



EVALUATING RENEWABLE DIESEL: ENVIRONMENTAL BENEFITS, ECONOMIC CHALLENGES, AND PATHWAYS FOR GLOBAL ADOPTION

Abstract

Renewable diesel is increasingly more prominent as a strategic fuel for cleaner heavy-duty transport, driven by its chemical similarity to petroleum diesel giving it full compatibility with existing infrastructure. Its recent growth has been shaped by three interdependent factors: advances in hydroprocessing technology, diversification of feedstocks, and policy incentives that favor low carbon fuels. On the other hand, renewable diesel's environmental performance varies greatly, as it is dependent on feedstock availability, land-use, and carbon intensity of hydrogen in the refining process. This paper provides a technical assessment of renewable diesel's production process, feedstock dynamics, regulatory drivers, and environmental implications.

Introduction

Carbon-based fuels have been widely used since the Industrial Revolution, which occurred almost 200 years ago. These fuels were a massive innovation at the time, changing the economic implication of society. However these carbon based fuels proved to be detrimental to the environment, leading to a call for newer forms of energy in the mid 1900's. Now more than ever the decarbonization of transport and productions is one of the greatest technical and policy challenges of the energy problem. While electric means of energy can be sufficient in lighter duty situations like such as automobiles, heavier duty technologies such as airplanes and cargo ships require sufficient liquid fuel with drop-in compatibility (a synthetic fuel's ability to be used interchangeably with its petroleum-based counterpart) [1]. Renewable Diesel has gained traction as a viable solution due to its chemical equivalence to petroleum diesel, a high cetane number of around 80 (which allows for better ignition and smoother startup [1]), and compatibility with existing technology and infrastructure (due to its similarity with petroleum diesel).

Over the last three years, rapid investment and policy support have transformed renewable diesel from a niche product into a central component of national low-carbon fuel strategies. In the United States, California's Low Carbon Fuel Standard and the Renewable Fuel Standard have driven surging demand, which aims to have a 20% reduction of carbon intensity from a 2010 baseline [2]. Figure 1 displays a graph of the current Carbon Intensity reduction and the target Carbon Intensity reduction in the future [2]. However, the rapid expansion of renewable diesel also raises important questions about its long-term

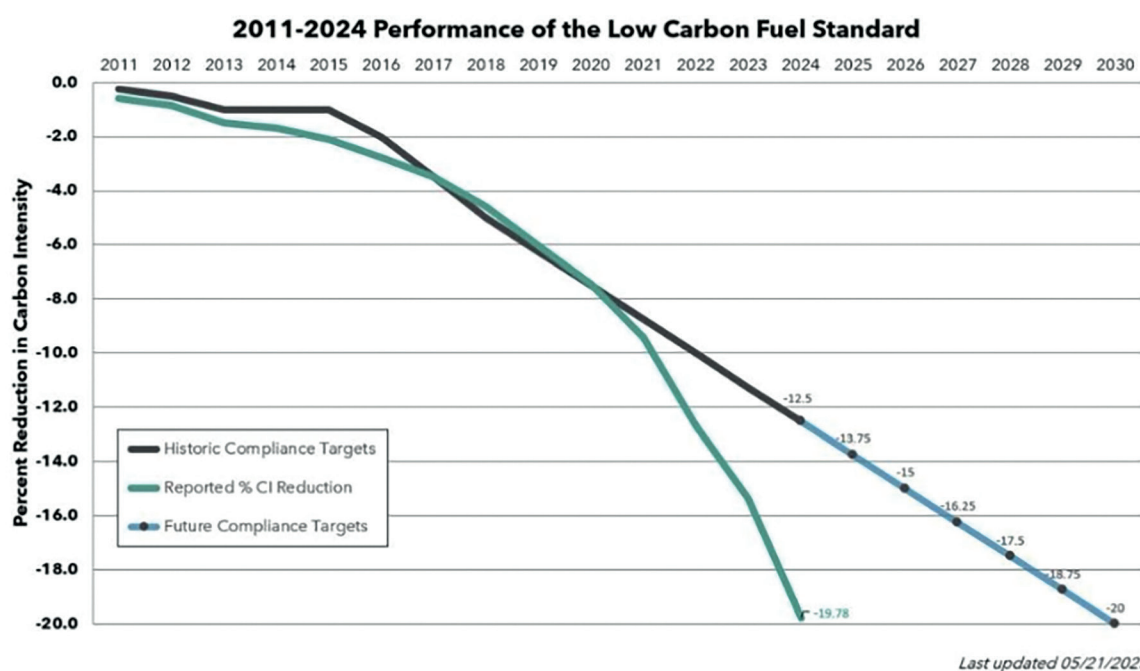


Figure 1: California's goal carbon intensity reduction vs reported carbon intensity reduction [2]

role in the energy transition. While it offers clear benefits in reducing emissions compared to petroleum diesel, the scale of these benefits depends heavily on how the fuel is produced and what materials are used. Renewable diesel made from waste oils or residues can deliver significant environmental gains, while production based on crops like palm or soybean oil may create new concerns around land use, deforestation, and agricultural pressures. In addition, the refining process requires large amounts of hydrogen, which is often produced from fossil sources, limiting the overall climate advantage. These factors show that renewable diesel is both a promising solution for reducing emissions in the near term and a fuel whose broader sustainability will depend on continued innovation, careful policy design, and responsible feedstock management.

Renewable Diesel Production

Renewable diesel is made using a process called hydrotreating, which takes oils and fats from sources like used cooking oil,

animal fats, and vegetable oils, and turns them into a fuel that works just like petroleum diesel [3]. This makes it especially appealing for industries like trucking, shipping, and aviation that need drop-in fuels without modifying equipment [3]. By being compatible with existing equipment, it would make renewable diesel more economically lucrative than other alternative energy options. Renewable diesel becomes even more lucrative when you pair this with a high cetane number, making it burn more efficiently and cleanly in engines [1]. As a result, it helps reduce harmful emissions like particulate matter and nitrogen oxides, while also cutting down on greenhouse gas emissions compared to fossil fuels [3].

Despite these benefits, renewable diesel also comes with significant trade-offs. One major challenge is the limited availability of feedstocks [4]. Used cooking oil and animal fats are helpful, but the demand for renewable diesel is growing much faster than these supplies. This has led to increased reliance on vegetable oils like soybean or palm oil, which raises concerns about deforestation, land use change, and food versus fuel [4]. The EU

has labeled palm and soy oil feedstocks as high deforestation risks [4]. Since renewable diesel relies on both these sources, increasing renewable diesel output could heighten deforestation, which ends up causing another problem in order to fix the original one [4]. The production process is also more expensive than traditional diesel (due to the complex processing), which can make renewable diesel less competitive if government subsidies or incentives were to decline or be eradicated altogether. On top of that, scaling up renewable diesel on a global level could strain agricultural systems and limit its role as a sustainable solution if not managed carefully [4]. Since renewable diesel involves burning food, it could lead to increased food prices and even lead to shortages. Especially since there are certain areas in the world that are suffering from overpopulation, decreasing the agricultural output, leading to a high risk of proliferation in famine in those areas (South Asia, Western Africa for example), increasing the renewable diesel output will most likely [4]. As a result, the production and distribution process of renewable diesel has significant benefits and drawbacks that complicate its viability.

Environmental Impacts

Renewable diesel has been shown to significantly reduce greenhouse gas emissions compared to traditional petroleum diesel. Data from the California Air Resources Board indicate that renewable diesel reduces carbon intensity on average by 65% [5] compared to traditional petroleum diesel (numbers vary based on the feedstock used). As a result, fuels derived from these feedstocks generally have a low carbon intensity score, meaning that they create far fewer emissions per unit of energy produced. Renewable diesel also has a higher cetane number, often between 70 and 90 compared to about 40 to 55 for petroleum diesel [1]. A higher cetane number allows for more cleaner startups, and leads to less emissions and pollutants [1]. These improvements make renewable diesel especially valuable in urban areas where air quality is a concern, as well as in sectors where decarbonizing can be difficult like in trucking and aviation.

Despite the advantages, renewable diesel could also pose environmental challenges. For instance in the EU, analysis by the non profit group Transport Environment suggests that by increasing renewable diesel usage, it increases the reliance on unsustainable feedstocks that are needed to produce the renewable diesel. These feedstocks, like palm and soy, actually would end up increasing emissions because of indirect land use [4]. Indirect land use occurs when land set for agricultural production is used for biofuel (like renewable diesel) production instead. These two feedstocks are linked to widespread deforestation and loss of biodiversity, which would obviously be environmentally detrimental, since previously flourishing areas of land could be at risk if they end up being used to produce feedstocks. This environmental challenge is a massive trade off of an otherwise very clean and safe fuel. Renewable diesel as a result will need to be implemented with a more cautious hand in order to maximize the environmental benefits.

Global Adoption and Policy

Renewable diesel production has expanded rapidly in the last five years, with major capacity growth in North America, Europe, and parts of Asia. The United States has become one of the largest markets due to state-level policies like California's Low Carbon Fuel Standard [5] and federal incentives under the Renewable Fuel Standard. Refineries operated by Marathon Petroleum, Valero, and Phillips 66 have converted existing petroleum facilities into renewable diesel plants, signaling a shift in industrial investment. In Europe, companies such as Neste in Finland [6] and TotalEnergies in France have led production growth [7], supported by EU climate policies. In Asia, Singapore has emerged as a hub through Neste's large production site, and interest is increasing in Japan and South Korea as they look to decarbonize transport fuels [6]. These trends show that renewable diesel is not confined to one region but is part of a broader global energy transition. With this great global backup, renewable diesel has a great opportunity to evolve and flourish as a low-carbon alternative.

The rapid expansion of renewable diesel relies on strong government policy frameworks. California's Low Carbon Fuel Standard (LCFS) has been the biggest driver in the U.S. The LCFS essentially creates a credit trading system where fuel providers can earn credits based on the carbon intensity of their fuel. Fuels with lower intensities earn credits, whilst fuels with higher densities would generate credit deficits that would need to be paid off [8]. This allows renewable diesel to become economically competitive with the existing fuels such as petroleum, even if production costs are more expensive. At the federal level, the Renewable Fuel Standard (RFS) forces refiners to blend renewable fuels (ethanol, renewable diesel, etc), into their supply [9]. This obligation promotes the use of renewable diesel in the economy, allowing it to become viable in society. The crucial feature of these two policies in the United States, is they create guaranteed long term demand. This would reduce the risk for possible investors and encourage large oil corporations to invest millions and even

billions of dollars in renewable diesel facilities, allowing renewable diesel to become a viable energy source. Without these crucial policies, renewable diesel would likely remain a smaller-scale solution, not being able to catch up to the established and larger traditional diesel market.

Economic and Market Outlook

The economics of renewable diesel are strongly shaped by its ability to leverage existing petroleum infrastructure while benefiting from policy incentives. Since renewable diesel is chemically similar to petroleum diesel it can be "dropped in" to pipelines, refineries, and engines without much modifications, which isn't the case for other biofuels (like ethanol). This compatibility reduces costs typically associated with transitioning to low-carbon fuels and allows refiners to scale production more efficiently. At the same time, renewable diesel markets are cushioned by generous policy frameworks like California's LCFS which provide credits to producers and create additional revenue streams, further boosting the economic viability. These advantages make renewable diesel competitive against petroleum diesel, even when feedstock costs fluctuate. However, the economics of renewable diesel are sensitive to input prices [4]. If a demand for vegetable oils, animal fats, and used cooking oils rise, feedstock costs can rise sharply, which could reduce profit margins for renewable diesel. This feedstock price issue is a major constraint, and it raises questions about long-term economic stability of renewable diesel. However, if governments could keep decarbonization programs like the LCFS and if feedstock supplies can become economically secure, renewable diesel could become a cornerstone in the low-carbon fuels market.

Conclusion

Renewable diesel has rapidly emerged as one of the most promising low-carbon liquid fuels. Its compatibility with existing infrastructure, high cetane number, and ability to utilize diverse feedstocks make it more versatile than other low-carbon liquid options. At the same time, global adoption is accelerating as governments use subsidies, tax credits, and blending mandates to stimulate investment, particularly in North America and Europe. These policies have driven impressive production growth and positioned renewable diesel as a key tool in decarbonizing transportation, especially for heavy-duty sectors where electrification is less practical.

Yet, renewable diesel's trajectory is not without complications. Its high reliance on subsidies highlights an ongoing tension between policy incentives and true market competitiveness, raising questions about long-term viability if government support wanes. The environmental benefits also hinge on sustainable feedstock sourcing, since large-scale reliance on crops like soybean oil risks land-use change and indirect emissions that erode its climate advantage. Moreover, expansion creates volatility in global feedstock markets, tying renewable diesel's future to larger agricultural and commodity dynamics.

Renewable diesel represents a technically mature and strategically valuable option for reducing carbon emissions in

raising concerns about economic sustainability if political views shift. Without these policy incentives, renewable diesel wouldn't be viable enough to compete with regular carbon-based fuels like petroleum. Feedstock availability is another major gap, as current reliance on vegetable oils risks creating competition with food markets and exacerbating indirect land-use emissions. Advances in waste-based and algae-derived feedstocks could mitigate this constraint, but these pathways are not yet developed enough to scale with renewable diesel. Looking ahead, renewable diesel is likely to serve as a transitional fuel in the global energy system, bridging the gap until electric and hydrogen based energy could be reliable enough in large scale operations like aviation and heavy trucking, which would then take its place. Renewable diesel's future outlook will depend on technological innovation, broader diversification of feedstocks, and carefully designed policies that balance growth with sustainability.

Sources

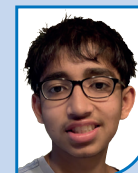
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