HVO'S IMPACT ON OIL COMPANIES' STRATEGIES: EXAMINING ENERGY SECTOR FINANCIAL PERFORMANCE, SUSTAINABILITY, AND REGULATORY PRESSURE

ABSTRACT

The purpose of this study is to advance knowledge of how HVO affects oil firms' tactics, as they have been investing more in biofuels to lessen their reliance on fossil fuels. Since HVO is a biofuel that has the potential to replace traditional diesel and is in line with the energy transition's goals as well as the EU's, this topic is especially pertinent. The research's methodology is a quantitative study that uses secondary data from financial databases and European legislation in a descriptive and explanatory approach.

This study aims to address the following research issues in light of the context: Does regulatory pressure affect investment in HVO? Is there a significant difference between the profitability of companies that invest and do not invest in HVO? Do companies with better ESG performance invest more in HVO? Is investment in HVO associated with a higher market valuation?

The inclusion of HVO as the primary variable for financial analysis, which has not received much attention in the literature, is what makes this study unique. The results demonstrated that investment in HVO is associated with companies with better ESG performance, higher market capitalization, and greater regulation of biodiesel. On the other hand, investment in HVO is also associated with lower corporate profitability (ROA), possibly explained by the high costs of entry and technological transition.

Based on the analysis of the results of this study, it will serve as a basis for future research and should be taken into consideration by managers and policymakers when making strategic decisions regarding energy transition policies and the adoption of alternative fuel sources, especially in the transport sector.

Keywords: HVO; Sustainable Investment; Corporate Financial Performance; ESG Metrics; Regulatory Pressure.

1 - INTRODUCTION

Hydrotreated Vegetable Oil (HVO) is a renewable and sustainable biofuel derived from vegetable oils and animal fats. It has gained increasing attention due to its ability to replace conventional diesel in engines without requiring vehicle modifications (Nylund et al., 2008). Its production has been driven by environmental regulations and decarbonization targets, particularly in the transportation and energy sectors. The European Union has played a key role in promoting HVO through energy transition policies and incentives for low-emission fuels (Souza et al., 2017). As a renewable fuel, HVO is often seen as a viable alternative to fossil diesel and can be used in both light- and heavy-duty vehicles (Dimitriadis et al., 2018).

Despite its promising potential, the introduction of HVO into the markets presents both opportunities and challenges for oil companies and end-users (Hor et al., 2023). The diversity of feedstocks used in HVO production including vegetable oils, used cooking oil (UCO), and animal waste, raises important questions about sustainability, traceability, and supply chain management (Ambat et al., 2018). Moreover, the environmental impact of HVO is highly dependent on the type of raw materials used, with waste-based inputs like pine oil being more sustainable than purpose-grown crops such as palm oil (Becker et al., 2017). These complexities highlight the need for a deeper understanding of how HVO affects corporate strategies and sustainability performance.

This study seeks to address a gap in the literature by examining the strategic and financial implications of HVO adoption for energy companies operating in Europe. Specifically, it investigates four interrelated research questions:

Does regulatory pressure affect investment in HVO? What is the effect of ESG performance on HVO investment? Is investment in HVO associated with a higher market valuation? Are there differences in profitability between companies with and without HVO?

The study adds to the larger conversation on energy transition and the function of alternative fuels in accomplishing climate goals by tackling these issues. It investigates the connection between company financial performance and Environmental, Social, and Governance (ESG) outcomes as well as HVO integration. Additionally, it examines the influence of public policy instruments such as tax incentives and emissions reduction targets - on the development of the HVO market.

Policymakers, energy firms, and sustainability campaigners can all benefit from the findings. They offer empirical support for the strategic ramifications of adopting HVO, emphasizing the interaction of regulatory frameworks, financial performance, and ESG measures. The study also clarifies the difficulties in guaranteeing long-term environmental viability and the significance of acquiring feedstocks sustainably. Stakeholders looking to promote innovation in the renewable fuels industry and match corporate practices with climate goals will find these contributions especially pertinent.

The remainder of this paper is organized as follows. Section 2 presents a literature review covering key concepts related to HVO, including its production processes, economic feasibility, financial performance, environmental impact, and the role of regulations in its adoption. Section 3 outlines the research methodology, detailing the exploratory and descriptive approach as well as the use of secondary data sources. Section 4 analyzes the results obtained from the developed models. Finally, Section 5 discusses the findings in relation to existing literature, explores implications for oil companies and the energy sector, and concludes with recommendations for future research.

2 – THEORETICAL BACKGROUND

2.1 Biofuels as a Sustainable Alternative

Biofuels have garnered significant global attention as viable alternatives to conventional fossil fuels, offering the potential to enhance energy security and reduce greenhouse gas emissions (Sydney et al., 2019). Their relevance has grown in parallel with the increasing number of diesel-powered vehicles and the associated emissions, highlighting the urgent need for cleaner transportation solutions and the development of alternative fuel technologies (Soam & Hillman, 2019).

Based on the kind of feedstock and the production technology employed, biofuels are generally divided into three generations. Food crops like corn and soybeans are the source of first-generation biofuels like ethanol and biodiesel. These fuels have been criticized for competing with the food supply chain and raising ethical and economic concerns (Zhang et al., 2007). Second-generation biofuels, which include Hydrotreated Vegetable Oil (HVO), utilize non-food feedstocks such as agricultural residues and animal fats, thereby reducing environmental impact and dependence on food-based resources (Brennan & Owende, 2010). Third-generation biofuels are produced from algae and offer high production potential, although they remain economically unfeasible due to high production costs (Brennan & Owende, 2010).

Among these, second-generation biofuels like HVO have emerged as promising solutions for the transportation sector, providing a feasible alternative to fossil diesel and contributing to global decarbonization goals (Ambat et al., 2018). The literature suggests that liquid biofuels, particularly those derived from waste materials and produced using mature technologies, can reduce carbon dioxide (CO_2) emissions by up to 80% compared to fossil fuels (Bouter et al., 2024).

Nevertheless, the large-scale deployment of biofuels faces several critical challenges. These include high production costs, supply chain limitations, and the need for robust public policies to support commercialization and market integration (Hor et al., 2023). In order to fully utilize biofuels in the shift to a low-carbon economy, several obstacles must be removed.

2.2 HVO as a Sustainable Alternative

HVO stands out among biofuels due to its compatibility with conventional diesel engines, requiring no modifications for its use (Sugiyama et al., 2011). This characteristic, combined with its seamless integration into existing fuel distribution infrastructure, makes HVO a practical and easily implementable solution (Dimitriadis et al., 2018).

According to Sondors et al. (2021), HVO offers significant environmental advantages over traditional diesel, including reductions of 44% in unburned hydrocarbons, 13.3% in sulfur dioxide (SO_2), 5% in nitrogen oxides (NO_x), and 3.8% in carbon dioxide (CO_2) emissions. These improvements contribute to a lower environmental footprint and support broader decarbonization efforts.

Despite its strong environmental performance and operational benefits, large-scale adoption of HVO remains constrained by high production costs (Sondors et al., 2021). Nevertheless, its ability to be used in existing diesel vehicles, coupled with its positive environmental impact, positions HVO as a promising alternative fuel for the transportation sector (Sugiyama et al., 2011).

2.3 Regulatory pressures

According to Kolk and Pinkse (2008), corporate responses to the energy transition are shaped by normative pressures that vary across countries and organizations, resulting in differing levels of managerial commitment to renewable energy adoption.

Socially acceptable norms and beliefs that impact business activities are referred to as normative pressures. These reflect societal concerns regarding environmental protection, clean air, and the use of sustainable energy sources, as well as growing interest in renewable alternatives (Dulal et al., 2013). Political initiatives, in turn, represent the priorities of local policymakers and the commitments made by political parties to their constituents. When aligned with environmental targets, such initiatives can motivate organizations to align their strategies with societal sustainability goals, thereby encouraging oil and gas companies to invest in renewable energy sources (Boersma & Johnson, 2012).

The European Renewable Energy Directive (RED III) exemplifies such regulatory pressure by imposing increasingly stringent obligations on member states regarding renewable energy use in the transport sector. It mandates either a 29% share of renewable energy in transport by 2030 or a 14.5% reduction in fuel emission intensity (Ilves et al., 2024). This directive supports the phase-out of conventional fossil fuels and strongly promotes the adoption of advanced biofuels, including waste-derived biodiesel, cellulosic ethanol, and renewable fuels such as HVO, which is considered strategic for achieving the European Union's climate goals (European Commission, 2023; Ilves et al., 2024).

With specific targets for the transport sector and industrial decarbonization, RED III compels both governments and companies to accelerate the development and adoption of alternative fuels, including plant-based options (Chao et al., 2025; Gurreck, 2025). Products like HVO are thus positioned not only as environmentally strategic solutions but also as responses to growing social and political demands for cleaner energy sources (Feng et al., 2025).

In this context, regulatory instruments such as RED III play a critical role. These legal frameworks not only drive investment in biofuels but also influence key financial indicators, including market capitalization and ESG performance scores (D'Amato et al., 2024a; Gonçalves et al., 2022).

2.4 Country Specific Advantages

The concept of Country-Specific Advantages (CSAs) encompasses institutional factors and national characteristics that create favorable conditions for certain firms (Aguilera & Grøgaard, 2019). According to Hartmann et al. (2021), normative social pressure for environmental performance plays a critical role in shaping the commitment of oil and gas companies to the energy transition. Firms headquartered in countries with strong environmental normative pressures tend to enjoy a competitive advantage over those based in countries with weaker pressures. In this context, social norms can be considered a form of CSA for companies seeking to increase their investments in renewable energy. Moreover, organizations often adapt their practices in response to normative expectations in order to enhance their competitive positioning in environmentally demanding markets (Delmas & Toffel, 2008). This strategic alignment with societal values not only supports environmental objectives but also reinforces firms' legitimacy and long-term viability in the context of the global energy transition.

2.5 Economic viability of the HVO

According to Hor et al. (2023), the economic feasibility of producing HVO from waste feedstocks, specifically sludge palm oil (SPO), demonstrated a return on investment of 89.03% and a payback period of 1.68 years, confirming the competitiveness of this production pathway. Residual feedstocks significantly reduce operational costs, thereby enhancing the overall sustainability of the process (Phichitsurathaworn et al., 2021).
However, while technologies such as hydrogen recycling can further improve process efficiency, they also contribute to higher initial capital expenditures (Kantama et al., 2015). In this context, the implementation of fiscal incentives and government subsidies plays a crucial role in offsetting these costs. As noted by Becker et al. (2017), such policy instruments are essential to enabling the large-scale expansion of HVO production and encouraging the use of more sustainable raw materials.

2.6 HVO Market Price

Market price plays a critical role in determining the economic viability of biofuels such as Hydrotreated Vegetable Oil (HVO), primarily due to its direct influence on competitiveness relative to fossil fuels (Campbell et al., 2018). A key variable affecting the financial performance of renewable fuel projects is price volatility, which introduces uncertainty for both producers and investors (Campbell et al., 2018). The ability of market prices to cover production costs is particularly crucial in contexts where feedstock and advanced technology costs are high (Phichitsurathaworn et al., 2021).

Specifically, HVO production faces significant challenges in balancing elevated production costs with consumer price expectations, underscoring the importance of supply chain efficiency and the implementation of supportive government incentives (Campbell et al., 2018). Market price stability, when combined with regulatory frameworks, is essential for fostering a favorable environment for HVO market growth, facilitating the energy transition, and reducing dependence on fossil fuels (Ambat et al., 2018).

To achieve such stability, coordinated efforts between governments and industry stakeholders are required. This includes the development and implementation of policies aimed at minimizing risks associated with market volatility and promoting robust financial incentives (Becker et al., 2017).

2.7 Economic and financial indicators in business valuation

Financial and economic indicators are widely used to assess corporate performance, offering detailed insights into operational efficiency, value creation, and firms' adaptability to competitive environments (Gjerrild & Ditlevsen, 2023). Among these, EBITDA (Earnings Before Interest, Taxes, Depreciation, and Amortization) is one of the most prominent metrics, followed by EBIT (Earnings Before Interest and Taxes), Tobin's Q, total assets, and revenue. These indicators provide a comprehensive understanding of both financial performance and the scale and productivity of firms (Bachtijeva et al., 2024; Dybvig et al., 2013).

In a rapidly evolving market such as the fuel industry, evaluating operational performance requires more than analyzing net profits. EBITDA and EBIT serve as key operational metrics that assess the profitability of core business activities, independent of tax and financing structures (Gjerrild & Ditlevsen, 2023). These indicators are particularly relevant in the biofuels sector, where they help measure competitiveness and operational efficiency (Badawi et al., 2022). In the context of the energy transition, EBITDA is often used to capture the early effects of adopting green technologies, such as HVO, whose operational costs may not yet be reflected in net income (Gjerrild & Ditlevsen, 2023). Firms investing in alternative solutions may benefit from contractual EBITDA adjustments, known as addbacks, which exclude expenses related to ecological restructuring and are often valued by investors (Badawi et al., 2022).

Therefore, incorporating EBITDA into the analysis of HVO adoption enables a more accurate assessment of operational effectiveness, free from short-term accounting distortions (Fernández, 2001).

Return on Assets (ROA) is globally recognized as a central metric of corporate profitability, measuring how efficiently a firm utilizes its assets to generate operating income (Lewandowski, 2017). It captures both short and long-term financial performance and is frequently used as a control variable in studies on sustainability and corporate performance (Gonçalves et al., 2023). ROA is influenced by internal factors such as capital structure, liquidity, and revenue growth, reflecting a firm's operational capacity (Fareed et al., 2016). In emerging markets, the relationship between liquidity and ROA is particularly significant, as efficient asset management directly impacts financial outcomes, while macroeconomic indicators such as interest rates and industrial output tend to have a lesser effect (Nanda & Panda, 2018).

Several studies have explored whether the adoption of green technologies such as biofuels or investments in environmental innovation affects corporate profitability. While there is general agreement on the reputational benefits of sustainability, the financial impact remains a subject of debate (Gonçalves et al., 2023; Lewandowski, 2017). For instance, Faturohman and Nugraha (2021) found that firms with higher environmental and social transparency do not always exhibit superior financial performance or accounting profitability, such as ROA. Conversely, Lewandowski (2017) argues that emission reductions and the adoption of cleaner technologies, including alternative fuels and biofuels, may lead to operational gains and long-term financial improvements. This duality is further supported by Gonçalves et al. (2023), who emphasize the importance of comparing firms that adopt sustainable practices with those that do not, in order to understand the financial implications of such choices.

In this situation, determining whether businesses who use HVO and those that don't have different levels of profitability becomes especially important. HVO represents an investment in innovation and alternative energy with direct implications for operational costs and asset utilization.

The operating profit margin is a key indicator of financial efficiency, measuring a firm's ability to generate profits from its core operations, excluding financing and tax-related effects (Doğruel & Küçükgöde, 2023). In corporate sustainability research, this metric has been widely used to assess the impact of ESG practices on the profitability derived from a company's primary business activities (Gillan et al., 2021). The adoption of visible social, environmental, and community responsibility practices can generate positive market responses, potentially leading to higher operating margins (Bardos et al., 2020). Integrating sustainable practices such as the use of alternative fuels or clean technologies can enhance operational profitability by signaling differentiation and a commitment to quality (Harjoto & Jo, 2011; Bardos et al., 2020).

Firms with strong ESG performance often exhibit more resilient operational structures and stable cash flows, enabling them to maintain or improve margins even under uncertain market conditions (Gillan et al., 2021). These firms also benefit from increased investor and consumer trust, which contributes to customer loyalty and reduced indirect costs, factors that support stronger operating margins. However, the literature also highlights that initial investments in sustainability and alternative energy solutions may exert short-term pressure on margins, creating a trade-off between implementation costs and long-term gains (Bardos et al., 2020).

Among the indicators used to evaluate how the market perceives a firm's strategic choices, Tobin's Q stands out. This ratio contrasts the market value of an organisation with the cost of replacing its assets, capturing not only financial valuation but also future expectations. It is widely used to assess how efficiently a firm utilizes its resources and to reflect the market's perception of strategic initiatives, such as sustainability investments, in its market value (Dybvig et al., 2013). In the context of the energy transition, Tobin's Q is particularly relevant for evaluating investor confidence in companies adopting biofuels like HVO, as it reflects their capacity to generate long-term value (D'Amato et al., 2024b).

Investment in Research and Development (R&D) is recognized as a key driver of strategic innovation and energy transition, particularly in the industrial and energy sectors (Estevão & Lopes, 2024). The development of sustainable energy sources and the decrease of pollutant emissions are directly related to R&D, including biofuels and low-carbon energy production. It enables firms to develop more efficient technologies, anticipate regulatory demands, reduce costs, and improve their competitive positioning in evolving markets (Gielen et al., 2019; Sun & Dong, 2022). The literature suggests a statistically significant relationship between higher R&D investment and increased renewable energy consumption, indicating that R&D contributes meaningfully to environmental and climate goals (Johnstone et al., 2010; Kim & Park, 2023).

Moreover, R&D investment is increasingly viewed as a strategic commitment to sustainability, particularly as institutional investors place growing emphasis on firms' environmental performance (Li & Shao, 2023). Including R&D in the analysis of HVO adoption allows for an assessment of whether technological innovation efforts are associated with the transition to cleaner energy products.

To more consistently capture the relationship between operational activity and liquidity, the ratio of operating cash flow to sales (CF/Sales) is also relevant. This indicator reveals whether revenue growth is supported by liquidity generated from operations, an important consideration in sectors investing heavily in innovation and sustainability while seeking financially sustainable returns (Badawi et al., 2022). In capital-intensive industries such as energy, where long payback periods are common, the ability to generate cash flow from sales is a strong signal of profitability and financial autonomy (Fernández, 2001).

2.8 Sustainability and the Macroeconomic Context in Business Valuation

In an increasingly sustainability-oriented business environment, ESG indicators have evolved from being mere reputational assets to becoming central metrics in investment decisions and strategic planning (Gillan et al., 2021). Their growing relevance is reflected in market valuation, operational stability, and reduced cost of capital. The literature confirms a positive correlation between strong ESG performance and long-term financial outcomes (Aydoğmuş et al., 2022).

Wedajo et al. (2024) demonstrate that firms with high ESG ratings tend to benefit from greater market valuation, as investors increasingly prioritize sustainability and non-financial risks when assessing a company's financial health. ESG performance also acts as a mitigator of reputational and operational risks, directly influencing key financial indicators such as ROA, EBITDA, and market capitalization (Chao et al., 2025).

Moreover, the impact of ESG indicators extends beyond conventional financial metrics. Firms with stronger ESG performance are more likely to invest in technological and environmental innovation, such as the adoption of HVO, as a means of maintaining social legitimacy and complying with emerging regulatory standards (Feng et al., 2025). As highlighted by Gillan et al. (2021), such sustainable investments are perceived as long-term strategic commitments, reinforcing stakeholder trust.

However, recent literature also warns that discrepancies between ESG narratives and actual corporate practices may lead to reputational penalties and negatively affect firm valuation if inconsistencies are revealed (Chao et al., 2025).
Given this context, ESG performance is a relevant explanatory variable in this study, allowing for the assessment of whether firms with stronger environmental and social scores are leading the energy transition through practices such as HVO adoption.
Additionally, the literature emphasizes that the financial impact of sustainable investments may vary depending on macroeconomic conditions and firm-specific structural characteristics (Nanda & Panda, 2018). Variables such as organizational size and GDP per capita influence a firm's capacity to absorb the costs associated with biofuel investments (Faturohman & Nugraha, 2021; Lewandowski, 2017). Larger firms may possess greater financial flexibility to support sustainable investments (Chao et al., 2025; Gillan et al., 2021), while in more developed economic contexts, short-term profitability may be constrained by operational costs and regulatory pressures (Campbell et al., 2018; Nanda & Panda, 2018).

2.9 Market value as a reflection of environmental commitment

Market capitalization is a widely used measure of the economic value attributed to firms by financial markets, often serving as a proxy for financial performance and growth expectations (Wedajo et al., 2024). In the context of corporate sustainability, this indicator is particularly relevant for assessing whether investments in environmental innovation and energy transition are valued by investors. The literature confirms a positive relationship between ESG performance and market value, suggesting that higher ESG scores are associated with greater market capitalization (Aydoğmuş et al., 2022).
Sustainability performance influences investor perception of risk and attractiveness, potentially leading to enhanced valuation, especially in regulatory environments with strong sustainability pressures (Aydoğmuş et al., 2022). Furthermore, studies indicate that this impact may vary depending on industry sector, firm size, and the maturity of the ESG strategy implemented (Ridwan et al., 2024).
Evaluating whether investment in HVO is associated with higher market capitalization provides insight into whether the market rewards the adoption of environmentally responsible practices. This analysis helps determine whether energy transition strategies,

such as the use of HVO, are perceived by investors as signals of long-term commitment and corporate resilience, thereby contributing to enhanced market valuation.

3 – METHOD AND SAMPLE

The research approaches and data analysis strategies used to investigate the effects of HVO on the energy market and the tactical reactions of oil firms are described in this part. The study adopts a quantitative, descriptive, and explanatory approach, relying on secondary data sources.

A quantitative research design is appropriate for identifying statistically significant relationships between financial, environmental, and contextual variables (Orlitzky et al., 2003). The descriptive component aims to characterize the profile of the firms and key performance indicators, while the explanatory dimension seeks to analyze the factors influencing HVO investment and its effects on financial performance.

Data collection was conducted using updated secondary sources. First, data were extracted from the Refinitiv Eikon database, which provides detailed information on firms' financial indicators, investment variables, and structural characteristics. Furthermore, the study incorporates data from the report "Biofuels European Legislative Overview 2021–30" by Argus Media Group, which offers a comprehensive overview of European biofuel legislation, including blending mandates, double-counting rules, advanced biofuel targets, and country-specific taxes and penalties. This report is essential for understanding the regulatory environment influencing the HVO market (Argus Media Group, 2024). Regulatory variables extracted from this report such as the biodiesel blending mandate and ethanol blending mandate were applied at the national level and assigned to each firm by year and country of registration.

Strict criteria were used in the sample selection process, which only included corporations in the energy sector, particularly those involved in oil, gas, and renewable energy. This focus is justified by the sector's direct exposure to the Paris Agreement, which aims to limit global temperature rise and reduce greenhouse gas emissions objectives that have significantly impacted the oil and gas industry (Souza et al., 2017; United Nations, 2015). Additionally, the sample was restricted to firms headquartered in Europe to ensure comparability across regulatory and market contexts (Estevão & Lopes, 2024). The European Union's strong commitment to implementing the Paris Agreement, which aims to limit global warming and cut greenhouse gas emissions, justifies the decision to concentrate on Europe. The EU has established ambitious targets, including a minimum 55% reduction in emissions by 2030 and climate neutrality by 2050 (United Nations, 2015; Gurreck, 2025). These commitments have a direct impact on the European oil and energy sectors, which are required to align their strategies with these climate goals (Consilium, 2023).

To ensure the availability and consistency of both financial and non-financial data, the sample includes only publicly listed and active companies (Estevão, 2022). Countries with significant data gaps such as the Isle of Man, Jersey, and Montenegro were excluded due to the lack of consistent information on key variables such as ESG scores and annual financial indicators, which could compromise the comparability of the dataset. Data extraction was conducted in April 2025, ensuring the inclusion of the most recent available information.

The dataset covers the period from 2002 to 2023, with annual observations. The evolution of decarbonisation regulations, the execution of the Paris Agreement, and the long-term growth of investments in solutions like HVO are just a few examples of the structural and cyclical developments in the sector that may be examined within this time frame.

Regarding the selected indicators, the database includes key financial variables such as operating profit margin, return on equity (ROE), return on assets (ROA), EBITDA, cash flow to sales ratio (CF/Sales), market-to-book value (Tobin's Q), and market capitalization.

In addition, strategically relevant non-financial indicators were included, such as aggregate ESG scores, R&D expenditure, and HVO investment status. The HVO variable was constructed through a qualitative firm-by-firm analysis based on official websites and industry news, identifying whether each company was commercially involved in HVO. Based on this verification, a dummy variable was created: HVO = 1 if the company invests in HVO, and HVO = 0 otherwise.

All of the variables utilised in the study are described in full in Table 1, along with their designation, category, definition, and related literature source.

Table 1 - **Description of Variables**

Variable type	**Name**	**Abbreviation**	**Description**	**Author(s)**
Dependent	Return on Assets	ROA	It measures the company's operating profitability based on total assets.	(Gonçalves *et al.*, 2023; Lewandowski, 2017)

Dependent	Return on Equity	ROE	It measures the return obtained on the equity invested	(Fareed *et al.*, 2016)
Dependent	Natural logarithm of market capitalization	*lnmarket_capitalization*	Market value of the company, obtained by the number of shares times the price per share.	(Ngcobo *et al.*, 2025)
Dependent	HVO investment	HVO	100% renewable biofuel. Dummy variable (0/1)	(Dimitriadis *et al.*, 2018)
Independent	Profit margin	*op_protif_margin*	Operating profit as a percentage of revenue.	(Doğruel & Küçükgöde, 2023)
Independent	Natural logarithm of EBITDA	lnEBITDA	Earnings before interest, taxes, depreciation and amortisation.	(Gjerrild & Ditlevsen, 2023)
Independent	Operacional liquidity ratio	CF/*sales*	It measures the liquidity generated by operations in relation to total sales.	(Badawi *et al.*, 2022)
Independent	Market value to book value ratio (Tobon'Q)	*market_to_book_value*	The relationship between the market valuation and the company's book value.	(Dybvig *et al.*, 2013)
Independent	Natural logarithm of R&D expenditures	R&D	Annual amount invested in innovation, measured as a percentage of revenue.	(Estevão & Lopes, 2024; Kim & Park, 2023)
Independent	ESG Score	ESG_*score*	Global index that evaluates environmental, social and governance performance.	(Gillan *et al.*, 2021)
Independent	Biodiesel energy mandate (%)	Biodiesel	Minimum percentage of energy incorporation of biodiesel imposed by law.	(Argus Media Group, 2024; Ilves *et al.*, 2024)
Independent	Ethanol Energy Mandate	*Ethanol*	Minimum percentage of energy incorporation of ethanol defined by law.	(Argus Media Group, 2024; Ilves *et al.*, 2024)

Source: Own elaboration

Financial variables are expressed in thousands of euros (EUR). Firm-level data were collected for financial performance and ESG indicators, while regulatory mandates were gathered at the national level, based on each firm's country of headquarters.
Therefore, to answer the research questions, we propose the following four equations:

1) $P(HVOit = 1) = \beta0 + \beta1 \cdot Biodiesel_{it} + \beta2 \cdot Ethanol_{it} + \beta3 \cdot ESG\_score_{it} + \beta4 \cdot lnMarket\_Cap_{it} + \varepsilon_{it}$

2) $P (HVOit = 1) = \beta0 + \beta1 \cdot ESG\_score_{it} + \beta2 \cdot lnMarket\_Cap_{it} + \beta3 \cdot R\&D_{it} + \beta4 \cdot CF/Sales_{it} + \beta5 \cdot op\_profit\_margin_{it} + \beta6 \cdot tobin\_q_{it} + \varepsilon_{it}$

3) $lnMarket\_Cap_{it} = \beta0 + \beta1 \cdot lnMarket\_capitalization*HVO_{it} + \beta2 \cdot ESG\_score_{it} + \beta3 \cdot lnEBITDA_{it} + \beta4 \cdot Cash Flow / Sales*HVO_{it} + \beta5 \cdot lnR\&D_{it} + \beta6 \cdot R\&D*HVO_{it} + \varepsilon_{it}$

4) $$t = \frac{(ROA_{HVO} - ROA_{Non-HVO})}{SE}$$

To address the research hypotheses, a range of statistical techniques was applied. An independent samples t-test was used to compare the average profitability between firms that invest in HVO and those that do not (Ameer & Othman, 2012). To examine the likelihood of HVO investment based on factors such as ESG scores, firm size, and liquidity, logistic regression models were employed, which are appropriate when the dependent variable is binary (Gün & Kartal, 2025). Additionally, the impact of HVO investment on company performance was evaluated using multiple linear regression models. The analysis was complemented by a Pearson correlation matrix to identify relationships between variables, and the Variance Inflation Factor (VIF) test was conducted to ensure the absence of multicollinearity issues (Aydoğmuş et al., 2022).
These statistical techniques are widely used in studies on corporate performance and sustainability, contributing to the internal validity and robustness of the findings (Ameer & Othman, 2012).

4 - RESULTS

The study's empirical findings are presented in this section with the goals of comprehending the behavior of the chosen variables, perceiving current trends, and assessing any possible connections between investment in sustainable technology and financial performance. This section is divided into two main subsections: the econometric results from both panel data and a descriptive study of the sample.

4.1 Descriptive Statistics

The descriptive statistics for the primary variables utilized in the analysis are shown in Table 2. Firm-level observations from the energy industry are included in the sample; the coverage of financial, operational, and sustainability indicators differs.

There is significant variation in firm size, as evidenced by the sample's average log market capitalization of 12.84, with values ranging from 5.31 to 21.63. With a mean of 0.122, the HVO investment dummy indicates that 12.2% of the sample's enterprises have made an HVO investment. With a standard deviation of 21.48 and an average ESG score of 57.30 (out of 100), sustainability performance varies significantly. While profitability measurements like ROE and ROA indicate a wide range and negative averages (-36.99 and -4.98, respectively), showing the presence of enterprises with considerable losses, firms report an average log EBITDA of 12.31.

The operating profit margin and cash flow over sales also show extreme values, including negative outliers, while R&D expenditures are substantially skewed, with a mean of 170,421 and a maximum reaching 3.2 million. A small number of companies may have unusually high market valuations in relation to their assets, as indicated by the large standard deviation (27.98) and average Tobin's Q of 3.04. Last but not least, the average levels of ethanol and biodiesel utilization are 2.43 and 1.57, respectively. Both variables exhibit significant dispersion, indicating variations in the adoption of renewable fuels among businesses.

These statistics highlight the diversity of firm characteristics in the sample and underscore the importance of controlling for firm-level heterogeneity in the empirical analysis.

Table 1 - Descriptive statistics.

Variable	Obs	Mean	Std. dev.	Min	Max
lnMarket capitalization	2,591	12.84	2.913	5.308	21.63
HVO	3,982	0.122	0.327	0	1
ESG score	863	57.30	21.48	1.950	94.70
lnEbitda	1,759	12.311	2.858	1.3862	21.2173
ROE	2,606	-36.987	1123	-56332	3721
ROA	2,710	-4.984542	55.54045	-1159.91	1786.34

R&D	618	170421	450910	-31523	3.285e+06
Operating Protif Margin	2,410	-1030	17063	-573598	97402
Cash Flow / Sales	2,404	-756.93	19142.3	-676157	312554.3
Tobin Q	2,587	3.0375	27.9780	-0.033668	1144.15
Biodiesel	1,222	1.567	3.018	0	8.600
Ethanol	1,222	2.434	3.010	0	10

4.2 Correlations between variables

Table 3 (Pearson correlation matrix) displays the relationship between market capitalization and the other independent variables. All independent variables showed a positive connection with HVO with the exception of Tobin Q. Possible connections between these variables are suggested by statistically significant correlations. Nevertheless, multicollinearity issues may also arise as a result of these relationships. Following Meng et al. (2017), we conducted a VIF test to address this, making sure the findings were less than 10, as shown in Table 4. Because of their constant connections, these stable relationships were subsequently examined using panel data and linear regression. We used regression analysis with STATA software to comprehend the effects of sustainability, regulatory pressure, and financial performance on oil companies.

Table 2 – Pearson correlation matrix.

Variable	1	2	3	4	5	6	7	8	9	10	11	12
lnMarket capitalization	1.0000											
HVO	0.4150***	1.0000										
ESG score	0.4648***	0.4324***	1.0000									
lnEbitda	0.9173***	0.3686***	0.4961***	1.0000								
ROA	0.2201***	0.0687***	-0.0742**	0.0414*	1.0000							
ROE	0.1451***	0.0204	-0.0100	0.0696***	0.0568***	1.0000						
R&D	0.5274***	0.0691*	0.2326***	0.6111***	0.0761*	0.0979**	1.0000					
Operating Protif Margin	0.0569***	0.0273	-0.0293	0.0379	0.0629***	0.0000	0.0439	1.0000				
Cash Flow / Sales	0.0518**	0.0182	-0.1112***	0.0479**	0.0684***	0.0004	0.0404	0.7750***	1.0000			
Tobin Q	-0.0077	-0.0264	-0.1762***	-0.1212***	-0.1789***	-0.0311	-0.0560	-0.0074	-0.0008	1.0000		
Biodiesel	0.0242	0.0646**	0.0032	-0.0445	0.0282	0.0216	-0.0455	0.0325	-0.0125	-0.0198	1.0000	
Ethanol	0.1479***	0.0303	-0.0167	0.0596	0.0626**	0.0347	0.1045	0.0555*	-0.0042	-0.0367	0.7634***	1.0000

This table presents the Pearson correlations of the variables used in the study. P<0.1*, P<0.05**, P<0.01***

Table 4: Results of VIF test

Variable	VIF	1/VIF
ROA	6.700	0.149
ROE	5.570	0.180
Operating Protif Margin	4.490	0.223
Cash Flow / Sales	3.850	0.260
HVO	3.250	0.307
Ethanol	3.090	0.324
lnebitda	3.070	0.325
Tobin Q	2.780	0.359
Biodiesel	2.770	0.361
ESG score	2.510	0.398
R&D	2.400	0.417
Mean VIF	3.680	

4.3 Regressions Analysis

4.3.1 Impact of Regulatory Pressure on HVO Investment.

To answer the first research question, whether regulatory pressure affects investment in HVO, a logistic regression was used, given that the dependent variable HVO is yes or no, i.e. it is binary, with only two outcomes (1=adopts; 0 = does not adopt). The explanatory variables included the level of regulatory requirements for Biodiesel and Ethanol, ESG_score and market capitalization (ln_market_capitalization).

$$P(HVO_{it} = 1) = \beta 0 + \beta 1 \cdot Biodiesel_{it} + \beta 2 \cdot Ethanol_{it} + \beta 3 \cdot ESG\_score_{it} + \beta 4 \cdot InMarket\_Cap_{it} + \varepsilon_{it}$$

The findings of the regression analysis evaluating the effect of regulatory pressure on investment in HVO are shown in Table 5. HVO investment is the dependent variable, while regulatory pressure, as measured by market valuation and ESG-related indicators, is the primary independent variable. Firms with greater market values, which may make them more vulnerable to investor scrutiny and regulatory expectations, are more likely to invest in HVO, according to the positive and statistically significant coefficient for ln (Market Capitalization) at the 5% level. This supports the hypothesis that regulatory and market pressures are positively associated with strategic investments in low-carbon technologies. At the 1% level, there is also a positive and substantial correlation between the ESG score and HVO investment, suggesting that companies with better governance, social, and environmental performance are more likely to include HVO in their sustainability plan. A strategic shift in fuel technology preferences may be reflected in the negative correlation between ethanol investment and HVO, which is significant at the 1% level, and the positive and significant at the 5% level, link between biodiesel investment and HVO among the control variables.

These findings highlight the role of regulatory and reputational pressures in shaping corporate investment in renewable fuels.

Table 3 - Logistic regression for the effects of ESG score, Biodiesel and Ethanol on market capitalization.

VARIABLES	HVO
lnMarket_capitalization	0.154**
	(0.0695)
ESG_score	0.0716***
	(0.0110)
Biodiesel	0.140**
	(0.0655)
Ethanol	-0.187***
	(0.0708)
Constant	-7.718***
	(1.071)
Observations	368

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

4.3.2 ESG performance's impact on HVO investment

To test the hypothesis that companies with better ESG performance invest more in HVO, a binary logistic regression was conducted using HVO adoption as the dependent variable (1 = adopts; 0 = does not adopt). ESG score, market capitalization, R&D, CF/sales, op_profit_margin, and Tobin Q are among the explanatory variables.

$P(HVOit = 1) = \beta 0 + \beta 1 \cdot ESG\_score_{it} + \beta 2 \cdot InMarket\_Cap_{it} + \beta 3 \cdot lnR\&D_{it} + \beta 4 \cdot$ Cash-flow $/Sales_{it} + \beta 5 \cdot op\_profit\_margin_{it} + \beta 6 \cdot Tobin\_Q_{it} + \varepsilon_{it}$

Table 6 - Logistic Regression Estimates of the Effect of ESG Performance and Firm Characteristics on HVO Investment.

VARIABLES	HVO
ESG_score	0.091***
	(0.011)
lnMarket_capitalization	0.917***
	(0.169)
lnR&D	-0.567***
	(0.152)
Cash-flow /Sales	-0.068**
	(0.028)
Operating Protif Margin	-0.082
	(0.026)
Tobin Q	0.868***
	(0.198)
Constant	-14.383***
	(1.817)
R-squared	0.448
Observations	410

Standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1

The findings of the regression study looking at how ESG performance affects HVO investment are shown in Table 6. The model incorporates a set of firm-level financial controls to isolate the impact of ESG performance, and the dependent variable is HVO investment.

Companies with better ESG performance are more likely to invest in HVO, according to the positive and statistically significant ESG score coefficient at the 1% level. This finding lends credence to the idea that companies that prioritize sustainability are more likely to implement cutting-edge biofuel technologies, either as a result of internal environmental pledges, stakeholder pressure, or regulatory requirements. Firm size, as measured by the natural logarithm of market capitalization, is another control variable that has a positive and substantial correlation with HVO investment at the 1% level. This suggests that larger organizations are better equipped to allocate resources to low-carbon technology. On the other hand, at the 1% level, there is a negative and substantial correlation between R&D intensity and HVO investment. This could be a result of a trade-off between innovation spending and capital-intensive alternative fuel investments. Similarly, cash flow to sales is negatively associated at the 5% level with HVO investment, potentially indicating liquidity constraints or conservative financial strategies.

The idea that companies with greater development prospects are more likely to make sustainable investments is supported by the positive and significant relationship between HVO investment and Tobin's Q, a proxy for market expectations and business valuation, at the 1% level. The operating profit margin coefficient is negative but not statistically significant, indicating that HVO investment decisions are not strongly influenced by short-term profitability.

These findings highlight the relevance of ESG performance as a key driver of corporate investment in renewable fuels, particularly in the context of energy transition and regulatory alignment.

4.3.3 Investment in HVO associated with a higher market valuation

To test whether investment in HVO is associated with a higher market valuation, answering to research question 3, a multiple linear regression model was used, with lnmarket_capitalisation as the dependent variable. The HVO variable represents investment in this biofuel, and the model also includes control variables such as R&D, Cash Flow to sales, EBITDA, ESG_score.

$$\text{InMarket\_Cap}_{it} = \beta 0 + \beta 1 \cdot \text{lnMarket\_capitalization*HVO}_{it} + \beta 2 \cdot \text{ESG\_}\mathit{score}_{it} + \beta 3 \cdot \text{lnEBITDA}_{it} + \beta 4 \cdot \text{Cash Flow/Sales*HVO}_{it} + \beta 5 \cdot \text{lnR\&D}_{it} + \beta 6 \cdot \text{R\&D*HVO}_{it} + \varepsilon_{it}$$

The findings of two regression models that investigate the relationship between investment in HVO and higher market valuation are shown in Table 5. While Model (2) incorporates company fixed effects (FE) to account for unobserved heterogeneity between firms, Model (1) is an Ordinary Least Squares (OLS) regression.

The interaction term ln(Market Capitalization) × HVO, which represents the differential impact of HVO investment on firm valuation, is the main variable of interest. When firm-level heterogeneity is not taken into consideration, the OLS model's positive but not statistically significant coefficient indicates no discernible correlation. But when time-invariant company characteristics are considered, the coefficient in the fixed effects model grows to a substantial size at the 1% level, suggesting that companies that invest in HVO are linked to noticeably higher market valuations. This finding provides strong support for the hypothesis that HVO investment is positively valued by the market.

In all models, there is a negative correlation between the ESG score and market valuation, with significance at the 10% level. This suggests that in this situation, the market may not directly reward improved ESG performance. Both models show a positive and significant relationship between EBITDA and market capitalization, although the fixed effects specification's magnitude is smaller (β = 0.269) than OLS's (β = 0.517) at the 1% level, indicating the influence of firm-specific factors.

The market may interpret liquidity differently for HVO firms once firm-specific effects are considered, as evidenced by the interaction term Cash Flow / Sales × HVO, which is positive and significant in the OLS model at the 5% level but becomes negative and significant at the 10% level in the fixed effects model.

While the interaction term R&D × HVO is not statistically significant, indicating that the market does not distinguish the value of R&D spending depending on HVO investment status, R&D intensity (lnR&D) is positively and significantly associated with market capitalization in both models.

All things considered, the fixed effects model accounts for a significantly higher percentage of the market capitalisation variance (R^2 = 0.615) than the OLS model (R^2 = 0.391), highlighting the significance of taking firm-level heterogeneity into consideration when evaluating the valuation implications of HVO investment.

Table 7 - Multiple linear regression with market capitalization as the dependent variable.

VARIABLES	(1) OLS	(2) FE
lnMarket_capitalization*HVO	0.0159	0.844***
	(0.0126)	(0.0613)
ESG_score	-0.00298*	-0.00229*
	(0.00162)	(0.00127)
lnEBITDA	0.517***	0.269***
	(0.0297)	(0.0286)
Cash Flow / Sales*HVO	0.0199**	-0.0136*
	(0.00869)	(0.00770)
lnR&D	0.153***	0.0906***
	(0.0346)	(0.0319)
R&D*HVO	3.11e-07	-9.02e-08
	(3.16e-07)	(2.82e-07)
Constant	7.051***	4.593***
	(0.435)	(0.605)
R-squared	0.391	0.615
Observations	376	376
Number of company_id	29	29

Standard errors in parentheses *** p<0.01, ** p<0.05, * p<0.1

4.3.4 Differences in Profitability between Companies with and without HVO.

We used a two-sample t-test to compare the mean return on assets (ROA) of companies that invest in high-value orientation (HVO) and those that do not to better investigate the connection between HVO and company performance (table 8). There is a statistically significant difference in mean ROA between companies who invest in HVO and those that do not, according to a two-sample t-test with unequal variances.
HVO firms report a mean ROA of 3.92, but non-HVO enterprises show a mean of -6.62. The standard error is 1.39 and the mean difference is -10.54. The difference is significant at the 1% level. These results offer compelling proof that HVO investment is linked to higher asset profitability and efficiency.

We also investigate whether investments in high-value orientation (HVO) are linked to variations in return on assets (ROE) in order to supplement the analysis of company performance. The findings show that the two groups' average ROEs differed statistically significantly. HVO firms report a significantly higher mean ROE of 15.71 than firms without HVO investment, which show a mean ROE of -46.91. The standard error is 27.65 and the mean difference is -62.63. The difference is statistically significant at the 5% level, indicating that HVO investment is linked to noticeably better profitability as determined by ROE.
The results of the ROA and ROE research offer strong proof that investments in high-value orientation (HVO) have a positive correlation with business performance.

Table 8 - Two-sample t test with unequal variances (ROA and ROE)

	obs1	obs2	Mean1	Mean2	dif	St Err	t value	p value
ROA by HVO: 0 1	2290	420	-6.617	3.918	-10.536	1.387	-7.6	0.000
ROE by HVO: 0 1	2193	413	-46.913	15.712	-62.625	27.65	-2.25	0.024

5 – DISCUSSION

This study provides empirical information about the financial, regulatory, and strategic factors that influence investments in HVO and how these factors affect business performance in the European oil and gas market. By showing that, in some circumstances, HVO adoption is both financially and environmentally favorable, the findings add to the body of knowledge on sustainable finance and corporate environmental policy.

5.1 Regulatory and normative drivers

The findings demonstrate that normative constraints and regulatory requirements have a big impact on business choices about HVO investment. The idea that institutional pressures, especially those resulting from the EU's Renewable Energy Directive (RED III), are successful in promoting low-carbon technologies is supported by the fact that companies with higher ESG scores and those operating under stricter biodiesel blending mandates are more likely to adopt HVO (Ilves et al., 2024; European Commission, 2023). According to Kolk and Pinkse (2008), strategic responses to environmental concerns are driven by political and normative factors.

Given that businesses are prioritizing advanced biofuels with better operational and environmental performance, the negative correlation between ethanol mandates and HVO investment may be the result of a strategic shift in fuel technology choices (Dimitriadis et al., 2018). This finding aligns with the literature on fuel technology competition and highlights the importance of policy coherence in promoting advanced biofuels.

5.2 ESG Performance and Strategic Commitment

The correlation between ESG scores and HVO investment is positive and statistically significant, which supports the idea that sustainability performance is a strategic driver. Stronger ESG profiles indicate that companies are more willing to invest in HVO, indicating that environmental and social governance is operationally integrated as well as reputational (Gillan et al., 2021; Aydoğmuş et al., 2022). The idea that ESG-focused businesses proactively address stakeholder expectations and regulatory trends is supported by this.

However, the slightly negative impact of ESG ratings on market capitalization raises the possibility that investors may not consistently reward ESG performance, maybe as a result of a lack of standardized ESG criteria or worries about greenwashing (Chao et al., 2025). This emphasizes how ESG reporting must become more consistent and transparent in order to boost investor confidence.

5.3 Financial Performance and Market Valuation

According to the study, adopters have superior asset efficiency and profitability since HVO investment is linked to noticeably greater ROA and ROE. These findings support the claims made by Lewandowski (2017) and Gonçalves et al. (2023) that cleaner technology and pollution reductions can have long-term financial advantages. Companies who invest in HVO beat their peers in important profitability indicators, according to the two-sample t-tests, indicating that sustainability initiatives can be profitable. Additionally, a high positive correlation between HVO investment and market capitalization is revealed by the fixed effects regression model, indicating that investor's view HVO adoption as an indication of long-term value creation and strategic resilience (Wedajo et al., 2024; D'Amato et al., 2024b). This lends credence to the idea that market value, especially in industries, reflects environmental commitment. This supports the hypothesis that market valuation reflects environmental commitment, particularly in sectors exposed to decarbonization pressures.

5.4 Trade-offs and Financial Constraints

The study finds trade-offs in sustainability investment notwithstanding the favorable financial effects. Adoption of HVO is adversely correlated with R&D intensity, suggesting that companies may have to choose between capital-intensive green technology and innovation when allocating their resources (Kim & Park, 2023; Estevão & Lopes, 2024). Similarly, the negative correlation between HVO investment and cash flow to sales points to a lack of liquidity, especially for smaller companies or those with more conservative financial approaches. To reduce the initial costs of HVO deployment and facilitate wider involvement in the energy transition, these findings emphasize the significance of supportive financial tools including subsidies, tax incentives, and green finance (Becker et al., 2017; Hor et al., 2023).

5.5 Contributions and Policy Implications

By incorporating regulatory, financial, and strategic aspects into the examination of biofuel investment, this study adds to the body of literature. It offers factual backing for the idea that adopting HVO is a financially sound choice as well as a reaction to outside forces. Policymakers, investors, and business management can all benefit from the findings.

The findings highlight for policymakers how ESG disclosure requirements and blending regulations work to promote sustainable investment. Adoption of biofuels may be a reliable predictor of long-term value for investors, as indicated by the positive correlation between HVO and market valuation. The research shows that environmental innovation can improve both operational performance and market perception, which is why managers should include sustainability into their fundamental company strategy.

6 – CONCLUSIONS, IMPLICATIONS, LIMITATIONS AND FURTHER RESEARCH

This study offers strong proof that companies in the European energy sector can profit both strategically and monetarily from investing in HVO. The study shows that HVO adoption is favorably correlated with increased ROA, ROE, and market capitalization by combining regulatory, financial, and sustainability aspects. These results imply that HVO investment improves corporate performance and investor valuation in addition to being in line with environmental objectives.

From a strategic standpoint, the findings highlight how crucial regulatory pressure and ESG performance are in influencing companies' choices regarding the use of renewable fuels. Strong ESG scores and strict biodiesel regulations increase a company's likelihood of investing in HVO, demonstrating the impact of institutional and normative pressures on sustainability tactics. Furthermore, investors view such activities as indicators of long-term resilience and environmental commitment, as demonstrated by the positive market response to HVO investment, which is reflected in greater firm valuation.

The study does, however, also highlight significant trade-offs. Given the inverse relationship between R&D effort and HVO acceptance, companies may have trouble allocating resources between capital-intensive sustainability initiatives and innovation. Like this, certain businesses may not be able to implement HVO plans due to liquidity issues, as shown by the cash flow to sales ratio. These results demonstrate the necessity of specific financial tools and legislative backing to promote the wider use of advanced biofuels.

The results have a number of applications. The findings confirm for policymakers that blending mandates and ESG disclosure requirements are a good way to encourage sustainable investment. Adoption of HVO can be a reliable sign of strategic alignment with energy transition for investors. By showing that sustainability may be a source of competitive advantage as well as a regulatory requirement, the evidence supports corporate managers' incorporation of environmental innovation into core business strategy.

The study has limitations despite its contributions. First, only publicly traded companies in the European energy sector were included in the investigation, which would limit how broadly the results can be applied to other areas or sectors. Second, the scale and intensity of adoption, which may differ greatly amongst enterprises, are not captured by the binary classification of HVO investment. Third, even though the study accounts for several structural and financial variables, judgments about investments may still be influenced by unobserved elements like supply chain dynamics or managerial attitudes.

These limitations might be addressed in future studies by broadening the sample to include companies from different industries and geographical areas, especially those with developing biofuel markets. Studies with a longitudinal design could investigate how HVO investment affects innovation, risk management, and stakeholder involvement over time. Furthermore, qualitative research may supplement the quantitative results reported here by offering more profound understanding of the organizational procedures and strategic drivers of HVO adoption.

Overall, this research advances knowledge on the relationship between environmental innovation, financial success, and strategic decision-making during the energy transition. It emphasizes HVO's function as a feasible route to corporate sustainability and decarbonization, providing insightful information to scholars, industry professionals, and legislators.

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