Enviro-Economic Assessment of Alternative Fuels in Internal Combustion Engines

Syed Muhammad Talha

Abstract

The rising global energy demand and environmental concerns have driven the adoption of alternative fuels in internal combustion engines. This study presents a comprehensive enviro-economic assessment of two alternative fuels, Fuel P and Fuel Q, in terms of engine performance, CO_2 emissions, and associated economic costs. The analysis integrates modern computational and analytical tools: report formatting and professional presentation using LATEX, graphical visualization with Origin Pro, statistical optimization using Minitab, and the Caliskan method for calculating annual CO_2 emissions and enviro-economic costs. Normalization techniques and the Enviro-Economic Index (EEI) were applied to identify optimal operating conditions for engine efficiency,environmental performance, and economic feasibility. Furthermore, a sector-specific carbon taxation policy for power plants and automobiles was developed based on the modeled CO_2 emissions,incentivizing operation at RPMs that minimize environmental and economic impact. Results highlight the optimal engine RPM range and provide recommendations for sustainable fuel utilization, demonstrating the integration of modern analytical tools to guide policy and operational decisions in Pakistan's transport and energy sectors.

Objectives

The objective of this project was to evaluate alternative fuels for internal combustion engines by integrating engine performance, carbon dioxide (CO_2) emissions, and economic cost into a unified enviro-economic framework. The study aimed to identify optimal engine operating conditions that balance power output with environmental and economic impact, and to provide insights for sustainable fuel selection and emission-based policy decisions.

Methodology

The analysis was carried out using a structured, data-driven approach:

- Engine power and CO_2 emission data were collected for two alternative fuels across multiple RPM levels.
- Annual CO_2 emissions were estimated using the Caliskan enviro-economic method.
- Regression and optimization techniques were applied to analyze RPM-dependent trends.
- Power, emission, and cost parameters were normalized to enable fair comparison.
- An Enviro-Economic Index (EEI) was developed to identify optimal operating conditions.

Results and Analysis

Key Graphs

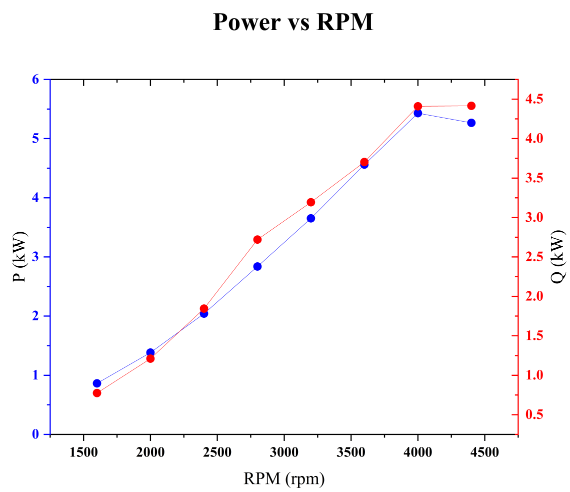

Figure 1: Engine Power vs RPM for Fuels P and Q

Engine power increases with RPM for both fuels; however, the rate of power gain reduces at higher RPMs, indicating diminishing performance returns.

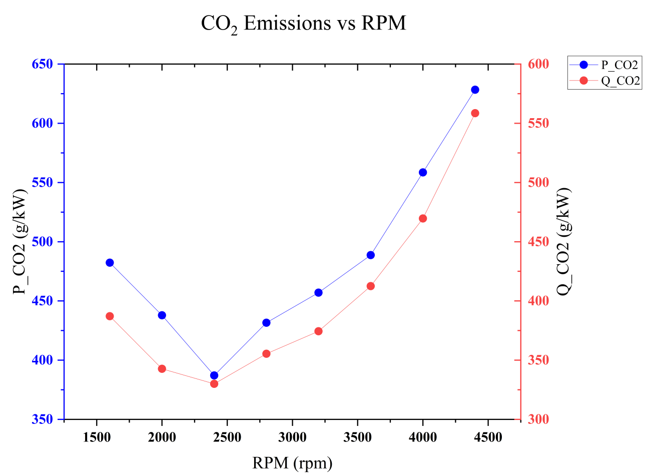

Figure 2: CO_2 Emissions vs RPM for Fuels P and Q

CO_2 emissions increase significantly with engine speed. High RPM operation results in disproportionately higher emissions for both fuels.

The EEI curve highlights the optimal operating range where power output, emissions, and cost are balanced.

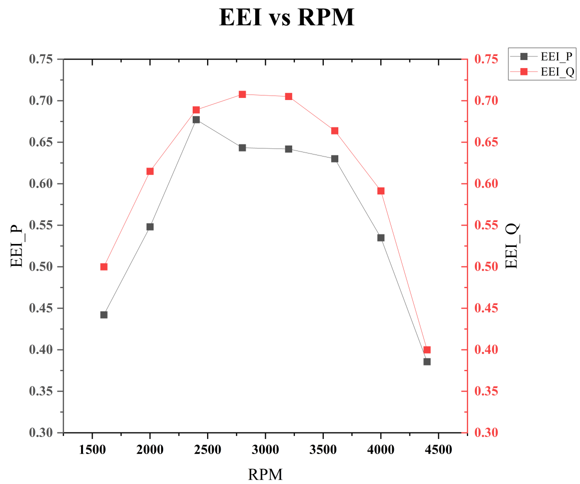

Figure 3: Enviro-Economic Index (EEI) vs RPM

EEI and Optimization Results

- Fuel P achieves maximum EEI at **2400 RPM**, indicating optimal low-to-mid RPM operation.
- Fuel Q achieves maximum EEI at **2800 RPM**, showing better performance at slightly higher RPM.
- EEI decreases at RPMs above 4000 due to sharp increases in emissions and carbon cost despite higher power output.

Key Observations

- Mid-range RPM operation provides the best compromise between performance and sustainability.
- High RPM operation yields limited power gains with significantly higher CO_2 emissions.
- Fuel type and operating RPM both strongly influence enviro-economic performance.
- The EEI is an effective metric for sustainable engine operation.

Conclusions

- The optimal engine operating range for alternative fuels lies between **2400–2800 RPM**.
- Fuel P performs better at lower RPMs, while Fuel Q becomes favorable at higher RPMs.
- Integrating environmental and economic parameters with performance analysis enables more informed engineering decisions.
- The enviro-economic framework supports sustainable fuel selection and emission reduction strategies.

Skills Demonstrated

- Engine performance analysis
- CO_2 emission modeling
- Enviro-economic assessment
- Optimization using EEI
- Data normalization and regression
- Engineering decision-making

Tools Used

- Minitab — regression and optimization
- Origin Pro — data visualization
- Microsoft Excel — data processing and EEI calculation
- LaTeX — technical documentation