IMPLEMENTING BIOENERRGY SOLUTIONS AMIDST GEOPOLITICAL INSTABILITY: A CASE STUDY OF SRI LANKA

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Abstract

This paper analyzes the 2026 fuel crisis in Sri Lanka as a case of energy vulnerability driven by dependence on imported fossil fuels and geopolitical instability. The study aims to evaluate the potential of biotechnology-based energy solutions in strengthening national energy resilience. The methodology is based on qualitative analysis of recent data, literature, and case-specific energy measures implemented during the crisis. The results highlight that decentralized bioenergy systems, such as biogas production, biomass valorization, and algae-based fuels, can partially substitute conventional fuels using locally available resources. However, technological and economic limitations restrict large-scale implementation in the short term. The study concludes that integrating bioenergy into national strategies offers a realistic pathway toward reducing external dependence, while its originality lies in linking geopolitical risk with biotechnology-driven energy solutions in the Sri Lankan context.

Key words: *Bioenergy, Sri Lanka, Energy Crisis, Biotechnology, Sustainability*

INTRODUCTION

Energy plays a fundamental role in sustaining modern societies, supporting activities ranging from transportation systems to household consumption. In the case of Sri Lanka, the heavy dependence on imported fossil fuels creates a structural vulnerability to external disruptions. In March 2026, escalating geopolitical tensions led to significant disturbances in global oil supply chains, triggering a severe fuel crisis in the country. As an immediate response, the government introduced emergency measures, including the implementation of a four-day working week to reduce national fuel consumption. This situation highlighted the fragility of energy systems that rely predominantly on external resources.

In recent years, Sri Lanka's energy crisis has been further intensified by economic instability, declining foreign currency reserves, and increasing global fuel prices. Due to the lack of domestic oil and gas resources, the country relies almost entirely on imports, which has resulted in fuel shortages, long queues at filling stations, power outages, and disruptions across transport, industry, and daily life. These challenges have not only affected economic productivity but have also amplified social vulnerabilities, emphasizing the risks associated with fossil fuel dependency [1].

The 2026 crisis was also influenced by instability in key global oil transport routes, particularly the Strait of Hormuz, through which a significant share of the world's oil supply passes. Any disruption in this strategic chokepoint led to delays in fuel shipments and a sharp increase in global oil prices, exceeding 120 USD per barrel. For Sri Lanka, this meant that even when

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financial resources were available, physical access to fuel remained uncertain, further exacerbating the crisis [1].

Under these conditions, the need for sustainable and locally available energy alternatives becomes increasingly urgent. Biotechnology offers promising solutions by enabling the production of renewable energy sources such as biogas, bioethanol, and biodiesel from organic waste, agricultural residues, and algal biomass [2,3]. These resources are widely available in Sri Lanka, making bioenergy a viable option for reducing dependence on imported fuels while also improving waste management and environmental sustainability [4].

Therefore, integrating biotechnology-based energy solutions into national strategies could contribute to the development of more resilient, decentralized, and sustainable energy systems. Although these approaches cannot fully replace fossil fuels in the short term, they provide practical pathways for enhancing energy security and reducing exposure to global market fluctuations.

MATERIAL AND METHOD

This study is based on a qualitative research approach aimed at analyzing the 2026 fuel crisis in Sri Lanka and evaluating the potential of biotechnology-based energy solutions. The research methodology involves a comprehensive review and synthesis of secondary data obtained from scientific literature, institutional reports, and recent case-specific analyses related to energy systems, bioenergy technologies, and crisis response measures [3, 5, 6].

The materials used in this study include published articles on biofuels and environmental biotechnology, reports on Sri Lanka's energy sector, and data concerning biomass availability and waste management practices [4,7]. Particular attention was given to sources addressing anaerobic digestion, lignocellulosic biofuels, and microalgae-based energy production, as well as their applicability within the local context [5,8].

The method consists of a contextual and comparative analysis, focusing on the relationship between geopolitical instability, fossil fuel dependency, and the feasibility of alternative energy systems. In addition, a case study framework was applied to examine Sri Lanka's specific conditions, including resource availability, economic constraints, and policy responses implemented during the crisis [1,9].

Furthermore, a descriptive evaluation of different bioenergy pathways was conducted, taking into account technical feasibility, resource potential, and scalability under current national conditions. This approach allowed the identification of both short-term and long-term solutions, as well as the development of a structured roadmap for integrating biotechnology into the national energy strategy.

RESULTS

The analysis of the 2026 fuel crisis in Sri Lanka highlights a structurally embedded vulnerability resulting from the country's near-total dependence on imported fossil fuels. Petroleum imports account for a major share of national energy consumption and require annual expenditures exceeding USD 3.8–4.0 billion, placing continuous pressure on foreign exchange reserves [1,9].. During the crisis, the combined effects of global supply disruptions and domestic financial constraints led to severe shortages, price increases, and significant socio-economic impacts.

The results indicate that diesel plays a critical role in maintaining essential sectors, including transportation, agriculture, and electricity generation, while household dependence on LPG and kerosene further extends energy vulnerability. Emergency measures such as fuel rationing, price adjustments, and the implementation of a four-day working week reduced consumption but also generated economic

and social disruptions, including reduced productivity, increased transport costs, and limited mobility.

From an environmental perspective, the crisis produced mixed effects. On one hand, reduced traffic contributed to temporary improvements in urban air quality. On the other hand, increased reliance on firewood due to rising fuel prices raised concerns regarding deforestation and indoor air pollution, highlighting the complex trade-offs associated with energy shortages.

The evaluation of biotechnology-based energy solutions reveals that Sri Lanka possesses significant potential for bioenergy production due to its diverse biomass resources, including agricultural residues, organic waste, and aquatic biomass [4]. Among the analyzed options, anaerobic digestion systems for biogas production emerge as one of the most immediately applicable solutions, offering the possibility to convert municipal and agricultural waste into usable energy while reducing environmental pollution [1,7].

Lignocellulosic biofuels derived from residues such as rice straw, coconut waste, and sugarcane bagasse present additional opportunities; however, only a limited proportion of these resources can be sustainably utilized without affecting soil quality and existing agricultural cycles [4, 5]. Similarly, microalgae-based biofuels offer high productivity and environmental benefits, but their large-scale implementation remains constrained by technological and economic challenges [8].

Overall, the findings suggest that while advanced bioenergy technologies have strong long-term potential, their immediate contribution is limited. In contrast, decentralized and waste-based bioenergy systems provide more feasible short-term solutions. The integration of such technologies into national energy strategies could reduce dependence on imported fuels, improve waste management, and enhance energy resilience. However, successful implementation requires supportive policies, investment, and alignment between the energy, agricultural, and environmental sectors.

CONCLUSIONS

The 2026 fuel crisis in Sri Lanka clearly demonstrated the structural vulnerability of an energy system highly dependent on imported fossil fuels and exposed to geopolitical instability. The combined effects of global supply disruptions and domestic economic constraints emphasized the urgent need for alternative, locally available energy solutions [1,9].

The analysis shows that biotechnology-based approaches can play a significant role in improving energy resilience. Solutions such as anaerobic digestion, biomass valorization, and algae-based fuels offer viable pathways for converting locally available resources into energy while contributing to environmental sustainability and waste management [4,7,8]. However, their implementation is limited by technical, economic, and infrastructural challenges, particularly in the context of large-scale deployment.

The findings suggest that short-term strategies should prioritize decentralized and waste-based bioenergy systems, which are more feasible under current national conditions. At the same time, long-term development should focus on advanced biotechnological solutions and integrated biorefinery systems capable of producing multiple outputs, including biofuels, biofertilizers, and biochemicals, thereby increasing economic viability and system resilience [11,12].

Ultimately, achieving energy security in Sri Lanka requires a coordinated approach that combines technological innovation with supportive policy frameworks, financial mechanisms, and cross-sectoral integration [9,10]. The transition toward bioenergy represents not only a response to the current crisis but also a strategic

opportunity to build a more sustainable and resilient energy system.

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