World Journal of Advanced Research and Reviews
eISSN: 2581-9615 CODEN (USA): WJARAI
Cross Ref DOI: 10.30574/wjarr
Journal homepage: https://wjarr.com/

(Research Article)

Diesel or Jatropha Biodiesel? A life cycle assessment approach for sustainable energy decisions

Jorge Nhambiu [1,*], José Gui Naldo Muchanga [1] and Fernando Chichango [2]

[1] *Mechanical Engineering Department, Faculty of Engineering, Eduardo Mondlane University, Maputo, Mozambique.*
[2] *ECROT Department, Faculty of Environmental and Natural Resource Engineering, Zambeze University, Chimoio, Mozambique.*

World Journal of Advanced Research and Reviews, 2025, 28(02), 1416–1426

Publication history: Received 08 October 2025; revised on 15 November 2025; accepted on 17 November 2025

Article DOI: https://doi.org/10.30574/wjarr.2025.28.2.3875

Abstract

This study compares the environmental and economic performance of diesel and Jatropha biodiesel using Life Cycle Assessment (LCA) and cost analysis for a functional unit of 1,000 km traveled. Results indicate that Jatropha biodiesel reduces overall environmental impact by approximately 37%, primarily due to net negative CO_2 emissions from carbon sequestration during cultivation, and offers significant improvements in global warming potential, fossil fuel depletion, and particulate matter formation. However, biodiesel requires 111.1 liters versus 100 liters of diesel for the same distance, reflecting its lower energy density (37 MJ/L vs. 43 MJ/L), and incurs a 42.7% higher cost per unit of useful energy (USD 0.157/MJ vs. USD 0.09/MJ), raising the total cost for 1,000 km from USD 136 to USD 225.53. Qualitatively, Jatropha biodiesel emerges as a cleaner alternative with strong climate benefits, but its competitiveness is constrained by higher production costs, land use, and water consumption. These findings highlight the need for technological improvements and policy support to enhance the economic viability of biodiesel while leveraging its environmental advantages.

Keywords: Life Cycle Assessment; Jatropha Biodiesel; Environmental Impact; Renewable Energy; Sustainable Fuel Alternatives

1 Introduction

The global energy sector is undergoing a significant transformation driven by the urgent need to reduce greenhouse gas emissions, mitigate climate change, and transition towards more sustainable energy systems. Fossil fuels, particularly diesel, remain dominant in transportation and industrial applications, but their environmental impacts and economic volatility have prompted the exploration of renewable alternatives [1, 2].

Biofuels have emerged as a promising solution, offering the potential to reduce carbon emissions and promote energy independence. Among them, biodiesel derived from Jatropha curcas has attracted considerable attention due to its non-edible nature, adaptability to marginal soils, and relatively high oil yield [3]. Unlike first-generation biofuels, jatropha biodiesel does not compete directly with food crops, making it a viable option for sustainable development in regions such as sub-Saharan Africa [4].

Mozambique, with its vast agricultural potential and growing energy demand, is well-positioned to benefit from the cultivation and use of jatropha-based biodiesel. Several initiatives have explored its feasibility, and recent policy frameworks have encouraged the integration of biofuels into the national energy mix [5]. However, the environmental and economic viability of jatropha biodiesel must be rigorously assessed to support informed decision-making.

* Corresponding author: Jorge Nhambiu

Life Cycle Assessment (LCA) is a standardized methodology that evaluates the environmental impacts of a product or process throughout its entire life cycle—from raw material extraction to end use and disposal [6]. By applying LCA to compare diesel and jatropha biodiesel, researchers can identify trade-offs, quantify emissions, and assess resource consumption across multiple impact categories [7].

This study aims to apply LCA to evaluate the environmental performance of diesel and jatropha biodiesel used in internal combustion engines. The analysis is based on a functional unit of 1,000 km traveled by a light-duty vehicle and includes a complementary economic assessment based on the cost per unit of useful energy. The findings are intended to inform sustainable energy strategies in Mozambique and contribute to the broader discourse on renewable fuel adoption.

2 Material and methods

This research applies the Life Cycle Assessment (LCA) methodology to compare the environmental performance of diesel and jatropha biodiesel used in internal combustion engines. The analysis was conducted using the SimaPro v.9.6.0.1 software and follows the guidelines of the ISO 14040 standard [8].

2.1 General Approach

The study adopts a cradle-to-grave approach, considering all stages from raw material extraction, fuel production, transportation, and final use in the engine. The analysis is focused on environmental impacts, using a causality-based model that quantifies the relationship between inputs and outputs of each system.

2.2 Goal and Scope Definition

The main goal is to evaluate and compare the environmental impacts of a light-duty vehicle operating with diesel and jatropha biodiesel. The functional unit is defined as 1,000 km traveled, ensuring a fair comparison between the two fuels. Based on average consumption rates—10 km/L for diesel and 9 km/L for jatropha biodiesel—the reference flows are 100 L of diesel and 111.1 L of biodiesel [9](Table 1).

Table 1 Scope Summary

Fuel	Diesel	Biodiesel
Function	To run a light vehicle	
Functional Unit	1,000 km	
Performance	10 km/L	9 km/L
Reference Flow	100 L	111.1 L

The table shows the reference flows for diesel and jatropha biodiesel to cover the functional unit of 1,000 km with a light-duty vehicle. Diesel requires 100 liters, while biodiesel needs 111.1 liters due to its lower fuel efficiency (9 km/L compared to 10 km/L). These values establish the basis for comparing environmental impacts in life cycle assessment.

2.3 Inventory Analysis

The inventory was built using data from the Ecoinvent database and complemented with bibliographic sources. The modeling in SimaPro involved defining unit processes, entering input/output flows, and quantifying emissions and resource use.

2.3.1 CO_2 Balance

A CO_2 balance was performed to account for carbon sequestration during jatropha cultivation. According to Wani et al. [10], a plantation of Jatropha curcas can sequester approximately 5,323 kg of CO_2 per hectare per year. For the required seed production, this results in a sequestration of 3,792 kg of CO_2 over four years, which was subtracted from the total emissions of the biodiesel system. The CO_2 balance was calculated by Equation 1.

Equation (1): $$CO_{2total} = \Sigma(Emissions\ of\ CO_2) - (CO_{2sequestred})$$

Where:

CO_{2total} - Total CO_2 released to the environment

Emissions of CO_2 - Sum of CO_2 emissions from all processes

CO_2 sequestered - Amount of CO_2 captured by Jatropha cultivation

This equation ensures that the net CO_2 impact accounts for both emissions and sequestration.

2.3.2 Global Warming Potential (GWP)

GWP measures the relative contribution of a greenhouse gas to global warming compared to CO_2.

Equation (2): $$GWP_i = \frac{\int_0^T a_i c_i(t)dt}{\int_0^T a_{CO2} c_{CO2}(t)dt} \quad [CO_2\ equivalent]$$

Where:

GWP_i - Global Warming Potential of substance I.

a_i - Radiative efficiency of gas I.

$c_i(t)$ - Concentration of gas i over time.

T - Time horizon.

a_{CO_2} - Radiative efficiency of CO_2.

$c_{CO_2}(t)$ - Concentration of CO_2 over time.

This ratio compares the warming effect of a gas to that of CO_2 over a specified time horizon.

2.3.3 Ozone Depletion Potential (ODP)

ODP expresses the relative impact of a substance on ozone layer depletion compared to CFC-11.

Equation (3): $$ODP_i = \frac{\delta[O_3]_i}{\delta[O_3]_{CFC-11}} \quad [CFC-11\ equivalent]$$

Where:

ODP_i - Ozone Depletion Potential of substance I.

$\delta[O_3]_I$ - Change in ozone column due to substance I.

$\delta[O_3]_{CFC-11}$ - Change in ozone column due to CFC-11

Equation (4): $$\text{Ozone Depletion} = \sum_i ODP_i \times m_i \quad [kg\ de\ CFC-11\ equivalent]$$

This equation quantifies the potential of a substance depleting ozone layer relative to CFC-11.

2.3.4 Acidification Potential (AP)

AP measures the potential of substances to cause acid deposition compared to SO_2.

Equation (5): $$AP_i = \frac{v_i/M_i}{v_{SO2}/M_{SO2}} \quad [SO2\ equivalent]$$

Where:

AP_i - Acidification Potential of substance I.

v_i - H^+ equivalent of substance I.

M_i - Mass of substance I.

v_{SO_2} - H^+ equivalent of SO_2.

M_{SO_2} - Mass of SO_2.

$$Acidicação = \sum_i AP_i \times m_i \quad [kg\ de\ SO2\ equivalent]$$

This equation expresses acidification potential relative to SO_2 as a reference substance.

2.3.5 Eutrophication Potential (NP)

NP indicates the potential of substances to enrich water or soil with nutrients, causing ecological imbalance.

Equation (6): $$NP_i = \frac{v_i/M_i}{v_{PO_4^{3-}}/M_{PO_4^{3-}}} \quad [N\ equivalent]$$

Where:

NP_i - Eutrophication Potential of substance I.

v_i - Biomass potential in N equivalents.

M_i - Mass of substance I.

v_$PO_4{}^{3-}$ Biomass potential of phosphate.

$M_{PO_4^{3-}}$ - Mass of phosphate.

Equation (7): $$\text{Eutrophication} = \sum_i NP_i \times m_i \quad [kg\ de\ N\ equivalent]$$

Where: m_i is the mass of the substance (i)

This equation compares nutrient enrichment potential to phosphate as a reference.

2.3.6 Ionizing Radiation Potential (IRP)

IRP measures the potential impact of radioactive emissions relative to Cobalt-60.

Equation (8): $$IRP = \frac{CD_{x,i}}{CD_{co-60,air}} \quad [Co - 60\ equivalent]$$

Where:

IRP_i - Ionizing Radiation Potential of substance I.

$CD_{(x,i)}$ - Collective dose from substance I.

$CD_{(Co\text{-}60,air)}$ - Collective dose from Co-60 in air.

Thus, ionizing radiation is defined by the following expression:

Equation (9): $$\text{Ionizing Radiation} = \sum_i IRP_i \times m_i \quad [kg\ de\ Co - 60\ equivalent]$$

Where: m-i. is the amount of the substance emitted in kg.

This equation expresses radiation potential in terms of Co-60 equivalents.

2.3.7 Particulate Matter Formation Potential (PMFP)

PMFP indicates the potential of substances to form fine particulate matter (PM2.5).

Equation (10): $$PMFP_{x,i} = \frac{iF_{x,i}}{iF_{PM2,5,world}} \quad [PM2{,}5\ equivalent]$$

Where:

$PMFP_{(x,i)}$ - Particulate Matter Formation Potential of substance I.

$iF_{(x,i)}$ - Inhalation factor for substance I.

$iF_{(PM2.5,world)}$ - Global average inhalation factor for PM2.5.

This equation compares particulate formation potential to global PM2.5 standards.

2.3.8 Land Use Impact

This category evaluates species loss due to land occupation compared to annual crop production.

Equation (11):

$$FCm_{occ,x} = \frac{S_{rel,x}}{S_{rel,annualcrop}} \quad [crop\ equivalent]$$

Where:

$FCm_{(occ,x)}$ - Characterization factor for land occupation.

$S_{(rel,x)}$ - Relative species loss for land use type x.

$S_{(rel,annualcrop)}$ - Relative species loss for annual crop production.

This equation expresses land use impact in crop-equivalent terms.

According to ReCipe [11] the factor $S_{rel,x.}$ is calculated by comparing field data on the richness of local species in specific types of natural and artificial land covers, using the linear relationship described by Köllner et al [12]:

Equation (12): $$S_{rel,x} = 1 - \frac{S_{LU,x,i}}{S_{ref,i}}$$

Where:

$S_{LU,x,i}$ – It is the number of species observed under the type of land use (x).

$S_{ref,i.}$ – It is the number of species observed from the reference land cover in the region (i).

2.3.9 Fossil Resource Depletion

This category measures depletion based on cumulative energy demand compared to crude oil.

Equation (13): $$CF_{midpoint,i} = \frac{CED_i}{CED_{ref}}$$

Where:

$CF_{midpoint,I}$ - Characterization factor for fossil resource I.

CED_i - Cumulative energy demand of resource I.

CED_{ref} - Cumulative energy demand of reference crude oil.

2.3.10 Mineral Resource Depletion

This category evaluates scarcity based on Surplus Ore Potential - SOP compared to copper.

Equation (14): $$SOP_{x,R} = \frac{ASOP_{x,R}}{ASOP_{Cu,R}} \quad [kg\ de\ Cu\ equivalent]$$

Where:

$SOP_{x,R}$ - Surplus Ore Potential for mineral x.

$ASOP_{x,R}$ - Absolute Surplus Ore Potential for mineral x.

$ASOP_{Cu,R}$ - Absolute Surplus Ore Potential for copper.

The impact of the scarcity of mineral resources is obtained through the following expression:

Equation (15): $$Mineral\ resource\ depletion = \sum_x SOP_{x,R} \quad [kg\ de\ Cu\ equivalent]$$

Where: $SOP_{x,R}$. is the Surplus Ore Potential of an (x) in a reserve (R).

2.3.11 Water Consumption

This category measures the total amount of water consumed.

Equation (16): $$FC = \begin{cases} 1\ if\ the\ inventory\ is\ in\ m^3\ consumed \\ Required\ rate\ of\ water,\ if\ inventory\ is\ in\ m^3\ consumed \end{cases}$$

Where:

FC - Characterization factor for water consumption.

This equation indicates that water consumption is directly proportional to the volume consumed.

2.4 Impact Assessment Method

The ReCiPe 2016 method was selected for impact assessment due to its robustness and integration of midpoint and endpoint approaches [13]. The midpoint approach identifies potential impacts (e.g., global warming, acidification), while the endpoint approach quantifies final damage to areas of protection such as human health, ecosystems, and resource availability.

ReCiPe includes 18 impact categories, which were grouped into 12 general categories for this study. Mathematical models and characterization factors were applied to calculate the environmental burdens of each system [14].

3 Results and discussion

This section shows the results from a Life Cycle Assessment (LCA) comparing diesel and jatropha biodiesel in internal combustion engines and discusses their environmental impacts. The study used the ReCiPe 2016 method, applying both midpoint and endpoint approaches. The analysis is based on a functional unit of a light-duty vehicle traveling 1,000 kilometers.

3.1 Environmental Impact Comparison

The ReCiPe midpoint results revealed significant differences between the two fuel systems across multiple impact categories. The diesel system showed higher values in global warming potential, acidification, particulate matter formation, and fossil resource depletion, while the jatropha biodiesel system had greater impacts in land use, water consumption, and eutrophication due to agricultural activities.

In terms of global warming, jatropha biodiesel demonstrated a net negative CO_2 emission due to carbon sequestration during cultivation, resulting in a 100% reduction compared to diesel [15]. This highlights its potential to mitigate climate change when managed sustainably.

3.2 Damage to Human Health

Using the endpoint approach, the damage to human health was quantified in DALY (Disability-Adjusted Life Years). Diesel use contributed more significantly to respiratory diseases due to higher emissions of PM2.5 and NOx. Jatropha biodiesel, although cleaner in combustion, showed increased water-related health risks due to irrigation demands [16] as shown in Figure 1.

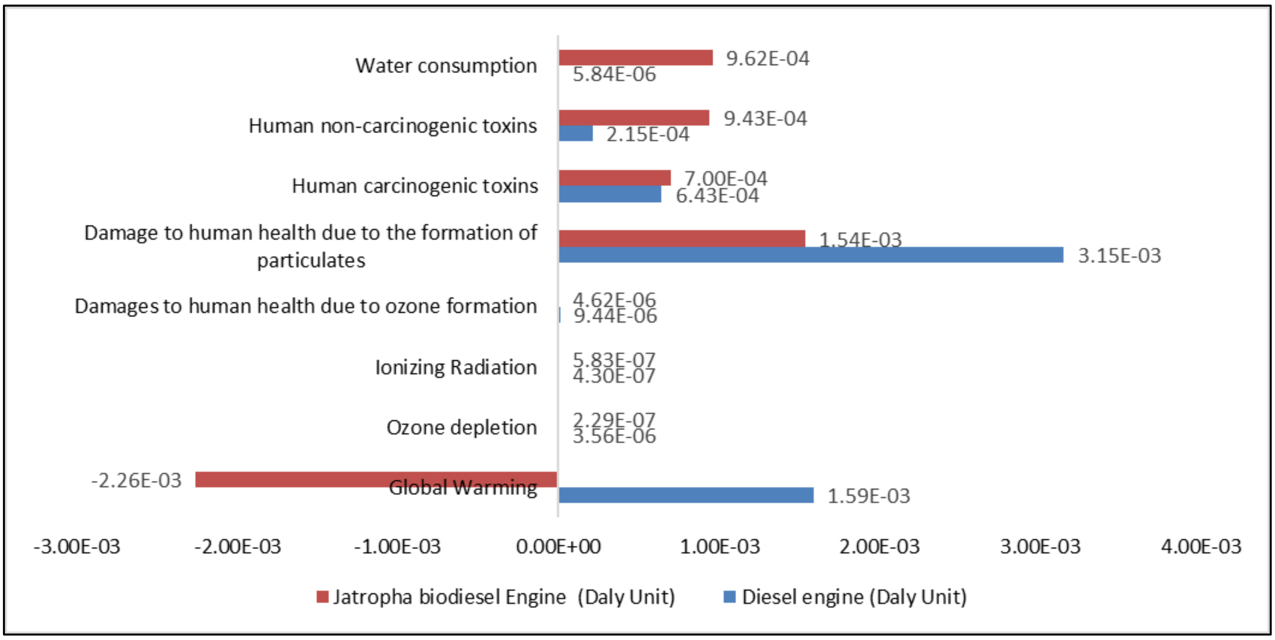

Figure 1 Results of damage to human health

Figure 1 shows that jatropha biodiesel emits fewer greenhouse gases and fine particles than diesel, reducing global warming and health risks. Both fuels have similar carcinogenic toxin impacts, though diesel is slightly worse due to higher emissions of certain compounds. Biodiesel production, however, demands significant water, affecting local potable water access, while diesel does not have notable impacts in this area. Neither fuel substantially affects ozone depletion, ionizing radiation, or ozone formation. Key impact categories for comparison are global warming, particulate matter, carcinogenic toxins, and water consumption.

3.3 Ecosystem Quality

As presented in figure 2, the diesel system caused greater harm to ecosystems through acid rain and ozone formation. However, jatropha cultivation led to land transformation and nutrient runoff, affecting biodiversity in freshwater systems.

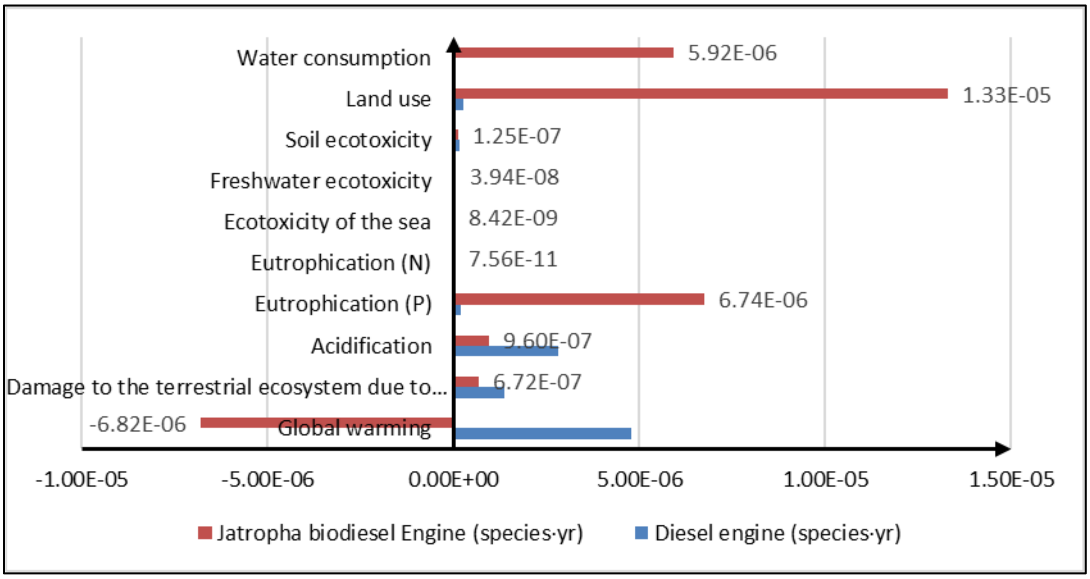

Figure 2 Comparison of impact on ecosystem quality

Figure 2 shows also that Jatropha biodiesel can reduce global warming and particulate pollution compared to diesel, but it uses more water and causes higher eutrophication due to fertilizer use. The key trade-off is between environmental benefits and increased resource consumption.

3.4 Resource Depletion

Diesel showed a significantly higher impact in fossil fuel depletion, as expected, while jatropha biodiesel had moderate contributions due to fossil fuel use in transportation and processing stages (Figure 3).

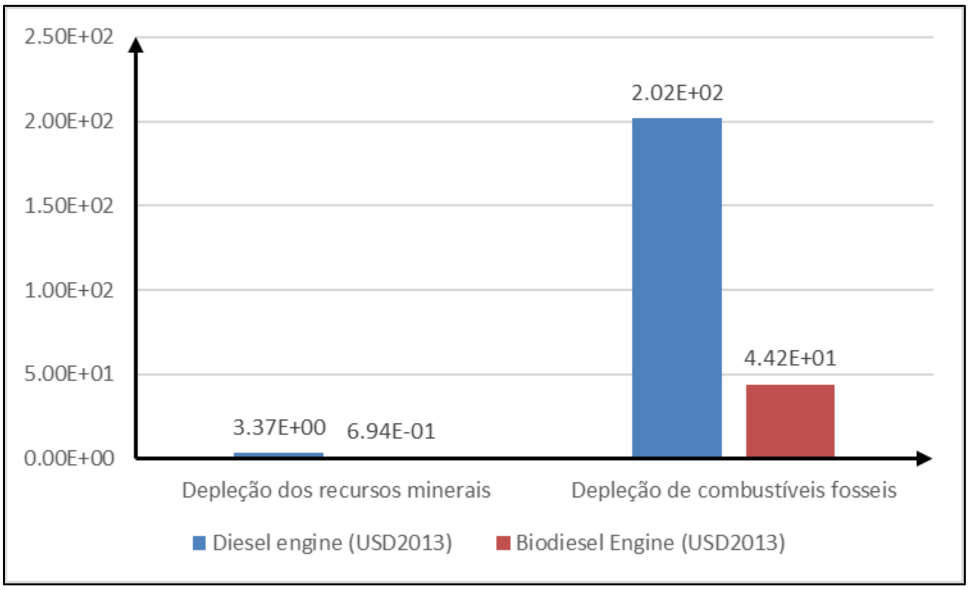

Figure 3 Comparison of impact of resource depletion

Figure 3 shows that fossil fuel depletion is significantly higher for the diesel engine (≈202 USD2013) compared to the biodiesel engine (≈44.2 USD2013), highlighting diesel's strong dependence on non-renewable resources. On the other hand, for mineral resource depletion, both systems present low values, but diesel is still higher (≈3.37 USD2013 versus 0.694 USD2013 for biodiesel). These results indicate that replacing diesel with jatropha biodiesel substantially reduces pressure on fossil fuels, although the impact on minerals remains relatively minor for both cases. In other hand, the mineral resource depletion was slightly higher for diesel due to refinery inputs, the finding was reached by Gmünder [17].

3.5 Overall Environmental Score

The overall results after normalization are presented in figure 4.

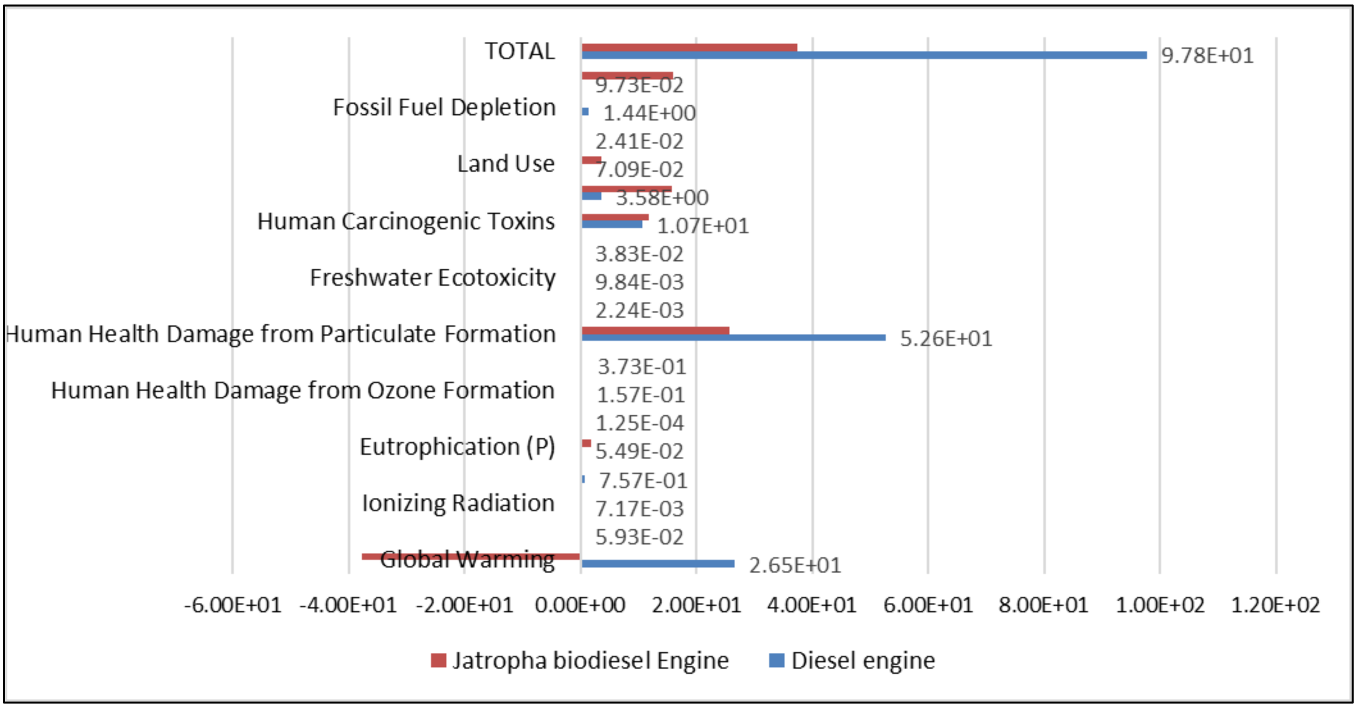

Figure 4 Overall Environmental Score

Picture 4 shows the comparison of the normalized and weighted environmental impacts of diesel engines and jatropha biodiesel engines across multiple categories. The most striking difference is in global warming, where jatropha biodiesel shows a negative value due to carbon sequestration during cultivation, while diesel exhibits a significant positive impact. This reinforces biodiesel's potential to mitigate climate change.

In contrast, water consumption and land use are considerably higher for biodiesel, reflecting the agricultural requirements of jatropha cultivation. Diesel, on the other hand, shows negligible impact in these categories. For human health damage from particulate formation, diesel is more than twice as harmful compared to biodiesel, indicating greater respiratory risk from fossil fuel combustion. Both fuels have similar values for carcinogenic toxins, though biodiesel is slightly higher for non-carcinogenic toxins.

When considering the Overall Environmental Score, diesel totals 92.47 points, while jatropha biodiesel scores 59.49 points, representing a 37% reduction in overall environmental impact when switching to biodiesel. This suggests that, despite trade-offs in water and land use, jatropha biodiesel offers significant environmental benefits, particularly in climate change mitigation and air quality improvement [19].

3.6 Economic Considerations

Considering the production efficiency of both fuels at 35%, the results of economic analysis are presented in Figure 5.

Figure 5 shows that Jatropha Biodiesel is more expensive and less energy-efficient than Diesel. Its higher cost (USD 2.03/L vs. USD 1.36/L), lower energy density (37 MJ/L vs. 43 MJ/L), and greater consumption for the same distance result in a higher overall cost. These disadvantages limit its competitiveness without policy support or technological improvements. It is observed that, despite its environmental benefits, jatropha biodiesel incurs a 42.7% higher cost per unit of useful energy relative to conventional diesel in concordance with approach of Raizen [20,21].

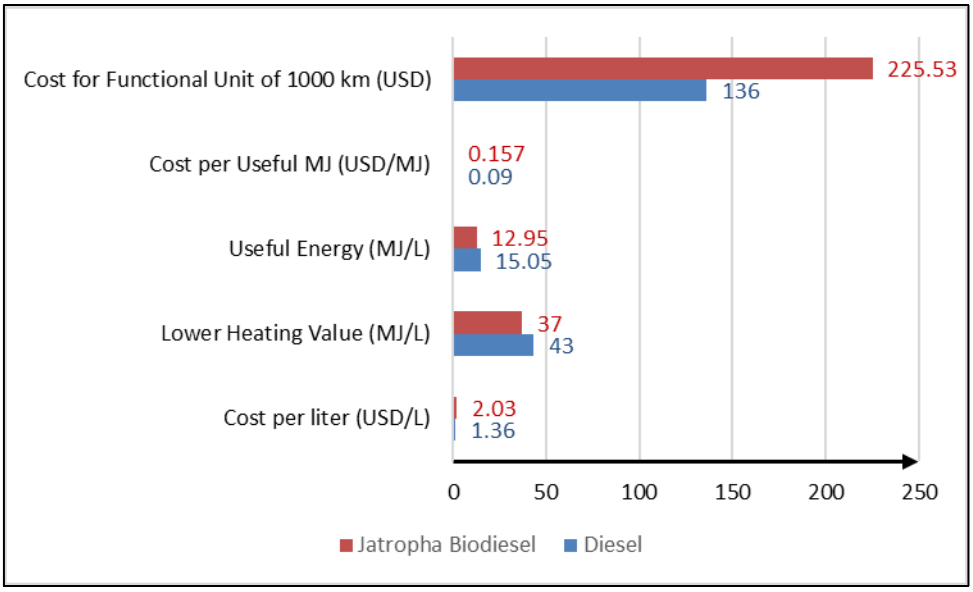

Figure 5 Overall economic analysis

4 Conclusion

The comparative Life Cycle Assessment demonstrates that Jatropha biodiesel reduces overall environmental impact by approximately 37% compared to conventional diesel, primarily due to its ability to achieve net negative CO_2 emissions through carbon sequestration during cultivation. It significantly lowers global warming potential, fossil fuel depletion, and particulate matter formation, contributing to climate change mitigation and improved air quality. However, these environmental benefits come with trade-offs: Jatropha biodiesel requires about 11% more fuel volume to cover the same distance (111.1 L vs. 100 L for 1,000 km), incurs 42.7% higher cost per unit of useful energy (USD 0.157/MJ vs. USD 0.09/MJ), and places greater pressure on land use and water resources due to agricultural requirements. Qualitatively, while diesel remains economically advantageous and energy-dense, Jatropha biodiesel offers a cleaner and more sustainable alternative, particularly in regions prioritizing low-carbon development and energy diversification.

Further studies should aim to reduce production costs and improve the energy efficiency of Jatropha biodiesel through advanced agronomic practices, integrated farming systems, and optimized transesterification processes. Research should also explore blending strategies with conventional diesel to balance economic and environmental performance, assess water resource management in biodiesel supply chains, and evaluate policy incentives that can enhance competitiveness. Additionally, socio-economic analyses focusing on rural development, job creation, and energy security will be critical to support large-scale adoption of Jatropha biodiesel in Mozambique and similar contexts.

References

[1] Achten WMJ, Maes WH, Verchot LV, Mathijs E, Muys B, Singh VP, et al. Life cycle assessment of Jatropha biodiesel as transport fuel. *Renewable and Sustainable Energy Reviews*. 2008;12(9):1067–1084.

[2] Ferreira G, Carvas R. *Análise comparativa do ciclo de vida do biodiesel obtido a partir do óleo dendê e etanol versus diesel de petróleo*. São Paulo: Escola Politécnica da Universidade de São Paulo; 2024.

[3] Heijungs R, Guinée JB, Huppes G, et al. Environmental Life Cycle Assessment of Products. In: *CML Report*. Leiden: Leiden University; 1992. p. 1–88.

[4] Knothe G. Biodiesel and renewable diesel: A comparison. *Progress in Energy and Combustion Science*. 2006;32(5–6):396–408.

[5] Krishnakumar R, et al. Biodiesel production from Jatropha oil and Castor oil by Transesterification reaction – Experimental and Kinetic studies. *International Journal of Chemical Technology*. 2013;5(2):45–52.

[6] Huijbregts MAJ, et al. ReCiPe 2016: A harmonized life cycle impact assessment method at midpoint and endpoint level. *RIVM Report*. 2016;2016-0104.

[7] Wani SP, Sreedevi TK, Rockström J, Sahrawat KL. Carbon sequestration and land rehabilitation through Jatropha curcas plantation in degraded lands. *Agriculture, Ecosystems & Environment*. 2012;161:112–120.

[8] Montesanti B, Carelli G. Life cycle assessment of food delivery packaging in Brazil. In: *Proceedings of the Brazilian LCA Conference*. Rio de Janeiro: UFRJ; 2021. p. 150–165.

[9] IPCC. *Climate Change 2022: Impacts, Adaptation and Vulnerability*. Geneva: Intergovernmental Panel on Climate Change; 2022.

[10] IIAM. Revisão sobre Jatropha curcas, seus usos e seu potencial para a produção em Moçambique. Maputo: Instituto de Investigação Agrária de Moçambique; s.d.

[11] Huijbregts, M. A. J., Steinmann, Z. J. N., Elshout, P. M. F., Stam, G., Verones, F., Vieira, M., ... & van Zelm, R. (2016). ReCiPe 2016: A harmonized life cycle impact assessment method at midpoint and endpoint level. *National Institute for Public Health and the Environment (RIVM)*. Retrieved from https://www.rivm.nl/publications/recipe-2016

[12] Köllner, T., Scholz, R. W., & Seidl, I. (2007). Ecological scarcity and biodiversity: Applying a new method for impact assessment in life cycle assessment. *Ecological Economics, 62*(2), 256–273. https://doi.org/10.1016/j.ecolecon.2006.06.015

[13] Petrobras. Óleo diesel – Informações Técnicas. Rio de Janeiro: Petrobras; 2024.

[14] Silva L. Processos de produção de biodiesel e análise de parâmetros de qualidade [Master's thesis]. Bragança: Instituto Politécnico de Bragança; 2014.

[15] Vianna F. Análise de ecoeficiência: Avaliação do desempenho económico-ambiental do biodiesel e petrodiesel [Master's thesis]. São Paulo: Universidade de São Paulo; 2006.

[16] Foidl N, et al. Jatropha curcas L. as a source for the production of biofuel in Mozambique: sustainability aspects and technological requirements. *FUNAE Technical Report*. Maputo: Fundo Nacional de Energia; 2011.

[17] Gmünder SM, Zah R, Bhatacharjee S, Classen M, Mukherjee P, Widmer R. Life cycle assessment of village electrification based on straight jatropha oil in Chhattisgarh, India. *Biomass and Bioenergy*. 2010;34(3):347–355.

[18] Energy Institute. BP Statistical Review. London: Energy Institute; 2023. Available from: https://www.energyinst.org/statistical-review/about

[19] CIP – Centro de Integridade Pública. Aumento do preço de combustíveis. Maputo: CIP; 2022. Available from: https://www.cipmoz.org/en/2022/03/22/aumento-do-preco-de-combustiveis

[20] Raízen's Sustainability and Corporate Communication Teams. Biofuel: after all, what are their advantages? São Paulo: Raízen; 2021. Available from: https://www.raizen.com.br/blog/biocombustiveis

[21] Chichango F. Análise de emissões de co2 na produção e utilização do biodiesel de óleo de coco em maganja da costa–Moçambique. 2021. Universidade Brasília e Universidade Zambeze. 2014;1-34; DOI: 10.13140/RG.2.2.19169.72803.