions. Downsizing and downspeeding strategies have been successfully applied for light duty gasoline vehicles to improve fuel economy and lower emissions and have proven to be effective and reliable [17].

Downsizing (reduction in displacement and cylinder count) of the medium-heavy diesel highway engine is one means to save fuel and thus reduce CO2 emissions, However, to maintain torque (to keep the freight moving), certain measures will be required: intake air manifold pressure and/or compression ratio will need to rise, which has implications for emissions of NOx. Downspeeding is also helpful to improve diesel fuel economy, within reason and where feasible. Application of the downspeeding strategy appears to be of rising interest to save fuel, and is mentioned in various industry research reports. To deliver sufficient torque in a slower engine, engine OEMs may need to boost intake manifold pressure, raise compression ratios, or increase displacement—counter to the downsizing/fuel-saving objective. Another means of restoring torque is variable valve actuation (VVA), adjusting lift and/or timing [18].

❖ Exhaust Gas Recirculation

EGR process involves by passing a calculated volume (mass) of engine out exhaust back to engine to mix with fresh intake. Exhaust gases mainly consists of CO2 and H2O, which are already combusted during previous cycle, they do not burn again when they are recirculate. With the use of EGR, reduction in NOx is accompanied with an increase of smoke, particulate and HC emissions. Fuel consumption also increases with the use of EGR. As the EGR is applied, excess air decreases. With 25% EGR in a turbocharged engine at full load operation, the excess air ratio decreased from around 1.7 to 1.3. Simultaneously with 25% EGR, the NOx reduced by 85%, smoke increased manifold from around 0.5 Bosch smoke units to 3.5 Bosch units and BSFC increased by 8%. Smoke and BSFC increased sharply beyond about 12% EGR rate [19].

At part loads when air-fuel ratios are high, EGR rates even up to 50% can be applied. In practice, on the production engines, EGR is applied at part loads and at high loads NOx control is obtained by retarding injection timing.

Cooling of EGR before mixing with air has the following possible effects;

- Lower intake charge temperature would further reduce NOx formation.
- Higher intake charge density, higher volumetric efficiency and higher oxygen content in charge would give higher flame temperatures resulting in higher oxidation of soot.
- A higher volumetric efficiency provides lower BSFC.
- Lower charge temperatures would result in longer ignition delay period, more premixed combustion and higher unburned HC emissions.
- For the same reduction in NOx, loss in fuel economy is lower with cooled EGR compared to un-cooled EGR [16].

Due to a better NOx-BSFC trade-off, the cooled EGR is more commonly employed in practice.

5.3 Exhaust After-Treatment Devices

Only a small number of heavy-duty vehicles are equipped with any after-treatment device till 2010, but the effect on emissions was substantial [15]. In order to assess the potential of different after-treatment strategies to meet future BS VI emission norms, implementing after treatment devices has become most important task for the car manufacturers. The typical after-treatment system in the production of light-duty diesel vehicles currently is a combination of DOC, DPF, and SCR.

With the industry focus placed on selective catalytic reduction (SCR) systems that require urea dosing to reduce NOx, how urea is delivered and dosed has many system and engine manufacturers considering sealing, pumping and environmental resilience of dosing systems. Heavy-duty diesel engines require significant reductions in NOX, PM, and HC emissions roughly 80%, 50%, and 70%, respectively [20]. Low sulfur diesel (less than 50 ppm) is required for use with catalyzed DPFs or DOC + DPF devices. HC and CO control is achieved with a DOC or using DPFs with catalyzed surface membranes. DOCs formulated for Euro VI applications are designed for improved oxidation capabilities at low temperatures. HC and CO control is achieved with a DOC or using DPFs with catalyzed surface membranes.

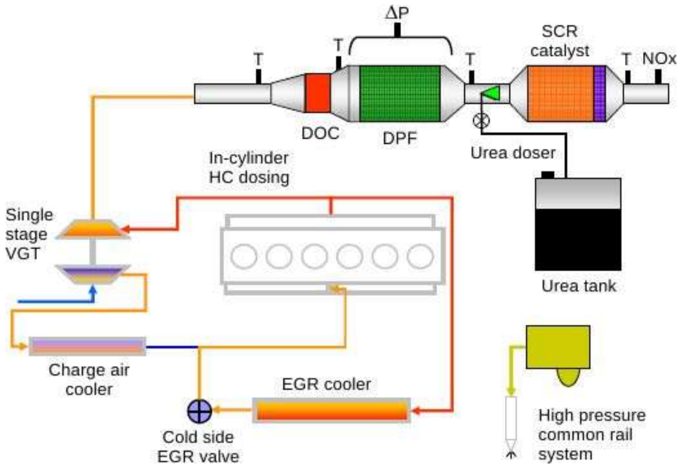

Figure 2: Emission control diagram for a BS VI compliant heavy-duty diesel engine

5.4 Summary of New and Emerging Technologies

New and emerging technologies have the potential to provide additional reductions in fuel consumption of diesel engines. Both short-term technologies, which are already appearing in production vehicles, and longer term technologies expected in the future are discussed in this section.

Following systems should be developed afresh for BS VI compliant from vehicle Engineering and packaging perspectives.

- After Treatment Devices such as SCR, EGR, DFP etc.
- Engine ECU development, calibration & validation
- New Wiring Harness
- Electronic OBD development and packaging
- Urea Tank development and positioning for filling at retail pumping stations
- Wheel Base, Masses & Dimensions changes

6. COST ANALYSIS OF EMISSION CONTROL TECHNOLOGIES

There are naturally costs associated with implementing any of the Program Scenarios.

The most significant expenditures are for the technology and other investments required for cleaner vehicles and fuels. In this section, these costs are compared with the benefits India stands to gain from lower vehicular PM emissions. The costs to comply with these regulations are primarily borne by the vehicle manufacturers and the petroleum producing companies. Vehicle manufacturers' costs are related to research and development, retooling of manufacturing plants, and certification of new vehicles. Petroleum producer costs are related to upgrading oil refineries to produce low sulfur fuels [2, 21]

The estimated cost to go from Bharat IV to Bharat VI was about 6,150 ($120) per gasoline passenger car or utility vehicle and about 40,000 ($590) per diesel passenger car or utility vehicle. Looking at commercial vehicles, the study estimated a cost of about 2.87 lakh ($5,700) per diesel vehicle and about 1.65 lakh ($3,300) per CNG vehicle. For two and three-wheelers, costs were estimated to be about 3000 ($60) and 2,400 ($50) per vehicle, respectively. The incremental costs are significantly higher for diesel vehicles compared with gasoline and CNG vehicles. As a result, moving to more demanding emission standards may also depress the sale of diesel vehicles which have higher PM and NOX emissions in favor of gasoline and CNG powered vehicles [22].

For public sector refiners, the incremental capital expenditure will go towards upgrading the refineries. The three public sector oil refiners will have to invest 30,000-35,000 crore over the next four years to produce auto fuels that will comply with BS VI emission norms [23]. These include capital and fixed costs as well as the increased incremental costs of production. While the costs are not trivial, the savings in health care expenditures and the increased economic activity unleashed by improved air quality will far offset any investment outlays. The cost of an OBD system was estimated to range from $350 to $500. As OBD systems are further integrated with engine control units, compliance costs will drop further and be increasingly difficult to distinguish [21].

7. CONCLUSIONS

- BS VI implementation requires significant changes to Engine & After treatment systems for controlling the levels of carbon monoxide, nitrogen oxides and particulate matter that can be released when petrol or diesel is burnt. Extensive calibration effort is required by OEMs for latest OBD and IUPR standards.

- BS VI commercial fuel quality & availability is critical for completion of development on time. Oil companies should make available BS-VI fuel to metro cities besides the national capital region (NCR) by April 2019. They should provide significant solutions to figure out the logistics to ensure supply at relevant pumps.

- Public awareness and strict implementation by government is required by providing reasonable knowledge about adverse effects of pollution on health, global warming and climate change through social media and campaigns to ensure the practical success of BS VI norms all over India.

- Retrofitting programs can be used for installing emission control technologies for older vehicles. Installing emission control technologies on older vehicles. This can be a very effective option for reducing harmful emission levels particularly from bus fleets and Commercial trucks.

- Make in India initiatives should be supported by OEMs and auto component manufacturers on all new technologies to have less impact on cost and availability. Use of safer, affordable, fuel efficient, low cost vehicles in India may be a key attribute for sustainable growth & development.

REFERENCES

[1] Shrivastava R. K., Saxena Neeta and Gautam Geeta., "AIR POLLUTION DUE TO ROAD TRANSPORTATION IN INDIA: A REVIEW OF ASSESSMENT AND REDUCTION STRATEGIES," Journal of Environmental Research and Development, Vol. 8 No. 1, July-September 2013

[2] Drew Kodjak., "POLICIES TO REDUCE FUEL CONSUMPTION, AIR POLLUTION, AND CARBON EMISSIONS FROM VEHICLES IN G20 NATIONS," International Council on Clean Transportation, May 2015

[3] Website: https://www.wikipedia.org

[4] Website: https://www.dieselnet.com

[5] Website: https://www.transportpolicy.net

[6] Technical Background on India BS VI Fuel Specifications, International Council on Clean Transportation, 2016

[7] Devendra Vashist, Naveen Kumar, et. al, "Technical Challenges in Shifting from BS IV to BS-VI Automotive Emissions Norms by 2020 in India: A Review," Archives of Current Research International, 2017, Article no.ACRI.33781

[8] Lee, Rob, et al. "Fuel Quality Impact on Heavy Duty Diesel Emissions:-A Literature Review." SAE Transactions, vol. 107, 1998

[9] Chevron, Diesel Fuels Technical Review, 2007

[10] Hussein I., Abdel-Shafy, Mona S., M.Mansour, A review on polycyclic aromatic hydrocarbons: Source, environmental impact, effect on human health and remediation, Egyptian Journal of Petroleum, Volume 25, Issue 1, March 2016

[11] Hochhauser, Albert M. "Review of Prior Studies of Fuel Effects on Vehicle Emissions." SAE International Journal of Fuels and Lubricants, vol. 2, no. 1, 2009

[12]https://www.thehindubusinessline.com/economy/emission-control-india-to-go-straight-to-bsvi-from-2020

[13]https://www.fev.com/NVHRefinementofDieselPassengerVehciles.pdf

[14]https://www.energy.gov/eere/vehicles/lightweight-materials-cars-and-trucks

[15] Nigel N. Clark, Justin M. Kern, et. al, "Factors Affecting Heavy-Duty Diesel Vehicle Emissions," Journal of the Air & Waste Management Association, 52:1, 84-94, DOI: 10.1080/10473289.2002.10470755

[16] Website: https://nptel.ac.in

[17] Website: https://www.nap.edu

[18] Nayan Mirgal, "Indian Automotive Industry towards Bharat Stage-VI Emission Norms: A Technical Review," International Journal of Engineering Research And Advanced Technology (IJERAT), Vol.3 (11) Nov -2017

[19] Kirtan Aryal, et. al, "VEHICULAR EMISSION CONTROL TECHNIQUES," International Journal of Advances in Science Engineering and Technology, Vol-4, Iss-4, Spl. Issue-2 Dec.-2016

[20] Ben Sharpe and Oscar Delgado, "Engine technology pathways for heavy-duty vehicles in India, International Council on Clean Transportation, 14 March 2016

[21] Francisco Posada, Sarah Chambliss, and Kate Blumberg, "COSTS OF EMISSION REDUCTION TECHNOLOGIES FOR HEAVY-DUTY DIESEL VEHICLES," International Council on Clean Transportation, February 2016

[22] Gaurav Bansal and Anup Bandivadekar, "OVERVIEW OF INDIA'S VEHICLE EMISSIONS CONTROL PROGRAM," International Council on Clean Transportation, 2013

[23]https://energy.economictimes.indiatimes.com/news/oil-and-gas/indian-oil-refiners-are-investing-rs-30000-crore-for-upgrading-to-bs-vi-technology-ssv-ramakumar-ioc/63574575