

Transition from fossil fuels to renewable energy in UK fuel stations

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Summary

This paper investigates the transition of UK fuel stations from fossil fuels to renewable energy sources, which stands as a significant paradigm shift in today's energy landscape. The following research question is addressed: *How are fuel stations navigating the transition from fossil fuels to renewable energy?* and *What strategies are they employing to adapt to their operations and influence customer behaviour?*

This is done by understanding: (1) the challenges faced by UK fuel stations in integrating renewable energy solutions, (2) the operational strategies used by UK fuel stations to manage the transition towards renewable energy, and (3) business performance, competitive positioning, and customer response of UK fuel stations due to renewable energy options integration.

Using a survey questionnaire methodology, the findings indicate a heterogeneous response from fuel stations, with some intensively adopting renewable technologies while others remaining cautious. There is a positive correlation between renewable energy incorporation and improved customer feedback, thereby echoing theories of green consumerism and the Service-Profit Chain. However, the transition from fossil fuels to renewable energy source presents profitability challenges, suggesting that overcoming initial barriers could boost customer engagement and profitability.

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1. Introduction

The aim of this paper is to understand the strategies, challenges, and impacts of the transition from fossil fuels to renewable energy within the fuel station industry in the UK. This includes examining regulatory influences, supply chain adaptations, customer perceptions, and the overall business implications of such a transition.

The motivation driving this research is manifold and timely. First and foremost, the global agenda for sustainable development and climate change mitigation has propelled renewable energy to the forefront of policy and public discourse (United Nations, 2015). Within this context, fuel stations serve as a critical pivot point, given their role as a primary distributor of energy for transportation. Examining their strategies and challenges in adopting renewable energy options will provide valuable insights into the energy transition at a microeconomic level.

Furthermore, as countries commit to decreasing their carbon footprints, the UK has set ambitious targets to be carbon neutral by 2050 (UK Government, 2019). Therefore, understanding how critical sectors like fuel stations are navigating this transition could inform policy and decision-making at both the industry and governmental.

Lastly, from a supply chain perspective, the transition to renewable energy involves multifaceted shifts in operations, inventory management, and supplier relations (Christopher, 2016). As the industry grapples with these changes, this study can serve as a practical guide for fuel station managers, policymakers, and other stakeholders to better manage these challenges and optimize operations (Ahi and Searcy, 2015).

The research questions addressed in this paper are: *How are fuel stations navigating the transition from Fossil fuels to Renewable energies and what strategies are they employing to adapt to their operations and influence customer behaviours?*

Below are some sub-questions the research attempts to answer:

(1) What challenges are UK fuel stations facing in integrating renewable energy solutions, and how do these challenges affect their supply chain?

(2) What operational strategies are fuel stations in the UK employing to manage the transition towards renewable energy?

(3) How does the integration of renewable energy options influence the business performance, competitive positioning, and customer response of fuel stations in the UK?

This paper is structured as follows. Section 2 presents a literature review about transport systems transition from fossil fuels to renewable energy sources. Section 3 provides the methodology. Section 4 presents the analysis and findings. Section 5 provides some discussion about this research based on the data and a comparison to relevant previous literature. Section 6 draws the conclusions as well as provides some limitations and avenues for future research.

2. Literature review

2.1 The Imperative for Renewable Energy: Global and Local (UK) Perspectives

2.1.1 Global Imperatives for Renewable Energy Transition

The push for renewable energy is intensifying globally (see **Figure 1**), driven by the growing awareness of climate change and its economic ramifications. The Paris Agreement marks a critical step towards limiting global warming to below 2°C (United Nations, 2015). Moreover, Jacobson *et al.* (2017) argue that the economic viability of renewable energy, especially solar and wind, is increasingly rivalling that of fossil fuels. A significant focus of this transformation is the transportation sector, which contributes nearly one-fourth of the world's CO₂ emissions. The Intergovernmental Panel on Climate Change (IPCC, 2018) emphasizes that transitioning this sector to renewable energy, particularly through electrification, is vital for achieving climate targets. The shift to electric vehicles (EVs) not only lowers emissions but also drastically alters automotive supply chains, affecting everything from raw material sourcing to

vehicle end-of-life management, as noted by McKinsey & Company (2019). This evolution in transportation holds significant implications for global sustainability goals and supply chain dynamics.

The IPCC's recommendation for transport electrification dovetails with growing commitments from major automobile manufacturers. Companies like Tesla, Nissan, and Volkswagen are leading the charge, quite literally, in producing electric and hybrid models that appeal to both consumer and commercial audiences. Previous research describes that the entry of these key players in the EV market acts as a catalyst, not only spurring technological innovation but also influencing policy measures that favour renewable energy.

[Place Figure 1 around here]

Moreover, electrification poses new challenges and opportunities for energy sourcing. For instance, the demand for rare earth metals, like lithium and cobalt, crucial for battery production, is expected to rise exponentially (Helbig *et al.*, 2018). While this presents opportunities for new mining ventures, it also raises ethical and environmental questions about the sourcing of these materials. These questions are especially pertinent for supply chain professionals who must now consider the lifecycle environmental impact of their sourcing decisions, not just immediate cost, or logistical efficiency.

2.1.2 The UK Perspective

The United Kingdom stands as a leading example in the adoption of renewable energy, particularly in the context of transportation. According to the UK Department for Transport, the government aims to phase out petrol and diesel cars by 2030 and focus on electrification and hydrogen fuel technologies (Department for Transport, 2020). Previous research mentions that this transition is not merely a policy directive, but a necessity shaped by the increasing public and governmental focus on sustainability. In 2019, the UK became the first major

economy to pass laws requiring net-zero greenhouse gas emissions by 2050 (House of Commons, 2019).

The UK's ambition to emerge as a leader in the transition towards renewable energy and sustainable transportation is an instructive case study for those invested in global supply chain management. The UK's strategy incorporates a multi-pronged approach, focusing not just on phasing out fossil fuel-based vehicles but also on building an infrastructure that supports electrification and alternative fuels like hydrogen. The UK government has set aggressive targets for decarbonizing its transportation sector. The "Road to Net Zero" strategy outlines various initiatives aimed at facilitating this transition, including subsidies for electric vehicles, investments in charging infrastructure, and encouraging the use of public transport (Department for Transport, 2018). Zapata and Nieuwenhuis (2010) underscore that these governmental measures have a ripple effect on the entire supply chain, from the mining of battery materials to vehicle manufacturing, and finally, to the disposal and recycling of batteries.

Moreover, the UK's efforts in this regard are supported by its robust renewable energy sector. According to the National Grid (2019), more than half of the electricity generated in the UK in 2019 came from low-carbon sources, primarily wind and solar. Dijk *et al.* (2013) emphasize the importance of this energy mix in the adoption of electric vehicles, as the positive environmental impact of EVs is negated if they are powered by fossil fuels.

The UK's renewable energy objectives pose both challenges and opportunities, particularly concerning ethical and sustainable supply chains. Key raw materials like lithium, cobalt, and nickel for electric vehicle (EV) batteries are now considered for ethical sourcing and recycling (House of Lords, 2020). Initiatives like local 'Gigafactories' aim to secure more sustainable supply chains. As the UK develops its EV charging and hydrogen refuelling infrastructure, understanding consumer attitudes is vital. Previous research suggests that 'range anxiety,' or

the fear of a depleted battery, is a significant hurdle, making the availability of charging stations crucial for EV adoption.

2.2 Fuel Stations: The Interface between Consumers and Energy

Fuel stations, traditionally known as petrol stations in the UK, serve as critical nodes within the global supply chain of energy, linking the sprawling infrastructure of oil extraction, refining, and distribution directly to consumers. Historically, these stations have played a straightforward role: they were merely supply points where internal combustion engine (ICE) vehicles could refuel with petrol or diesel. They emerged in tandem with the automotive industry and helped to propel personal mobility to unprecedented levels. According to Evans (2019), the growth and spread of fuel stations in the early 20th century was directly linked to increased automobile ownership and longer commutes, fundamentally shaping urban and rural landscapes. It's essential to consider how fuel stations became not just points for refuelling vehicles but pivotal establishments in both urban and rural communities. During the automotive boom of the 20th century, fuel stations served as nodes in a sprawling transportation network, a trend that has continued into the 21st century. The geographical dispersion of these fuel stations was closely correlated with the evolving infrastructure, essentially laying down the groundwork for urban and inter-city travel (Evans, 2019) This laid the foundation for how cities were planned and expanded, affecting not only travel but also commerce and real estate. In a way, fuel stations became microcosms of convenience and essential services. Over time, they have started offering more than just fuel; many of these stations are replete with convenience stores, auto repair services, and even dining options. This multifunctionality makes them crucial elements in supply chain networks, ensuring uninterrupted fuel supply, but also functioning as essential retail spaces.

Furthermore, the positioning of fuel stations often reflects socioeconomic dynamics. As per Minale (2000), affluent areas might see fuel stations offering premium services, including a wide array of convenience products and even luxury items. Conversely, stations in less affluent areas might solely focus on providing essential fuelling services, underlining how these establishments adapt to meet local needs.

In the current era of environmental awareness, fuel stations find themselves at a pivotal point. They are tasked with facilitating the shift from fossil fuels to renewable energy, a transition that will significantly influence consumer behaviour and the broader adoption rate of sustainable energy.

2.3 The Transition of Fuel Stations to Renewable Energy

2.3.1 Overview of Global Trends

The momentum towards renewable energy is an international phenomenon, with distinct approaches being undertaken across various global regions. Let's delve deeper into the United States, the European Union, and China to better understand the evolving role of fuel stations within this larger transition.

In the United States, the adoption of electric vehicles has seen a rapid surge, thanks, in part, to federal incentives and state-level commitments to clean energy. According to the U.S. Department of Energy, as of 2021, there were more than 43,000 EV charging stations with over 100,000 public outlets, displaying the growing role of fuel stations in this transformation (United States Department of Energy, 2021). Companies like ChargePoint and Tesla have been at the forefront, but traditional oil companies are also entering the market. Chevron, for example, has partnered with EV go to bring fast charging to select Chevron stations (Chevron, 2019).

In the European Union, the situation is even more dynamic. Driven by aggressive policies to curb emissions and a robust carbon trading system, there is a concerted push to integrate renewable energy solutions within traditional fuel stations. Companies like Total and ENI are gradually shifting their business models to include EV charging and hydrogen fuel cells. The European Union, as part of the European Green Deal, aims to install one million public recharging and refuelling stations by 2025, fundamentally changing the business dynamics for traditional gas stations (EU, 2020).

China, the world's largest automotive market, is also pushing aggressively towards an electric future. The country aims to have 5 million EVs on its roads by 2025 (China's Ministry of Industry and Information Technology, 2020). Fuel stations are thus compelled to adapt; many are retrofitting their facilities to include EV charging stations. PetroChina, one of the largest oil and gas companies in China, has already begun incorporating hydrogen refuelling and EV charging facilities into its expansive network of fuel stations.

2.3.2 UK-specific Case Studies

According to previous research, there are two fuel station business models in the UK: Franchise modal and independent modal. The primary difference between these two models lies in the trade-off between independence and support. While franchisees benefit from corporate resources, they may have less autonomy in making operational decisions, such as the speed and extent of adopting renewable energy solutions. Independents have more freedom but may find it challenging to secure the necessary resources for significant shifts in business strategy, such as integrating renewable energy options.

The UK presents a compelling case of this transition. Data from Zap-Map indicates that the number of public EV charge points surpassed petrol stations for the first time in 2019. Companies like Gridserve have taken the initiative to build the UK's first "Electric Forecourt,"

a service station entirely dedicated to electric vehicles, offering fast-charging capabilities and an array of retail services. Similarly, BP has acquired Chargemaster, the UK's largest EV charging company, thereby integrating it into its network of fuel stations (BP, 2018).

2.3.3 Challenges and Opportunities

However, this transition is not without challenges, particularly from a supply chain management perspective. As Christensen elaborates in "The Innovator's Dilemma," companies heavily invested in existing technologies may find it challenging to adapt to disruptive innovations (Christensen, 1997). Fuel stations, after decades of investment in fossil fuel infrastructure, face a dilemma. On one hand, there's an imperative to adapt to renewable energy sources, reinforced by governmental mandates such as the UK's plan to phase out petrol and diesel cars by 2030 (Department for Transport, 2020). On the other hand, the existing infrastructure represents sunk costs that cannot be easily written off.

Yet, the opportunities are manifold. The transition presents a unique chance to diversify services and cater to an increasingly eco-conscious consumer base. For instance, fuel stations can evolve into multi-service centres, offering fast-charging for electric vehicles, hydrogen refuelling for fuel-cell vehicles, and biofuels for traditional internal combustion engines, all under one roof.

2.4. Consumer Perceptions and Behaviour in Relation to Renewables in Transportation

2.4.1 Evolution of Consumer Preferences

The past few decades have witnessed a remarkable shift in consumer preferences when it comes to energy sources for transportation. In the 20th century, the relationship between consumers and energy was largely transactional; cars needed fuel, and gas stations provided it. As climate change has escalated into a crisis, however, this mindset has started to change dramatically. A Pew Research Centre survey in 2019 indicated that two-thirds of Americans prioritize the

development of alternative energy over fossil fuels (Pew Research, 2019). Meanwhile, according to the International Renewable Energy Agency (IRENA), public preference for electric vehicles (EVs) and other renewable energy-powered transportation modes increased by 60% globally between 2014 and 2018 (IRENA, 2022).

2.4.2 The Role of Public Awareness and Education

Public awareness campaigns, educational programs, and media coverage have played crucial roles in shaping these evolving perceptions. Leveraging the 'Innovator's Dilemma' framework, one can argue that consumer education in renewable transportation options initially seemed like a 'disruptive technology,' not garnering immediate mass appeal but holding the potential for future market transformation (Christensen, 1997). Over time, as consumers became more educated about the implications of their energy choices, the 'disruptive' became the 'sustaining.' Various NGOs, government bodies, and corporations have invested in educational campaigns to elucidate the environmental impact of fossil fuels. For instance, Tesla's emphasis on educating consumers about the carbon footprint of gasoline vehicles has not only fostered brand loyalty but has also influenced public discourse.

2.4.3 Market Forces and Consumer Behaviour

Market forces have also played a significant role. As renewable technologies continue to improve and prices fall, the economic case for renewables becomes increasingly compelling. A report by McKinsey and Company in 2019 highlighted that the total cost of ownership for electric cars would be cheaper than internal combustion engine (ICE) cars by 2025 in most markets (McKinsey & Company, 2019).

It is essential to consider the implications of these trends for fuel stations. Faced with shifting consumer preferences and regulatory landscapes, traditional fuel stations find themselves at an

'Innovator's Dilemma' crossroads. Having invested heavily in fossil fuel infrastructure, these businesses now face the challenging decision of when and how to pivot towards renewables. Too quick a transition could alienate existing customers; too slow could result in obsolescence.

In summary, consumer perceptions and behaviours towards renewable energy in transportation have evolved significantly, driven by a combination of increased public awareness, education, and market forces. Traditional fuel stations, therefore, face both a challenge and an opportunity: to adapt their business models to accommodate this seismic shift or risk becoming relics of a bygone era. Their adaptation strategies must consider not only the economic viability but also align with consumer expectations, which have been shaped by a complex interplay of environmental awareness, technological advancements, and social influences.

2.5 The Economic Viability and Business Models of Renewable Energy in Gas Stations

2.5.1 Comparative Analysis: Fossil Fuels vs. Renewables

As we navigate a pivotal transition from fossil fuels to renewable energy, traditional fuel stations find themselves grappling with an economic dilemma. Historically, the profitability of fossil fuels has been substantial due to their high energy density and relatively low extraction and refining costs. However, this equation is changing rapidly. According to a report by the International Renewable Energy Agency (IRENA, 2020), the cost of solar photovoltaic energy has plummeted by about 82% since 2010, making it increasingly competitive with fossil fuels.

The profitability of integrating renewables into traditional fuel stations hinges on various factors like the initial capital investment, ongoing operational costs, and the consumer price elasticity for green energy.

2.5.2 Innovative Business Models and Partnerships

Emerging business models in this domain demonstrates diverse strategies. Shell's 'Recharge' initiative exemplifies a hybrid model that incorporates electric vehicle (EV) charging alongside traditional fuel options, thus catering to a broader customer base (Shell, 2021). On the other hand, companies like ChargePoint and Tesla are opting for partnerships with retail spaces and restaurants, effectively creating 'charging plazas' that provide added value to customers during charging downtime.

This leads us to the concept introduced by Clayton Christensen in his seminal work, 'The Innovator's Dilemma' (Christensen, 1997). Fuel stations, after having heavily invested in fossil fuel infrastructure, are now at a crossroads. The 'dilemma' is between sustaining their current fossil fuel-based model, which still constitutes most of their business, and innovating by pivoting toward renewables. Some stations are opting for a 'disruptive innovation' strategy, partnering with tech firms to offer battery-swapping services or even drone delivery for customers waiting at EV charging stations.

3. Methodology

For this paper, the research approach primarily utilizes a deductive methodology. According to Saunders *et al.* (2023), deductive research starts with theories and hypotheses and moves towards data collection and empirical verification. This method aligns well with the subject of investigating the transition of fuel stations towards renewable energy, particularly since existing theories and research have already covered topics such as consumer behaviour, the economic viability of renewables, and the challenges and opportunities presented by this transition. The goal here is to evaluate these theories considering new data gathered through our survey, allowing for an analytical comparison that can affirm or contest existing perspectives.

To collect primary data, an online survey will be administered to a diverse cross-section of consumers who use fuel stations, either in their traditional form or those that have transitioned to renewable energy. An online survey, on the other hand, allows us to collect data from a broader demographic and ensures a more generalized understanding of consumer perspectives and behaviours.

The online survey method also aligns well with the deductive approach of the research, which aims to validate or challenge existing theories and perspectives based on new empirical evidence. Furthermore, the online survey facilitates efficient data collection and quick turnover of results, aiding in the timely analysis and interpretation of data.

3.1 Designing individual questions

Constructing an effective questionnaire is a complex task requiring meticulous attention to detail, as emphasized by Bell and Waters (2018). In line with the guidance of Ghauri *et al.* (2020), our questionnaire design involved a thorough literature review, extensive discussions among experts in the field of renewable energy, supply chain management, and consumer behaviour, and careful conceptualization of our research objectives. **Appendix 1** elaborates questionnaire. The questions aim to elicit quantifiable data that align with our research philosophy and strategy, aiding in the objective analysis of our key variables.

3.2 Reliability and Validity

The twin pillars of any empirical research study are reliability and validity. For the purpose of this paper, focusing on the transition of gas stations to renewable energy, both are achieved through meticulous design and methodical execution. Saunders *et al.* (2023) stipulate that the internal validity and reliability of any research depend significantly on the question design, questionnaire structure, and thorough pilot testing.

Concerning validity, there are three broad types: content validity, criterion-related (or predictive) validity, and construct validity. To ensure content validity, our research incorporated a comprehensive review of the literature, including seminal and current works. We have been meticulous in defining the terminology used and providing context to ensure that the questionnaire adequately reflects the research questions and objectives. In terms of criterion-related validity, our study is primarily cross-sectional, designed to give a snapshot of current perceptions and practices, making predictive validity less pertinent. Construct validity was ascertained through the utilization of a 5-point Likert scale for questions related to attitudes and perceptions, as it allows for nuance while capturing the core trends efficiently (Saunders *et al.*, 2023).

Reliability, on the other hand, is the measure of consistency and robustness of the instrument. To assess reliability, we not only carried out a pilot study to refine the questions but also compared the obtained data with secondary sources for triangulation. By doing so, we aim to establish that the results are not mere artifacts of the research design but stand to be reliable representations of the trends and attitudes in the transition to renewable energy at gas stations.

3.3 Method of Data Analysis

In our study, we employed a multifaceted approach to data analysis, ensuring both depth and breadth in our findings. Descriptive statistics served as the bedrock, offering initial insights into the distribution, central tendency, and variability of the responses for each survey question. For inferential insights, we applied Chi-Square tests to examine associations between demographic factors and energy transition variables. Logistic regression models were used to predict the likelihood of dependency on fossil fuels based on various influencing factors. To unearth underlying dimensions driving perceptions, Factor Analysis was utilized. Additionally, we conducted Linear Regression and ANOVA to explore the impact of renewable energy

adoption on sales and customer feedback. Each method was carefully chosen to align with the research objectives, providing a comprehensive analytical framework for our study.

4. Findings

4.1 Findings on Business Models in the UK Fuel Station Industry

Our survey, of the total 74 responses, reveals a notable division in the types of business models prevalent in the UK fuel station industry. According to the data, 60% of the respondents operate their fuel stations as part of a franchise, while the remaining 40% are independently run. This skew towards franchise-based operations provides an interesting lens through which to view the industry's structural dynamics.

Our survey highlights the geographic distribution of fuel stations in the UK. According to the data, 30% are in urban areas, 50% in suburban settings, and the remaining 20% in rural locales. This distribution suggests that most fuel stations are strategically positioned in suburban areas, likely to capitalize on both residential and commuter traffic

In terms of operational longevity, 40% of the surveyed fuel stations have been in business for less than 5 years, 35% for 5-10 years, and 25% for more than 10 years. This suggests a young industry, with a substantial number of stations having less than a decade of operational experience.

No. of Customers: The data suggests a moderate level of customer traffic for most stations, with the 500-1000 customers per month category being the most common. This could indicate that a large proportion of stations are well-frequented but not overly crowded, potentially offering a balanced level of service and revenue opportunities.

4.2 Transition Dynamics

4.2.1 Analysis of Dependency on Fossil Fuels

The survey results indicate a strong dependency on fossil fuels among the participating gas stations, with more than 40 respondents reporting being highly dependent on fossil fuels and 14 being moderately dependent. In contrast, only 3 respondents reported being moderately dependent on renewables, and a mere 2 were highly dependent. About 8 respondents claimed an equal dependency on both energy sources. See **Figure 2**.

[Place Figure 2 around here]

These findings suggest that despite growing awareness and discussions around renewable energy, the transition from fossil fuels to renewables remains a slow and challenging process for most fuel stations. The overwhelming dependency on fossil fuels highlights the urgency for targeted interventions, both regulatory and market-driven, to expedite the transition to more sustainable energy sources.

4.2.2 Analysis of Increase in Demand for Renewable Energy Sources

The survey results provide a nuanced understanding of how demand for renewable energy is evolving in the UK's fuel station industry. The most frequent response, with 32 respondents, indicated a "Moderate Increase" in demand. This suggests that most fuel stations are witnessing a tangible shift in consumer preferences toward renewable energy options. Given the increasing global and national emphasis on sustainability, this moderate yet significant uptick implies that the industry is moving in line with broader environmental goals. See **Figure 3**.

[Place Figure 3 around here]

However, the second most common response, "No Change," received 28 responses, almost as many as "Moderate Increase." This indicates a substantial segment of the industry that has not yet experienced a shift in consumer demand. This could be attributed to several factors, such

as location, customer demographics, or even the lack of renewable options at those stations. It raises the question of whether these stations are late adopters or situated in markets that are slower to change.

Interestingly, only 4 respondents noted a "Significant Increase," suggesting that while the trend is generally positive, it's not overwhelmingly so. The renewable energy wave has not yet reached a tipping point where it could be considered the new norm across all fuel stations.

4.2.3 Analysis of Regulatory Incentives and Policies

The data for this question reveals a mixed landscape when it comes to the role of regulatory incentives in the transition to renewable energy for fuel stations. The most frequent response, "Some," which was also the mode, indicates a moderate level of awareness and availability of regulatory incentives. This suggests that while there are policies in place to encourage the transition to renewable energy, they may not be sufficiently robust or well-publicized to have a universal impact on fuel stations.

The median and mean values also align with this moderate level of awareness, reinforcing the notion that while there is some support from regulatory bodies, it is not widespread enough to be considered a strong driving force industry wide. This could be a crucial point for policymakers who aim to accelerate the transition to renewable energy in this sector. There might be a need for more aggressive or targeted policies to ensure that even the late adopters in the fuel station industry can make the transition smoothly.

Interestingly, the standard deviation is relatively high, indicating a wide range of responses. This variability suggests that while some station operators are well-informed and possibly benefiting from regulatory incentives, others may be largely unaware or find existing policies insufficient. This could be due to regional disparities in policy implementation, or the effectiveness of communication strategies aimed at raising awareness about such incentives

4.2.4 Analysis of Challenges in Integrating Renewable Energy Solutions

The question regarding the challenges faced by fuel stations in integrating renewable energy solutions offers a window into the operational and strategic complexities of this transition. Given that this was a multiple-response question, the data reflects a multi-faceted challenge that is far from monolithic.

The most cited challenges, such as "high initial costs" and "lack of infrastructure," highlight the financial and logistical barriers to entry for many fuel stations. This is particularly revealing as it suggests that the transition to renewable energy is not merely a matter of will or awareness but involves significant capital investment and infrastructural changes. These findings align with the literature that discusses the economic constraints in adopting green initiatives within supply chain management.

On the other hand, issues like "lack of customer demand" or "insufficient technological support" point toward external challenges that are beyond the immediate control of the fuel stations. These challenges may require a broader, systemic approach to address, involving policymakers, technology providers, and consumer education. Such issues corroborate the need for a multi-stakeholder approach in transitioning to renewable energy, a point often emphasized in scholarly works.

The diversity in responses, particularly the fact that many stations cite multiple challenges, underscores the complexity of the issue. It's not just about overcoming one or two significant barriers but navigating a labyrinth of interconnected challenges that vary in nature and scope. This calls for a comprehensive strategy that goes beyond financial incentives, requiring educational initiatives, public-private partnerships, and community engagement.

4.2.5 Analysis of Perceptions on Technological Infrastructure for Renewable Energy

The survey results reveal a mixed perception regarding the availability of sufficient technological infrastructure for a complete transition to renewable energy sources. While the responses ranged across the spectrum, a significant number were inclined towards uncertainty

or scepticism. This suggests that there is a general lack of confidence in the existing technological infrastructure's ability to support a full-scale transition to renewable energy. These findings point to an urgent need for improvements in renewable energy technologies and infrastructure, as well as better communication of these advancements to gas station operators, to facilitate a smoother and more confident transition away from fossil fuels.

4.2.6 Future Role of Fossil Fuels in the Next Decade

Most respondents anticipate a diminished role for fossil fuels, signalling awareness of a shift towards renewable energy, driven by consumer preferences, environmental concerns, and regulations. However, a portion still sees a significant role for fossil fuels, reflecting either uncertainty or resistance to change. This could stem from large investments in existing infrastructure, doubts about the economic feasibility of renewables, or inertia from established business practices. The varied responses suggest the industry is at a critical juncture, lacking a unified vision for the future. This divergence also reveals tension between the need for innovation and the practical challenges of implementing it. Those favouring a reduced role for fossil fuels seem prepared for operational changes, while others may be prioritizing short-term gains, potentially neglecting long-term sustainability.

4.3 Operational strategies into Renewable energy

4.3.1 Operational Strategies Implemented in Response to the Transition Toward Renewable Energy

The data from this question offers valuable insights into how fuel stations are adapting their operational strategies in response to the growing emphasis on renewable energy. A notable number of respondents indicated implementing various changes, such as introducing EV charging stations, expanding inventory to include biofuels, and modifying infrastructure for

renewable energy storage. This suggests an active engagement with the transition toward sustainability, and it signifies that stations are looking beyond mere compliance with regulations to integrating renewables into their core business model.

However, the dispersion in the strategies adopted reflects an industry that is still in the exploratory phase of this transition. Some stations seem to be taking a comprehensive approach, investing in multiple avenues of renewable energy. In contrast, others appear to be adopting a more cautious stance, perhaps testing the waters before committing to significant changes. This cautiousness could be due to the high costs associated with infrastructural changes or uncertainty about consumer demand for such services. See **Figure 4**.

[Place Figure 4 around here]

Overall, the range of operational strategies being employed shows that there is no one-size-fits-all approach to this transition. Instead, fuel stations are adopting a portfolio of strategies to mitigate risks and capitalize on new opportunities. This finding highlights the complexity of the operational challenges involved in the transition and indicates that managing this change effectively is a multifaceted task requiring a strategic, rather than merely tactical, approach.

4.3.2 Challenges Faced in Adapting Supply Chain to Accommodate Renewable Energy

Products

Figure 4 shows that most respondents identified "High Costs" and "Lack of Supplier Availability" as the main challenges in adapting their supply chain for renewable energy products. This provides a nuanced understanding of the obstacles fuel stations are facing during this transition.

"High Costs" being a prevalent response highlights the financial constraints that many fuel stations are grappling with. These costs could include a variety of expenses, from the initial investment in renewable energy infrastructure to ongoing operational costs. The transition to

renewable energy is not simply a matter of willingness but is significantly impacted by the economic viability of such a move.

The challenge of "Lack of Supplier Availability" points to a systemic issue in the renewable energy sector. This suggests that while fuel stations may be willing to integrate renewable options, the broader supply chain may not yet be adequately equipped to support this transition. It implies that for a more seamless transition to renewable energy, systemic changes beyond the individual fuel stations are necessary.

The fact that fewer respondents flagged "Regulatory Challenges" indicates that current policies may not be viewed as a significant barrier to renewable energy adoption at fuel stations. This might suggest that existing regulations are either sufficiently supportive or not restrictive enough to be considered a hurdle, at least in the perception of the fuel station operators.

[Place Figure 4 around here]

4.4 Business performance and Consumer preferences

4.4.1 Findings on the Impact of Renewable Energy Incorporation on Overall Sales

The analysis of this findings suggests that incorporating renewable energy options into fuel stations is more than just an environmental gesture; it's a business strategy that is showing promising signs of economic viability. A significant majority of respondents reported a positive or moderate impact on their overall sales, debunking the notion that transitioning to renewables might adversely affect revenue. Very few reported a negative impact, further solidifying the case for renewable energy as a competitive differentiator in today's market. These insights underscore the importance of renewable energy not just in achieving sustainability goals, but also in appealing to a changing consumer base that values eco-friendly options.

The linear regression analysis between the incorporation of renewable energy options and customer feedback revealed a statistically significant positive relationship. Specifically, an

increase in overall sales due to renewable options was found to positively influence customer feedback, a key indicator of market acceptance and business viability. The F-statistic and p-values confirm the model's significance, while the R-squared value of 25.8% indicates that about a quarter of the variability in customer feedback can be attributed to changes in sales due to renewable energy options. These findings suggest that integrating renewables is not only an ethical and regulatory compliance move but also a strategic one that can enhance customer satisfaction and potentially drive sales. Therefore, gas stations could benefit from adopting a customer-centric approach in their transition to renewable energy.

4.4.2 Challenges in Maintaining Profitability and Customer Interest in Renewable Energy

The one-way ANOVA analysis conducted between the challenges faced in maintaining profitability since integrating renewable energy options and the level of customer interest in renewable energy revealed a statistically significant relationship, as evidenced by an F-statistic of 4.13 and a p-value of 0.0086. This suggests that specific challenges in profitability, such as high initial costs or regulatory hurdles, significantly influence customer interest in renewable energy options. Therefore, gas stations may need to strategically prioritize overcoming those challenges that have the most considerable impact on customer interest. This insight could be vital for planning future investments and operational changes as it highlights the direct correlation between overcoming profitability challenges and enhancing customer engagement in renewable energy. See **Figure 5**.

[Place Figure 5 around here]

5. Discussion

Deloitte's (2022) report three main trends of service stations in the future. First, it is the customer-centric function or demand driven. Second, is the emphasis of the service rather than the product, e.g. mobility instead of fuel stations. Third, the focus on net zero emissions.

Some recent case studies of EV charging are presented in UNECE (2025), which can be complementary to the results of this paper.

5.1 Transition Dynamics

The survey findings provide a nuanced view of the transitional dynamics that gas stations are experiencing in shifting towards renewable energy, thereby corroborating, and elaborating on existing scholarly literature. High dependency on fossil fuels reflects institutional inertia highlighted by Sovacool (2011) and Heiskanen *et al.* (2017), emphasizing the persistent barriers like high costs and technological scepticism that slow renewable energy adoption. The mixed responses regarding the effectiveness of regulatory incentives echo Heiskanen *et al.* (2017)'s insights into the conditional impact of policy measures, suggesting that current initiatives may lack the depth and reach needed for universal adoption. Furthermore, the varying outlooks on the future role of fossil fuels align with Sovacool (2011)'s concept of "incumbent resistance," indicating an industry in flux and underlining the need for targeted, multi-stakeholder strategies.

The results also resonate with Rogers' Diffusion of Innovations, as the moderate increase in renewable energy demand could signify an accelerating phase in market adoption. Yet, the lingering presence of 'no change' responses implies a bifurcation within the industry, potentially due to regional or demographic factors. This complexity confirms scholarly arguments like those of Geels (2014) and Kern *et al.* (2019), who stress that energy transitions are long-term, complex endeavours requiring comprehensive strategies and strong leadership. These findings collectively indicate that gas stations' transition to renewables is a multifaceted challenge, replete with financial, technological, and perceptual hurdles that call for an integrated approach.

5.2 Operational strategies into Renewable energy

The sources of renewable energy such as electric vehicle charging point have increased around the globe in the last few years (IEA, 2024), with expected 300,000 EV public charge points in the UK. The survey findings on operational strategies reveal a complex interplay between risk-taking and caution among fuel stations, strongly resonating with Clayton Christensen's "Innovator's Dilemma". "Aggressive Transitioners" embody the disruptive innovators willing to make bold shifts, while "Moderate" and "Conservative Transitioners" show varying degrees of hesitance, reflecting the financial and systemic barriers cited in existing literature. This complexity in operational approaches highlights that transitioning to renewables is not merely about technology adoption but also involves a strategic reorientation, aligning well with the literature's emphasis on multi-faceted solutions for overcoming the Innovator's Dilemma. Therefore, the industry's transition involves not just logistical but also strategic shifts to achieve long-term sustainability.

5.3 Business performance and consumer performance

The survey findings illustrate a symbiotic relationship between renewable energy adoption and business performance, substantiating theories like "Green Consumerism" and Heskett *et al.* (1994)'s "Service-Profit Chain." Investment in renewable energy not only aligns with consumer preference for sustainability but also positively impacts sales and customer feedback. This dual benefit lends statistical credence to Christensen (1997)'s "Innovator's Dilemma," suggesting that stations embracing renewable energy gain both immediate customer satisfaction and long-term market viability. Moreover, the ANOVA analysis indicates that overcoming initial profitability challenges can enhance customer loyalty, corroborating the idea that customer satisfaction is intricately linked to economic success in the renewable transition.

6. Conclusions

Implications of this study are two-fold: it validates the imperative for fuel stations to innovate for long-term viability and suggests immediate business gains in doing so. Implications for practice is to keep abreast of developments and to invest in renewable energy sources. Implications for policy makers include the need for more investment in the relevant infrastructure, also the provision of financial support both in terms of incentives and deterrents to achieve a more sustainable future.

Limitations include the focus on fuel stations, which may not be representative of the broader energy sector, and the reliance on self-reported data that could carry biases. For example, in the survey, fuel station owners or managers might have provided answers based on their own perspectives or experiences. The issue with self-reported data is that it's subject to various forms of bias, such as social desirability bias, where respondents may provide answers, they think are socially acceptable rather than what's true.

Future research should expand the scope to include other stakeholders in the energy supply chain and employ longitudinal designs to track changes over time, thus providing a more comprehensive view of the industry's transition to renewable energy. Also, profitability panels or cross-regime case comparisons with mixed-methods triangulation.

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Appendix: Survey Questions

Section 1: Station Details

1. What is the name of your fuel station? (* OPTIONAL)

Open-ended answer.

2. Is your station independent or part of a chain/franchise?

- Independent
- Part of a chain/franchise

3. In which geographic region is your station located? (*OPTIONAL)

- Open-ended answer

4. How many years has your station been in operation?

- Less than 1 year
- 1-5 years
- 6-10 years
- 11-20 years
- More than 20 years

5. How many fuelling points or pumps does your station have?

- 1-5
- 6-10
- 11-15
- More than 15

6. On average, how many customers do you serve monthly?

- Less than 500
- 500-1,000
- 1,001-5,000

- 5,001-10,000
- More than 10,000

7. What is the percentage split between the types of fuels you sell? (Provide an estimated percentage for each fuel type.)

- Diesel: _____%
- Petrol: _____%
- Biofuels: _____%
- CNG (Compressed Natural Gas): _____%
- Electric Charging (if available): _____%
- Other (please specify): _____%

Section 2: Transition Dynamics from Fossil Fuels to Renewable Energy

8. How would you rate your current level of dependency on fossil fuels as opposed to renewable energy sources?

- Highly dependent on fossil fuels
- Moderately dependent on fossil fuels
- Equally dependent on both
- Moderately dependent on renewables
- Highly dependent on renewables

9. Has there been an increase in the demand for renewable energy sources among your customers in the last five years?

- Significant increase
- Moderate increase –
- No noticeable change
- Moderate decrease
- Significant decrease

10. Are there any regulatory incentives or policies encouraging you to integrate renewable energy options?

- Yes, many
- Some
- Not aware
- No

11. What challenges are you facing in integrating renewable energy solutions at your station?

(Multiple choices possible)

- High initial investment
- Lack of skilled workforce
- Absence of customer demand
- Regulatory challenges
- Other (please specify)

12. Do you believe there's a sufficient technological infrastructure available for transitioning to renewable energy sources fully?

- Strongly agree
- Agree
- Neutral
- Disagree
- Strongly disagree

13. How do you perceive the future role of fossil fuels at your station in the next decade?

- Primary source
- Equal role with renewables
- Supplementary to renewables
- Phasing out

- No role at all

14. To what extent do you believe that local community awareness and demand are driving the integration of renewable energy solutions at your station?

- Very significant
- Significant
- Moderately
- Not significant
- Not at all

15. Do you believe that integrating renewable energy options has had (or will have) a direct impact on the branding and image of your gas station?

- Strongly positive
- Positive
- No impact
- Negative
- Strongly negative

Section 3: Strategies and Operations

16. Which of the following operational strategies have you implemented in response to the transition towards renewable energy? (Choose all that apply)

- Introduction of EV charging stations
- Inventory expansion to include biofuels
- Infrastructure modifications for renewable energy storage
- Training programs for staff on renewable energy products
- None of the above

17. How often do you review and adjust your operational strategies in response to market demand for renewable energy products?

- Monthly
- Quarterly
- Bi-annually
- Annually
- Never

18. What challenges have you primarily faced in adapting your supply chain to accommodate renewable energy products? (Choose the most significant)

- Supplier issues (availability, reliability)
- Increased costs
- Storage and handling challenges
- Regulatory hurdles
- Lack of expertise or knowledge

19. With the introduction of renewable energy products, how has your inventory turnover rate been affected?

- Increased significantly
- Increased slightly
- Remained the same
- Decreased slightly
- Decreased significantly

20. Have you engaged in any collaborations or partnerships to assist with the transition to renewable energy solutions?

- Yes, with technology providers (e.g., EV charging station manufacturers)
- Yes, with renewable energy suppliers (e.g., biofuel providers)
- Yes, with governmental or regulatory bodies
- No collaborations or partnerships

21. As renewable energy products gain traction, how do you foresee the change in procurement frequency for traditional fossil fuels over the next 5 years?

- Increase
- Remain the same
- Decrease slightly (0-25% reduction)
- Decrease significantly (25-50% reduction)
- Phase out entirely

22. How do you prioritize the location and distribution of renewable energy infrastructure (e.g., EV charging stations) at your gas stations?

- Proximity to urban areas or high-traffic zones
- Availability of renewable energy supply
- Regional demand and customer feedback
- Regulatory incentives or mandates
- Cost-effectiveness and ROI projections

23. Which of the following measures have you adopted to educate and inform customers about the benefits of renewable energy products?

- In-store informational displays or brochures
- Staff training to answer customer queries on renewables
- Promotional campaigns or discounts on renewable energy products
- Collaboration with environmental or sustainability organizations for awareness campaigns
- None of the above.

Section 4: Business Performance and Customer Response

24. How has the incorporation of renewable energy options influenced your overall sales in the past year?

- Significantly increased
- Moderately increased
- Remained the same
- Moderately decreased
- Significantly decreased

25. Since the transition toward renewable energy sources, how would you rate customer feedback about the changes?

- Very positive
- Positive
- Neutral
- Negative
- Very negative

26. Which of the following challenges have you faced in maintaining profitability since integrating renewable energy options?

- High initial costs of renewable infrastructure
- Decreased sales of traditional fuels
- Lack of customer interest or awareness in renewables
- Regulatory or policy challenges
- Maintenance costs of renewable infrastructure
- None of the above

27. What percentage of your customers inquire or express interest in renewable energy options when visiting your station?

- Over 75%
- 50% to 75%
- 25% to 49%

- Less than 25%
- Very few or none

28. How has the transition to renewable energy options influenced your station's competitive positioning in your local market?

- Greatly improved our competitive positioning
- Slightly improved our competitive positioning
- No change in competitive positioning
- Slightly hindered our competitive positioning
- Greatly hindered our competitive positioning

29. To what extent has adopting renewable energy options affected the loyalty and repeat business of your existing customer base?

- Significantly increased loyalty and repeat business
- Moderately increased loyalty and repeat business
- No significant change
- Moderately decreased loyalty and repeat business
- Significantly decreased loyalty and repeat business

Figures

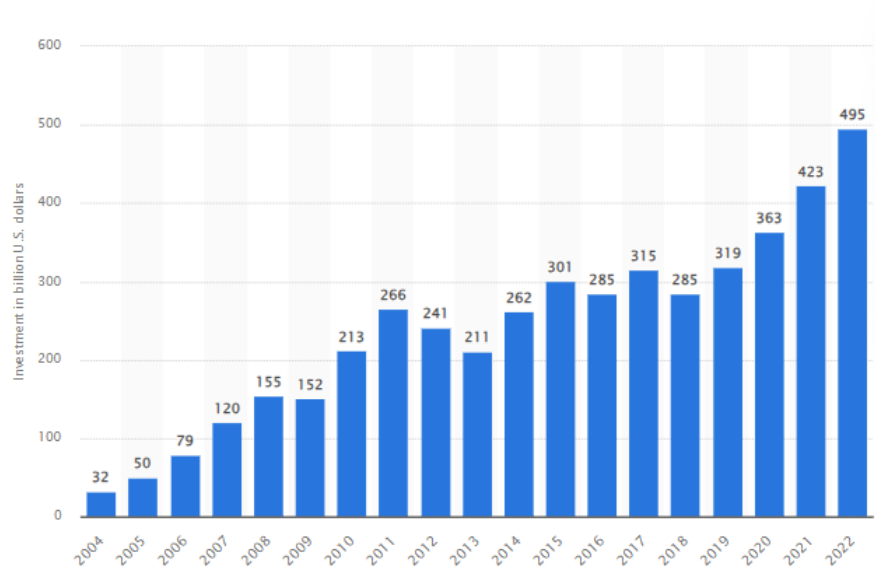


Figure 1: Worldwide renewable investments, 2022

Source: Statistica 2022

How would you rate your current level of dependency on fossil fuels as opposed to renewable energy sources?

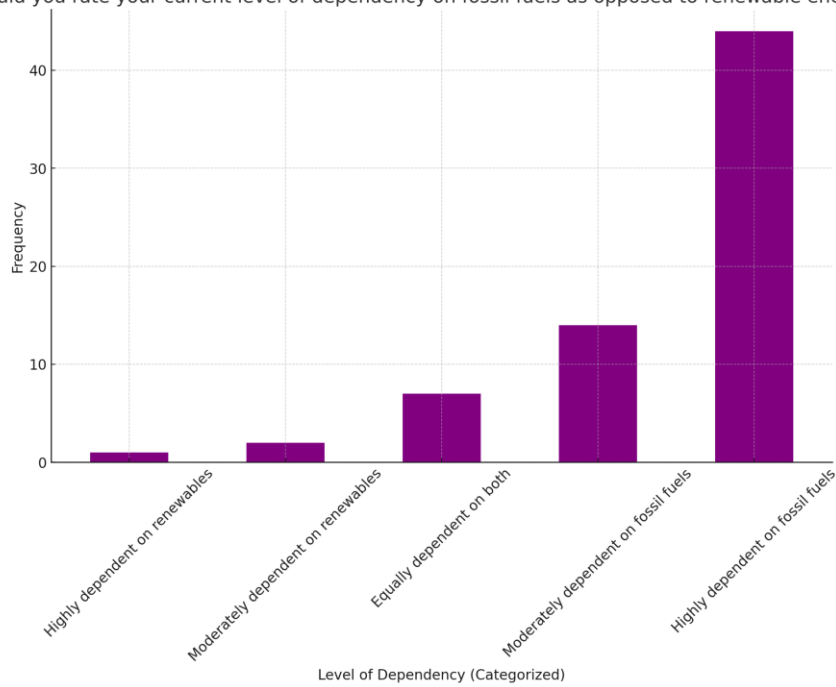


Figure 2: Level of Dependency on Fossil Fuels Among Gas Stations

Has there been an increase in the demand for renewable energy sources among your customers in the last five years?

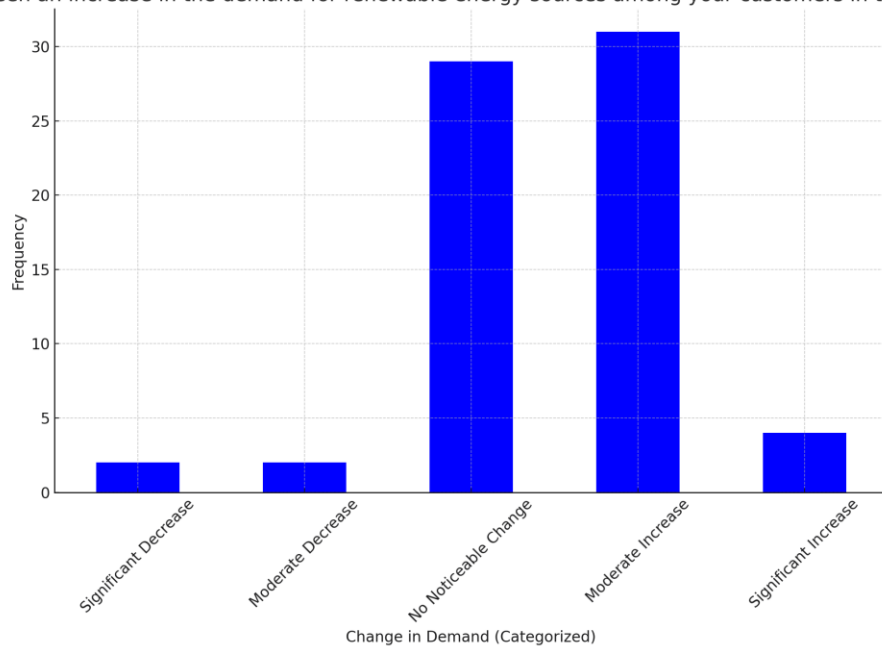


Figure 3: Responses for Dependency on Fossil Fuels

Which of the following operational strategies have you implemented in response to the transition towards renewable energy? (Updated)

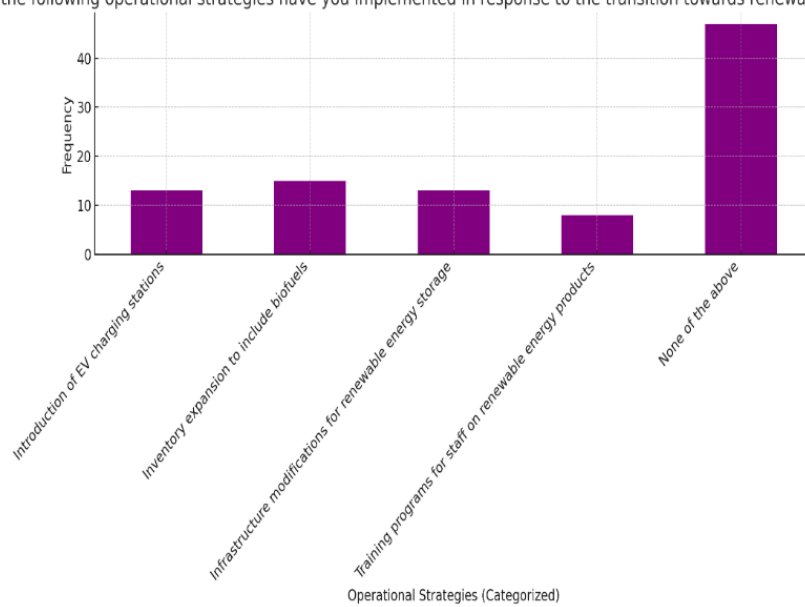


Figure 4: Operational Strategies Implemented in Response to the Transition Toward Renewable Energy

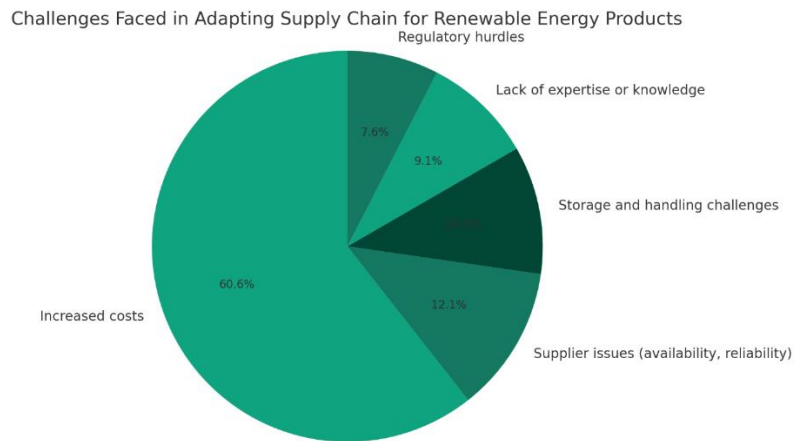


Figure 4: Challenges Faced in Adapting Supply Chain to Accommodate Renewable Energy Products

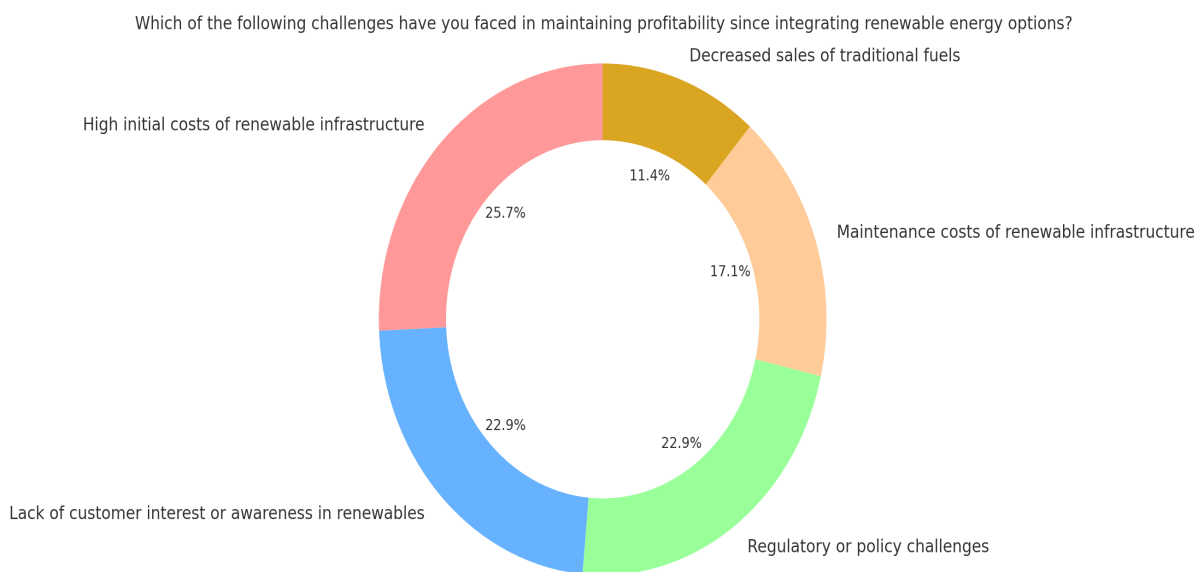


Figure 5: Doughnut chart showing profitability after Integrating Renewable energy options