

Enviro-economic analysis and optimization of various fuels utilization in internal combustion engine

PLOs	PLO1, PLO2, PLO5 & PLO6
CLOs	CLO1 to CLO4

Deadline: 30 Dec 2025

Complex Engineering Problem Attributes

Complex Engineering Problems have characteristics **WP1** and at least two or more of **WP2** to **WP7**.

CEP Attribute	Contextual Definition	Attribute Mapped
WP1: Depth of Knowledge Required	Cannot be resolved without in-depth engineering knowledge at the level of one or more of WK3, WK4, WK5, WK6 or WK8 which allows a fundamentals-based, first principles analytical approach	<input checked="" type="checkbox"/>
WP2: Range of conflicting requirements	Involve wide-ranging and/or conflicting technical, non-technical issues (such as ethical, sustainability, legal, political, economic, societal) and consideration of future requirements	<input checked="" type="checkbox"/>
WP3: Depth of analysis required	Have no obvious solution and require abstract thinking, creativity and originality in analysis to formulate suitable models	<input checked="" type="checkbox"/>
WP4: Familiarity of issues	Involve infrequently encountered issues or novel problems	
WP5: Extent of applicable codes	Address problems not encompassed by standards and codes of practice for professional engineering	
WP6: Extent of stakeholder involvement and conflicting requirements	Involve collaboration across engineering disciplines, other fields, and/or diverse groups of stakeholders with widely varying needs	
WP7: Interdependence	Address high-level problems with many components or sub-problems that may require a systems approach	

1. Problem Description

The increasing energy demand worldwide has had a negative impact on the reserves of petroleum. This has led to a growing interest in the use of alternative energy sources, one of the most promising alternatives being energy from fuels other than conventional. The very fuels have gained significant attention in the power/automobile sector as a potential solution to meet the needs of human beings.

Pakistan has heavily relied on imported oil to meet its energy needs, resulting in a significant trade deficit. The primary energy supply consists of majorly natural gas, and oil. In 2020, Pakistan imported petroleum products of USD 10.31 billion, and its trade deficit stood at USD 21.11 billion. This heavy reliance on imported oil not only leads to a trade deficit but also exposes the country to the volatility of international oil prices.

Shifting towards renewable/alternative fuels could help reduce Pakistan's oil consumption, ultimately lowering the oil import bill and the trade deficit. Additionally, it could stimulate local job creation and provide economic benefits in the long run. Due to its high energy generation potential, these fuels are widely used in power generation and automobile sectors in different countries. Attempts to secure more energy, food, and infrastructure leave a trail of environmental contamination and human health hazards.

The power and automobile sectors in Pakistan are also responsible for a significant amount of the country's environmental pollutants. Thus, there is a need to explore environmental impacts along with the power production using non-conventional energy sources as a fuel in Pakistan. Furthermore, in economies with limited supplies of petroleum, alternative fuels can play a vital role in solving the issue to some extent. Therefore, the complex engineering problem aims to evaluate the use of various types of fuels along with impact on environment and society.

In the very context, implement and elaborate the enviro-economic analysis for the data of two fuels P and Q (given in Table 1) by making use of the method developed by Caliskan. Also, evaluate the engine characteristics to ascertain the optimized set of operating conditions in context of power production, CO₂ emissions generation and carbon pricing.

Table 1: Various parameters of the test engine for two different fuels.

RPM	P(kW)	Q(kW)	PCO ₂ (g/kWh)	QCO ₂ (g/kWh)
1600	0.864166	0.775103	482.372	387.167
2000	1.383308	1.210847	437.943	342.738
2400	2.041199	1.845139	387.167	330.044
2800	2.839004	2.720655	431.596	355.432
3200	3.651537	3.193355	456.984	374.473
3600	4.561962	3.702889	488.719	412.555
4000	5.430333	4.410318	558.536	469.678
4400	5.266979	4.415778	628.353	558.536

2. Objectives

- To analyze the operation of the internal combustion engine
- To perform enviro-economic analysis of the two different fuels utilization in engine
- To optimize the system in context of power production and environmental impacts

3. Deliverables

Following deliverables are required from the student:

- Introduction encompassing the theoretical background and literature.
- The complete enviro-economic analysis leads to carbon pricing at each rpm of the engine operation. (methodology and calculations).
- The optimization of the data set provided along with enviro-economic terminologies. (methodology, modelling)

- The recommendation in terms of power and emission production from the fuels (Results and Discussions).
- Comparison (Origin Pro and optimization software) and recommendations in terms of practicality and environmental impacts (Results and Discussions).
- Conclusive remarks

Following characteristics are targeted in this complex engineering problem of Energy Resources & Utilization:

Depth of Knowledge Required	Depth of Knowledge is required in the area of Fuels and Combustion, and various laws of thermodynamics for combustion, energy calculations, and required principles for engine operation.
Range of Conflicting Requirements	There are various types of fuels available for catering to the energy demand of the consumers. However, these resources carry different elements depending on the chemical formula. Therefore, students must find out and suggest the impact of using various fuels for energizing internal combustion engines in terms of environmental assessment.
Depth of analysis required	The students will perform enviro-economic analysis for the data of two fuels P and Q (given in Table 1) by making use of the method developed by Caliskan. In the same way, they will optimize the system in context of power production and environmental impacts. The students will recommend the best type of fuel in terms of practicality and in-depth analysis of carbon content and pricing.

4. Assessment

The report of complex engineering problem should have the following sections:

Abstract

Introduction

Methodology

Results and Discussion

Conclusions

References

Rubrics

Description	Excellent (4)	Good (3)	Fair (2)	Poor (1)
Problem awareness (4)	Shows excellent awareness of properties and states of the systems	Shows appropriate awareness of properties and states of the systems	Shows little awareness of properties and states of the systems	Ignorance of few properties and states of the systems
Modern tool usage (4)	Shows good awareness of tools, capabilities and features	Shows appropriate awareness of tools, capabilities and features	Shows average awareness of tools, capabilities and features	Shows no/little awareness of tools, capabilities and features
CEP solution approach (4)	Provide a comprehensive solution to the problem	Provide an appropriate solution to the problem in general understandable manner	Average solution with few required features	1. Obvious solution, sketchy functionalities 2. Bare usage of Engineering knowledge
Overall structure of report in context of writing tool usage (4)	1. Has outstanding organizational structure 2. Points are logical and interesting	1. Has a clear organizational structure 2. Points are generally logical	1. Has moderate organizational structure 2. Some points are clear and logical	1. Does not have a clear organization 2. Points are vague
Knowledge of environmental pollution in context of the impact of combustion products of fuels (4)	Deep understanding of the importance of environment	Focuses on the importance of environment	Average interest in environmental impacts of the fuels	Minute information/ Ignorance about the relation between combustion and its effects on environment