

## ***Impact of Emission Norms On Automotive Engine Design***

***Dr. Shalini Verma,***

*Assistant Professor,*

*Department of Mechanical Engineering,*

*Aryabhata Institute of Technology, Pune, Maharashtra, India*

*Email: shalini.verma@aryabhata.ac.in*

***Mr. Arpit Sen,***

*Research Scholar,*

*Department of Automotive Engineering,*

*Dr. A.P.J. Abdul Kalam Technical University, Lucknow, Uttar Pradesh, India*

*Email: arpit.sen@aktu.edu.in*

### ***Abstract***

*The progressive tightening of vehicular emission norms has significantly influenced the design and performance of internal combustion engines (ICE). With global pressure to reduce environmental pollution and greenhouse gas emissions, automotive manufacturers have had to integrate innovative technologies to comply with standards such as Euro VI, Bharat Stage VI, and Tier 3 norms. These regulations have resulted in notable changes in fuel injection systems, exhaust after-treatment devices, combustion optimization, and electronic control systems. This paper explores the evolution of emission norms and their direct implications on engine architecture, efficiency, and sustainability. Additionally, it addresses the balance between performance, compliance, and cost-effectiveness through a systematic examination of engineering adaptations driven by legislation.\**

***Keywords:*** *Emission norms, Engine design, Euro VI, BS VI, After-treatment systems, Automotive engineering, NOx reduction, GHG emissions.*

## INTRODUCTION

Emission norms are legal standards introduced by governments and international organizations to regulate the output of air pollutants from internal combustion engines. They aim to reduce the impact of transportation on air quality, public health, and the environment. Over the past three decades, there has been a sharp escalation in emission stringency worldwide, forcing original equipment manufacturers (OEMs) to redesign various aspects of vehicle engines to meet regulatory compliance.

## EMISSION NORMS: GLOBAL PERSPECTIVE

Emission norms have evolved gradually, becoming stricter with each successive stage. In Europe, the Euro norm system has progressed from Euro I (1992) to the current Euro VI (2014), with Euro VII expected soon. In India, the transition has moved from Bharat Stage I (2000) to Bharat Stage VI (2020), skipping BS-V entirely to leapfrog to a cleaner standard.

## MAJOR POLLUTANTS TARGETED

- **Carbon Monoxide (CO):** Result of incomplete combustion.
- **Hydrocarbons (HC):** Unburnt fuel components.
- **Nitrogen Oxides (NO<sub>x</sub>):** Formed under high combustion temperatures.
- **Particulate Matter (PM):** Soot and metal particles primarily from diesel engines.
- **Carbon Dioxide (CO<sub>2</sub>):** A greenhouse gas; not toxic but regulated for climate impact.

## ENGINE DESIGN MODIFICATIONS

### Fuel Injection System Advancements

The shift from carburetors to electronic fuel injection (EFI) and then to common rail direct injection (CRDi) has enabled precise control over air-fuel mixture and injection timing, significantly reducing emissions.

### Turbocharging and Downsizing

To meet both emission and performance goals, manufacturers have adopted engine downsizing combined with turbocharging. Smaller engines with forced induction maintain power while reducing fuel consumption and emissions.

### Combustion Optimization

Advanced combustion strategies such as homogeneous charge compression ignition (HCCI) and stratified charge operation have been implemented to enhance fuel-air mixing and lower combustion temperatures to reduce NOx formation.

### EXHAUST AFTER-TREATMENT TECHNOLOGIES

A suite of after-treatment solutions is employed depending on the fuel type and the emission standard being met.

*Table 1: Overview of Exhaust After-Treatment Technologies and Their Application*

Technology	Application	Description
Diesel Particulate Filter (DPF)	Diesel engines	Captures soot and particulate matter.
Selective Catalytic Reduction (SCR)	Diesel engines	Reduces NOx using urea-based AdBlue.
Three-Way Catalytic Converter (TWC)	Petrol engines	Reduces CO, HC, and NOx simultaneously.
Gasoline Particulate Filter (GPF)	GDI Petrol engines	Controls particulate emissions in modern petrol cars.

### ELECTRONIC CONTROL UNITS AND SENSORS

Modern engines incorporate a network of sensors and electronic control units (ECUs) that continuously monitor engine parameters, optimize combustion, and ensure adherence to emission standards.

- **Oxygen (O<sub>2</sub>) Sensor:** Monitors exhaust oxygen to adjust air-fuel mixture.
- **NOx Sensor:** Ensures effective functioning of SCR.
- **Engine Control Unit (ECU):** Central unit for coordinating fuel injection, ignition, and emission controls.

### DESIGN CHALLENGES DUE TO EMISSION NORMS

1. **Increased Cost:** The integration of emission control technologies adds manufacturing and maintenance costs.
2. **Reduced Power Output:** Engine detuning to meet standards may lower peak power.

3. **Fuel Economy Trade-offs:** Some emission-reduction techniques may adversely affect mileage.
4. **Thermal Management:** Maintaining after-treatment devices at operational temperatures during cold starts is challenging.

**CASE STUDY: TRANSITION TO BS VI IN INDIA**

India’s leap from BS IV to BS VI in 2020 presented massive challenges for OEMs. BS VI mandates a 68% reduction in NOx and a 90% cut in PM for diesel engines compared to BS IV.

**Key Changes Made:**

- Introduction of DPF and SCR systems in diesel vehicles.
- Shift to high-pressure CRDi systems.
- Calibration of ECUs for real-world driving conditions.

*Table 2: Comparison of Key Parameters Between BS IV and BS VI Standards*

Engine Parameter	BS IV Specification	BS VI Specification
NOx (Diesel)	0.25 g/km	0.08 g/km
PM (Diesel)	0.025 g/km	0.0045 g/km
Fuel Sulphur Content	50 ppm	10 ppm

**ALTERNATIVE SOLUTIONS TO ICE ENGINES**

With tightening norms, the automotive industry is also exploring alternatives to traditional combustion engines:

- **Hybrid Vehicles:** Combine ICE with electric propulsion to reduce emissions.
- **Electric Vehicles (EVs):** Produce zero tailpipe emissions.
- **Hydrogen Fuel Cells:** Offer clean mobility using hydrogen as fuel.
- **Synthetic Fuels:** Carbon-neutral and can be used in existing ICE platforms with modifications.

## **FUTURE OUTLOOK**

As regulatory agencies gear up for next-level norms like Euro VII and potential BS VII, the push will be toward real-driving emissions (RDE) compliance and further integration of on-board diagnostics (OBD). Predictive emission control, AI-integrated engine management, and cloud-connected powertrains will become pivotal.

## **CONCLUSION**

The imposition of stringent emission norms has led to a technological revolution in the design of automotive engines. From advanced fuel injection systems to after-treatment devices, nearly every engine component has undergone transformation. These regulations, while challenging, have spurred innovation, resulting in cleaner, more efficient, and sustainable vehicles. The future of engine design lies in harmonizing performance with environmental responsibility, paving the way for hybridization and electrification as complements to clean combustion technology.

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